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A Review of Power Quality issues in Electrical power system

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Abstract: Now a days the use of power electronics devices is increased and hence the power quality monitoring is essential. The PQ monitoring mainly includes the electrical disturbances like harmonics, sags, swells, etc., and the development of Power Quality indices to quantify the power supply quality. This allows to know the condition of the electric power systems. The principle aim of this paper is to know the power quality issues, the way to solve the problem and a solution for good power quality.

***Keywords*– Power Quality monitoring, Harmonics, Flicker, Voltage Sag, Voltage Swell.**

1. INTRODUCTION

Power quality analysis is very important because of the increasing entanglement and size of electrical networks. Regulating authorities and power suppliers around the world usually monitor the amount of power that is being delivered to the end-users by placing meters at different points in the power grid. These meters measure different power quality parameters such as current, voltage , frequency, harmonics, etc. As electronic equipment are sensitive to power supply events inspecting power quality is very important. Hence these parameters must be maintained at suitable levels so that they will not cause any damages to the electronic devices at the user side. Control devices are being used for power analysis and control. The analysis devices enable the engineers and the network operators to test the network for certain quality attributes that can have major effects on the system. Some of these quality elements are the frequency, supply voltage variation, rapid voltage change, Supply voltage unbalance, harmonics and inter harmonic voltage, main signaling voltage, voltage swells/sags, let up on the supply voltage, and transient overvoltage. Voltage variation and harmonics are considered to have a greater effect on the quality of power. Harmonics occur due to the presence of non-linear loads. Those harmonics can affect the electrical devices by generating heat which might cause damage. Quality of power is enhancing a very important requirement in the new, decontrol, and restructured power industry.

The importance is associated both with a need to have a "cleaner" power delivery due to a variety of sensitive loads and to provide a premium service to gain a competitive edge. A major part of achieving a higher quality of power is the ability for assessing the quality. There are many standards and classifications for the levels of the harmonics in distribution systems as specified by different standards such as IEC 1000-3-2, IEEE-519, and IEC 61000-4-30 Class A. These standard values are referred while analyzing the network.

What is Power Quality?

Accuracy and quality are two important aspects of any electrical power supply system. Power Accuracy means availability of power supply 24×7 basis which constitutes adequacy of the electrical system at all levels from generation, transmission to distribution. However, power quality refers to both the extent of aberration or slant ion in the pure supply waveform and the continuity of supply. Any significant aberration in the magnitude, frequency, waveform, or symmetry of line voltages is a potential power quality problem. Ideally, a waveform should be smooth and free from disturbances. But even the best power systems are subject to change and all electrical equipment is susceptible to damages caused by these change. When the quality of the power supplied is deficient, it results in performance degradation and reduced life expectancy of equipment. Therefore, we may understand poor power quality as any power problem manifested in voltage, current, or frequency aberrations that fail, increased energy loss or malfunctioning of equipment, thus causing economic loss.

Poor power quality can also result in problems with electromagnetic empathy and noise. It can affect sophisticated protection systems and/or malfunctioning/failure of vital control and signal systems. Typical electrical loads, such as lighting, heating, and motor, are less sensitive to change in the supply voltage, and more sensitive to availability of supply. However, electronic/digital equipment is more sensitive to change in supply voltages. Quality that affects power quality is voltage fluctuation, harmonic on, voltage unbalance, flicker, supply let up, voltage sags, voltage swells, and transients, etc.

2. NEED FOR POWER QUALITY:

In the power scenario, the quality of loads, and the requirements of electrical systems have changed significantly. The devices and equipment used presently in industrial, commercial, and domestic efficiency are more sensitive to supply change than equipment used in the past. It is due to the increased use of power electronics and microprocessor-based technologies in equipment and appliances. The increasing penetration of Renewable sources of energy, semiconductor-based electronic equipment, non-linear loads, data centre industries running on adjustable speed drives and arc furnaces, etc. slant voltage/current waveforms in non-conformity to their desired form. This brings challenges to maintain the quality of power to an ideal one and ensuring efficacy.

