DIE VERENIGING VAN MUNISIPALE ELEKTRISITEITSONDERNEMINGS VAN SUID-AFRIKA

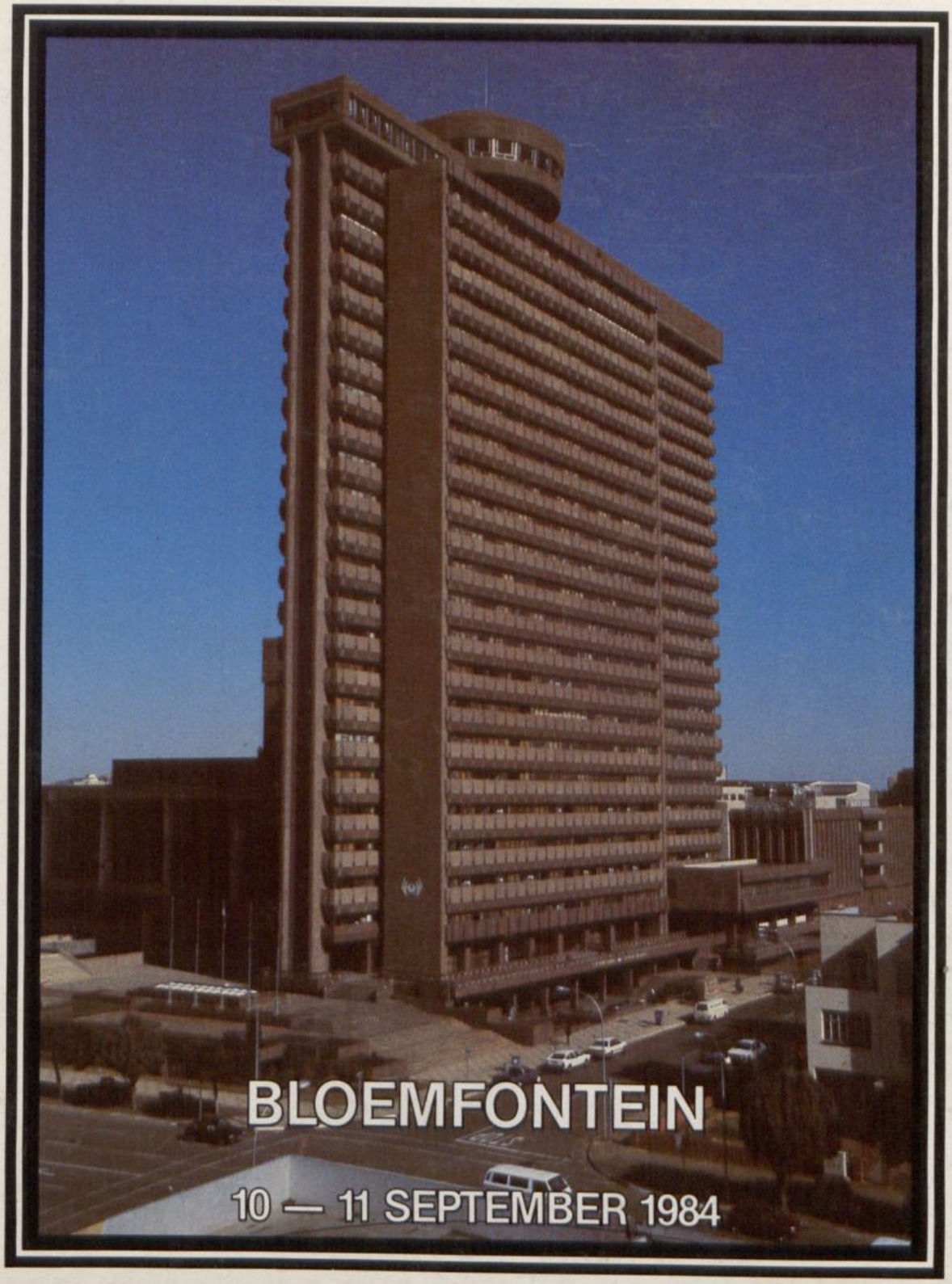
THE ASSOCIATION OF MUNICIPAL ELECTRICITY UNDERTAKINGS OF SOUTH AFRICA

TIENDE

TENTH

TEGNIESE VERGADERING

TECHNICAL MEETING



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10 — 11 SEPTEMBER 1984

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PROCEEDINGS
10TH TECHNICAL MEETING
10 – 11 SEPTEMBER 1984
BLOEMFONTEIN

VERRIGTINGE
10e TEGNIESE VERGADERING
10 – 11 SEPTEMBER 1984
BLOEMFONTEIN

The Rev. W W Pretorius opened the proceedings with scripture reading and prayer
Ds. W W Pretorius het die verrigtinge met skriflesing en gebed geopen

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UITGEWERS EN EIENAARS

The Association of Municipal Electrity Undertakings of South Africa.
Die Vereniging van Munisipale Elektrisiteitsondernemings van Suid-Afrika.

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M. van der Spuy	– Highveld/Hoëveld
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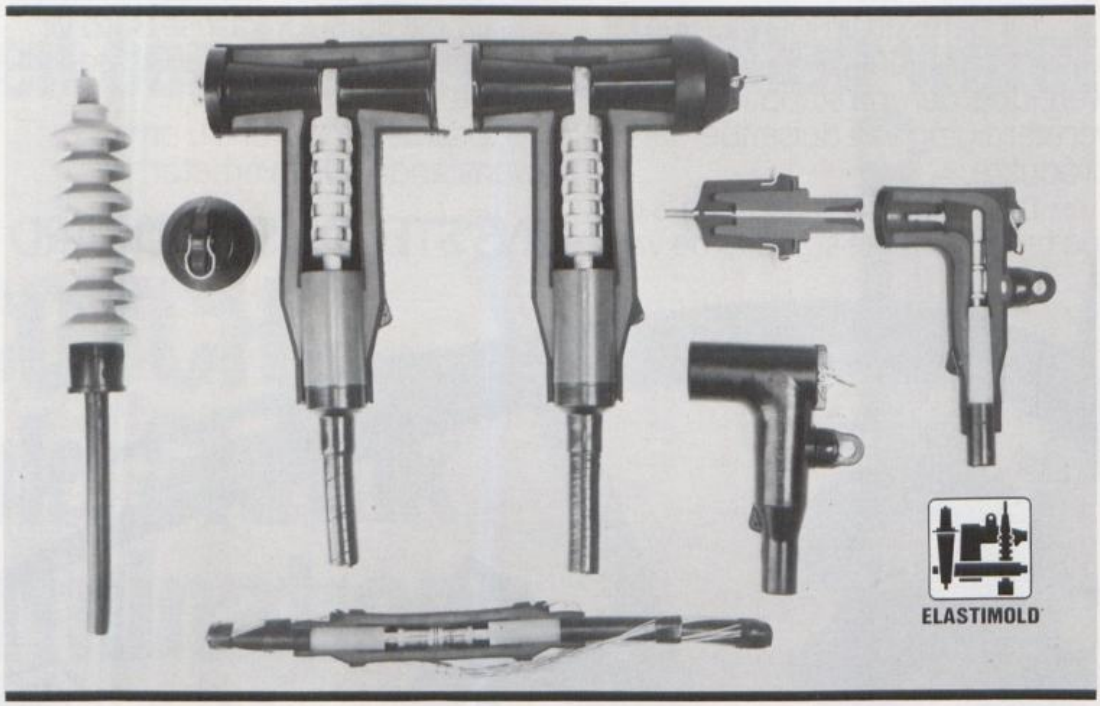

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OFFICIAL OPENING
AMPTELIKE OPENING

DIE PRESIDENT
Wessel Barnard verwelkom
Lede en Afgevaardigdes.

MNR WESSEL BARNARD: PRESIDENT

U agbare, Die Burgemeester van Bloemfontein, Raadslid Ströhfeldt en mev Ströhfeldt, erelede, gaste, dames en here, dit is vir my 'n besondere voorreg om u almal hartlik welkom te heet by hierdie 10de Tegniese Vergadering van die Vereniging van Munisipale Elektrisiteitsondernemings van Suid-Afrika. The first Technical Meeting of the AMEU was held in 1966, and on the occasion Bloemfontein was also the host. These meetings held on alternative years to the conventions have proved to be a most useful platform for the exchange of ideas and discussions of perennial technical problems. We are therefore Mr Mayor, after an absence of 18 years, extremely pleased to be back where it all started, the Judicial Capital of our Country, your beautiful city of Bloemfontein. I thank you and your Council for the kind invitation which enabled us to hold the 10th Technical Meeting in your City.

Dit is nou met genoeë dat ek sy agbare die Burgemeester vra om die 10de Tegniese Vergadering van die VMEO amptelik te open. It is with great pleasure that I call on his Worship the Mayor to officially open the 10th Technical Meeting of the AMEU.

DIE BURGEMEESTER RAADSLID J A STRÖHFELDT

Mr President, Mr Barnard, when I approached the City Hall this morning, I felt that I was penetrating a magnetic field. And the nearer I came to the City Hall the heavier the load was on me. It tinkled inside me, and once when I walked in here, I felt the severe shock. I never realised that the electrical technical people can be so truthful to their occupation in coming in such large numbers. I compliment you on this.

Mnr die President, eregaste, afgevaardigdes, dis vir my 'n besondere voorreg om u vandag in Bloemfontein te verwelkom. Soos u weet, staan Bloemfontein vandag bekend as die "Stad van Rose", asook seer sekerlik daarby aangesluit, die "Kongresstad". 'n Onderskeiding wat hoofsaaklik te danke is aan twee feite, naamlik eerstens is dit as gevolg van die sentrale ligging van Bloemfontein, pragtig, so in die middel van die land. U spaar geld van Transvaal af hier-

natoe, u spaar geld van die Kaap af hiernatoe. Dis heerlik om in die middel van ons land geleë te wees en na alkante te kyk, net jou kop te draai en te sien wat gaan aan in ons land. Ook is Bloemfontein se mense bekend as baie vriendelike mense, en ek hoop en vertrou dat u gedurende u verblyf in Bloemfontein dit seer sekerlik sal ondervind, dat ons werklik goeie, vriendelike mense is. Moenie bekommerd wees oor die bietjie koue wat u hier buite voel nie, 'n lewende draad lyk mos altyd koud totdat jy aan hom vat, of hoe? So ook, sal Bloemfontein miskien vir u lyk op die TV as 'n koue plek, totdat u hier kom, dan ondervind u, en beleef dit dat ons lekker warm mense is. Kyk maar na mnr Nico Botha, my stad se Elektrotegniese Stadsingenieur. Hy het al van ver af geglimlag toe ek met die kar nader kom.

Mnr die President, soos ek gesê het, dit is vir ons 'n voorreg om die Vereniging van die Munisipale Elektrisiteitsondernemings vir hulle 10de Tegniese Vergadering te verwelkom. Ons hoop en vertrou dat u 'n geslaagde vergadering sal hou.

Menere, verstedeliking is tans een van die grootste vraagstukke in Suid-Afrika, en dit is veral die behoefte aan beter kwaliteitsdienste en meer dienste wat met verstedeliking gepaard gaan. Uit die aard van die saak beïnvloed die voorsiening van elektrisiteit deur munisipale owerhede letterlik miljoene mense in die republiek van Suid-Afrika se lewenswyse; die belangrikheid van elektrisiteitsvoorsiening kan dus nie oorbeklemtoon word nie. Sommige mense beweer dat die voorsiening van elektrisiteit en die verbruik daarvan inderdaad 'n barometer is van 'n land se ontwikkeling, asook die standaard van sy lewenswyse.

Ek kan dus onomwonde sê dat elektrisiteitsvoorsiening vandag een van die mees aktuele sake is, eintlik is elektrisiteitsvoorsiening onmisbaar vir die meeste vorms van menslike aktiwiteite. Dink net wat sou gebeur het as daar nie elektrisiteit was nie. U sou almal gehuil het oor Dallas, of so 'n paar van die ander soort – Dynasty. Ek weet nog nie watter een is die beste van die twee nie. Maar wat – sien wat maak JR op die ou end. Inagnemend dat wat ek so pas gesê het, word die rol van die Elektrotegniese Ingenieur, volgens my mening dikwels onderskat. Sodra 'n kragonderbreking egter plaasvind, besef almal die onmisbare rol wat elektrisiteitsvoorsiening in die moderne samelewing speel. U weet mos, sodra daar 'n kragonderbreking is, sê hulle "nou waar is daardie Elektrotegniese Stadsingenieur" asof die arme man en sy departement al die drade kan oppas. As ons besef hoe vernaam is ons Elektrotegniese Stadsingenieur met sy departement, met sy mense, dan miskien sal 'n Stadsraad en sy Stadsraadslede werklik besef hoeveel hulle moet uithaal om op te maak vir die dienste gelewer deur 'n Elektrotegniese Stadsingenieur. Ek doen nie afbreuk aan ander departement nie. Ek doen nie afbreuk aan die meganiese sy nie, maar 'n Elektrotegniese Stadsingenieur sal sekerlik 'n gedenknaald, 'n standbeeld, in elke stad moet kry om te sê hy doen soveel en het soveel opgeoffer. Ons waardeer wat 'n Elektrotegniese Stadsingenieur in 'n stad beteken. Mr President, although I believe that it would be interesting to hear that our electricity department is spending more than 10 million Rand on 132kV equipmnent alone at this moment, I would rather not delay you, except to ask you kindly to spend a few minutes in the foyer, where I believe our electricity department is explaining certain aspects of its activities. Mr President, it now gives me great pleasure to declare the 10th Technical Meeting of the Association of Municipal Electrical Undertakings of South Africa officially open.

MNR WESSEL BARNARD: PRESIDENT

Mnr die Burgemeester, dames en here, graag wil ek eers vir Ds Pretorius bedank vir die treffende wyse waarop hy ons voorgegaan het met skriflesing en gebed. Aan u, mnr die Burgemeester, baie dankie vir die vriendelike verwelkoming, asook die opening van hierdie verrigting. Na my mening is Bloemfontein baie gelukkig om so 'n verligte, of moet ek liewer sê, beligte Burgemeerster te hê, wat soos aangedui is in sy toespraak, so 'n goeie kennis het van die waarde van die rol van die Elektrotegniese Stadsingenieur in die moderne samelewing. Meneer, indien u sou werkloos raak na u ampstermyn, dan is ek seker dat ons vir u 'n pos as die Burgemeester van Johannesburg kan aanbied. Nou kom ek by Nico Botha, wat oor baie maande die reëlings van hierdie Tegniese Vergadering om hom gehad het. U sal met my saamstem dat die reëlings puik is, en dat Nico homself oortref het daarmee, en dat Bloemfontein baie bevoorreg is om so 'n uitstaande Elektrotegniese Stadsingenieur in sy diens te hê. Mr Mayor, once again, thank you for your kind remarks, and warm welcome. I express a very special welcome to our honorary members and as is customary I would like to ask you as I call your names to please stand up so that we can recognise you in this regard:

Die Burgemeester van Bloemfontein, Raadslid J.A. Ströhfeldt verwelkom afgevaardigdes by die 10de Tegniese Vergadering in Bloemfontein.

William Beesley
Hennie Hugo
Chris Lombard
Terence Marsh
Gawie Theron
Pat Middlecote
Jules Von Alhften.

Mr Mayor, Ds Pretorius, we are now planning to proceed with the programme, which is the working section, and while you are very welcome to stay, I'm sure you have a lot of other matters that you have to attend to, and if you wish to leave now, we won't delay you any longer. Ladies and Gentlemen, I don't think the ladies want to stay much longer, and they have a very fine programme arranged for them, so we will take leave of them as well.

Die President, Wessel Barnard saam met Bennie van der Walt, Sekretaris van die VMEO en Nico Botha, Stadselektrotegniese Ingnieur van Bloemfontein.

Die Burgemeester, Raadslid Ströhfeldt oorhandig mansjetknopies aan die President, mnr W Barnard terwyl die Aangewese President, mnr Jan Loubser toekyk.

Die President, mnr Wessel Barnard, Ken Robson van Oos-Londen en Eugene Pretorius van Potchefstroom geniet 'n grappie tydens teetyd.

Piet Botes van Roodepoort en David Briërs van Kroonstad geniet tee.

INTRODUCTION OF MR R HERMAN

MR W BARNARD : PRESIDENT

Our first technical paper is:

"Computer Aided Design of Electrical Distribution Networks".

I have much pleasure in introducing Mr R Herman. For those of our members who frequently extol the virtues of the Maties compared with the Ikies, Mr Herman is probably neutral on the matter. He gained his first degree at the University of Cape Town in 1962. After a spell with ESCOM, from 1963 to 1971, he joined the staff of the University of Stellenbosch as a senior lecturer. In 1976 he was awarded his Master's degree in engineering.

Apart from his lecturing duties he is engaged in research, his speciality being Power System Analysis and Computer Application to Power Circuits. I am sure that the paper he is now to present on "Computer Aided Design of Electrical Distribution Networks" will be of particular interest to municipal electrical engineers.

R HERMAN
Pr. Eng.

COMPUTER AIDED DESIGN OF ELECTRICAL DISTRIBUTION NETWORKS

1. INTRODUCTION

The analysis of electrical power networks have presented operations- and planning engineers with a variety of problems for several decades which have arisen as a result of certain complicating features in the nature of these networks. Firstly there is the problem of size. Power systems, and in particular distribution networks consist of a large number of nodes (or substations) interconnected by an even larger number of branches (lines).

Next, there is the problem of interdependence. Due to the interconnections between nodes, the nodal voltages and hence the resulting branch currents are not independent of one another, demanding the simultaneous treatment of all interconnected branches.

Another feature of the power system is that its performance may only be evaluated using complex quantities in order to determine both magnitude and phase angle of voltages, currents and powers.

Finally, there is the complication arising from the load specification. Unlike some electrical circuits, the loads of a power system are expressed in terms of complex power (kVA and power factor) instead of impedance. This results in network equations which are non-linear. Associated with this there is also the difficulty with which loads can accurately be specified.

Prior to the advent of the digital computer, attempts were made at solving the problem using analogue devices (calculating boards) [1] for simulating the actual network. For many years and until quite recently, the AC-network analyser was used for the solution of particular power system problems [2]. In recent years computer technology has made it possible to address the problem elegantly and with minimum effort [3].

2. SCOPE

Some comments about the scope of this paper would be in order at this stage. Much of the research to date has been concentrated on the power transmission system

rather than the distribution system. Reasons for this are that often more data has to be handled in order to analyse the performance of a distribution system, making the latter a more ponderous task. Further, the "distributed" nature of distribution systems provide great resiliency in terms of system operation, thereby muting the urgency in performing distribution system studies. By continuing in the historically acceptable manner, there is little concern that the distribution system will not perform satisfactorily and the rule-of-thumb approach can be relied upon to produce a feasible scheme of planning or operation.

Traditionally, standard procedures have been used for distribution system planning. These procedures result in adequate designs but it is often difficult to ascertain the optimality of the given pattern. It is extremely useful to be able to evaluate the relative merits of various patterns in order to select options, even though the choice of the absolute optimal design may not always be possible. It is suggested that the use of a computer program can assist the engineer in this matter.

Because of the nature of the large number of variables and the qualitative nature of certain parameters it is not possible to replace the role of the experienced engineer with that of a computer. The primary responsibility for solving a problem rests with the engineer. The computer merely extends the computational capability of the user. Such a program should relieve the engineer from performing tedious and repetitious computations, thereby freeing him to exercise his intelligence to the fullest extent. It is therefore not intended to produce a program which will automatically design optimal distribution systems. In a local sense it is evident that many distribution authorities will possess computer facilities of limited capacity. It is also noted that generation and transmission is principally the responsibility of ESCOM and a few of the larger cities. With these considerations in mind a computer program has been written which could be used by a larger number of distribution authorities or consulting firms for the analysis of distribution networks.

3. PROGRAM PARAMETERS

In order to develop the desired software, certain parameters and functions have to be investigated and specified. Ultimately the program will be used as an aid to the effective operation of a given system as well as evaluating the performance of proposed new additions to such systems, culminating in the choice of a reliable and economical combination. To this end the computer program must provide the following facilities.

3.1. Line and Transformer Loading

Estimates of the ADMD (after diversity maximum demand) for a given consumer area may be obtained from historical records and projected trends in load growth and general development patterns. A knowlege of this loading together with power factor and cable details (proposed or existing) provide the basis for determining the current distribution in the various interconnecting feeders and step-down transformers. Any resulting overloading should then become evident.

3.2 Voltage Levels

Another important parameter that has to be considered and calculated is the bus voltage level at various points in a system. These voltages will, in general, be interdependent and contingent upon the topology of the network. When the extended effect of the voltage drops in the low voltage reticulation is appended to these levels, the statutory values must not be violated. The combined calculations of 3.1 and 3.2 serve as a guide in the determination of the appropriate cable conductor size.

3.3 Losses

When it is feasible to evaluate a total system, or a significant part thereof, it becomes possible to estimate the operational performance of a given configuration in terms of copper loss in the system elements. Such a facility could then be employed in determining optimal operating strategies under varying conditions, including contingency planning in the event of a loss of plant.

3.4 Data Base Facility

As distribution systems extend in size, data handling becomes a formidable task. It is therefore desirable to include this aspect into the considerations dealing with the parameters of the contemplated program. The software ought to include a database facility which would provide a convenient structure for the editing and storage of the relevant electrical parameters of the distribution network.

3.5 "User-Friendliness"

This term, used in computer jargon, describes the attribute of the program which allows the user to operate the program with minimum effort and training. To this end it ought to prompt the user, provide him with a simple set of options and also monitor invalid entries, where possible.

3.6 Computer Capacity

For reasons already mentioned in the introductory paragraph, power systems analysis has traditionally been associated with large institutions employing large main-frame computers. These programs, when available to the public, are generally extremely expensive and often too sophisticated for the kind of work envisaged in this paper. In addition they require access to a large computing facility. Experience has shown that, even when such a computer is available, access is often inhibited due to the divergent demands the computer would be subjected to in practice.

The 8-bit microcomputer and 16-bit personal computer have become affordable to many engineers and organizations. These machines, if fully exploited, are able to provide adequate computing capacity where execution time is of lesser importance.

4. NETWORK RESTRICTIONS AND REPRESENTATION

4.1 Restrictions

For reasons which are evident from the foregoing discussion, the constraints which will be imposed on the networks which could be investigated with the program will be determined within the framework of a typical South African, small town distribution system. Such a system is typified in the schematic representation shown in fig. 1.

The typical system would generally consist of a high voltage (say 66kV) major supply and metering point which would be linked to the major transmission grid. This HV supply would then be transmitted to one or more step-down locations, often connected in a ring,

from where the medium voltage (11kV) distribution system would be interconnected.

The distribution system often goes through several stages of development with the progress of time and accompanying load growth. Such stages could typically be:

(a) simple radial feeder
(b) radial distributor
(c) ring

These types are illustrated in fig. 2 [4].

In determining the constraints which are to be imposed on the kind of distribution system that may be analysed, the major consideration is that of memory capacity. It has been determined that the maximum size which can be accommodated on a computer with 64 k-byte data memory storage is in the region of 300 substations and 400 lines. While the ratio of lines to substations can vary depending on the combinations of the types shown in fig. 2, a general ratio would be in the region of around 1,2.

With the 380/220V reticulation regarded as load points, the distribution network can be considered to operate at a base voltage of 11kV [MV], while the HV cable/overhead network could be assumed to form part of an extended input busbar, as illustrated in fig. 3. This simplification does not significantly limit the effectiveness of the program as the HV side can easily be analysed by hand, by regarding the step-down substations as load points. Alternatively it may be analysed as a separate network using the same program.

A facility which could be useful is to account for adjustable tap positions at the step-down substations which would normally be on-load-tap-changing transformers (OLTC's). However, the inclusion of these transformers in the computer program has a detrimental effect on the convergence rate of the iterative process of the computing algorithm: in fact it increases the number of iterations required for convergence by a factor of more than 10. It will therefore be discussed as an optional extra feature. For general calculations this has not been found to impose serious restriction as the effect of the automatic tap changing is to provide a constant secondary voltage under nominal loading conditions which is equivalent to considering that point of supply as an infinite busbar.

In order to determine the relative load contribution of interconnected transformers, an alternative approach would be to simulate the transformers by very small series impedances, similar to a short line section. The method is used in the example in the section on applications. For a system containing 250 substations there are not likely to be more than say, 20 of the OLTC's.

4.2 Representation of Network Elements

In order to input the required system data the electical parameters of the network elements have to be derived. For the type of system under consideration this involves the specification of the step-down transformers, the cable interconnections and the loads.

4.2.1 Step-Down Transformers

The equivalent circuits for a transformer are shown in fig. 4. The representation in fig. 4(a) is for a two winding transformer with magnetizing reactance included, while that of fig. 4(b) is an approximation which is generally accepted as adequate for most calculations. In this representation the series impedance is a combination of the primary plus secondary referred impedance. Fig. 4(c) is the representation required for simulating an OLTC operating at off-nominal tap position [5]. When $c = 1$ the transformer tap position is zero (ie nominal) and the equivalent circuit reverts to fig. 4(b).

When the tap changing option is desired it is therefore necessary to specify %Z, tap position and the kVA rating of the OLTC-transformer. The program uses an impedance to resistance ratio of 7, which is a typical value according to the manufacturers.

4.2.2 Lines

For distribution systems the line lengths are short enough to validify the use of the simple series equivalent curcuit of fig. 5(c). For a typical 11kV cable, 1 km in length, the ratio of shunt reactance to series impedance is about 100 000 which substantiates the simplifying assumption. Data handling is minimized by specifying the resistance and reactance per km for the particular cable types used in the system. Individual feeders then only require specification of length and cable type.

4.2.3 Loads

Accurate analysis of the distribution system requires that loads be specified in terms of complex quantities, usually demand kVA and power factor. However, it is in the treatment of the loading that the greatest uncertainty lies, particularly with respect to the diversity factor. No attempt will be made in this paper to examine this topic further as it is a departure point irrespective of the method of calculating employed. It is here that the experience of the design engineer is of particular value and it would be wise for municipal engineers to maintain relevant statistics and trends from which estimates may be prepared.

5. DISTRIBUTION ANALYSIS PROGRAM

The operation of the computer program and its value in assisting in making decisions about design options will be illustrated by way of a small demonstration example using the distribution network depicted in fig. 6, which is based on an actual system.

5.1 The Design Problem

It will be required to investigate various alternate schemes to supply a proposed new industrial site at the location shown on the geographical map in fig. 7. All the existing substations in the network have been sequentially coded from 1 to 26 with the proposed substation coded number 27.

For the purposes of this analysis it will be assumed that the OLTC's will automatically maintain their secondary voltages at the nominal value of 11 kV but in order to determine the relative sharing between the two transformers, both will be represented as short line elements.

Examination of the geographical map suggests that there are four possible supply routes to this new substation – from points 14, 16, 19 and 22.

The associated cable route lengts are:

14 to 27 – 650 m

16 to 27 – 450 m
19 to 27 – 600 m
22 to 27 – 350 m

For the purpose of this example it will be assumed that the loading at this new site will be say, 1300 kVA with a power factor of 0.9.

All relevant data will be stored in a file for which a file name will be assigned – in this case STB2. This information remains in the file and may be accessed and manipulated as required.

After the system name has been entered the following main menu options will be displayed on the screen:

1. INSERT/ALTER DATA
2. LOADFLOW
3. TERMINATE

For a new system option 1 must be used to enter the data which will display the following menu:

1. INSERT LINES/TRANSFORMERS
2. REMOVE LINES/TRANSFORMERS
3. BREAKER STATUS CHANGE
4. BUS DATA UPDATE
5. CABLE DATA UPDATE
6. TRANSFORMER DATA UPDATE
7. PRINT LINE/TRANSFORMER CONNECTIONS
8. PRINT BUS DATA
9. PRINT CABLE DATA
10. PRINT TRANSFORMER DATA
11. EXIT TO MAIN MENU

The function of each of these options is described below.

1. Line data is entered using the instruction by answering the prompts which will be: sendbus; endbus; length; cabletype. The cabletype will be defined by option 5.

2. This instruction is used to permanently remove a line from the system file but is not required when line switches are opened or closed as this function is performed by option 3.

3. The status of a line switch may be altered by answering the prompt '0' or 'C'.

4. Bus loading specifications are entered using this instruction. Prompts here are: bus number; apparent power (kVA); power factor. After specifying the loading at a substation it will be regarded as 'valid'. (Zero loading must also be entered where applicable).

5. For this option answers to the following prompts are required: cabletype; resistance/km (ohm); reactance/km (ohm); amps. The last entry here refers to the current carrying capacity of the cable.

6. Step-down transformer data is entered using this option. This may be omitted when the transformer is regarded as a short line section, as discussed earlier.

7. to 10.
Are various print instructions which will appear later in the example.

11. This instruction returns the user to the main menu when editing has been completed.

Option 2 on the main menu displays the following prompts:

GIVE REQUIRED ACCURACY (%):
GIVE ACCELERATION FACTOR (BETWEEN 1,0 AND 2,0):

The mathematical method employed in solving the unknown bus voltages is the Gauss-Seidel algorithm. This iterative method converges more rapidly when it is accelerated with a correctly chosen acceleration factor. It is not possible to predetermine this value as it depends upon the topology and size of the network but experimenting with a particular system will yield a suitable figure. It has also been found that an accuracy of about 0,0001% in bus voltages in required for acceptable results for the calculation of the overall system performance which is computed at the end of the analysis.

A complete computer listing of the data for the sample system is shown in the following tables.

Option 2 on the main menu is now invoked to perform the loadflow analysis. The various alternative links between the proposed substation and the available points are simulated in turn and the loadflow operation is repeated, yielding the results as shown.

5.2 Computer Results

The four suggested cases will be examined in turn.

5.2.1 CASE 1 – connection 22 to 27

This is physically the shortest route to the proposed new substation. A complete network parameter listing is shown in the table headed by Line data, Bus data and Cable data. The results show that the bus voltages have been calculated within an accuracy of 0,0001%, i.e. to 0,11 volt which have then been used to calculate the line currents in all the connected branches, including the proposed feeder from points 22 to 27. The effect that this configuration would have on the rest of the system can now be examined and feeders approaching their current carrying capacity noted. The ring from substation 5 has been left closed on purpose and it is clear from the current distribution pattern that the link between 15 and 16 is the natural place to run an open point. The performance of the system as a whole may be gauged from the loss calculations – 0,67% in this case.

5.2.2 CASE 2 – connection 16 to 27

Before doing this run the line between 22 and 27 is opened and the line 16 to 27 closed. The results of some of the relevant bus voltages and all the branch currents are shown. Notice that although the currents appear to be evenly distributed, the voltage levels at points 16 and 17 are significantly lower. The overall losses are also the highest for the four cases – 1,03%.

This represents an increase of 26 kW or 28 kVA above that of case 1.

5.2.3 CASE 3 – connection 14 to 27

The procedure is repeated for this connection. This cable route is physically the longest but the results show that the voltage at substation 27 is a healthy 10,831 kV and the overall loss is only 0,55% – the lowest of the four cases.

5.2.4 CASE 4 – connestion 19 to 27

Only the current distribution for this configuration is shown. Obviously feeder 6 to 19 now carries a greater load (156,4 A). The efficiency of this case is depicted by the system loss of 0,75%.

5.3 Assessment

Obviously some factors have been ignored in this example such as future possible expansion in the immediate area, load growth at substation 27 – and whether the existing and proposed plant would be able to accomodate such increases and also whether security of supply is to be given further consideration. In any event, such conditions would be the basis for further analyses, giving more support to the design choice.

Transformer losses at the main substation have also been ignored, but with the current sharing between the two transformers known, these losses may be calculated. It may be noted that on demand charge alone, based on R9,80/kVA, the 40 kVA difference between cases 2 and 3 amounts to R4700 per annum – sufficient to buy a personal computer!

6. ACKNOWLEDGEMENTS

The author wishes to express his appreciation to Mr L.P. du Toit of the University of Stellenbosch for his valuable assistance during the research associated with the development of the computer package.

Indebtedness is expressed towards the Technical Papers Committee of the AMEU for the opportunity of presenting this paper and it is hoped that it will serve to reinforce the links between the universities and the engineering profession.

7. REFERENCES

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[2] Stevenson, W.D. 'Elements of power system analysis', ch1.
[3] Goven, T. 'Bibliography of power distribution system planning', IEEE Trans. on PAS, Vol PAS-102, 1983, p1778.
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[5] Gross, C.A. 'Power system analysis', ch 5.

FIG. 1 – Schematic Diagram of Supply System

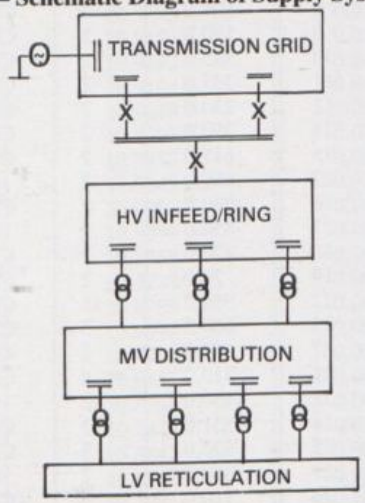


FIG. 2 – Distribution System Types

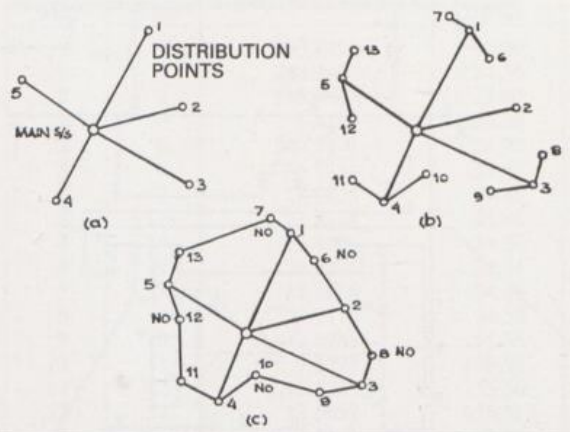


FIG. 3 – Simplification of HV Infeed

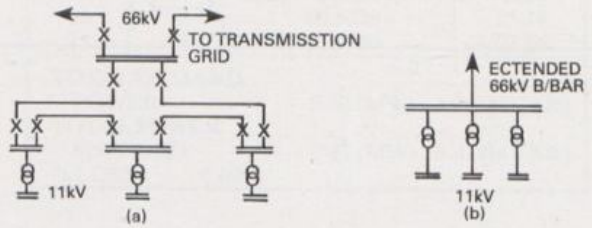


FIG. 4 – Transformer Network Models

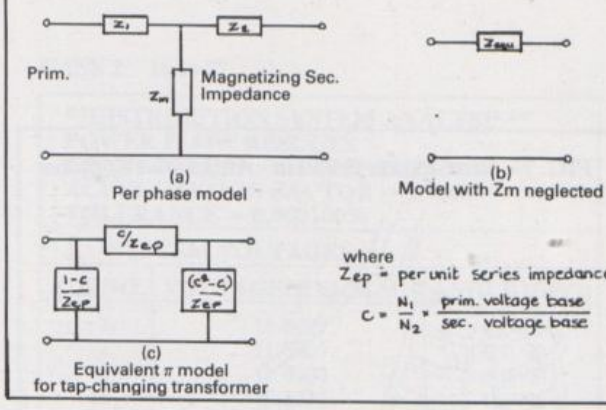


FIG. 5 – Transmission Line Models

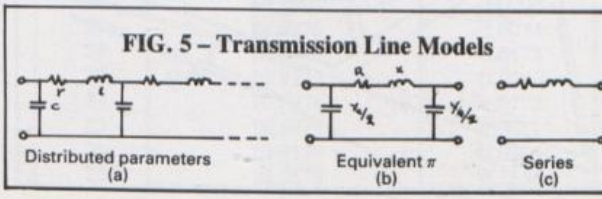
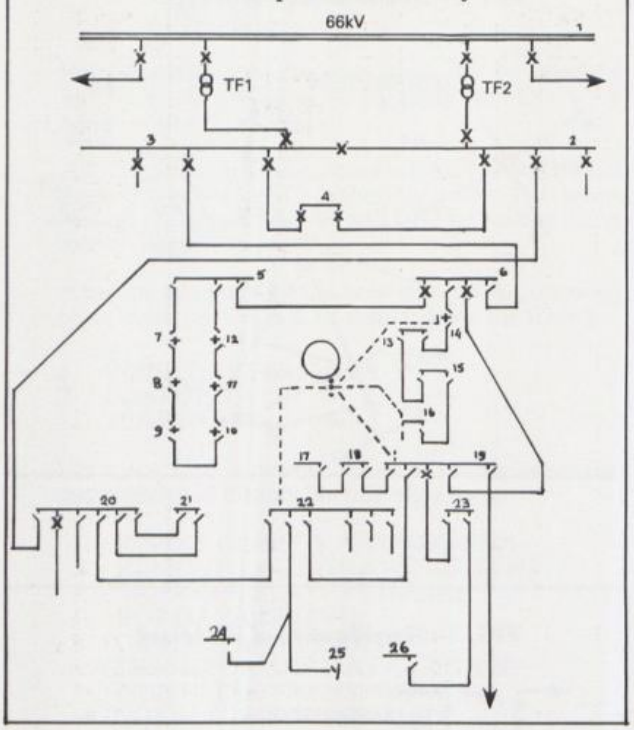


FIG. 6 – Sample Distribution System

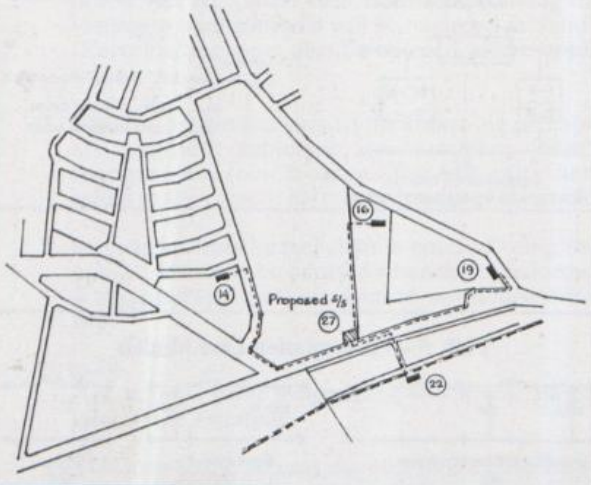


SAMPLE SYTEM DATA

BUSDATAFILE**stb2** BUS NO.	BUS POWER kVA	PF	BUS STATUS DATA	BUS
1	0.00	1.000	VALID	CONNECTED
2	43.00	.900	VALID	CONNECTED
3	0.00	1.000	VALID	CONNECTED
4	3613.00	.920	VALID	CONNECTED
5	293.00	.910	VALID	CONNECTED
6	221.00	.910	VALID	CONNECTED
7	112.00	.910	VALID	CONNECTED
8	156.00	.910	VALID	CONNECTED
9	125.00	.910	VALID	CONNECTED
10	131.00	.910	VALID	CONNECTED
11	117.00	.910	VALID	CONNECTED
12	133.00	.910	VALID	CONNECTED
13	156.00	.910	VALID	CONNECTED
14	63.00	.910	VALID	CONNECTED
15	81.00	.910	VALID	CONNECTED
16	0.00	1.000	VALID	CONNECTED
17	43.00	.890	VALID	CONNECTED
18	0.00	1.000	VALID	CONNECTED
19	43.00	.900	VALID	CONNECTED
20	43.00	.920	VALID	CONNECTED
21	117.00	.850	VALID	CONNECTED
22	1360.00	.920	VALID	CONNECTED
23	100.00	.920	VALID	CONNECTED
24	27.00	.920	VALID	CONNECTED
25	37.00	.920	VALID	CONNECTED
26	25.00	.920	VALID	CONNECTED
27	1300.00	.900	VALID	CONNECTED
29	0.00	1.000	VALID	ISOLATED

LINEDATAFILE**stb2** SEND-BUS	END-BUS	LENGTH(M)	CABLE-TYPE	BREAKER
1	2	1.0	30	CLOSED
1	3	1.0	30	CLOSED
2	4	90.0	7	CLOSED
2	20	270.0	1	CLOSED
3	4	95.0	21	OPEN
3	6	570.0	1	CLOSED
5	6	375.0	22	CLOSED
5	7	605.0	2	CLOSED
5	12	480.0	2	CLOSED
6	14	220.0	2	CLOSED
6	19	1250.0	11	CLOSED
7	8	595.0	2	CLOSED
8	9	150.0	2	CLOSED
9	10	385.0	2	CLOSED
10	11	325.0	2	CLOSED
11	12	230.0	2	CLOSED
13	14	350.0	2	CLOSED
13	15	613.0	2	CLOSED
14	27	650.0	2	OPEN
15	16	920.0	2	CLOSED
16	27	450.0	2	OPEN
17	18	420.0	2	CLOSED
18	19	20.0	2	CLOSED
19	22	550.0	11	CLOSED
19	23	600.0	3	CLOSED
19	27	600.0	2	CLOSED
20	21	310.0	4	CLOSED
20	22	1450.0	2	OPEN
22	24	531.0	3	CLOSED
22	25	520.0	3	CLOSED
22	27	350.0	2	OPEN
23	26	110.0	3	CLOSED

FIG. 7 – Distribution Problem - Alternative Supplies



**CABLE DATA TYPE NO.	RESISTANCE/km (ohm)	REACTANCE/km (ohm)
1	0.138	0.089
2	1.252	0.123
3	0.288	0.097
4	0.573	0.108
7	0.214	0.092
11	0.228	0.087
21	0.107	0.046
22	0.228	0.063
30	0.000	0.000

2. LINE CURRENTS

SEND-BUS	END-BUS	CURRENT (MAG)	ANGLE (DEG)
1	2	200.1915	- 23.39
1	3	240.3866	- 24.39
2	4	189.7545	- 23.07
2	20	8.4186	- 29.28
3	6	240.3779	- 24.39
5	6	56.3741	155.53
5	7	18.0835	- 24.46
5	12	22.8344	- 24.46
6	14	15.8229	- 24.50
6	19	156.5374	- 24.34
7	8	12.1666	- 24.45
8	9	3.9110	- 24.50
9	10	2.6985	155.55
10	11	9.6295	155.55
11	12	15.8145	155.56
13	14	12.5057	155.51
13	15	4.2740	- 24.49
15	16	0.0007	182.26
17	18	2.2874	152.90
18	19	2.4020	153.47
19	22	145.2702	- 24.34
19	23	6.6308	- 23.02
20	21	6.1277	- 31.67
22	24	1.4258	- 23.36
22	25	1.9580	- 23.29
22	27	69.5226	- 25.74
23	26	1.2555	- 23.96

TOTAL DEMAND POWER	7.62 (MW)	3.38 (MVAR)
TOTAL POWER SUPPLIED	7.67 (MW)	3.41 (MVAR)
% LOSS 0.69		

CASE 1 22 to 27

POWER FLOW RESULTS
CONVERTED IN: 40 ITERATIONS
ACCELERATION FACTOR = 1.7500
TOLERANCE = 0.000100%

1. SYSTEM VOLTAGES

BUS NO.	VOLTAGE(KV) (MAG)	ANGLE (DEG)
1	11.0000	0.0000
2	11.0000	-0.0000
3	11.0000	-0.0000
4	10.9931	-0.0001
5	10.9529	-0.0229
6	10.9615	-0.0299
7	10.9303	0.0174
8	10.9154	0.0442
9	10.9142	0.0464
10	10.9163	0.0425
11	10.9228	0.0310
12	10.9303	0.0175
13	10.9452	-0.0009
14	10.9543	-0.0170
15	10.9398	0.0088
16	10.9398	0.0088
17	10.8768	0.0004
18	10.8788	-0.0036
19	10.8789	-0.0038
20	10.9994	-0.0002
21	10.9976	0.0034
22	10.8452	0.0069
23	10.8768	-0.0030
24	10.8448	0.0071
25	10.8447	0.0072
26	10.8767	-0.0029
27	10.7954	0.1038

CASE 2 16 to 27

****DISTRIBUTION SYSTEM ANALYSIS****
POWER FLOW RESULTS
CONVERTED IN: 38 ITERATIONS
ACCELERATION FACTOR = 1.7500
TOLERANCE = 0.000100%

1. SYSTEM VOLTAGES

BUS NO.	VOLTAGE(KV) (MAG)	ANGLE (DEG)
1	11.0000	0.0000
2	11.0000	-0.0000
3	11.0000	-0.0000
16	10.6332	0.5938
17	10.9135	-0.0166
18	10.9154	-0.0206
19	10.9155	-0.0208
20	10.9994	-0.0002
21	10.9976	0.0034
22	10.8980	-0.0173
23	10.9135	-0.0200
24	10.8976	-0.0172
25	10.8975	-0.0171
26	10.9134	-0.0200
27	10.5678	0.7236

2. LINE CURRENTS			
SEND-BUS	END-BUS	CURRENT (MAG)	ANGLE (DEG)
1	2	200.0371	- 23.34
1	3	241.6429	- 24.22
2	4	189.7564	- 23.07
2	20	8.3368	- 29.17
3	6	241.6362	- 24.22
5	6	56.3744	155.52
5	7	18.0842	- 24.45
5	12	22.8358	- 24.46
6	14	86.9860	- 24.97
6	19	86.6337	- 23.25
7	8	12.1644	- 24.44
8	9	3.9065	- 24.48
9	10	2.6991	155.65
10	11	9.6240	155.56
11	12	15.8113	155.54
13	14	83.6643	155.01
13	15	75.3640	- 25.06
15	16	71.0219	- 25.12
16	27	71.0204	- 25.12
17	18	2.2803	152.94
18	19	2.3754	154.17
19	22	75.4252	- 23.09
19	23	6.6135	- 23.02
20	21	6.1318	- 32.00
22	24	1.4161	- 23.30
22	25	1.9456	- 23.25
23	26	1.2481	- 23.86
TOTAL DEMAND POWER		7.62 (MW)	3.38 (MVAR)
TOTAL POWER SUPPLIED		7.70 (MW)	3.40 (MVAR)
% LOSS	1.03		

CASE 4 19 to 27

2. LINE CURRENTS			
SEND-BUS	END-BUS	CURRENT (MAG)	ANGLE (DEG)
1	2	200.5018	- 23.37
1	3	240.2879	- 24.38
2	4	189.7490	- 23.07
2	20	8.3759	- 29.80
3	6	240.2820	- 24.38
5	6	56.3765	155.53
5	7	18.0837	- 24.46
5	12	22.8347	- 24.46
6	14	15.8225	- 24.50
6	19	156.4390	- 24.32
7	8	12.1670	- 24.45
8	9	3.9099	- 24.48
9	10	2.6993	155.57
10	11	9.6284	155.56
11	12	15.8146	155.55
13	14	12.5056	155.51
13	15	4.2742	- 24.49
15	16	0.0007	177.50
17	18	2.2901	152.93
18	19	2.4176	154.27
19	22	75.6805	- 23.08
19	23	6.6347	- 23.02
19	27	69.5345	- 25.68
20	21	6.1636	- 31.74
22	24	1.4210	- 23.19
22	25	1.9522	- 23.16
23	26	1.2468	- 23.87
TOTAL DEMAND POWER		7.62 (MW)	3.38 (MVAR)
TOTAL POWER SUPPLIED		7.68 (MW)	3.41 (MVAR)
% LOSS	.75		

CASE 3 14 to 27

2. LINE CURRENTS			
SEND-BUS	END-BUS	CURRENT (MAG)	ANGLE (DEG)
1	2	200.0371	- 23.34
1	3	239.7789	- 24.36
2	4	189.7564	- 23.07
2	20	8.3368	- 29.17
3	6	239.7757	- 24.36
5	6	56.3716	155.54
5	7	18.0842	- 24.46
5	12	22.8365	- 24.46
6	14	85.1666	- 25.40
6	19	86.6344	- 23.25
7	8	12.1673	- 24.44
8	9	3.9051	- 24.51
9	10	2.6978	155.63
10	11	9.6253	155.55
11	12	15.8166	155.55
13	14	12.5432	155.57
13	15	4.2863	- 24.40
14	27	69.2972	- 25.62
15	16	0.0011	131.84
17	18	2.2796	152.91
18	19	2.3738	153.90
19	22	75.4224	- 23.09
19	23	6.6117	- 23.01
20	21	6.1318	- 32.00
22	24	1.4193	- 23.31
22	25	1.9489	- 23.25
23	26	1.2495	- 24.00
TOTAL DEMAND POWER		7.62 (MW)	3.38 (MVAR)
TOTAL POWER SUPPLIED		7.66 (MW)	3.39 (MVAR)
% LOSS	.55		

DISCUSSION – BESPREKING

MR DENIS FRASER : Durban

The relative ease of access to digital computer facilities today has provided designers with a tool to eliminate the drudgery involved in the evaluation of alternative solutions to give a problem.

As the engineer has an obligation to produce the optimum solution, taking into consideration initial capital outlay and subsequent operational costs, it is encumbent upon him to utilise this facility to the utmost and to endeavour to keep abreast of the rapid advances in computer technology and the avaibility of the associated software packages. In this regard I would be interested to know whether Mr Herman explored the availability in the libraries of computer suppliers of existing software packages to produce the required system analysis, before embarking on the compilation of his own programme.

The biggest difficulty in attempting to design distribution systems is, as Mr Herman points out, the inability to forecast loads accurately, both in terms of magnitude and time. For this reason it would appear superfluous to calculate currents as his programme does to 4 decimal places, when the load could vary quite easily by 25% from the estimated.

The optimal design of distribution networks provides constraints on system expansion, since an optimally designed

system is less able to meet an unforseen change such as the doubling of load by a single large consumer.

Our own experience with small portable computers is that the entry of data is slow and since they are generally only capable of being programmed with low level languages, they are not particularly economic on available memory capacity. The output format is also usually limited and this can be seen in the outputs appended on the paper.

It is rather comforting to me and perhaps to other engineers of my vintage, who may not be quite "with it" in terms of computer knowledge that, to quote the author, "it is not possible to replace the role of the experienced engineer with that of a computer".

However, Mr Herman's paper provides a very timely reminder that we need to apply this experience with an open mind and test the validity of "rule of thumb" solutions against other options, which could not so readily be done before the current "computer age".

A few queries arise in my mind after studying the paper and Mr Herman's replies thereto would be appreciated.

1. Can the program be used to determine the optimum size and physical location of substations and cables in new residential townships with a given ADMD?

2. An important consideration in determining cable sizes in an electrical distribution system is the available fault current that the cable has to withstand. Does the program determine the cable size, taking fault level into account, or has one to input various cable sizes in addition to the other options of alternative cable route lengths?

3. Should there be an 11 000 Volt cable fault on a system, can the program be used to determine the most economical alternative feeding arrangements?

