A very different approach was introduced by the National Energy Regulator of South Africa in 2003 [1]. Under a framework agreed by all stakeholders, licensees are required to implement a Power Quality Management System (PQMS) which focuses on "continuous improvement" through the interaction between the licensee and its customers based on more transparent communication on the causes and impacts on customers (including financial impacts) of such events.

This paper discusses these two approaches in managing voltage dips – i.e. contractual dip performance or regulatory minimum standards vs. "continuous improvement" that underlies the new South African framework. Emphasis is placed on the benefits gained from utilising active interaction and the impact this has on the relationship between utility and customer. Specific case studies investigating the implementation of the PQMS with large industrial customers are discussed.

The Power Quality Directive of the National Energy Regulator of South Africa (NERSA) defines a framework for the management of power quality, which is applicable to its licensees (who are responsible for its implementation) and to customers served by these licensees [1]. The focus is on a management process that aims at improving the power quality management processes of South African utilities (licensees of NERSA), and the initiatives taken by customers of the design and operation stage of their plant in addressing the dip performance in the area of the network where the plant is connected.

One of the requirements of the directive is that utilities provide the regulator with details of the Power Quality Management System (PQMS) to be implemented. In the process of developing such a system, Eskom has undertaken a series of case studies based on its submission to NERSA [2] to test the value added to Eskom and its customers in the implementation of a PQMS utilizing web-based interactions and measured data from Eskom’s many power quality recorders currently connected in transmission and distribution systems.

**Voltage dip limits**

The application of voltage dip limits are intended to ensure that licensees meet minimum levels of voltage dip performance. Historically these limits were derived in South Africa from measurements conducted on a limited number of sites across a range of voltage categories [5]. The utilization of dip limits has the disadvantage of not accounting for the specific environmental conditions that a given measurement site is subjected to or the year-on-year seasonal variations that are inevitable for any given region. Studies show that dip performance can be dramatically different in different countries and regions, and hence harmonized limits cannot be defined internationally [6]. In the case of a customer plant (sensitive to dips) being connected to a relatively well-performing network, limits derived for "typical" networks may be inadequate (i.e. the number of dips may be much higher than those experienced – and there is no incentive for the utility to further improve on the existing performance, even if this is possible). A utility on the other hand, may be placed in a position where environmental conditions make it extremely costly to meet limits based on "typical" networks – and customers connected to these networks may in fact not even be sensitive to voltage dips. These issues gave rise to all stakeholders agreeing that for South Africa (with its very different environmental conditions and customer densities etc), dip limits were not a satisfactory approach to voltage dip management [7].

**Customer-utility interaction**

The philosophy on which the PQMS is based is one of interactive "continuous improvement" [1]. The framework within which this improvement takes place is one of open communication and a clear understanding of the responsibilities of each party within the management process.

**Role player responsibilities**

The responsibilities of the roleplayers within the PQMS are [2]:

**Utility responsibility** – The utility is not required to meet global voltage dip limits but to implement a quality management process focused on interaction with the customer and the causes of events that affect sensitive customers. The aim is to address such causes, or risk of such events, as and when they arise (in practice the nature of such fault causes changes from time to time).

**Customer responsibilities** – Customers are expected to focus on the manner in which power quality parameters impact the plant and this needs to be considered in both the design and operation of the plant. During operation this is based on taking reasonable measures to provide mitigation against voltage dips. The onus is thus on the customer to be educated about the plant requirements.

---

**Fig. 1: NRS-048 voltage dip window [3]**
and provide the required mitigation to ensure that minimum immunity level are met. These are defined in NRS-048 [3]. Fig. 1 illustrates the recommended minimum level of immunity of customer plant (i.e. Y-type voltage dips), and also additional desired immunity levels (X1-type voltage dips). The desired level is based on a recognition of the difficulty that some customers may find to mitigate such events (unless at greater cost), and also the fact that many voltage dips on actual networks fall into this area. It is the responsibility of a customer to weigh up the cost of implementing such immunity levels and the cost of not implementing these.