In India, various sectors are prone to both generations of higher power quality pollution as well as susceptible to power quality disturbances. The losses due to power quality allots are economic as well as technical. Both utilities as well as consumers are heavily impacted due to the techno-economic losses arising out of poor power quality. Poor power quality not only causes performance degradation and immature failure of electrical equipment but also results in increased system losses, financial loss, etc. Therefore, apart from the Accuracy i.e. continuous supply, the choice of the electricity consumers is shifting towards quality power supply from the distribution licensees. Optimal power quality can increase productivity and reduce losses.

The analysis systems help the engineers and operators to detect the previously mentioned power quality attributes and identify their causes. The analysis process could be an online analysis process whereby the system will be monitored continuously for any conflict or failure that might occur. Then there could be an alarm indicator for the system operator to take the required action. It could also be a long-term analysis process whereby the measurements of the various quality qualityand attributes are being stored into databases for generating periodic reports that will help in improving the overall system, make future increase, or take prevention actions. Placing the monitors smartly in the network helps in reducing the cost of the power quality analysis system. The figure below shows the overall electrical network with meters placed at various points to monitor the power. One of the targets in quality is to achieve customer satisfaction.

This is done by ensuring that the customer's needs and requirements are met. For that, it is important to understand the type of end-users (industrial, residential, etc.) in the network to supply power levels that match their needs. The appeal in the area of power quality is driven mostly by the customers' complaints; therefore many efforts are being made to insure that good power quality exists at all times.

3. FACTORS AFFECTING POWER QUALITY MONITORING

The objective of the power quality Standards is to insure reliable and quality power to the electricity consumers. The Electricity Act 2003 has preserved the basic need of consumers to be provided with continuous, reliable, and quality supply by the distribution utilities. Meanwhile, the accelerated growth of renewable energy along with the meteoric rise of non-linear loads, are posing serious challenges for the quality of conventional in directions power flow from generation to consumption points. India is the 4th largest consumer of electricity in the world but despite being one of the leaders both in electricity generation and consumption, it is facing major allots related to power quality. A lot of power quality remained largely ignored in the electricity supply industry of India.

There are many reasons like the huge gap between demand and supply just a decade back, lack of awareness and capacity to understand allots and challenges associated with quality of power, secured availability of technology in detecting and overcoming such challenges. Power quality is drawing increasing consideration due to the heavy penetration of power electronics-based loads in every walk of our lives. Power quality parameters like frequency, voltage quality (interruptions, variations, unbalances, flicker, sags, and swells), harmonics, and power factor are key matrices/indicators for defining a good power quality environment. Poor quality of power leads to immature failure or reduced/degraded performance of equipment. It also caused increased system losses. Discerning consumers are looking for clean and quality power to drive their sensitive equipment at all levels. In this context, allots on power quality need for greater managing conflict in ensuring the quality of power supply.

At present, a few parameters related to power quality are covered under the Central Electricity Authority (CEA) and SERCs Regulations. The Grid Code, Supply Code, and Standard of Performance laid by various SERCs do mandate the quality of power to be maintained. The State Regulations, when dealing with the aspect of power quality through Supply Code/Grid Code or Standards of performance are not harmonious across different States and does not cover all aspects of power quality. Even there is a lot of change in similar power quality parameters specified by different SERCs. Therefore, there is a strong need to introduce adjust regulation on power quality across all states. SERCs are also required to emphasize measurement and introducing incentive/disincentive mechanism to insure compliance to power quality parameters within certain limits. Business and the economy in the digital era also depend upon a reliable and quality power supply.

So far, the focus of the sector was limited to providing an uninterrupted power supply to consumers. This was understandable at the time of deficit when the limited supply of power was available to meet peak demand and the expectation of end consumers was the availability of power supply. But now India has become one of the purples power countries, thus, the quality power supply becomes the priority.

4. POWER QUALITY PARAMETERS

The standards for voltage and other technical norm are there which can be used to measure power quality. Parameters affecting power quality can be divided into two categories, i.e. Steady-state (or continuous) and Disturbances. Steady-state power quality parameters include Harmonics, frequency aberration, voltage unbalance, voltage change, and flicker. Disturbances include outages, momentary let up, momentary or transient overvoltage or surges, voltage dips, and voltage swell. The important parameters are defined below with their possible causes and effects on the electrical equipment or supply system:

4.1 Frequency

Any variation of the power system basis frequency from its specified nominal value (e.g. 50 Hz in India) is defined as a frequency aberration. Frequency change that go outside of the normal limits for normal steady-state operation of the power system can be caused by faults on the bulk power transmission system, a large block of load being disconnected, or a large source of a generation going offline. Large frequency change result in long-term damage to both generator and end-use rotating electrical equipment whose rated output may suffer in low-frequency regime. It may affect system stability and also leads to a blackout of the grid. In interconnected power systems, significant frequency change are rare.