MR R HERMAN : Stellenbosch

Just a few comments on some of your queries. *The availability of software.* Originally I did have a look at some of the software available. Some of the better material I saw in a software magazine, which was not a distribution/analysis programme, but was a power system package from the United States. I wrote to them and at first they didn't even reply. Eventually they replied and said "Do you have a vax?". Yes we do have a vax. The vax is a main frame type of computer. The cost of the package was 100 000 dollars. That is why we did not pursue that one too far. In any event the whole exercise was to gain an inhouse experience of this sort of thing. *Your comment about accurately forecasting.* I know that this is, as the Afrikaners would put it, a "turksvy". Sure this is a problem, but I think in any event, whatever you do, there are still some decisions to be made. At least, based on given values, you can use the program to determine the relative merits of alternative ideas and that is what this is all about.

About memory capacity. I remember two years ago, when I heard someone talking about using a micro-computer for this kind of work, that I really laughed and I must ashamedly say now that I can see the folly of my ways then. With a little bit of jiggling, and looking at the algorithms again, we have found that we can overcome this problem to a large extent. As a matter of fact the IBM-PC, which is not a very sophisticated computer, can probably handle about six hundred substations and eight hundred lines, so it is big enough. *Optimization.* The program as such is not an automatic optimization program. I see this is a challenge for the future. One would first have to use another Afrikaans terminology, "die mense mak maak" with an interactive program, before one can look at automatically determining cable sizes. This is possible with mixed integer mathematical programming, but I think we would rather leave that one there.

You spoke about fault levels. Again no, it does not automatically select the right cable size according to fault levels. You'd have to use it interactively. It is just a tool. And a very definite, yes, to your last question about *investigating alternative supplies.* The package is not just used as a design tool, but it can be used to do ongoing investigation of the system. As loads are updated and the whole system becomes updated, one can get a quick picture of what is going on in the whole system. And you can, and this is done very easily by just switching certain feeders in and out, do your contingency planning to see what the currents look like under those conditions and voltages.

MR ALWIN FORTMANN : Boksburg

You took the 66kV busbar as being a common busbar. Having said that, then surely all those feeders leaving that busbar, would supply a system which could be treated as an entity. In other words, the capacity of that computor need not be as big as 600. You said your computer could take 600 substations and 800 lines. Then each branch leaving that 66kV busbar, which is now a common busbar, could be treated as a separate entity. Is that correct? In other words, it would possibly be a lot smaller than the whole system of a medium size city or town. Thank you, Mr President.

MR R HERMAN : Stellenbosch

Yes, I agree with you, that if one regards each OLTC, shall we say, with its area of supply, you can then regard just that small area as a unit, and that is all that I have done for this example. But the program does make provision for inclusion of the whole set-up. This would also help with a data base facility that you are providing. It also means that one would then be able to shift areas from one area of supply to another. It would be awkward to edit or to maintain on the program, if you just had little subsections that you would treat separately. This would mean you would not be able to transfer electrical data or lines basically to another section. So if you can include it all in one, it will make it a bit easier for the data handling.

MR MAX CLARKE : Randburg

What does Mr Herman see as the future? It seems to me he is developing or has developed a program which is of importance in practice, and is at the moment really an academic excercise. What is going to happen ? Will we, as practising engineers, benefit by this program, or will we send engineers for training to the university? Or will we send down a series of bits of data for inputting to his program to get answers out?

MR R HERMAN : Stellenbosch

We have been fortunate at the University of Stellenbosch, to start an Institute of Electrical Technology, headed by Mr Rapha Pretorius. This body will make available its services to the profession at large in an advisory capacity. The package is also for sale.

MR TREVOR GAUNT : Affiliate

Mr President, Mr Herman is to be commended for his work reported in this paper, which shows how the power of small computers can be applied to the design of electrical power systems. He has shown that two advantages may be gained from the use of computers : storage of the system details and multiple calculations. These would be too long to carry out by hand. With these two ideas in mind I have a few comments and questions on Mr Herman's paper.

First, I note that loads have been represented as constant power loads, expressed as kVA and power factor. As most load transformers in the distribution network operate on fixed tap, virtually only rotating machines would be constant power loads. A very high proportion of the loads in a municipal area are constant impedance loads – lighting and heating. The calculations can be greatly simplified by assuming constant impendance loads, without reducing significantly the accuracy of the solution. I would appreciate Mr Herman's comments on this.

My second comment relates to the evaluation of the results. Mr Herman has assessed the alternatives studied in his example, purely on the basis of sytem efficiency, from which case 3 appears the most attractive. The saving in losses of case 3 over case 4 has a value of less than R2 000 per year, based on the maximum design loads, while the initial capital cost of the extra 250m of cable could easily outweigh the saving in losses. As he said, other criteria used in evaluation of results may include operating flexibility or provision for future growth. Because evaluation can depend on so many aspects which may be difficult to build into a small program, we have found that computer solutions to similar problems must be viewed very critically. This is not to say that the computer solutions are not worthwhile. On the contrary, they permit investigation of design alternatives which entail many calculations and would be beyond the reach of manual study. For examply, in the recent design of a new large high density, high economic category township we were able to test various lay-outs, distribution transformer sizes, cable sizes and materials to meet given design criteria. The saving achieved in the final design can easily be as much a 10% of the cost of what could normally be accepted as an acceptable design. Ten percent may sound a lot, but if we remember the country requires perhaps a million new erven to be supplied within the next few years, then a 10% saving throughout the network design represents a saving to the country of hundreds of millions of rand. Therefore, Mr Herman's encouragement of the use of computers in distribution network design should not be taken at all lightly.

MR R HERMAN : Stellenbosch

This reminds me of one possible sort of solution that I attempted before I had a computer. I was in charge of planning and I made use of a DC board, in other words, I just represented the loads and the lines as fixed resistors, based on the impedance values. This was the best I could aim at, at the time. I suppose there is some merit in choosing it. The accepted classic path that engineers follow is along the lines that I have mentioned. About the losses and flexibility of choosing a design, I still see that the computer replaces to a large extent the slide-rule voltage-drop chart or whatever. It is just a tool. It needs an engineer to use it and the idea is not that it will untimately give you the perfect design. You have got to *use* it, and the aim is to provide something with which a person can do a lot of calculations. For the particular system that I showed you there, getting down to a 0,0001% accuracy on voltage, requiring about 38 calculations. I think with an IBM-PC plus and 8087 co-processor, this took only about 17 seconds. I think that is quite a bit faster than you could do by hand. The beauty is that one can have a look at the result and try different things. It is interactive and in the end decides on a solution. So the decision is yours.

MR R R SLATEM : Affiliate

Mr Herman, thank you very much for a very interesting paper, and very useful concepts. My contribution is to suggest that there could be an extension of the use of the computer from the 3-phase fault study, but also in my realm of protection. We need the results of earth fault studies. This would also be very, very useful in determining the required setting for relays, particularly on networks where the earthing is effective or solid and not resistance earthing.

MR PIET BOTES: Roodepoort

Mnr die President, mnr Herman het 'n baie interessante referaat gelewer oor 'n onderwerp wat vir my besonder interessant is. Die probleem is egter dat daar 'n tekort aan ingenieurs is om die rekenaar te gebruik, asook die feit dat ek met my administratiewe pligte self sukkel om aan die gang te kom.

In die gebruik van 'n rekenaar moet daar wees:

1. Netwerkvoorstelling vir lasbepaling van voerders;

2. Netwerkvoorstelling vir foutstroomberamings;

3. Netwerkvoorstelling vir relè instellings.

Selde kan dieselfde netwerkvoorstelling gebruik word. Dit beteken dan 'n groot geheue om hierdie netwerkvoorstellings te bewaar, want jy wil uit die aard van die saak hierdie netwerkvoorstelling behou vir latere gebruik. Dit beteken 'n redelike groot rekenaar en die nodige bybehore om hierdie netwerk voor te stel. Kommentaar hieroor word verwelkom.

MNR R HERMAN : Stellenbosch

'n Mens sal graag baie aspekte wil inbou in so 'n program, maar daar is 'n grens. 'n Mens moet op die ou end besluit tot hierso en nie verder nie. Maar wat betref die geheueprobleem was dit 'n uitdaging vir my, want ek is gewoond aan die hoofraam rekenaar, die rekenaar met die groot geheue. Die normale manier om hierdie probleem op te los is by wyse van die admittansie stam-matriks, waarin daar 'n hele klomp nulle is. Wat ek hier gedoen het, is dat ek heeltemal ander algoritmes gebruik en glad nie van matrikse gebruik maak nie. Ek stoor slegs die nie-zero elemente van die matriks. Wat betref die geheue is dit nie so 'n groot probleem nie. Hedendaagse geheue is goedkoop en ons praat hier van 'n rekenaar in die orde van 4 – 4½ duisend rand vir hierdie soort van pakket.

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INTRODUCTION OF MR R SLATEM

MR W BARNARD : PRESIDENT

Mr Slatem is well known as one of the country's leading experts in electrical protection. His early training was an apprenticeship with the Johannesburg City Council. He is one of our first scholars and his subsequent career with ESCOM was devoted to protection. He ended his career with ESCOM as head of the protection division. Since 1979, when he went on early retirement, he has been self-employed as a consulting engineer.

Mr Slatem has had extensive experience in lecturing and we look forward to another of his erudite and lucid presentations on a subject which is of interest to all power electrical engineers.

R R SLATEM

Pr Eng BSc (Rand)
FSAIEE Private Consultant

PROBLEMS AND ADVANTAGES OF STATIC RELAYS

1. INTRODUCTION

Static relays were first introduced on the market in the 1960's, largely because of the flexibility of design possible with static as compared with electromagnetic components. In these early days little was known about the electrical environment in substations as far as secondary circuits were concerned. The early experience with static relays was disastrous because of the high levels of induced and electrostatically coupled transient overvoltages present in the stations and the vulnerability of the static circuits to such overvoltages.

Fig. 1 illustrates the situation that existed. The transient overvoltage levels present in the station far exceeded the withstand capability of the early designs of relays and all over the world static relay failures were the order of the day. This caused a considerable set-back in their use and there are still application engineers who are prejudiced against them because of those early experiences.

But the attractive features of static designs were so outstanding that both users and relay designers were determined to overcome the problems and in the early 1970's the situation was brought under control. The users learned to reduce the levels of overvoltages produced by relatively simple inexpensive methods and the relay designers increased the withstand capability of the relays by isolation and filtering techniques so that we now have the situation depicted on the right hand side of fig. 1 where the relay withstand capability exceeds the levels of transient overvoltages by a comfortable margin.

Stringent type testing requirements were introduced by authorities such as BEAMA, ANSI, IEC and other national standards organisations such as the Swedish SEN, and, provided that these requirements are included in the specifications for static relays and the relays pass the tests, it can now be stated that transient overvoltages need no longer be a problem for static relaying on stations where the control cables have armouring earthed at both ends.

Having overcome this major hurdle, the way was open

to exploit the advantages of static relays and this has been tackled vigorously by virtually all major relay manufacturers.

This paper addresses those areas of interest to the municipal engineers and discusses briefly some of the problems and advantages of static relaying.

2. PROBLEMS

2.1 Probably the most pertinent problem for the municipal engineer is that of power supplies for static relays, especially when these are to be used in small substations normally fitted with tripping batteries and chargers of limited capacity. Users are reluctant to depart from their standard arrangements by providing batteries and chargers capable of meeting the standing load of static relays. Some relay manufacturers have addressed the problem by powering the static relays from the CTs but this tends to defeat one of the important advantages of static relays, namely, their low burden on the CTs, about which more later. Another approach which does not have this disadvantage is to power the relay from the AC supply normally and only snatch the battery for the short time the relay requires to operate and this only if the fault caused a collapse of the AC supply voltage. Capacitor bridging standby ensures that there is no interruption of supply to the relay or trip circuits during this process, see fig. 2. The unit is designed as part of the relay assembly and provides an economical alternative to increased charger and battery capacity.

The combination of a small battery and an AC supply for the normal standing load of the relay is also preferable to the use of pure AC energised capacitor tripping units which have the disadvantage that they may not operate when closing into a fault after a prolonged circuit outage.

2.2 A second problem which may be experienced by users of static relays is that of trip testing the breaker from the relay. Normally with static relays it is not possible to gain easy access to the output trip relay contacts and operate them to trip the breaker. With electromechanical relays it is usually easy to obtain access to the contacts and provided these are handled with due care, cause them to close and trip test the breaker.

This is not a problem when the circuit is being injection tested for commissioning or during routine relay tests since the required quantities to cause relay operation can be injected and allowed to result in breaker tripping. It may be a problem,however,when changes have been made to the circuit breaker or its control wiring and it is desired to prove that the trip function is still healthy on completion of the modification, without resorting to injection testing.

There are two solutions to this problem. The first and simplest consists merely in the bridging of the output trip terminals on the relay, or on the test device, to simulate a contact make. This can be considered perfectly satisfactory if the relay has recently been injection tested to prove that the injected quantities close the contacts and either trip the breaker or stop a timer, i.e. that they are functional up to the test device.

If this is not considered satisfactory as a universal solution, it is possible to arrange for a Spring return key switch to cause momentary operation of the final output relay so that its actual contacts do the tripping of the breaker. Only authorised personnel would have access to the key. This is actually an ideal solution in my opinion since it controls the access to the trip test function and prevents unauthorised (and probably ham-fisted) personnel from having access to and possibly damaging the relay or its contacts. It also prevents the prevalent and undesirable practice of some technicians who insert slips of paper between the contacts to prevent tripping when testing and either forget to remove them, or introduce dirt to the contact surfaces to the detriment of the protection reliability.

2.3 Finally, there is still a psychological problem for field staff accustomed to electromechanical relays to adjust to static relays where they cannot see discs turning or armatures operating etc. Experience shows that this problem is soon overcome if the staff are allowed to experiment by setting and testing static relays following a programme of instruction in their use and advantages. The ease with which the relays are tested and the delight which their accurate and consistent response produces soon win acceptance by the field staff and in many instances original prejudice turns to preference for static relays.

3. ADVANTAGES OF STATIC RELAYS

3.1 Summary

The following list details the many features of static relays and it is intended to show by typical applications pertinent to municipal service how some of these can be used to advantage.

1 Better characteristics (e.g. directional and differential relays).

2 Higher accuracy (% of actual setting not maximum setting).

3 Better repeatability.

4 Low overshoot.

5 Better reset ratio.

6 More flexible and adaptable.

7 Wider current setting ranges.

8 Low burdens on CTs and VTs

9 Simpler testing and repair (card level replacement).

10 Virtually no maintenance.

11 More compact.

12 Lower cost (especially in more sophisticated applications) e.g. differential and distance relays.

3.2 Static Inverse Time Relays (IDMT)

3.2.1 Starting characteristic

Electromechanical relays of the induction disc type start to move at a certain multiple of the setting, usually somewhere between 105% and 110%, and complete their travel at a higher multiple – usually somewhere between 110% and 130%. At these multiples the relays are crawling and the torque levels are very low so they take very long times to complete their travel and often don't operate both the flag and the contacts. Attempting to set these to operate together is both trying and tedious.

Static IDMT relays, on the other hand, have a definite pick-up within 5% of the setting, and the fact that they have picked-up is usually indicated by a LED. Once pick-up has occurred, it is certain that a sound relay will complete its travel and operate both contacts and trip indication. The start function also has a reset value greater than 90% of the setting which guarantees that the relay returns to the full "travel" position as soon as the reset value is reached whereas elecromagnetic relays will tend to crawl slowly back at this current level.

On some static IDMT relays a separate pair of output contacts is available and this can be used either for indication purposes or for a form of slightly delayed busbar protection for MV circuits (e.g. 11 kV) which is superior to the common frame leakage protection since it covers both phase and earth-faults and eliminates the need for insulating cable glands and the switchboard from earth. The principle of the bus protection is illustrated in fig. 3. If the starting relay on the incomer A operates, it starts a timer which will trip A after, say 0,1 seconds. If one of the starting relays on an outgoing circuit B picks-up, however, the timer is blocked and B trips after its set delay in the usual way. With the incoming relay A located on the HV side of the transformer, as shown, this bus protection provides much faster cover for both transformer and busbar faults than would be possible with the normal inverse-time back-up settings.

3.2.2 Inherent in most static IDMT relays is a highset instantaneous overcurrent element with low transient over-reach. Because of its low transient over-reach the instantaneous overcurrent element can be set much closer to the fault current level at the remote terminal and this increases both the possible number of applications and the cover aforded where there is significant variation in the source impedance. The latter factor is illustrated by figs. 4 and 5. 4A shows the symmetrical fault current obtained when an inductive circuit is energised at a voltage peak. Ideally the instantaneous high set relay should be capable of being set at say 110% to 120% of this peak current as shown. Because faults seldom occur exactly at the voltage peak, however, there is usually a DC offset transient component of fault current, fig. 4B, which causes the transient instantaneous current to exceed this setting and result in undesired operation of the simple high set overcurrent relay usually included in IDMT relay assemblies. Consequently such relays normally have to be set at approximately double the maximum symmetrical current level at the point of maximum desired reach, and they may not even operate for the minimum fault current IF1 on the protected circuit, as illustrated in fig. 5, where the minimum high side fault current level is 6 pu but the setting required for a normal high transient over-reach relay is about 8,1 pu if it is not to operate for a transformer LV side fault with maximum source (i.e. minimum source impedance).

Obviously such a relay will only operate for transformer high side faults F1 if both generators are in service.

In our example, setting low transient over-reach static relays at 120% of the maximum rms value of IF2 = 4,5 pu results in a setting of about 5,4 pu which is less than the minimum high side fault current of 6 pu so the low transient over-reach relay can operate for all high side transformer faults.

Even where the high side fault current IF1 is sufficient to operate both types of relay, the low transient over-reach static relay will provide faster fault clearance because of its inherently greater speed and the greater multiples of the setting which will result from the lower settings.

The transient over-reach in % is defined as:

$$\% \text{ over-reach} = \frac{(1-k)}{k} \times 100$$

where k (less than 1) is the highest pu value of the rms relay setting current that will not cause relay operation when the current is switched on in a highly inductive circuit.

Conventional electromechanical high-set overcurrent relays have a % over-reach of the order of 90 – 100 (k = 0,5 – 0,53).

Static high set instantaneous overcurrent relays, on the other hand, usually have a % transient over-reach of the order of only 10% (k = 0,91).

3.2.3 Electromechanical IDMT relays have relatively high burdens compared with the equivalent static relays and the ohmic value of these burdens varies considerably with the setting, which is not the case with static relays, as illustrated by fig. 6 for a typical earth-fault relay. The reduced static relay burden could result in a marginal saving in CT costs if lower output CTs were specified but this is not the area where maximum benefits result from the use of static relays and their low CT burdens. Of far greater importance is the behaviour of the CT/relay combination for low CT ratios and high fault levels. With conventional CTs of say 10 VA class 10P 15 the CTs will retain accuracy up to a much higher fault current with static relays and the relative independance of these relays from the effect of saturation harmonics means that relay co-ordination can be ensured up to these levels even with low primary settings. Also the CT voltage required to cause relay operation is considerably reduced even for low relay settings with the consequence that the magnetising currents of the CTs are also very low and their effect on the actual primary setting is minimal with static relays. This is of value in applications where the CT ratios are high but earth-fault currents are limited to low values by neutral earthing resistors resulting in the requirement for low relay settings. With electromechanical relays, reducing the relay setting will generally result in an actual increase in the relay primary setting, as shown in fig. 7 but the low burden of static relays makes virtually any value of primary setting possible.

Another area where the low and virtually constant burdens of static relays can be of value is in the application of overcurrent, earth-fault and restricted earth-fault relays to transformers. It is absolutely taboo to combine electromechanical IDMT relays with restricted earth-fault relays on the same CTs because of the effect variations of the electromechanical relay burden with the setting, has on the ohmic impedance in the restricted earth-fault relay circuit. This is shown in fig. 8 where the required restricted earth-fault settings are worked out for a typical case assuming combined use of the CTs. It is obvious that the setting of 3050 volts for the electromechanical relay is completely impractical whereas for the static relays the setting voltgage of 90V is by no means unattainable or impractical for 1A CTs.

Fig. 9 shows the standard arrangement that would be required if overcurrent and earth-fault protection and restricted earth-fault protection had to be applied to a transformer star winding, assuming electromechanical relays. A total of 8 CTs would be required for this winding. Fig. 10 shows the standard arrangement possible and perfectly acceptable with static relays where only 4 CTs are required, which would represent a saving of typically R400/R600 per circuit.

3.2.4 Because the accuracy of static relays is based on the actual setting of the time multiplier and not on the setting corresponding to TM = 1, as for electromechanical relays, the relay accuracy and the repeatability of the operating time is greater for static relays. This can be compared to digital and analogue instruments where the accuracy of the latter is always specified as a percentge of full scale deflection, not of the actual reading.

The low overshoot, greater accuracy and improved repeatability, which is characteristic of static IDMT relays, combined with the consistent and faster operating times of modern SF6 and vacuum circuit-breakers, means that reduced grading intervals are possible and this in turn means that more breakers in series can be co-ordinated with the supply authority breaker whose setting is usually the determining factor.

It has been found practical to use grading intervals as low as 0,2 seconds with static relays and SF6 or vacuum breakers.

3.2.5 Electromechanical IDMT relays have reset times of up to 10 seconds at TM = 1 and this means they can integrate during reclose sequences and lose co-ordination. Static relays reset in 40 – 60 ms so there is no integration and consistent co-ordination is ensured between such relays, even on rural systems with multiple reclosures. In fact the lack of integration means that additional reclosures can often be introduced on such systems when static relays are used.

3.2.6 Testing of static IDMT relays is simpler than that of the electromechanical versions. As already pointed out, pick-up is a definite point within 5% of the setting so this requires only one test per current tap to be checked and simultaneous contact and flag operation are assured. There is no problem of creep and also no problem of having to try and co-ordinate flag and contact operation. It is not necessary to measure the reset time.

Timing tests with electromechanical relays often yield results differing from the standard curves and this is frequently due to an inadequate test set giving test current wave-form problems. These relays are highly susceptible to timing errors if the wave form is not sinusoidal and, as their burden is not linear but is a function of the multiples of the setting due to saturation, it has a tendency to create significant third harmonic components unless the test circuit-impedance is reactive, linear and at least 6 – 10 times that of the relay's unsaturated impedance.

Fig. 11A shows the burden variation with respect to current of typical electromechanical relay and of a static relay. If the electromechanical relay is fed from a low impedance (voltage) source the test wave form will be peaky, as shown in fig. 11B, whereas that for the static relay with its linear burden will still be sinusoidal. Attempts are often made to test relays from low voltage sources (e.g. a primary injection test set) and this can often give unacceptable timing errors with electromechanical relays especially on low plug settings. A word of warning! If you find large timing errors,don't attempt to re-calibrate the relay until you have established that your test circuit is giving a sinusoidal wave-form without obvious visible distortion.

Fig. 12 shows a simple test set developed mainly for testing static relays. It includes a variable current source up to 50 amperes continuous rating and has a separate circuit for supplying the power supply to the test relay.

It includes a CT and a VT for test circuit isolation from earth (most important!) and for checking the magnetising currents of CTs. It has built-in circuit loading resistors and a capacitor which can be used for checking directional relays.

The test set can be used for electromechanical relays if an additional swamping reactor (available for the set) is included.

3.3 Transformer Differential Protection

In this important application static relays can offer several advantages:

3.3.1 High Stability

High stability for external faults even in the presence of CT transient saturation. The majority of differential relays require that the CTs should not saturate up to the maximum through fault current, allowing for the X/R ratio (usually between 5 and 10) of the primary circuit. This normally requires expensive class X CTs since other protection CTs cannot be guaranteed to have adequate performance. Because of the flexibility of the static design such differential relays can have additional safeguards built in to ensure stability for external faults. One such technique is called pulse width integration and this recognises the difference between operating current or spill current due to internal and external faults with CT saturation by requiring the width of the operating pulse and the off period between pulses to have a certain ratio. This ratio is always satisfied for internal faults but not for the spill current associated with external faults during transient saturation. The principle is illustrated in Fig. 13. Because of this technique, far less expensive CT's having approximately 20% of the knee point voltage required for electromechanical relays can be used. This can be extremely useful especially where low ratio CT's have to be accommodated in the HV bushings of transformers.

3.3.2 High Set Unbiased Instantaneous Feature

One of the requirements of a protection scheme is that the speed of operation should be matched to the severity of the fault, i.e. it should be as fast as possible during severe faults to reduce damage, etc. to a minimum but it can afford to be slightly less rapid for lower fault stability. Biased differential relays can sometimes be slowed down during severe internal faults because of CT saturation. Again the flexibility of static designs enables the relay manufacturer to overcome this undesirable feature by including a fast high set unbiased instantaneous trip feature which detects severe internal faults rapidly but is unaffected by external faults and which can be set so that it is not affected by magnetising inrush currents. With this feature severe faults will result in a trip im-

pulse to the breakers in 10 – 20 ms compared with approximately 30 ms for the biased feature.

3.4 Directional relays

Directional relays are used for controlling IDMT overcurrent relays where it is required to maintain grading on ring or parallel feeds and for separation of systems for reverse power where there is co-generation. Co-generation probably only applies in the case of the larger municipalities. In these relays static designs have made their impact by providing greater sensitivity, combined with much lower CT and VT burdens.

3.4.1 A static relay is available for controlling directional overcurrent relays which is virtually independent of the polarising voltage level provided this is above 0.15% of normal. This high sensitivity in terms of voltage, combined with quadrature polarisation, means that the relay will still maintain directional sensing correctly for all arcing faults, including three-phase faults because the arc voltage drop will never be less than the required polarising voltage. Even for bolted three-phase faults, (e.g. working earths left on) the directional sensing will be correct provided that there is length of busbar or cable, carrying the fault current, of only a few metres between the VT and the fault. And at these low voltages the relay only requires a secondary current of 3A for correct operation while maintaining its continuous current carrying capability at 15A (i.e. at 3 x FL current for a 5A CT).

Comparative figures for typical electromechanical relays would be of the order of 15A required at a minimum voltage of 0,5% – 0,6% of nominal.

Hence the sensitivity of the static relay ensures that correct directional action will be maintained down to much lower levels of voltage and current than its electromechanical counterpart and this increases the attractiveness of direction overcurrent relaying on ring or parallel feeds.

3.4.2 This relay is available in a variety of current setting ranges and, combined with a timer, can be used for definite-time directional overcurrent or earth fault protection where the fault current has significantly the same level throughout the protected network, i.e. where its value is determined largely by the source rather than the network impedances, e.g. on a cable network having short lengths of cable and fed by a relatively weak supply, or having resistance earthing in the case of earth-faults. Because it does not require separate overcurrent relays, it provides a highly economical directional overcurrent and earth-fault protection.

3.5 Distance Relays

On the higher voltage circuits at 132 kV and above in use by the larger municipalities, and being introduced at an increassing tempo by others, distance relays can offer significant advantages over pilot wire protection (see Appendix 1). For example, distance relays will still provide fast protection for 60% of the circuit even when the pilot communication link is out of service, and will still cover faults instantaneously for 80% of the circuit from the relaying terminal, besides providing back-up superior to that of overcurrent relays and also a measure of delayed back-up protection for busbars. The problem of multiple transformer feeds tapped from the main circuit can also be solved elegantly by distance relays, provided that the neutrals of the tapped transformers are not earthed. This is a most important requirement since multiple earthed neutral taps make both pilot wire and distance earth-fault protection virtually impossible due to the zero-sequence infeed at the tap points.

It is possibly not always appreciated that distance relays can be applied to both cable and line circuits at all voltages from 11 kV upwards and this has been made possible by the superior characteristics that can readily be achieved by static relays compared with electromagnetic relays. Virtually all modern distance relays are static but not all of them have the flexibility of being able to adjust the reach in the resistive and reactive axes independently, a feature which makes the same relay equally well applicable to lines and cables as shown in fig. 14. Distance relays usually have better directional discrimination than the directional elements used with directional overcurrent relays and can function correctly and instantaneously for zero voltage faults.

In this brief review of static relays it is not possible to treat the many other features of distance relays. This could well be the subject for a future technical discussion.

4. CONCLUSION

This review of the problems and advantages of static relays has endeavoured to illustrate by way of random examples how the features of static relays can be used on municipal networks and to provoke discussion of this important and ever expanding development in protective relaying.

If there is any doubt in the minds of municipal engineers about the reliability of static relays, perhaps the following facts will provide food for thought:

(a) Static relays for on-load tap changer control have been in use in this country on municipal networks for many years with great success. In fact, many local authorities have a programme for replacing their existing electromechanical tap-changer control relays by the superior static relays.

(b) Koeberg Power Station, for which the highest possible reliability is essential, has a large proportion of static relays.

(c) Escom's new major power stations, Matimba and Kendal, will be equipped entirely with static relays of all types, including those for overcurrent and earth-fault on the auxiliary supply circuits and for motors. This plant is essential for the correct operation of the station and therefore there can be no compromise on their reliability.

It is important to consider static relaying in its overall context and not merely to compare its first cost with that of EM equivalents. Often static relaying is more cost effective in spite of possible higher initial relay prices because of its compactness which can result in less panel space, smaller relay rooms, and in the need for fewer and less expensive CTs.

APPENDIX 1

A CRITICAL COMPARISON BETWEEN PILOT WIRE PROTECTION WITH OVER-CURRENT BACK-UP AND DISTANCE PROTECTION

While pilot wire protection may be the obvious choice for

networks where pilot cables are already available and the expense of adding cores for the protection is negligible, many networks do not lend themselves to the use of inverse time over-current relays for back-up. It is often difficult if not impossible to obtain grading of over-current relays even if these are provided with directional features, unless some form of automatic network splitting is resorted to. Since pilot wire protection has proved in the past to be somewhat vulnerable, it is essential to have fast and selective back-up protection. On some networks this can only be provided by means of distance relays and these would require the special characteristics now available on modern distance protection, with independent setting for reactance and resistance cover. The relative advantages and disadvantages of pilot wire protection with overcurrent back-up compared with distance protection are given below:

PILOT WIRE PLUS OVER-CURRENT BACK-UP

Advantages

1. The pilot wire scheme provides unit protection.
2. This is fast.
3. The unit protection is fully selective.
4. It is more sensitive to high resistance earth faults.

The above advantages apply provided that the pilot cable is healthy.

Disadvantages

1. The back-up protection is slow.
2. It may be impossible to co-ordinate it correctly for the network.
3. There is frequently difficulty in arranging settings with suitable co-ordinating intervals that can ensure operation of the protection in advance of the Escom protection.
4. The pilot cables are vulnerable to mechanical damage, electrical damage and theft.
5. The main protection is entirely dependent on the pilot cable for fast and selective operation.
6. It is liable to trip incorrectly if the pilot cores are shortcircuited. (Unless starting and supervision relays are provided).
7. Experience with pilot wire protection in South Africa has been poor where the pilot cable runs in the vicinity of transmission lines.
8. The current transfomers for the pilot wire scheme must have high transient performance capability to ensure that they do not saturate for maximum through-fault current and system time constant.
9. Conventional directional phase and earth fault relays will possibly not operate satisfactory for three-phase faults or earth faults on a multiple earthed network.
10. IDMT OC, EF and high set instantaneous relays are difficult to set. A full network study is required and this must be repeated every time there is a network or system change. It is difficult to ensure that the settings are always correct as the network develops and as the source feeding the network changes.

DISTANCE PROTECTION

Advantages

1. Distance relays, if used in conjunction with a pilot cable, can provide both unit protection and back-up protection.
2. The unit protection is available for at least 60% of the line even if the pilot cable is out of service. It will also cover faults in the first 80% of the line from the relay instantaneously without the pilot being available.
3. Distance relays can be used in the overlapping mode to provide fast cover for the whole line without a pilot link but there is some risk of overtripping for faults on the first 20% of the adjacent zone. It is considered that this risk, coupled with auto-reclosing, can be accepted for overhead line schemes where the loads are domestic and brief interruptions of supply are of no significance.
4. The back-up protection is relatively fast compared with inverse time overcurrent relays and it can be made more selective.
5. Distance relays provide relatively fast protection for all faults on the line and also for remote busbar faults, transformer bushing faults, etc.
6. Distance relays are fully directional for close-up faults, whether these are balanced or unbalanced, even with the pilot link out of service.
7. There is normally no problem in grading the distance relays from complex systems. They will normally provide superior grading with the supply authority relays.
8. The relays can be used to provide HV and EHV busbar protection at the transformer station by making use of the reverse reach facility available on modern distance relays.
9. Generally there is a voltage transformer available at every line terminal and there will therefore be no additional cost in this respect for distance relays.
10. Distance relays are extremely simple to set. No network study is required. The settings are unaffected by changes elsewhere on the network, in general. They are also unaffected by changes in source conditions.
11. Modern distance relays are relatively easy to commission and require virtually no maintenance.

Disadvantages

The major disadvantage of distance relays is their additional cost but this is negligible in the total cost of most HV and EHV schemes and fully justifiable in view of the improved instantaneous protection and back-up protection that can be afforded even with the pilot link out of service. If the distance relays are used in the overlapping mode there is some chance of overtripping for a fault on the next section of line but the extent of this is considerably reduced by infeeds from parallel lines and of zero sequence current from transformers connected to the busbars.

It should be appreciated that distance relays having mho characteristics are not necessarily suitable for use on networks having such short lines or cables but modern distance relays with independent reactance and resistance setting are designed to be able to function correctly for extremely short lines and cables. From the above, it will be obvious that distance relays will not only provide superior protec-

tion characteristics for many networks particularly if trouble is experienced with the pilot cables but also for busbar faults and any condition requiring the back-up protection function.

One relatively large 132 kV municipal overhead line network was planned with pilotwire protection and distance back-up. For various reasons the pilot cables were not installed and the system has been running with complete success for several years now using the distance relays in the normal zone stepped mode. This example shows how the additional expense of pilot cables, significant in overhead line networks, can be avoided by the use of distance relays thus making the latter cost effective.

APPENDIX 2

PILOT WIRE PROTECTION FOR MULTITERMINAL FEEDERS

Although the protection to be described briefly does not really fall under the category of static protection in the sense that it does not require a separate power supply, but it does use static components, it is a product of the static era and is compatible with static relays. The main reason for its inclusion in the paper is the belief that a real need exists for a multi-terminal pilot wire protection. In many applications loads are tapped off a feeder which is part of a ring main or of an interconnected system. If these loads are of significant size compared with the through load of the circuit, conventional two-terminal pilot wire protection will be unstable particularly for faults on the load taps. Tripping of breakers, however, is usually only required at the two ends of the circuit; all that is required at the tee points is that the protection shall be stabilised for currents which flow out at these points.

The pilot wire protection system shown in fig. 15 provides a tripping relay at each end of the feeder and the necessary means to ensure that faults or loads beyond the tee points will not cause the protection to function incorrectly. The protection is shown for a single tee point but there is no theoretical limit to the number of tees that can be accommodated, the limit being a practical one based on the number of pilot cores available, since for "n" terminals the protection requires "n + 1" pilot wires between all stations.

At each station the CTs are connected to a conventional summation CT which produces a single phase output for each and every possible fault or load condition. At the two terminals A and C these summation CTs are connected to the measuring circuits via diode pairs across which is connected the stabilising resistor RS. The differential circuit is connected between the mid-points of these stabilising resistors and carries the phasor sum of the currents from each terminal. For external faults beyond the terminals A and C or on the tap B, this sum is zero. At the same time the currents set up a bias voltage US across the bias resistors RS.

Any spill current Id1 due to CT mismatch or transient saturation will tend to set up an operating voltage Ud3 across resistor Rd3. The sum of the operating and bias voltages is applied across the differential circuit X – Y and it can be shown that, with correct choice of Rs and Rd3, Ud3 will always be less than US for external fault – and load conditions, so there is no tendency for current to flow through the polarised differential relay dR and the protection is therefore stable. For internal faults above the relay setting, however, it can also be shown that Ud3 will always exceed US so that operation is guaranteed at both ends of the feeder.

The protection has the following features:

1. It can be applied to a number of terminals, provided enough pilot wires are made available, and that only two terminals require tripping.
2. It can be used with CTs of different ratios at each terminal.
3. It can accommodate up to 900 ohms of pilot resistance per wire.
4. Pilot capacitance does not adversely affect its operation.
5. It can accommodate cable or line shunt capacitance up to 30% of the CT ratio.
6. The CTs normally used with pilot wire protection are perfectly satisfactory.
7. It is based on a principle which has been proven in practice on thousands of busbar protection circuits.
8. The only requirement for the pilot cables, as far as the relay is concerned, is that they shall be capable of withstanding the normal 2 kV, 60 second power frequency test between cores and to earth. Of course the normal requirements for induced longitudinal voltages must also be satisfied.
9. The scheme can be provided with pilot supervision, starting relays and intertripping.
10. Settings within the range 10% – 40% In are possible for all faults but higher setting can be provided if required.
11. Internal faults are detected within 1 ms and a trip output given to the breaker within 6 – 8 ms. So the protection is exceptionally fast.
12. The protection can be used for overhead lines or cables at any voltage level from 11 kV up to 500 kV. At the higher voltage levels the transient charging current of cables, normally a problem for fast pilot wire protection, is overcome by introducing a simple R-C filter in the measuring circuits.

    A variant of this protection that will be capable of providing tripping at every terminal is being tested at present.

