Power Quality Portal – a Practical Web Based PQ Management System

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***Abstract* — This paper analyse the current state of the South African Electricity Supply Industry (ESI) to motivate the importance of managing PQ on a daily basis. Different PQ Management role-players are then identified and their PQ management strategies discussed to derive the user requirement of a Southern African Power Quality Monitoring system. The paper then introduces a practical strategy on how to manage PQ Incidents and voltage waveform quality parameters. Finally the paper introduces the main features of a web-based PQ Management System.**

Keywords- PQ Management, PQ reporting, Online, NRS048,

I. INTRODUCTION

Eskom was founded in 1923 by the government of South Africa in terms of the Electricity Act (1922). The widespread proliferation of electrical infrastructure and an interconnected network comprising generation, transmission and distribution followed during the next four to five decades. The South African Electricity Supply Industry (ESI) is therefore relatively young but simultaneously contending with distribution equipment that are relatively old in terms of life-time expectancy, as it has never been replaced in some networks.

Unique operating conditions exists in South Africa:

- Eskom recently had to resort to load shedding to attain safe operating margins in meeting demand levels which cause, amongst others, additional electrical stresses in ageing equipment and switchgear.
- Modern loads are much more complex than the traditional loads these networks were designed for. Non-linear loading is growing commensurately with the higher power levels being controllable by solid-state technology..
- The Power Conservation Programme (PCP) caused a new emphasis on energy saving measures to be implemented by both the supply and user industry.

We now play a new game – who is watching?

Voltage magnitude (for one) is an important PQ parameter in an ageing power system due to its known impact on equipment availability. Risk management is further complicated as the ESI is experiencing a world shortage of distribution equipment resulting in long lead-times and excessive prices.

Limited visibility exists on the impact of poor quality and the importance of PQ management is therefore not recognised by most utility managers .

A minimum standard in the Quality of Supply (QoS) at all times at the output of every primary transformer in a distribution network will optimise the availability of distribution (and end-user) equipment. For example, distribution equipment already accounted for in terms of capital value represents an excellent opportunity to maximise return-on-investment (ROI) values by means of extending the useful service life as far as possible. The latter requires that the energy converted by these transformers be of better quality than minimum compatibility levels.

Good quality electricity is therefore as important to equipment as proper maintenance!

Many South African utilities have limited SCADA functionality in the support of power system operation. Valuable power system operational information is available from a PQ monitoring system if proper systems engineering practises are employed. These PQ monitoring systems are not as capital intensive as SCADA systems, are easy to install and easy to operate.

PQ Monitoring will never replace SCADA systems, but it does provide a low cost alternative where SCADA systems are not in place.

II. PQ MANAGEMENT STRATEGIES

The Southern African ESI can be divided into different categories. Each category has adopted its own strategy on how to manage PQ.

A. *Regulators*

Electrical energy is recognised as a major role-player in sustaining economic activities and stimulating new growth in a developing country/region such as South Africa. The role of the energy regulator is of strategic importance to these issues as it has to evaluate the performance of role-players in the ESI and use the results thereof in the formulation of policies to incentivise (or penalise) the ESI to achieve its desired national goals.

The electricity regulator traditionally requires annual submission of PQ statistics by licensees. This information is to be used in benchmarking the performance of licensees and to define characteristic values in PQ parameters on a national, regional and network-specific basis. Evidence thereof is not readily available.

To generate PQ performance information of practical value to business processes of licensees is not straightforward. The extent of the science and technology required to translate PQ data as recorded to useful information is easily underestimated.

It is first necessary to recognise that PQ data as obtained from field recordings is not press-ready.

Steady state network operating conditions can mask the "true" PQ performance of a licensee. Practical examples are shown in [1]. Voltage regulation (for one) can affect the recording of sags and swells at a site (set-point near a high or low value).

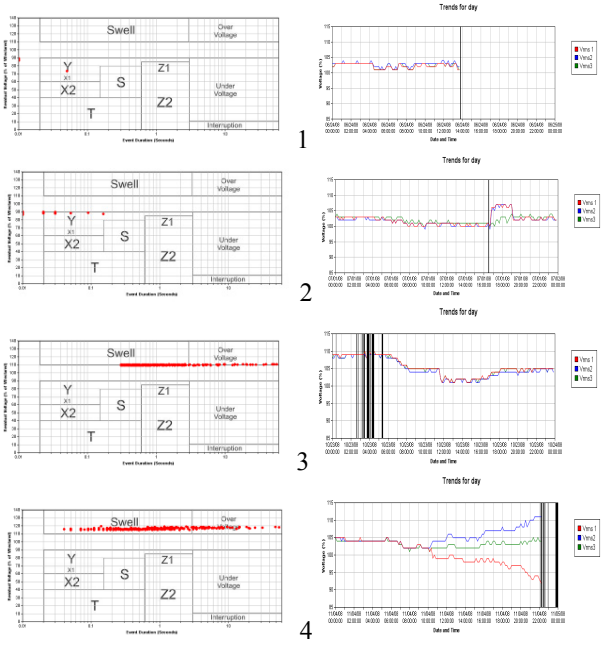


Figure 1. Daily 10 min voltages for sites involved in high event count incidents.