4.2 Voltage

Voltage is a most important parameter in the power system which affects the quality power in several ways like supply voltage let up, voltage change, voltage unbalance, voltage sag, voltage swell, voltage transients, and voltage harmonics, etc. as given below:

Supply Voltage: It is a condition in which the voltage at the supply terminals is lower than 10 percent of the nominal voltage. It may be long or sustained interruption if the duration is longer than 1 min. and short interruption if the duration is up to and including 1 min. Voltage let up longer than 1 min. are often permanent and require human conflict to repair the system for restoration. For poly-phase systems, an interruption occurs when the voltage falls below 10 percent of the nominal voltage on all the phases otherwise, it is considered to be a voltage dip. Long power let up are a problem for all users, but many operations e.g. continuous process operations, multi-stage batch operations, digital data processing semiconductor fabrication, etc. are very sensitive to even very short let up.

Voltage Change: It is defined as a cyclic variation of the voltage envelope or series of random voltage changes, the magnitude of which does not normally exceed the specified voltage ranges. They are relatively small (less than +5 or +10 percent) change in the RMS line-voltage. This change can be caused by static frequency converters, cycle-converters, arc furnaces, rolling mill drives, main winders, and large motors during starting, etc. Voltage change may cause trouble tripping due to mal-operation of relays and contactors and unwanted triggering of UPS units to switch to battery mode. It may stress electrical and electronic equipment toward detrimental effects that may disrupt production processes with the considerable financial loss.

Voltage Unbalance: It is a condition in a poly-phase system in which the root mean square values of the line-to-line voltages, or the phase angles between consecutive line voltages, are not equal. The sources of unbalanced voltages are due to malfunctioning of equipment, discord transformer taps and impedances, blown capacitor fuses, open-delta regulators, or open-delta transformers. It can also be caused by uneven single-phase load distribution among the three phases. Unbalanced systems indicate the existence of a negative sequence component of supply voltage, which is harmful to all poly-phase loads, especially three-phase induction machines. It can cause an overload on induction machines and malfunctioning of frequency converters. Voltage unbalance can create a current unbalance which can be 6 to 10 times the magnitude of voltage unbalance. In turn, current unbalance produces heat in the motor windings which put down motor insulation causing progressive performance deterioration and permanent damage to the motor.

Voltage Slide (dip): It is a condition in which the voltage reduces at the supply terminals ranges for a duration of about half a cycle to several seconds. Common sources of slide are the starting of large induction motors and system faults. Sags can happen due to an overloaded circuit, malfunction of a transformers tap changer, breakers connecting a large inductive load to the grid, or a disconnected capacitor bank. Also, arc furnaces initially take large amperes to produce high temperatures causing voltage sag. Voltage slide results in malfunction of equipment/ relays and contactors, under-voltage tripping, loss of efficiency of motors and intermittent reduction of light illumination, etc. In case the voltage is too low, accelerated aging may take place in components and eventually causing faults in the network.

Voltage Swell (rise): It is a condition in which the voltage rises at the supply terminals for a duration of about half a cycle to several seconds. Over-voltage could be the result of connecting a capacitor bank or disconnecting a large inductive load. Other sources of voltage swells are line faults and incorrect transformer tap changer settings in the sub-stations. It also occurs due to the transfer of loads from one source to another. Voltage swells results in malfunction of equipment, insulation failure, intermittent increase in light illumination, tripping of relays and contactors, etc. In case of a very high voltage, damage to electrical appliances may occur.

