1 INTRODUCTION

Substation designs have generally followed air insulated technology or gas insulated technology. When faced with space constraints or the need to reduce the investment cost of substations, creative adaptations of air insulated substation designs like transformer feeders and Jericho schemes together with smaller protection schemes have been successfully used.

Space constraints often emerge when substations need to be extended to cater for local load growth requirements, more flexible switching arrangements or to allow for more sophisticated protection systems.

Hybrid switchgear, utilising the advantages of SF6 gas insulation and multi-functional switchgear has provided the opportunity for resolving these space constraint challenges for some time now.

Mixed technology switchgear (MTS) is defined by the installation and functionality considerations of the switchgear and uses AIS, GIS or Hybrid IS technologies.

The considerations affecting the technology choice are the substation location, the equipment design and manufacturing, engineering, construction, impact on the environment, impact of the environment, on-site time efforts, operation and service, availability, testing, flexibility, personnel safety, physical security and life cycle costing.

Examples of 4 applications of MTS will be presented showing a substation upgrade from 66 kV to 132 kV on the same footprint, a greenfield substation using combined AIS switchgear, a substation retrofit creatively using double busbar hybrid switchgear and a greenfield substation using double busbar hybrid switchgear at both 66 kV and 132 kV voltage levels.
2 TECHNOLOGY OPTIONS FOR SUBSTATIONS

The different design technologies for high voltage switchgear can be clustered into three groups: conventional air insulated switchgear solutions, conventional gas insulated switchgear solutions and hybrid insulated switchgear solutions.

Some of the drivers for the technology choices are the need to optimize the investment costs, space constraints and the need for redundancy and high reliability of the single line layout.

2.1 AIS (Air Insulated Switchgear)

Switchgear of which the bays are fully made from AIS technology components. The insulating medium is air.

The conventional AIS devices of surge arrestors, instrument transformers and circuit breakers are shown in Fig 1.

AIS switchgear has the flexibility to be configured into all types of substation layouts.

2.2 GIS (Gas Insulated Switchgear)

Switchgear of which the bays are fully made from GIS technology components. Only the HV connections to overhead lines or cables, etc. can have external insulation. The insulating medium is normally SF6 or an SF6 mixture.

GIS switchgear can be configured in single busbar, double busbar or 1 and ½ breaker layouts.

The indoor GIS shown in Fig 2 is a SBB layout.

2.3 Hybrid IS (Hybrid Insulated Switchgear)

Switchgear of which the bays are fully made from a mix of AIS and GIS technology components.

Hybrid switchgear can integrate many functions into one unit.

The PASS M0 unit shown in Fig 3 integrates disconnectors, earth switches, current transformers and a circuit breaker to give a complete bus section bay.
3 SWITCHGEAR STANDARDS

The IEC 62271 suite of standards for 'High-voltage switchgear and control gear' covers AIS, GIS and MTS switching devices.

- IEC 62271 – 100 : High voltage AC circuit breakers
- IEC 62271 – 102 : AC disconnectors and earthing switches
- IEC 62271 – 108 : High voltage AC disconnecting circuit breakers
- IEC 62271 – 203 : Gas insulated metal enclosed switchgear
- IEC 62271 – 205 : Compact switchgear assemblies

Part 205 of this standard has been developed to cater for the new arrangement possibilities that have been developed by manufacturers and to ensure that the complete switchgear assemblies are covered by a single standard.\(^{(1)}\)

4 DEFINITIONS ACCORDING TO CIGRE WORKING GROUP B3-20

The Cigre’ Working Group B3-20 is developing a brochure which evaluates different switchgear technologies for rated voltages of 52 kV and above. The following definitions are used to describe the switchgear.\(^{(2)}\)

Conventional Switchgear – Switchgear of which bays only include conventional components

Compact Switchgear – Switchgear of which at least one or more bays are compact bays, i.e. in which at least some components share common support structures and cannot be placed individually.