Other steady state operational conditions such as specific voltage unbalance conditions are also shown in Figure 1 to cause the recording of numerous sags.

Recognising that the "traditional" root cause of sags is network faults and that of swells the switching of network equipment and lightning, the flagging of data requires attention. Data acceptance evaluation is required and agreed-upon methodologies requires research and standardisation in order to generate PQ information that can be used to benchmark licensees against a national, regional and network dependent norm.

Regulators do require raw time-stamped Profile and Event data from each licensee to properly evaluate and benchmark the PQ performance of each licensee and not the statistics as currently the case.

PQ performance information is internationally shown to be an important contributor to a self-regulating PQ environment and the regulator could play a major role in facilitating access to such information. Regulators have to analyse the recorded data with the goal to publish annual PQ benchmarking statistics, to compile characteristic values (sags, swells and waveform quality parameters). This should be done for different type of networks for example as function of voltage level and geographical location. The regulator could also, from a national perspective, benchmark the performance of different utilities and indentify trends in development.

The above can be regarded as core services to be expected from the energy regulator in the acknowledgement of their responsibility to the national economy which relies on electrical energy at acceptable compatibility levels. Expertise needed for this service can then be hosted at the regulator, which allow local authorities (especially those with tight budgets) to rather focus on daily business such as maintenance and operation of electrical networks.

The regulator will have to support the utilities though by some extent with education and training in the use of PQ statistics to ensure it is of practical value.

B. *Eskom*

Eskom collects PQ statistics per region from a network of remotely installed instruments. They have developed powerful in-house PQ Reporting tools capable of compiling key performance indexes (KPI's) from the raw data. A PQ representative (expert) is appointed to oversee the management of PQ in each of their regions. PQ Management is a well established function within Eskom and PQ information is readily available throughout the organisation. It must be noted that Eskom is unique in its ability to be self-sufficient in the Southern African region.

C. *Regional Utilities*

Regional utilities like Nampower and Tanesco have installed PQ instrumentation at most of their load-centres. Although they do not require many instruments, they do require a high

level of diagnostic information to allow them to assess the origin and root-cause of each incident.

Regional utilities are plagued with PQ incidents as networks are exposed over large geographical areas. Regional utilities will typically appoint one or two PQ experts to investigate and manage PQ throughout the organisation. Broadband communication infrastructure and a central PQ database are required to collect and process data from remotely installed instrumentation. This database could disseminate PQ information throughout the organisation and to key customers by utilising the Internet.

D. Metros

Most Metros have a high voltage backbone with a few large primary transformers feeding each load-centre. A small number of permanently installed voltage quality instruments is required to monitor PQ and only a few roaming instruments is required to investigate complaints. Metros will typically appoint one or two PQ experts to investigate and manage PQ throughout the organisation.

Metros will experience a lower number of PQ incidents per month compared to regional utilities as they are located in a smaller geographical area. Communication infrastructure and a central PQ database are required to collect and process data from remotely installed instrumentation. This database could also disseminate PQ information throughout the organisation and to key customers by utilising the Internet.

Metros buy electrical energy from regional utilities which means that some PQ incidents could have an external origin. But, metros are both client and supplier. The PQ database must be capable of classifying the origin (internal or external) of a PQ incident and assign a root cause in order to actively manage PQ events. Transformers in metropolitan networks are in general loaded near rated capacity which means the cost associated to a PQ monitoring system is dwarfed by the revenue sustained by these primary transformers.

E. Smaller Municipalities

Unlike metros, most transformers within smaller municipalities are loaded to a lesser degree. Smaller municipalities mostly do not have a dedicated PQ management function. In many cases the amount of internal incidents is small compared to the amount of incidents imported from the supply network for many smaller municipalities being located at the end of long exposed rural lines. An outsourced business model could further the access to the similar resources and expertise in PQ management as found in the bigger utilities.