FIG. 1 – Transient Overvoltages

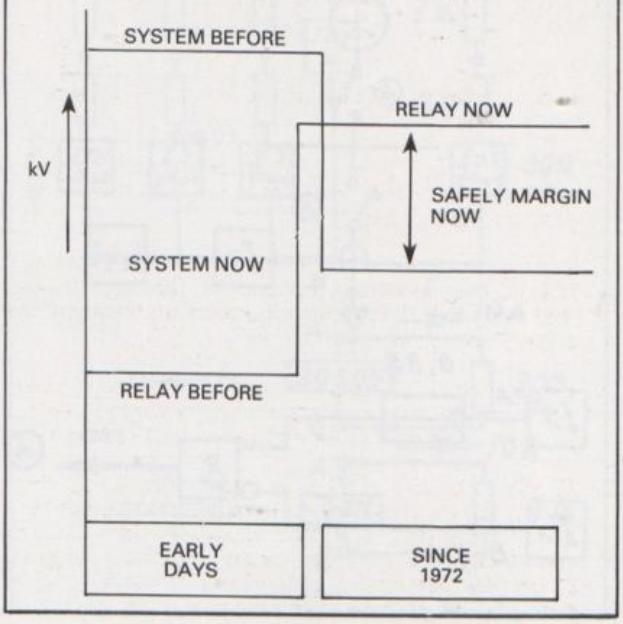


FIG. 2 – Auctioneering Power Supply Unit for Static Relays

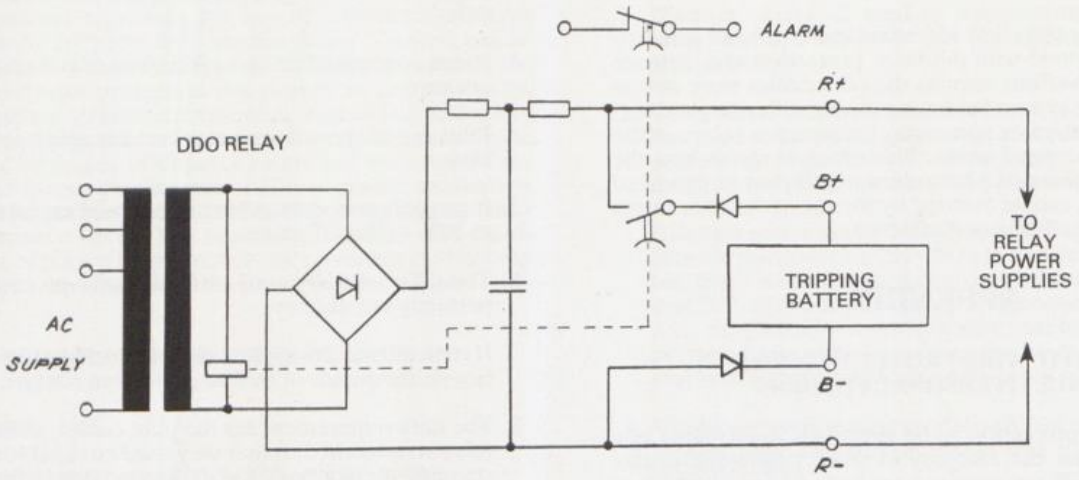


FIG. 3 – LV Bus Protection

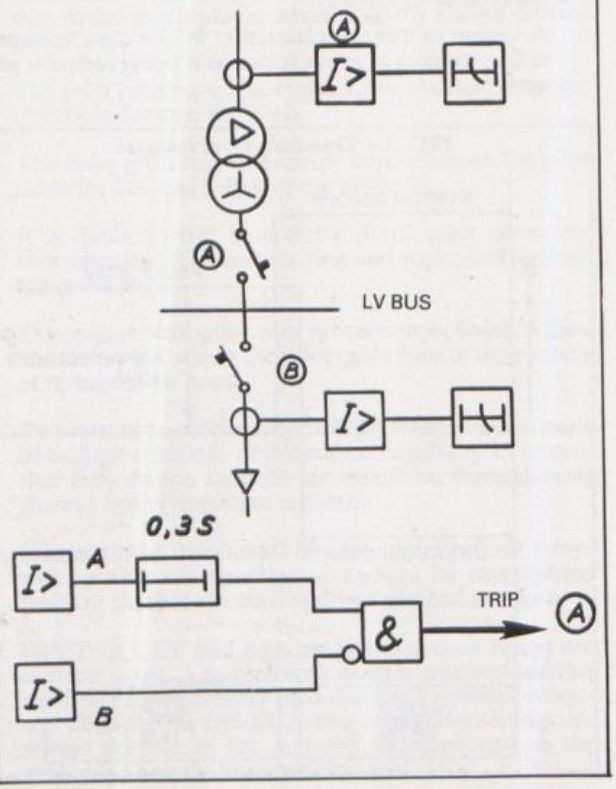


FIG. 4A FIG. 4A Symmetrical Fault Current

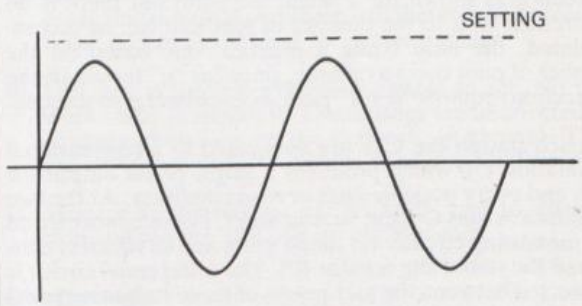


FIG. 4B Offset Fault Current

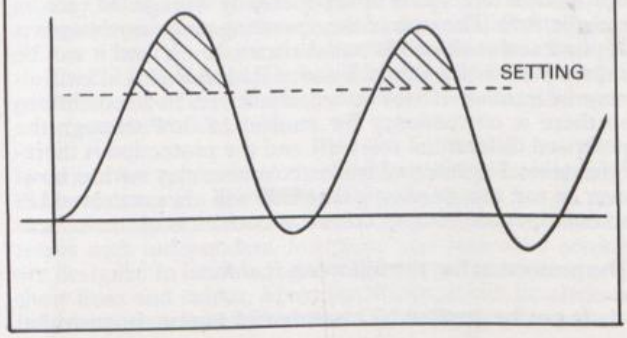


FIG. 5 – I ›› Transient Overreach

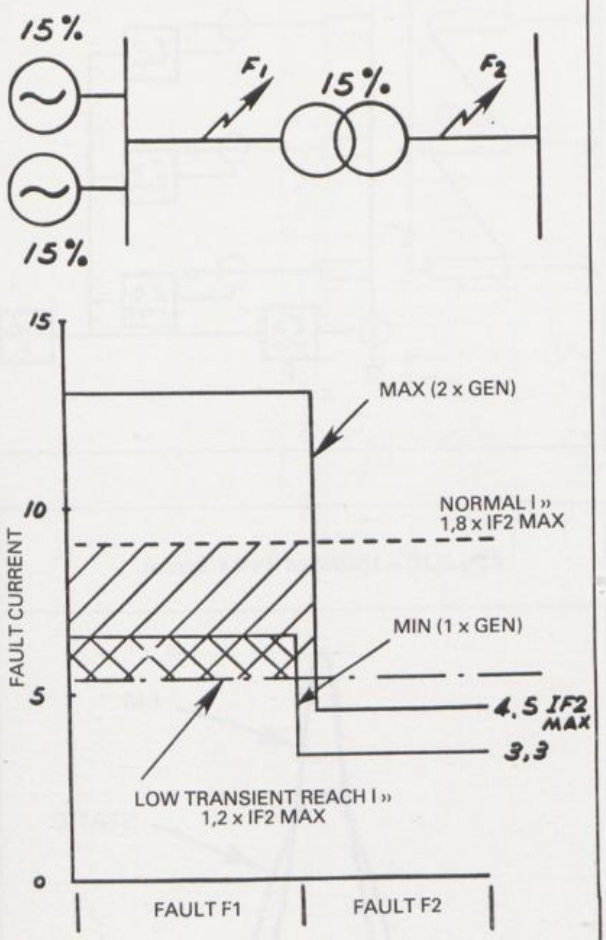


FIG. 6 – 1 Amp Relay
Burden at setting EM-3VA static-‹0,04VA

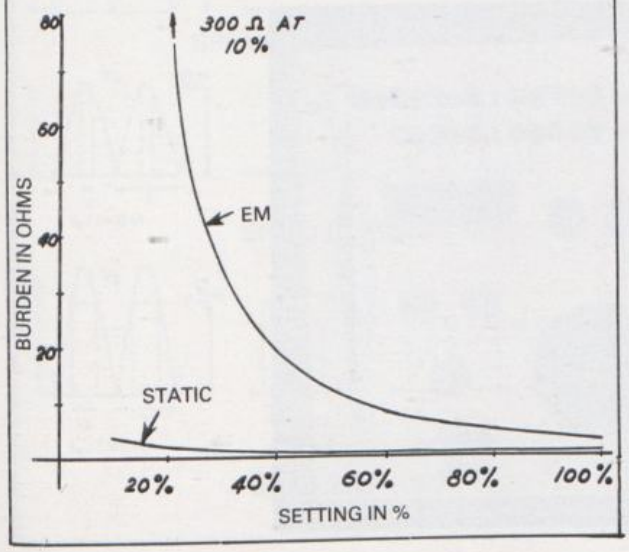


FIG. 7 – Effect of CTs On Relay Setting

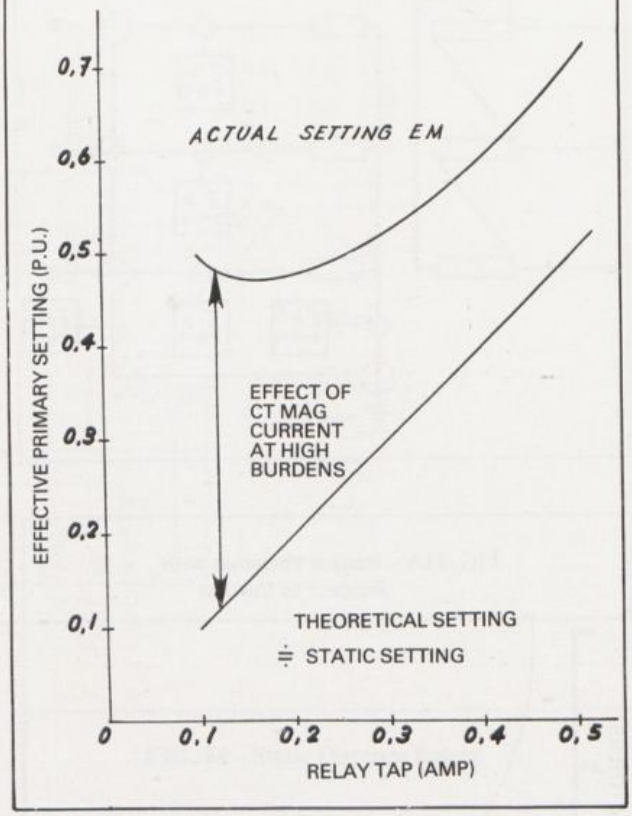


FIG. 8 – Restricted EF Settings

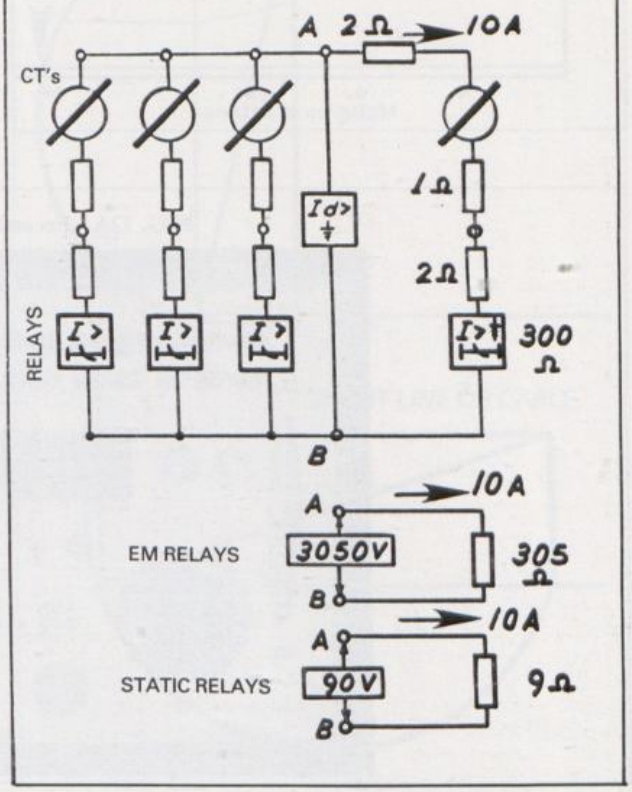


FIG. 9 – Standard Arrangement 8 CT's

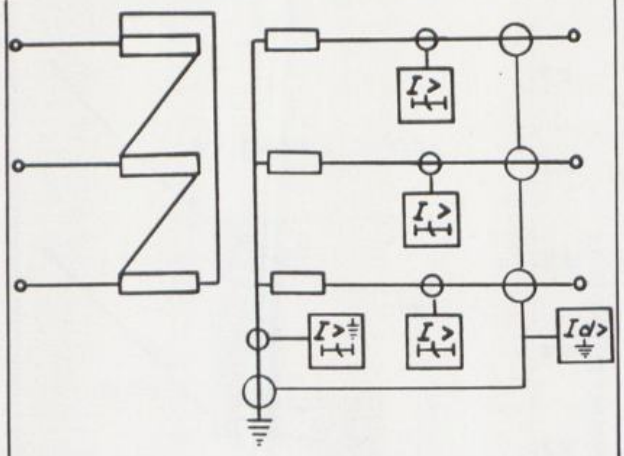


FIG. 10 – With Static Relays
Only 4 CT's

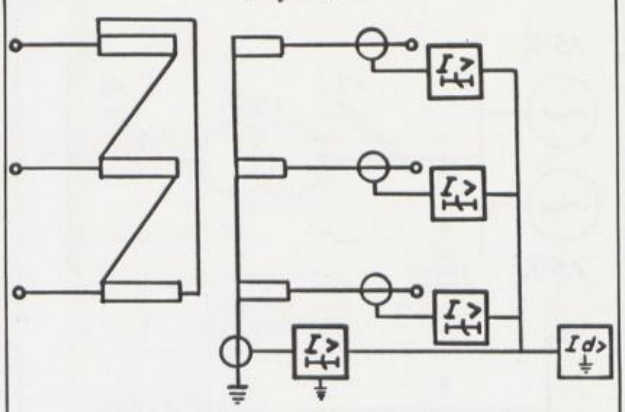


FIG. 11A – Burden Variation with
Respect to Current

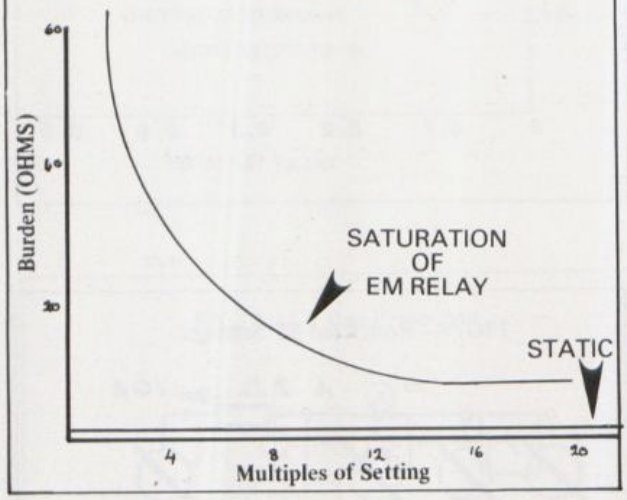


FIG. 11B – Distorted Test Current

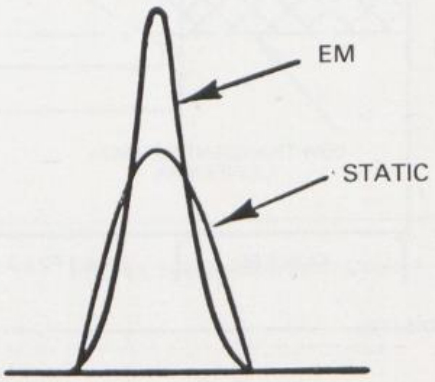


FIG. 12A – Secondary Injection Test Set

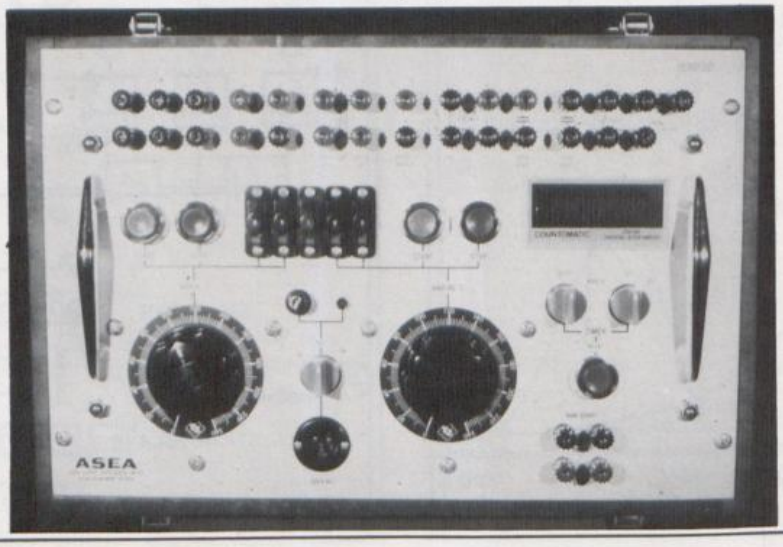


FIG. 12B – Secondary Injection Test Set

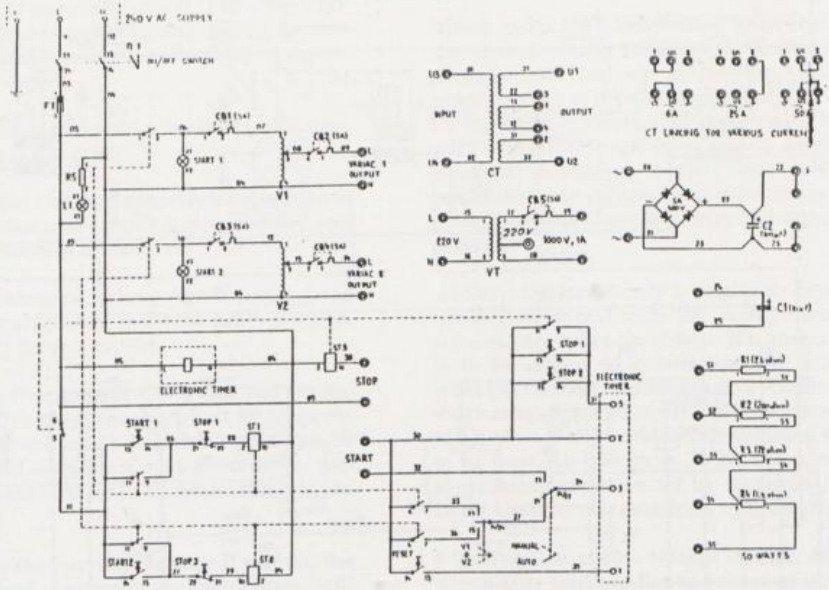


FIG. 13 – Transformer Differential Protection - Pusle Width Integration

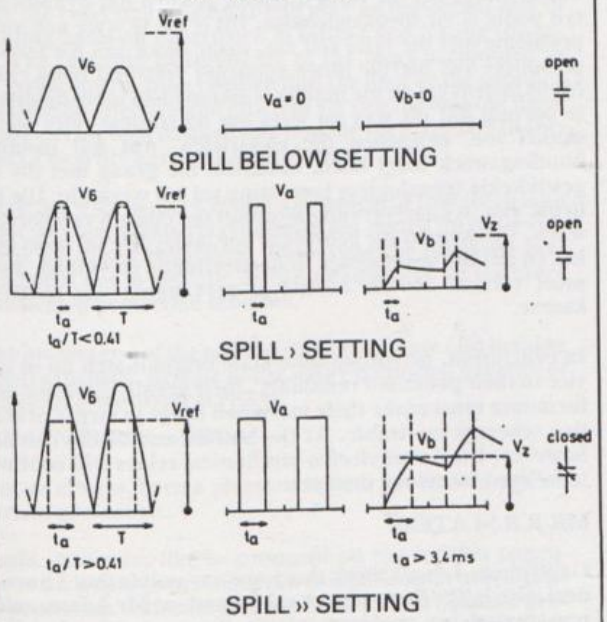


FIG. 14 – Static Distance Relays

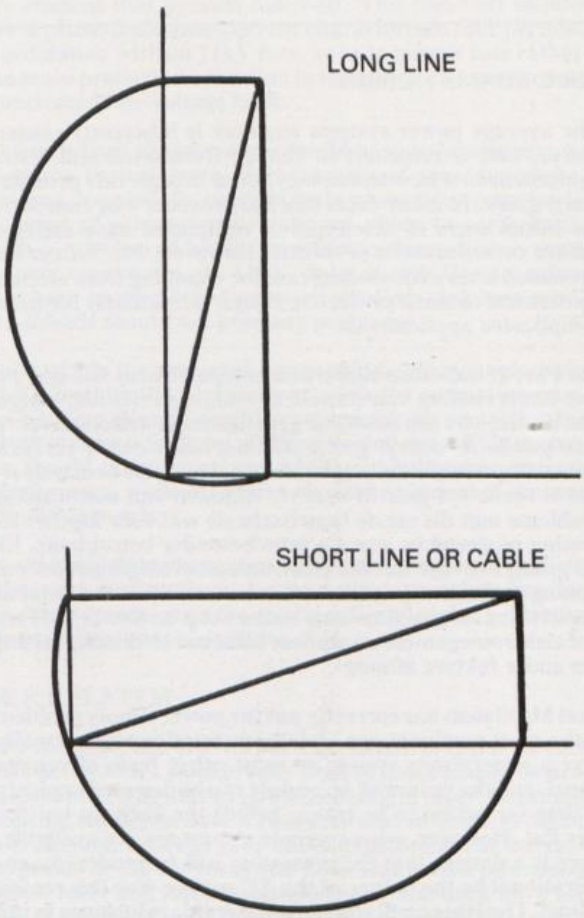
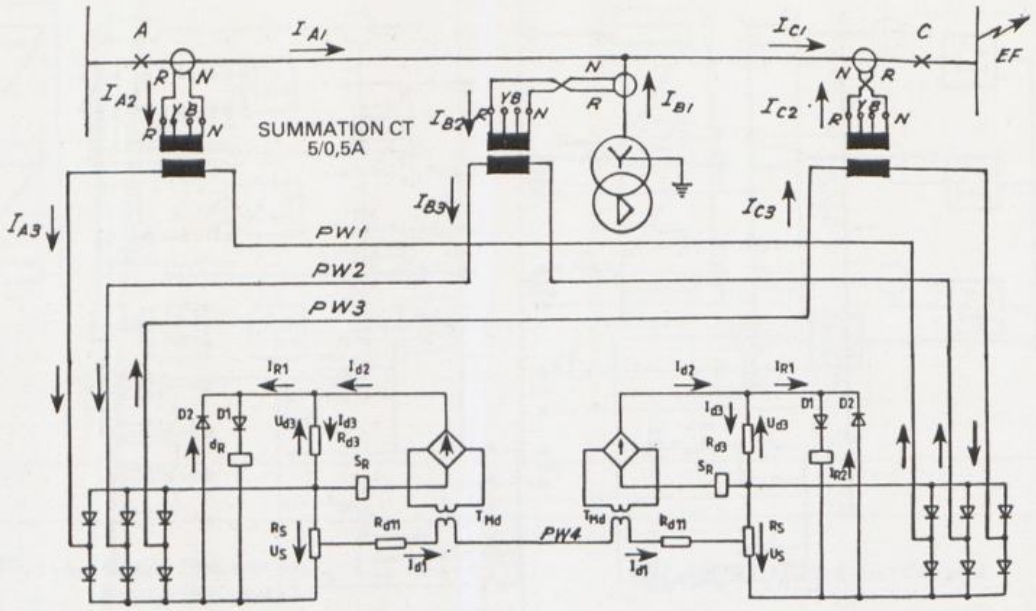


FIG. 15 – Multi - Terminal Pilot Wire



DISCUSSION – BESPREKING

MR C ADAMS : Affiliate

The average power systems engineer is inherently conservative, and is reluctant to change from tried and tested equipment to a new technology, even though this promises many gains. In many cases this has proved a wise course, as the initial users of new types of equipment have suffered failure or unforeseen problems. However, Mr Slatem has presented a very convincing case for changing from electromechanical to static protective relays, particularly for more complicated applications.

Die Port Elizabethse Elektrisiteitsdepartement het nog nie veel ondervinding van statiese beveiligingsrelès nie, aangesien dit slegs by één substasie geïnstalleer is wat ongeveer 'n jaar gelede in bedryf gestel is. Daarbenewens is verskeie statiese tapwisselrelès in gebruik geneem en die oudste daarvan is reeds vyf jaar in bedryf. Afgesien van aanvanklike probleme met die eerste tapwisselsrelè wat voor ingebruikneming reggestel is, was die relès besonder betroubaar. Ek wil graag aanvaar dat die elektroniesebeveiligingsrelès wat vandag gebruik word, uiters betroubaar sal wees, veral as dit eers aan 'n geskikte toets onderwerp is. Die besluit om van elektromeganiese na statiese relès oor te skakel, sal dus van ander faktore afhang.

I feel Mr Slatem has correctly put the power supply problem as the most pertinent one. A large substation will normally have a supervisory system or some other form of remote alarm, and the failure of AC supply can be detected in plenty of time for action to be taken, before the back-up battery goes flat. However, where remote alarms are not available, there is a danger that the protection will be rendered non-operational by the failure of the AC supply. For this reason, at least, I feel there will still be considerable reluctance to use static relays in smaller substations using the present means of power supply. I feel the best solution would be to design a static relay with zero battery drain under non-operative conditions. This would obviously require some sort of a starting relay to switch on supply to the main relay and would inherently be slightly slower.

However, in the appliction envisaged, the slight reduction of speed would probably not be important. This type of relay could be used to replace the AC tripping relays used in some substations, still maintaining the advantage of not needing any auxilliary supply.

Daar word tereg gesê dat personeel wat met instandhouding en bedryf gemoeid is, beslis vertroud moet wees met statiese relès. Met die ingebruikstelling van 'n 132kV substasie met sy statiese OVBM en afstands- en beperkte aardingsfoutbeskerming, het dit veral duidelik geword dat bykomende tyd nodig is vir toetsdoeleindes. Dit is nie te wyte aan enige probleme met die relès self nie, maar bloot aan die feit dat personeel met hierdie nuwe apparaat vertroud moes raak. Myns insiens sal dit nie maklik wees om klein munisipaliteite te oortuig dat dit wys sal wees om na statiese relès oor te skakel nie, aangesien die elektrisiën, wat hul instandhoudingswerk moet doen, moontlik nie graag met die ingewikkelde tegnologiese toerusting sal wil werk nie. Die gebruik van 'n kaartvervangingstelsel ten opsigte van herstelwerk, betekendat die gebruiker oor onderdele sal moet beskik en dat die leweransier 'n doeltreffende en vinnige diens moet verskaf vir die herstel of vervanging van foutiewe kaarte.

In conclusion, providing solid state relays match up in service to their promised reliability, their greatly superior performance must make their increased usage in larger protective schemes inevitable. At the bottom end of the market, however, I feel that electro mechanical relays will continue to be used for a long time yet.

MR R R SLATEM

Gentlemen, I don't think there are any points that I have to deal with in the first matters raised and, as Mr Adams said,I pre-empted his problems of the Power supply. It is not correct to say that there is a need to delay the protection in

order to switch the power supply on if the auctioneering mode is used, as described in the paper.

Regarding the motivation to use static relays, I find the ability to use overcurrent relays to provide me with a superior form of phase and earth fault medium voltage busbar protection, a very exciting prospect.

Indeed, I would say that this feature alone could be sufficient incentive to go over to the static relay.

There is another point about static relays which I consider to be particularly advantageous and I don't know whether you have suffered from this problem or not.

To test a high set instantaneous relay, which has a poor transient over-reach characteristic, is a real pain, because one tries to test it at a very large current.

If, for example, you have five amperè CT's and you set the relay at say 16 times the five amperès, that is at 80 amperès and you have a small test set which is able to give you 80 amperès, but only just and only for a very short time, you have to try and adjust the current up to 80 amps slowly to see if the relay operates.

You cannot just switch on the current because if you do, the relay with its poor transient overreach characteristics, will tend to operate at as low as 50% of the setting, or something near that. Consequently you actually have to bring the current up slowly to the 80 amps level and this results in everything associated with the relay and the test set, overheating and possibly being damaged.

It is a very nerve-racking business. I find it very difficult to test such a relay, whereas if you have a low transient overreach free relay such as you find in the static relays, you can actually switch the current on to the relay and test it in that fashion. You set your current on a dummy load and then switch it on to the relay and this gives you an accurate idea of its pickup performance.

Some of these factors, I feel, should lead one at least to start thinking about the static relay as a possible alternative.

I heartly endorse Mr Adams's statement that it is necessary for test personnel to become completely familiar with the new static relays, particularly when testing these. This is where the relay manufacturer can play an important role in providing hand-on experience in setting and testing the relays. The fact that maintenance of the relay is confined to card replacement, does require that the user or the supplier must have an effective and efficient service for making these printed circuit boards available and for their repair. In this respect I heartily agree with Mr Adams.

Experience with modern relays has indicated that there is no reason why solid state relays should not match up in service to their promised reliability. Their superior breaking performance is not in dispute, as Mr Adams says, in the more sophisticated protection schemes.

At the bottom end of the market static relays are also making extensive inroads, in spite of the long established practice of using electro-mechanical relays.

MR L GINSBERG : Affiliate

It has, as always, been a pleasure to hear Mr Slatem talk on electrical protection.

I would, however, like to comment on the written appendices to his paper concerning the comparison between pilot wire protection with overcurrent back-up and distance protection, and to pilot wire protection for multi-terminal feeders.

At the outset I must stress, that I am confining my remarks to municipal 6,6kV or 11kV network, and not to any of the higher voltage networks.

Many municipal distribution networks have developed over the years, usually utilising a combination of pilot wire and overcurrent back-up protection. As the networks have grown,so the difficulty in grading the relays has increased. In particular,where ringmain units have been used, pilot wire relays have not been widely used hitherto, because of bleed-off problems. While I agree with Mr Slatem that the use of distance relays could solve the present technical problems, I believe there is a financial aspect that should be considered.

At the 11kV level only a relatively few circuit breakers are usually equipped with the voltage transformers necessary for distance relay operation. If a busbar voltage transformer is to be added to a switchboard, a major outage results, whereas the cost of adding cable-connected voltage transformers at approximately R2 000 each soon mounts up. To this must,of course,be added the installed cost of distance relays of at least R6 000 each. With the present financial restrictions being experienced by municipalities, it might be difficult to commence such an upgrading program.

I believe that at this voltage level, a cheaper but technically acceptable solution lies in a form of pilot wire protection for multi-terminal feeders. Once again we must look at upgrading our present networks. It is then somewhat costly to apply the relay discribed by Mr Slatem, as numerous tee-offs by means of 11kV ringmain units without current transformers, are already in use.

An apropriate form of protection would seem to be one that embraces a normal overcurrent back-up element and a pilot wire element that permits bleed-off. This bleed-off should have a phase-fault time-current characteristic that permits co-ordination with an 11kV fuse, so as to permit fuse rather than main protection operation in the event of a transformer or uncleared low-voltage fault.

The earth fault characteristic would have to be sensitive to detect the limited earth fault currents of some networks. This may occasionally result in main protection operation in the event of a transformer internal phase to earth fault, which is not cleared by the transformer fuses. This is not a frequent occurrence. At 11kV, most distribution transformers have an unearthed primary winding, and zero sequence infeeds should not pose any problems.

Faults within the protected zone could be cleared relatively quickly by this pilot wire element, while the normal overcurrent back-up element would provide back-up protection for failure to clear a fault out of the protected zone. This protection should not require any additional voltage or current transformers, while the relays should be somewhat cheaper than distance relays.

Would Mr Slatem please comment on this proposal, particularly using static relays. I would also appreciate hearing members' comment on the applicability of such a protective scheme to their Municipalities.

MR R R SLATEM

Mr President, this is a very tricky matter to assess at such short notice,and I would really need to think about the problem before being able to give a meaningful reply. Generally speaking,when you have a ring network, in order to obtain co-ordination between your back-up protection at the various points in the network, you do in fact need a directional type of relay and for a directional relay one must have voltage. If you must have voltage you must have VT's, so on a ring network in which you want to have discrimination for

your back-up protection, I think it is necessary that you must have a VT.

If you are going to use directional relays of the conventional electro-mechanical type, there is a limitation in that, when you get a close-by fault, your voltage may not be sufficient to polarise the relay and the relay may fail to operate. That is where a static relay with its greater sensitivity could give you a distinct advantage.

Distance type relays are designed in such a way that the ditectional features are very sensitive indeed, and even for very close-by zero voltage 3 phase faults they have a memory built in and this memory enables them to remember the voltage that was there before the fault, and still give the correct directional discrimination.

So, while I agree that the distance relays can be expensive, compared with pilot wire and overcurrent relays, my contention is that the pilot wire itself is a very expensive element.

Very often cables are not available for the protection function, so the use of pilot wire protection under such circumstances is very doubtful, whereas a distance relay without any pilot link would give one excellent protection both main and back-up.

I am talking particularly about a 132kV system, but with modern distance relays, one can actually apply them right down to 11kV levels. It is very commonly done in Europe.

If one has a problem where one wants to get discrimination fo an important network even at 11kV, one could do better by using distance relays and forgetting about pilot wire and over current protection.

MR M VAN DER SPUY : Development Board West Rand

Mr Slatem is to be congratulated on his very lucid presentation to us this morning.

The advent of "Black Box Technology" is something that we as Power Engineers will be accepting much more readily as time goes on.

The advantages of solid state hardware is of course very evident and cannot be disputed.

One problem regarding transistorised equipment remains however : failure of transistors and integrated circuits is sudden and catastrophic. This is evident even in very refined technology such as used in the space shuttle programme.

Could Mr Slatem perhaps indicate whether the reliability rating has now been improved or what technology is available enabling a self-checking device to trip the circuit in the event of a device failure?

One must bear in mind that up to now nuclear power stations are not allowed to use any solid state relays on a *nuclear safety circuit* i.e. a circuit which, if it fails, could release nuclear material, due to insufficient reliability of the devices.

MR R R SLATEM

Mr President, it is undoubtedly true that the problem of the failure of the transistors IC's will always be with us. But I must say that in my experience the failure rate of electromechanical relays has been every bit as high as that with static relays. I can give you some examples. I am at present engaged in a programme of testing a large number of relays at pump stations (routine testing) and there is not one station where I don't find electro-mechanical relays which are not defective. I have also found static relays that are defective. The defect was,however,caused by fiddling. Somebody decided they wanted to "improve" the protection. They therefore cut printed circuit board tracks and soldered additional diodes and IC's in, etc. This is asking for trouble! If the relay is left as manufactured and tested by the manufacturer, the failure rate will not be greater than with the electro-mechanical relays. I am certain of that. In fact, I believe it will be less.

If one goes to reputable manufacturers they have programmes of selecting components through a central organisation for all electronic devices. By a vigorous programme of selection and testing components, the failure rate is reduced to a very large extent.

So testing the finished product also plays an important part in eliminating rogue components.

On the question of the use of static relays for nuclear stations, I am not sufficiently informed to say whether in certain areas in such stations they are not permitted. But Koeberg power station uses a large number of static relays. On the question of the reliability of static relays, some major power stations presently built by ESCOM are equipped entirely with static relays right throughout the station. ESCOM have obviously decided that the reliability of the static relay is equal to that of the electro-mechanical relay, if not better.

MR R J WEDDERBURN : Affiliate

I have read and listened to Mr Slatem's paper with some interest, but was perturbed at the implications that prior to the early 1970's, relays were not type-tested. Type-testing was introduced before 1970 and covered both the electromechanical and electronic or static relays. BS 142 of 1966, although not covering static relay, lays down some of the foundations on which more recent standards were based.

Static relays were introduced in the ESCOM network in the mid 1960's and many are to my knowledge still in operation.

In addressing some of the so-called problem areas I wish to state:

1. Standing drain can be as low as less than 1 watt, with an AC burden on the current transformer of 0,5 VA, and this is over the complete range of the relay. This low VA burden could be advantageous to both the switchgear manufacturer and the municipal engineer. However, if the standing drain is a problem, self powering of the relay is a possilility and with the introduction of self powering, the VA burden is raised slightly, but is still within the linear characteristic of a 5P10 10VA low ratio 5 amp CT.

   One advantage of self powering is that a 30 Volt DC tripping supply is also made available from the CT and this obviates the necessity of having a tripping battery at all. This is an advantage for remote substations within the municipal system.

2. The practice of removing covers of electro-mechanical relays to move the disc and so close the contacts, can be a problem in very dusty conditions, because if this dust on top of the relay cover is not removed, it could end up on the surface of the disc. This could cause eventual malfunctioning of the relay due to the dust build-up between disc and damping magnet.

However, on a more positive note, could Mr Slatem please comment on the possibility of incorporating the complete substation protection scheme on a "one out of two" or a "two out of two" micro computer system.

Could he give possible advantages and disadvantages of:

(i) the problem of putting all your eggs in one basket,

(ii) the possibility of creating a more economical and standardised form of substation protection scheme which can be tailored, in situ, to individual needs and requirements,

(iii) the incorporation of load control and substation voltage control within the same microcomputer.

MR R R SLATEM

Mr President, I am a little surprised to find that Mr Wedderburn says we can get the same VA burden as the electromechanical relay, using the self powered static relay, because I have actually seen a device which has been designed to do this powering from the CT's and which takes 7VA. This is almost double the VA taken by an ordinary electromechanical relay. However, I have no doubt that one can design a scheme whereby one can get relatively low VA burdens on the CT's, in order to power the relays correctly. But you do lose one of the advantages of the very low burden on the CT and I think that is a slight disadvantage to the self powering scheme. It would not enable you, for example,so readily to apply the combined functions, which seem to be so dearly loved by many people. By this I mean the ability to put all eggs (relays) in one basket, i.e. on one set of CT's. I am therefore a little sceptical of the value of self powering. I have no doubt that, in time, people will develop relays and self powering relays, which will still have the advantage of low burden. At the present time, I do not think that that is quite the case and in many instances people have relatively high burdens for the self powered relays, which to a certain extent defeats one of the main objects of having a static relay.

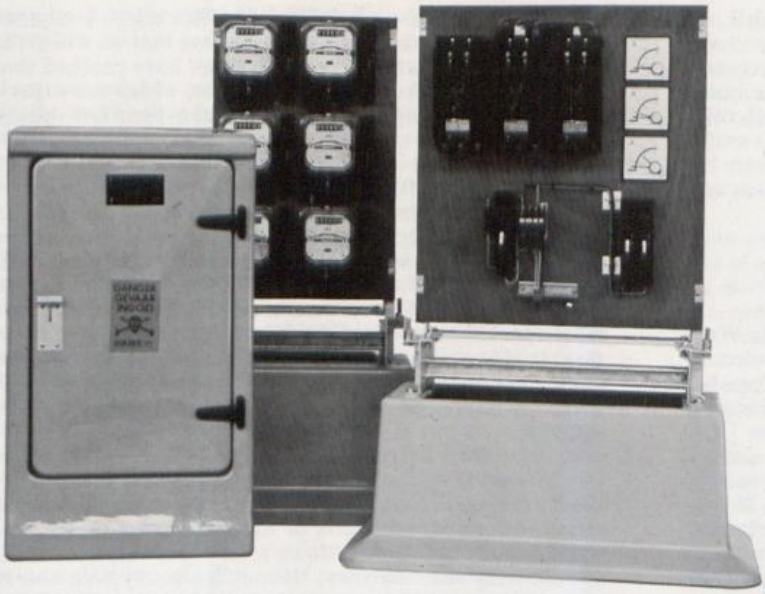
As regards the removing of relay covers and the dust one gets on them, I could not agree with you more. Static relays, with their built-in covers, where one does not require access to the discs, contact etc., are a distinct advantage.

Now, as regards the possibility of on-line micro computer schemes for the entire station, I do believe that we will get to that eventually. But I do not believe we have reached that point yet. There are certain companies, which are experimenting with a complete protective system for a low voltage station.

With everything built into a micro computer, centrally located and possibly adding two out of three, (one out of two only gives greater security but not greater dependability), this fact, combined with the centralisation of the protection, necessitates going to a two out of three scheme. Two relays must operate out of three in order to give a tripping function. In that way one gets improved dependability and security. One can also get other features, such as an analysis of what has happened and so forth. (e.g. self checking of the relay).

Where designers have tried to develop the characteristics of relays with micro-computer or digital techniques, the best one has really been able to do up to now is to emulate the dedicated relay charactristics. Nobody has really been able to improve on those characteristics and has been able to say, that we can get operation of a digital distance relay in a fraction of the time that it takes a conventional dedicated relay. At this stage there is a lot of work going on in this area all over the world. I am sure we will eventually see centralised digital protection schemes, but I do not think we are yet able to make use of this technique with confidence. Personally, I would prefer individual dedicated relays, because if one has to expand one's station, one can simply add relays for the new functions. With a micro computer scheme it must be large enough initially to take all the possible expansion that may occur. This will increase the initial cost of the scheme significantly.

In conclusion, I would like to express my thanks to the AMEU and the ASEA Electric for the opportunity to present these views.



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INTRODUCTION OF MR R R GILMOUR

MR W BARNARD : PRESIDENT

Gentlemen, Mr Gilmour is going to address us on the subject of Electrolytic Corrosion with special reference to Electrolysis. Mr Gilmour has had a long and distinguished career as an electrical engineer, mainly in the Electricity Department of Cape Town. He was the test and meter engineer for 20 years and retired in 1981. During his career he took on many additional duties. Amongst his many activities he has been a part-time lecturer at the Cape Town Technikon, served on the Cape Western Committee of the SAIEE for many years and was chairman for several years. He chaired and served on the wiring regulations sub-committee of the SAIEE Western Cape, and has been chairman of the Cape Western regional field corrosion committee since 1970.

This will be the third occasion on which Mr Gilmour has presented a paper to the AMEU and we look forward to his contribution today.

R R GILMOUR
Pr. Eng., C.Eng., F.S.A.I.E.E., F.I.E.E., F.S.A.A.I.
Chairman Cape Western Electrolytic Corrosion Regional Field Committee since 1970 to date.
Formerly Test and Metering Engineer
Cape Town City Council's Electricity Department
Now Retired

THE ELECTRICAL ENGINEERS ROLE IN CORROSION CONTROL WITH SPECIAL REFERENCE TO ELECTROLYSIS

SUMMARY

The paper deals with certain corrosion problems which require the attention of electrical engineers, particularly those who are associated with municipal electricity undertakings, for solution or mitigation.

While brief reference is made to the more common forms of corrosion, the main theme of the paper is electrolytic corrosion arising from stray or other currents which flow in the ground and consequently cause corrosion of such installations as pipelines, cables, earthing electrodes, etc. These currents usually stray from traction systems, neutral earthing, cathodic protection installations, etc. Earthing in relation to corrosion is also discussed.

Methods of assessing propagation and distribution of earth currents emanating from traction and cathodic protection systems are discussed and equations for currents in certain bonds between buried pipes and adjacent railway lines are derived from results of field tests.

As much care as practical or possible has been taken to avoid repetition and to this end a reasonably adequate and appropriate bibliography is appended.

1. INTRODUCTION

Corrosion as a word, or the way in which it ultimately manifests itself in one form or another, is known to almost everyone of nearly all ages, but there are many aspects about this destructive force which are not so widely known such as its mechanism, counter protection techniques, the extent of research already carried out, available published data, the existence and work of various relevant organisations and relevant conferences which are convened from time to time.

As the scope of this subject is far wider than most people, including many engineers, may be aware, and furthermore, as the results of a lot of associated research has been discussed at conferences and usually published, an attempt has been made in this paper to avoid as far as possible, or practical, treading on ground already covered

and published. The aim is rather to apprise in particular those engineers associated with local authorities of the hazards, control and other factors related to corrosion with which they may not be familiar but,apart from pressure of their normal duties,are nevertheless of necessity involved with corrosion problems periodically.

Services threatened by corrosion include therefore cables, water and gas pipes, earth electrodes, storage tanks, etc. The emphasis is largely on the effects of electrolysis or electrolytic corrosion which are usually the result of stray or other electric currents flowing in the ground and,as far as the engineer is concerned,its impact is technical. This problem was investigated as far back as 1893 and has continued ever since. The paper is based on nearly 20 years study and experience in this field as a member of the relevant Cape Western Regional Committee.

2. PRESENT STATE OF THE ART

During the last decade at least two major important conferences embracing corrosion technology and the updating of various prevention and control techniques have been held in South Africa alone. The first of these was conducted under the format title of "Think Tank" and was held on board RMS Windsor Castle on a voyage from Durban to Cape Town in June 1976 which was part of an on-going communication effect to discuss problems and achievements. The theme itself was the development and use of stainless steel for resisting corrosion in various applications and environments on a cost saving basis. This was similar to earlier conferences aboard ships. The second important relevant conference at which papers of a fairly general nature were presented and discussed was held at the CSIR conference centre in Pretoria over the period 17 to 19 March 1980. Copies of the papers were generally available to delegates and in some instances copies which were in bound form were on sale to other interested parties on application. Although much valued information was released at these conferences and the state of the art in detecting. combating and controlling corrosion as it stood at the time was outlined, there still appears to be a fair amount of experience and miscellaneous data of which many engineers are unaware. Some of these problems include electrolysis not only from the effects of direct currents flowing in the earth, but also from the possible effects of stray alternating currents arising from the introduction of a.c. traction at high voltages and those associated with protective multiple earthing systems. Furthermore,protective measures including the so called cathodic protection systems, although improved and somewhat more sophisticated in design and installation also appear to lack a certain amount of clarification. There are many organisations in the world which are dedicated to solving problems associated with corrosion in its various forms and some of these and the work they do towards the control of corrosion, development and improvement of methods in this regard are outlined as follows:

1. The Council of Scientific and Industrial Research (CSIR) – Corrosion Research Division of the National Chemical Research Laboratory[1]. This body has undertaken extensive research into corrosion behaviour of the more common metals of construction in various South African environments and has produced maps which indicate known underground corrosive conditions, atmospheric corrosion rates and areas where stray current electrolysis could be expected in the Republic of South Africa. Such maps are bound to be of assistance to architects and engineers concerned with the design and installation of metal structures.

2. The South African Corrosion Institute which is virtually a professional body concerned with corrosion technology and formed to stimulate research. However, it provides for both sustaining and personal membership with six categories of membership in all, admission to any category being subject to qualifications and experience.

3. International Copper Research Association Inc. (INCRA). The headquarters of this association are based in New York, U.S.A. It is mainly concerned with the application of copper. One of its relatively recent assignments was, for example, the investigation of corrosion of buried bare concentric neutrals of copper and aluminum by alternating currents [3].

4. British Iron and Steel Research Association Corrosion Committee which has been operating since 1929 [2]. Its work has included tests on specimens of various types of ferrous metals exposed to corrosion in the atmosphere, soil and water, both in the bare condition and when protected in various ways particularly by paints and other coatings.

5. South African Transport Services. The Test and Research Section of the electrical engineering department has done a lot of important and useful work in its laboratories and also in the field in connection with corrosion resulting from ground currents.

6. South African Electrolytic Corrosion Committee. This Committee and its regional field committees, of which there are four at present spread over the Republic, was formed in 1966 to replace the old Witwatersrand Electrolysis Committee which was formed in 1941 [4]. The reason for the change was due to the expansion of traction electrification and the increasing number of cathodic protection installations in the country, although street railways were already being phased out then. The concept of forming committees consisting of member organisations owning and operating buried assets or services which may be susceptible to corrosion, particularly electrolysis, originated overseas before the last war. Sir Gordon Radley of British Post Office fame and others [5] confirmed that in areas where stray currents are significant such committees are conducive to selecting the best engineering and most economic solutions to these problems. Another advantage of such committees is the relatively greater frequency of meetings of the interested parties compared with conferences. The extensive use of cathodic protection, by virtue of the fact that the system injects current into the ground, is another sound reason for the existence of these committees, since they enable users of the system to inform other members whose services could possibly be adversely affected by such neighbouring installations.

The overall advantage of conferences, symposia and committees is to provide opportunities for delegates or members to discuss matters of mutual interest and to exchange their experiences and ideas in solving corrosion problems thus promoting at the same time progress in the state of the art.

It has been reported that in the U.S.A. the cost arising from corrosion dropped to something like one third of its former amount within two years of forming relevant committees [5].

Experience has also shown that engineers employed by local authorities or electricity undertakings are usually too occupied with other daily routine problems directly associated with the services their organisations render.

This makes it difficult for them to keep pace with corrosion technology. Thus the conferences and committees already referred to must surely be of benefit to these engineers.

Apart from the sterling work carried out by the abovementioned bodies in their various ways it should be noted that the S.A. Navy has carried out a good deal of research on marine corrosion problems and related activities.

Furthermore credit should also be accorded to certain South African undertakings for their own research work and also for the actual production of improved corrosion resistant alloys, protection devices and protective materials, etc.

Another important aspect which has also received special attention by these and other bodies is the study of costs in relation to assets to which consideration has to be given for protection against corrosion equated with the rate of corrosion. The iron and steel industry, to give an example in this regard, has produced certain stainless steels and alloys as a result of its research programme, from which also has developed the art of analysing the qualities and equating corrosion resistance with strength, chemical, thermal and other factors depending on the application, as, for example, boiler tubes, water and fuel storage tanks, etc. and the costs relative to these applications.

Techniques in carrying out the various tests and measurements have improved and in many cases have become more sophisticated producing conclusive results and predictions. Associated instruments and equipment have advanced and improved in design and construction.

To keep pace with the art of detecting and controlling corrosion, a specialist should have at least a working knowledge if not intimate, of a number of relevant sciences such as chemistry, electrical technology, basic civil and mechanical engineering technology and even mathematics, if he hopes to solve all problems that arise expediously and successfully. This is another good reason for the formation of committees.

Experience and advances in corrosion technology have been responsible for the introduction of new codes of practice, e.g. on cathodic protection and amendments to others, e.g. on earthing practice. Furthermore the proposed code for muliple earthed systems has to cater for the stray current problem and return paths in a.c. reticulation, etc. An existing code is SABS 0121 of 1977, Cathodic protection of buried and submerged structures. Many figures have been mentioned and published to indicate the extent of metal corrosion in the world.

In South Africa alone it appears from statistics available that unless corrosion is strictly controlled in future, the resulting loss is heading for something like R1 000 million per annum. It is possible, however, that if the state of the art in its present form is strictly and correctly applied the loss could well be reduced between 40% and 50% of its present estimated value. Fig. 1 gives a rough indication of the estimated wastage on a cost basis of metal by corrosion for the years 1971 – 1982. The rising costs are no doubt due to normal inflation, discoveries of more corroded metal due to increasing soil pollution and increasing ground currents arising from expansion of various electricity services, etc. Graph B is based on a 40% reduction if known technology had been applied.

Furthermore, it has also been estimated that about 40% of ferrous metal produced is used to replace corroded metal.

3. TYPES AND CAUSES OF CORROSION

It is not the intention to dwell on all the types, forms and various causes of corrosion in this paper as much of this is obtainable from books and other published data, particularly in regard to the chemistry of corrosion.

Most chemistry text books define such terms as atomic weight, equivalent weight, valency, etc. of various or more common elements. These terms are usually refered to hydrogen as a basis and as the electro-chemical equivalent (ece) of this gas is 0,0104 mg/c approximately, the ece of any other element is

$$\frac{0{,}0104a}{v} \text{ mg/c}$$

where a and v are the atomic weight and valency respectively of the element in question c = coulombs.

Table 1 lists the ece of some common metals.

Although engineers have to deal with many forms of corrosion, public utility personnel such as electrical, water and gas engineers are frequently faced with electrolytic corrosion problems which are invariably caused by electric currents flowing in the ground. The buried metals involved include iron, steel, lead, aluminium and copper used in the construction of tanks, pipes, cables, etc. associated with services which they control.

Due to pressure of their various duties and responsibilities these engineers usually have to confine their attention to the effects of corrosion, having little time for its cause. Corrosion may be defined as the destruction of a metal by chemical or electro-chemical action. The metal is,however,usually converted into some compound or ore from which it was originally refined as in the case of iron the oxide being usually recognised as rust. Even chemical action is generally associated with minute electric currents which circulate locally in restricted paths. This is auto-electrolysis. A distinction may be made between land and offshore installations in respect of corrosion.

Offshore installations include marine outfall pipes but in most cases these problems are associated with piers, jettys, rings, etc. With the advance of engineering and corrosion technology, pre-stressed concrete appears to have been replaced almost entirely by steel for piling, particularly where the structures are subject to both corrosion and stresses not normally encountered on shore such as, for example, the mooring of large ships in bad weather. It is interesting to note that dual equipment is often provided on board vessels for the protection of their hulls, namely against corrosion and also for retarding marine growth using cathodic and ultrasonic techniques respectively.

Offshore installations and structures are rarely the concern of local authorities except sewerage or other effluent outfall pipes which will be referred to later under protection techniques. Oxygen is an important contributing element in the corrosion process. It is reasonable to expect therefore that pipes buried in soils which are impervious to oxygen are immune to corrosion. It is understood,however,that, notwithstanding this theory, oxygen can still be released in the soil by certain bacteria which attack certain sulphates during their metabolism, thus causing corrosion of metal buried in the soil in which they are active. Their content is usually expressed as colonies per gram, etc. The more common cause of corrosion of buried metals is due to electro-

chemical action by currents flowing in ground. As is well known by electrical engineers these currents find their way into the ground, or earth, for a number of reasons. In alternating current systems these currents could arise from induction, e.g. from overhead powerlines, or return paths in parallel with neutral conductors which could be signficant in underground residential distribution systems, particularly if bare neutrals are used; whereas in the case of traction systems with rail return these could be due to current leaking or straying, into the earth. These currents usually enter nearby buried pipes, cables or other structures. At points where current leaves the metal for the surrounding soil which is virtually an electrolyte, the metal is thus anodic and corrosion occurs. For the benefit of those who may not have had the opportunity or time to evaluate or conceive the extent of the loss of metal in relation to these stray currents the following example and analysis may therefore be of interest. Iron and steel are probably the most common among the metals usually susceptible to corrosion and the theory is based on Faraday's laws in the example.

The electro-chemical equivalent for the ferrous element is about 0,00029 gram of metal liberated by one coulomb (ampere-second) of electricity discharged, i.e about 1 gram of iron lost per ampere-hour. Thus if a steady direct current of one ampere is discharged from a buried iron pipe and left unchecked for say one year the loss of metal during this period would be about 9 000 grams, or 9 kg.

To give a clearer conception of what such a hypothetical loss means,the analysis may be extended as follows:

Consider an iron pipe of any diameter and length and assume that its wall thickness is 7mm and the corrosion has manifested itself in the form of a number of holes, or pitting. Assume also that the diameter of each hole is 6 mm, i.e. a radius of 3 mm each.

The mean density of ferrous metal is 8 gm per cc and as the volume of metal lost in the example is 3,14 x 0,3 x 0,3 x 0,7 = 0,2 cc per hole the loss by weight = 8 x 0,2 = 1,6 gm per hole. Since the total loss of metal from the pipe in question arising from the current discharge of one ampere continuously for the year = 9 000 gms, the number of such holes would be ± 5 600 at this rate.

This analysis assumes that the electro-chemical action is 100% efficient and that no other corroding process such as natural or auto electrolysis or bacterial action are contributing to the loss of iron otherwise the loss as calculated will be less than the actual loss.

Research carried out so far in connection with the effect of alternating current on buried metals indicates that any corrosion that could be attributed to stray a.c. alone is unlikely to be more than about one per cent of that which would occur with the equivalent value of direct current. Thus the number of holes as calculated in the above example would be ±56 per annum per ampere which although considerably lower could nevertheless be cause for concern.

It may be of interest to mention that analyses have indicated that holes are usually conical in appearance. For the pipe in question if the diameters of the frustum are say 12 mm and 3 mm, this represents nearly 3 gm of steel corroded away which could occur in about 1 week for a current of 20 milliamperes per hole.

Incidentally more recent investigations have indicated that a.c. and d.c. combined produce a greater rate of corrosion than with d.c. alone. Among other corrosive buried assets of concern to electricity undertakings are earthing electrodes of various forms, cables, etc. Installations such as boilers and associated steam turbines are rarely affected by stray earth currents, any corrosion being usually due to chemical reactions. Earthing systems will be dealt with in the next section. A brief reference to thermal power stations will also be referred to briefly later.

According to periodic reports received by the relevant committees, it would appear that the sheaths of telecommunication cables have corroded from stray currents to a greater extent than in the case of power cables, due possibly to more superior serving in the latter. Much research has been carried out by various bodies in connection with corrosion problems associated with cables since before World War I and most of the results have been published, e.g. ref. 5 & 6. Some of these bodies are based in other parts of the world, e.g. the French Mining Society, United States Bureau of Standards, CCIF, British Post Office and the corrosion committee of the Swedish Academy of Engineering Services.

The corrosion of lead sheaths in cases where there has been an absence of electrical stimulation has been investigated by these organisations and studied. The process of such a form of corrosion is a somewhat involved phenomenon the details of which are beyond the scope of this paper. Depending on the environment, composition and pH value of the water or the soil in which the affected cable has been immersed or buried, various types of lead oxide are evident as the fruits of corrosion. It is therefore advisable to submit a specimen section of the affected cable to a competent person with a properly equipped laboratory at his disposal, for examination and analysis. Statistics so far available suggest that about only twenty per cent of all instances of cable corrosion currently reported is attributed to electrolysis most of it being usually purely chemical action.

In this connection,it is interesting to note from C M Longfield's report [23] that whereas the number of cable faults reported as being due to electrolysis had reached 200 per annum by 1929, the rate dropped to about 40 per annum by 1933 after the commencement of an extensive drainage scheme in 1929, i.e. an 80% reduction within 4 years.

Transmission line components such as towers, clamps, anchors and conductors are all liable to some form of corrosion, the usual forms being associated with galvanic action, leakage or stray currents. A lot of investigation in this regard has been carried out in this and other countries, notably for example by the Central Electricity Generating Board (CEGB) of Great Britain whose planning of refurbishing arrangements for its super grid [6] is of particular interest. It has been noted that most of the conductors used in this grid system are aluminium reinforced with central strands of galvanised steel for strength and, while galvanic corrosion and mechanical fatigue or damage are considered to be important factors, from one stand to another as it distributes near a fitting, may accelerate corrosion.

Although galvanised steel towers are less likely to corrode while this protective covering remains, trouble at the footing is more likely if they discharge any leakage or stray currents to earth.

With regard to thermal power stations any corrosion associated with steam turbines is mainly chemical action usually related to the pH value and purity of the feed and cooling waters. The effect of wet steam on turbine blades tends to cause erosion rather than corrosion and superheated steam often contains low concentrations of

certain acids which are conducive towards actual corrosion. It has also been reported that cracks which have appeared in certain turbine blades were caused by stress corrosion [7].

Although it has been reported that boiler tubes have been known to have corroded by stray currents this appears to be a rare occurrence. The mechanism of this type of corrosion is somewhat involved and not generally or clearly understood. Accordingly it is virtually essential to include a well and appropriately equipped laboratory in the design of a power station with properly trained personnel capable of making the correct measurements and accurate interpretation and analysis of the results. Care should also be taken to distinguuish between corrosion, erosion and scale formation. Apart from erosion of turbine blades as already referred to, this also occurs in pipes by the flow of liquid within. However, the rate of motion of water in a pipe may also cause corrosion as the flow may promote aeration. The formation of mill scale is probably familiar to most engineers. Unlike loss of weight of corroding metal, scale obviously adds to the general mass of piping, and it may be of interest to indicate the possible rate at which scale may increase. The following example may therefore serve this purpose.

Consider a water cooling system of the closed recirculation type having a capacity of say 4 kilolitres, and assume that water used in the process has been treated with lime or an allied additive which frequently follows a bacteria destroying chlorination process, usually intended to improve the taste, and that the resulting carbonate content is of the order of 100 parts per million parts of the water, the resulting hardness being regarded as the temporary form, i.e. capable of being removed by boiling or by a sufficiently high temperature. If the temperature of the cooling water in this instance is high enough to precipitate all the hardness in the given volume of water then the amount of scale deposited by the initial volume of water may theoretically be deduced as follows:

weight of 4 kl of water = 4 000 kg

$$\text{weight of scale formed} = \frac{4 \times 10^3 \times 10^2}{10^6} = 0{,}4 \text{ kg}$$

If water is lost in the system at a rate of say 20 litres per day, i.e. 20 kg of weight per day, then the rate of increase in weight by scale by the make up water will be:

$$\frac{20 \times 10^3 \times 10^2}{10^6} = 2 \text{ grams per day}$$

Actual corrosion in these systems is rarely associated with electrolysis, being usually attributed to the presence of oxygen and carbon dioxide in the feed water as it enters the system, and may be accelerated by foreign materials adhering to the metal. It is possible, however, that softening the water may also tend to accelerate corrosion in which case some other additive will be required to increase the pH value.

It is also beyond the scope of this paper to discuss in detail all such characteristic forms of corrosion which are often associated with miscellaneous installations such as, for example, filtration plants, sewerage disposal systems, oil refineries, sea water distillation plants, etc. or even domestic water heaters, other than by electrolysis.

4. EARTHING CURRENTS AND ASSOCIATED CURRENTS

Power and light current electrical engineers are generally familiar with the role of earthing in relation to the operation and protection of services and equipment under their control. Many papers and books on the subject have been published but most of the work refers to safety in respect of people and animals, protection of equipment, interference in telecommunication circuits, miscellaneous electronic devices and the propagation of radio signals, such as, for example, the theory based on the celebrated Sommerfield analysis.

Much less appears to have been published on the significance and relevance of earthing in respect of corrosion engineering which is particularly applicable to the stray current problem associated with electrolytic corrosion as already mentioned.

While soil resistivity is a significant parameter in assessing the value of earth connections and the extent of coupling between power and communication circuits, especially the increase in mutual inductance caused by fault or leakage currents which return via earth and usually enhances consequent induced interfering voltages, this resistivity also influences the density of any other currents flowing in the ground from other sources such as those which stray from electrified railways, cathodic protection systems, etc. Furthermore, depending on the content of the soil and its good conductivity the more aggressive it is likely to be towards certain buried metals such as iron. This is usually if the resistance of the soil is less than 50 ohm/m.

However, uncontaminated soil which has not been disturbed in any way usually has a resistivity which is so high as to virtually classify it as an insulator. Therefore trenches should not be filled with ashes or other wastes. Clays, silts and particle size are usually also related to low soil resistivity.

As distribution engineers know, there is another soil characteristic, namely thermal resistivity, which is particularly important in connection with the selection of cable ratings. sizes and method of installation. Another interesting and important aspect which has arisen from these studies is the result of work carried out by such men as JR Carson, F Pollaczek et al [13] in connection with earth currents and associated phenomena. Although much of this work deals with fault currents in overhead lines, i.e. zero sequence components, in which harmonics add to the problem of interference with communication, it is evident that mutual inductance and depth of a current path in the earth or depth of penetration are related inversely to the expression.

$$\frac{1}{4\,\pi\,aw} \qquad [1]$$

in which a = conductivity and w = $2\pi f$ f = hertz. Rearranging terms and replacing (a) by its reciprocal resistivity (p) the depth of penetration is proportional to

$$\frac{p}{f} \qquad [2]$$

Hence the lower the resistivity the shallower the current path in the ground the converse being the case for the frequency of the current. This concept of depth is similar in principle to the skin effect characteristic [12] and the theory of penetration depth relating to induction heating processes. It seems logical to infer therefore that as the depth of the current path in the ground is greater for lower a.c. frequencies little was heard of stray currents from 16 hz a.c. traction systems causing corrosion, while the introduction of 50 hz traction and pme systems has stimulated interest and research in this regard. This is food for thought and more research.

