NEW CHALLENGES FACING THE UTILITY ENGINEER

OCTOBER 2017
PAUL GERBER
WE ARE DISCUSSING TECHNICAL SOLUTIONS FOR A NEW BUSINESS MODEL.

IN THIS PRESENTATION....

• THE FOCUS WILL BE ON UNDERSTANDING THE CHALLENGES PRIOR TO FINDING SOLUTIONS;
• EMPHASIS WOULD BE PLACED ON QUALITY OF SUPPLY AS A KEY ELEMENT OF THE NEW BUSINESS MODEL;
• QUALITY OF SUPPLY, IN RETURN, WILL BE DISCUSSED ALONG THE ROUTE OF 3 QoS PARAMETERS.
THE "TRADITIONAL" SYSTEM?

POWER FLOW

PoM

ESKOM

| MUNIC

THE "MODERN" SYSTEM
<table>
<thead>
<tr>
<th>THE “TRADITIONAL” SYSTEM MUNIC</th>
<th>THE “MODERN” SYSTEM ROLE SHIFT</th>
</tr>
</thead>
<tbody>
<tr>
<td>• SELLING kWhrs, generated remotely, to customers;</td>
<td>• “RENTING OUT” a system used for storing and wheeling of electrical energy;</td>
</tr>
<tr>
<td>• MAIN COST IS IN THE</td>
<td>• COMPLYING WITH NATIONAL QoS PARAMETERS A MUST;</td>
</tr>
<tr>
<td>– GENERATION OF THE ELECTRICAL ENERGY;</td>
<td>• BALANCING LOAD &amp; DEMAND;</td>
</tr>
<tr>
<td>– THE TRANSMISSION &amp; DISTRIBUTION OF THE ENERGY;</td>
<td>• BE ON STANDBY TO REPLACE RENEWABLE SOURCES BY A BASE SOURCE WHEN “THE SUN GOES UNDER”;</td>
</tr>
<tr>
<td>• TARIFFS BASED ON UNIT COSTS (GENERATION) AND MAXIMUM DEMAND (INFRASTRUCTURE) SUFFICE.</td>
<td>• TARIFFS SHOULD REFLECT THE TRUE COST OF THE ABOVE.</td>
</tr>
</tbody>
</table>
THE BIG PLUS OF THE MODERN SYSTEM

• IT COULD INDEED CONTRIBUTE TOWARDS SAVING THE EARTH:
  – MORE “GREEN” ENERGY;
  – LESS FOSSIL FUELS.
  – A COUNTER-ACT FOR GLOBAL WARMING;
• ENERGY SOURCE DIVERSITY;
• OPTIMUM USE OF EXISTING SPACE.
The technical design and the operation of the modern system (if done professionally) is a whole lot more challenging:

- It is a challenge to keep the network safe;
- It is a challenge to keep the quality of supply within the parameters of standards such as NRS048.
SOME QUALITY OF SUPPLY ISSUES

• PARTICULAR QUALITY OF SUPPLY CHALLENGES:
  – POWER FREQUENCY RESONANCE (PARTICULARLY ON THE MV SIDE);
  – THE VOLTAGE IMPACT OF THE GRID CONNECTION OF PV OR SIMILAR INSTALLATIONS AT VARIOUS POINTS ON THE LV SYSTEM;
  – THE HARMONIC IMPACT OF PV TYPE SSEG’S INSTALLED ON THE LV NETWORK.
Fig. 1 – Reduced (approximate) transformer model.

Fig. 2 – Model of unloaded transformer.
Fig. 3 – Possibility of series resonance between an unloaded distribution transformer and system capacitances under un-ganged switching scenario’s.
SOME QUALITY OF SUPPLY ISSUES

• PARTICULAR QUALITY OF SUPPLY CHALLENGES:
  – SYSTEM RESONANCE (PARTICULARLY ON THE MV SIDE);
  – THE VOLTAGE IMPACT OF GRID CONNECTED PV OR SIMILAR INSTALLATIONS AT VARIOUS POINTS ON AN LV SYSTEM;
  – THE HARMONIC IMPACT OF PV TYPE SSEG’S INSTALLED ON THE LV NETWORK.
VOLTAGE IMPACT OF GRID CONNECTED LV PV INSTALLATIONS

EACH CDU HAVE 7 CONSUMERS @ A 15 YEAR ADMD OF 4.72 kVA ADMD ARRANGED AS CYCLIC 322.

<table>
<thead>
<tr>
<th>100 m</th>
<th>100 m</th>
<th>100 m</th>
<th>100 m</th>
<th>100 m</th>
</tr>
</thead>
<tbody>
<tr>
<td>240 mm²</td>
<td>150 mm²</td>
<td>95 mm²</td>
<td>70 mm²</td>
<td>50 mm²</td>
</tr>
</tbody>
</table>
VOLTAGE IMPACT OF GRID CONNECTED LV PV INSTALLATIONS

NO PV INSTALLATIONS
VOLTAGE IMPACT OF GRID CONNECTED LV PV INSTALLATIONS

AT CDU 5, ADD A PV INSTALLATION ON EACH OF THE RED AND BLUE PHASES.