F. End-Users

Some end-users monitor both voltage and current of supply points and act upon an alarm if a deviation from the norm is detected. They can investigate and record the impact (technical and financial) of each PQ event. An annual report on the frequency, type of events and consequences will help to understand and identify sensitive equipment and possible mitigation procedures. A healthy relation between supplier and user is as a powerful PQ mitigation tool with less requirement on expensive PQ mitigation equipment to be installed locally.

III. PQ MANAGEMENT PHILOSOPHY

Little business integration of power quality management (PQM) is forthcoming amongst electrical utilities in Southern Africa. Restricted access to proper PQ information is the main reason. An integration of tools, procedures and people is required by an electrical utility to be operational in management of the quality of electrical energy. A Web-based PQ Management system can continuously disseminate PQ information extracted from data recorded at numerous sites distributed all over an electrical network in near real time. The time-value of information is thus exploitable.

A. Managing PQ Incidents

Events simultaneously recorded by several instruments on the same network could be attributed to a common network incident. All measured events within a small time window are automatically assigned by the PQ portal to a single network incident.

The PQ engineer will have to investigate the origin, root cause and impact of each incident as and when it happens (on Ad Hoc basis) regardless of its depth or duration.

The result should be visible throughout the organisation. Employees and managers must gain visibility on the impact of each incident to take corrective or preventative measures.

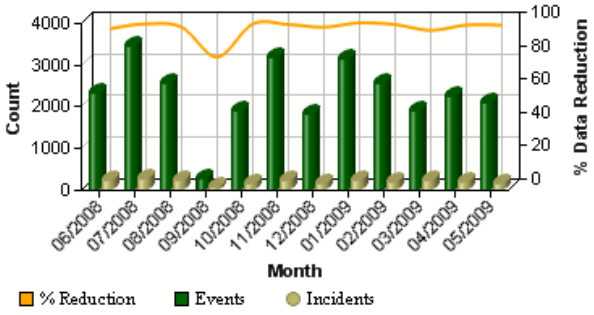


Figure 2. Number of events and incidents per month, as well as the data reduction obtained by matching events to incidents

B. PQ Incident Management Tool Requirements

Recorded data has to be scrutinised for PQ events recorded within a pre-defined time window as it most possibly represent the same PQ incident. Detailed information on each incident must be made available in a reporting format in near real time. Alarms need to be raised to notify the engineer on occurrence of a network incident. PQ Incident management tools must have the capability to report on and rank incidents according

to root cause and origin to assist engineers to take ownership of internal incidents and to prioritise the problem areas.

C. *Managing Trended PQ Parameters*

The NRS048 documents define the limit and compatibility assessment methods for PQ parameters such as voltage regulation, THD and voltage unbalance. Each utility might have internal operational requirements for example in the lowering of the magnitude of voltage to residential customers to adjust the energy demand at specific times of the day.

The PQ engineer have to assess the 7-day sliding 95% CPF values on a daily basis to determine NRS 048 compliance and then to pro-actively implement corrective or preventative action.

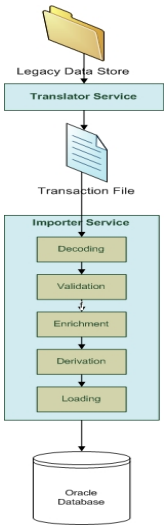
Findings must again be made visible throughout the organisation to inform employees and managers on the impact of corrective or preventative actions (to learn from both mistakes and successes).

D. *PQ Trend Management Tool Requirements*

A daily PQ Assessment Report assists the engineer in identifying compliance issues. Subtle deviations from the norm must be identified. Visibility of these deviations assists the engineer in investigating and understanding the underlying parameters controlling the trends. Equipment adjustments and operational changes can be implemented to prevent exceedance of limits. Numerous reports on each parameter are required to assist the engineer to understand and identify the influence of different parameters on each other.

IV. POWER QUALITY PORTAL

Empowering people with appropriate tools and procedures in Power Quality Management by the creative application of modern technology is the goal of a web-based PQ Management system hosted at www.pq-portal.com. This virtual portal was developed to continuously disseminate PQ information extracted from data recorded at different sites in near real time.



An overview of the automated services of this PQ portal follows below.

A. *On-Line Communication Network*

Most of the management value of PQ information is lost if the data is not available in near real time. An on-line data retrieval system is required to accumulate recorded PQ data into a central database in near real time.