It is generally recognised that the so-called trench form of earth electrode is relatively more effective and efficient than other forms such as rods and plates. Buried pipelines may be regarded as ideal forms of such an electrode on account of their lengths. Thus even when buried in soils of high resistivity, their effective overall resistance to earth can be relatively low. Although deplored by most water engineers a ferrous pipeline usually provides a convenient and effective earth return circuit but it also makes it vulnerable for collecting straying earth currents. Thus when planning the route of a pipeline it is advisable to take into account proximity to traction or any other system from which currents are liable to be discharged into the ground. It is also advantageous to carry out a soil resistivity of the route which will assist in determining what steps should be taken to protect the pipeline against corrosion.

Earlier studies indicated that pipelines installed within about 8 km of an electrical railway were prone to stray current pick-up but more recent observations suggest that this could occur at distances up to 60 km from such a railway. This apparent increase in the spread of stray earth currents is feasible considering the relatively greater haulage over the permanent way these days and also the introduction of d.c. transmission. It must also be appreciated that increased use of cathodic protection systems is now being made, which is why it is always advisable to inform a relevant committee or the local authority of an intention to install such a system, as protection of one service against corrosion could have an adverse effect on neighbouring installations with possible legal implications. In a cathodic protection installation or as in the case of direct current transmission when only one overhead conductor is used, with earth return, the anodic earth electrode must be given more careful consideration in respect of material, installation and maintenance. If these electrodes are immersed in the presence of water other problems could arise due to possible migration of water from the electrode thus increasing its resistance. A cathodic electrode tends to be protected against corrosion by the formation of hydrogen. A somewhat anomalous characteristic of copper is the fact that although its electrolytic loss by mass is higher than iron, its resistance to corrosion is greater, provided however, that it is not surrounded by coke as is frequently done in attempts to reduce the resistance to earth of other buried electrodes.

Certain museums have on display pre-historic copper utensils which they claim were buried for as long as 5 000 years approximately. In spite of this they are in a remarkable state of preservation [25]. It may be appropriate also to refer at this stage to a report [26] in which it is claimed that the copper work in a submarine which was raised from the sea bed after being immersed for 69 years was found to be in good condition. One theory advanced for this is that the copper may have been cathodically protected by surrounding steel piping which has perished. This theory is feasible since the potential of steel is about -0,44v while that of copper is +0,43v in the galvanic series (table 2).

Salting the soil may improve its conductivity and the efficiency of electrodes but such treatment could prove corrosive. Any electrode chosen for an installation in which it is required to discharge current into the ground, particularly direct current associated with cathodic protection, where the discharge is usually continuous, should obviously possess as low an electro-chemical constant as other relevant factors will permit.

Obviously, the lower the resistance to earth obtainable for the electrode the lower the voltage required to drive a prescribed current into the electrolyte. However the voltage will have to be consistent with the environment and safety, i.e. acceptable touch and step voltages. It may therefore be necessary to surround the electrode site with a suitable fence.

It is interesting to note that the organisation CIGRe formed a special committee to deal inter alia with electrodes for cathodic protection. It is a somewhat unfortunate anomaly of soil characteristics that, although the efficiency of electrodes is inversely proportional to its resistivity, the lower the resistivity the greater the possibility of currents straying into buried pipes, etc. with consequent corrosion hazards.

Although as already indicated the extent of electrolytic corrosion by alternating earth currents is much less relatively than by d.c. it cannot be overlooked any more. Accordingly much research in this regard has been carried out by such bodies inter alia as CSIR, S A Transport Services and INCRA.

The results of the investigations carried out so far suggest that a.c. corrosion is a complex phenomenon and not clearly understood yet. It depends on various factors such as PH, salt content, soil composition, current density, voltage and possibly others. The rate of any corrosion by stray a.c. is therefore difficult to predict. Incidentally it appears that aluminium is more susceptible to a.c. corrosion than iron and copper. However, corrosion due to direct current straying into the ground is still the major problem insofar as electrolysis is concerned.

With regard to partially insulated rail return traction systems, tests have been carried out on wood sleepers removed from service and on sleepers composed of a special concrete aggregate. The tests revealed that mean volume resistivity of dry wood sleepers was of the order of 1 200 k.ohm-meters and for the concrete sleepers 2 750 k.ohm-meters. However, while the use of these concrete sleepers reduce the leakage of current into the mass of earth, higher rail to earth voltages may occur.

As a result of some considerable research into the electrical properties of concrete, it is now possible to produce mixes in which the aggregate contains ingredients yielding either high electrical resistivity, such as the railway sleepers referred to, or very low resistivity, i.e. high conductivity, making it useful for the construction of earthing electrodes or anti-static floors in hospitals and computer rooms, etc. [9]. With regard to sleepers, if the resistance is viewed from the rails to earth it may be deduced that with constant resistivity of the concrete the resistance to earth will be constant for a given width, regardless of the other two dimensions, provided that they remain equal to each other.

The density of current which strays from a railway line and is consequently picked up by buried services, bonded neutral conductors in pme systems and protective ground wires associated with transmission lines, depends not only on soil resistivity and earthing resistances but, to a significant extent on the spacing of the relevant substations, the number of such substations in the section, the number in operation at any time, the relative transformer tap positions and any earthing of negative busbars.

A particular and important aspect in connection with d.c. traction systems, is the question of regenerative braking when such a facility has been provided. The rails are usually the designed negative return conductors and are therefore normally anodic with respect to any neighbouring buried metal services or structures. While the locomotive is hauling, i.e. motering, the predomi-

nant anodic condition of the buried structures is close to a substation, where most of the picked up current leaves these structures. At this point relatively severe corrosion may be expected. However, when regenerative braking operates, the predominant anodic field shifts to points under the train.

Thus where train operation under these alternative modes is possible special precautions are necessary in the protection arrangements which will be referred to later.

In areas where multiple neutral earthing has been established, stray current may enter the neutral conductor. This subsequently discharges from buried pipes or electrodes connected to it. Where the current returns to the ground, the pipes, etc., then being anodic to the soil, are liable to corrode. Such points are usually located near traction substations.

It should also be noted that stray direct current picked up by the neutral conductor may spread to phase conductors through connected loads. If these connected devices are transformed or motor windings, adverse operation is possible.

Calculation of these currents whether entering or leaving pipes, etc. is very difficult, if not impossible, in most cases. Such factors, for example, as varying soil resistance, irregular track and insulation resistances and the presence of other pipes, etc. are some which make these complicated cases almost incapable of solution.

An approach to such a complex assessment of current density could possibly be based on the theory of line transmission. For example, it is well known that voltage and current vary according to the propagation constant (P) of the line exponentially in the form

$$e^{-Px}$$

where e = 2,718 (base of naperian logarithms) and, x = distance of the point at which current is considered. In a long pipe or rail line, where only direct current is involved, the familiar expression for P viz,

$$\sqrt{(R + jwL)(G + jwC)} \qquad [4]$$

reduces to $\sqrt{RG}$ where R is the resistance of the pipe or rail line and G is the leakance, i.e. the reciprocal of the insulation resistance to earth. This propagation characteristic will be referred to again later.

5. CONTROL AND MITIGATION OF CORROSION

A relatively wide range of control techniques has been developed and introduced over many years of dedicated study of the cause, effects and control of corrosion, much of which has been published. However, the measures and treatment adopted obviously depend basically on the cause and nature of a particular corrosion problem, the material, the design application and environment, etc. Prevention of corrosion often relies on careful selection of material and other measures in early stages of manufacture, as for example using appropriate copper alloys in the construction of measuring devices such as, for example, pressure sensors rolled from a brass containing about 20% zinc. Such an alloy has been claimed to possess both good elastic properties and resistance to corrosion, for which reason it is suitable for control springs in various measuring instruments. However, should such instruments be exposed to acid fumes or damp situations which could lead to electrolytic action, it is then advisable to seal these parts hermetically.

Corrosion resistant steels or steel alloys have been developed but their use must be considered in relation to environment and other factors such as temperature, strength, fatigue, costs, etc. It is advisable to discuss the proposed use of steel for tanks, boilers or other structures with a specialist in this field before compiling a specification.

It is claimed that a mere 6% chromium content in stainless steel reduces atmospheric corrosion by about 75%, and 12% to 20% chromium renders the alloy almost totally resistant to this type of corrosion. However, these slow corroding low alloy steels are more costly than ordinary steel and consequently their application and the economics should be equated. They have become attractive in respect of their superior corrosion resistant properties for use as earthing electrodes, particularly in the U.S.A.

Applications such as galvanising and the use of other liquid primers, etc. are familiar to most engineers and need no introduction.

A technique which has received a lot of attention and has improved over the years is the use of certain protective coatings for buried pipes. This includes tape wrappings. Some of these coatings comprise materials or substances such as petroleum – asphalt bases, coal tar enamels and certain epoxy films. Other fluid applications take the form of certain paint systems which may be preferable or more effective, for example in protection arrangements associated with sewage treatment plants where pH values may vary between alkaline and acid conditions. Thus if paint is selected or prescribed for this type of aggressive environment certain resin based paints are essential on account of their superior chemical resistance properties. Chlorinated rubber appears to cope with such demands. Wrapping systems usually consist of plastic tapes where common compounds used in their manufacture comprise polyvinyl chloride, ethylene, etc. Factors to be considered for successful or prolonged protection against corrosion include water content of the soil in which a pipe is to be buried, soil stress resistance and nature of soil composition, backfill, etc. To prevent the tape from possible damage by abrasion and chemical attack it is advisable therefore to surround the pipe with stone free and rubble free sand which has a pH value as near 7 as possible, i.e. chemically neutral.

It should be noted that should the wrapping be insecure or damaged at any point discharging current will be localised and consequently corrosion at that point will be relatively more intense.

Wrapping a long pipe line should therefore be undertaken by a specialist in the field. Costs will depend on factors already mentioned, including the material and possibly also on the cartage of suitable sand, etc.

In order to estimate the cost of all the tape which would be required for a given pipeline this may be calculated on the following lines:

Let the length of pipe line be L_1 and its diameter d mm, i.e. circumference = 3,14 d mm.

the length of one turn of tape = 3,14d mm.

If there is no overlapping of adjacent turns and the width of the tape is W mm this is also the proportionate length of pipe covered by one turn,

$$\frac{L1 \times 10^3}{w} \text{ turns} \qquad [5]$$

hence total length of tape required for covering the whole pipeline would be at least,

$$\frac{3{,}14d\,L1}{w} \text{ metres} \qquad [6]$$

If the tapes are sold in rolls of L_2 m and the cost is C rand per roll, the minimum cost of tape required will be

$$\frac{3{,}14dL1C}{wL_2} \text{ Rand} \qquad [7]$$

This estimate is, however, lower than what the actual cost is likely to be since no allowance has been made for overlapping, which could be about 10 mm, or the provision of any outer wrapping which might be prescribed.

Depending on the material, purpose, environment and general working conditions, the thickness of fluid type applications can vary between something like 50 and 400 micrometres (um). Tape thickness usually lies about halfway between these extreme values.

The insulating criteria of a coating is often expressed in terms of conductivity in the form micro-siemens (us) per square metre. Their initial values can frequently be misleading as they tend to be much lower than subsequent, and possibly more settled, values, which may take many years. Approximate figures available show that certain fluid type coatings can change from say, 80 us to about 2 000 us per m^2 after 10 years underground service, whereas certain tapes change from about half of that initial value to only one tenth of the conductivity of its fluid counterpart during the same period and in similar environments.

Flues associated with boilers may tend to weaken by corrosion and this is often provided with protection in the form of increasing thickness or factor of safety. However modern coating for these parts and turbine blades, etc. are now applied to a large extent.

A more popular and effective approach to the control of corrosion affecting buried or immersed pipes, etc. is the use of cathodic protection systems, sometimes referred to as Geppert's and also claimed to have been used by Humphrey Davy. Many papers have been presented and, including the books already published, this subject has been covered fairly extensively. However, certain aspects of the technique will be dealt with.

In corrosion engineering it is important that careful and most accurate electrical measurements are made when assessing corrosive conditions and specifying remedial measures. It is also obviously essential that careful observation of polarities is very necessary. The usual way is to measure the potential of the buried structure with respect to a reference electrode in the ground or aqueous solution, the characteristics of which are known. The common electrodes used for these measurements are in the form of half cells namely silver chloride, which is more suited to salt water, and the copper-copper sulphate half cell. The more popular cell is the latter, the construction and particulars of which have been adequately covered in many publications, e.g. Ref. 5 et al.

Some engineers consider these non-polarising half cells inconvenient to transport, handle, connect up, etc. and prefer an electrode of the same metal as the one being measured, particularly where they may be permanently installed at points where only periodic measurements are required to detect changes in potential.

Making allowance for the natural or absolute potential of the $CuSO_4$ electrode and that of a ferrous structure to be protected, then if the nett potential of the structure measured this way is less negative than −0,85 volt, the structure may be considered to be in a corrosive condition. It is important that the resistance of the voltmeter used is as high as possible as the resistance of the electrode in soil can be fairly high. Electronic meters are recommended and in some cases, particularly where continuous monitoring and automatic control of protecting currents injected into the ground are provided, potentiometric measurement is better. Such control will no doubt be taken over by microprocessors in future.

It is advisable to adjust the protecting current so that the measured potential of the ferrous structure is −1,0 volt or even a little more negative as such values may also protect against corrosive effects attributable to the bacteria already referred to.

Effective cathodic protection is partly influenced by the buried sacrificial anodic electrode employed, the manner in which it is installed and soil resistivity. Calculation of electrode resistance to earth or the decay of current or voltage in a transmission system involves logarithmic and exponential functions. Thus in a cathodic protection system, current and potential will obviously change along the pipe route in this manner. It should be mentioned that this system of protection can be quite costly, particularly if a long pipeline is involved. It is therefore more economical to use it as a back up for a coated pipeline. Such a line is virtually a form of single wire transmission line with earth return. Therefore, it is feasible to consider that current and voltage vary exponentially according to a propagation constant assuming constant soil resistivity, etc.

As mentioned earlier the propagation of direct current along a line is a function of the resistance of the designed conductors and the insulation or any leakage only, since inductance and capacitance have no effect on steady d.c. According to this concept the change in current or voltage along a pipeline under cathodic protection is thus related to the expression

$$e^{-x\sqrt{rg}}$$

where e = 2,718, × = distance from sacrificial anode
r = resistance of pipe (ohms per unit length)
g = leakance (mhos or siemens per unit lenth)
$\sqrt{rg}$ = propagation constant [8]

Some idea of the spread of the current or voltage or attenuation may be gained from the following hypothesis.

Assume that a long iron pipeline is required to be protected and is buried 1 m below the surface, and is 1 m in diameter having a wall thickness of 10 mm, and that the rectifier output has been adjusted so that the pipe-soil potential at the drainage point is −2 v with respect to a copper-copper-sulphate half cell reference electrode.

Fig. 2 and 3 show graphs which indicate the relative change in pipe-soil potential for bare and wrapped pipe installation.

Calculations for plotting these graphs were based on the equation

$$V = 2e^{-x\sqrt{rg}} \qquad [9]$$

i.e. $$\log_e \frac{2}{V} = \times\sqrt{rg} \qquad [10]$$

Where V is the potential in volts × metres away from the drainage point and r and g are the pipe resistance and leakage conductance to earth in ohms and siemens respectively, per metre, being determined as follows:

The resistivity of iron is of the order of 12×10^{-8} ohm-metre hence the resistance of 1 m length of pipe is

$$\frac{12 \times 10^{-8}}{0{,}01 \times 3{,}14} \text{ ohm}$$

$$= \quad 4 \times 10^{-6} \text{ ohm} \qquad (r)$$

The bare pipe may be regarded as a horizontal form of earth electrode for the purpose, taking the resistivity of the surrounding soil as 100 ohm-metres which is not uncommon in the Western Cape. Hence its resistance to earth based on Dwight's formula is about 15 ohms per metre so that

$$g = \frac{1}{15} = 0.07 \text{ siemen}$$

If the same pipe is wrapped, the material could yield a value of 300 us for g which is sometimes specified or based on a leakage not exceeding 100 us per metre. Under all these conditions the protective potential could be maintained at not less than −0,85 V for distances of 2 km and 25 km for bare and wrapped pipes respectively. This means that the next drainage point or rectifier would have to be located 4 km and 50 km away respectively.

Increasing the rectifier output to give 3 volts at the first drainage point would increase rectifier spacings to about 5 km and 74 km respectively.

These extremes indicate that the economics associated with buried pipeline involve a balance between the cost of cathodic protection alone, which could be appreciable, and the cost of good insulating covering material with lasting insulation, possibly backed up with a cathodic protection system then requiring a very much lower kVA demand.

Protection of a bare pipe in average soil may usually be achieved with densities up to 50ma/m^2 but could be over 1 a/m^2 in acidic soils or other adverse conditions. A well coated pipe may require a current density of the order of only 10 ua/m^2.

It should be pointed out that measurement or assessment of current flowing in a pipeline is by no means easy. The best approach is probably one based on the measurement of the magnetic field set up.

As already mentioned it is advisable to inform the nearest relevant committee of any intention to install a cathodic protection system and of any alterations or adjustments to such a system.

Limited cathodic protection is invariably applied where the corrosion rate is not severe by connecting to the pipe or other buried metal structure a buried or immersed anode comprising a less noble metal but higher in the emf series, i.e. more negative than the metal to be protected and if this metal is ferrous then magnesium with possibly a small zinc content may be used as the anode vide (Table 2). The output will of course depend on the soil resistivity. It is advisable to connect these anodes to the structure via test links.

Referring again to the report [26] on the submarine mentioned earlier there appears to be merit in the theory that the copper may have been cathodically protected by the adjacent steel work during the 69 years immersion.

All other anodes used in power operated systems should be either graphite, silicon iron or scrap iron masses. In one installation protecting a marine outfall pipe, old steel pole bases were immersed in the sea for the purpose but apart from the necessity to replace these anodes when corroded, frequent damage and severing of the connecting cable by the varying tides and turbulent waters occurred. These anodes were therefore replaced by silicon-iron units buried deeply on the shore.

It should also be mentioned that over protection can result in other adverse consequences. Negative potential exceeding 2 or 3 volts negative may cause too much hydrogen to form at the cathode which could result in embrittlement of steel and damage to coatings, etc. Furthermore, cathodic currents have been reported [5] to give rise to adverse chemical action to lead sheaths of cables.

Bonding and cross-bonding sheaths and armourings of adjacent 3 core a.c. cables can usually be done successfully since their losses are usually negligible. However, bonding these sleeves to neighbouring services such as water, gas and petroleum pipes or sheaths of communication cables with the object of draining stray currents could cause other problems, particularly if the various services or buried assets, belong to different parties.

Furthermore, the bonding of single core hv a.c. cables could create other problems such as undersirable induced voltages and currents [17 & 18].

When these services are parallel with an electrified railway traction system which uses the rails as the designed return conductor, at least two common methods are practiced each relying on a bond connected to the rails. One of these requires an independent source of direct current injected into the bond at a point remote from the substation, or near the pick-up point in such a way so as to reverse the pipe-rail potential at those points. If injected into a bond near the substation the object is to make the pipe-rail potential more negative thus virtually forcing or "sucking" the stray current out of the pipe, etc. Another practical or more natural connection commonly employed is bonding pipes, etc. directly to the rails as close to the substation as possible. This method has been found to be more convenient and effective provided that steps are taken to prevent any possible reverse current flow at this point. A suitable diode is thus inserted in the bond with adequately rated hrc fuses, frequently supported by circuit breakers and even non-linear resistors (e.g. varistors) for surge protection, etc.

Tests made on such a bond located on a section of electrified single track railway in the Western Cape have produced some interesting results and information.

The length of the section concerned is about 20 km long, with a traction substation situation at each end. As there are occasions when only one substation is in operation the principal object of the tests was to compare the currents in the natural bond for dual and single substation operation. The bond is connected between three bare major pipelines of ±800 mm diameter and the rails close to the terminal substation. The results of these tests are shown in fig. 4. It will be seen that when the terminal substation is in operation alone, the maximum current in the bond occurs when the train commences its journey at the beginning of the section travelling towards the terminus, and attains a value of nearly 600a for these conditions. When both substations are contributing to the

same section of track for the same train operation, the maximum value of the bond current is then 120a occurring when the train accelerates from a station mid-way between substations. Graphs A and B and fig. 4 show these characteristics respectively.

It is obvious that the voltage drop across the section of rail involved in the run is virtually applied across the parallel pipe, except of course that allowance must be made for the resistance to earth at the pick up and discharge points. The equivalent circuit is shown in fig. 5 on a lumped resistance basis for simplicity.

In a previous paper [14] it was shown that voltage and current vary in a conducting layer according to the equation,

$$V = \frac{rI}{2\pi t} \log_e x \qquad [11]$$

where r = resistivity of the layer
t = thickness of the layer
x = distances from point of contact

The equation may be expressed in the form

$$R = \frac{r}{2\pi t} \log_e x \qquad [12]$$

where R is the resistance involved. The equation is similar in character to the formula for earthing electrodes. If the rails made uniform contact with the soil all along the route they could then be considered to be similar in principle, or equivalent to a long horizontal wire form of earth electrode so that their resistance to earth would be of the form

$$R = \frac{r}{2\pi L} \log_e y \qquad [13]$$

where R and r represent the same parameters as above and y is a constant depending on length and cross-section of the rails so that for a length of 20 km the value of R could be negligible.

However, the rails usually rest on stone ballast via wood sleepers. The more recent introduction of the less conductive sleepers referred to earlier, reduce the amount of current straying from the tracks but as already mentioned, with possible increased rail to earth voltages. High rail resistance, with consequent high earth currents have been evident from touching e.g. water taps, wire fences, etc. to earth in the vicinity. Sometimes it is necessary to insulate pipe sections and in other circumstances to keep them continuous electrically. Decisions in these cases cannot be taken lightly as they depend to a large extent on other neighbouring services which could be adversely affected in respect of such factors as accelerating corrosion or creating unwanted voltages, etc. particularly where pipes may be exposed, e.g. bridging streams, etc.

The thickness of the layer referred to in equation 11 is comparable to the depth of penetration of current into the earth referred to in expression 1 and 2. It seems feasible therefore to infer that direct current projects much deeper into the earth, where the resistivity is usually relatively lower than the upper layers sought by alternating currents. Conversely the work and theories of Carson, Sommerfield et al suggest that, for perfectly conducting layers, paths, etc., the depth of penetration may be considered on the basis of image conductors in the ground as is done in the assessment of propagation properties or radio antennae. In such conditions the image, i.e. the return path in the ground is situated at a depth equal to the height of the conductor above the surface.

If this concept can be applied to traction systems with rail return, where the rails are partially earthed all the time, it is then possible to get some idea of the depth of the stray current path. However, the presence of waterpipes in the vicinity of the railway and their being located in relatively shallow ground, attracts most, if not all, the stray current away from the general mass of earth.

The ratio (m) of currents between source and any point along a pipe can be expressed as

$$m = e^{x\sqrt{rg}} \qquad [14]$$

or

$$\log_e m = x\sqrt{rg} \qquad [15]$$

Thus it may be inferred from the last four expressions that the equation for graph A, fig. 4, is of the form

$$I = k \log_e D \qquad [16]$$

where I is the current in amperes in the bond, when a train is D km from the bond, k is a constant and e = 2,718. This is also apparent from the shape of the graph, and for practical purposes the equation in this instance is,

$$I = 200 \log_e D \qquad [17]$$

and when a train is 2,718 km from the bond the current flowing in it is 200 amperes, and as it approaches the substation near which the bond is connected the current in the latter approaches zero, all the locomotive current then returning directly to the substation through the designed return path of diminished resistance.

With regard to graph B of fig. 4 i.e. when both substations operate, the pattern is quite different. The shape is somewhat cycloidal but it is not then practical to equate I and D. On the other hand it is something like the statistical or normal law of chance curve or rather a catenary upside down. The rise and fall character is in each case exponential which is feasible as indicated earlier. However, in its simplest form the catenary may be considered to be a parabola.

Thus if the equation for graph B is expressed as

$$I = aD^2 + bD + C \qquad [18]$$

it is found that the equation becomes

$$I = 19 + 21{,}3D - 1{,}11D^2 \qquad [19]$$

its derivative, is,

$$\frac{dI}{dD} = 21{,}3 - 2{,}22D = O \qquad [20]$$

It is found that the current in the bond reaches a maximum value of 120 amperes when the train is 9,6 km away i.e. in the middle of the section, which agrees with the graph.

Obviously the constants, as derived for these two graphical presentations of the test results in question, will not necessarily be valid for other areas or situations as these are dependent on a number of factors such as inter alia, type of sleepers, ballast, substation spacing, type of locomotive, soil resistivity etc.

It cannot be emphasized too strongly that it is imperative that any connection to a railway line be made only with the consent and close assistance of the railway authority. Indiscriminate connections could for example interfere with the proper operation of signalling systems and automatic booms at level crossings among other possible problems. Also, the relevant committee should be advised.

It is also an advantage when the railway authority advises all concerned, usually through the Committee, of any significant relevant changes such as commissioning, or closing down, of substations, transformer tap positions, earthing arrangements etc.

There are other techniques involved in the mitigation or control of corrosion whether electrolytic, chemical, atmospheric etc., too numerous to mention in this paper, most of them having been published elsewhere already.

However, to mention a few briefly, these include hot dip galvanizing and such devices as oxidation inhibitors intended for protection against airborne corrosion. The CEGB recommends greasing overhead line conductors, particularly steel reinforced aluminium standed conductors [6], although such an application has been known for some time.

This Board has designed an eddy current probe intended to detect early stages of corrosion, and it has developed a technique for detecting corrosion in tower footings in concrete using a special d.c. meter [6].

Cetain manufacturers of electric motors (e.g. 15 & 16) have endeavoured to meet demands for efficient corrosion protection and accordingly consider that the primary factor determining the practical use of a product in corrosive environments is the surface treatment rather than the choice of material. Anti-corrosion varnishes and the method of application have been developed to meet these requirements.

In concluding this section of the paper it may be prudent to add another note on transmission lines. Where such overhead lines cross electrified railways or are close to, say within 800m of them, the so-called ground wire which is provided for protection against lightning and reliable operation of the relevant relays under fault conditions, must be connected to the towers and earth in a manner which will restrict as far as possible the entry and discharge of any current which may be straying from the traction system, but nevertheless consistent with the designed object of that wire.

This applies both to lines feeding the traction substations and those owned and operated by other parties. The method of connection should be discussed with the railway authorities in advance of the planning stage and the decisions reported to the relevant committee.

In any case it is necessary to approach the railway authorities when it is intended to cross tracks, whether overhead or underground, when certain requirements will be specified, one of which is bound to cater for the reduction of stray current pick up.

Periodic washing of stone ballast under the rails could also restrict the leakage of current to earth. A back-up return path by insulated cable should reduce the rail to earth voltage to within about 50 volts, and thus further restrict current flowing into the earth.

6. DISCUSSION AND CONCLUSIONS

It is fair reasoning to conclude from the scope covered in this paper that the corrosion problem has received at least as much attention and investigation as for example noise and atmospheric pollution. However, it is also fair to say that due to the ever increasing scope, volume of work and responsibilities, it is difficult for most engineers, particularly those in municipal service, to carry out more research in the field of corrosion technology. Therefore reliance has generally to be placed on published data, attendance at meetings of relevant committees and appropriate professional institutions.

There is an apparent division of responsibility in the work undertaken in the control and mitigation of corrosion generally. Attack by atmospheric and chemical action has to a large extent been dealt with by chemists, chemical engineers and others in the industrial sphere who have dedicated themselves to these problems resulting in the production of such inhibitors as oxidation suppressors, special coatings in various forms, steel alloys etc with ultimate cost saving in mind.

The electrical engineer's role is virtually exclusively involved with electrolytic corrosion and in the application and control of electric currents for the mitigation of corrosion.

Since rail tramway systems have now been phased out in the country, any stray currents flowing in the earth now are due to electric trains, hv dc transmission, cathodic protection or other systems such as pme, men etc.

The railways administration is most co-operative and consequently stray current from its system and any associated corrosion is therefore well under control.

With the introduction of more ac traction at customary power frequency and the increasing application of pme and men, more attention has been given to corrosion by alternating current in recent years. Research in this regard is continuing, as there is still much to be discovered. The mechanism of this form of corrosion is not yet clearly understood but when it is presented it tends to accelerate corrosion in certain soils by about three times. Cathodic protection has been found to be applicable for protection against ac corrosion also.

Cathodic protection is regarded as the most popular form of protection against electrolysis and other forms of corrosion but it must be applied with caution, particularly where there are neighbouring buried services belonging to different parties, to avoid possible undersirable repercussions and should therefore be arranged through the relevant committee.

Incidentally, solar cells are now being used as a source of current for cathodic protection where it is difficult to operate the system from other power sources.

The usual precautions such as current loading capacity, thermal stability etc. for earth electrodes must be taken into account for any system designed to discharge current into the ground or any electrolyte.

Systems in which the neutral conductor is earthed with the object of discharging current only under fault conditions are usually provided with devices such as unrestricted or restricted earth fault relays or differential patterns, such as, for example, the units referred to in the Code of Practice for the Wiring of Premises [8]. The use of these various devices restricts the duration of such earth currents for periods usually less than three seconds on average.

Unfortunately no devices have so far been developed for inhibiting currents from straying into the mass of earth from traction systems or from the neutral conductors in pme systems etc.

Corrosion of ferrous pipes is not always due to stray current electrolysis but is often due to auto-electrolysis as in other structures when minute currents flow over the surface. These pipes tend to corrode more rapidly in soft waters and in soils of low resistivity or which are contaminated with certain aggressive salts or polluted with corrosive wastes etc. It is therefore essential to carry out a chemical and resistivity survey of the soil in which a pipeline is intended to be buried.

Furthermore cast iron pipes can be allergic to internal growths, or turberculation as this phenomenon is also known, and another somewhat disastrous effect known as graphitization which leaves the metal in a spongy weakened state. This failure may be due inter alia to the presence of the bacteria already referred to.

In sea water cooled power stations the presence of non-ferrous metals in the cooling systems have been know to accelerate the corrosion of adjacent ferrous portions.

Reinforced steel concrete pipes may require special attention as, depending on the electrical properties of the concrete and its porosity etc, there is for example a possibility of weakening the bond between the two materials by current flowing from concrete to steel.

To sum up the position it may be mentioned at the outset that some of the factors that go a long way towards combating corrosion include the services of people with a good working knowledge of the various sciences referred to in section 3 and the ability to make careful and accurate electrical measurements and current interpretation of the results.

Membership of established committees dedicated to the study and solution of corrosion, particularly by owners of buried services or assets, is virtually imperative.

Furthermore, considering the important role engineering technology must perforce play in solving most corrosion problems, the relevant professional institutions should encourage a wider interest among their members and call for more papers on this vital subject. There appears to be a dearth of interchange of information and published data in their respective journals, etc.

Whenever there is any doubt regarding the correct remedial measure for a particular corrosion problem expert advice should then be sought as incorrect treatment could defeat any cost effective attempt. Each case requires careful and usually special attention appropriate to the cause, effect and environment. This approach together with adherence to relevant codes of practice, including any requirements of the Railways Administration for cables, pipes and transmission lines near or crossing tracks, will surely produce the best results obtainable, and therefore go a long way towards reducing the cost to the country of corrosion in its various forms.

Finally it is probably also pertinent to mention that buried or immersed electrodes used in connection with the operation of certain biological systems, including electrified fences and barriers for repelling animals, sharks etc., also require special consideration in order to reduce their corrosion rate and frequency of renewal etc. Furthermore codes of practice related to earthing and corrosion have taken cognizance of the necessity to strike a balance between the safety of persons, animals, buildings, etc., and the corrosion hazard.

Over-heating of electrodes, pipes and conductors by stray currents should be avoided. Analysis of current distribution and temperature field is probably most accurately formulated in terms of certain differential equations, making it possible to compute temperature profiles in the vicinity of electrodes depending on their shape and current [24].

Furthermore, the chances of corrosion between the connecting wire and the electrode can be considerably reduced if the same metal is used throughout and care is taken over the method of connection. Copper normally offers a resistance to corrosion in most soils, provided the electrode is not surrounded by coke as although this substance generally reduces resistance to earth, it tends to be aggressive towards copper.

When the electrode is in the form of a buried plate, more elaborate precautions are necessary, particularly if different metals are involved, in making the connection since it is underground and therefore not readily available for inspection. Corrosion at the connection does not necessarily have to proceed too far to introduce a high electrical resistance in the earthing circuit.

7. ACKNOWLEDGEMENTS

Thanks and appreciation are due to the South African Transport Services for its full co-operation at all times in combating electrolytic corrosion in South Africa and together with the Cape Town City Council for permission to present certain test results in the paper, the City Electrical Engineer and members of his staff and also to the South African Electrolytic Corrosion Committee for permission to make use of certain data as far as its Constitution provides.

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TABLE 1 : Electrochemical equivalents (ece) of some common metals (hydrogen = 0,0105 mg/c)

METAL	LOSS MILLIGRAM/ COULOMB	GRAM/ AMPERE/HOUR
ALUMINIUM	0,094	0,338
MAGNESIUM	0,125	0,45
IRON	0,289	1,04
COPPER	0,328	1,181
ZINC	0,337	1,213
CHROMIUM	0,91	3,276
LEAD	1,071	3,856
SILVER	1,118	4,025
GOLD	2,06	7,4

TABLE 2 : Potential of some common metals with respect to hydrogen (neutral or zero potential) : galvanic series

METAL	POTENTIAL (VOLTS)	REMARKS
MAGNESIUM	−2,34	ACTIVE METALS
ALUMINIUM	−1,67	
ZINC	−0,76	
CHROMIUM	−0,71	
IRON	−0,44	
LEAD	−0,13	
COPPER	+0,43	NOBLE METALS
SILVER	+0,8	
GOLD	+1,42	

FIG. 1 : Estimated Annual Cost of Wastage by Corrosion

GRAPH A : Estimated actual cost so far.
GRAPH B : Estimated possible cost if present known technology was applied correctly and timeously.

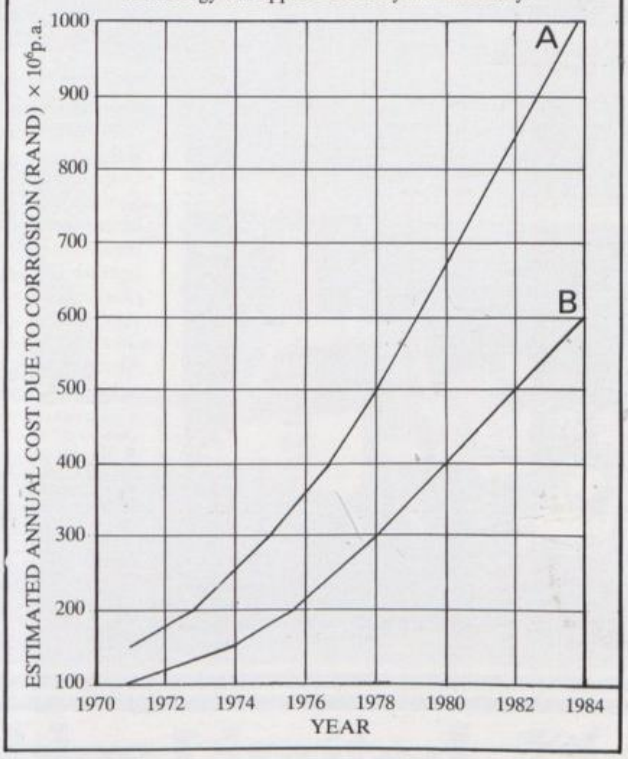


FIG. 2 : Cathodic Protection : Fall of Pipe-line Potential

PROTECTION OF IRON PIPE : MIN. POTENTIAL 0,85 V

$$V = \frac{-x\sqrt{rg}}{2e} \quad \log_e \frac{2}{V} = x\sqrt{rg}$$

A = BARE PIPE $r = 4 \times 10^{-6}$ ohm per metre

$g = \frac{1}{14} = 0.07$ siemen per metre

B = WRAPPED PIPE $r = 4 \times 10^{-6}$ ohm per metre

$g = 0.0003$ siemen per metre

x = DISTANCE FROM DRAINAGE POINT (metres)

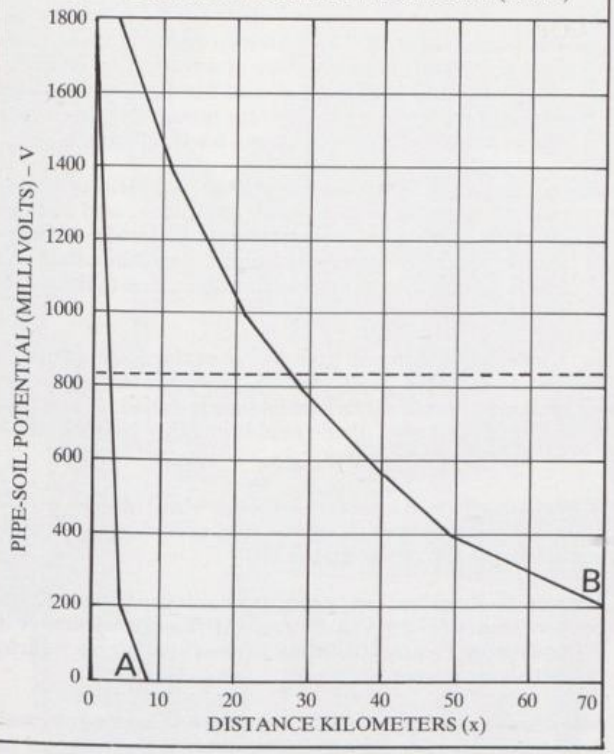


FIG. 3 : Cathodic Protection of Wrapped Iron Pipe : Min. Potential 850 mv (as in Fig. 2 showing distribution to left and right of drainage points)

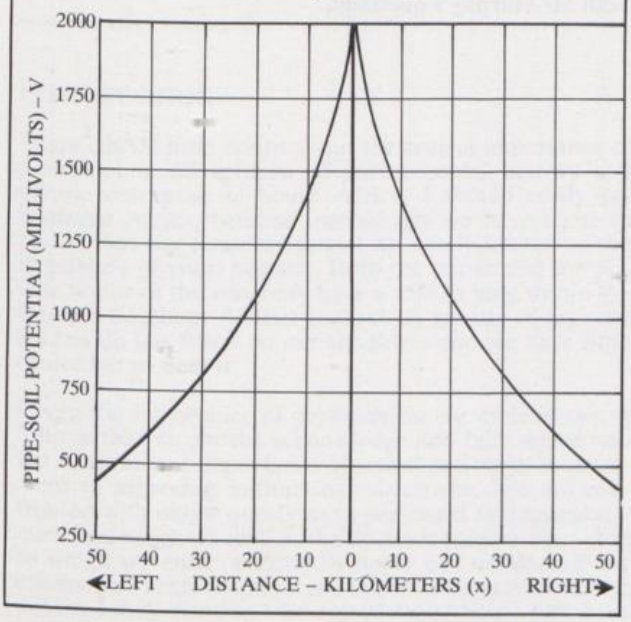


FIG. 4 : Steenbras Dam Pipes : Protection against Electrolytic Corrosion

Train travelling between Faure and Strand
Current in pipe-rail diode drainage bond near Strand Traction sub-station
A = Strand sub-station On, Eerste Rivier sub-station OFF. ($I = 200 \log_e D$)
B = Both sub-stations operating ($I = 19 + 21,3D - 1,11D^2$)

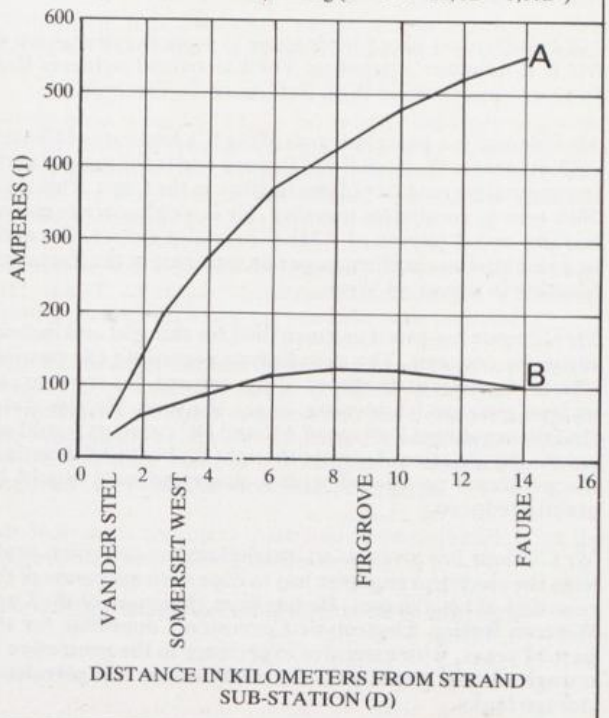
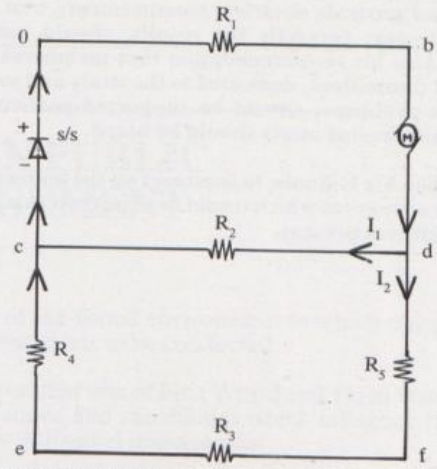
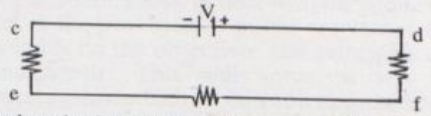


FIG. 5 : Electric Traction System with Rail Return



a – b = overhead conductor/contact wire; res. R_1 ohms
c – d = running return rail; res. R_2 ohms
e – f = pipe line; res. R_3 ohms
$R_4 + R_5$ = resistance to earth which may include series resistance of any protective covering
s/s = traction sub-station
M = electric locomotive/unit
I, I_1, I_2 = current amperes; I, R_2 = rail potential V

(A) Resistance network and current distribution



(B) Equivalent circuit for rail and pipe return combination

DISCUSSION – BESPREKING

MR K J MURPHY : Somerset West

Mr President, it give me pleasure to open the discussion of Mr R R Gilmour's paper on The Electrical Engineers Role In Corrosion Control With Reference To Electrolysis.

Mr Gilmour is a past chairman of the S A Institute of Electrical Engineers, Western Cape Branch and is the longest serving committee member of the Insitute in the Cape. This is his 30th year as committee member. He is well known to us and has presented papers at AMEU meetings before. Recently he presented an excellent paper on metering at the Technical Meeting in Somerset West.

Mr Gilmour has given us much food for thought and indeed, cause for concern. The calculations regarding the possible effects of a current discharge of one ampere, for one year, on an iron pipe are frightening, to say the least. He also states that the combined leakage of AC and DC currents would agravate the situation. I always thought that with AC traction, the problems associated with leakage currents would be greatly reduced.

Mr Gilmour has given us an insight into the corrosion problems the electrical engineer has to cope with and some of the remedies at his disposal. He has been chairman of the Cape Western Region Electrolytic Corrosion Committee for the past 14 years, with extensive experience in the protection of sewage outfall, water, gas, electricity mains and petroleum storage tanks.

His observations about employing staff having a good working knowledge of the various sciences, the ability to take careful and accurate electrical measurements, and the ability to interpret correctly the results, should not go unheeded. Also his recommendation that membership of established committees, dedicated to the study and solution of corrosion problems, should be supported particularly by owners with buried assets should be noted.

I should like Mr Gilmour to comment on the following questions, the answers to which would be of interest to most practicing engineers present.

(a) Cable earth fault locating with loop fault locators has been found to be particularly difficult, if not impossible, on cable running parallel to electrified railways, due to stray currents. Though this is not the subject of the paper, Mr Gilmour's practical experience will be of interest.

(b) How effective are the drainage sumps installed on either side of electrified railways, where they are crossed by underground cables? Ours are flooded most winters and I have reason to believe that it could also be the case elsewhere.

(c) The buried assets of South African electricity undertakings are almost always cables of one kind or another, often with lead sheathing. Could Mr Gilmour perhaps advise us on types or grades of the metal used, which are less susceptable to corrosion and bacterial attack?

(d) As mentioned in the paper, the PME and MEN system of neutral earthing is in common use today, and leakage currents will be at power frequency. Is Mr Gilmour aware of any serious electrolytic corrosion that has taken place anywhere in the Republic, due to the use of these systems?

(e) Could Mr Giulmour give us an explanation of how a simple cathodic protection circuit to protect a pipeline or a tank would be connected and installed. If this cannot be done today, then could it possibly be done in the published proceedings?

Omdat ons altwee Kapenaars is, het ek Mnr Gilmour kennis gegee van diè vrae en is ek seker dat hy gereed is met interessante antwoorde.

Meneer die President, ons neem met dank kennis van die besondere samewerking van die Suid-Afrikaanse Spoorweë in die opsporing van elektrolitiese korrosie probleme waarby hul betrek mag wees.

Mag ek dan ten slotte mnr Gilmour gelukwens met sy weldeurdagte referaat, waarna ons dikwels in die toekoms sal verwys.

MR R R GILMOUR

Owing to lack of time, Mr Gilmour could only deal briefly with Mr Murphy's questions.

INTRODUCTION OF MR I H ROBSON

MR W BARNARD : PRESIDENT

Gentlemen, it is with great pleasure that I introduce Mr Robson, Chief Director of the Commission for Administration.

Mr Robson is vanaf 1952 'n lid van die Staatsdiens en het wye ervaring in owerheidsorganisering en openbare personeel administrasie opgedoen. Hy is vanaf 1979 verbonde aan die Kantoor van die Kommissie van Administrasie en hy beklee tans die pos van Hoof-direkteur.

Mnr Robson is 'n lid van die Nasionale Mannekragkommissie, die Permanente Finansieskakelkomitee (Plaaslike Bestuur) en hy dien ook op verskeie ander komitees.

Mnr Robson het onlangs die leiding geneem in twee ondersoeke van besondere belang vir plaaslike bestuur, te wete 'n ondersoek na Administrasierade en 'n ondersoek onder die besoldiging en die Permanente Finansieskakelkomitee na die bepaling van die besoldiging en ander diensvoorwaardes van plaaslike owerheidspersoneel.

Mr Robson is therefore particularly well qualified for the subject on which he will address us viz:

"New Approaches in Public Personnel Management".

I H ROBSON

NEW APPROACHES IN PUBLIC PERSONNEL MANAGEMENT

INTRODUCTION

There can be little doubt about the critical importance of personnel in all spheres of governmental activity and private enterprise in South Africa. I should really say **Southern** Africa, because increasingly we have come to realise that our concerns cannot be neatly limited to the Republic's physical borders. Both the public and the private sector of the economy have a role to play within the broader Southern African context. A mantle of regional leadership has fallen on our shoulders and we have little choice but to wear it.

Given the importance of personnel in our endeavours, it follows that we should acknowledge and fully appreciate the concomitant importance of sound personnel management in achieving institutional objectives. We are confronted with major questions in personnel management – questions which we shall probably never fully resolve – but to which we must concertedly apply our minds and our efforts if we are to maintain and improve our services to the public. I shall mention – by way of illustration – just three aspects of the broad environment in which our personnel management has to be conducted:

- The peculiar mix of First World and Third World needs, aspirations and capabilities which influence the nature of our personnel management.
- The formidable structural problems manifested in the labour force – notably the critical shortages in the higher skilled categories and unemployment in the semi- and unskilled categories.
- The relatively low productivity with serious implications for the stability and growth of the economy.

In this paper I should like to deal with the pre-eminence of personnel in the provision of public services, followed by some thoughts on the objectives and principles of personnel management. This will serve as the necessary background against which certain new approaches in public personnel management can be submitted for your consideration.

THE PRE-EMINENCE OF PERSONNEL

Once we know what we want to achieve, in other words when we have clarified and defined our objectives, the practical question to be answered is the following: What do we need to achieve our objectives? When one reflects on this question, one realises that there are three basic inputs which are always necessary if we are to achieve a substantial objective. It doesn't really matter what an institution or body wishes to accomplish, if the objective is a substantial one, it will need people, money and organisation. Please note that all three basic inputs must be available at the same time and in sufficient measure if something worthwhile is to be achieved. I shall not dwell on the point, but leave it to you to test the relevance and accuracy of the argument in your own situation.

Of the three basic inputs, personnel is unquestionably the most critical one. No matter how important organisation and finance may be in the delivery of public services – and their importance is not in dispute – it is the people in public employ who at the end of the day determine whether or not objectives are achieved. Of course the achievement of objectives by public institutions is merely another way of saying that the community is properly served.

If a department, at whatever level of government, has efficient and motivated people at its disposal it can achieve much even if the organisational arrangements are unsatisfactory and the availability of finance problematical. However, good organisation and adequate finance as such can never make up for serious shortcomings in the numbers, quality and motivation of the personnel corps. The people factor is the decisive one, and whatever the nature and scope of our responsibilities and programmes, it is well always to remember this. It goes without saying that particular attention should be paid to this critical factor, with the expectation that success in personnel management will almost certainly lead to the realisation of institutional objectives.

THE OBJECTIVES AND PRINCIPLES OF PUBLIC PERSONNEL MANAGEMENT

Public personnel management consists of a wide range of activities; indeed everything that needs to be done to create, establish, develop, motivate, apply and maintain an efficient personnel corps. Public personnel managment has its own peculiar goal, viz. to attract to the service of a public employer sufficient numbers of the right categories and quality of staff, to retain them in service and to mobilize and liberate their full potential. The success of a public institution in the field of personnel managment can be determined by noting the degree to which the stated goal is achieved. Personnel management is the concern of everyone who has been placed in charge of employees, and not only the responsibility of designated personnel officials. This is a point to which I shall return later in this paper.

To further appreciate the importance of personnel managment one needs to note that labour is indeed a very "elastic" resource. A given number of employees does not produce a fixed quantity and quality of goods and services.

The productivity of the labour resource can in fact vary within wide limits depending on the way in which employees are treated. By applying scientific selection principles and procedures and striving to ensure that every employee is placed in a job in line with his abilities and interests, the groundwork can be laid for achieving optimum productivity levels. Each employee should then be trained and developed to the point where his full potential can be realised. Productivity can be further enhanced by paying careful attention to the selection of supervisors at all levels and by ensuring that supervisors are properly trained for their job. If we go further and ensure that employees are at all times treated fairly and reasonably and are rewarded for superior performance, we can expect a further increase in productivity. If we do all this and in addition succeed in inculcating in employees a positive attitude of service to the community, we could in the end be astonished at what can be achieved with a given personnel corps. It is clearly the quality of personnel management which will make the difference between a noticeably productive personnel corps and one which is performing poorly.