Equipment supplier responsibilities – A key problem identified by all stakeholders was that suppliers of equipment used in the processes used by customers, were often unable to provide information on the immunity of their equipment (e.g. variable-speed drives, contactors, etc.). The level of interaction between the utility and the supplier will result in the suppliers being required by their customers to provide dip performance characteristics (as well as mitigation options) for their equipment. This in turn will, from a dip performance point of view, better facilitate the evaluation of the technology that the customer will purchase.

Interactive communication

The emphasis within the PQMS is shifted away from the actual number of voltage dips measured at sites to the interactive communication of events and the impact of these events on the customer. This requires that the utility communicates the nature and causes of voltage dips recorded at the customer site and in return the customer actively identifies voltage dips that impact his plant and the magnitude of this effect (typically in financial terms).

The Eskom Quality of Supply database is ideally positioned to provide a platform on which such interaction may take place. The Eskom QOS database in its present form provides data on voltage dips, and the implementation of dip-to-tip matching on the database allows users of the database to identify and in many cases track the causes of voltage dips. This data, along with information provided by customers then provides for the open exchange of information that is required for successful implementation of the PQMS.

This opens up the requirement for a set of tools that promotes bi-directional communication between the customer and the utility. Currently customers already have web access to view the measured dip (and other power quality) performance.

PQMS tools

Wires performance information

Tools were identified to provide information on the network dip performance to customers as well as enabling Eskom as the utility to identify trends in voltage dip performance of networks feeding the customer. These tools are:

- Zone of sensitivity – listing of the circuits that affected the plant for the reporting period
- Zone of influence - cost impact breakdown for a selected circuit, for all customers impacted or for a given customer
- Ranking circuit and fault type breakdown - fault types (cost and frequency impact per circuit) that affected the plant for a given reporting period
- Circuit fault type trend
- Total circuit customer impact (economic) - total or average cost impact per circuit for all customers engaged in the IR process for a given reporting period
- Total circuit customer impact (nuisance) - frequency per fault type per circuit.

The above tools provide an overview of what circuits are impacting the dips measured at a customer site, the cause trends and the impact of these dips on the customer.

Customer plant immunity information

The aim of these tools are to provide customers with information that allows tracking of supply quality related cost impacts as well as a basis for decision-making on mitigation measures and specifications for new equipment. These tools are:

- Plant immunity profile – actual plant dip immunity profile based on historical performance data of events that impact on existing plant
- Plant immunity profile - benchmarked - modified plant immunity profile based on benchmarked or standard immunity
- Plant cost impact trend – 12 month moving average and monthly costs for plant under consideration

The wires performance and customer plant immunity information tools were matched against available data from the QOS database as well as information from customers and the following feedback was identified as the key feedback requirements for both the customers and Eskom:

- Count of dip cause trends
- Top 15 (dip causing/faulted) circuits vs. line group ownership
- Top 15 contributing circuits categorized per dip type
- Top 15 dip contributing circuits (excluding X1 and X2 dip types)
- Top 15 contributing circuits with associated fault causes
- Dip cause with associated line group
- Cost to customer per NRS window dip type (annually)
- Equipment vs. cost contribution
- Cost contribution for specific dip types (annually)
- Dip types with associated costs (phases dip specified)
- Cost of dips with unknown causes

Implementation pilot studies

Case studies were conducted to develop ‘best practices’ for the application of the PQMS as well evaluating the value added by the PQMS and the effectiveness of the feedback mechanism between Eskom and the customer.

The paper industry was selected as an industry within which to conduct these studies due to the positive feedback received from this industry on the PQMS. The process followed was to request data from the customer on events that affected plant production and correlate this data with events stored on the Eskom QOS database. This was done to get

![Fig. 2: Top 15 contributing feeders and associated causes.](image-url)
a historical perspective of the relevant events and their impacts.

Customer A – paper mill

Customer A is a paper mill which has issued Eskom with quality of supply complaints in the past. The customer’s perception was that Eskom is not taking adequate action to address their concerns regarding the Quality of Supply and specifically the dip performance at their plant.

The PQMS concept was introduced to the customer as a proposed solution to resolve the customer’s concerns around quality of supply. Role clarification for both Eskom and the customer was conducted. The customer was then asked to provide feedback on date and time of events as well as the plant impacted by these events. This was then used to analyse the relationship between network dip performance and the impact on the customer.

