Ekurhuleni has implemented a web-based power quality management system (PQMS). Power quality management has proven to be an important aspect of managing risk in the electrical supply industry (ESI) within Ekurhuleni. An understanding of the quality of the power from Eskom to the point of delivery to the end-user, is needed to formulate maintenance, repair and other intervention measures ensuring minimum standards in QoS.

Instrumentation has been placed at points in the network to ensure comprehensive visibility on voltage parameters. If QoS is above minimum standards, some validity exists in the assumption that the quality by which the energy used is not of concern.

A single voltage waveform incident can result in numerous voltage waveform events all over the network. Each voltage waveform event, if the duration and depth are sufficient, can cause a local interruption in production to the end-user. Although an interruption in the voltage supply was not recorded, the effect to the end-user is similar. Voltage waveform incidents are thus a "global" network problem which can require more comprehensive intervention measures than, for example, solving reliability issues at only a local feeder to a single client.

The widespread integration of QoS instrumentation in the Ekurhuleni network and on-line access to information enabled voltage waveform incidents (e.g. dips) to be analysed in the context of the root cause and source of the incident. It is therefore possible to assign ownership (internal/external) to each voltage incident and to extract the root cause from operational information such as copper theft, vegetation, lightning etc. Minimum specialist knowledge to use the system is needed as the web-based SQL interrogation of the PQ database provides the user with practical information, in proper context, rather than a tsunami of PQ data recorded at many instruments due to single incident. Data analysis is mostly automated and operational personnel can focus on using the information on a day-to-day basis.

Analysis of PQ data collected in this database for a number of years has resulted in Ekurhuleni being able to benchmark network performance. Characteristic levels in steady state parameters could be established and trends identified by understanding how, for example, voltage total harmonic distortion (VTHD) changes with time within a specific network. Indicative numbers in voltage sags could be calculated as functions of network type (cable/overhead) and voltage level.

The intention is to use characteristic numbers in voltage sags to benchmark any singular site against what the rest of the network experiences.

The benchmarking results are useful in supporting potential investors by means of information on the network distortion levels which they can use to specify equipment immunity levels to obtain a realistic compatibility level between supply and use conditions.
The Ekurhuleni distribution networks are supplied with electricity from 45 Eskom intake points, at voltage levels ranging between 132/88/66/44/33/22/11/6,6 kV. From here a mixed base of approximately 350 000 customers are supplied with electricity connections. The sum of all the maximum demands at the various Eskom intake points during the winter months exceed 2400 MVA. Approximately 99,5% of the City of Ekurhuleni’s electricity is purchased from Eskom and 0,5% from a neighbouring metro municipality, namely City Power, Johannesburg.

The City of Ekurhuleni has made strong progress to implement a proper power quality management system that complies with the NERSA directive and reporting requirements. The city has developed a power quality charter which defines its commitment to ensuring the delivery of electricity of appropriate quality and of dealing with problems that customers may experience with regard to quality from time to time. This charter has been approved by the South African National Energy Regulator as meeting the requirements of its power quality directive.

The Ekurhuleni Metropolitan Municipality tries to minimise potential quality of supply problems arising in its networks, but it should be noted that the type of network e.g. overhead lines or underground cables, that supply customers will have a significant impact on the quality of the supply.

The steady state voltage is the voltage a customer can expect to receive under normal operating conditions. Since the loads on a utility are constantly changing, it is impossible to maintain a complete constant voltage. South Africa’s NRS-048 addresses compliance limits set at 95% of measurement intervals and allows utilities and customers to source appropriate equipment for the quality of power they will be exposed to.

Note: From above the standard statistical model allow 8,4 hours per week (or 52 x 8,4 per year) of unregulated power quality, and utilities compliance (or non-compliance) is assessed regardless of the severity of the event!

Voltage regulation magnitude indicates a slow but definite upward trend when analysing annual data. If one would have only looked at the monthly data, the added value may have been missed.

Generally, the Ekurhuleni networks meet the standardised limits of maximum and minimum voltage limits. Many customers actually experience voltage variations better than the plus and minus 5% compatibility levels and seldomly report on exceedance of the plus or minus 10% maximum and minimum.

With the increased globalisation of industry, including free trading of electrical equipment, it will be increasingly necessary for power quality to be monitored and regulated. From the best practices, it will provide a common framework for quality of supply and a step in the right direction towards globally acceptable standards and limits.

In a visionary step, the head of Department: Energy, Mark Wilson, recommended to the mayoral committee of the City of Ekurhuleni to commit to a power quality monitoring program, as far back as September 2003. A resolution was taken that a power quality management system and programme must be implemented for its entire network, as well as those identified by experience as requiring special attention e.g. key customers above 1 MVA.

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instruments to both Ekurhuleni personnel and to key customers via the Internet. The network of remotely installed instruments is permanently connected via a GPRS communications link to the internet-based PQ database. More than 400 metering points are currently operational.

**Daily system operation**

Information is captured daily, audited for completeness, and then e-mailed daily by means of a PQ assessment report of the previous day to the control room operators. Ekurhuleni personnel (control room operators) classify each incident direction, external or internal (transmission or distribution), while the area engineers have to classify the root cause of each incident. Ekurhuleni personnel generate all monthly and ad-hoc reports.