Combined switchgear – Switchgear of which at least one or more bays are combined bays, i.e. in which at least some components are multifunctional

Mixed technology switchgear (MTS) is described as switchgear assemblies which incorporate a mixture of the insulating characteristics of both AIS and GIS and/or which implements traditionally discrete functions (devices) in a compact and/or combined design in such a way that they can no longer be considered for the purposes of design and testing, in isolation.

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Fig 4 – MTS showing insulation, installation and functionality considerations
5 EXAMPLES OF MTS (DCB, WCB, COMPASS AND PASS)

Mixed technology switchgear can thus made up one of the following combinations:

- AIS in compact and/or combined design
- GIS in combined design
- Hybrid IS in compact and/or combined design

assembled together and using a common structure in order to minimize the installation time.

Typical examples of MTS assemblies are shown in Fig 5.

![Disconneecting Circuit Breaker Combined AIS](image1)
![Withdrawable Circuit Breaker Compact AIS](image2)
![COMPASS Unit Compact AIS](image3)
![PASS Unit Hybrid IS](image4)

Fig 5 – Various examples of MTS assemblies

6 MIXED TECHNOLOGY SWITCHGEAR CONSIDERATIONS

When the various technologies of AIS, GIS and MTS are compared, the Cigre' document\(^2\) rates the following aspects to guide utilities and customers in the correct technology choice:

1. Location (Outdoor rural, outdoor urban, indoor, underground or container)
2. Equipment design and manufacturing (Conceptual design, material, manufacturing from factory perspective, manufacturing from site and commissioning perspective)
3. Engineering (Complexity, SLD, schedule, specification, layout, civil work and secondary system)
4. Construction (Site, transport, foundations, erection, impact on existing services, commissioning)
5. Impact on the environment (Aesthetics, noise, EMF/EMC, nature, leakages)
6. Impact of the environment (Climatic conditions, pollution, corrosion, seismic activity)
7. On-site time efforts (Preparation time, erection time, commissioning time, repair time, maintenance time)
8. Operation and service (Control, condition monitoring, expected lifetime, replacement of components, dependence on OEM)
9. Availability (Maintainability, reliability, MTTM, MTTR, tools and gas equipment)
10. Testing (Type tests, routine tests, on-site tests, test equipment)
11. Flexibility (Extendibility, upgrading, refurbishment, mobile or temporary)
12. Personnel safety (Injury risk during service, maintenance and in the case of catastrophic failure)
13. Physical security (Security against terrorist threat, vandalism and metal theft)
14. Life cycle costing (Cost of acquisition, ownership and disposal)

MTS shows clear advantages in less space required for the same SLD, extended SLD in the same space, higher flexibility of layout, easier engineering and integration with the secondary systems and reduced maintenance efforts and costs.
7 EXAMPLES

The following four examples are intended to show the suitability of MTS for AIS substation upgrading, extensions and greenfield projects with space constraints.

7.1 Newton Park Substation (66 kV to 132 kV upgrade)

7.1.1 Scope

Newton Park Substation was an existing 66 kV substation located on the top of a hill with a steep slope. There were two incoming lines directly feeding onto transformers. These transformer feeders were used to reduce the initial investment costs of the substation and no HV circuit breakers were installed.

When the initial 66 kV layout was designed, the future need for this to be upgraded to a 132 kV substation was not considered. If the substation platform were to be increased to allow for a 132 kV AIS substation, there would be considerable civil work expense in backfilling to extend the platform or develop a multi-level substation.

![Fig 6 - Layout for the original 66 kV substation](image)

7.1.2 Solution

The busbar spacing had to be increased to allow for the required 132 kV clearances. The same bay width was maintained as this was determined by the transformer plinth spacing. The PASS M0 132 kV hybrid switchgear was used for the incomers and the bus section.

The work could be completed without a total outage. There is now a greater level of flexibility with the busbar and bus-section bay installed.

