Eskom
Quality of supply
The means to safe, reliable and sustainable operations
Causes, effects and solutions for poor electrical quality of supply in power systems

Provision of electricity supply

In today’s global society the importance and necessity of electricity as part of everyday life can’t be underestimated. Electricity is the driving force behind various fields of human activity: engineering, communication and transport, entertainment, health and more importantly it fuels technological development and transformation. It is almost impossible to imagine life without electricity.

It is therefore important to have a look at electricity power quality. Wikipedia describes electric power quality as follows: “Electric power quality or simply power supply quality involves voltage, frequency and waveform. Good power quality can be defined as a steady supply voltage that stays within the prescribed range, steady AC frequency close to the rated value, and smooth voltage curve waveforms (resembles a pure sine wave) without the proper power an electrical device (or load) may malfunction, fail prematurely or not operate at all.”

However it is impossible to provide or guarantee a completely disturbance-free and uninterrupted electricity supply in the real world. The reliability and quality of supply varies in different parts of any electrical system. Individual customers may experience more or fewer than the average number and duration of interruptions and disturbances. In most cases, equipment and appliances will function as expected however, electricity supply conditions or the quality of supply (QOS) that might cause problems or unsatisfactory performances may exist. It is essential that facility owners are aware of and respond to these factors before making commitments to purchasing any equipment or altering installations.

Objective

The objective of this fact sheet is to inform and educate the public at a high level about electricity power quality. The misconception is that good power quality means a perfect wave form and/or uninterruptable power supply.

The definition of supply in power systems

Causes, effects and solutions for poor electrical quality of supply

Power interruptions: Power interruptions are microsecond events and are typically short durations lasting less than 30 seconds long in transmission and distribution networks. Customers may experience more or fewer than the average number and duration of interruptions and disturbances. In most cases, equipment and appliances will function as expected however, electricity supply conditions or the quality of supply (QOS) that might cause problems or unsatisfactory performances may exist. It is essential that facility owners are aware of and respond to these factors before making commitments to purchasing any equipment or altering installations.

Quality of Supply (QOS) therefore refers to all disturbances in the supply and consumption of electricity and is classified in various parameters as set out in the following section.

The causes and effects of a non-conformance in electrical quality of supply

Voltage sags or dips in voltage

Voltage sags or dips in voltage are a short-term reduction in voltage that is 4% of nominal voltage. Voltage sags (or dips) are non-repetitive as they last only a few times.

Voltage dips cause problems only if voltage is zero (i.e. interrupted). Voltage sags are more likely caused by capacitor switching. Equipment failure or damage, system lock-up, data corruption, data loss, etc.

Source: http://www.st-ingegneria.com

Power factor: Power factor is a measure of how efficiently electrical energy is delivered to an electrical load. Power factor is defined as the ratio of the actual real power to the product of voltage and current. Power factor is caused by inductive loads such as motors and transformers (proportional to load). Negative power factor is caused by capacitive loads (similar to Power Factor below).

Voltage flicker is rapidly varying voltage sag.

Voltage flicker is most commonly caused by equipment switching loads, large increases in load currents, transformers and motors (especially at low loads). Voltage flicker is caused by capacitor switching. Equipment failure or damage, system lock-up, data corruption, data loss, etc.

Sensitivity exhibited by human visual system when subjected to luminance variations emitted by lamps. Besides the visual perception, flicker can disrupt control systems. Equipment failure or damage, system lock-up, data corruption, data loss, etc.

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Problems

Description

Examples

Impact

Source

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Perfect power quality of supply (QOS)

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Perfect power quality of supply (QOS)

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Perfect power quality of supply (QOS)
**Power surges:**
A power surge is a high energy electrical event on the network that lasts for about two nanoseconds or less. During power surge damage, HVAC systems, appliances and electronics can be damaged. To protect electronic equipment, prevents components from being damaged due to over-voltage. To prevent damage, use surge protectors.

**Vacuum:**
Vacuum tubes are commonly used in telecommunications and radio frequency applications. They are less susceptible to interference (RFI) and electromagnetic interference (EMI). They are used in applications where high-voltage spikes and surges are not an issue.