Voltage Transients: Transients are momentary changes in voltage or current which occur over a short period usually for microseconds. It is divided into two categories. Impulse transient, which is a brief, in directions variation in voltage, current, or both on a power line and Oscillate transient, which is a brief, bidirectional variation in voltage, current, or both on a power line. The most common causes of impulsive transients are lightning strikes, switching of inductive loads, opening and closing of energized lines, and tap changing on transformers. Oscillate transient can occur due to the switching of power factor correction capacitors, or transformer Ferro-resonance. Poor or loose connections in the distribution system canalso generate transients. Due to transients, electronic devices may operate erratically. Motor winding insulation is degraded and resulting in eventual failure. The electrical distribution system is also changed by transient activity. Voltage Transients degrade the contacting surfaces of switches, isolators, and circuit breakers. The intense transient activity can produce troubletripping of breakers. Transformers may get saturated if exposed to high voltage transients. In such cases,stresseslosses will increase thus causing transformers to run hotter than normal.

Voltage Harmonics: It is a sinusoidal component of a periodic voltage waveform having a frequency that is an integral multiple of the basis frequency. It is the aberration from the original or pure voltage sine waveform. Generally, at the source point, the Voltage harmonics are absent. As the power flow progresses towards the load end, voltage harmonic creeps in due to the effect of current qualityof non- linear loads reflecting on network impedances. Voltage harmonics are generally expected to be managed by the utility service provider.

4.3 Flicker

It is the impression of uncomfortable visual sensation induced by a light stimulus whose luminance or spectral distribution fluctuates rapidly with time. It is caused under certain conditions by voltage change resulting in a change of the luminance of lamps. Quantitatively, it may be expressed as the change in voltage over nominal voltage expressed as a percent. The main cause of these effects is the fast switching operations of industrial processes and electrical appliances connected to the supply system. Flicker is considered the most significant effect of rapid voltage change because it can affect the production environment by causing personnel fatigue and lower work concentration levels.

4.4 Current Harmonics

It is a sinusoidal component of a periodic current waveform having a frequency that is an integral multiple of the basis frequency. It is the aberration from the original or pure current sine wave. Voltage and Current Harmonic pollution can be quantified. Current harmonics in the system are produced by non- linear loads and cause power pollution akin to air pollution caused by automobile emission. Examples of such non-linear loads are power electronic equipment including different speed drives, fan regulators, CFLs, LEDs, Televisions, Switched Mode Power Supplies, Data Processing equipment, high-efficiency lighting, electrical machines working under magnetic saturation, arc furnaces, welding machines, rectifiers, DC brush motors, etc. These harmonics have serious effects on various electrical equipment such as overheating of cables and equipment. Further Harmonic causes increased system losses, conflict with communication lines, errors while indicating electrical parameters, the probability to produce resonant conditions, etc.

4.5 Power Factor

The power factor is a key indicator of efficient energy delivery in the AC electrical system. It is a measure of how expertly a specific load consumes electricity to produce work. The power factor may be categorized into a displacement power factor and a true power factor. The displacement power factor is the cosine of the angle between the basis voltage and current waveforms. However, the presence of harmonics introduces an additional phase shift between voltage and the current. The true power factor is calculated as the ratio between the total active power used in a circuit (including harmonics) and the total apparent power (including harmonics) supplied from the source. The true power factor is always less than the displacement power factor if harmonics are present in the system. Poor power factor results in the requirement of higher apparent power and thus higher current flow at nominal voltage to do the same work against a higher power factor. To comfort with these higher currents due to a poor power factor one has to increase conductor sizes or capacities of electrical equipment like generators or transformers thus resulting in blocked capital expense (CAPEX) and increased operating cost of the system. The large current at low under developed power factor causes greater voltage drops in alternators, motors, transformers, and transmission cum distribution lines. This leads to a decrease in voltage at the driving end and forces the use of extra equipment like voltage stabilizers to counteract the voltage drop or FACTS devices. Improving the power factor can bloat current-carrying capacity, improve voltage to equipment, reduce power losses, and lower electric bills. The simplest way to improve the power factor is to add power factor correction capacitors preferably at load ends of the electrical system but ensuring network resonance due to harmonics is not magnified.

5. Conclusion

It is being concluded that the power quality analysis is caused due to factors like voltage sag, voltage swell, harmonics, power factor. The power quality allots are being understood correctly. The causes can be reduced by using the simulation method through MATLAB software. It has been discussed above that Under voltage and overvoltage problems are very common and can create a problem for consumer goods and industrial applications.

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