To my mind there are two basic principles which underlie sound personnel management. These are the principles of **efficiency** and **merit**. I would go as far as saying that any particular aspect of personnel managment can be taken to be well-founded if it is designed to give practical effect to either one or both of these principles. There may be other principles which need to be acknowledged in personnel management, but the two I have mentioned are particularly significant, both as a starting point for and a final test of all actions affecting personnel.

To say that personnel management should be directed at efficiency means basically two things. In the first place, personnel actions should be directed in such a way that the best result is obtained for a given input of resources. We can say that productivity per unit of input should be raised to an optimum level. However, and in addition, actions should ultimately also be seen to be **effective**. Here we should look beyond immediate results to broader objectives, such as the stability and motivation of the personnel corps and its ability to satisfy the needs of the community at an acceptable level.

The merit principle in personnel management has two clearly distinguishable aspects. It means, in the first place, that subjective preferment and discrimination should be kept out of personnel management. This in itself fosters confidence in the system. But the merit principle in addition requires that there should also be positive action to encourage and reward excellence in service. The consistent and determined application of the merit principle is indispensable if we want to utilise our human resources to the full.

The two basic principles – of efficiency and merit – submitted for your consideration, do not fuction separately from each other. More often than not one will find that a particular personnel action can be validly explained, or rejected, in terms of the extent to which it does, or does not, promote efficiency or acknowledge merit. I cannot elaborate at this stage and must leave it to you as managers to test the dynamics of the interplay of the two principles in your own organisations.

NEW APPROACHES TO OLD PROBLEMS

Because of the importance of personnel, and the consequent importance of our actions affecting personnel, we should constantly be striving to improve the quality and effectiveness of our personnel management. I should like to discuss briefly two new approaches in personnel management which are aimed at improving its quality and effectiveness.

I use the expression "new approaches" with some hesitation as there is probably nothing which is completely new in personnel management. However, we have started doing things differently and placing particular emphasis on certain aspects – in this broad sense we could speak of new or fresh approaches to old problems. My frame of reference is the broad government sector. I shall be dealing firstly with renewal in the structural aspects of personnel management and then with the role of line managers.

OCCUPATIONAL DIFFERENTIATION

Theoretically, the ideal way to provide an employee with pay and other conditions of service, would be to devise a package which exactly matches his particular value on the labour market and which fits all other salient features of his particular set of circumstances. He would then be the recipient of fully personalised treatment, and there is no way in which he could be treated in a more exact and accountable manner. However, with a personnel corps of substantial size an approach focusing on each individual member of the corps would not be a feasible one in practice. We simply haven't the time or the resources to design and maintain separate valid packages for each and every member of the staff.

At the other extreme, an approach in which every member of the personnel corps is treated exactly the same, would similarly be an impractical and dysfunctional one. We would simply arrive at some form of generalised, average package of pay and other conditions of service which per chance may suit some employees but which would be unsuited to others. There is also a particular danger inherent in the "happy average" type of approach, viz. it tends to satisfy and thus attract employees of lower ability and to not satisfy and thus repel the above average performer. Surely this is not a situation in which a responsible manager would like to find himself.

In devising plans and packages for the employment and management of personnel, the answer lies somewhere between the **personalised** and the **generalised** approaches. We call such an approach by the name of **occupational differentiation.** We have been following this approach for some years now in the Public Service. It is working well and has tended to reach beyond the statutory limits of the Public Service into other parts of the broadly defined government sector. What is the essence of this new approach in personnel management?.

Essentially, occupational differentiation establishes and maintains a personnel management system in which the total personnel corps is divided into occupational groups and each group is then provided with a tailor-made dispensation which accommodates all relevant needs, requirements and circumstances pertaining to the group. Some examples of occupational groups are accountants, engineers, clerks and nurses. In the Public Service we are also beginning to apply the occupational group concept to the senior management cadre.

An occupational group is defined in terms of what members of the group do, in other words in terms of their function or particular set of work activities. This is a fundamental point of departure in occupational differentiation. Occupational groups are set up on the basis of the distinguishing features of the various underlying jobs. It follows that separate groups are established and defined in terms of substantial, verifiable differences in the functional content of the work involved. When we encounter and find that we can point out such differences in a particular area of activity, then, on the face of it, we have more than one occupational group to contend with. On the other hand, if we study a particular block of work and cannot find substantial differences in job content, there would be no grounds for setting up more than one occupational group.

I have used the expression "substantial differences" and it is necessary to mention that such differences are not always immediately apparent. In fact, the classification of a personnel corps into occupational groups can be quite demanding in a technical and even intellectual sense; that is if we consistently use job content as the basic point of departure. The engineering family of occupational groups presents a good example: Here we need to distinguish on a basis of job content between the professional engineer, the technologist, the technician and the artisan. To place the classification of occupational groups on a scientific basis, one obviously needs suitable **classification criteria**. We have developed such criteria for the Public Service but a discussion of this technical aspect of occupational differentiation would take us beyond the scope of this paper. In general, it would be true to say that a separate occupational group is set up when there are clear differences in job content and substantial grounds for managing such a group as an entity different from all other occupational groups.

Having distinguished an occupational group and circumscribed its job content, the next step is to determine the job levels at which members of the group will be utilised. This will depend largely on organisational factors. A general pattern or model followed, is to determined learner, journeyman and supervisory levels. Once determined, a job level is specified as to its peculiar job content in relation to other such levels for the occupational group concerned. Having progressed this far, we have at our disposal an occupational group defined in terms of both line of work and levels of work. The next step is to devise a grading structure consisting of a number of designations, ranks or job titles if you like, to adequately fit the occupational group and to provide for the employment of people as members of the occupational group to perform the work, at various levels, for which the occupational group has been set up. Of course, there are a number of key considerations to be weighed in determining a suitable grading structure for an occupational group – considerations which I cannot discuss here in detail – but the general picture should be clear. It goes without saying that for every occupational group the requirements and rules for entry to a particular grade, and for progression through a series of grades, will have to be determined and prescribed if we are to have orderly personnel management.

After we have structured an occupational group – as I have briefly described – we can proceed with the determination of a suitable package of pay and other conditons of service for the group. Our approach is to design such packages to fit the occupational group as precisely as possible. Included in the package are all relevant service benefits, employee rights and obligations, employer prerogatives and even an indication of relevant job facilities to which members of the occupational group will be entitled. The focus is on the group – with its needs, requirements and circumstances – and we consciously strive to come up with a total dispensation which is tailor-made for the group in question. Of course, the dispensation of one occupational group will often include elements corresponding exactly to elements in the dispensations of other occupational groups, for example pension rights, leave privileges and medical aid. However, where there are substantial differences in needs, requirements and circumstances, these will be reflected in the various dispensations. The total dispensation should still be tailor-made for each individual group – at least this is our aim.

The total dispensation of an occupational group is contained in an all-embracing document called a **personnel administration standard**. Everything one needs to know concerning an occupational group will be found in its personnel administration standard. As far as I know, our public service is the first to use such a document as an instrument of personnel management.

It is the policy of the Government to pay public servants at rates which are reasonably market-related and occupational diffferentiation has played an important role in making this policy effective. However, pay is **not** the "be all and end all" of occupational differentiation; it is but one element – albeit and important one – in an occupational group's total dispensation. It is the **total** dispensation which at the end of the day determines whether or not one can

SIEMENS

Even here, the new SF_6-insulated ring main unit would operate maintenance free.

Siemens announces the new SF_6-insulated, sealed metal enclosed ring main unit 8 DJ.

The new Siemens ring main unit is completely maintenance free.
All switching chambers are sealed and gastight. The combination of corrosion free materials, the insulating gas SF_6, and the extremely long mechanical and electrical life eliminate any problems with spare parts. Because you don't need them.

The new Siemens ring main unit is completely reliable and operationally safe.
Once installed you can forget this Siemens ring main unit 8 DJ for years and years. Because all live parts are completely isolated from environmental conditions.

The new Siemens ring main unit is universally applicable.
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Ask for the most reliable Switchgear from Siemens.
The ring main unit 8 DJ is a new member of the worldwide proven family of switchgear from Siemens. From 6 kV up to 800 kV the whole range is SF_6-insulated. Based on the most up to date circuit-breaking technology, which is also available in air insulated versions.

Siemens: Switch to the future.

attract and retain sufficient numbers of the right kind of staff.

THE ROLE OF THE LINE MANAGER

I have described to you what I consider to be an important new approach concerning the **formal or structural** side of public personnel management. On this occasion I would also like to deal with a somewhat more **dynamic** aspect of personnel management, viz. the role of the line manager Up to this point, I have been dealing with developments actually taking place at the present time; the treatment has thus been descriptive. In what follows, I shall be discussing what ought to be rather than what perhaps is; the treatment in this case will therefore have a normative emphasis. I shall be speaking in general terms, as the actual role played by line managers in personnel management can differ greatly from organization to organization and from manager to manager.

What I wish to submit for your consideration, is that the importance of the line manager's role be re-established and acknowledged by both line managers and personnel specialists. However, this is not enough: Line managers especially need to fully accept their inalienable responsibility as managers of personnel and to rededicate themselves to the optimal utilisation of the human resources placed at their disposal. In the light of our formidable manpower problems, such acceptance and rededication is essential in the interest of every employer and employee, and ultimately of society itself.

A major problem, as I see it, is that line managers have over the years tended more and more to adopt the attitude that personnel management is a function to be attended to by those designated as personnel officers or personnel managers. A partial explanation for this phenomenon may lie in their pre-occupation with carrying out their programmes of work and reaching institutional objectives, which require so much of their time and energy that very little is left to devote to personnel management. At the same time, the emergence of the personnel specialist has perhaps had the unfortunate side effect of tending to blur the line manager's responsibility for personnel management and even to lead to some transfer of responsibility to the personnel specialist. Whatever the full explanation might be, it would seem opportune that there should be a restatement of the line manager's responsibility in the personnel area.

The line manager's most important resource is the people at his disposal, and it is a very scarce and important resource indeed. He is required to manage this resource to the best advantage of his employer and this is something which is required of him on a continuing, day by day basis. This makes him a manager of personnel and imposes on him an essential duty, viz. that of efficient and effective personnel management. He cannot escape this duty; the appropriate question to pose is how well or how poorly he discharges his duty. To my mind, the line manager is the true personnel manager. The staff experts in the personnel department are best designated by titles other than "personnel manager", for example "personnel officer" or "personnel adviser" or "personnel specialist". This would help to obviate uncertainty about where the true management responsibility lies.

In pointing to the responsibility of the line manager in personnel management, I am not saying that he should have unlimited power to hire and fire and in general to deal with his staff as he sees fit. Obviously in an organisation of substantial size, it would not be possible to maintain order if every line manager was given a free hand in personnel matters. There is a clear need for a comprehensive personnel policy, for pay rates and other employment standards, and for guidelines and rules covering the typical personnel actions which need to be taken day by day. But having established such a framework, the line manager should be given the greatest measure of latitude consistent with the overall good management of the organisation. This applies to both the formal aspects of personnel management such as appointments, promotions and disciplinary actions, as well as to the less formal aspects such as job assignment, motivation and on the job training.

By emphasising the important role of the line manager in personnel management and calling for a fresh approach to the question, I in no way wish to detract from the importance of the role of the personnel specialist, The personnel specialist has a crucially important role to play in the development of personnel policy and practices, in advising line managers on personnel matters, in the centralised processing of certain personnel actions, and in the general overseeing of the functioning of the personnel system. Line managers are indeed heavily dependent on the personnel specialists, and the ideal situation is obtained when there is mutual understanding and appreciation of each other's roles.

To properly discharge their personnel management responsibilities, line managers will obviously need the necessary knowledge and skills. Their own training programmes will have to provide for this and clearly it is no easy task to adequately master the working of the personnel system. Yet this will have to be done if line managers are to release the full potential of the human resources at their disposal. Over and above knowledge of the personnel system, line managers also need insight into human nature, and this is something I would like to comment on briefly.

To manage personnel successfully, one obviously needs an adequate knowledge of people; of their needs, drives, motives, fears and expectations. All these and other aspects of the human condition and make-up – of what makes a man "tick" – need to be related specifically to the work situation. Armed with the appropriate knowledge and the necessary depth of insight, the manager would be in a position to manage his peole with confidence and an expectation of success. The average manager could be forgiven for emitting a bark or even a howl of protest at this point. How – in addition to everything else he needs to know and to do to achieve his goals – can he also be expected to be a competent, practising personnel psychologist? Shouldn't he leave the psychlology to the experts and get on with the job?

One can sympathise with the manager in his predicament – but only up to a point. The fact of the matter is that, goals are achieved through people. There is no other way. The good manager knows this and realises that in the final analysis his success in achieving institutional goals will have been largely determined by his success in dealing with the people who work for him. So it would seem essential that the manager achieves a workable understanding of the human psyche and a substantial level of competence in applying his knowledge.

I believe the knowledge and skills I am referring to, are attainable by any manager willing and determined enough to make the effort. An appreciation of the importance of knowledge and skills in this area of management is an excellent beginning. I would caution against gimmicks and easy recipes but at the same time point to the fact that managers in general have a fund of experience of human nature and human reactions to draw upon. What managers need to bear in mind especially, is that an employee spends the major part of his waking hours at his place of employment and that he will consciously or unconsciously strive to satisfy his needs and aspirations in the work situation. Of the various needs recognised by psychologists, the needs for security, for social acceptance, for status, and for self-realisation are particularly relevant to the work situation.

CONCLUSION

If there is a critical factor in the delivery of public services, it must assuredly be personnel. It follows therefore, that there is a heavy responsibility resting on all governments and managers to raise their personnel managment to the highest possible level of efficiency and effectiveness and to maintain it at that level. Because personnel management is such a universal phenomenon, we are inclined to take it for granted, whereas it constantly needs to be reviewed, to be improved and to be practised with insight and imagination. I trust that what I have had to say may make some contribution, however small, towards a renewed appreciation of this very important aspect of management.

DISCUSSION – BESPREKING

MR J A LOUBSER : Benoni

Mr President, before thanking Mr Robson on his excellent paper may I thank your for asking me to start the discussions. When you originally approached me I was very hesitant in accepting your invitation, but when receiving Mr Robson's paper a couple of days ago I opened it and one of the first titles I saw was "Occupational Differentiation". These two words, Mr President, are the same to Municipal Electrical Engineers as waving a proverbial red flag in front of a bull. Please, do not misunderstand me, it is not the principle that we are against, but the way it was up to now applied in our country. The reason of course is because this principle was applied only in the Government Sector and not in the Municipal Sector as well. If my memory is correct then the new salaries that resulted in the Government Sector because of this Occupational Differentiation have now been in force for more than two years. It is also noticeable that for quite some time now there are very few, if any, vacant posts for engineers in the State Departments advertised in newspapers. This means that they have been successful in filling most of their vacant posts, naturally with a resultant loss of qualified engineers, amongst others in the Municipal Sector.

Mnr die President, u sal onthou dat die Uitvoerende Raad my benoem het om te dien op 'n komitee wat deur die Verenigde Munisipale Bestuur in die lewe geroep is om te besin oor die "Werwing, Opleiding en Behoud van personeel in Plaaslike Bestuur". Hierdie komitee se werk is ook nou-al vir bykans 'n jaar afgehandel en die verslag is aan die V.M.B. gestuur. Onder andere is een van die aanbevelings dat Beroepsdifferensiasie ook in Plaaslike Bestuur toegepas word, as eerste prioriteit, maar tot dusver het daar nog absoluut niks gebeur nie. Dit laat by my 'n gevoel van moedeloosheid in verband met die toekoms van Munisipale Ingenieurs en soos mnr Robson self in sy referaat uitgewys het dra dit hoegenaamd nie by tot die motivering van sodanige personeel nie.

Mr President, Mr Robson said in his paper that every employee should be placed in a job in line with his abilities and interests. I consider this to be the ideal position, but in practice, specifically in smaller towns, everyone is usually trained to do all the work applicable to his group simply for the reason that someone has got to do it in the absence of the other employee who normally does that job. Also with the limited market availability it is not unlikely that you may appoint an engineer in a vacant position who is really more interested in an equivalent position which has already been filled. This means that the *optimum* level to which productivity can be raised will be *lower* than the ideal position.

Mr Robson also refers to the merit principle and states that subjective preferment and discrimination should be kept out of personnel management. Although I agree with Mr Robson this requirement is a very difficult one to obtain because of the human element. How often does it happen that an employee who, for example, is an excellent electrician is promoted to the position of superintendent because of the second aspect mentioned by Mr Robson namely "there should also be positive action to encourage and reward excellence in service". Needless to say, the best electrician does not always make a good superintendent.

Mr Robson also mentioned in his paper the different kinds of groups of employees to which occupational differentiation could be applied e.g. accountants, engineers, clerks and nurses but goes on to state that the Public Service is also beginning to apply the groups concept to the senior management cadre, regardless of the fact that they may be Heads of Departments, for example Electricity, Civil, M.O.H., Parks, etc. Is this perhaps because in those positions they are more managers than Engineers, Doctors, etc?

Another aspect that worries me about occupational differentiation is the grouping of employees; for example: Will all artisans be in the same group? Does a qualified painter deserve to be in the same group as a qualified Electrician? Does scarcity have any effect on the group placing?

What can be done to an Engineer who was originally placed in the correct group but then developes skills which makes him superior to the other engineers in the group? Must I as an employer be willing to lose him? In the private sector he will be remunerated at a higher level just to retain his service. In other words, does occupational differentiation allow for merit increments?

I also note that Mr Robson says that pay is not the be all of occupational differentiation. Can he perhaps suggest a few other ways to remunerate a person in a local authority? Remember, you can't put thank you in a till.

I am very glad to see that Mr Robson considers the line Manager to be the real personnel manager of his staff. Perhaps Local Authorities should consider changing the title of the present so called "Personnel Managers". Mr Robson also said that the special knowledge and skills needed to be a good Personnel Manager are obtainable by any Manager willing and determined enough to make an effort. So gentlemen, let's get stuck in and do exactly that!

In conclusion, Mr President, may I congratulate Mr Robson on an excellent thought-provoking paper very ably read. I personally enjoyed it very much and I am sure everybody else did as well.

Thank you, Mr President.

MNR N S BOTHA : Bloemfontein

Mnr die President, mnr Robson het in sy referaat op verskeie aspekte klem gelê. Sodanig dat ons 'n hele dag nodig sou hê om personeeladministrasie behoorlik te bespreek. Die kombinasie van "mense, geld en die organisatoriese struktuur" is beklemtoon. Tereg is die bevordering van doeltreffendheid en motivering van personeel uitgelig as baie belangrik.

Is dit nie egter so dat personeelbestuur op organisering volg nie? En nie andersom nie?

Op bladsy *vier* verwys mnr Robson na die korrekte keuse van toesighouers. My ondervinding met lynbestuurder(s) is – alhoewel ons besef dat ander hoedanighede van toepassing is by toesighouers as byvoorbeeld die vakman – dat dit 'n feit bly dat die keuse *normaalweg* op die beste ambagsman val

vir bevordering. Die vraag bly derhalwe watter effek sou 'n aanstelling of bevordering hê van 'n swakker vakman, maar dalk wel beter toesighouer op die res van 'n personeelkorps?

Om terug te keer na beroepsdifferensiasie, glo ek in die staatsdiens is dit waarskynlik suksesvol vanweë die groot hoeveelheid poste wat elke groep groot en buigbaar maak. Ek het meer kommer in die Munisipale wese dat dit miskien sal lei tot 'n versnippering.

Die referaat van mnr Robson het my laat soek na die woorde van Clarence Francis wat eenmaal gesê het:

"You can buy a man's time.
You can buy a man's physical presence in a given place.
You can even buy a measured number of skilled motions per hour or per day.
But you cannot buy enthusiasm . . .
You cannot buy initiative . . .
You cannot buy loyalty . . .
You cannot buy the devotion of hearts, minds and soul.
You have to earn those things."

RAADSLID MNR JAN BURGER : Johannesburg

Mnr die President, ek wil mnr Robson gelukwens met 'n uitstaande referaat. Hy het die groepe werknemers veral op bestuursvlak, hul vermoëns en prestasies met groot kundigheid uitgelig. Dit is so dat ons werk met mense, met die individu. Dit verontrus my ietwat dat ons miskien te haastig gegaan het oor die posisie van die enkeling.

Ons verkeer in 'n unieke posisie in die Republiek van Suid-Afrika met sy verskeidenheid mense. Ongelukkig is hulle, die swartes, kleurlinge en asiërs, swak voorberei vir hul lewenstaak.

Wat gaan ons doen om die potensiaal van hierdie karig opgeleide arbiedsmag maksimaal te benut?

MNR ROBSON

Mr President, with regard to your own question, my feeling is that it is better to use a designation which has a relevance to what a man does. I am inclined to agree with you that an engineer should be called an engineer, an architect should be called an architect, whilst and administrator should be called an administrator.

Met verwysing na mnr Botha se vraag, kan ek meld dit is so – 'n mens begin met 'n behoefte wat bevredig moet word en dan skep jy 'n organisasie om jou behoefte te bevredig. Dan moet jy begin om mense in diens te neem om daardie behoefte te bevredig.

Personeelbestuur volg dus op organisering. Die èèn aspek is nie belangriker as die ander nie, maar die personeelbestuur aspek is op die lang duur die kritieke aspek, want dit bepaal of die doelwit bereik is.

Die keuse van 'n toesighouer is moeilik. Hierby moet senioriteit ook in ag geneem word.

Ek dink uit 'n beginsel oogpunt moet gekyk word na die spesifieke pos en die vraag gevra word: watter tipe persoon en hoedanighede is nodig in die pos? Die pos en sy inhoud moet dikteer wat benodig word. Indien 'n hoë premie geplaas word op toesighouding, behoort 'n persoon met goeie toesighouershoedanighede aangestel te word.

Beroepsdifferensiasie kan, wanneer dit oordryf word, lei tot versnippering. Daar moet genoeg definisie wees met beroepsdifferensiasie, sodat alle belangrike beroepsgroepe geïdentifiseer word en na waarde kan behandel word.

Die vraag, wat gedoen gaan word om die ander bevolkingsgroepe maksimaal te benut, kan nie maklik beantwoord word nie. Indien almal hier teenwoordig met hierdie vraag huiswaarts keer, is dit al 'n goeie begin.

CLR. MR VAN DER VELDE : Cape Town

Mr President, it is an accepted fact that South-Africa is going through a depression, the seriousness of which is still to be felt by the man in the street.

It has been said, and I subscribe to that view, that the number of employees in the public sector is growing rapidly, almost exponentially, and that the growth is unfortunately inversely proportional to productivity.

What has our speaker to say about the numbers of the employees of the private sector?

I would like te know which is the tail and which is the dog.

Can we not rely on the private sector to supply the necessary resources, both personnel and machinery, in times of emergency? Should we not be setting up guidelines which can communicate with the private sector, to obtain such staff in times of emergencies without the normal tender procedure.

I would like to know also what criteria we place on the status of a line manager. Has it not too often been number of staff in his employ and not necessarily the productivity of his department? Is it not a proud factor that we in Cape Town can boast that we produce a megawatt per person of energy more than we used to thirty years ago. In other words, it takes less personel today to produce one megawatt of electricity. It is always a problem and has been mentioned before that the efficient and excellent engineer is promoted to a managerial position. I think this is what we have to watch out for in our staff. It happens in the private and public sector.

RLD T BUYS : Germiston

Mnr die President, meen mnr Robson dat daar 'n te groot gaping tussen die vergoedingpaket vir 'n spesifieke beroep in die owerheidssektor en die privaatsektor is? Indien wel, is daar korrektiewe maatreëls wat getref kan word?

MNR ROBSON

Mnr die President, met betrekking tot groei in openbare indiensneming is iets waarna met groot verantwoordelikheid gekyk moet word. Daar is baie berigte in die pers wat verdraaid is wanneer dit gaan oor die toename in getalle mense in diens van die openbare sektor. Dikwels word vergelykings met ander lande getref wat uiters moeilik is. In die VSA byvoorbeeld is die grootste hoeveelhied polisie nie in diens van die staat nie, maar in diens van plaaslike owerhede.

Daar moet egter voortdurend gewaak word teen indienshouding van surplus werknemers.

Aan die kritici wat kla oor die grootte van owerheidsdienste, vra ek die vraag: Waar moet ons begin verminder? Daar moet gekyk word waar die grootste konsentrasie van personeel is. Moet vermindering kom by die weermag of by die Polisie of by die mediese en verpleegdienste?

It is a suggestion to consider that local authorities should only carry the staff really needed for normal services and obtain help from the private sector on a contract basis during emergencies.

I agree with councillor Van der Velde that managers should be assessed in terms of positive results and not merely on the size of the organisation.

Met verwysing na Raadslid Buys se vraag oor die gaping in vergoeding, wil ek meld dat daar nie 'n te groot gaping kan wees nie. Wanneer die gaping te groot is, sal plaaslike owerhede nie werknemers hê nie.

Kortliks wil ek interessantheidshalwe noem dat dit die staatsdiens se beleid is dat daar 'n redelike mark verwanthied moet wees. Die staatsdiens wil nie die beste betaler in die land wees nie, maar ook nie die swakste nie, want dit sal die einde van die owerheidsdienste beteken.

Die nasionale vergoedingskoers word vir 'n bepaalde beroepsgroep bepaal uit opnames deur konsultante en die Raad vir Geesteswetenskaplike Navorsing. Nadat die gangbare gemiddelde koers bepaal is, word 'n afskaling gedoen, want daar is sekere positiewe faktore in die dienspakket van 'n amptenaar wat die vermindering regverdig.

INTRODUCTION OF MR R LUUKONLAHTI

MR W BARNARD : PRESIDENT

Mr Luukonlahti is from Nokia Corporation Engineers Helsinki, where he holds the post of director of the installation department. He has had wide overseas experience, particularly in the Middle East. His company was employed by the Ministry of rural electrification in Egypt and Mr Luukonlahti spent some 4 years in that country as project manager, on a scheme for the electrification of some 350 Egyptian villages.

His paper to be presented today, which is entitled "Rural Electricity Supply Fast and Easy", could have application to those of us responsible for rural electrification. I am sure that the subject will be of interest to all of us.

REIJO LUUKONLAHTI

RURAL ELECTRICITY SUPPLY – FAST AND EASY

During December 1983, the African Technology Conference was held at the Bari University in Italy.

Professors G. Cafaro, B. Maione and P. Pugliese presented papers on the electrical reticulation techniques they thought most adaptable and reliable in the rural areas on the continent of Africa.

The papers presented at this conference indicated the use of aerial bundled cables as one of the most suitable for these environmently conditions in rural Africa. Not only was this type of reticulation in the low voltage range inexpensive but far more reliable than open line construction.

During the eight years prior to 1983, Nokia Engineering have installed many thousands of kilometres on the African Continent with complete reliability.

Nokia Engineering of Helsinki Finland, was the first country in Europe to manufacture and install aerial bundled cables, these first installations taking place in 1960.

From 1960 to the present date, over 150 000 kilometres have been installed in Finland alone with a further 22 countries throughout the world taking advantage of the system under discussion.

In all instances the advantage of self-supporting overhead cables compared to bare conductors was the deciding factor.

The advantages for the use of self-supporting cables have been detailed as follows:

1. IMPROVED RELIABILITY

(a) Uninterrupted distribution can be guaranteed to the end user in spite of rain and lightning.

(b) Uninterrupted distribution should the cable become detached from its pole clamp support.

2. IMPROVED SAFETY

Self-supporting insulated aerial bundled cables do not cause any danger to humans or animals thus accidents are reduced decisively.

3. MAINTENANCE COSTS REDUCED

(a) Maintenance costs reduced by 50% compared to uninsulated bare conductors.

(b) In third world countries, maintenance is of the upmost importance where maintenance staff are in very short supply.

4. LOW TOTAL COST

(a) Insulated conductors are naturally more expensive than the uninsulated ones but when we observe the small amount and low price of installation accessories, the total cost will be lower than with corresponding bare conductors.

(b) In addition to this it is also cheaper than bare conductors in operating and maintenance costs. This makes the system very economical in the long term.

(c) The research made by the Finnish Association of Electricity Supply Undertakings in 1982 proved that the total price for erection of the ABC system was 25% lower on average than the erection costs of a corresponding bare conductor network.

(d) As to the operating and maintenance costs the research made by Revon Sähkö showed 58% saving for the ABC system compared to bare conductor network.

(e) The demand on the electrical lines is that the route required shall be as narrow as possible to reduce the compensation costs of cutting trees which may be very valuable for the village inhabitants. An overhead cable needs no special route.

(f) Another advantage of the overhead cable is the possibility of using the same poles for low and high voltage cables and telecommunications. Several lines can run in parallel and also existing poles for street lighting could be used. This feature of overhead cables may be particularly useful in small villages and in older parts of cities where underground cables would be too complex and expensive.

5. LOW VOLTAGE OVERHEAD CABLE "AMKA"

(a) An AMKA cable (Fig. 1) consists of two to five plastic-insulated aluminium conductors, stranded around a bare or insulated aluminium alloy messenger. The messenger is also the neutral conductor.

(b) One or two of the insulated conductors in the bundle are intended for street lighting and have a standard cross-section area of 25mm^2 while the main phase conductors can vary from 25mm^2 to 185mm^2 depending on the load currents, maximum acceptable voltage drop and short circuit currents required in the network. The size of the messenger (neutral conductor) is determined by the mechanical and electrical conditions.

(c) The phase conductors are made from hard-drawn aluminium to reduce the risk of mechanical damage and to keep the cable rigid for handling under difficult conditions. Stranded conductors are compacted to reduce the risk of damaging the insulation and to make stripping and jointing easier.

(d) The insulation of all conductors and the insulated neutral consists of an extruded layer of black weather-resistant polyethylene (low density, high density or cross-linked).

(e) The conductors are easy to identify by the number of longitudinal ridges on their insulation plus lettering requested by the SABS.

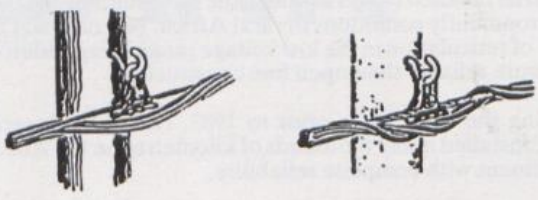
FIG. 1

6. ACCESSORIES

(a) Stringing up on wooden poles has proven to be a simple and economical solution in Finland and many other countries for this cable.

(b) Suspension and dead-end clamps are as shown in Fig. 2 and 3. With these clamps stringing up, installation can easily be accomplished in all possible combinations. The suspension clamp is made of aluminium alloy for an uninsulated messenger, and for the insulated messenger the lower part of the same aluminium alloy clamp is plastic coated.

FIG. 2 – Suspension Clamps



Insulated Messenger Uninsulated Messenger

Fig. 2 – Suspension Clamps

FIG. 3 – Dead-end Clamps

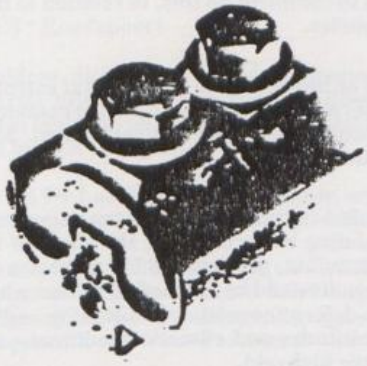
Insulated Messenger Uninsulated Messenger

Fig. 3 – Dead-end Clamps

(c) Two types of dead-end clamps are also manufactured. The first one is suitable for an uninsulated messenger and the other for an insulated messenger.

(d) Connectors are of screw type and are made of aluminium alloy profile (Fig. 4).

FIG. 4 – Aluminium to Aluminium Connector



7. RELIABILITY ANALYSIS OF MEDIUM AND LOW VOLTAGE NETWORKS

(a) As proven before, it is evident that the reliability of distribution network increases substantially when proceeding to use insulated conductors.

Disturbances caused by interruption of supply are extremely difficult to clear up in sparsely populated areas because of the long distances. This is why the good reliability of the insulated conductors has great importance in the country electricity network.

Bare conductors cause immediate interruptions of service if growing trees or their branches come into contact with them, especially in areas where growth of trees is rapid, this kind of disturbance is usual.

(b) Insulated conductors are coated with material which has a high resistance against chaffing of branches so the cleaning of wayleaves is not so urgent and frequent. Because of the occurrence of interruptions on medium voltage lines, the use of twisted overhead cables has increased especially in tropical jungle areas like Malaysia. The SAXKA cable developed by Nokia is particularly suitable for this purpose. An essential factor when talking about reliability is the choice of insulation material. According to the test and experiences of Nokia, the insulation material based on PE is the best. The following materials have been studied:

LGPE	= Low density polyethylene
XLPE	= Cross-linked polyethylene
HDPE	= High density polyethylene
LLDPE	= Linear low density polyethylene

(c) LDPE is suitable for installations in cold climates because it has good resistance against low temperatures (−45°C). At temperatures of +35°C LDPE softens and loses its mechanical abrasion resistance.

(d) This is why we are studying the use of HDPE and XLPE for tropical use because both are suitable owing to their thermoduric nature. Especially UV-radiation is dangerous for the plastics used as insulation material on overhead cables. This problem was studied in UV- test cabins in the early 1970's.

(e) According to the results, HDPE seems to retain its mechanical properties better than XLPE when the samples were exposed to intensive solar radiation. Because of this, HDPE was chosen in 1975 to be the insulation material for AMKA cables to be used in the tropics. The first large installation took place in Egypt in 1976. Because the plastic materials were used in the Assuan area, where the solar radiation is the highest in the world (220 k cal/m^2 per year), the success of the installation is of great interest. Experiences of these installations will be discussed in paragraph 9.

8. ALUMINIUM CONNECTORS AS A PART OF A RELIABLE NETWORK

(a) The use of aluminium as a material for conductors was obstructed for a long time by unreliable connection techniques which were used in the 1950's. When these problems were considered carefully, it was possible in the early 1970's, to achieve connections as reliable in all circumstances as when using copper.

(b) Nokia has also conspicuously been working with this development. With twisted overhead cables it was decided to use connectors made of aluminium alloy profile with bolt tightening.

(c) When using these connectors it is necessary to peel the conductor insulation at the connection point. When the connector is correctly tightened, it is very reliable. Peeling of cables intended for tropical use is rather difficult. This is why the piercing type connectors were recently studied very intensively. These connectors have not, however, been as reliable as those made by peeling the insulation.

(d) Ageing tests done according to European standards have proved to be severe enough to guarantee a long life for the connections. Especially the short circuit tests, where the conductor heats up to 250°C, have forced many connector types out of the market. Just recently some piercing type connectors which pass this test have come onto the market. One of these is type SL11 manufactured by Nokia.

9. EXPERIENCES DURING EIGHT YEARS OF VILLAGE ELECTRIFICATION USING AMKA-OVERHEAD CABLE SYSTEM IN TROPICAL CLIMATE CONDITIONS

During 1976 – 1977 350 villages were electrified in Egypt. The Nokia AMKA system with HDPE insulation was used. A total of 3500 kilometres of cables were installed, mostly directly on the walls. The Ministry of Foreign Affairs in Finland studied in the autumn of 1983 the condition of the installation in six villages installed in 1976. The study was carried out because Finnish development aid was used for the materials. The results were very positive as to the success of the system in Egyptian circumstances. No aging of the material used was indicated.

Nokia has been following the situation continuously with the Egyptian electricity authorities. The most important target for the follow-up is the village of El Forok in Assuan.

We have taken samples from the real installations for our laborotary tests in 1980 and 1984. The results for the tests in 1980 show that UV- radiation and all other possible troubles had caused no changes in the characteristics of the insulation material.

The samples taken in 1984 are at present in our laboratory under tests and the results will be released shortly.

In addition to Egypt, Nokia has executed similar projects in 21 different countries. Also these projects are followed carefully and all results until now have been good.

10. SOME NOTES ON FUTURE TECHNICAL SOLUTIONS FOR DISTRIBUTION SYSTEMS

As mentioned above the insulated twisted overhead cables will supersede the bare conductors in low voltage networks. Many countries like Finland, Sweden, France, Norway, Turkey, Syria, Irak, Banglodesh, North Yemen, Malaysia and Indonesia have proceeded to use exclusively twisted overhead cables in new installations and many more countries are making similar decisions.

Also in medium voltage networks 12 ... 36 KV corresponding systems have been used during the last 15 years. Nokia has developed its own SAXKA- system which is already in use, in addition to Finland, Syria, Malaysia and Saudi-Arabia.

The medium voltage twisted overhead cables are economical in forest areas where wayleave maintenance is difficult and especially in rocky areas, where excavation is difficult and expensive.

DISCUSSION – BESPREKING

MR M P P CLARKE : Randburg

Mr President, in opening the discusion on Mr Luukonlahti's paper, may I, on your behalf, thank him not only for its presentation, but also for taking the trouble to be with us at this, our 10th Technical Meeting. I ask him to convey our thanks to his company for making him available and for enabling him to be with us today.

It comes as a supprise to many of us I am sure, to learn that Finland has been in the forefront of development work on bundled conductors for many years, having started, as he has pointed out, in 1960.

Because of its reletive newness on the South African scene, there is some doubt in my mind as to the accuracy of the statement that the *total* price for erection of this type of conductor is 25% lower than corresponding barewire networks – as stated in paragraph 4(b). I would suggest that prospective users look closely at *their* local conditions before embarking on any scheme on that basis alone.

The many other advantages of the system must obviously all be evaluated and taken into account, before any decision is taken.

Perhaps the most controversial part of these systems is the size of the neutral conductor LV three phase system. Standard South African practice is to use neutral conductors of equal size to the phase conductors on most distribtion systems. Clearly overseas practice is more flexible in this regard and it seems to me that there could be merit in looking into this aspect more closely, because of the obvious economic advantages which exist. I would like Mr Luukonhlati to comment on this, in relation to the practices in other countries.

It would also be interesting to hear to what extent *bare* neutral conductors are used on these bundled conductor systems compared with the insulated neutral version, based on factory production runs.

Bearing in mind that these systems pre-supposed the use of reliable insulating materials and, the effect of local conditions on any insulant, particularly UV radiation on "plastic" type materials, it would be interesting to hear what work has been done to determine material-suitability and anticipated life at high altitudes and climatic conditions, as found for example on the highveld.

As I have said on previous occasions, I am convinced that the use of this type of system will play an increasingly important role on many of our networks, particularly for LV distribution. It is up to us as engineers to examine each type as it becomes available, clear any problems in a systematic and rational way and apply the one which is best suited to our requirements.

Perhaps the biggest problem that we are going to encounter is that caused by the proliferation of accessories and it is unfortunate that the overseas manufacturers have apparently not been able to develop "standard" or "universal" type connectors and other accessories, something that could be used with confidence on any of the various bundled conductors of given size, irrespective of manufacturer.

Should the AMEU, in collaboration with ESCOM and the CSIR and SABS set up some form of investigation, to determine the extent of interchangeability between existing commercially available systems and their accessories? This could be an invaluable exercise and would enable us to reduce stockholdings, as well as eliminate many of the operational faults, which are bound to occur in time, as maintenance and construction staff use more and more of the equipment.

Mr President, this paper is another valuable and timely contribution to the work of our Association and I thank Mr Luukonlahti for his contribution.

MR C CROMPTON : Johannesburg

Mr President, Although in Johannesburg we do not do much rural electrification we have had several years of experience with aerial bundled conductors.

We have used bundled conductors, not for the reticulation of new suburbs, but rather to replace the old conventional overhead mains, in suburbs where trees cause continual problems. Replacing these mains with a bundled conductor system not only results in a more reliable supply, but also saves us from having to hack the trees continually, to prevent branches from touching the mains.

The existing steel poles are re-used, as are the existing service cables. We therefore had to develop a system to suit our existing network.

The conductor configuration of our system has therefore been designed to fit in with an existing network. The system consists of three phase conductors, and street light conductors, one neutral, a separate earth and a separate supporting member.

We are stil! experimenting with different accessories, but would welcome a SABS specification for Aerial Bundled conductors and would certainly be prepared to adjust where possible.

MR P BOTES : Roodepoort

Mnr die President, dit is vir my nuus dat Johannesburg hierdie stelsel eerste gebruik en ontwerp het. Roodepoort het hierdie sisteem lankal in gebruik. Die personeel is opgelei en hulle verkies hierdie tipe lyne.

Ons gebruik dit vir Lae Spanning retikulasie, ook op 6,6kV en 11kV leidings, waar dit ekonomies regverdig kan word.

Onlangs het ons 'n bestelling geplaas vir 'n 33kV sisteem, wat gebruik kan word indien van ons 33kV bogrondse lyne dalk beskadig raak en 'n lengte dringend gespan moet word. Dit word net gebruik vir 'n nood toestand.

MR L SILVERMAN : Affiliaat

Mnr President, Nokia are to be complemented on their paper. Indeed, aerial bundled cables have made dramatic strides forward in the last 20 years.

In South Africa, we at Elcentre Control Systems have found a very wide degree of acceptance for aerial bundle control systems amongst local authorities during the last three years.

Importance of standards cannot be under estimated, if one compares the difference between Nokia cables and French cables.

There are many similarities, but there are also some design differences and they should be noted:

- **Insulation thickness**
- **Type test**
- **Impulse test**
- **Markings, especially with the neutral**

In the case of markings, this could cause confusion between the various systems.

Elcentre Control Systems have taken the liberty of producing a comparison chart, showing the differences between the systems available in South Africa and it is available here for your information.

The client (you, the member) should take care, when purchasing, not to mix and match items of, say, hardware and connectors from various systems. This could give problems in the future. We look forward to the drawing up of the SABS specification on aerial bundled control systems.

MR LUUKONLAHTI

Mr President, with regard to the questions asked, I wish to comment as follows:

As regards the size of the neutral conductor at low voltage three phase systems, according to European standards, the conductivity of the neutral must be at least half the conductivity of the phase conductors. Because of the lower conductivity of aluminum alloys, the neutral conductor is one size bigger than the phase conductor.

The bare neutral conductor is widely applied in overseas countries where 2 phase systems are used and also with the use of wooden poles the bare neutral is quite safe. For steel poles and wall installations an insulated neutral condutor is recommended.

My company produces both bare and insulated conductors according to customers' needs.

We found the marking of our product to be more durable and visible than the common paint markings. Many countries originally specified paint markings, but have now changed to ridges.

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BEKENDSTELLING VAN PROF. D DE VOS

MNR W BARNARD : PRESIDENT

Menere, ons het die voorreg om Professor de Vos hier te hê om ons toe te spreek in verband met die registrasie van professionele ingenieurs.

You have all received my circular letter on the registration of professional engineers, which is going to be applicable to all organizations and more particularly to municipalities in 1986. This circular letter was sent out in conjunction with Professor de Vos' talk.

Professor de Vos will briefly summarise the position of the municipal engineer and discuss certain matters as far as registration of municipale engineers is concerned.

THE PROFESSIONAL ENGINEERS ACT 81/1968
DIE WET OP PROFESSIONELE INGENIEURS 81/1968

Mr President, thank you for the invitation to address you. Vanaf Mei 1986 sal die Wet op Professionele Ingenieurs ook op munisipaliteite van toepassing wees. Dit beteken dat die werk, wat gereserveer is vir professionele ingenieurs, deur professionele ingenieurs gedoen sal moet word.

I first want to read the actual reservation of work notice, as far as it applies to professional electrical engineers and then I will explain.

(Professor de Vos here read out notice R3063 in terms of Section 7(6) of the Professional Engineers Act 1968 which was gazetted on 8 August 1969.)

Dit kom eintlik hierop neer, in baie kort terme, dat die werk wat gereserveer is en wat vir vergoeding gedoen word vir ander mense, werk is wat 'n professionele ingenieur se opleiding nodig het. Met ander woorde, werk op 'n vlak wat bepaal word deur die vier-jarige Baccalaureus graad in Ingenieurswese.

'n Gediplomeerde ingenieur kan doen waarvoor sy opleiding en ervaring hom bekwaam. Dieselfde vereiste geld vir 'n professionele ingenieur ook. Hy moet self besluit of hy bekwaam is om die werk te doen al dan nie.

Afgesien hiervan is daar 'n paar beskermingsmaatreëls ten opsigte van die gediplomeerde ingenieur. Indien 'n gediplomeerde ingenieur werk doen wat iemand ander oordeel dit behoort die werk van 'n professionele ingenieur te wees, kan die gediplomeerde ingenieur hom verweer dat hy in terme van die regulasie bekwaam is om die werk te doen, aangesien hy sy kennis op 'n ander wyse as die voorgeskrewe eksamen op gedoen het.

'n Gediplomeerde ingenieur, wie se aansoek om registrasie nie geslaag het nie en wat voor 1969 reeds werk van hierdie aard gedoen het, is dubbel veilig, want nadat sy aansoek nie geslaag het nie, moes SARPI besluit het dat die werk wat hy doen, nie gereserveerde werk is nie.

Werk wat wel van so 'n aard is moet gedoen word deur 'n professionele ingenieur. Dit het 'n implikasie vir ingenieurs wat gegradueerd is en wat kwalifiseer om te registreer. Indien hulle werk van hierdie aard doen, kom dit volgens definisie neer op voorgeskrewe werk en sal hulle teen Mei 1986 geregistreer moet wees.

Tot dusver moes alle ingenieurs, wat voorbehoue werk doen, geregistreer wees as Professionele ingenieurs. Gedurende die afgelope 15 jaar, sedert die wet in werking getree het, het nog geen geval voorgekom dat iemand aangekla is nie.

Slegs in 'n geval waar 'n persoon werk bo sy bevoegdheid doen en dit het misluk, sal so 'n saak in 'n hof beslis moet word.

Die maatreëls moet dus eerder as 'n afskrikmiddel gesien word.

Some certificated engineers are still worried. But I want to assure you that there is no need for concern. The aim of the reservations was to ensure that the engineering profession receives a fair share of the labour market.

SACPI, protects the interests of the public and FESPI protects the interests of the professional engineer. These two organizations are committed not to upset, but rather to support industry, government and the related professions. About 10 years ago, FESPI addressed a letter to the provinces asking them not to insist on a professional engineer for a town Electrical Engineer's post, where the post does not require professional engineers' knowledge.

A profession is a body of people sharing a common body of knowledge, subject to a minimum standard of education and training, submitting to a code of conduct administered by their peers. Four professions in the engineering context are identified, namely: professional engineers, engineering technologist, engineering technicians and certified engineers.

In order to make all four categories attractive and to build them up, the Professional Engineers' Act was changed to provide for three boards of control, in addition to the Council for Professional Engineers i.e. one board for each group. This will enhance the stature and image of all four categories. There is therefore no need for a certificated engineer to battle to be registered. The four mentioned categories are equal but different. It will be necessary for certificated engineers to be registered at the board of control, in order to build up the status of each board of control. The aim will be for the four bodies of control to be co-ordinated.

There are grey areas, where the job does not require a professional engineer's qualification. Therefore, where the job requirements are not of a high level, a person with the required knowledge should get the job.

Managment and Maintenance are not specified in the regulations. A manager does not need any technical qualifications. Any person can therefore be a manager. Only highly sophisticated maintenance work is reserved. Other maintenance work can be done by any person, as long as he is capable of doing it. The intention is to reserve the title of civil engineer, mechanical engineer and electrical engineer for registered professional engineers.

For instance, where the services of a registered professional engineer are not required the authorities should consider changing the name of the post of town electrical engineer to, say, manager of the electricity department.

Thank you Mr President.

DISCUSSION – BESPREKING

MNR N S BOTHA : Bloemfontein

Mnr die President, vir sommige mense is dit moeilik genoeg om in 'n saal vol mense te praat. Wanneer 'n saak soos hierdie onder bespreking is, wat so baie mense (oor die hele land) raak, dan is dit nog moeiliker. Nietemin, mnr die President, baie dankie dat u professor de Vos vandag hierheen genooi het om toeligting oor hierdie belangrike saak te kom gee. Ek aanvaar dat daar vir baie 'n groter mate van sekerheid en tevredenheid gegee is. By andere sal die onsekerheid egter bly voortbestaan.

Ek wil graag 'n paar vrae aan professor de Vos stel:

***Eerstens:* Is die "deur" finaal toe vir diegene wat nie die geleentheid daartoe gehad het en wie wel die beroep eer sou kon aandoen?**

***Tweedens:* Op 'n sekere stadium was SARPI bereid om 'n sekere kundigheidsvlak en ervaringsvlak vir toelating as professionele ingenieur te aanvaar. Desnieteenstaande tegnologgiese vooruitgang die afgelope dekade, is die kundigheidsvlak waarna ek verwys het, nie meer vandag aanvaarbaar nie. Kan u asseblief toelig?**

***Derdens:* Ek aanvaar u Raad is net soos hierdie vereniging bekommerd oor die blanke ontvolking van die platteland. Voorsien u nie dat die onsekerheid wat bestaan en eise wat gestel word, nie 'n bydraende faktor kan wees tot die wegdreinering van munisipale elektriese ingenieurs na ander bedrywe nie?**

***Laastens:* Is evaluering van kandidate op grond van kundigheid, ervaring en bekwaamheid in die algemeen nie moontlik nie? Ons weet mos kwalifikasies is maar 'n enkele faktor wat tot bevoegdheid en bruikbaarheid lei.**

Baie dankie vir u geduld.

PROFESSOR DE VOS

Mnr die President, na aanleiding van mnr Botha se vrae wil ek daarop wys dat daar nie van lidmaatskap gepraat moet word nie. Die Raad registreer slegs professionele ingenieurs.

Die "deur" is nie finaal toe vir persone wat nie oor die nodige kwalifikasies beskik nie. Daar is 'n alternatiewe wyse vir registrasie as professionele ingenieur.

Die eerste geregistrasie moontlikheid is by wyse van die oorbruggings klousule 18(4) b, waarvolgens 'n persoon voor 1969 vir 3 jaar werk van professionele ingenieurs aard gedoen het. Sodanige persone kan, indien hulle van mening was dat hulle professionele ingenieurs werk gedoen het, aansoek doen vir registrasie as professionele ingenieur. Indien die Raad oordeel, dat die persoon se werk van professionele ingenieurs aard was, is die persoon geregistreer. Dit sal vir werk gedoen voor 1969 moontlik wees om, in terme van klousule 18(4) b, aansoek te doen vir registrasie as professionele ingenieur.

Die sogenaamde "oupa" klousule 18(4) (a) geld deurlopend ten opsigte van persone wat ouer as 50 jaar is, wat 25 jaar lank ingenieurs werk gedoen het en vir die laaste 10 jaar verantwoordelike ingenieurswerk gedoen het. Sodanige persone word beskou op die vlak van professionele ingenieur te wees en kan te enige tyd aansoek doen om registrasie as professionele ingenier. 'n Eksamen, wat die vlak van hul denke en toepassing van die basiese ingenieursbeginsels beoordeel, word afgelê voordat registrasie plaasvind.

SARPI is besig om te oorweeg of die ouderdomsperk nie verlaag moet word nie.

SARPI is baie bewus daarvan dat ons nie mense wil wegdreineer nie. Ek is bly om te sien, dat die kandidate vir die sertifikaat van bevoegdheid toeneem. Die aantal kandidate was, gedurende die laaste paar jaar sedert die wet afgekondig is, meer as voorheen. Die doel van drie beheerrade en die Raad is om die totale spektrum te trek na die ingenieurs beroep en die ingenieurs spektrum. Enige een, afhangende van sy kwalifikasies en ondervinding, behoort 'n plek te hê in die Ingenieursberoep. Ons wil juis so veel mense as moontlik betrek. Ek is nie bang, dat ons mense sal wegwys deur die streng toepassing van die registrasie vereistes as professionele ingenieur nie. Daar is alternatiewe moontlikhede en status.

MR L F KNEALE : Affiliate

How does Professor de Vos see the position of Electrical Contractors, who have always involved themselves in and have undertaken the design, supply, installation, testing and commissioning of electrical installations in building factories, town reticulations, etc.?

If an electrical contractor is registered as an engineering technician or master engineer technician in terms of the Professional Engineers Act, is he precluded from undertaking the above mentioned work? If this is the case, then we as electrical contractors will have to apply for exemption.

PROFESSOR DE VOS

The areas that Mr Kneale has mentioned, probable do not require a professional engineer. This type of work will not be reserved for professional engineers, unless it is sophisticated work of a level required in the fourth year of an engineering course. There is only a small percentage of engineering work that will require this type of knowledge. I therefore do not foresee any problem.

An engineering technician is registered with the board of control as an engineering technician or as a professional engineering technologist or as a certificated engineer. These people are allowed to do the work which is within their capabilities.

MR D H FRASER : Durban

Mr President, would it appear that what Professor de Vos has said is that, if a person in charge of a municipal electricity undertaking has been doing his work satisfactorily, but has been refused registration as a professional engineer, then his work cannot be regarded as being reserved for professional engineers?

May I propose a hypothetical example of two towns of similar size with electricity undertakings of similar complexity. The person in charge could at present, in one instance, be refused registration on the grounds of insufficient academic qualifications,and in the other instance be registered on the grounds of having the required qualifications and training. Does it follow that the work which the first is doing is not work reserved for professional engineers, and that being done by the second is so reserved?

I am under the impression that, when the Act was intorduced in 1969 and applied officialy to engineers in private practice, persons currently practicing as Consulting Engineers obtained registration without possessing the academic qualification subsequently called for. Could the same principal not be applied to municipal Electrical Engineers, when section 21(1) (a) of the Act is extended to municipal activities?

Mr President, may I ask Professor de Vos whether the application of section 21(1) (a) in 1986 to all sectors will need to be publicised in the Government Gazette?

It will presumably be necessary for Town Councils to determine those posts in their service, for which professional engineers are required. The definition of work "reserved" for professional engineers is perhaps unavoidably vague, but could Professor de Vos advise how such a determination should be made?

PROFESSOR DE VOS

Mr Chairman, I thank Mr Frazer for those questions. I will start with the last one. The regulations have already been gazetted in terms of notices R108 and R1142 of May 29, 1981. These notices specify that from 5 years after May 29, 1981 local authorities must comply.

When the Act came into operation it applied within 6 months to engineers in private practice. They were given a chance to apply and if they had been doing professional engineering work for three years, they were registered. People who had been doing consultant work at a lower academic level could carry on. Those engineers who had been doing consulting work which was not judged to be work "reserved" for professional engineers, were safe.

A certified town engineer will be allowed to perform work within the framework of his knowledge. For work beyond his field of knowledge, he will have to obtain the services of a professional engineer.

MR J K VON AHLFTEN : Springs

Ek wil graag 'n reguit vraag aan Professor de Vos stel. Indien 'n persoon bewys kan lewer dat hy werk van 'n professionele aard kan doen, sal hy kan registreer as 'n professionele ingenieur?

MR KEN MURPHY : Somerset-Wes

Mnr die President, mag ek ook Professor de Vos bedank vir sy teenwoordigheid hier vandag en sy vriendelike verduidelikings.

Geagte Professor, as ek u reg verstaan dan word 'n geregistreerde ingenieur, streng gesproke, slegs vereis waar suiwer navorsing, gesofistikeerde ontwerp en laboratoriumwerk gedoen word.

U sê dat 'n elektrotegniese stadsingenieur nie geregistreer hoef te wees nie. As gediplomeerde ingenieur is ek op aansoek nie geregistreer nie. Aangesien ek dieselfde werk doen as my kollegas wat wel geregistreer is, moet ek daarvan aflei dat ek òf geregistreer moet wees òf dit is nie nodig dat hulle geregistreer moet wees nie.

Daar is voorts in die verlede gesê, dat selfs firmas wat byvoorbeeld elektriese toerusting soos straatligte, kabels, ens. vervaardig en dan 'n gratis ontwerp met die gebruik van hul toerusting vir kliënte doen, verplig sal word om 'n geregistreerde professionele ingenieur aan te stel vir sodanige werk, wat tans deur opgeleide tegnici gedoen word.

PROFESSOR DE VOS

Mnr die President, na aanleiding van mnr von Ahlften se vraag. Dit is nie moontlik vir 'n persoon wat professionele ingenieurs werk doen om as professionele ingenieur te registreer sonder die nodige kwalifikasies nie, tensy hy die werk vir drie jaar voor 1969 gedoen het.

Aan mnr Murphy kan ek sê dat indien die werk wat hy doen van professionele aard is, niemand hom summier kan aankla dat hy werk doen wat hy nie veronderstel is om te doen nie, aangesien hy nie as professionele ingenieur geregistreer is nie. Mnr Murphy kan sy kennis opdoen op 'n ander wyse as formele studies en hy is op grond daarvan bevoeg om die spesifieke werk te doen. Hy moet net nie werk doen waarvoor hy nie bevoeg is nie.

In die geval van firmas wat byvoorbeeld retikulasie stelsels ontwerp, is dit so dat die spesifieke werk gedoen kan word sonder die nodige ingenieurskwalifikasies.

MR KEN MURPHY : Somerset-Wes

Mr President, problems have been experienced in the past in obtaining the approval of Provincial Authorities for large capital projects. Engineers, with years of experience in a particular field, were told to have their designs and specification vetted and approved by a registered professional engineer or consultant.

Are you going to issue a guideline to the authorities concerned? Particularly under the new dispensation?

PROFESSOR DE VOS

Mr President, I am aware that this problem did occur in the Cape Province. The federation warned the authorities in the past not to specify that certain work should be done by a professional engineer. The boards of control will be able to help with problems like this, by taking it up with the authorities.

MR J DAWSON : Uitenhage

On behalf of the President of the AMEU and all the engineer members, please accept our sincere thanks for attending this meeting and explaining the implications of the implementation of Section 21(1) (a) of the Professional Engineers Act.

A number of our members were very concerned that SACPE'S proposal would be to their disadvantage, but I hope that they are now much happier after listening to your explanations.

I assure you that the AMEU is very appreciative of the sacrifices you have made in giving of your time to attend today's meeting and as Chairman of the Technical Training Committee, I would like to place on record my thanks to you for attending our committee meeting on the 15th June.

Professor de Vos, thank you very much.

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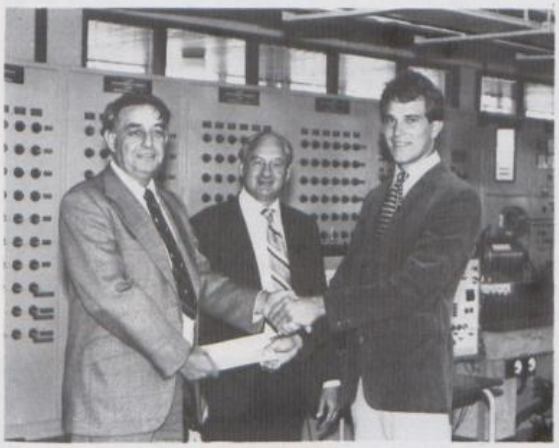
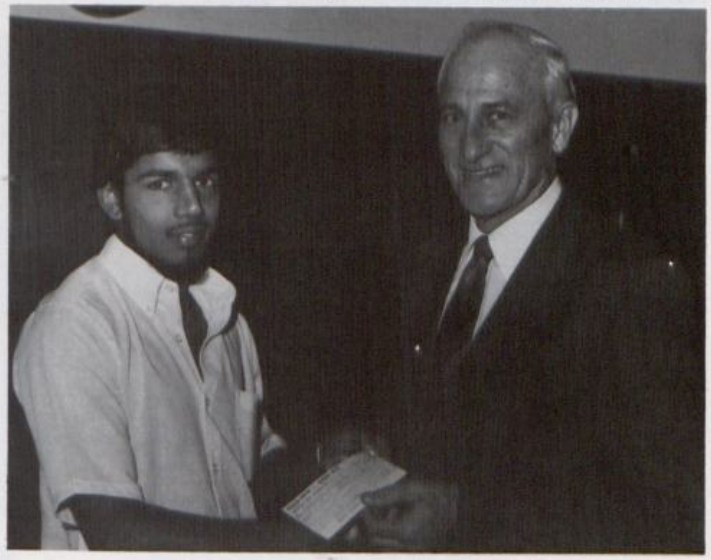


TECHNIKON PORT ELIZABETH
Mr L P Nortje, Mr D C de Kock – Head of Department Electrical Engineering Heavy Current, Technikon Port Elizabeth, and Mr W H Atteridge – Deputy City Electrical Engineer Port Elizabeth at an AMEU Award Ceremony.
Photographed in the heavy current machines laboratory – P.E. Technikon.



DURBAN PRESENTATION
Mr M S O Mohamed is receiving his AMEU Bursary of R1 000 from Mr Denis Fraser, City Electrical Engineer of Durban.

TRAINING AWARDS

Mr W M Humphries of Port Elizabeth is receiving a bursary cheque for R1 000 from Charles Adams, Chief Electrical Engineer of Port Elizabeth.

EAST LONDON TECHNICAL TRAINING CENTRE
Mr M E Weppelman, Aprentice Electrician, receives the AMEU Award form His Worship The Mayor of East London, Clr. S E Spring.

DURBAN PRESENTATION
Mr W Barnard, President of the AMEU presenting the Annual Training Award to Mr Noel Rau. In the background from left to right are Mr P M van Zyl, Associated Town Clerk, His Worship the Mayor of Durban, Clr S Hertz and Mr J L Fletcher, Deputy City Electrical Engineer, Durban.

BENONI TEGNIESE OPLEIDINGSENTRUM
Mnr Stanley Wilson ontvang die VMEO-toekenning van sy Agbare die Burgemeester, Rld. Wheeler van Boksburg. Mnre Alwin Fortmann, Stadselektrotegniese Ingenieur, Boksburg en Jan Loubser, Stadselektrotegniese Ingenieur, Benoni, kyk toe.

TOPICS FOR DISCUSSION
ONDERWERPE VIR BESPREKING

AN ELECTRICITY PREPAYMENT METER USING HOLOGRAPHICALLY CODED TOKENS

By P.S. Hibberd BSc. Hons.
Electronics Manager Landis & Gyr Limited, UK

ABSTRACT

The Landis & Gyr token pre-payment meter offers significant advantages over the equivalent coin operated system in terms of security against fraud and vandalism. When this technique is coupled with the advantages of modern electronics additional features can be enjoyed by both the user and the supply authority.

INTRODUCTION

Generally speaking, there are two ways of paying for a product or service. You can "pay as you go" or, if your credit is good, settle up an outstanding debt after a given period.

Traditionally the former method has been prevalent, credit being a luxury enjoyed by only the wealthier members of society. When electricity became widely available the credit meter was the only economical way of charging for consumption and was soon accepted. The higher cost of installing and maintaining a coin operated pre-payment meter and the inconvenience of collecting the money has meant that, until recently, it has only been used to collect money from bad payers when all other methods (e.g. special budget accounts) have failed and disconnection is the only alternative. Indeed, often the threat of installing a prepayment meter is sufficient to persuade an awkward user to pay up. Not surprisingly, the pre-payment meter has accrued considerable social stigma.

If these facts are coupled with the growing acceptance of living on credit (via credit cards, shopping accounts, etc.) and a gradual move towards the "cashless society" the future of the pre-payment meter looks bleak.

1 THE NEED FOR THE PRE-PAYMENT METER

For consumers who find it difficult to budget for the cost of their usage the pre-payment meter is the only solution despite its expense and inconvenience (when compared to an ordinary credit meter). In order to understand why a token pre-payment system of the type described in this paper can not only supersede the traditional coin system for this type of problem but also offer sufficient advantage to both the user and the supply authority to outweigh the increased cost, it is necessary to investigate present usage of the pre-payment meter.

1.1 Population of Pre-payment Systems

In the United Kingdom there are currently approximately 1.3 million pre-payment electricity meters which represent 7% of the total meter population. Fig. 1 shows the population has varied since 1977. A gradual decrease of around 0.3% per year reversed in 1980/81 and now shows a similar rate of increase. There are no indications that this is likely to change in the near future. What the figure shows is that the market is expanding but we have to dig deeper to find out why.

1.2 Political Influences

As has been indicated above, to the local supply authority the pre-payment meter is a necessary but unwanted expense. They have been quite happy with the social stigma associated with it. However, in 1980, the UK government at the time decided that this attitude was not in the public interest and applied political pressure to the Electricity Council, who in turn changed their code of practice to the effect that anyone who wanted a pre-payment meter could have one, on demand. The effect is shown in fig. 1 as a reversal of the steady decline in pre-payment meters.

The stigma phenomenon is now reduced as not everyone who has a pre-payment meter is a bad payer. The resulting positive feedback effect explains the rise in the pre-payment meter population. The effect is supported by the so-called world recession where people have less disposable income to meet large infrequent bills.

1.3 Social Influences

The stigma phenomenon has already been adequately discussed although it is undoubtedly a social influence. If this effect can be turned around, i.e. it is socially advantageous to have a pre-payment meter, the population curve (fig. 1) may be affected dramatically. Because of the basic competitive nature of the human being, he likes to be one step ahead of his peers, better car, hi-fi etc. than the neighbour. If his meter can be put into the "state of the art high technology" bracket the consumer may be tempted to have one even if he does not need one, particularly if the control electronics are contained in an aesthetically designed housing mounted in the kitchen or living room rather than being banished to a cellar, garage or cupboard under the stairs where the metering is usually situated. If, in addition, the word "pre-payment" is replaced by a more sympathetic one such as "budget" the stigma phenomenon may dissappear altogether.

This all could come to nothing if there were no advantages for the supply authority. After all, why replace an inexpensive reliable credit meter with a pre-payment meter which, apart from gaining revenue which otherwise might be difficult, holds no advantage?

1.4 Supply Authority Influences

Apart from the higher unit cost there are many disadvantages inherent to the coin type pre-payment meter when compared with the credit meter.

1.4.1 Expensive servicing

Being mechanical, they are subject to wear and tear and will periodically need servicing. This needs skilled technicians and can be expensive, both in parts and time off circuit.

1.4.2 Cost of collection

Clearly the coins must be collected periodically. Sending a man to site costs money and large amounts of cash are always a temptation to the more dishonest members of society.

1.4.3 Damage due to attempted fraud or theft

Any box containing money is potentially open to various degrees of attack.

1.4.4 Calculation of standing charge

Where the consumer's tariff includes a standing charge, billed irrespective of the amount of electricity consumed, this must be collected by adjusting the unit rate so that over the billing period the standing charge is collected. A standard bill is then produced from the meter reading, and the difference between the bill and the amount of money in the box may be returned to the consumer as a rebate.

1.4.5 Security

Typically, coin mechanisms check the validity of coins on the basis of size and weight. It can be possible to produce metal "tokens" of similar size and weight more cheaply than the face value of the coin. Frequently a lower value foreign coin which fits can be found.

In extreme cases the combined effects of the above problems totally preclude the use of coin type pre-payment metering as a means of billing.

1.5 The Landis & Gyr Pre-payment Meter

Landis & Gyr have developed, using holographic techniques, a means of encoding value information onto a plastic strip. The information can be simply read and erased by the pre-payment meter. The details of both the holographic encoding technique and the pre-payment meter are discussed in the next two sections, but it is interesting to show the disadvantages of the pre-payment meter mentioned in section 1.4 can be avoided with this system.

1.5.1 Solid state components have an increasing reputation for being more reliable than mechanical components. However, this apart, solid state systems can usually be replaced more cheaply than they can be repaired and so highly skilled technicians are not required. In theory electronic modules could be replaced on site although there are other reasons why this may not be desirable.

1.5.2 As there are no coins in the pre-payment (tokens are physically erased) there is no need to send staff to the consumer's premises to collect money. Indeed, as tokens have to be bought in advance, the supply authority will receive their money sooner than with a coin system.

1.5.3 Clearly in an instrument which does not store money, except perhaps electronically, there is little incentive to physical attack other than pure vandalism.

1.5.4 As the pre-payment side of the token meter is controlled by micro-electronics a standing charge collection function has been easily included as a standard feature of the token meter. Any value programmed into the instrument will be gradually decremented from available credit irrespective of the rate of use of electricity.

1.5.5 The holographic technique has been specifically chosen as a basis for a pre-payment meter because of its inherent high level of security when compared to the intrinsic cost of the token. It is also virtually inert to external environment influences (eg. heat, sunlight, electric or magnetic fields, radiation etc.). It can be shown that without significant capital investment and technical expertise it is impossible to produce a fake token which can be accepted by a token meter. Conversely it is impossible to interfere with a token meter in such a way that it will accept fake tokens. The technique is thus fail safe and is the most secure system for this type of application.

1.6 Advantages of the Landis & Gyr System

There are of course other modern token meter systems available, each with their own characteristics, but it is worth considering for a moment the particular advantages the holographic technique holds.

Holographic tokens are at least as secure as coins of the realm and could be used as such, in that they can, for example form part of welfare payments to the unemployed or other entitled groups.

Once the value on the holographic token is used the token is erased and can be thrown away. Thus there is nothing to collect or "recharge" by the supply authority.

As holographic tokens are inert, no special handling precautions are necessary. They can be handled and distributed in any modern environment by persons with no special skills and thus could be made available to the user through outlets other than the supply authority itself, eg. Post Offices, supermarkets etc.

Not only does this technique have significant advantages over coin type systems, but it also offers the opportunity to introduce pre-payment metering where it has not been feasible in the past.

2. The Holographic Token

Although an indepth understanding of holography is not necessary to fully appreciate the advantages offered by this technique a brief description of the fundamentals may be helpful.

2.1 Creation of Holograms

Light which is detectable by the naked eye covers a range of frequencies bounded by the infra-red and ultra- violet regions of the electromagnetic spectrum. In general all visible light is a mixture of these frequencies. Coherent light, that is light which consists solely of energy of a single frequency, does not occur naturally and has to be manufactured. One such source of coherent light is the laser. Now it is a characteristic of coherent light that if two such coherent light sources interfere with each other a spatial pattern of high and low intensity zones is produced which can be recorded on a photographic plate. This interference pattern is unique to the light sources producing it and its photographic reproduction is called a hologram.

To produce the hologram of an object the technique outlined in fig. 2 can be employed. A coherent light source, such as a laser, is set up such that it illuminates both a mirror and a photographic plate. The mirror is so angled to reflect incident light onto the object which again reflects the light onto the photographic emulsion. The plane wave from the laser (the reference wave) thus interferes with the spherical waves

arising from the multiple reflections as the surface of the three dimensional object. One such reflection is shown emanating from point P on the object in fig. 2. The interference pattern is thus captured on the photographic plate.

Fig. 3 shows how the image of the object can be reproduced. The hologram is illuminated by a plane reference wave similar in nature to the one that produced it. A three dimensional real or virtual image is obtained exactly reproducing the shape of the object in space.

2.2 The Properties of Holograms

Holograms possess many interesting and unique properties and a definitive list is beyond the scope of this paper. Several of these properties are however relevant to the discussion of the holographic token.

Unlike a normal photograph the information recorded is not an image but a spatial pattern distributed over the photographic plate. Thus all the information necessary to accurately reproduce the image is available from a very small area of the hologram. This means that the hologram is particularily insensitive to defects in the recording medium, dirt, scratches and even manufacturing inaccuracies.

Because of this spacial distribution of the hologram it follows that the position of the image is independant of position of the hologram itself. In other words if the hologram is shifted sideways the image will not move. Precise optics are therefore not required to read a hologram.

Under certain conditions relatively simple images can be reconstituted from holograms using compact and cheap non-coherent light sources. In other words information can be extracted from a simple hologram using, for example, a light emitting diode source.

From the above discussion we can conclude that although some fairly expensive and delicate optical equipment, coupled with significant expertise in the field of coherent optics is required to produce a hologram, the basic hologram itself can be reproduced fairly easily for about the same cost as printing a banknote.

2.3 The Landis & Gyr Pre-payment Token

The pre-payment token, shown in fig. 4, contains holographically encoded digital information contained in a small area of the token. The information present consists of a family code, type code and a value code. This information is read by means of illuminating the relevant area of the token by means of an infra-red light emitting diode and by monitoring the intensity of the reflection by means of solid state detectors. Fig. 5 shows a typical arrangement. It should be noted that the diagram is an over-simplification in that it only represents two dimensions whereas the reflections from a hologram may not necessarily be in the plane of the incident light. Also, the hologram is read through the token as it is transparent to infra-red radiation.

Referring to fig. 5, if a plot is made of reflected light intensity against angle of reflection (Y) a graph similar to that of fig. 6 will be produced. On a plane reflecting surface one would only expect to see the large zero order peak, reducing rapidly as the angle X was passed. However in the presence of the hologram there is always a first order reflection (although not necessarily in the same plane), and its size in proportion to the zero order reflection is constant. This is true even in the case of the dirty or scratched token shown by the dotted curve. Detection of the first order reflection and its proportion to the zero reflection forms the basis of measurement.

2.4. Coding and Erasing the Token

In this system two types of token are used, a value token which can be of up to three different values and is used to "buy" electricity and a service token which is used by a representative of the supply authority to examine and perhaps alter various operating parameters of the token meter. Clearly there must be a way of differentiating between the types and values of token. How this is done is quite complicated but in simple terms more than one hologram is used to define the token. All are illuminated together and it is the combined effects of all the holograms which is measured. To determine value the token is partially erased and the effects of the remaining holograms measured. By comparing the two measurements the composition of the original holograms can be determined and the value of the token identified. The token can then be completely erased.

Erasing the token is, in principle, the simplest part of the system. A small electric heating element in close contact to the hologram is heated very rapidly to a high temperature, thus melting the hologram. This process causes a localised colour change on the token so that an erased token is easily recognised. There is no way by which the hologram can be reconstituted.

In summary it can be stated that holograms are difficult to create, and impossible to imitate. Once created they can be easily and cheaply mass produced and can be read by inexpensive and readily available components.

3. THE PRE-PAYMENT METER

The token meter itself consists of an induction type electricity meter, a token reader, a microcomputer circuit and a contactor arranged as shown in the block diagram, fig. 7. All are mounted in a single enclosure as shown in figure 8.

3.1 Components

3.1.1 Electricity Meter

The electricity meter is a standard Ferraris type single phase, two wire, class 2 meter fitted with an optical impulsing device, providing an impulse to the microcomputer circuit one per revolution of the meter disc.

3.1.2 Token Reader

This unit includes the opto-electronic parts for measurement and provides a digital signal to the microcomputer unit corresponding to the received light intensity reflected from the token.

3.1.3 Microcomputer Circuit

The circuit board contains a single chip microcomputer which performs all the operations necessary to control the accounting and housekeeping functions associated with pre-payment metering and certain other special functions.

3.1.4 Contactor

The contactor used in the meter is a 240 volt, 80 amp resistive bistable type and is controlled by the microcomputer circuit.

3.2 Mode of Operation

The token meter has two possible modes of operation depending upon which type of token is used. There are two possible types of token, the value token and the service token. The former is the only type of token available to the user and the latter is used by the supply authority representative.

3.2.1 User Operation

The user can have up to three different value tokens. To "buy" electricity with the token it must be inserted into the slot on the front of the token meter (fig. 8). Normally the meter will display the amount of unused credit available but when a hologram is detected in the slot of the token reader this display is replaced by a testing symbol followed by an indication of the result of the test.

Normal display, e.g.	12.34
Token detected	o
Token accepted	Acc
or Token rejected	noAcc
Token removed	13.34 (for token value 1.00)
or Token removed	12.34 (if token rejected)

The token accepted symbol is accompanied by an acoustic signal to confirm acceptance. The token value contained on the accepted token is transferred to the logic circuits and the credit register, which is integrated in the logic, incremented accordingly.

The credit register is decremented at a rate proportional to the speed of rotation of the disk of the Ferraris meter. If the value of the credit register reaches or falls below zero the contactor will open.

A facility available to the user is "emergency credit". If the user's credit lies between zero and a predetermined value the user has the option of borrowing an amount of credit (determined by the supply authority). The availablity of emergency credit is indicated on the display and if so desired the user can push the emergency credit button (see fig.8). This will increase the credit display by the amount borrowed. A blinking display indicates borrowed credit.

E	1.00 Emergency credit available
Push button	2.00 (blinking) Emergency credit released
	0.10 (blinking) Credit almost fully used
	-1.00 (steady) Credit used, supply off.

This facility is particularily useful if the user runs out of tokens at a time when the normal source is unavailable (e.g. weekends).

The pre-payment meter can also be programmed to collect a standing charge. With this facility the standing charge amount is gradually decremented from the credit register over the billing period. This facility can also be used to collect previous debts or hire purchase agreements.

3.2.2 Service Operation

A service engineer (or other utility employee) who has a service token may examine or charge various parameters of the token meter. Unlike the value token, the service token is re-usable and is never erased. Once the token reader detects the service token the instrument goes into service mode. In service mode the emergency credit button is used to step the display through a set of registers containing various parameters, for example:

Register	Code	Digits	Remark
Tariff 1	1	xxx.xx	Cost per kWh
(Tariff 2	2	xxx.xx	Cost per kWh)
Standing Charge	3	xxx.xx	Cost per quarter
Emergency Credit	4	xxx	Credit available
TOTAL (value) of valid cards	5	xxxxx	Resettable only
Current Credit	6	xxxx.xx	Resettable only
Note that values in brackets are optional			

As soon as the service token is removed the pre-payment meter returns to normal mode.

4. CONCLUSION

As has been shown, holography provides a very effective basis for pre-payment of electricity. It has been designed to be attractive not only to the supply authority but also to the user and has many advantages over the traditional coin type pre-payment meter.

The technique of encoding digital information by means of holograms is not new. Landis & Gyr have been using this technique successfully for a number of years in the "PHONOCARD" prepaid card operated telephone, currently being used in quantity by British Telecom. Although a different application, the basic technique is the same and it is rapidly becoming recognised throughout Europe as a secure and reliable means of billing.

FIG. 1 – Population of Pre-payment Meters

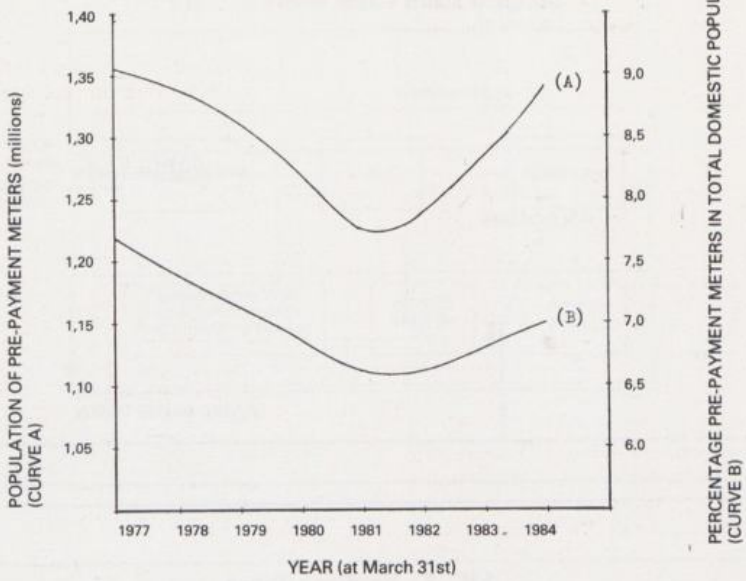


FIG. 2 – creating a Hologram

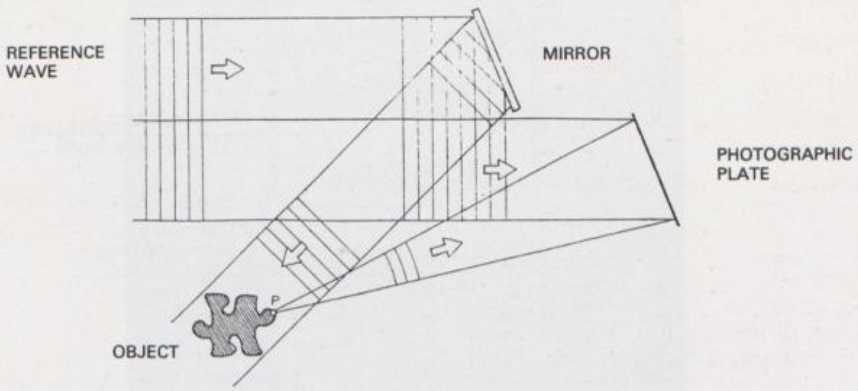


FIG. 3 – Reading a Hologram

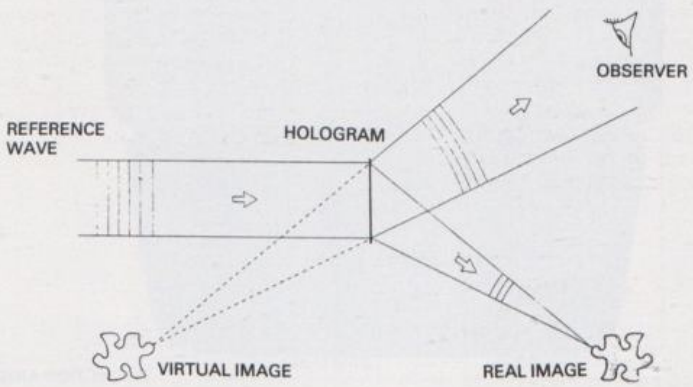


FIG. 4 – Holographically Encoded Tokens

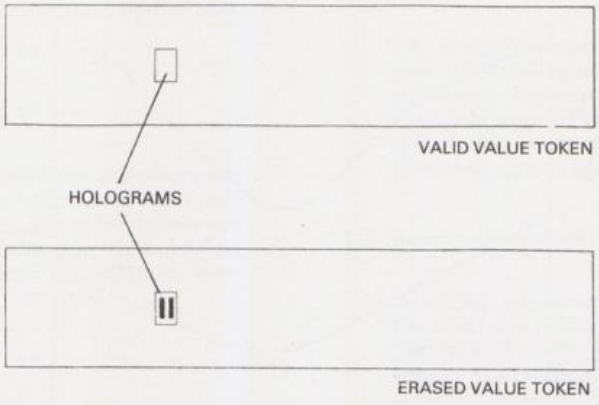


FIG. 5 – Reading a Token

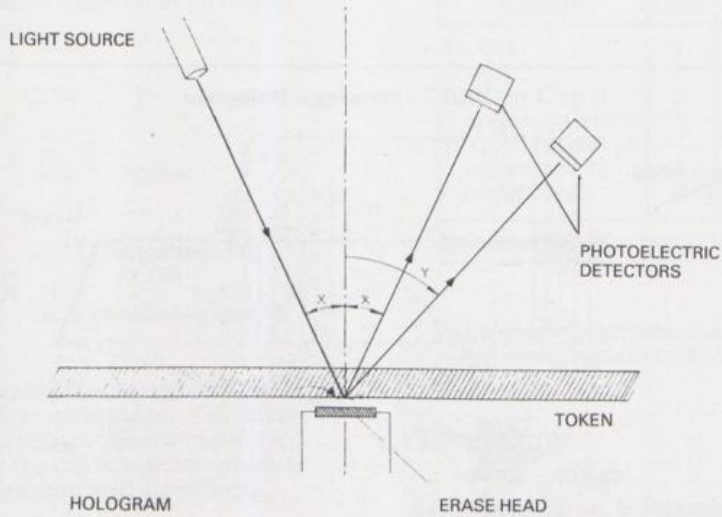


FIG. 6 – Light Reflected from a Hologram

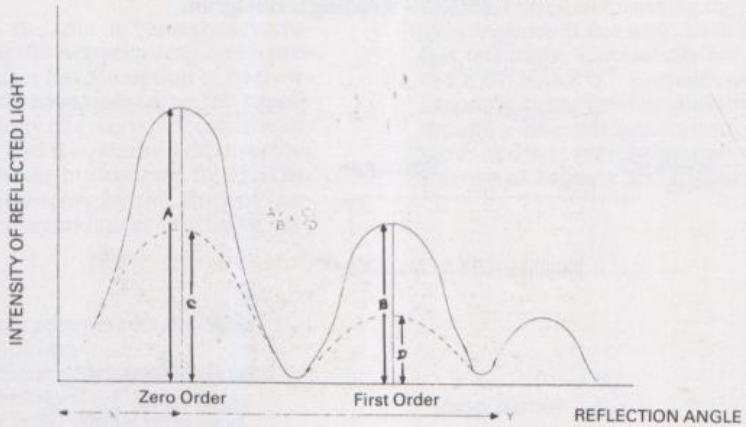


FIG. 7 – Token Meter Block Diagram

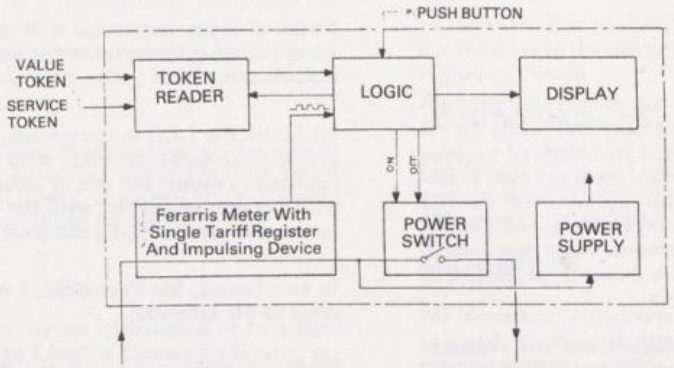


FIG. 8 – The Landis & Gyr Pre-payment Meter

DISCUSSION – BESPREKING

MR D C PALSER : Cape Town

I personally have been interested in token-operated prepayment meters for a number of years now and while on an overseas study tour some years ago, I investigated various different systems. In point of fact, some six years ago, I submitted a comprehensive report to my Council on the economic, social and practical implications of token-operated prepayment meters and recommended that a small number be purchased and installed in domestic premises, in certain selected areas, on a trial basis.

My Council adopted my recommendation, but unfortunately no meters have yet been purchased and installed, the reason being that up to the present no suitable, reliable meters have become commercially available. The main disadvantage of all systems so far has been that none has proved secure against fraudulent use.

The author has now described the system adopted by his company, which appears to have overcome all previous objections. As he mentioned, though, there are other systems available, the principle ones being the following:

Holographic token
EAROM Key
Magnetically encoded card
Plastic coins

While in Europe a month ago, I took the opportunity of again discussing these various systems and other related matters with the London Electricity Board (LEB). The LEB is in the forefront of research into the use of various token-operated prepayment systems because of the considerable problem they have experienced with the lower social level consumer in the London area. The LEB currently has around 120 000 coin-operated meters in service and experiences a lot of trouble with theft, with an average of about 10% to 15% of the meters being broken open. They are accordingly looking at various alternative easy-payment systems, with a view to phasing out coin-operated meters completely.

The LEB is presently carrying out trials with two different token-operated systems, namely the holographic system and the key system. These two systems are seen as superior to magnetically encoded systems and plastic coins, because of the higher degree of security they offer against fraud.

I agree with the author that because of the social stigma attached to the word "prepayment", some form of alternative terminology should be adopted. He has mentioned "budget meters" and this is the term also favoured by the LEB.

But the prepayment meter system, be they meters coin- or token-operated, is only one of a number of easy payment systems offered to domestic consumers in Britain. The following three systems are also available:

Monthly budget
Electricity saving stamps
Pay-as-you-go.

Under the monthly budget system the consumer arranges for regular monthly payments sufficient to cover the likely annual cost, either by way of a banker's stop order or using a post office Giro account. This system has clear advantages in Britain, where accounts are generally rendered quarterly and not monthly.

Electricity savings stamps are bought either from electricity area board offices or certain post offices and used towards the payment of accounts.

Under the pay-as-you-go system, you pay what you like, when you like. Unfortunately, no interest is paid on any credit balance.

As far as the LEB is concerned, the various easy-payment systems are quite popular, with about 15% of all domestic consumers opting for one or another of the various alternative schemes available, with the budget payment and coin-in-the-slot system being the most popular at the moment.

In conclusion, Mr President, I would like to put two questions to Mr Hibberd.

Firstly, reference is made to decrementing the standing charge gradually over the billing period. Is the available credit decreased continuously or in discrete steps? If the latter, what is the usual decremental period?

My second and final question concerns the reference to the fraudulent production of tokens. Mention is made in the paper "that without significant capital investment and technical expertise" it will not be possible to produce false tokens. But if the market for token meters in Britain is seen as being likely to increase, and if a figure of around one million meters, as envisaged, is likely, then assuming an average domestic consumer bill of R400 annually, the potential market for false tokens could be in the region of tens of millions of Rand annually. Surely such a potential market would be most tempting.

Could Mr Hibberd, therefore, give us some idea of the likely capital investment, leaving aside the question of technical expertise, required to produce acceptable false tokens. Should the market expand as expected, then this could well become a problem. There is always someone ready to try to beat the system – if the monetary return is right!

MR HIBBERD

Mr President, the standard charge is debited in fixed increments every two hours in the particular device. A value is programmed into the device to be decremented over a 3 months period whch is also the billing period.

In order to prevent false tokens from circulating, a special token will have to be produced at very high cost and would require very special expert knowledge. Tokens are,however, only produceable by highly sophisticated equipment under special environmental conditions. It will therefore not be feasible to produce these tokens, no matter what the reward will be.

MR C ADAMS : Port Elizabeth

The prepayment meter described by Mr Hibberd is a very interesting development. Bad payers are a problem to any supply authority, and the use of prepayment meters is one way of reducing the problem.

A considerable amount of research is being done world-wide to find a system which eliminates the old problem of having cash boxes broken into. The technique used by Landis and Gys is very novel, and if it is as secure as Mr Hibberd claims, it could be the solution to the problem.

This meter however, still has one big disadvantage, in that the meter records the value of the token and is programmed to decrease this stored value at a set value per kWh's. When a tariff change takes place, it will be necessary to visit all the consumers and reset the value per kWh to the new tariff value. As tariff changes can occur quite frequently, and at least once a year, this will be a considerable work load for the supply authority. In my view the meter would be much more acceptable, if the tokens were coded in multiples of kWhrs; tariff changes could then easily be accommodated by altering the price of the token.

Mr Hibberd has said that the manufacture of the tokens would be very expensive. Does this mean that the token would have to be purchased from Landis and Gyr, or would they sell the equipment for making the token?

MR HIBBERD

The device I showed on the screen is designed to be a field trial model developed for the London Electricity Board, according to their specifications. It was their requirement that the token should have a monetary value and that the tariff be programmed into the instrument. The instrument can also be programmed for kWh instead.

For reasons of security, I don't foresee the possibility that local authorities will be allowed to produce their own tokens.

MR R R GILMOUR : Affiliate

Mr President, I have been involved in the study of prepayment meters, including the token-operated versions.

My existing meter is located in a common position in a cubicle or kiosk mounted in the public road to which consumers have no access.

Should I elect to apply for such a meter to replace the credit type meter, will I have to bear the cost of alterations to my distribution box to accommodate the meter? Are separate prepayment units available and if so, would a pilot cable be required?

MR HIBBERD

Mr President, meters in a cubicle will be a problem because the consumer will have to go outside to put the token in the instrument. With more than one meter in the same cubicle, it might happen that the consumer puts the token in the wrong instrument.

It will be better if the token meter is installed in the consumer's house. Shifting of the meter will probable involve the laying of pilot cables.

MR BARNARD : President

I would like to see the installation of a cheap not necessarily accurate version of this type of meter all over Johannesburg. The present meter in the cubicle will be kept as a check meter, to make adjustments once a year.

MR D KNEALE : Affiliate

Mr President, I envisage that the prepayment meter would be installed by the consumer's electrical contractor and that it would form part of the consumer's distribution board in the case of a new house.

In the case of an existing installation, the electrical contractor would add the prepayment meter to the consumer's distribution board.

MR FORTMAN : Boksburg

Mr President, may I ask how does the price of the prepayment token meter compare with a standerd 80 ampère or 100 ampère single phase meter?

MR HIBBERD

Mr President, only a trial model of such a meter has been developed. I anticipate that a prepayment meter will be more expensive than a standard single phase meter.

It will also be more expensive than equivalent magnetic systems. But to balance the cost you will have higher security.

It is not really fair to compare this meter price for price with a standard credit meter. One must bear in mind that this meter is a self-contained billing instrument, because it charges and accepts money from the consumer. You will therefore save the cost of producing a bill and collecting the money. The necessity to disconnect and reconnect consumers who do not pay their bills, also falls away.

MR D FRASER : Durban

Mr President, the current trend in consumer spending patterns appears to be in favour of greater use of credit, even for relatively small purchases, as evidenced by the growing popularity of the credit card. If "Holograms" tokens were to be available only for cash, this facility would no longer be available to the pruchaser and possibly there would be an expectation for the tokens to be available at a discount.

Problems with non-payment of accounts arise more often in the UK than here, since they are normally only rendered quarterly and it is not the practice to require all consumers to pay deposits. In general, only consumers with a bad record of payment are called upon to give deposits.

MR W BARNARD : President

Mr Fraser, I have already been negotiating with "Pick-'n-Pay", so that the housewife can buy her tokens together with the groceries, every month.

About having to pay in advance and not getting credit, I think that people are already paying in advance today by virtue of having to pay a deposit, which I think most local authorities impose on their consumers and on which no interest is paid in many cases.

So by buying a token in advance the consumer is not better or worse off than before.

MODERN CONCEPTS OF RECLOSERS AND SECTIONALIZERS AND SYSTEM CO-ORDINATION OF DISTRIBUTION SYSTEMS

By L.G. Baker

INTRODUCTION

Circuit Reclosers and Sectionalizers have been used on distribution systems in the Republic and neighbouring territories, for more than 30 years with tremendous success, and are recognised as valuable equipment for providing simple, economical and reliable overcurrent protection by reducing the number of power failures. I would like to give a brief overview of the application of reclosers and sectionalizers.

RECLOSERS

A recloser, as defined in the standards, is a self-contained device for automatically interrupting and reclosing an AC circuit with a predetermined sequence of opening and reclosing followed by resetting, hold closed or lockout.

Studies of overhead distribution circuits have confirmed that as many as 95% of faults are temporary of which approximately 80% are between phase and earth and are usually caused by:

1. Windblown conductors touching one another
2. Lightning surges flashing over an insulator
3. Birds, reptiles or small animals contacting between energised lines and earth
4. Tree branches and even switching surges creating temporary faults.

When a fault occurs the recloser trips or opens its contacts and interrupts the current. After a brief time interval the contacts close automatically and if the fault has been cleared the recloser mechanism resets. If the fault is still present the recloser continues its programmed sequence of open-close operations giving temporary faults repeated chances to clear or be cleared by downline devices. For a permanent fault the recloser completes its programmed sequence and locks its contacts in the open position.

Reclosers can be set for 1, 2, 3 or 4 operations to lockout and are also designed to give a combination of fast and delayed opening times in order to obtain co-ordination with other protective devices such as fuses.

Based on statistics approximately 88% of faults are cleared on the first recloser operation followed by 5% on the second and 2% on the third with the balance of 5% being permanent.

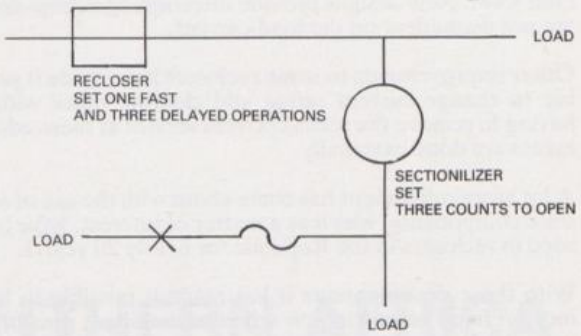
It can be appreciated that in the event of a one shot device such as a fuse or non reclosing circuit breaker being installed without reclosers that 95% of faults experienced would mean a repair man being called out to replace a blown fuse or reset a circuit breaker which is not only costly, but annoying to consumers.

SECTIONALIZERS

Basically a sectionalizer is a circuit opening device that automatically opens its contacts while the circuit is de-energised by a backup recloser or circuit breaker. Because a sectionalizer is not designed to interrupt fault currents it is always used in series with a backup fault interrupting device and because it does not interrupt faults it has no time/current characteristics. This is one of its major advantages as it makes it easy to apply to new or existing co-ordination schemes, but I must add that a sectionalizer is designed for load break fault make conditions.

Sectionalizers can be set for 1, 2 or 3 counts to open in order to co-ordinate with other protective devices.

At this point I would like to give a simple explanation or description of a scheme giving co-ordination with a recloser, sectionalizer and fuse and in this instance have set the recloser on 4 operations to lockout, using a 3 fast 1 delayed sequence, with the sectionalizer set on 3 counts to open.



It is assumed that we have a fault at X which could have been cleared by the first recloser operation causing the sectionalizer to count once, but if in the event of the fault being permanent, the recloser, which is now on a delayed time, would give the fuse time to blow, and would mean that only this faulted portion of the line would be isolated.

It can be appreciated that, depending on the length of line and take off points, a number of reclosers and sectionalizers would be used to give the best results.

There are numerous co-ordination schemes in use at present which are as follows:

Recloser/Recloser Co-ordination

This is acquired by either selecting different trip values of reclosers in series or setting the back-up recloser for one operation more than the down line recloser. Co-ordination can also be achieved by using different clearing times on the reclosers and in some instances it is necessary to use a combination of current settings, time settings and number of operations to lockout.

Recloser/Sectionalizer Co-ordination

Possibly the most simple, as the sectionalizer has no time/current characteristics and is set to operate at one operation less than the recloser.

Recloser/Sectionalizer/Fuse Co-ordination

Ideally the characteristic curves of the fuse link should fall between the fast and delayed time of the recloser.

In actual practice there are intersection points which provide a range of co-ordination and for all current values between these two points the recloser and fuse would co-ordinate.

For example, when experiencing high magnitude faults a fuse could clear within a few milliseconds whereas a mechanical device such as a recloser has a minimum clearing time of 30 milliseconds plus. This would also apply to low fault conditions, e.g. a 20 amp fuse link at 200 percent overload would operate in approximately 300 seconds whereas a recloser with its most delayed timing would have a clearing time of approximately 10 seconds.

During the past years a lot of improvements have been made to reclosers and sectionalizers which include sensitive and/or earth fault sensing, increased reclosing intervals and instantaneous lockout normally used to avoid reclosing into faults of high magnitude.

Most of these accessories do not require external sources of power and are completely self-contained.

Further development has allowed increased interrupting ratings by the elimination of series trip coils which limit the fault level. New designs provide interrupting ratings which are not dependent on the load current.

Other improvements to some reclosers have made it possible to change current rating and clearing times without having to remove the reclosers from service as these adjustments are done externally.

A lot more refinement has come about with the use of solid state components, which as a matter of interest, have been used in reclosers in the Republic for nearly 20 yearrs.

With these developments it has made it possible to have more refined co-ordination schemes making it possible to open or close reclosers via remote or supervisory systems.

This is particularly useful where loading shedding is required.

CONCLUSION

Reclosers and sectionalizers are most essential tools for electrical supply authorities in attaining their principal objectives in supplying electrical service continuity simply, reliably and economically.

DISCUSSION – BESPREKING

MR J FATH : Affiliate

Mr President, I would like to confirm Mr Baker's comments that pole mounted auto-reclosers and sectionalisers have provided a simple, elegant and economical protection and control facility on distribution systems for many years. Recently, the additional features of vacuum contacts, resulting in low maintenance, external adjustments of current ratings and timing sequences, have added to their value.

We have found two particularly useful uses for the auto recloser. Although I do not recommend it as good distribution design practice, I am sure there are many Town Engineers here, who have rural feeders fed from some point on a 11kV town ring feed. The use of an auto-recloser at this point will obviate many interruptions to the town consumers.

Again in the outskirts of the town or smaller substations, it may be necessary to provide an HV transformer switch with a short time tripping facility. The auto-recloser set to one shot to lockout, provides an economical solution with an added benefit of overcurrent protection, even when the station batteries are flat. From experience of having installed several thousand of these units on distribution systems, I have two points which will be of interest to members here today.

1. **The majority of failures which did occur, and that was not often, indicated that lightning arresters must be installed, and in some cases on both sides of the units.**

2. **The Sensitive Earth Fault feature has had a maximum time delay setting of 11 seconds. This time delay is insufficient to allow staff to close all three links out on the overhead system.**

Could Mr Baker comment on these two areas of concern?

MR L BAKER

Mr President, you should have surge protection on both sides of a recloser and preferably as close as possible to the bushings.

Reclosers can be delayed. Electronic reslosers can be delayed up to 120 seconds. I don't think that one should delay the recloser too long. My experience is that from half a second to one second is sufficient. I do know that you will not get co-ordination with the fuse link.

There are certain points of co-ordination, where if one tries to protect or co-ordinate with fuse links, under overload conditions one's recloser will lock out long before the fuse link operates. In the opposite way if one tries to co-ordinate fuse links with reclosers under high fault conditions, one will find that the fuse link will beat the recloser. There is therefore a gap in co-ordiantion.

MR D FRASER : Durban

The paper states that as many as 95% of faults are temporary, of which approximately 80% are between phase and earth.

How were these statistics obtained and on what types of construction of overhead line? viz:

1. **Line with earth wire**

2. **Semi High Impulse with wooden poles and wooden cross-arms with insulator pins bonded together to prevent burning of cross arm.**

or

3. **High impulse with wooden poles and wooden cross arms and insulator pins not bonded.**

Based on statistics, approximately 88% of faults are cleared on the first recloser operation, followed by 5% on the second and 2% on the third, with the balance of 5% being permanent.

How are these figures obtained?

In my opinion, the frequency of lockout of reclosers and sectionalisers with no permanent cause being established, is excessive on the Durban 11kV and 6,6kV system. During the 6 month period March to August 1984, for example, 16 auto-reclosers and 46 sectionalisers locked out for no obvious reason. This represents a high proportion of the total number i.e. 104 reclosers and 155 sectionalisers, controlling the 743 km of 11kV and 6,6kV overhead lines.