![Fig 7 – Bus coupler bay using the 132 kV Pass M0 hybrid unit.](image)
7.2 Gull Substation (Greenfield 132 kV Substation)

7.2.1 Scope

Gull Substation is a greenfield 132 kV substation in the built up residential area of Lonehill in Johannesburg where there has been a large increase in load in the area and there is insufficient space for a conventional AIS technology substation. The substation layout was SBB with 2 x incoming circuits, 2 x transformer circuits and a bus coupler.

Fig 8 – SLD showing the MTS solution comprising an OHL incoming bay, the transformer bay, AIS Busbar VT’s and an AIS bus section disconnector

Fig 9a – MTS incoming bay using a COMPASS unit

Fig 9b – MTS transformer bay using a COMPASS unit

7.2.2 Solution

The COMPASS 132 kV compact technology switchgear was used in all the substation bays. This MTS solution demonstrates the clear advantages of less space required for the same SLD.
7.3 Bloemendal Substation

7.3.1 Scope

The existing substation layout shows an overhead line going in and out of the substation via two parallel paths, one path through two disconnector switches and the other path through two disconnector switches with a circuit breaker between them. The two transformers are connected to each end of the two parallel paths via transformer disconnector switches.

The requirements for the Bloemendal Substation retrofit project was to take the existing 132 kV AIS Substation and construct a complete incomer bay (consisting of a line disconnector and earth switch, circuit breaker, current transformers and surge arrestors) for each of the overhead line in and out bays. The transformers would still be fed via transformer disconnector switches and the overhead lines are still connected via two disconnector switches and a circuit breaker.

The customer constraint was to implement the solution within the boundaries of the existing substation. No outage for any part of the substation could be more than 24 hours duration.

Fig 10 – Existing substation layout

Fig 12 – MTS Solution using PASS M0 DBB Units combined with an AIS CB.

Fig 11 – New substation layout using MTS

Fig 13 – MTS PASS M0 DBB Unit
7.3.2 Solution

The MTS solution implemented here used 2 x PASS M0 132 kV double busbar units connected together with an AIS circuit breaker between the PASS units. The bus section switch on each side of the AIS circuit breaker is within the PASS unit. This solution also allows the flexibility to earth the transformers or the overhead lines or the bus section switch through the PASS unit circuit breakers.

When the redundant existing equipment is removed, there will be sufficient space to place more transformers in the same existing substation area if required.

7.4 Briers Substation (Greenfield 132 kV DBB and 66 kV DBB Substation)

7.4.1 Scope

Briers Substation has a DBB layout at both 132 kV and 66 kV voltage levels. The 132 kV side has 2 x OHL incomers, 2 x transformer feeders and a bus coupler. The 66 kV side has 2 x transformer incomers, 3 x OHL feeders and a bus coupler with provision for 2 x future bays.

Fig 14 – Substation layout using MTS
7.4.2 Solution
MTS was selected as the appropriate technology because of the space constraint for the substation. It was not possible to design an equivalent AIS technology substation within the same available area.

Fig 15 – Side elevation of MTS for the OHL incomer bay.

Fig 16 – PASS M00 132 kV DBB unit used as the MTS solution in this application.

Fig 17 – Side elevation of MTS for the transformer bay

Fig 18 – PASS M00 66 kV DBB unit used as the MTS solution in this application
8 CONCLUSION

Mixed technology switchgear has been defined in relation to AIS, GIS and Hybrid IS with the advantages clearly shown. Four different examples demonstrating the implementation of mixed technology switchgear have been discussed and this has demonstrated some of the practical applications of this technology. There are still many further applications that can be discussed.

MTS shows clear advantages in less space required for the same SLD, extended SLD in the same space, higher flexibility of layout, easier engineering and integration with the secondary systems and reduced maintenance efforts and costs.

9 REFERENCES

9.1 IEC 62271-205
High-voltage switchgear and control gear – Part 205: Compact switchgear assemblies for rated voltages above 52 kV.

9.2 WG B3-20 Brochure:
Evaluation of Different Switchgear Technologies (AIS, MTS, GIS) for Rated Voltages of 52 kV and above.