Fig. 2 identifies the two feeders which have the greatest impact on the dip performance for Customer A. Lines 1 and 2 had the greatest number of faults on them and the primary causes of these faults are storm related faults as well as faults with unknown causes. A concern that was highlighted during the analysis of the events was the high number of voltage dips with unknown causes.

The time of day in which a dip occurred was segmented into groupings of 3-hours and plotted. This was matched against fault patterns typical to thunderstorm caused faults as well as bird activity and pollution.

Fig. 2 and 3 illustrate some of the detailed analysis that is provided by the PQMS reporting on network performance.

The identification of Line 1 and 2 as the highest contributing feeders led to an aerial inspection of these lines that identified cases of: loose earth wire bolts (split pins); bird droppings and flash over marks; insulator flash over marks on loop in loop out feeder structure on top of escarpment; broken earth wire on single pole, double circuit structure on escarpment.

Fig. 4 identifies the voltage type dips that customer plant is sensitive to. This identifies the digester, certain subsystems identified as KLB and newsprint and uptake machines as having been affected by Y-type dips.

The feedback to the customer on the identification of the highest impact feeders, the underlying causes for voltage dips as well as the detailing of a plan of action to rectify these concerns was welcomed by the customer. The customer was placed in the position where he had free access to the information regarding the QOS to his plant and could query the analysis conducted, the decisions made and provide input into the need and type of action. The customer expressed great satisfaction at the level of detail included in the analysis and was satisfied that Eskom was adequately identifying his needs and concerns.

A benefit that became immediately apparent when conducting this study was that the detailed analysis on the network performance combined with the clear identification of events which impacted the customer led to a tool that assisted Eskom’s technical staff in the motivation of projects to improve performance on networks based on the impact to customers. This particular study initiated a motivation to improve the lightning protection and grounding on the identified feeders.

Customer B – platinum mine

Customer B is a platinum mine where the installation of bird guards failed to resolve the voltage dips measured at the customer point of common coupling. The customer complaint indicated that voltage dips persisted despite Eskom action to install bird guards to mitigate against vulture activity. This action did not result in an improvement in voltage dip performance on line 1 and created doubt amongst technical staff about the root cause of the voltage dips. There was uncertainty about the cause of the ongoing voltage dip problem and the PQMS framework was used to assess the unknown causes of the voltage dips.
Fig. 5 illustrates the large impact on line 1 due to unknown causes after the installation of bird guards.

Time of day analysis as illustrated in Fig. 6 indicated that the hourly voltage dip pattern corresponds to bird related faults. This finding identified that this specific installation of bird guards was not effective in mitigating the vulture streamer impact. Consequently a visual inspection concluded that the installation of the bird guards on line 1 was not done in accordance with Eskom design guidelines for such installations.

This case study illustrated the usefulness of PQMS as a tool to analyse the impact of projects conducted on the network to improve performance.

Lessons learnt from case studies

The following lessons were learnt from conducting the case studies:

- The PQMS methodology in its present state is a powerful tool for the identification of circuits affecting voltage dip performance at a site
- The PQMS methodology enables engineers to motivate for network projects on the basis of impact on customers
- The PQMS allows easy analysis of the impact of projects conducted on network performance
- The utility-customer relationship improves due to an understanding from the customer of the challenges facing the utility technical staff
- Interaction with the customer was shown to improve the confidence that the customer has in the technical staff dealing with his concerns.

Conclusions

A power quality management framework which formally focuses on “continued improvement” has significant benefits over one based on “minimum standards”. This has been supported by stakeholder opinions, as well as the reactions of large customers involved the case studies presented in this paper.

Acknowledgement

This paper was presented at the IEEE PES Power Africa 2007 conference and exhibition in Johannesburg, and in republished with permission.

References

[4] W.L. Vosloo, R.E. Macey and C. de Tourreil., The practical guide to outdoor high voltage insulators, Crown Publications, July 2004, Figure 11.12, page 177

Contact

Ulrich Minnaar, Eskom
ulrich.minnaar@eskom.co.za
Andrew Sprunt, Eskom
andrew.sprunt@eskom.co.za
Thinus Du Plessis, Eskom
thinus.duplessis@eskom.co.za
Robert Koch, Eskom
robert.koch@eskom.co.za
Dharmesh Bhana, Eskom
dharmesh.bhana@eskom.co.za