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Power Quality Problems, Effects and Solution Techniques in Electrical Power System

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***Abstract*: Power quality is an issue that is becoming increasingly important to electricity consumers at all levels of usage. Sensitive equipment and non-linear loads are common place in both the industrial and domestic environment and disturbances can originate from these loads which includes non-linear loads like adjustable speed drives, traction drives, starting of large induction motor etc., typical power quality disturbance are voltage fluctuation, flickering, sag, swell, spikes in waveforms, harmonic distortion and unbalance. This paper reviewed the power quality problems, effect of power quality problem in different apparatus and methods for its correction.**

***Keywords*: Frequency variation, Harmonics, Power Quality, Voltage spikes, and voltage sag.**

1. Introduction

Power Quality related issues are of most concern now days. The widespread use of electronic equipment, such as information technology equipment, power electronics such as adjustable speed drives, programmable logic controllers, energy-efficient lighting etc. led to a complete change of electric loads nature. These loads are simultaneously the major causers and the major victims of power quality problems [1]. The types of Power Quality problems that a customer may encounter classified depending on how the voltage waveform is being distorted. There are transients, short duration variations (sags, swells and interruption), long duration variations (sustained interruptions, under voltages, over voltages), voltage imbalance, waveform distortion (dc offset, harmonics, inter harmonics, notching, and noise), voltage fluctuations and power frequency variations. Among them, three Power Quality problems have been identified to be of major concern to the customers are voltage sags, harmonics and transients. This paper is focusing on these major issues.

2. Power quality

Power quality is defined as 'Any power problem manifested in voltage, current, or frequency deviations that result in failure or mis-operation of customer equipment' while poor power quality can be defined as any event elated to power system network that actually results in financial loss [2]. The term is used to describe electric power that drives an electrical load and the load's ability to function properly.

3. Power quality analysis-information and standards

The quality of electricity has become a strategic issue for electricity companies, the operating, maintenance and management personnel of service sector and industrial sites, as well as for equipment manufacturers, for the following main reasons:

- The economic necessity for businesses to increase their competitiveness.
- The wide spread use of equipment which is sensitive to voltage disturbance and/or generates disturbance itself.

4. Power quality issues

In an electrical power system, there are various kinds of PQ disturbances. Some of the most common power supply problems and their likely effect on sensitive equipments are:

A. Variation

The common problems of voltages have to do with their magnitudes. Voltage variation is deviation from nominal voltage value which can be for a very short duration (millisecond to seconds) or long duration (longer than one minute). Short-duration voltage variation mostly occurs as dips or sags, spike or surge, swells, while long duration voltage variation occurs as flicker (voltage fluctuation), under-voltage, overvoltage, and interruption. These cause the line voltage to go higher or lower than the nominal voltage magnitude for certain period. Voltage variations occur as result of faults on the transmission or distribution network, switching of capacitive loads, loading problems.

B. Voltage Sag (a dip)

Voltage sag is reduction in rms nominal voltage for short period of time. Voltage dip occurs when the supply voltage falls within 0.1 to 0.9 pu of the nominal voltage for period of up to one minute. It is caused by fault on the line, starting of electric motor or switching of heavy load, excessive loading etc.

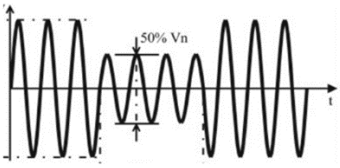

Fig. 1. Voltage sag

C. Voltage swells

Momentary increase of the voltage at the power frequency outside the normal tolerances with duration of more than one cycle and typically less than a few seconds. The main causes are Start/stop of heavy loads, badly dimensioned power sources, badly regulated transformers (mainly during off-peak hours). Consequences are data loss, flickering of lighting and screens, stoppage or damage of sensitive equipment, if the voltage values are too high [3].