The successful contractor has to see that the entire system is on-line and up-to-date for 95% of the time. In the event of an unforeseen system failure, it is expected from the contractor to have the system restored within five working days.

**Annual report**

The EMM PQMS is capable of compiling annual PQ reports. This type of reporting is a science in its infant stage. The report is mainly used as a management report, but parts of it will be published to EMM’s customers and will comply with NERSA power quality directive requirements and with NRS048.

**Product training, power quality training, and power quality mentoring**

Ekurhuleni receives product training on an annual basis to accommodate new personnel and to remain updated on the latest functionality and features.

The training includes the following (as a minimum):

- Discussion of power quality instruments and the abilities of each instrument type.
- Installation, commission, configuration and management of power quality instruments and communication equipment.
- Introduction to all measured parameters.
- Product usage.
- Software Installation.

The PQ training includes the following (as a minimum):

- Fundamental principles of power quality.
- Up-to-date overview on the NRS 048 and NERSA’s power quality directive.
- Overview on power quality management principles.

Ekurhuleni also provided for a power quality mentoring programme as part of its bid.
After power quality instrument installation a commissioning snapshot of voltage phasors is stored for future reference and proves acceptance of installation (see Fig. 3).

**Voltage magnitude assessment (voltage regulation)**

Fig. 5 depicts voltage magnitude compliance with NRS 048-2, and it is expressed as a percentage of the declared RMS voltage. Daily, seven-day sliding assessment values are compared to specific compatibility and limit criteria. Upon evaluating this voltage-RMS level it is immediately clear that the voltage level has risen above the upper compatibility level of 105% and requires attention.

**Voltage dip/swell assessment**

Categorised voltage dips (a sudden reduction in RMS voltage supply as defined in NRS 048-1:1996 section 3.1.20 and IEC 61000-4-30:2003 section 5.4.) Customised report periods can be selected (see Table 1) e.g. daily, monthly, quarterly, yearly etc. (see Fig. 6).

By selecting (clicking on) any dip event a detailed drill-down of the event is obtained (see Fig. 7).

**Supply reliability assessment in terms of interruptions**

Supply reliability is assessed according to NRS 048-2:2003 section 4.3 in terms of interruptions. These interruptions are classified as either momentary (short) or sustained (long) (see Tables 2 and 3).

Incidents are formed by grouping classified events (dips, surges etc.) that occurred within a specific time window from each other. They share the same cause in all probability.

Reports include:

- **Show most recent incident:** this will bring up the most recent incident that occurred on the network.
- **Incident browser:** used to investigate incidents over a selected period of time. A list of incidents is given for the period selected. Each incident can then be viewed and the related classified events can be drilled down to each incident (see Fig. 10).

With the implementation of a PQMS, Ekurhuleni is already in a better position to establish network-wide performance criteria as a means of informing end-users regarding the level of service that they can expect, or as a means of proactively identifying and investigating potential problem circuits.

**Voltage regulation systems and power quality analysis**

The latest series of voltage regulators found on the market today for control requirements to appoint a contractor. This is to fast-track the learning curve and to ensure sustainable growth and knowledge transfer.

**Investigation assistance**

The contractor is required to provide for power quality investigation process and procedure in-line with Ekurhuleni’s PQ management system. The power quality investigation process makes provision to address customer complaints received from Ekurhuleni’s connected customer base.
of transformer tap changers are far better than those which go back to the post world war era. State-of-the art voltage regulating systems today offer ease of use and simple operation, from manufacturers that have proven track records. However, measuring and monitoring the voltage levels due to possible manual overriding of the control systems, e.g temporarily placing an automatic tap changer on a fixed tap position, may affect the voltage levels. By monitoring this on a daily basis, this will be picked-up very soon, especially where the loading on the transformer varies considerably (see Fig. 11).

When the voltage regulating control system is combined with permanent and continuous power quality monitoring instruments, the overall number of tap changes may be reduced. This will also have a positive impact on the maintenance budget (it is already possible to monitor and record which taps have been used the most and then service those only).

**Conclusion**

Although the City of Ekurhuleni has made much progress in establishing a power quality monitoring system, it has certainly not reached the fully matured state envisaged for the future.
The implementation and results obtained by the power quality monitoring program at the City of Ekurhuleni have identified the essential need for assessing and monitoring power quality.

At the onset of the PQMS project, Ekurhuleni agreed to lead into unchartered territories for the benefit of the industry.

The implementation of Ekurhuleni’s PQMS can be seen as a milestone reached in the submission of power quality reports to NERSA.

The cost impact of managing a power quality instrument per primary transformer is insignificant compared to the monthly revenue stream generated by the output of that transformer.

System power quality benchmarking applications involve the installation of permanent power quality measurement instrumentation at predetermined sites on the system.

Note: This paper was prepared by Stephen Delport and the views contained in it do not necessarily represent the views of Ekurhuleni Metropolitan Municipality or of the AMEU(SA).

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