**Frequency variation:**
A frequency variation occurs when a change in frequency occurs on the grid. This can cause problems with electronic systems, appliances and electronics. The voltage on the grid may vary from the nominal voltage, which can cause problems with electronic devices.

**Electricity loss rate:**
Electricity loss is defined as a ratio of kilowatt-hour (kWh) energy received by the end-user to kWh energy delivered to the end-user. This can be caused by various factors such as electricity theft, equipment failure, and installation issues.

**Smart meters:**
A smart meter is a device that monitors electricity usage and provides feedback to customers. This can help customers reduce their electricity consumption and lower their electricity bills.

**Impact of the above:**

<table>
<thead>
<tr>
<th>Description</th>
<th>Cause</th>
<th>Effects/Impact</th>
<th>Typical wave diagram</th>
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<tbody>
<tr>
<td>Blackouts</td>
<td>A power failure or blackout is caused by a power failure on the grid that lasts for more than two electrical cycles.</td>
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**Electrical:**
- **Power factor:** Power factor is a measure of how efficiently electrical energy is used. A power factor of less than 1 indicates that energy is being wasted.
- **Harmonics:** Harmonics are caused by switchgear, static equipment, fault clearing devices, static electricity, lightning, switching impulses and spikes.
- **Thermal:** High neutral currents, overheated neutral conductors, overheated transformers, voltage distortion and loss of system capacity. Causing these problems is the result of the grid's inability to handle the load. Damage to electrical equipment, loss of profits and increased costs.

**Impact of poor maintenance:**
- High maintenance cost.
- Damaged equipment.
- Wastage of electrical energy.
- All the aforementioned may be due to incorrectly sized equipment, incorrect installations and poor QOS.
The impact of a non-conforming QOS

A poor QOS can reduce the speed and quality (increased repair time) of production in businesses, as a buffering of downtime equipment, affect the electrical power infrastructure and supply stability and voltage fluctuations can disastrously impact production. Extended outages have a much greater impact.

The impact of the embedded generation equipment, such as renewable generation equipment and UPS

Some forms of renewable energy have elements of instant uncontrollability at various levels such as wind speeds for wind turbines, water levels for hydro and cloud cover for Photovoltaic (PV) plants. The output of PV systems, which cover the majority of renewable energy sources (inverters, converters, etc) add further QOS issues which need to be factored in their design.

With the increased penetration of embedded renewable generation systems, specifically Photovoltaic (PV) and Wind generator systems, the safety and the operation of power supply infrastructure will be greatly affected and will be vulnerable to rapid outages, specifying that they require power quality protection circuits to increase the level of protection they offer.

The output of PV systems, which cover the majority of renewable energy systems in the market, is directly related to the intensity of the sun on the solar panels, where the intensity is greatly influenced by cloud cover and shading. The intensity of sunlight can be influenced by cloud cover, and this can affect the electrical power infrastructure and supply stability.

The general steps associated with investigating the QOS problems and effects, each having different capabilities, strengths and weaknesses:

1. Surge suppressors: A surge suppressor is often used to shield important, but less critical or highly sensitive equipment from voltage surges and sags. It is also used to complement line conditioning and voltage protection devices to increase the level of protection they offer.

2. Voltage regulation/conditioning: A voltage regulator may be referred to as a ‘power conditioner’, ‘line conditioner’, ‘voltage stabiliser’, etc. Regardless of the terminology used, these devices are essentially the same in that they provide additional regulation and/or protection of electrical power-related functions. A voltage regulator can also perform voltage regulation and filtering functions to the stand-by UPS and emergency lighting in case of a blackout. However, they are commonly used to limit harmonic distortions to the levels detailed in standards, recommendations (IEEE 519) and regulations. Power factor correction can be done by using equipment that absorbs or supplies reactive power to the AC circuit. Generally, these devices are designed to correct level of power factor and/or the drop in wind speed could result in a total, or a large percentage of a renewable system.

3. Uninterruptible power supplies (UPS) - three basic types of UPS exist:

1. Standby (or off-line): The standby UPS is the simplest of a UPS system and is essentially a line conditioner, which absorbs or supplies reactive power to the AC circuit. Generally, these devices are designed to correct level of power factor and/or the drop in wind speed could result in a total, or a large percentage of a renewable system.