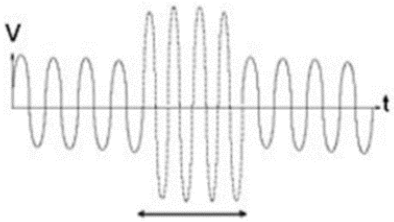

Fig. 2. Voltage swell

D. Voltage fluctuation

Oscillation of voltage value, amplitude modulated by a signal with frequency of 0 to 30 Hz. Causes are arc furnaces, frequent start/stop of electric motors (for instance elevators), oscillating loads. Most consequences are common to under voltages. The most perceptible consequence is the flickering of lighting and screens, giving the impression of unsteadiness of visual perception.

E. Voltage spikes or surge

Voltage surge is similar to voltage swell but it is very high increase on the nominal voltage usually for very short duration. It is usually caused by lightning strikes, arcing during switching operation on circuit breakers and contactors, switching surge or transient.

F. Harmonics

Harmonics are AC voltage and current integral multiples of the supply fundamental frequency. For instance, in a 50Hz system, a second harmonic is 2× 50 = 100Hz, third harmonics is 3 × 50Hz = 150Hz while the seventh harmonic is 350Hz. Inter-harmonics are frequencies that are not integer multiples of the fundamental power frequency.

When harmonics and fundamental frequency are added together, it results in single distorted waveform. Normally in a three-phase system, only odd harmonic occurs (3rd, 5th, 7th etc.) [4].

Harmonic frequencies in the power systems are common cause of power quality problems. Harmonics distorts current and voltage waveform of the supply. Causes of harmonic are usually nonlinear electric loads which include UPS, rectifier, inverter, variable drives, arc furnace, welders, voltage controller, and frequency converters [5].

In fig. 3, the green waveform shows the normal ac voltage at 50Hz which is sine wave or sinusoid. The smaller waveform at 150Hz is the third harmonic. Its presence, combined with normal sine waveform to make the operating voltage waveform to be distorted as shown in the figure.

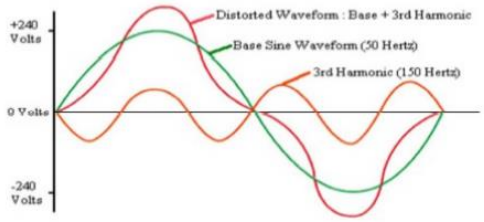

Fig. 3. Harmonic

G. Frequency fluctuation

Frequency variation or fluctuation is deviation of power system frequency from acceptable standard nominal value (usually 50 or 60Hz). At any time, power generation on power system should be equal to power demand, if there is more demand than generation the frequency tends to drop but if demand is less than generation, frequency tend to go higher. Fault on transmission line, disconnection of large load, shutting down or going off of large generator may also result in frequency fluctuations. Frequency fluctuations outside tolerance value of ± 5% is not healthy for power system which may lead to system collapse.

H. Supply interruptions

Instability of or epileptic power supply is still major socioeconomic concern particularly in the developing countries. In fact, it is the major power quality problem in these countries. This is due to acute shortage in the grid to meet electricity demand, occasioned by lack of adequate investment in the power sector. Aging power facilities and poor maintenance of the existing ones contribute in no small measure to power quality problems.

5. Effect of Poor Power Quality

The effect of power quality problem is distortion in voltage waveform of the supply from sinusoid, or deviation from its nominal value or complete outage. Power quality problem can last for milliseconds to up to hours. The nonlinear load characteristics of several power electronic, domestic, industrial office equipment connected to electric power supply could cause electrical disturbances leading to poor power quality. Equipment such as photocopier, computer, printer etc. can produce electrical disturbance that can destroy certain sensitive equipments.

6. Regulating Standards on Power Quality

There are quite a number of professional standard organizations for power quality while many are national body, few are transnational. The most widely accepted standards are International Electro technical Commission IEC and Institute of Electrical and Electronics Engineer IEEE. These standard organizations provide the minimum benchmark required,

acceptable technical practice and gives recommendation on electrical and electronic technical issues. Table 1 provides recognize international standard on specific power quality issues.