Perhaps Mr Baker could comment on this in his reply.

MR L BAKER

Mr President, with regard to the operation of reclosers and sectionalisers, I would like to say that for many years we found the sectionalisers were not accepted, especially by municipal engineers, because they came out under false counting condition such as magnetic inrush currents on switching in a transformer.

We found about 2 years ago that there were numerous open ends of sectionalizers under storm conditions. We managed to adapt the sectionalizers to ignore inrush current as a count. This has eliminated a lot of false lock-out on sectionalisers.

The statitics I use were taken from world wide statistics and could differ from other persons' records.

MR WALTER : ESCOM

Mr President, during 1983 some 40% of outages on circuits, controlled by reclosing breakers, were found to be what we at ESCOM refer to as "closed on-load faults". It means that the breaker has locked out after following its normal reclose cycle. When the breaker was reclosed manually by an operator, some time later the breaker closed in and stayed in.

This indicates that faults do last for some considerable time while storms are passing through, particularly in areas with a lot of trees.

I would like to ask Mr Baker, if it is possible to extend the final delay before final reclose to up to 10 minutes.

MR L BAKER

Mr President, yes, we have built in an adjustable time delay for up to 10 minutes.

THE TREATMENT OF TRANSFORMER OIL

By V.A Raynal Pr. Eng

INTRODUCTION

At one thime or another most of us are involved in the handling or use of insulating oil – commonly known as transformer oil.

We know:

(a) it must be handled carefully during transport and when filling transformers and switchgear, in order to preserve its insulating qualities.

(b) it needs periodic checking to monitor its condition.

(c) it needs reconditioning after it has been in service for some years.

What we don't know is what is the general attitude adopted by engineers today in the treatment of transformer oil.

Such questions as:

1. How frequently should one check the condition of oil?
2. Should one bother to test the condition of oil in small transformers (below 315kVA)?
3. At what limits of dielectric strength, moisture content or acidity should one "treat" – i.e. purify – transformer oil?
4. What are the most advantageous methods of treatment?
5. At what stage should one not waste time and money on treatment but completely drain and refill oil-insulated equipment?

The purpose of introducing this topic for discusion is to obtain AMEU Members' views on the main issues relating to the treatment of transformer oil.

The following information is given as a background to this topic:

The need to "treat" transformer oil

New transformer oil complying with SABS 555 is extremely pure but nonetheless highly hygroscopic and is rapidly contaminated when in contact with air, paper and fibre insulation, metals and compounds. It has a tendency to absorb oxygen, moisture, fibres and other impurities which lower its dielectric strength and produce acids and sludge that impair its cooling properties.

This deterioration in condition can be detected by regular tests on oil samples and when certain pre-determined limits are reached the oil can receive treatment to restore its purity.

A rational maintenance programme

A planned maintenance programme is highly desirable and the least costly method is to carry out regular tests on oil samples to determine when maintenance is necessary.

If this is done on all high voltage oil-filled equipment fitted with the necessary drain cocks or sampling valves, the incidence of unforseen breakdowns can be reduced to a minimum.

As far as oil treatment is concerned, one cannot do better than adopt the heat/vacuum process of purification which requires the use of expensive plant and well-trained staff. The frequency of treatment and whether purification should be done by one's staff or by oil-purification contractors is largely a matter of economics, dependant on one's capital and labour resources.

The above is a brief outline of some of the factors involved in the treatment of transformer oil and I trust they will encourage some healthy discussion on this topic.

DISCUSSION – BESPREKING

MR J C VAN ALPHEN : SABS

It is now more than a decade ago, when ESCOM decided to order from then onwards distribution transformers to SABS 780, having a welded cover. This decision was not taken without a thorough study of the hazard of a transformer becoming a pressure vessel.

Tests were done on a co-operative basis between the SABS and The Test Department of the Johannesburg Electricity Department. Between no-load and a moderate overload condition, pressures only changed moderately and within safe limits. This was partly the result of the inherent flexibility of transformer tanks with fairly large tank walls. Even when the transformer tank was considerably stiffened, pressure variations remained acceptable as a result of gas absorption; when the pressure inside the tank was positive and the gas was evoluting, when the pressure was negative. These results were later verified by further tests conducted at the S.A.B.S.

The satisfactory performance of transformers with welded covers appeared to have confirmed the wisdom of ESCOM's decision, which is being adopted by an increasing number of users.

The use of welded covers is limited to 630kVA, but above 630kVA, hermetically sealed transformers with domed covers can be used to the upper limit of SABS 780 of 3 150kVA.

It would therefore not appear to be of economic advantage to consider oil treatment of sealed transformers.

MR W BARNARD : President

My own philosophy, as far as the maintenance of transformers is concerned, is to make sure that they are completely sealed. We had some of our transformers welded completely. From experience we found that a transformer, which is completely sealed with no oil gauges or dipsticks, will last from 40 to 50 years without any maintenance. After this period the transformer will collapse completely because of excessive corrosion. I think that is a good lifespan for any type of electrical equipment without any maintenance.

I would like to ask Mr Raynal the size limit of transformer he would recommend, that could be sealed completely.

MR D A GARDNER : Affiliate

Mr President, I would like to ask the following questions:

1. **How many transformers have failed due to contamination of oil?**

2. **What tests are considered to be the most important:**

   Moisture test,
   Sludge test; or
   Acidity test.

3. **How does one decide when filtration or purification of the oil should be carried out?**

4. **The discussion has been limited to transformers, but what about the oil in switchgear, which is subject to carbon contamination?**

MR RAYNAL

Mr President, with regard to Mr Van Alphen's question, I would not support the theory that if a transformer has not been attended to for 10 years, it should be left as it is. The first step will be to take a sample from the bottom of the transformer tank, to be tested. If filtration is necessary, it should preferably be done with a switched off transformer.

ESCOM was the first to weld transformers. The SABS have stipulated that transformers can be sealed off, up to a size of 630kVA.

The oil of a transformer is an insulator and anything that lowers the insulation value must be regarded as important. I think that the moisture test is the most important. With the modern type of oil, sludge is not a very big problem. Acid has a long term corrosion effect. It can soften insulation, it can make oil more hygroscopic, but acid is more like a bad cold – it will not kill a transformer.

Regarding filtration, every two years is very arbitrary. Like a motor car, one does not need to change the oil every 10 000 kilometers. It depends how one feels about the equipment. It is better to filter the oil than not to filter it.

If switches operate quite often, one gets deposits of carbon. Moisture is normally not a problem, because switchgear does not go through the same temperature cycles as a transformer. Generally today, the oil is completely drained from the switch and replenished every 5 or 10 years, depending on the service life of the equipment.

THE STANDARDIZATION OF VOLTAGES IN SOUTH AFRICA WITH SPECIAL REFERENCE TO ESCOM'S VARIOUS SUPPLY VOLTAGES TO LOCAL AUTHORITIES

By J.C. van Alphen Pr. Eng.
Senior Engineer, South African Bureau of Standards
and
H.B. Norman Pr. Eng.
Chief Engineer System Planning
Operations Department, ESCOM

Standard voltages for electricity supply in South Africa as specified in SABS 1019 "Standard voltages and currents for electric power supply" and which are in current use in a number of systems of ESCOM and local authorities are the following:

High voltage for equipment, kV	Nominal phase-to-phase voltage, kV
7,2	6,6
12	11
24	22
36	33
52	44
72,5	66
100	88
145	132
245	220
300	275
420	400

Most of the regions of ESCOM's supply network have in the voltage range up to 132 kV a limited choice which is of historical origin. For instance the following voltages are available:

Rand and OFS	11	22	–	44	–	88	132
Natal	11	22	33	–	–	88	132
Cape	11	22	33	–	66	–	132

Because of the benefits to both the manufacturer and the user Escom has evolved a range of standard transformers having the parameters listed in Table 1.

Of these the preferred or recommended ratings for most applications are those listed in Table 2.

Escom also standardized its circuit breaker ratings as given in Table 3.

The ratings of standard transformers were chosen such that two units of Rating 1 or four units of Rating 2 could be connected to a busbar without the fault level exceeding that corresponding to the higher standard circuit breaker rating. Two units of Rating 2 or four units of Rating 3 could be connected to a busbar without the fault level exceeding that corresponding to the lower standard circuit breaker rating. Transformers of Rating 4 are used where small loads are involved. For very large loads it is possible to use three units of Rating 1 with only two connected to the busbar, the remaining unit being switched in only in the event of loss of one of the connected units.

Thus using Escom standard transformers and switchgear the maximum loads that can be supplied from one busbar are as follows:

Secondary voltage, kV	Maximum load, MVA
6,6	20
11	40
22	80
33 or 44	160
66	320
88	630
132	1 000

CONCLUDING REMARKS

The choice of a standard voltage for local authorities is determined by existing supply voltages in the district and also on future load demands. The above information which is based on Escom practice may help in making the most cost effective choice.

SABS 1019 is under revision and will include information with regard to standard insulation levels and insulation co-ordination. The revised specification will be known as SABS 1019 "Standard voltages, currents and insulation levels for electricity supply", and should be available from early 1985.

TABLE 1 – Standard ESCOM Large Power Transformers

Nominal voltage, kV		MVA rating main/ tertiary				Impedance, %		Taps	Connection
HV LV	Tertiary	1	2	3	4	Min.	Max.		
400 275	22		800/40	400/40		10	13,5	OLTC	Yyo/
400 220	22		630/40	315/40		11	14,3	+0% to	
400 132	22	500/40	250/40	125/20		13	16,3	-15%	Ydl
400 88	22		315/40	160/20		13	16,3	of HV in 12 steps	
275 132	22	500/40	250/40	125/20		11	14,3	OLTC	
275 88	22	315/40	160/20	80/10		12	15,0	+5% to -15% of	
220 132	22	500/40	250/40	125/20		9	11,7	HV in 16	
220 66	22	160/20	80/10	40/10		11	13.75	steps	
132 88	*22 or 11	315/40	160/20	80/10		8	10,8		
132 66	*22 or 11	160/20	80/10*	40/10*		9	11,7		
132 44	*22 or 11	80/10*	40/10*	20/5*		10	12,5		
88 44	*22 or 11	80/10*	40/10*	20/5*		8	10,4		
132 33	–	80	40	20		10	12,5	OLTC	
132 22	–	40	20	10		10	12,5	+5% to	Ydl
132 11	–	20	10			10	12,5	-15% of	
132 6,6	–	10				10	12,5	HV in 16 steps	
88 33	–	80	40	20		9	11,25	Optional	
88 22	–	40	20	10	5	9	11,25	off-cct	
88 11	–	20	10	5		9	11,25	±2½%	
88 6,6	–	10	5			9	11,25	±5%	
66 22	–	40	20	10	5	8	10,0		
66 11	–	20	10	5	2,5	8	10,0		
44 11	–	20	10	5	2,5	7	8,75		
44 6,6	–	10	5	2,5		7	8,75		
33 11	–	20	10	5	2,5	7	9,8	Off-cct**	
6,6		10	5	2,5		7	9,8	+0% to -10% of HV in 4 steps	Yyo
22 11	–	20	10	5	2,5	6	8,4		
6,6	–	10	5	2,5		6	8,4		

*22 kV or 11 kV optional.
**Where on-load tap changing is required the range is +5% to -15% in 16 steps and the impedance range changes to 7 – 8,75% and 6 – 7,5% for 33 kV and 22 kV respectively.

TABLE 2 – Recommended Ratings of Power Transformers

Primary voltage range, kV	Secondary voltage,	Tertiary voltage	Apparent power rating, MVA			
			1	2	3	4
22-44	6,6		10	5	2,5	
22-132	11		20	10	5	2,5
66-132	22		40	20	10	5
88-132	33		80	40	20	
88-132	44	22 or *11	80/10	40/10	20/5	
132-400	66	22 or *11	160/20	80/10	40/10	
132-400	88	22 or *11	315/40	160/20	80/10	
220/400	132	22	500/40	250/40	125/20	

*The 11 kV rating is an alternative tertiary voltage when the primary voltage is 88 kV or 132 kV.

TABLE 3 – Standard Escom Circuit Breakers

System nominal voltage, kV	Fault current rating, kA	Load current, A
66 and below	12,5; 20	800; 1 600
88	16; 25	1 250; 2 500
*132	16; 25	1 600; 2 500
*220	20; 31,5	1 600; 2 500

*Because of large consumers being connected to these systems, fault current limits were sometimes exceeded as a result of large fault in feeds from consumers plant.
Because of these problems Escom has now increased the fault current rating to 25 kA and 50 kA for 132 kV and 220 kV. These increased ratings need not necessarily apply to local authorities.

DISCUSSION – BESPREKING

MR D H FRASER : Durban

Mr President, the Durban Corporation Electricity Department's existing and proposed standard transformer ratings are detailed in the attached data sheet and differ widely from the recommended ratings in table 2 on page 4. It is not proposed to change our standard transformer sizes for the following reasons:

(i) As it is not intended to expand the 33kV system appreciable in the future, it is considered preferable to adhere to the existing standard departmental sizes for any limited reinforcement of this system.

(ii) The largest rating of 132/11kV transformers recommended in table 2 is 20 MVA. This size is considered to be too small for most applications in a high density urban distribution system. Fault level limitations and the consiequently high impedance requirements make the use of transformers larger than 30 MVA undesirable, but if it were not for this limitation, 132/11kV transformers of up to 40 MVA could well be used in areas of high load density. Overall, the Durban standard of 30 MVA is still considered to be the best compromise.

(iii) It is established policy that for corrosion reasons, the Durban Corporation Electricity Department will use aluminium alloy conductors for all new transmission lines. The largest standard conductor for all new transmission lines. The largest standard conductor of this type is "Yew", with a twin rating of 706 MVA at 275kV and 75 C maximum temperature. When considering the rating of 275/132kV transformers, 2 × 315 MVA transformers match the line rating more closely than multiples of the recommended 250 MVA rating. In addition, as fault level considerations do not place an excessive impedance requirement on 315 MVA 275/132kV transformers, it is considered that 315 MVA units are more economical than the equivalent capacity made up of 250 MVA units. It should be noted that both 250 MVA and 315 MVA are preferred values in terms of BS 171 and IEC 76.

MR K VAN ALPHEN

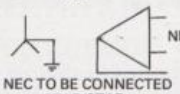
Mr President, these standards given by ESCOM are based on typical ESCOM practices. ESCOM also tried to standardize a very large number of undertakings. These standards are not meant to be the only and right choice.

The aim of ESCOM is to bring this standardization to your attention and not to impose it on the AMEU members.

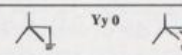
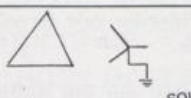
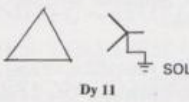
Due to the large number of undertakings of ESCOM, the main reason for standardization is to standardize buying of equipment.

DURBAN CORPORATION
TRANSFORMER DATA SHEET

PRINCIPAL SUBSTATIONS

RATIO (kV)	VECTOR DIAGRAM (H.V.) (L.V.)	RATING (MVA)	MINIMUM PERMITTED SYSTEM FAULT LEVEL H.V.	MINIMUM PERMITTED SYSTEM FAULT LEVEL L.V.	EXISTING TRANSFORMERS No. on System & Approximate Impedance	EXISTING TRANSFORMERS Resultant L.V. fault level with two tran'rs in parallel at maximum H.V. fault level	PROPOSED TRANSFORMERS Theoretical minimum impedance	PROPOSED TRANSFORMERS Inpedance to be specified* (Minimum/Maximum)
132/33	Yd 1  NEC TO BE CONNECTED STAR/STAR	100	5 716 MVA 25 kA	1 500 MVA 26,2 kA	4 at 15,7%	1 040 MVA	9,83%	17,2/20,5 Ω
		80			2 at 12,5%	1 046 MVA	7,87%	17,2/20,5 Ω
		45			21 at 10,0%	1 092 MVA† 1 369 MVA‡	6,64%† 8,85%‡	25,7/30,8 Ω† 34,3/41,1 Ω‡

MAJOR SUBSTATIONS

RATIO (kV)	VECTOR DIAGRAM (H.V.) (L.V.)	RATING (MVA)	MINIMUM PERMITTED SYSTEM FAULT LEVEL H.V.	MINIMUM PERMITTED SYSTEM FAULT LEVEL L.V.	EXISTING TRANSFORMERS No. on System & Approximate Impedance	EXISTING TRANSFORMERS Resultant L.V. fault level with two tran'rs in parallel at maximum H.V. fault level	PROPOSED TRANSFORMERS Theoretical minimum impedance	PROPOSED TRANSFORMERS Inpedance to be specified* (Minimum/Maximum)
132/11	Yy 0 	30	5 716 MVA 25 kA	350 MVA 18,4 kA	8 at 14,4% 2 at 12,8%§	388 MVA 433 MVA	16,1%	93,5/112,2 Ω
33/11	 Dy 11 SOLID	25	1 500 MVA 26,2 kA	350 MVA 18,4 kA	2 at 10,9%§§ 2 at 15,0% 2 at 16,0%	375 MVA 273 MVA 259 MVA	10,95%	4,8/5,7 Ω**
		15			10 at 10,0% 4 at 17,0%	250 MVA 188 MVA	6,57%	
33/6,6	 Dy 11 SOLID	25	1 500 MVA 26,2 kA	250 MVA 21,9 kA	2 at 10,0% 4 at 17,0%	375 MVA 250 MVA	16,67%	
		15			32 at 10,0% 4 at 13,0%	250 MVA 200 MVA	10,0%	7,3/8,7 Ω**

FORMULAE

$$M_L = \frac{100\,M_H M_T}{(100 M_T + M_H X}$$

$$X = \frac{100\,M_T(M_H - M_L)}{(M_H M_L)}$$

M_H HIGH SIDE FAULT LEVEL
M_L LOW SIDE FAULT LEVEL
M_T CAPACITY OR TRANSFORMNERS
X TRANSFORMER IMPEDANCE

LEGEND

† STANDARD FORMERS IN PARALLEL
‡ 4TRANSFORMERS IN PARALLEL
ø NEUTRAL FAULT CURRENT LIMITED TO 800 AMPS PER TRANSFORMER
§ CHATSWORTH SUBSTATION
§§ McWILLAWS SUBSTATION
* SPECIFIED PERMISSIBLE RANGE OF IMPEDANCE (EXPRESSED IN OHMS AS VIEWED FROM THE H.V. SIDE)
** IMPEDANCE EXPRESSED AS PHASE TO NEUTRAL EQUIVALENT

EXPERIENCES WITH EARTH LEAKAGE RELAYS IN DOMESTIC INSTALLATIONS

Should they be made mandatory in existing premises?

By E.G. Davies

Earth leakage relays were first introduced in South Africa in 1968 and therefore a great wealth of operating experience should be available. The basic function of the earth leakage relay is to avoid a person being electrocuted and to prevent fire due to earth leakage currents. Whilst these requirements are admirable, in practice any equipment to provide for this would not be acceptable if it resulted in numerous, spurious, unnecessary operations. I believe that some of the early earth leakage circuit breakers which were marketed, were subject to damage by lightning, to tripping out due to transient voltage spikes, and also suffered from the defect that the setting was too low to be practical. However, most of these defects now appear to have been overcome.

It is most difficult to obtain any statistics in regard to the operation of earth leakage relays, but the inspectorate of the Pietermaritzburg Electricity Department has, over the past few years, monitored the installation of earth leakage relays in domestic premises and in our experience there has been only one fatality with an installation incorporating an earth leakage relay, but is was subsequently ascertained that the earth leakage relay was faulty when installed – by an unlicensed electrician – and the unfortunate victim had never used the test button. Durban, I believe, have had no such accidents. It is, however, pertinent to enquire how many fatal accidents have been avoided by the use of earth leakage circuit breakers, but this is a question which we believe will never be answered. However, from our experience, I believe the earth leakage relay has resulted in a substantial reduction in the number of fatalities.

One point that should not be overlooked is that the earth

leakage relay will not operate in the event of a person touching both the phase and neutral conductors if there is no earth leakage current, but experience will show that this type of occurrence is relatively rare.

The question posed is whether they should be mandatory in existing premises? In essence, I do not believe that any legislation should be made retrospective and undoubtedly the fitting of earth leakage relays to some of the older installations wired with V.I.R., would not be practical – the earth leakage current would in most cases be exceeded. However, it is these very installations which pose the biggest threat of fire and electric shock, and I do not believe that it would be practical to insist on what amounts to a complete re-wiring of an older dwelling because of a mandatory requirement to install and earth leakage relay. On the other hand, it would certainly be in the interest of the consumer to do so, and perhaps this re-wiring could be paid for over a period of time, i.e. through an assisted installation scheme. Perhaps if the installation of earth leakage relays were made mandatory, they could initially protect only those circuits which did not cause operation – at least some of the installation would then be protected, with a proviso that the remaining circuits be brought up to standard within a period.

DISCUSSION – BESPREKING

MR W BARNARD : President

I want to make one point clear. I added the last sentence in the title: "should they be made mandatory". It was not my intention to make earth leakage relays mandatory for the whole installation, but for socket outlets only.

MR A MIDDLECOTE : Honorary Member

Mr President, I would rather have spoken later, after all other comments.

However, I would like to say that I believe that earth leakage relays have done a very good job and we should appreciate this.

I agree with the president that earth leakage relays should only be made compulsory on new installations (as is the case at present). It would take a very bad installation to leak 20mA.

One thing is true – electric accidents are less than 1% of the total domestic accidents – fewer people are killed by electricity than by taking poison.

This is because of the responsible attitude of installation engineers. One of these is to promote the use of the very useful earth leakage relay, by requiring this on all socket outlets on new installations.

MNR N BOTHA : Bloemfontein

Mnr die President, in die onlangse jare is veel studie gewy aan die effek van elektriese stroom en energie op die mens en die gevolge van dood onder bepaalde omstandighede. Sodanig, dat ons almal weet dat die menslike liggaam in werklikheid 'n betreklike komplekse elektroliet is en dat die biologiese effek van elektrisiteit bepaal word deur verskillende faktore. Na gelang van omstandighede is die grootte van die stroom, die duur daarvan, die energie wat verkwis word en die baan waarlangs dit vloei, van die belangrikste faktore.

Dit, mnr die President, wat ek nou genoem het, bring my by die vraag of aardlekrelê(s) verpligtend gemaak moet word in bestaande huishoudelike installasies? Mnr Davies van Pietermaritzburg het in die verband 'n sinvolle en werkbare benadering voorgestel.

Daar is egter by my twyfel of daar in die wêreld sinvolle statistiek oor aardlekrelês, en dit wat daarmee saamgaan, bygehou word. Alhoewel daar wêreldwyd konsensus is dat aardlekrelês noodlottige ongelukke met ±60% verminder, bly dit 'n geval dat ons grootliks besluite neem volgens vermoedens.

Derhalwe, mnr die President, wil ek voorstel dat die VMEO oorweging daaraan behoort te skenk om 'n projek te loods waar daar op sinvolle- en uniformewyse statistiek bymekaar gebring word oor aardlekrelês en dit wat daarmee saamgaan.

Uit die aard van die saak sal betroubare inligting en kennis tot 'n groter mate bydra tot die beveiliging van noodlottige ongelukke en verder is dit ook onontbeerlik vir die korrekte tegniese ontwerp van die toerusting.

MNR P BOTES : Roodepoort

1. **Aardlekrelês het foute wat nie deur die normale toetse van die SABS of vervaardigers aangewys kan word nie. Vervang die relê met 'n nuwe en die probleme is opgelos.**

2. **Deur ons installasies onder hierdie relê beveiliging te plaas is om moeilikheid te soek.**

3. **Laat dit liewer aan die ingenieur oor om stadigaan die mense bewus te maak van aardlekbehoeftes. My persoonlike gevoel is dat ons 'n fout gemaak het om aardlekbeveiliging verpligtend te maak.**

Die koste is hoog en hier het ons 'n moeilike vraag, veral in die lig van die huidige ekonomiese klimaat. Die vraag is: wat is die koste van 'n lewe?

Wanneer 'n aardlek apparaat geïnstalleer is, word maklik gesê dat die installasie veilig is. Dit is nie so nie, mnr die President.

MR WALTER : ESCOM

Mr President, ESCOM has recently had a fatal accident which occurred on an installation supplied by us. The earth leakage relay was defective. It was found that the test button only tests the mechanical operation of the relay. It does not prove that earth fault current would cause the protection to operate.

There was a second case recently, when one of our engineers found the earth leakage device defective on his own installation. The device did not operate under actual fault conditions, but did operate with the test button.

I believe that testing should be done with a supply plug.

MR CROMPTON : Johannesburg

Mr President, as Mr Davies has already mentioned, we have no means of knowing how many accidents have been avoided due to the existence of electric relays.

May I, however, give some statistics of reported accidents in Johannesburg over the past 12 years.

38 fatal and 3 non-fatal accidens have been reported, a total of 41. Of these, 30 were caused by plug-in appliances. All would have been avoided if the installation had been protected by an earth leakage relay.

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— performance
— durability
— versatility

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MRT BARTONS

STEEL TUBE AND PIPE DIVISION OF MB

eAsilock powercore

Of the remaining 11 accidents, some would have been avoided if the installations had been protected by a earth leakage relay. These accidents included touching a live washline and working on a live installation.

In recent years we have not experienced any damage to relays due to lightning. We have also had no problem with the relays tripping due to lightning in the vicinity, provided the surge arrestor is mounted on the line side of the earth leakage relay.

Mr President, we would support the recommendation that earth leakage relays be made mandatory.

MR D C PALSER : Cape Town

Mr President, without in any way detracting from the undoubted advantages of earth leakage relays, I do feel that we in South Africa have tended to go a little overboard in the promotion of this excellent device!

I fully agree that the provision of earth leakage relays on new domestic installations should be mandatory as presently provided for in the Wiring Code, but honestly believe that making their installation also mandatory on all existing installations is quite unwarranted!

We, in Cape Town, probably have more domestic consumers than any other municipal electricity undertaking in the country – currently close on 200 000. But over the past 30 years or so, I know of only two instances where electrocutions could possibly have been prevented had earth leakage relays been installed.

At present we estimate that well over a third of all our domestic installations are now covered by earth leakage protection. Under the present – and quite adequate – provisions of the Wiring Code, I believe that it will not be unduly long before most installations are protected.

I accordingly see no need to make the provision of earth leakage relays mandatory on all existing installations.

Then Mr President, as far as statistics are concerned, you might be aware of the new township Mitchells Plain, a city for 250 000 people and 25 000 homes. All these houses were equipped with earth leakage relays. Our records indicate that 100 of these relays failed during the guarantee period and were replaced by the manufacturer. This is a failure rate of ,25%.

MR K NUSSE : Affiliate

Mr President, in reply to Mr Walter, I would like to make the following comments:

1. In most earth leakage units the test button operation will simulate an earth fault and not trip the unit mechanically only.

2. Heinemann units will fail safe if the release mechanisim of the unit becomes faulty. The power supply is interrupted.

MR P TOLMAY : Affiliate

Mr President, SABS 767 of 1982 is the test code for earth leakage relays. The SABS Curve and test are done at:

1. 50 ms applying 200 MA;

2. 200 ms applying ± 52 MA; and

3. 500 ms applying ± 24 MA.

Tests by the SABS on our earth leakage relays are as follows:

1. At 12 ms, it trips at 200 MA;

2. At 18 ms, it trips at 58 MA; and

3. At 30 ms, it trips at 24 MA.

Danger to Heat Ventricular Fibrillation is at least 500 ms at ± 105 MA.

Therefore, if an earth leakage relay is installed, the probability of heart failure, due to electric shock, is negligable.

MR GILMOUR : Affiliate

When introducing me this morning, prior to delivering my paper on corrosion, the President mentioned that this is the third paper I was presenting to the AMEU. My first paper dealt with the subject of electrical accidents and was presented at the convention, held in Margate, during May 1963. In this paper, I presented graphs equating electrocutions with total consumption of electricity and numbers of consumers. In a report by the chairman of an electrical contractor's association published in a Cape Town newspaper recently, a similar relation was given, according to which there appeared to be little changed in 21 years.

In 1963, earth leakage relays were virtually still in their infancy and considering the quantity of relays installed since then, I wonder if the latest figures are correct and how and where they were obtained?

MR BARNARD : President

If I may just make a short comment. This is a subject with which I have been very deeply involved during the last few years. Johannesburg has a fully earthed system with double earth wires on low voltage overhead lines.

Since 1940, an earth connection has been provided to the municipal earth system on the consumer's premises. Prior to 1940, we did not provide this earth connection. A large number of consumers in the older suburbs had to make use of their cold water system as their main earth. More recently, with major problems with the water supply in Johannesburg, the steel water system was replaced with non-metallic water mains. In all such consumer areas, the consumer is left without an earth which complies with the wiring regulations.

In studying this problem, the Johannesburg City Council has taken the decision that we will provide an earth connection to all our consumers, at a cost of R600 000 over the next 3 years.

In the interim, the consumer will have to make sure that his system will operate under certain earth fault conditions.

We recommend to consumers that they install a 25 milli-amp earth leakage relay, in order to comply with the regulations.

MR A MIDDLECOTE : Honorary Member

Historically we have developed an excellent product. We started in 1953 and were pioneers in the world. We were enthusiastic and went a little far in our sensitivity – down to 5 milli-amps and suffered from instability. But the years have given us a good product. It is stable and I believe if our manufacturers combine to apply sound quality control, we will have little trouble.

I believe that with the present standard of earth leakage relays – and the SABS can continue to improve the standard – it is advisable in the interest of public safety to continue to promote its use. I believe, as the President, that they should continue to be made compulsory on all new installations and

only be made compulsory on socket outlets. It is advisable though to take precautions against spurious tripping of for example supplies to refrigeration or essential lighting circuits.

MR W BARNARD : President

Gentlemen, we have a major point of difference. I suggest compulsory installation of earth leakage relays to all socket outlets for all installations within three years.

MR P BOTES : Roodepoort

Mnr die President, ek steun u ten volle. Wanneer aardlek beveiliging aangebring word in 'n huis behoort dit net op sokuitgange te wees en nie op ligte- en stoofkoppelings nie.

Probleme word ondervind met die gebruik van die aardlek eenheid, wat as stoofskakelaar gebruik word ter wille van kostebesparing. Dit is nodig dat die installering van aardlekeenhede slegs op sokuitgange, so spoedig moontlik verpligtend gemaak word.

RETICULATION OF NEW TOWNSHIPS

By J.K. von Ahlften Pr. Eng.

This topic refers to the guidelines for the provision of engineering services in residential townships issued in 1983 by the Department of Community Development and experience and feedback so far gained with the application thereof persuant to the NBRI-CSIR Seminars : Guidelines for Township Services that were held in Pretoria, Cape Town, Port Elizabeth and Durban during February/March 1984. Repeat Seminars in Bloemfontein and Windhoek are being contemplated.

In the first instance it must be recorded that the attendance by AMEU Engineer Members at these Seminars was most disappointing in comparison to the attendance by Consulting Electrical Engineers and the municipal feedback therefore very limited. However, the following points did arise after the presentation and discussion of the electrical distribution section of the guidelines which may be of interest to Engineer Members.

1. DESIGN ADMD

Consulting engineers expressed concern regarding the possibility of overdesigning the low voltage distribution network if this is designed in accordance with the guidelines and parameters given.

It was submitted by Mr. Don Hull of Durban Corporation Electricity Department, the Natal AMEU representative on the Electrical Working Subcommittee, that these contentions require careful examination and further information will be required on the basic ADMD, unbalance and diversity parameters used in the examples. The guidelines only provide guidance for the selection of ADMD's considered appropriate for future residential townships in South Africa but stress the need to modify these in the light of further local investigation and experience.

Indications are the ADMD's could vary significantly for groups of consumers who at first sight would appear to fall into a particular category or grouping and obviously a choice of a too high ADMD for design purposes will result in oversized cables and increased cost.

Local knowledge and experience will therefore be all important in the final choice of the ADMD for design purposes taking into consideration the application of any load management systems and acceptable voltage variations applicable to low voltage distribution networks in South Africa.

2. VOLTAGE DROP CHART V/S VOLTAGE DROP CALCULATIONS

The voltage drop chart included in the guidelines takes into account the effects of unbalance and diversity in accordance with the A.C.E. report No. 13 (1966) on "The design of medium voltage underground networks for new housing estates" accepted by the 1966 Conference of Chief Engineers of the Electricity Area Boards in the United Kingdom. It is, however, accepted that the unbalance and diversity correction factors taken from the report will require further examination in the light of South African experience, but in the absence of specific data similar to that offered in the A.C.E. report it was decided to accept the chart used by Durban Corporation Electricity Department as a starting point.

The comment that the calculated voltage drops using the data within the guidelines does not agree with the voltage drops obtained when using the chart could however not be substantiated as the chart proves to be sufficiently accurate for this purpose and incorporates unbalance and diversity factors which vary according to the number of consumers and the ADMD applied.

Mr. Ken Murphy, the Western Cape AMEU representative on the Electrical Working Subcommittee, commented that with electric cooling commonplace in South Africa and our reasonable electricity tariffs for domestic consumers, the use of air conditioning on domestic premises is becoming popular and considering these factors and actual load readings taken, the diversity and unbalance figures given in the guidelines are considered realistic. Mr. Pat Middlecote of the SABS at the recent AMEU Convention also made reference to the considerable voltage fluctuation experienced in this country which confirms that low voltage distribution networks are often underdesigned or soon become overloaded.

It would therefore appear that the statutory percentage voltage drop laid down for this country including the present standard voltage may need to be reviewed to enhance more economic low voltage distribution networks for future residential townships.

3. SERVICE ARRANGEMENTS

In terms of the guidelines service cables can be tee-jointed or connected to mini-pillars or metering kiosks situated on the erf boundary and the point of supply is considered to be where the service cable crosses the erf boundary.

It was however the general opinion expressed by Engineer Members at the Seminars that this point should be the suppliers metering point on the erf boundary or at the meter cabinet where this is provided on the outside wall of a dwelling. At these points statutory voltage checks may readily be made. Members of the Committee which drew up the guidelines felt that voltage checks at the point of supply were not essential. The point of entry could also be a buried joint on the boundary.

No doubt discussion and further opinions by Engineer Members on this issue will be appreciated at this Technical meeting and if necessary the guidelines could be updated accordingly.

4. EARTHING

The earthing of the electrical system as prescribed in various codes and publications as well as the establishment of a suitable earth as recommended in the guidelines, found general acceptance and could be extended further by the guideline presently being prepared by a Sub-committee of the AMEU for the earthing and protection of low voltage overhead power lines in the event of a broken or fallen conductor in terms of regulation C56 of the Factories Act.

5. STREETLIGHTING

The streetlighting to be provided in purely residential roads at a lower level than that prescribed in the SABS Code of Practice for Public Lighting as recommended by the Working Sub-committee was not generally acceptable. It was mentioned at the Seminars in Cape Town and Port Elizabeth that frequent requests are being received to provide a higher level of lighting in residential townships for safety and security reasons especially in townships for the coloured population groups.

It was therefore recommended that the SABS Code be not amended to provide for lower levels of streetlighting in residential townships.

6. LOCATION OF SERVICES IN ROAD RESERVES

The AMEU Highveld Branch did not find the proposal in the guidelines acceptable that street light poles be placed against the erf boundary in purely residential roads whereas the Engineer Members present at the Seminars in Cape Town and Durban had no objection and do in fact place the poles well back against the erf boundary in residential townships to avoid restricting pedestrian traffic as well as vehicular damage to both the poles for streetlighting and for low voltage overhead distribution networks.

Further opinions on this issue will therefore be welcome at this meeting so that final proposals can be submitted to amend the guidelines to suit the requirements and needs of member undertakings and ESCOM.

7. GENERAL

In conclusion it can be said that the guidelines for electricity distribution found general approval and acceptance at the Seminars and it is hoped that with further feedback from engineer members with the practical implementation thereof that they can eventually be updated to meet the technical and economic needs of all suppliers in the country.

DISCUSSION – BESPREKING

DENNIS PALSER, Cape Town

The following comments based on our experience in Cape Town may be of interest.

DESIGN ADMD

The design ADMD figures in the guide lines have proved quite realistic and give the designer adequate scope to meet individual circumstances.

In the case of Mitchells Plain in Cape Town, a new town of 25 000 houses, the relevant design figure of 4 kVA has proved satisfactory, the actual figure at the main substation being 3 kVA per consumer.

SERVICE ARRANGEMENTS

The point of supply is likely to remain a contentious issue. We prefer to designate the point of supply as the point of termination on the consumer's premises. But one could probably argue that making the point of supply the erf boundary also has certain advantages.

If it has not already been done I would suggest that a questionnaire be addressed to all AMEU members enquiring which system they follow and the reasons why. A proper analysis of the pros and cons, both economic and practical, could then be undertaken in a balanced and rational manner.

STREET LIGHTING

I totally oppose any move to reduce lighting levels below those presently laid down in the SABS Code of Practice for the Lighting of Public Roads, certainly in urban areas. On the contrary, a case could probably be made out for increasing levels in the interest of security.

LOCATION OF SERVICES IN ROAD RESERVES

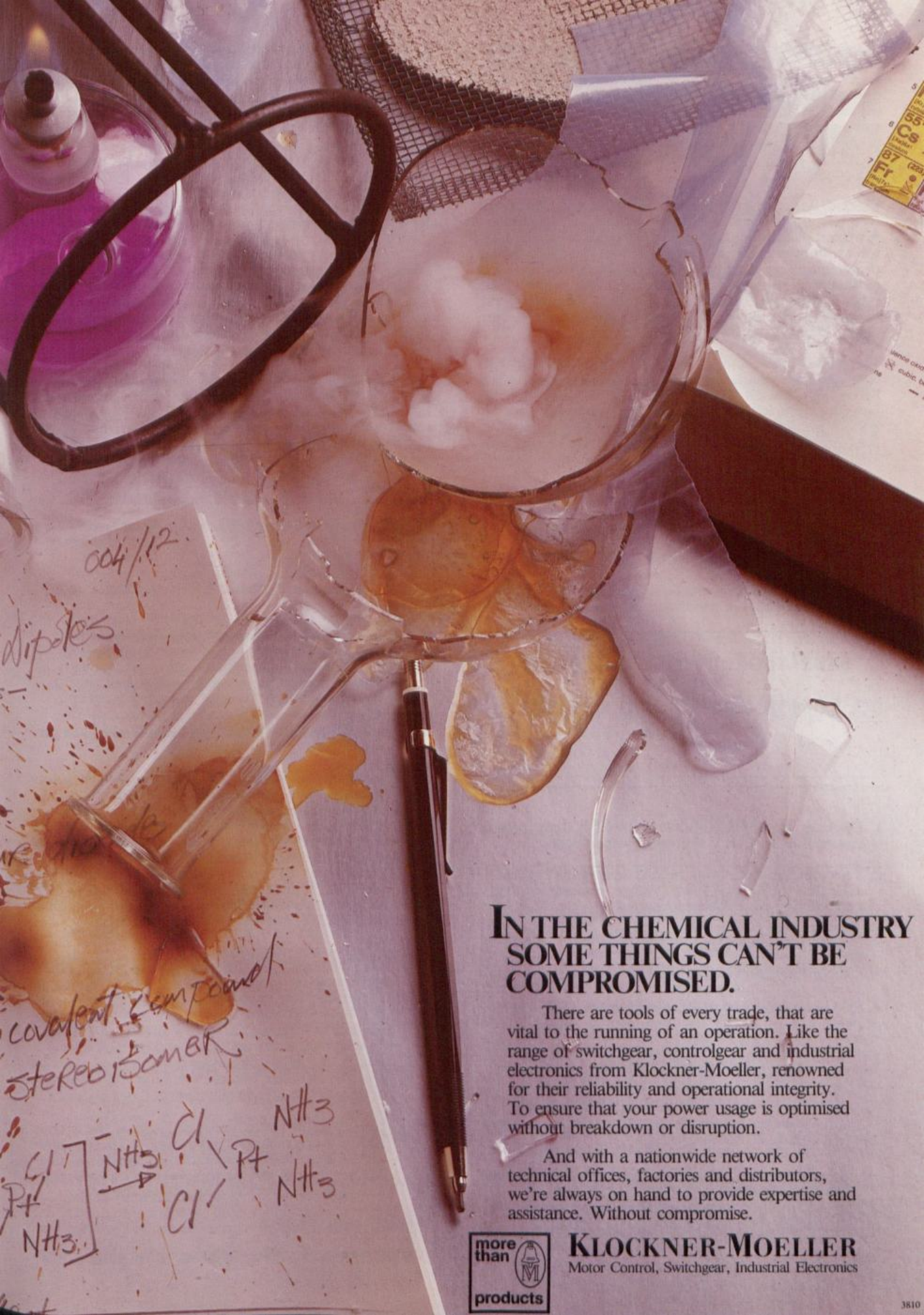
In Cape Town we have found it best to place street lighting poles on the property boundary, with appropriate outreaches, in the lower social class areas where damage due to cars is prevalent. In upper income areas where the incidence of damage is far lower, post top lanterns on the kerb have proved quite satisfactry and is the preferred arrangement.

STRANDED COMPACTED ALUMINIUM CABLE VERSUS SOLIDAL CABLE

By E.B. Martin

Solid conductor power cables in larger sizes were first used during World War 2 in Berlin by BEWAG, the local supply authority, as an emergency measure. These were,however, round conductor cables and the idea was abandoned at the end of the war. It remained to a South African expatriate, Stanley Rice, to fully exploit the ductility and softness of pure aluminium in the form of shaped sectors for low voltage cables (I wonder if any delegate remembers him from the 1950's when Huletts Aluminium was known as the Aluminium Company of South Africa).

By the late 1950's Stanley was working for the Aluminium Industry in Britain, promoting the use of aluminium in electrical applications, but was not having much success in the cable industry. He refined the idea of the solid aluminium conductor into a low voltage three core cable of accurately shaped triangular sectors encircled by a combined neutral/armour comprising flat aluminium wires. This gave a cable of minimum diameter with no fillers and the minimum amount of insulating material, thus partially offsetting the fact that the larger size of aluminium cables resulted in more insulation materials being required. A key factor in his strategy was also that such cables would be sufficiently



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simple to make, not requiring wire drawing and stranding equipment, and that they could be produced by manufacturers engaged in the production of bare overhead transmission lines by the addition only of equipment for extruding the PVC insulation and laying up the cable cores. This strategy was successful in that the first British manufacturer of solidal cables was Aluminium Wire and Cable Company (AWCO), who had previously only produced transmission line conductors.

In South Africa, the first manufacturer was Scottish Cables who had the advantage of being close to an aluminium extrusion plant in Pietermaritzburg, which could produce solid sectors by extruding them. The first large installation of aluminium cable in South Africa was by the Municipality of Bloemfontein, who in 1960 installed 20 000 feet of 0,2 in^2 cable in what was then the new suburb of Universitas. At the time this was the largest installation in the world for this type of cable.

This was all rather a long time ago and things change with time and I am wondering whether the solidal cable is not becoming outdated. Firstly, two of the original concepts have not been followed through. The concentric neutral/armour for use on protective multiple earthed systems has not been widely adopted. Four core cables with round wire armouring have been preferred resulting in a cable of larger diameter, more difficult to bend and less economical. Secondly, fully annealed cable cores are not being used which also makes the cable more difficult to bend. This factor of ease of handling is becoming much more important today as with increased loads much larger cables are being used than when the idea of solidal was first conceived.

There have also over the intervening years been considerable advances in cable making technology. Particularly as regards the manufacture of cable cores, we now have very high speed wire drawing machines capable of drawing all the wires for a stranded core in less time than it takes to push a solid core out of an extrusion press. Then, there have also been considerable advances in machines for stranding and compacting cores and it is now possible to produce a stranded core with almost as good a space factor and shape as a solid core. Finally, cable crimping techniques for aluminium cables have been improved to the stage that it is possible to obtain better joints on stranded than on solid cable.

In Europe, where aluminium cables are used almost exclusively for all sizes over 25mm^2, solidal cables are virtually unknown. They seem to feel that with the larger sizes of cable used today, the greater difficulty in handling and bending solidal cables outweighs the savings, if any, compared to compacted and shaped stranded cables.

PROGRESS REPORT
VORDERINGS VERSLAE

SABS CO-ORDINATING COMMITTEE REPORT
KOÖRDINERENDE SABS-KOMITEE VERSLAG

Eugene Pretorius

1. Die lede van hierdie Komitee is mnre J A Loubser, J K von Ahlften en E de C Pretorius (sameroeper).

2. Tensy anders gestel, dek hierdie verslag die tydperk 1 Julie 1983 tot 30 Junie 1984. (Vorige verslae het die tydperk voor 1 Julie 1983 reeds gedek.)

3. Tot en met 10 Augustus 1984 het die Komitee 5 keer vergader. Op 2 Maart 1984 is vrugbare samesprekings met die SABS gevoer oor diverse aangeleenthede.

4. **Sake voortspruitend uit die verslag aan die 1983-Konvensie.**

4.1 **Item 4.2(b): Standaard laespanning.**
Die Hoëveldtak het met 'n oorweldigende meerderheid besluit **teen** die aanbeveling van die Komitee naamlik dat die VMEO nie die oorskakeling na 'n RSA-standaardspanning van 230/400 V, in plaas van die huidige 220/380 V, steun nie.

4.2 **Item 4.2(e): Standaard spesifikasie vir stoofaansluiters (-kontaksokke)**
Die SABS het 'n voorvervaardigingsondersoekvraelys aan alle belanghebbende partye uitgestuur.

4.3 **Item 4.2(d): Nuwe 16-A-kontakprop en -sok**
Die lidlande van die betrokke IEK-komitee moet nie later nie as Oktober 1984 oor die voorstelle vir 'n internasionale standaard kontakprop en -sok stem (SABS mondelings.)

4.4 **Item 4.2(g): Gebruikskode vir die bedrading van persele**

4.4.1 **Subitem (ii): Stopkontakte vir toevoere aan woonwaens**
Hierdie aangeleentheid sal heelwaarskynlik, as een van baie items op die betrokke agenda, deur WG4 (van die Hoofkomitee) bespreek word op sy eersvolgende vergadering in Oktober 1984 en enige aanbeveling sal daarna na die Hoofkomitee verwys word vir 'n finale besluit. Ook die kwessie van individuele aardlekrelês vir elke woonwa sal in heroorweging geneem word. (SABS mondelings.)

4.4.2 **Sub Item (iii): Regulation 5.4.3(b)(6)**
(Rigid nonmetallic wireways): The SABS submitted the following proposed amendment to the Main Committee (by correspondence): "With the exception of vertical runs, wireways installed under plaster shall be installed not more than 600mm from ceilings or 1200 mm from floors and not less than 100 mm from ceilings, floors and the vertical sides of door frames and window openings. All wireways under plaster shall be either vertical or horizontal".

According to verbal information from the SABS, this proposal met with opposition or adverse comment from certain members of the Main Committee. The matter will now be thrashed out by WG4 at its next meeting scheduled for October this year.

5. **Diverse aangeleenthede**

5.1 Die SABS het besluit om 'n enkele Komitee op die been te bring om 'n oorkoepelende standaardspesifikasie vir elektriese kabels en geleiers op te stel wat ongeveer 7 bestaande kabelspesifikasies sal saamvat (o.a. SABS 97, 150 en 1339).

5.2 In opdrag van die VMEO se Uitvoerende Raad is 'n versoek aan die SABS gerig om die Gebruikskode vir die Bedrading van Persele so te wysig dat 'n voorsiener die reg sal hê om te vereis dat 'n elektriese installasie deur stuwingsweerders, op die hoofverdeelbord, beskerm moet word. Die SABS gee aandag hieraan.

5.5 Die SABS het sy kommer teenoor my uitgespreek oor die ooglopende kondonering van sekere voorsieningsowerhede van die installering van onder andere kabels en gevormdehulsstroombrekers wat nie voldoen aan die betrokke SABS-spesifikasie nie. Baie hiervan is van twyfelagtige gehalte en veiligheid.

VMEO-lede word versoek om hierop bedag te wees.

6. **Vorderingsverslae/Progress reports**

6.1 **Projek nr. 712/50220: Mobiele kommunikasietoerusting vir landgebruik:**
Die konsepspesifikasie is op 2 Augustus 1984 deur die betrokke komitee oorweeg. (SABS.)

6.2 **Project no. 721/50040: Tungsten filament GS electric lamps:**
Amendment no. 1: The specification has been amended to increase the tolerance in the requirement for initial power. (J K von Ahlften).

6.3 **Project no. 721/50120 (SABSS 1250-1979): Capacitors for use with fluorescent and other discharge lamp ballasts:**
Amendment no. 1: The specification has been amended to change the requirements for the capacitance of capacitor elements at maximum temperature, capacitor losses, and the condition in respect of supply voltage of the endurance test. (A J v d Berg verbal).

6.4 **Projek nr. 751/50010 (SABS 0142): Gebruikskode vir die bedrading van persele:**
Wysiging nr. 2: Die kode is gewysig om die magtigingsprosedure ("authorization procedure") te bespoedig. (VMEO-lede is deur middel van die VMEO-bulletin van hierdie wysiging in kennis gestel.)

6.5 **Projek nr. 751/50110: Handlugbreukskakelaars:**
Algehele hersiening van dokument 2 en 3 is op 1984-05-23 aanvaar na ondersoeke wat die SABS versoek was om te onderneem. (J K von Ahlften.)

6.6 **Project no. 761/50020 (SABS 97): Impregnated paper-insulated electric cables:**
Amendment no. 4: The specification has been amended to change the definition for "Acceptable" and certain requirements for marking. (J K von Ahlften).

6.7 **Projek nr. 781/50150: Veiligheid van elektriese toestelle:**
Die formaat en bestek van die SABS veiligheidspesifikasie sal nou streng aangepas word in ooreenstemming met die IEK Spesifikasie sonder enige wysigings. (J K von Ahlften.)

6.8 **Project no. 791/50010 (SABS 03): Protection of structures against lightning:**
Committee work has been completed; the final document will be submitted to the SABS board at the February 1985 meeting: publication will follow shortly thereafter. (M P P Clarke.)

6.9 **Projek nr. 791/50170: SABS 780-1979: Verspreidingstransformators:**
Wysiging nr 3: Die spesifikasie is gewysig deur die verandering van die verwysing na omgewingslugtemperatuur(ture) in die vereiste van maksimum temperatuurstyging, die toetsmetode vir die meting van nullasverlies en nullasstroom en die voorstelling van 'n tipiese driefasige primêrewikkelingsverbinding, en deur sekere korreksiefaktore toepaslik te maak gedurende 'n temperatuurstygingstoets.

6.10 **Projek no. 791/50310: LV system earthing:**
The preparation of a Code of Practice for PME Systems is starting and will be based on the AMEU and SAIEE recommendations. It is expected to be available for comment in 1985 and is not expected to involve a protracted approvals process. (M P P Clarke.)