2. Line interactive: Line interactive UPSs are hybrid devices which offer a higher level of performance by adding better voltage control and more protection circuits to increase the level of protection they offer.

3. Double conversion (or online): Double conversion UPSs exist, which have different levels of power protection and are an ideal choice for shielding the equipment performance. The most expensive solution is however not always the right solution for the problem. Both correct identification of the problem and the customer needs should be identified and addressed in order to achieve accurate assessment.

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Systems. Shunt active power filters compensate load current for reactive power compensation in power transmission similar to that of a static compensator (STATCOM) used for harmonic elimination. Active power filters can be targeted.

7. Active power filter

Active power filters (APF) can perform a series of inductors and capacitors to filter harmonic frequencies generated by the drives and supply equal amounts of harmonic current in phase to the generated harmonics. These causes output, resulting in an acceptable level of harmonics. One of the greatest benefits of these units is that they are controlled and current limited and will not exceed their thermal limits.

This means that if the harmonics should increase, the inverter will not affect, although it might not reduce all of the primary harmonics. Some active units provide a broad adjustment over four or five harmonic frequencies whilst others allow individual frequencies to be targeted.

7.1 Shunt active power filter

Shunt active power filters are general purpose shunt filters that can be used to compensate for a variety of load characteristics. They are designed to cancel current harmonics and compensate the load kVA rating, typically 5%. However, the apparent power rating of the series active power filter may increase in case of voltage compensation. Hence, series active filters work to compensate the voltage harmonics on the load side. Series filters can also be useful for fundamental voltage disturbances. The series filter during oscillating supply voltage drop keeps the load voltage almost constant and for small instabilities and oscillations are observed during initial and final edges of disturbances.

Basic compensation principle: A voltage source inverter (VSI) is used as the active power filter which contains all of the circuits to measure the actual current and the compensating current (Ic) from or to the utility, such that it cancels voltage harmonics on the load side, i.e. this active power filter compensates currents. In this case the shunt active power filter is controlled so as to draw or supply a compensating current, which is opposite to the current harmonics, reactive power and load current unbalances. In addition, it regulates the DC link capacitor voltage. The power supplied or absorbed by the series compensator and the power required by the series compensator and the power required to cover losses. General UPQC consists of the combination of a series active and shunt active filter. The main purpose of the series active filter is harmonic isolation between a sub-system and distribution grid. In addition the series active filter has the capability of voltage flicker/intermittence compensation as well as voltage regulation and harmonic compensation at the utility-consumer point of connection. This means that the shunt active filter is to absorb current harmonics, compensate for main power and regulate reactive current, and regulate the DC link voltage between both active filters.

Since renewable energy forms part of the energy mix on a network, various methods are developed to deal with quality of supply issues. Some methods are technology orientated and some just a means of responsible connection methods.

In the case of renewable energy the following should be done to improve QoS

Aggregators: Where PV systems are connected to the same power grid, a coordination of generation and absorption among each other is required. This is done in a way such that the same weather conditions do not affect all PV systems at the same time. Moreover, the information from the PV systems can reduce fluctuations in the grid. Coordination criteria: Interconnection requirements need to be stipulated to ensure a smoother integration of PV systems on a network. Specific criteria for renewable energy at distribution grids by limiting its rise in voltage due to high solar irradiation, thus assisting in higher PV penetration levels. Smarter inverters are able to engage a smart grid to varying a preferred characteristic curve and avoid wake effects in mid-frequencies or to use battery storage to reduce fluctuations in the generated load. Interconnection requirements need to be stipulated to ensure a smoother integration of PV systems on a network. Specific criteria for renewable energy at distribution grids by limiting its rise in voltage due to high solar irradiation, thus assisting in higher PV penetration levels. Smarter inverters are able to engage a smart grid to varying a preferred characteristic curve and avoid wake effects in mid-frequencies or to use battery storage to reduce fluctuations in the generated load. Interconnection requirements need to be stipulated to ensure a smoother integration of PV systems on a network. Specific criteria for renewable energy at distribution grids by limiting its rise in voltage due to high solar irradiation, thus assisting in higher PV penetration levels. Smarter inverters are able to engage a smart grid to varying a preferred characteristic curve and avoid wake effects in mid-frequencies or to use battery storage to reduce fluctuations in the generated load.
General measures to improve QoS:

- **Connective criteria:** To ensure quality of supply both the utility and the customer have grid connection obligations in meeting the set parameters in terms of Voltage dips, Frequency, Voltage harmonics and waveform. All electricity generation needs to adhere to the NERS 142-0-1 standard and is incumbent on the designer or customer to take into consideration in the design and specification of the facility. The customer’s obligation is to not interfere with an efficient and economical supply to other customers of Eskom by adhering to the harmonics (IEC61000-3-3) for inverters larger than 4.6kVA must be balanced three phase and the number of voltage changes which must not exceed the limits set out and stipulated in the standards mentioned.

- **Smart grids:** A smart grid is an electrical supply network that uses digital communications technology to detect and react to local changes in usage, has the ability to change the uncontrollability of some customers to control their electrical usage and to interface and communicate with appliances. 

Metering and monitoring, identifying, QoS issues

Rower quality monitoring and assessments vary according to the type of facility and the equipment being used. The following provides some guidance on how to go about assessing or monitoring the power quality.

Rower quality monitoring is the process of gathering and interpreting raw power measurement data into useful information. It involves, over a period of time, process of measuring voltage and current of the supply and examining its waveform, although the analysis is not limited to these two quantities. It includes inspection of wiring grounding and equipment connections. The monitoring of power supply helps to detect present and potential power quality problems. Power quality monitoring helps to improve facility power quality performances. Power utilities should ensure that the quality of power supplied is within specified and acceptable standards and be ready to normalise any technical issues that affect the quality of power delivered. However, the latest advances in electronic communication technology offers opportunities for monitoring and metering all sizes and complex power systems in an efficient manner. Facility owners and stakeholders can use this advantage to collect data on different parts of power networks, assess the performance of the system and respond accordingly.

Good power monitoring instruments provides useful information while then enabling solutions to QoS issues.

- **Disturbance analysers** can measure a wide variety of power disturbances from very short duration transient voltage to long duration undershoots and swells.

- **Oscilloscopes** measure voltage and current and can display multiple levels of information on each power quality parameter including harmonic power flows, flickering, sag and swell.

- **Digital Fault Recorders** trigger on fault events and provide accurate, reliable and fast alarm detection and second part focusing on statistical analysis of the behaviour of the set lamp-eye-brain and the average human eye and brain observation. It has special analysers which models the chain of (flickering) level of voltage flicker annoyance. Flicker meters are measuring devices to evaluate the performance of the system and respond accordingly. These include:

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- **Power Quality Meters and Analysers** is an instrument similar to an oscilloscope but more suitable and more versatile for a power quality monitoring. It can measure frequency, voltage, current, phase rotation, apparent and real power (Power Factor), harmonics and can also record and store the measured data and analyse it with PC software.

High maintenance, equipment or electricity bills

Generally, 5 main QoS-related actions can be undertaken to reduce high maintenance, equipment, or electricity bills.

- **Understanding the facility equipment loads and needs.**
- **Improving the equipment power factor.**
- **Protecting managing or unplugging electronic devices.**
- **Investigating the latest technology and process developments, like free cooling and heat-pumping.**
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Eskom’s Energy Advisors, in regions across South Africa, offer advice to business customers on how to optimise their energy use by:

- Understanding their energy needs
- Understanding their electrical systems (including QoS) and processes
- Investigating the latest technology and process developments, like free cooling and heat-pumping
- Analysing how to reduce energy investment costs
- Optimising energy use patterns in order to grow businesses and industries

Call 0860 37 3704. Leave your name and number and request that an Eskom's Energy Advisor in your region contacts you. Alternatively, e-mail an energy advisor as part of the team that the business selects.

Eskom’s role is to aid the client with basic information in the decision-making process. Thereafter the Eskom Advisor will fulfil the role of energy advisor as part of the team that the business selects.

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