Table 1
IEC and IEEE Standard on power quality issues

Power quality issues	Appropriate Standards
Voltage sag/swell	IEC61000-4-11, IEC 61000-4-31, IEEE P1564
Flickers	IEC 61000-2-2, IEEE P1453
Harmonics	IEC SC77A, IEEE 1346, IEEE SA-519-2014
PQ test, Measurement and monitoring	IEEE 1159, IEC SC77A/WG9, IEC 61000-4-1, IEC 61000-4-30

7. Power quality solution techniques

The mitigation of PQ problems may take place at different levels: transmission, distribution and the end use equipment. As seen in Fig. 4, several measures can be taken at these levels.

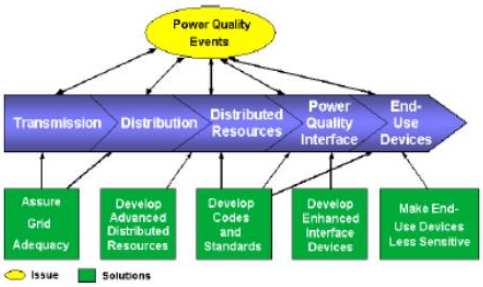

Fig. 4. Solutions for digital power

A. Grid adequacy

Many PQ problems have origin in the transmission or distribution grid. Thus, a proper transmission and distribution grid, with adequate planning and maintenance, is essential to minimize the occurrence of PQ problems.

B. Distributed resources– energy storage system

Interest in the use of distributed energy resources (DER) has increased substantially over the last few years because of their potential to provide increased reliability. These resources include distributed generation and energy storage systems. Energy storage systems, also known as restoring technologies, are used to provide the electric loads with ride-through capability in poor PQ environment.

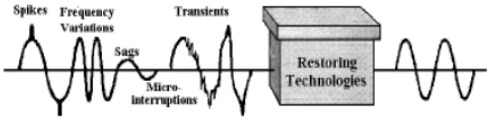

Fig. 5. Restoring technologies principle

C. Distributed resources – distributed generation

Distributed Generation (DG) units can be used to provide clean power to critical loads, isolating them from disturbances with origin in the grid. DG units can also be used as backup generators to assure energy supply to critical loads during sustained outages. Additionally, DG units can be used for load management purposed to decrease the peak demand.

The most common solution is the combination of electrochemical batteries UPS and a diesel gen-set. At present, the integration of a flywheel and a diesel gen-set in a single unit is also becoming a popular solution, offered by many manufacturers.

D. Enhanced Interfacing devices

Besides energy storage systems and DG, some other devices may be used to solve PQ problems. Using proper interface devices, one can isolate the loads from disturbances deriving from the grid.

1) Power Conditioning equipment

Several types of power enhancement devices have been developed over the years to protect equipment from power disturbances. The following devices play a crucial role in developing an effective power quality strategy.

1. Transient Voltage Surge Suppressors (TVSS)
2. Filters
   - Noise
   - Filters
1. Harmonic Filters
2. Isolation Transformers
3. Voltage Regulators
   - Tap Changers
   - Buck Boost
   - Constant Voltage Transformer (CVT)
1. Dynamic Voltage Restorer
2. Uninterruptible Power Supply (UPS)
   - Off-Line UPS (also called Standby)
   - Line-Interactive UPS
   - True On-Line UPS
1. Motor-Generators Set
2. Static Var Compensators (SVCS)
3. Thyristor-Based Static Switch
4. Unified Power Quality Conditioner (UPQC)

2) Energy Storage Systems

Energy storage systems are:

1. Flywheels
2. Super-capacitors
3. Superconducting Magnetic Energy Storage (SMES).

8. Conclusion

This paper has properly expatiated what power quality is. It pointed out the causes of power quality problems as inadequate grid, voltage variations/deviation, frequency fluctuations and waveform distortions. The effect of power quality problems include inefficiency, overheating and shortening service-life of equipment, loss of data, process interrupt, insulation breakdown. While, it is not feasible to completely eliminate the causes, the quality of power supply can be improved and the remaining effect in the supply can be mitigated by the use of power quality improving devices (tap changing transformer, lightning arrestor, SVS), use of filter to block harmonics, as

well as proper grounding of electrical installations.

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