B. *Importation of Data*

PQ data as obtained from field recordings is not press-ready. Normal operational criteria must be defined upfront and all data to be imported must be evaluated against pre-defined criteria before being accepted. For example, if a VT fuse is blown, one line voltage will be zero and voltage unbalance will be at 100% which is impossible for normal power system operation. The data importer will reject such data unless forced otherwise and motivated by the operator. By rejecting data according to pre-defined criteria representing normal operational conditions, the generation of false alarms and misleading statistics are minimised.

C. *Enrichment of Data*

PQ Instruments store the minimum data to save disk space and to minimise data traffic between the instrument and the database. The database enriches the recorded data by additional information to be derived such as the voltage profiles in a % of the declared voltage. Another example is the derivation of three-phase power factor based on the recorded power per phase.

D. *Calculation of daily 95% CPF values*

The 7-day sliding 95% CPF values for each of the profiled parameters at the end of each 24 hour period is calculated from the recorded data and added to the database.

E. *Grouping of Events to Incidents*

The probability that more than one network incident occurs within a small time window is low. All PQ events as recorded at different instruments (and locations) and that have been time-stamped within a pre-defined time window are grouped together to indentify the occurrence of a network incident possibly causing these events. In the unlikely event of more than one (and different) incident automatically being grouped together, the operator has the ability to intervene and re-group. Incidents are classified according to two criteria:

- Origin of Incident (Internal, External or Unknown
- Root Cause of Incident (Lightning, Equipment Failure, Theft, etc)

An alternative application of the NRS 048 scatter plot on sags and swells reveals powerful information on the nature of a PQ incident form a system perspective. Plotting all PQ events

associated to a single PQ incident (regardless of voltage level) onto the same scatter diagram visually reveals the system impact. The penetration through the network is easily understood and the origin of the dip as being internal or external could be deducted (from voltage data only) with much more ease than studying each and every recorded event in detail which is more labour and experience intensive.

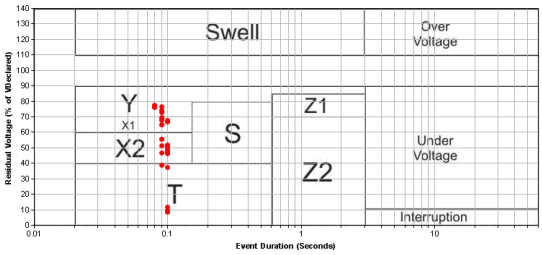


Figure 3. Dip scatter plot showing visual fingerprint for dip source internal to utility's network.

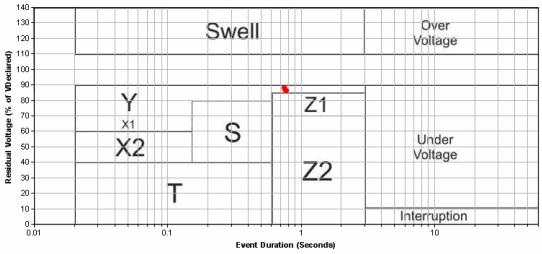


Figure 4. Dip scatter plot showing visual fingerprint for dip source external to utility's network.

F. Generation of Reports

The standard NRS 048 reports per recording site can be generated with a few mouse clicks and exported to various electronic formats. The PQ portal adds additional value in terms of informative reporting. Custom-made reports to support daily business processes, for example, is a mouse click away. A daily assessment report on the PQ performance of a pre-definable region is valuable in pro-active management of a power system. Not only PQ events that have occurred during the past 24 hours are extracted from the database, waveform quality parameters depicting compliancy to voltage magnitude, unbalance, distortion and flicker is valuable in the continuous assessment of operational status of the power system under consideration.

G. PQ Benchmarking

Benchmarking the PQ performance of sites against each other and against NRS 048 compatibility norm in terms of the power system as a whole, do not require a PQ expert as the expertise is already built into the PQ portal. Similarly, generation of the NRS 048 annual report that put a premium to the internal human and technical resources at a utility is a mouse click away.

H. Custom Branding

The PQ web portal can host multiple Service Providers simultaneously. Each utility can request a unique URL that can be linked onto their existing website (e.g. www.pq-portal.com/ekurhuleni). The top banner as well as the centre frame of this landing page is customisable. Public domain PQ information items such as the annual PQ report, the PQ Charter, the NERSA dispute procedure and local contact details can be published on this site.

V. CONCLUSION

The management of PQ has become a priority in both supply and demand side markets.

The economic benefits to be realised is significant, but is not widely recognised due to a lack of knowledge and leadership!

PQ engineers and managers in South Africa are still inexperienced regarding the operation and implementation of PQ Management programmes.

Powerful tools are available, but proper training and on-going mentorship from industry experts is mostly required.

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