EACH OF THE 2X PV INSTALLATIONS COMPLY WITH NRS097 GUIDELINES OF < 25% NMD AND = 4.6 kVA.
VOLTAGE IMPACT OF GRID CONNECTED LV PV INSTALLATIONS

PV INSTALLATIONS ON THE RED AND BLUE PHASES OF CDU 5
SOME QUALITY OF SUPPLY ISSUES

• PARTICULAR QUALITY OF SUPPLY CHALLENGES:
  – SYSTEM RESONANCE (PARTICULARLY ON THE MV SIDE);
  – THE VOLTAGE IMPACT OF THE GRID CONNECTION OF PV OR SIMILAR INSTALLATIONS AT VARIOUS POINTS ON THE LV SYSTEM;
  – THE HARMONIC IMPACT OF PV TYPE SSEG’S INSTALLED ON THE LV NETWORK.
“Is There Really a Harmonics Problem? Yes, there is a problem. In fact, there are so many difficult problems that hundreds, if not thousands, of theses, papers, articles, and case studies have been published on this subject. To define and limit harmonic problems, IEEE has published ANSI/IEEE Std. 519-1992 -- Recommended Practices and Requirements for Harmonic Control in Electrical Power Systems.”

http://www.powerqualityinternational.com
BACK TO THE HARMONIC IMPACT OF PV INSTALLATIONS ON A LV NETWORK...

THE PV INSTALLATION COULD PLAY A ROLE BOTH IN (1) GENERATING AND (2) SINKING HARMONIC CURRENTS.
Comparison of PV Harmonics to Other Appliances

THE HARMONIC IMPACT OF LV PV INSTALLATIONS

THE HARMONIC CURRENTS GENERATED BY PV INSTALLATIONS COMPARE “FAVOURABLE” WITH THAT OF OTHER APPLIANCES

Source data re-worked from: https://era.library.ualberta.ca/files/h702q6756#.WcuZ9fRqR2U
THE HARMONIC IMPACT OF LV PV INSTALLATIONS

THE PV INSTALLATION AS A SINK FOR HARMONIC CURRENTS.

Fig. 8a – PV Installation

Fig. 8b – PV Installation as Harmonic Generator

Fig. 8c – PV Installation as a "sink" for other Harmonic Generators
THE HOUSEHOLD MODELLED AS A HARMONIC GENERATOR

Fig. 9 – A household modeled as a harmonic generator.

https://era.library.ualberta.ca/files/h702q6756#.WcuZ9fRqR2U
THE HARMONIC IMPACT OF LV PV INSTALLATIONS

COMBINING THE SYSTEM, A HOUSEHOLD AND A PV INSTALLATION MODELLLED AS A SINK.

Fig. 10 – Household as harmonic generator with PV installation connected to supply.
THE HARMONIC IMPACT OF LV PV INSTALLATIONS

INCREASING THE NUMBER OF HOUSEHOLDS & PV INSTALLATIONS

Fig. 11 – Multiple households connected to the PCC.

Fig. 12 – Multiple PV installations connected to PCC
THE HARMONIC IMPACT OF LV PV INSTALLATIONS

Fig. 13 – System supplying distribution transformer

11 kV busbars

11 kV Cable.

Z_{equivalent}
THE HARMONIC IMPACT OF LV PV INSTALLATIONS

Z AT DISTRICT SUB BB WITH NO PV’S

Z AT DISTRICT SUB BB WITH PV’S ON ALL HOUSEHOLDS (STILL COMPLYING WITH NRS097)
### 21st HARMONIC “PACKAGE” INJECTED AT 50% OF THE HOUSEHOLDS

<table>
<thead>
<tr>
<th>Appliance</th>
<th>Number</th>
<th>Current (A)</th>
<th>Amplitude</th>
<th>Angle (deg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>40 W CFL</td>
<td>2</td>
<td>0.032</td>
<td>0.032</td>
<td>4.7</td>
</tr>
<tr>
<td>Laptop</td>
<td>1</td>
<td>0.16</td>
<td>0.16</td>
<td>-91.4</td>
</tr>
<tr>
<td>Washer</td>
<td>1</td>
<td>0.077</td>
<td>0.077</td>
<td>-79.5</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td></td>
<td><strong>0.24</strong></td>
<td><strong>0.24</strong></td>
<td><strong>-79.8</strong></td>
</tr>
</tbody>
</table>

Source data re-worked from: [https://era.library.ualberta.ca/files/h702q6756#.WcuZ9fRqR2U](https://era.library.ualberta.ca/files/h702q6756#.WcuZ9fRqR2U)
THE HARMONIC IMPACT OF LV PV INSTALLATIONS

THE INFLUENCE OF PV FILTERS ON 21ST HARMONIC WITH 50% OF HOUSEHOLDS SUBJECT TO A "PACKAGE" HARMONIC INJECTION

- Sub BB
- CDU 1
- CDU 5

Harmonic Peak Voltage (V)