6.11 **SABS 0199: Design and installation of earth electrodes:**
A completely new document has been prepared and finalized. It will be submitted to the SABS board for approval in October 1984 and published thereafter. (M P P Clarke).

6.12 A draft Code of Practice for Earthing of Industrial Power Systems has now been prepared and will be issued for comment shortly. (M P P Clarke.)

6.13 **Ook aan die volgende projekte is wysigings aangebring:**
721/50060: Binne-armature vir flouresseerlampe.
721/50100: Ballaste vir fluoresseerlampe (SABS).

6.14 Van die betrokke tegniese komitees het sommige vergader; ander wysigings is by wyse van korrespondensie afgehandel.

7. Ek wil my dank betuig teenoor die SABS en die betrokke VMEO-verteenwoordigers vir sommige van die inligting in hierdie verslag.

SATEKG-VERSLAG

Piet Botes

Soos reeds aan die Uitvoerende Bestuurslede verslag gedoen is, word sekere verbruikers, soos hospitale, ouetehuise ensovoorts, van die voorkeurlys uitgesluit.

Dit is dus duidelik dat net 'n klein aantal verbruikers, indien enige, kwalifiseer vir noodkrag.

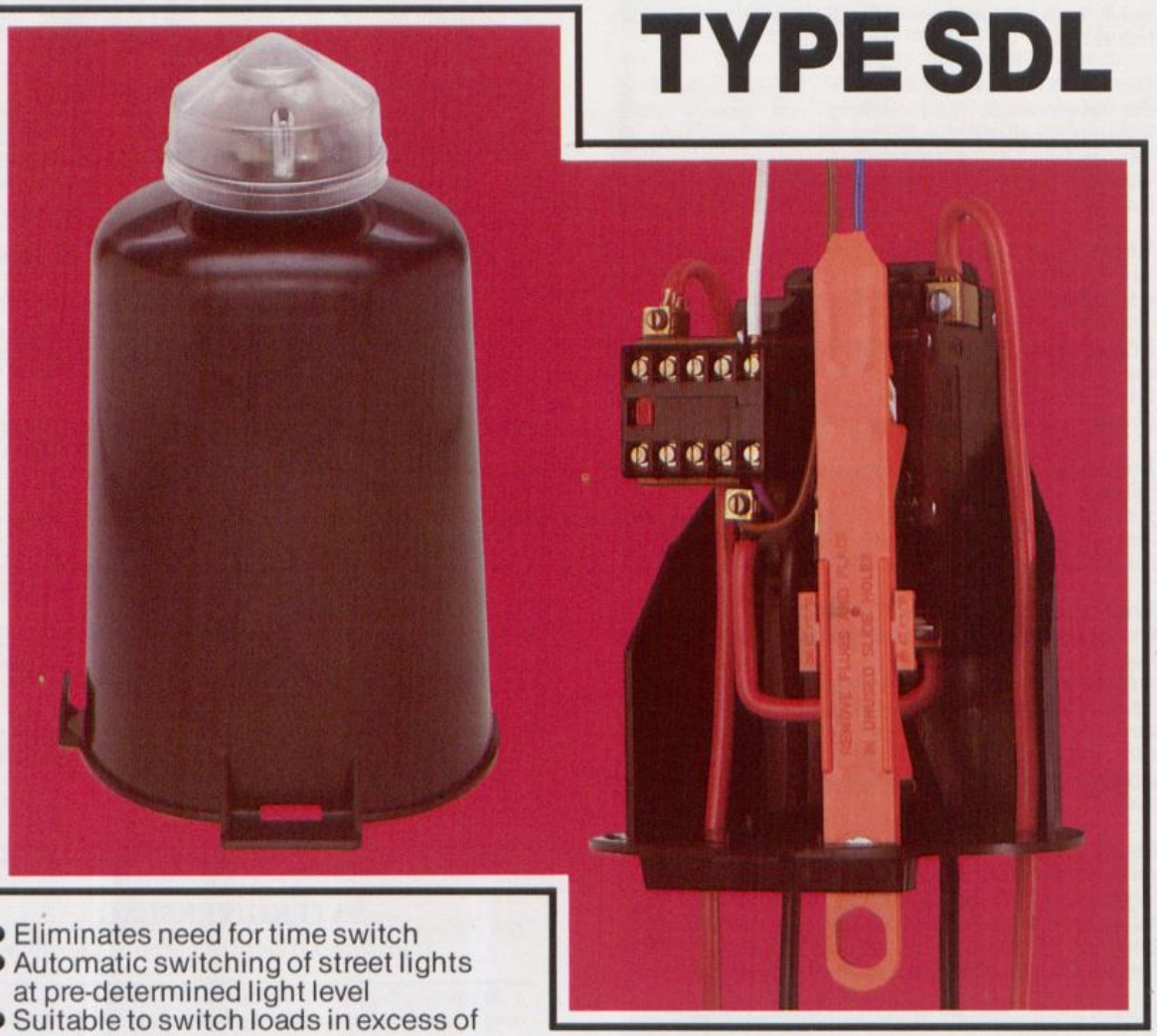
Noodkrag, dit wil sê, wanneer minder as 30% opwekkingsvermoë beskikbaar is en ook net gedurende die eerste 48 uur, sal na alle waarskynlikheid voorafgegaan word deur 'n algemene kragonderbreking wat ten minste 'n paar uur sal duur. Wanneer teruggeskakel moet word, moet net die voorkeurverbruikers teruggeskakel word.

Die Nasionale Noodkragplan is grootliks 'n plan van hoe toevoer aan primêre voorkeurverbruikers herstel sal word.

Vir die sekondêre voorkeurverbruikers, dit wil sê, indien tussen 30% en 70% opwekkingsvermoë beskikbaar is, sal eerstens die krag aan die voorkeurverbruikers verskaf word en die balans sal dan eweredig onder die sekondêre

POLE MOUNTING BOX WITH DAYLIGHT SWITCH

TYPE SDL



- Eliminates need for time switch
- Automatic switching of street lights at pre-determined light level
- Suitable to switch loads in excess of daylight switch rating — via contractor (40A resistive 24A incandescent)
- Easy mounting to cross arm, pole or porcelain insulator
- Fully insulated, giving excellent dielectric and mechanical properties
- Supplied with single or three phase circuit breaker
- Available in 5,15,20,25,30,35 & 40 ampere ratings
- FIVE different designs available

SDL 1 — single phase unit with intergral daylight switch
SDL 2 — single phase with PROVISION for plug-in daylight switch
SDL 3 — single phase with a plug-in daylight switch
SDL 4 — three phase with PROVISION for plug-in daylight switch
SDL 5 — three phase with plug-in daylight switch

HEINEMANN

HYDRAULIC MAGNETIC CIRCUIT BREAKERS AND EARTH LEAKAGE EQUIPMENT

verbruikers verdeel word. Elke voorsieningsowerheid sal die elektrisiteit aan hom toegeken versprei so goed as wat prakties moontlik is en na sy eie goeddunke met die veronderstelling dat primêre voorkeurverbruikers hoogste prioriteit van voorsiening sal geniet. 'n Pro rata kwota sal geld wanneer 30% tot 70% krag beskikbaar gestel word.

Die voorkeurverbruikers se lyste sal bygewerk moet word en 'n vereenvoudigde vraelys sal teen die einde van die jaar aan die verbruikers gestuur moet word.

Alle nuwe aansoeke vir inligting op die voorkeurlys en die verandering van huidige voorkeurtoewysigings moet voor die einde van April 1985 ingedien word.

Daar word beoog dat hierdie, die derde voorkeurlys, teen die einde van September 1985 aan die Werkskomitee van SATEKG voorgelê word en op 1 April 1986 in werking sal tree.

Die beoogde wysigings aan die voorkeurvraelys sal op 'n vergadering van SATEKG (Krag) wat vir 19 Oktober 1984 gereël is, versprei en goedgekeur word.

Na die 48 uur noodtoestand verander die prioriteite drasties, wanneer ander prioritiete soos die verskaffing van kos aan die gemeenskap, hospitaaldienste en ander gemeenskapsdienste, meer noodsaaklik word as die verskaffing van krag aan die primêre voorkeurverbruiker.

STANDARDISATION OF ELECTRICITY TARIFFS

INTERIM REPORT

Dennis Palser

You will recall that at our Convention in Johannesburg last year I opened the discussion on the subject of the possible standardisation of electricity tariffs and proposed the appointment of a committee to investigate this matter.

I first raised this subject at the Durban Convention in 1975 but unfortunately nothing further was done at the time. The Executive Council, however, at its meeting following last years' Convention in Johannesburg considered the matter and appointed me as a one-man committee.

As a first step I drafted and distributed a circular to all A.M.E.U. members. In this circular I outlined the objective of the exercise and requested copies of members tariffs and any other comments they might care to make.

In response thereto replies were received from 92 authorities, that is substantially less than half the A.M.E.U. membership and only about a quarter of the toral number of electricity undertakings in the country. A further approach, therefore, willl be made to those authorities who did not reply in an attempt to improve the return.

Nevertheless, despite the rather disappointing response, certain trends have emerged in respect of the three main tariff groups, namely

- Domestic
- General and Commercial
- Industrial and Large User

The relevant figures, expressed as percentages of the total number of authorities who responded, are as follows:

Factor	Domestic (%)	General or Commercial (%)	Indusrial or Large User (%)
Minimum and/or Service Charge .	78	79	73
Circuit Breaker Capacity Charge	23	25	–
Maximum Demand Charge:			
Single	5	16	92
Multiple	1	1	8
Energy Charge:			
Single	75	72	72
Multiple (or Block)	25	27	16

From the above figures the following general facts may be deduced.

DOMESTIC

Clearly the most popular rate is the conventional single, fixed energy rate coupled with a minimum and/or service charge, this rate being favoured by about three-quarters of those who responded. Less popular, being favoured by

STANDAARDISASIE VAN ELEKTRISITEITSTARIEWE

VOORLOPIGE VERSLAG

Dennis Palser

U sal onthou dat ek verlede jaar tydens ons Kongres in Johannesburg die bespreking oor die onderwerp van die moontlike standaardisasie van elektrisiteitstariewe ingelei het en die aanstelling van 'n komitee om hierdie saak te ondersoek, voorgestel het.

Ek het in 1975 vir die eerste maal hierdie onderwerp by die Durban-kongres geopper, maar ongelukkig is destyds niks verder daaromtrent gedoen nie. Die Uitvoerende Raad het egter op sy vergadering wat gevolg het op verlede jaar se Kongres in Johannesburg die saak oorweeg en my as 'n eenmanskomitee aangestel.

As 'n eerste stap het ek 'n omsendbrief opgestel en versprei. In hierdie omsendbrief het ek die doelwit van die onderneming in hooftrekke beskryf en het afskrifte van die lede se tariewe en enige kommentaar wat hulle sou wou lewer, gevra.

In reaksie daarop is van 92 owerhede antwoorde ontvang wat aansienlik minder as die helfte van die ledetal van die V.M.E.O. en slegs 'n kwart van die totale aantal elektrisiteitsondernemings in die land is. 'n Verdere beroep sal gedoen word op daardie owerhede wat nie geantwoord het nie.

Ten spyte van die effens teleurstellende reaksie het sekere neigings nietemin ten opsigte van drie hooftariefgroepe naamlik

- Huishoudelik
- Algemeen en Kommersieel
- Industriële en Groot Gebruiker

na vore getree.

Die toepaslike syfers uitgedruk as persentasies van die totale aantal owerhede wat gereageer het, is as volg:

Faktor	Huishoudelik (%)	Algemeen of Kommersieel (%)	Indusriële of Groot Gebruiker (%)
Minimum- en/of Diensheffing	78	79	73
Heffing op stroombrekerkapasiteit	23	25	–
Heffing op maksimum aanvraag:			
Enkel	5	16	92
Meervoudig	1	1	8
Energieheffing:			
Enkel	75	72	72
Meervoudig (of Blok)	25	27	16

Uit die bogenoemde syfers kan die volgende feite afgelei word.

HUISHOUDELIK

Die gewildste tarief is ongetwyfeld die konvensionele, enkel, vasgestelde energietarief gekoppel aan 'n minimum- en/of diensheffing, soos deur ongeveer driekwart van diegene wat gereageer het, verkies is. Minder gewild, en

only about a quarter, was the circuit breaker capacity charge.

GENERAL OR COMMERCIAL

The pattern here is very similar to that for the domestic group, the only difference being that more interest was shown in a maximum demand charge, namely the usual two-part maximum demand tariff. Even so, only 16% favoured this form of tariff for this class of consumer.

INDUSTRIAL OR LARGE USER

Clearly, as one would have expected, by far the most popular rate is the conventional two-part maximum demand tariff, coupled again with a minimum and/or service charge.

The above figures and comments are intended merely to give a broad, general impression at this stage. The next step is to study these various tariffs in more detail and to comment on their respective pros and cons, along with an outline or the underlying principles of tariff formulation.

A further matter to be considered – possibly at a later stage – is the question as to whether tariff rates should be based on historical costs, in the established traditional manner, or on marginal costs and current cost or inflationary accounting principles.

It might also be of interest to mention here that the U.M.E. at a recent meeting also considered this question of the standardisation of electricity tariffs. I understand, though, that as it was thought that it might prove difficult to apply standardised tariffs with any degree of uniformity across the country as a whole, it was resolved that no further action be taken now, but that at a later stage consideration might again be given to referring this matter back to the U.M.E. Action Committee and an approach made to both the A.M.E.U. and I.M.I.A. for their comments.

I would stress, however, that what is being investigated is the possibility of offering certain basic guide lines for proposed standard tariff structures. The emphasis here is on "structures". Clearly standard or uniform monetary rates across the country are not possible because of differing cost structures, as well as because of different political and social constraints which tend to dictate a degree of cross-subsidisation between tariff rates.

In conclusion, I would mention that all being well, it is hoped to present a more detailed and comprehensive report at next year's Convention in Benoni.

slegs deur ongeveer 'n kwart verkies, was die heffing op stroombrekerkapasiteit.

ALGEMEEN OF KOMMERSIEEL

Die patroon is hier baie soortgelyk aan die van die huishoudelike groep, die enigste verskil synde dat meer belangstelling in 'n maksimumaanvraagtarief, naamlik die gewone tweedelige maksimumaanvraagtarief, getoon is. Nietemin het slegs 16% hierdie vorm van tarief verkies.

INDUSRIËLE OF GROOT GEBRUIKER

Soos 'n mens kon verwag het, is die konvensionele maksimumaanvraagtarief, weer gekoppel aan 'n minimum- en/of diensheffing, ongetwyfeld verreweg die mees gewilde tarief.

Die bogenoemde syfers en kommentaar is slegs bedoel om op hierdie stadium 'n breë, algemene indruk te gee. Die volgende stap is om hierdie verskillende tariewe in meer besonderhede te bestudeer en om op hulle voor- en nadele kommentaar te lewer, saam met 'n bespreking in breë trekke van die onderliggende beginsels van tariefvasstelling.

'n Verdere saak om te oorweeg – moontlik op 'n latere stadium – is die vraag of tariewe gebaseer behoort te word op historiese kostes, volgens die gevestigde tradisionele manier, of op grens- en lopende koste of inflasionistiese boekhoubeginsels.

Dit mag ook van belang wees om hier te noem dat V.M.B. by 'n onlangse vergadering ook die kwessie van die standaardisasie van elektrisiteitstariewe oorweeg het. Ek verstaan egter dat aangesien dit die mening was dat dit moontlik moeilik sou wees om standaardtariewe eenvormig deur die hele land toe te pas, dit aanvaar is dat geen verdere optrede tans onderneem word nie, maar dat dit by 'n latere geleentheid oorweeg sal word om die saak terug te verwys na die Aksiekomitee van die V.M.B. en beide die V.M.E.O. en I.M.T.R. te nader vir kommentaar.

Ek wil egter beklemtoon dat wat ondersoek word, is die moontlikheid om sekere basiese riglyne vir voorgestelde standaardtariefstrukture aan te bied. Die klem val hier op "strukture". Dit is duidelik dat standaard- of eenvormige geldtariewe oor die hele land nie moontlik is nie as gevolg van verskille in kostestrukture, sowel as weens verskillende politieke en maatskaplike dwang wat neig om 'n mate van wisselsubsidiëring tussen tariewe te dikteer.

Ten slotte wil ek meld dat as alles goed gaan, ek hoop om 'n meer gedetailleerde en omvattende verslag by volgende jaar se Kongres in Benoni te lewer.

CLOSING SESSION
AFSLUITINGSESSIE

MNR J LOUBSER : Aangewese President

Mnr die President, dames en here, ek weet u berei u nou voor vir die afsluitingsfunksie. Voordat u sover gaan, dink ek dit is ons, wat hier teenwoordig is, se voorreg om nou u dankie te sê vir die baie bekwame manier waarop u die afgelope twee dae hierdie vergadering gelei het.

Ek weet nie hoeveel voorbereiding dit u gekos het nie, ek weet ook dat u vir die regte mense sal danksie sê. Ek is van mening dat u 'n natuurlike talent het wat u miskien onderskat. Almal van ons is beïndruk met die wyse waarop u die vergadering gelei het en wil net vir us baie dankie daarvoor sê.

MNR W BARNARD : President

Ladies and Gentlemen, the affiliate members of the AMEU are a very important part of our association.

I have tried to project an image that they are not in any way here to serve any other member of the association. We are in this together and we all have a role to play. I want to say to our affiliate members again: we are very appreciative of the role they play. That is why I have commented on a number of occasions on the displays they have put up at the hotels.

I wish to thank the City Council of Bloemfontein, all the affiliate members and other companies and organisations, who contributed in some or other way to the success of this meeting, as well as the programme for the ladies.

To all of you who have contributed in one way or another by presentation of papers or contribution or just your presence being here, thank you very much.

I also must express a word of thanks to Bennie van der Walt, who has been busy organising and planning this meeting for months and his involvement over the last two days.

When it comes to my good friend Nico Botha, words fail me, I think he is unbelievable. A person who, can be so pupular with his council, make one a bit suspicious. I think he has a very good council which appreciates a good City Electrical Engineer.

You know that Nico had a critical path and logistical plan for this meeting, with so much back-up protection that nothing could go wrong.

Nico, baie, baie dankie vir alles wat jy gedoen het.

Aan mev du Plessis en mnr Lombard wil ek elk 'n klein geskendie oorhandig, as 'n blyk van waardering vir wat hulle gedoen het om hierdie vergadering suksesvol te laat verloop.

Now ladies and gentlemen, that concludes this Tenth Technical Meeting. I wish you all a safe journey home.

Die vergadering het om 15h45 op Dinsdag, 11 September 1984, verdaag.

OBITUARY

ARTHUR ROBERT SIBSON
PAST PRESIDENT OF THE AMEU 1952 – 1953

Robby, as he was affectionately known in Bulawayo, died on Thursday 10th October 1984 in his 78th year.

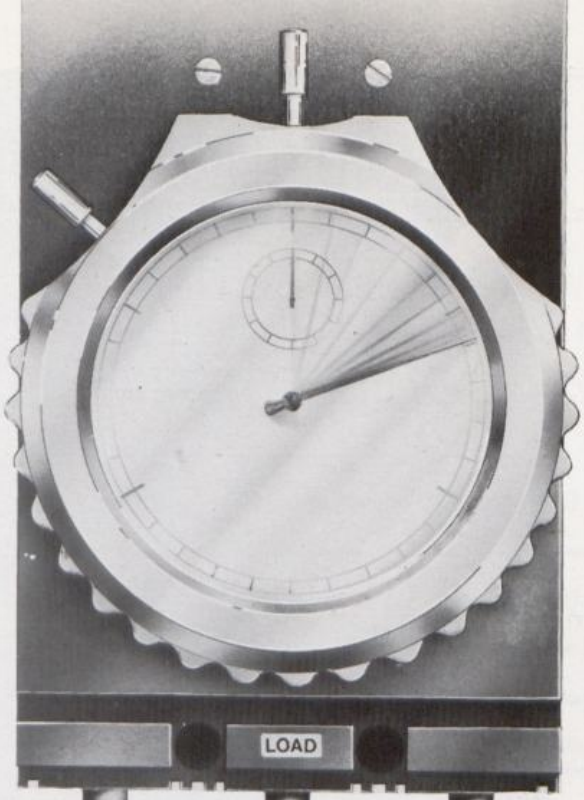
He was an accomplished Electrical Engineer of distinction, who reached a goal in his professional career as City Electrical Engineer – Bulawayo, when he successfully planned, constructed and commissioned departmentally, the Bulawayo 13th Avenue Coal Fired, Power Station, the third to be built in Bulawayo since 1895 and one which stands working with almost maximum capacity today, as a monument to his ability as a truly professional Engineer.

He left the Electrical Engineering profession to start another career as a successful musician, becoming Director of the Academy of Music and the Bulawayo Philharmonic Orchestra which he had co-founded in 1937.

He was alert and active to the end, working as Deputy Director and Lecturer in wind instruments.

He leaves a widow, Dorothy and daughter Stella with whom we share our sorrow and sincere condolences.

TRIPS ON TIME....

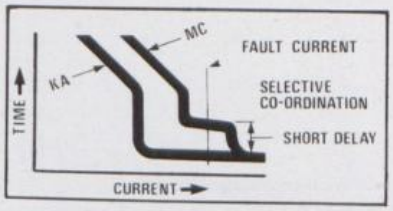


...TIME AFTER TIME

Fuchs Seltronic circuit breakers – the first moulded case circuit breakers with reliable solid state tripping elements – feature dependable **TIME**-current tripping characteristics even under repetitive overload or fault conditions.

The **MAJOR ADVANTAGE** achieved by the Seltronic breaker is superior coordination and selective tripping with downstream devices. Seltronic breakers are supplied with adjustable current rating plugs. Thus, even breakers of the same nominal rating can be adjusted on site to prevent the interruption of power to an entire plant when one section is overloaded.

The magnetic trip levels on all three poles may be simultaneously adjusted. The characteristics of the short circuit range of the Seltronic's tripping curve (e.g. the MC curve) make it ideally suited for selective coordination with conventional circuit breakers (e.g. the KA) as indicated on the graph.



The short delay indicated in the curve makes this device ideally suitable for direct on-line starting of motors as it caters for initial inrush currents.

A test kit is available for field testing of this circuit breaker.

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DAWSON, C: Electricity Supply Commission, P.O. Box 2408, Durban 4000.
DREYER, MC: Kommissarisstraat 107, Welgemoed 7530.
DUNSTAN, RS: P.O. Box 15024, Emerald Hill, Port Elizabeth 6001.
ERIKSON, JGF: P.O. Box 24, Margate 4275.
FORD, WP: 16 Abrey Road, Kloof 3600.
GAMBLE, JS: 114 Formosa Garden Village, P.O Box 416, Plettenberg Bay 6600.
HARVEY, AQ: 71 Garden Street, Redhouse, Port Elizabeth 6001.
HEASMAN, GG: P.O. Box 77, Fort Victoria, Harare.
HESS, I: De Roek, Cushat Lane, Constantia 7800.
HONNIBALL, GT: P.O. Box 17031, Groenkloof 0027.
LIEBENBERG, SJ: Posbus 98, Pretoria 0001.
MOGOWAN, JM: (Chairman) The Standard Bank, P.O. Box 373, Harare.
McGIBSON, J: P.O. Box 164, Carletonville 2500.
McINTYRE, HA: 95 Gen Hertzog Road, Three Rivers, Vereeniging 1930.
MOLE, EW: P.O. Box 39663, Bramley 2018.
McWILLIAM, EA: 202 Nicholson Street, Brooklyn, Pretoria 0181.
MULLER, HMS: 1 Neser Street, Graaf-Reinet 6280.
POTGIETER, NA: Webbstraat 1211, Queenswood, Pretoria 0186.
PSOTTA, KU: Malherbestraat 9, Upington 8800.
REICHERT, WJ: P/a Universiteitsingenieur, Universiteit van Kaapstad, Privaatsak, Rondebosch 7700.
ROSSLER, A: 3 Greenwood Road, Pietermaritzburg 3201.
RUSH, W: 135 Emmett Street. P.O. Box 1104, Vryheid 3100.
SCHREUDER, TP: P.O. Box 591, Vredendal 8160.
SMITH, AM: 22 Bownemouth Street, Summerstrand, Port Elizabeth 6001.
SCHOLES, EH: 20 Gavin Avenue, Pine Park 5194.
WILLIAMS, JT: P.O. Box 1617, Pretoria 0001.
WEAKLY, SL: 41 Hospital Street, Cradock 5880.
WYLIE, RJS: P.O. Box 217, Germiston 1400.

ENGINEER MEMBERS – INGENIEURSLEDE

A
ADAMS, CE: City Electrical Engineer, P.O. Box 369, Port Elizabeth 6000.
ALGERA, JD: Elektrotegniese Stadsingenieur, Posbus 16, Rustenburg 0300.
ANDREWS, KI: Elektrotegniese Stadsingenieur, Posbus 86, Walvisbaai 9190.

B
BAKER, AB: Electrical Engineer, P.O. Box 20, Swellendam 6740.
BARNARD, W: City Electrical Engineer, P.O. Box 699, Johannesburg 2000.
BARTHOLOMEW, WG: P.O. Box 47, Koffiefontein 9986.
BEARD, GR: Town Electrical Engineer, P.O. Box 176,

Grahamstown 6140.
BEKKER, MJ: Elektrotegniese Ingenieur, Posbus 96, Louis Trichardt 0920.
BECK, HD: Deputy City Electrical Engineer, P.O. Box 529, East London 5200.
BOOYSENS, L: Eletrotegniese Ingenieur, Posbus 155, Vrede 2455.
BOSHOFF, JJ: Elektrotegniese Stadsingenieur, Posbus 3, Vanderbijlpark 1900.
BOTES, PJ: Elektrotegniese Ingenieur, Posbus 217, Roodepoort 1725.
BOTHA, A: Hoof, Elektriese Afdeling, Posbus 6, Delmas 2210.
BOTHA, JJ: P.O. Box 708, Welkom 9460.
BOTHA, NS: Elektrotegniese Ingenieur, Posbus 3704, Bloemfontein 9300.
BOTHA, PJ: Posbus 37, Viljoenskroon 9520.
BOTH, A: Posbus 6, Delmas 2210.
BOTHMA, O: Elektrotegniese Ingenieur, Posbus 25, Mosselbaai 6500.
BOZYCZKO, W: P.O. Box 56, Ladysmith 3370.
BRIERS, DB: Elektrotegniese Ingenieur, Posbus 302, Kroonstad 9500.
BRINK, PSJ: Town Electrical Engineer, P.O. Box 20, Hermanus 7200.
BRINK, HJ: Groepingenieur, Posbus 288, Bloemfontein 9300.
BRUMMER, JG: Elektrotegniese Ingenieur, Posbus 17, Stellenbosch 7600.

C

CLARE, CA: Borough Electrical Engineer, P.O. Box 5, Howick 3290.
CLARKE, MMP: City Electrical Engineer, Private Bag 1, Randburg 2125.
CLAXTON, HD: Electrical Engineer, P.O. Box 71, Graaf-Reinet 6280.
CLOETE, DJ: Privaatskap X7, Virginia 9430.
CLOETE, J: Chief Electrical Engineer, P.O. Box 44, Ceres 6835.
CLOETE, RH: Dorpsingenieur, Posbus 20, Senekal 9600.
CRONJE, GP: Hoof Tegniese Beampte, Posbus 36, Duiwelskloof 0835.
CRONJE, PJ: Posbus 1548, Lichtenburg 2740.
CUNNINGHAM, T: P.O. Box 45, Heilbron 9650.

D

DAVIES, EG: City Electrical Engineer, P.O. Box 399, Pietermaritzburg 3200.
DAUTH, WJ: Chief Electrical Engineer, P.O. Box 48, Volksrust 2470.
DAWSON, JD: Municipal Electrical Engineer, P.O. Box 45, Uitenhage 6230.
DE BRUIN, HJ: Elektrotegniese Stadsingenieur, Posbus 218, Randfontein 1760.
DE BRUYN, CD: Elektrotegniese Ingenieur, Posbus 10, Carnarvon 7060.
DE KOCK, FP: Posbus 156, Virginia 9430.
DELPORT, JLFH: Elektrotegniese Stadsingenieur, Posbus 25, Edenvale 1610.
DEKENAH, KC: Town and Electrical Engineer, P.O. Box 33, Barberton 1300.
DERNIER, W: Electrical Engineer, P.O. Box 206, Aliwal North 5530.
DU PIESANIE, SJ: Posbus 2879, Brits 0250.
DU TOIT, E: Elektrotegniese Stadsingenieur, Posbus 16, Brits 0250.
DU TOIT, GB: Hoof, Elektriese Departement, Privaatsak X3, Hopetown 8750.
DU TOIT, PL: Posbus 34, Orkney 2620.
DE VILLIERS, EE: Hoof-Elektrotegniese Ingenieur, Posbus 1341, Pretoria 0001.
DE VRIES, GS: Posbus 52, Robertson 6705.
DE VRIES, JM: Hoof Tegniese Beampte, Privaatsak X12, Vredenburg 7300.
DE WET FOURIE: Posbus 155, Kinross 2270.

E

EHRICH, JA: Town Electrical Engineer, P.O. Box 66 Standerton 2430.
ERASMUS, PR: Elektotegniese Ingenieur, Posbus 2, Secunda 2302.

F

FORTMANN, AHL: Town Electrical Engineer, P.O. Box 215, Boksburg 1460.
FRASER, DH: City Electrical Engineer, P.O. Box 147, Durban 4000.
FRENCH, EM: Borough Engineer, P.O. Box 712, Greytown 3500.
FUTCHER, L: Municipal Electrical Engineer, P.O. Box 13, Kempton Park 1620.

G

GELDENHUYS, PJA: Posbus 17, Wolmaransstad 2630.
GOUSSARD, PJ: Hoofelektrisiën, Posbus 14, Koppies 9540.
GREYLING, JPJ: Posbus 23, Piet Retief 2380.
GROBLER, J: Elektrotegniese Stadsingenieur, Posbus 551, Bethlehem 9700.
GROVE, CR: Hoof-Elektrotegniese Ingenieur, Posbus 43, Harrismith 9880.
GROTIUS, RJ: Posbus 13, Dewetsdorp 9940.

H

HAIG-SMITH, D: Town Electrical Engineer, P.O. Box 113, Queenstown 5320.
HALLIDAY, KWJ: Municipal Electrical Engineer, P.O. Box 5, Port Shepstone 4240.
HAMMERSCHLAG, SN: Town Electrical Engineer, P.O. Box 3, Bedfordview 2008.
HARVEY, PH: P.O. Box 15, Estcourt 3310.
HEYDENRYCH, JE: Elektrotegniese Ingenieur, Posbus 14, Middelburg 1050.
HUGO, AHW: Town Electrical Engineer, P.O. Box 78001, Sandton 2146.
HUGO, JG: Electrical Engineer, P.O. Box 51, Bredasdorp 7280.
HUMAN, MJ: Elektrotegniese Stadsingenieur, Posbus 15, Brakpan 1540.
HUNT, LE: Town Electrical Engineer, P.O. Box 2, White River 1240.

J

JANTZEN, GH: Elektrotegniese Stadsingenieur, Posbus 29, Henneman 9445.
JANSE V RENSBURG, WW: Posbus 14064, Benoni 1500.
JELLIMAN, CE: P.O. Box 36, Fort Beaufort 5720.
JORDAAN, DJP: Posbus 35, Vereeniging 1930.
JORDAAN, PW: Hoof-Elektrotegniese Afdeling, Posbus 34, Potgietersrus 0600.

K

KOK, JA: Elektrotegniese Ingenieur, Posbus 55, Middelburg 5900.
KREBS, WF: Privaatsak 2209,Otjiwarongo 9210.
KRIGE, WA: Elektrotegniese Ingenieur, Posbus 14103, Verwoerdburg 0140.

L

LAAS, CP: Elektrotegniese Ingenieur, Posbus 15, Kenhardt 8900.
LE ROUX, DE: P.O. Box 2, Stutterheim 4930.
LEWIS, L: Town Electrical Engineer, P.O. Box 59, Windhoek 9100.
LINDE, AP: Hoof Elektrisiën, Posbus 2, Frankfort 9830.
LOCHNER, J VAN S: Elektrotegniese Ingenieur, Posbus 111, Pietersburg 0700.
LOTTER, GA: Elektrotegniese Ingenieur, Posbus 34, Potgietersrus 0600.
LOUBSER, D PVP: Posbus 27, Douglas 8730.

LOUBSER, JA: Elektrotegniese Ingenieur, Posbus 1014, Benoni 1500.
LOUW, HAL: Elektrotegniese Stadsingenieur, Posbus 12, Paarl 7620.
LOUW, L: Posbus 16, Prieska 5940.
LUUS, AJ: Posbus 520, Witbank 1035.

M
MALLINSON, RJ: Elektrotegniese Ingenieur, Posbus 21, Somerset-Oos 5850.
MARAIS, CHA: Stads Elektrisiteits/Meganiese Ingenieur, Buitenstraat 30, Parys 9585.
McMILLAN, KHD: Electrical Engineer, P.O. Box 47, Umtata 5100.
McNAMARA, AB: Electrical Engineer, P.O. Box 21, Komga 4950.
MILLEN, TJ: Electrical Engineer, P.O. Box 24, Tzaneen 0850.
MOSTERT, SA: Elektrotegniese Ingenieur, Posbus 19, George 6530.
MOSTERT, AH: Posbus 53, Swakopmunnd 9180.
MURPHY, KJ: Municipal Electrical Engineer, P.O. Box 19, Somerset West 7130.
MYBURGH, G: Elektrotegniese Ingenieur, Posbus 4, Kuruman 8460.

N
NEL, JTF: Elektrotegniese Stadsingenieur, Posbus 33, King Williamstown 5600.
NORTJE, GJ: Elektrotegniese Stadsingenieur, Posbus 145, Germiston 1400.

O
ODENDAAL, MW: Elektrotegniese Stadsingenieur, Posbus 4, Alberton 1450.

P
PAGEL, PVE: Elektrotegniese Ingenieur, Munisipaliteit Plettenbergbaai 6600.
PALSER, DC: City Electrical Engineer, P.O. Box 82, Cape Town 8000.
PETERS, AG: Town Electrical Engineer, P.O. Box 278, Gwelo, Harare.
PIENAAR, JF: Elektrotegniese Ingenieur, Posbus 10, Glencoe 2930.
PIKE, E: P.O. Box 57, Vryheid 3100.
POLLOCK, T: Electrical Engineer, P.O. Box 3, Gordons Bay 7150.
PRETORIUS, E DE C: Elektrotegniese Stadsingenieur, Posbus 113, Potchefstroom 2520.
PRETORIUS, PJR: Elektrotegniese Stadsingenieur, Posbus 35, Vryheid 8600.
PRITCHARD, MR: Elektrotegniese Stadsingenieur. Privaatsak X7, Virginia 9430.
PURDON, D: Town Electrical Engineer, P.O. Box 67, Phalaborwa 1390.

R
RATTEY, WP: Electrical Engineer, P.O. Box 3, Strand 7140.
RAUTENBACH, GF: Elektrotegniese Ingenieur, Posbus 99, Klerksdorp 2570.
RHEEDER, RJB: Posbus 41, Cathcart 5310.
ROBSON, KG: City Electrical Engineer, P.O. Box 529, East London 5200.
ROHRBECK, WD: Posbus 39, Hoopstad 2670.
ROODT, JSG: Posbus 26, Reitz 9810.
ROSSOUW, GT: Posbus 241, Kempdorp 8550.
ROSSOUW, SPJ: WNDE Elektrotegniese Ingenieur, Munisipaliteit van Wellington, Posbus 12, Wellington 7655.

S
SMALL, CTR: Town Electrical Engineer, P.O. Box 9, Beaufort West 6970.
SMITH, FH: Electrical Engineer, P.O. Box 42, Despatch 6220.
STAPLETON, R: Borough & Electrical Engineer, P.O. Box 37, Eshowe 3815.
STRAUSS, JC: Elektrotegniese Ingenieur, Posbus 60, Sasolburg 9570.
SWART, JCP: Posbus 29, Velddrif 7365.
SWART, TL: Elektrotegniese Ingenieur, Posbus 10, Glencoe 2930.
SWARTS, JTE: Elektrotegniese Ingenieur, Posbus 201, Heidelberg 2400

T
TENCATE, JI: Elektrotegniese Stadsingenieur, Posbus 67, Phalaborwa 1390.
THERON, TA: Stadselektrotegniese Ingenieur, Posbus 48, Ermelo 2350.

V
VAN DEN BERG, AJ: Elektrotegniese Ingenieur, Posbus 94, Krugersdorp 1740.
VAN DER MERWE, DS: Elektrotegniese Ingenieur, Posbus 3, Witbank 1035.
VAN DER MERWE, FJ: Elektrotegniese Ingenieur, Posbus 3, Carletonville 2400.
VAN DER MERWE, G: Posbus 96, Louis Trichardt 0920.
VAN DER MERWE, PJ: Stads & Elektrotegniese Ingenieur, Posbus 20, Stilfontein 2550.
VAN DER SCHYFF, GW: Stadsingenieur, Posbus 3, Bethal 2031.
VAN DER WALT, FSP: Privaatsak 5005, Kimberley 8300.
VAN DER WALT, PS: Posbus 3, Bultfontein 9670.
VAN NIEKERK, PJS: Borough Electrical Engineer, P.O. Box 21, Newcastle 2940.
VAN ROOYEN, HE: Dorps-Waterwerke en Elektrotegniese Ingenieur, Munisipaliteit, Kirkwood 6120.
VAN SCHALKWYK, AP: Assistent-Elektrotegniese Stadsingenieur, Posbus 288, Bloemfontein 9300.
VAN TONDER, CJ: Elektrotegniese en Werktuigkundige Ingenieur, Posbus 21, Odendaalsrus 9400.
VAN WYK, AA: Elektrotegniese Ingenieur, Posbus 45, Nelspruit 1200.
VENTER, GA: Elektrotegniese Ingenieur, Posbus 9, Meyerton 1960.
VENTER, JA: Posbus 90, Thabazimbi 0380.
VELDSMAN, DE: Elektrotegniese Ingenieur, Privaatsak X7, Goodwood 7460.
VIDLER, JA: P.O. Box 21, Jeffreys Bay 6330.
VON AHLFTEN, JK: Elektrotegniese Ingenieur, Posbus 45, Springs 1560.
VOSLOO, C: Posbus 628, Kimberley 8300.

W
WHEELER, DJ: Posbus 13, Burgersdorp 5520.

ASSOCIATE MEMBERS – ASSOSIAATLEDE

B
BAILEY, RV: Acting Electrical Engineer, P.O. Box 72, Stanger 4450.
BECK, HD: Deputy City Electrical Engineer, P.O. Box 529, East London 5200.
BOSCH, LA: Elektrotegniese Superintendent, Posbus 13, Burgersdorp 5520.
BOTHA, JN: Posbus 1, Fochville 2515.
BRINK, HJ: Groepingenieur, Posbus 288, Bloemfontein 9300.

C
CLOETE, DJ: Posbus 99, Klerksdorp 2570.
COETZEE, CJF: Adjunk-Elektrotegniese Stadsingeneur, Privaatsak X30, Roodepoort 1725.
COOPER-CHADWICK, L: P.O. Box 57, Germiston 1400.

D
DE BEER, WH: Adjunk-Elektrotegniese Stadsingenieur, Posbus 48, Warmbad 0480.
DU PLESSIS, CJ: Posbus 868, Kempton Park 1620.
DU PLESSIS, GC: Adjunk-Elektrotegniese Stadsingenieur, Posbus 94, Krugersdorp 1740.

F
FLETCHER, JL: Deputy City Electrical Engineer, P.O. Box 147, Durban 4000.

G
GOWIE, E: P.O. Box 35, Matatiele 4730.

H
HILL, DR: City Electrical Department, P.O. Box 147, Durban 4000.
HOBBS, JL: Deputy Electrical Engineer, P.O. Box 45, Uitenhage 6230.

K
KLOPPER, TJ: Elektrotegniese Ingenieur, Posbus 201, Heidelberg 2400.

L
LABUSCHAGNE, PHJ: Adjunk Direkteur, Tegniese Dienste, Atherstonestraat 19, Vanderbijlpark 1900
LAMPRECHT, BC: Privaatsak X014, Benoni 1500.
LEIGH, RA: Deputy Electrical Engineer, P.O. Box 699, Johannesburg 2000.
LIEBENBERG, HDG: Posbus 64, Ladybrand 9745.

M
MALAN, JG: Assistent Elektrotegniese Ingenieur: Posbus 13, Kempton Park 1620.
MULDER, JAC: Posbus 60, Piketberg 7320.

O
OPPERMAN, DJ: Adjunk-Elektrotegniese Ingenieur, Posbus 45, Springs 1560.

P
PEENS, JG: Posbus 6, Wesselsbron 9680.
PRETORIUS, JW: Assistent-Elektrotegniese Ingenieur, Posbus 23, Nigel 1490.

S
SMIT, AH: Posbus 3, Bethal 2310.
SMIT, JJ: Assistent-Elektrotegniese Ingenieur, Posbus 3, Witbank 1035.
SMITH, AM: 22 Bournemouth Street, Summerstrand, Port Elizabeth 6001.
SURTHEES, EH: Deputy Town Engineer, P.O. Box 215, Boksburg 1460.

V
VAN DER WALT, CJ: Privaatsak X014, Benoni 1500.
VAN SCHALKWYK, AP: Assistent-Elektrotegniese Stadsingenieur, Posbus 288, Bloemfontein 9300.

LOCAL AUTHORITIES – PLAASLIKE OWERHEDE

A
The Town Clerk, P.O. Box 38, Adelaide 5760.
The Town Clerk, P.O. Box 46, Aliwal North 5530.
The Town Clerk, P.O. Box 4, Alberton 1450.
Die Stadsklerk, Posbus 73, Alexandria 6185.

B
The Town Clerk, P.O. Box 33, Barberton 1300.
The Town Clerk, P.O. Box 9, Beaufort West 6970.
The Town Clerk, P.O. Box 3, Bedfordview 2008.
The Town Clerk, P.O. Box 45, Benoni 1500.
The Town Clerk, P.O. Box 3, Bethal 2310.
The Town Clerk, P.O. Box 130, Bethlehem 9700.
The Town Clerk, P.O. Box 3704, Bloemfontein 9300.
The Town Clerk, P.O. Box 215, Boksburg 1460.
The Town Clerk, P.O. Box 10, Bonnievale 6730.
The Town Clerk, P.O. Box 12, Bothaville 9660.
The Town Clerk, P.O. Box 15, Brakpan 1540.
Die Stadsklerk, Posbus 13, Brandfort 9400.
The Town Clerk, P.O. Box 51, Bredasdorp 7280.
The Town Clerk, P.O. Box 106, Brits 0250.
The Town Clerk, P.O. Box 13, Burgersdorp 5520.
Die Stadsklerk, Posbus 3, Bultfontein 9670.

C
The Town Clerk, P.O. Box 82, Cape Town 8000.
The Town Clerk, P.O. Box 3, Carletonville 2500.
The Town Clerk, P.O. Box 10, Carnarvon 7060.
The Town Clerk, P.O. Box 24, Carolina 1185.
The Town Clerk, P.O. Box 44, Ceres 6835.
The Town Clerk, P.O. Box 24, Cradock 5880.

D
Die Stadsklerk, Posbus 43, Daniëlskuil 8405.
The Town Clerk, P.O. Box 42, De Aar 7000.
The Town Clerk, P.O. Box 6, Delmas 2210.
Die Stadsklerk, Posbus 42, Despatch 6220.
The Town Clerk, P.O. Box 13, Dewetsdorp 9940.
Die Stadsklerk, Posbus 20, Dordrecht 5435.
Die Stadsklerk, Posbus 27, Douglas 8730.
The Town Clerk, P.O. Box 36, Duiwelskloof 0835.
The Town Clerk, P.O. Box 76, Dundee 3000.
The Town Clerk, P.O. Box 147, Durban 4000.
The Secretary, Divisional Council of the Cape, P.O. Box 1073, Cape Town 8000.

E
The Town Clerk, P.O. Box 134, East London 5200.
The Town Clerk, P.O. Box 25, Edenvale 1610.
The Town Clerk, Private Bag, Empangeni 3880.
The Town Clerk, P.O. Box 48, Ermelo 2350.
The Town Clerk, P.O. Box 37, Eshowe 3815.
The Town Clerk, P.O. Box 15, Estcourt 3310.
The Town Clerk, P.O. Box 55, Evander 2280.

F
The Town Clerk, P.O. Box 1, Fochville 2515.
The Town Clerk, P.O. Box 36, Fort Beaufort 5720.
Die Stadsklerk, Posbus 2, Frankfort 9830.

G
The Town Clerk, P.O. Box 19, George (C.P.) 6530
The Town Clerk, P.O. Box 145, Germiston 1400.
The Town Clerk, P.O. Box 10, Glencoe 2930.
The Town Clerk, P.O. Box 33, Gobabis 9140.
The Town Clerk, P.O. Box 3, Gordons Bay 7150.
The Town Clerk, P.O. Box 71, Graaf-Reinet 6280.
The Town Clerk, P.O. Box 176, Grahamstown 6140.
The Town Clerk, P.O. Box 71, Greytown 3500.
Die Stadsklerk, Posbus 15, Groot-Brakrivier 6525.

H
Die Stadsklerk, Posbus 83, Hartswater 8570.
The Town Clerk, P.O. Box 201, Heidelberg 2400.
Die Stadsklerk, Munisipaliteit, Heilbron 9650.

The Town Clerk, P.O. Box 20, Hermanus 7200.
The Town Clerk, P.O. Box 29, Henneman 9445.
Die Stadsklerk, Munisipaliteit, Hoopstad 2670.
Die Stadsklerk, Privaatsak X3, Hopetown 8750.
The Town Clerk, P.O. Box 5, Howick 3290.

J
Die Stadsklerk, Posbus 241, Jan Kempdorp 8550.
The Town Clerk, P.O. Box 21, Jeffreys Bay 6330.
City Electrical Engineer, P.O. Box 699, Johannesburg 2000.

K
The Town Clerk, P.O. Box 174, Kakamas 8870.
The Town Clerk, P.O. Box 25, Keetmanshoop 9020.
The Town Clerk, P.O. Box 13, Kempton Park 1620.
The Town Clerk, P.O. Box 15, Kenhardt (C.P.) 8900.
The Town Clerk, P.O. Box 194, Kimberley 8300.
The Town Clerk, P.O. Box 33, King Williamstown 5600.
The Town Clerk, P.K. Kirkwood 6120.
The Town Clerk, P.O. Box 99, Klerksdorp 2570.
The Town Clerk, P.O. Box 21, Knysna 6570.
Die Stadsklerk, Posbus 7, Koffiefontein 9986.
The Town Clerk, P.O. Box 21, Komga 4950.
The Town Clerk, P.O. Box 14, Koppies 9540.
The Town Clerk, P.O. Box 302, Kroonstad 9500.
The Town Clerk, P.O. Box 94, Krugersdorp 1740.
The Town Clerk, P.O. Box 4, Kuruman 8460.

L
The Town Clerk, P.O. Box 64, Ladybrand 9745.
The Town Clerk, P.O. Box 29, Ladysmith 3370.
The Town Clerk, P.O. Box 7, Lichtenburg 2740.
The Town Clerk, P.O. Box 6, Lydenburg 1120.

M
Die Stadsklerk, Posbus 111, Marble Hall 0450.
The Town Clerk, P.O. Box 42, Mafikeng 8670.
The Town Clerk, P.O. Box 35, Matatiële 4730.
The Town Clerk, P.O. Box 11, Melmoth 3835.
The Town Clerk, P.O. Box 9, Meyerton 1960.
The Town Clerk, P.O. Box 55, Middelburg (C.P.) 5900.
The Town Clerk, P.O. Box 14, Middelburg (TVL.) 1050.
The Town Clerk, P.O. Box 47, Mooi Rivier 3200.
The Town Clerk, P.O. Box 25, Mossel Bay 6500.
Die Stadsklerk, Posbus 24, Montagu 6720.

N
The Town Clerk, P.O. Box 45, Nelspruit 1200.
The Town Clerk, P.O. Box 21, Newcastle 2940.
The Town Clerk, P.O. Box 23, Nigel 1490.
Die Stadsklerk, Privaatsak 1008, Nylstroom 0510.

O
Die Hoofdirekteur, Ontwikkelingsraad Hoveldgebied, Posbus 349, Standerton 2430.
Die Hoofdirekteur, Ontwikkelingsraad Sentraal-Transvaal, Privaatsak X449, Pretoria 0001.
Die Hoofdirekteur, Ontwikkelingsraad Suid-Transvaal, Privaatsak X2016, Standerton 2430.
Die Hoofdirekteur, Ontwikkelingsraad Oos-Kaap, Posbus 14025, Sidwell 6061.
Die Hoofdirekteur, Ontwikkelingsraad Oos-Transvaal, Posbus 888, Nelspruit 1200.
Die Hoofdirekteur, Oranje-Vaal Ontwikkelingsraad, Privaatsak X029, Vanderbijlpark 1900.
Die Hoofdirekteur, Oos-Randse Ontwikkelingsraad, Posbus 57, Germiston 1400.
Die Hoofdirekteur, Ontwikkelingsraad Suid-OVS, Posbus 2313, Bloemfontein 9300.
Die Hoofdirekteur, Ontwikkelingsraad Noord-Kaap, Privaatsak X5005, Kimberley 8300.
Die Hoofdirekteur, Ontwikkelingsraad Wes-Kaap, Privaatsak X7, Goodwood 7460.
Die Hoofdirekteur, Wes-Randse Ontwikkelingsraad, Posbus 4414, Johannesburg 2000.
The Town Clerk, P.O. Box 21, Odendaalsrust 9480.
The Town Clerk, P.O. Box 34, Orkney 2620.
The Town Clerk, Private Bag 2209, Otjiwarongo SWA 9210.
The Town Clerk, P.O. Box 255, Oudtshoorn 6620.

P
The Town Clerk, P.O. Box 12, Paarl 7620.
The Town Clerk, P.O. Box 359, Parys 9585.
Die Stadsklerk, Posbus 12, Petrus Steyn 9640.
The Town Clerk, P.O. Box 67, Phalaborwa 1390.
The Town Clerk, P.O. Box 321, Pietermaritzburg 3200.
The Town Clerk, P.O. Box 111, Pietersburg 0700.
The Town Clerk, P.O. Box 23, Piet Retief 2380.
The Town Clerk, Municipality, Piketberg 7320.
The Town Clerk, P.O. Box 26, Plettenbergbaai 6600.
The Town Clerk, P.O. Box 13, Port Alfred 6170.
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