- No PV filters
- PV filters on all 35 customers
THE VOLTAGE AT CDU 5 DISTORTED BY THE 21ST HARMONIC
NRS 048 LIMIT ON 21\textsuperscript{ST} HARMONIC  = 0.3 \% \\
AT CDU 5 $V_{\text{peak}21h} = 2.6$ V WITH PV INSTALLATIONS \\
= 0.9\% \\
HENCE NOT COMPLIANT WITH NRS 048. \\
IN FACT : 200\% MORE THAN WHAT IT SHOULD BE.
WE HAVE LOOKED AT 3 AREAS OF SUPPLY QUALITY, EACH OF WHICH COULD BE NEGATIVELY IMPACTED UPON BY SSEG’ S:

- POWER FREQUENCY RESONANCE;
- THE VOLTAGE LEVELS OF LV DISTRIBUTORS;
- THE HARMONIC IMPACT OF PV TYPE SSEG’ S INSTALLED ON THE LV NETWORK.

AND WE HAVE NOTICED THE CHALLENGES.
“Is There a Solution?
Yes, there is a solution.”
CONCLUSION

• **THE UTILITY NEEDS TO KNOW** OF EACH EXISTING AND NEW **SSEG** IN ITS AREA OF SUPPLY - EVEN IF THE SSEG IS NOT GRID CONNECTED (RESONANCE) ;

• **INFORMATION PERTAINING TO SSEG’S** IS CRITICAL TOWARDS VERIFYING THEIR IMPACT ON THE SYSTEM. SUCH DETAIL INCLUDES THE **FILTER PARAMETERS AND ISLANDING DETECTION DEVICES**. (THE LATTER ACTUALLY BECOMES THE PROTECTION DEVICE UNDER CERTAIN CONDITIONS.) ;
• EACH NEW SSEG INSTALLATION NEEDS VERIFICATION IN TERMS OF ITS GRID IMPACT IN LINE WITH AN EXTENDED LIST OF PARAMETERS TO BE CHECKED. DESIGN SOFTWARE SHOULD ACCOMMODATE PARAMETERS SUCH AS DIVERSITY, UNBALANCE, HARMONICS AND RESONANCE WITH RELATIVE EASE;
• NATIONAL STANDARDS IN TERMS OF HARMONIC GENERATORS, THEIR DIVERSITY AND THEIR APPORTIONING, ARE LACKING.
THANK YOU
“Measurements in a bungalow park in the Netherlands with a high penetration of PV have shown a lot of harmonic distortions at the point of coupling. There harmonics are concerning resonances and the interaction of current harmonics generated by the inverters and the voltage harmonics coming from the grid.”

PRACTICAL CHALLENGES OF MODERN GRIDS

VOLTAGE @ POINT OF SUPPLY

THE WIDER SPREAD USE OF SSEG’S ENHANCES THE CHANCES OF UNLOADED OR LIGHTLY LOADED DISTRIBUTION TRANSFORMERS;

UNLOADED TRANSFORMERS, TOGETHER WITH CERTAIN NETWORK STATUSES, COULD LEAD TO SERIES RESONANCE (EVEN AT POWER FREQUENCIES) AND CONSEQUENTLY OVER VOLTAGES AND EQUIPMENT DAMAGE.
SOME QUALITY OF SUPPLY ISSUES

• FOR UTILITIES TO REMAIN RELEVANT IN THE ELECTRICITY BUSINESS, A GOOD QUALITY SYSTEM IS NOT NEGOTIABLE, I.E. IT SHOULD FORM THE HEART OF THE NEW BUSINESS MODEL:
  – EXISTING CUSTOMERS WOULD WANT TO REMAIN CONNECTED TO THE NETWORK AND GET VALUE FOR MONEY IN DOING SO;

• PARTICULAR QUALITY OF SUPPLY CHALLENGES:
  – SYSTEM RESONANCE (PARTICULARLY ON THE MV SIDE);
  – THE VOLTAGE IMPACT OF THE GRID CONNECTION OF PV OR SIMILAR INSTALLATIONS AT VARIOUS POINTS ON THE LV SYSTEM;
  – THE HARMONIC IMPACT OF PV TYPE SSEG’ S INSTALLED ON THE LV NETWORK.
“The effects of harmonic currents on electrical distribution systems are not understood by most in the electrical industry.” - Mike Holt.

https://www.mikeholt.com/technical-power-quality-harmonics.php
“Harmonic currents increase the r.m.s. current in electrical systems and deteriorate the supply voltage quality. They stress the electrical network and potentially damage equipment.” – Schneider.

http://www.electrical-installation.org/enwiki/Problems ARISING FROM POWER-SYSTEM HARMONICS
“...the utilities (also) cannot ignore their duty to assess network performance, even if a single small generator is added.”

- Prof. Jan de Kock & Jaco Alberts (Wattnow, April 2017)
UTILITY CHALLENGES POSED BY THE MODERN SYSTEM

• LESS REVENUE IF CONVENTIONAL TARIFF STRUCTURES ARE GOING TO BE APPLIED TO THE MODERN SYSTEM:

• THE TECHNICAL DESIGN AND THE OPERATION OF THE MODERN SYSTEM (IF DONE PROFESSIONALLY) IS A WHOLE LOT MORE CHALLENGING: