Power Quality Problems

Pooja Sharma, PG Student
Department of Electrical Engineering
United College of Engineering and Research Allahabad, India

Sadika K, P.hd Student
Department of Electronic Engineering
Institute of Engineering and Technology , Lucknow

Abstract- **Power quality is the electrical network's or the grid's ability to supply a clean and stable power supply. As a result of the wide usage of electronic equipment, the development of electric power consumption and increasing nonlinear loads in power system leads to many power quality issues. If the power quality is poor, then it becomes the major issue due to increase in loss and heat, over burdening of the power system. All electrical equipment such as generator, motor, transformers, computers, house hold appliances fails when it exhibits power quality issues. This paper summarizes different power quality issues such as voltage variation, transient, harmonics etc.**

Keywords: power quality, voltage sag, voltage swell, harmonics distortions, frequency variation.

I. Introduction

The electric power industry comprises of three major stages, namely electricity generation (AC power), electric power transmission and electricity distribution to an end user. The complexity of the system to transmit electrical energy from the production point to the consumption point combined with irregularities in weather, generation, demand and various other factors provide many opportunities for the supply of quality to be compromised.

Power quality is an important concern for both power supplying establishment and end-users. It refers as the ability to supply a clean and stable power supply. It wills always available as a free noise pure sinusoidal wave shape even it is always within a voltage and frequency tolerance. Therefore, power a complete change of electric loads nature due to the use of electronic equipment, such as information technology equipment, power electronics such as adjustable speed drives (ASD), programmable logical controls (PLC), and energy efficient lighting etc. Due to the non-linearity, all these loads cause disturbances in the voltage forms.

Power quality disturbances can also increases based on that type of switching phenomena that result in create an oscillatory transient in the electrical systems or supply. Power quality problems can caused the lot of problems such as equipment failure, increased electricity bills, wasted energy, interference with communications systems and even shut down entire plants.

II. Power Quality issues Review

Power quality is referred as the electrical network's or the grid's ability to supply a clean and stable power supply. Power quality is a major concern because of the sensitivity of digital and modern control equipment to distortion power quality deterioration. The power is to be provided to the consumer in clean sinusoidal wave form at a frequency of 50Hz that does not contain any power quality issues.

The Electronic devices can face the lot of problems without quality of the power such as malfunction of the equipment damage the devices likely effect of sensitive of the equipment. The power quality problems are voltage sag, voltage swell, voltage fluctuations, voltage dips, voltage unbalance, flicker, and harmonics distortions, frequency variations, very long interruptions, and very short interruptions, electrical noise, under voltages.

1. Voltage Sag

Voltage sag or voltage dip is a short duration reduction in the rms voltage which can be caused by a short circuit or overload or starting of electric motors. It happens when the rms voltages decreases between 10 to 90 percent of the nominal voltage for one half cycle to one minute. The frequency of occurrences is between a few ten and hundred times per year. It one of the most important power quality problem faced by many industrial customers since equipment used in modern industrial plants such as process controllers and adjustable speed drives is becoming more sensitive to voltage sag.

The factors which cause voltage sag are:

- The electric motors draw more current, when they are starting than running at their rated speed
- Starting an electric motor can be a reason of voltage sags.
- Some accidents in power lines can be a cause of line-to-ground fault and voltage sag as aresult.
- During line-to-ground fault, there will be voltage sag until the protective switch gear operates.
- In households, voltage sags are sometimes seen when refrigerators, air-conditioners, or furnace fans start up.
- Sudden load changes can cause voltage sag.
- Transformer's energizing could be reason for voltage sags occurrences.

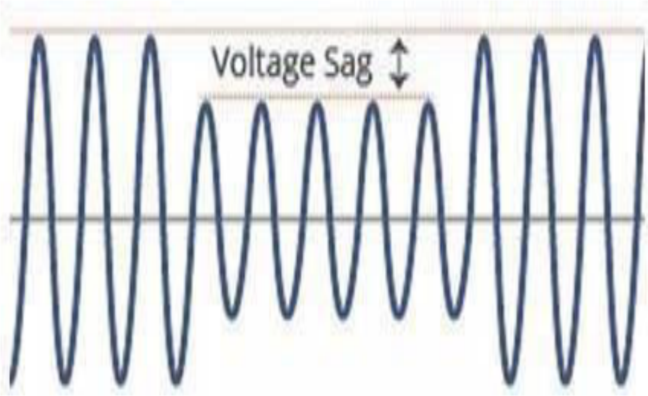


Fig.1 Illustration of voltage sag

2. Short-Duration Voltage Variation

A deviation in voltage for duration less than 1 min at power frequency is termed as short duration voltage variations. Short-duration voltage variations are resultant of energization of big loads which need high starting currents, irregular loose connection in power wiring or by fault conditions. Depending on the system conditions and fault location, the fault can cause either interruption (complete loss of voltage), swells (voltage rise). The fault condition can be remote or close to point of interest. In both cases, the impact of actual fault condition on the voltage is of short-duration variation until protective devices operate to clear the fault.

Voltage Swell

Voltage swell is the opposite of the voltage sag which is momentary increase in nominal supply voltage. Voltage swell is the increase the rms voltage level to 110% to 180% of the swell is normally associated with system fault conditions. It system where the suddenly change in the ground reference system finally it can cause voltage rise on the ungrounded phase.

Change in the ground reference systems finally it can cause voltage rise on the ungrounded phases. Faults at different points along four-wire, multi-grounded feeders will have varying degrees of voltage swells on the un-faulted phases. Some interruptions may be preceded by the voltage sag when these interruptions are due to faults on the source system.

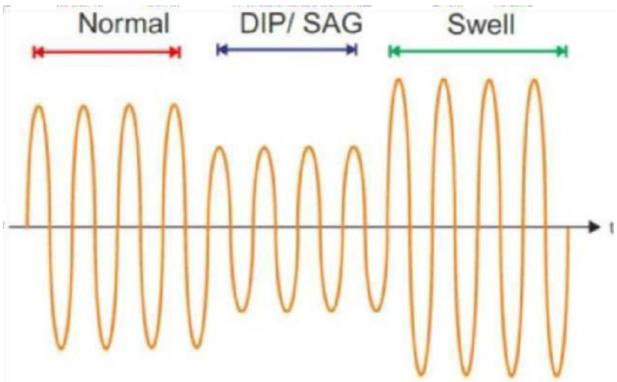


Fig. 2 Illustrates voltage swell and dip

Voltage rise on the ungrounded phase. Change in the ground reference systems finally it can cause voltage rise on the ungrounded phases. Faults at different points along four- wire, multi-grounded feeders will have varying degrees of voltage swells on the un-faulted phases. Some interruptions may be preceded by the voltage sag when these interruptions are due to faults on the source system.

Interruption

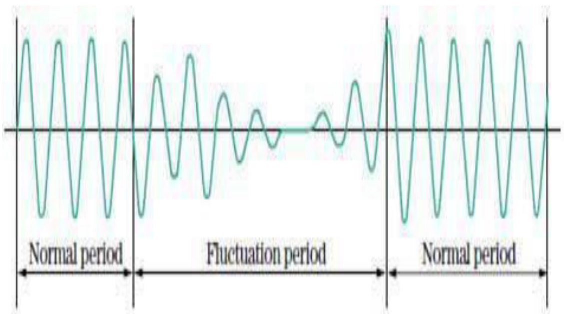
A decrease in the load current or supply voltage to less than 10% for a period of time not more than 1 min is termed as interruption. Interruption can be result of equipment failures, control malfunctions and power system faults. Since the magnitude of the voltage is always less than 10% of the nominal, the interruption are generally measured by their duration. Utility protective devices operating time determines the interruption duration due to a fault. Immediate reclosing will usually limit the interruption caused by a nonpermanent fault to less than 30 cycles. Delayed reclosing of protective devices may cause a momentary or temporary interruption. The interruption duration due to equipment malfunctions or loose connections can be irregular. When an interruption occurs due to faults on the source system, voltage sag might follow it.

Fig.3 Interruption

3. Voltage Fluctuations

Voltage fluctuations are defined as systematic or random variations in the magnitude of supply voltage. The magnitude of these variations does not usually exceed 90% to 110% of nominal supply voltage. Loads that can exhibit rapid and continuous variation in the load current magnitude causes voltage variation that are often referred to as flicker. However, small changes in magnitude occurring at particular frequencies can give rise to an effect called “lamp flicker”.

Fig.4 Voltage fluctuations



Lamp flicker describes the impression of unsteadiness of visual sensation induced by a light source whose luminance or spectral distribution fluctuates with time. Arc is the one of the main cause of voltage fluctuation on distribution system and utility transmission.

4. Voltage Unbalance

Voltage unbalance means that a voltage variations in the three phase system in which the three phase voltages magnitudes or the phase angle differences between them are not to equal. Voltage unbalance mainly due to the large single phase load (incorrect furnaces, traction loads) and incorrect of the big size single phase loads through the three phase system. The important consequence of this voltage unbalanced existence of the negative sequence is all harmful to all three phase loads even the resistive loads also. Voltage unbalance can also occur from a blown fuse on one phase of a three phase bank.

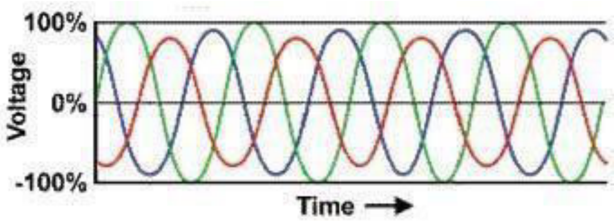


Fig.5 Illustrates voltage unbalance of a three phase system

5. Frequency variations

Frequency variation means the change in frequency from the normal utility frequency in the 50Hz. The frequency is directly related to the rotational speed of the generators. There are small variations in the frequency when a dynamic balance between load and generation changes. The size of the frequencies shift and its duration depend upon the load characteristics and the response of the generation control system to load changes. For normal steady-state operation of the power system ,frequency variation that go outside of accepted limits can be caused by faults on the bulk power transmission, a large block of load being disconnected, or a large sources of generation going off-line.

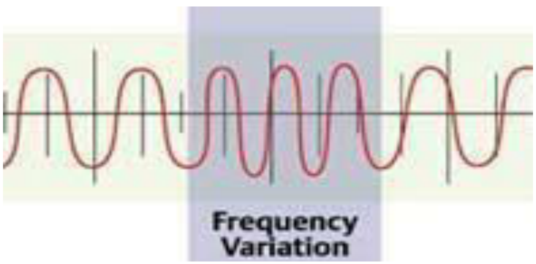


Fig.6 Frequency variation

6. Long Duration Voltage Variation

A deviation in the voltage at power frequencies for longer than1 min is termed as long duration voltage variations. Long –duration variations may be either over voltage or under voltages. Over voltages and under voltages are not usually the results of system faults, but are caused by system switching operations and load variations on the system. Such variations are normally displayed as plots of root mean square (rms) voltage versus time.

Over Voltage

An increase in voltage greater than 110% for duration greater than 1 min at the power frequency is termed as over voltages. Over voltages are typically the results of load switching (e.g., energizing a capacitor bank or switching off a large load). The over voltages are outcomes of incorrect tap settings on transformers, the system might be too weak for the desired voltage regulation or voltage controls are not enough.

Under Voltage

A decrease in voltage less than 90% for duration greater than 1min at the power frequency is termed as under voltage. A switching off capacitor bank or switching on load can cause an under voltage in the system until voltage regulation equipment on the system brings the voltage back within tolerance range. Circuits which are overloaded can result in under voltages. Sustained periods of under voltage initiated as a particular utility dispatch plan to decrease power demand is termed us brownout.

Sustained Interruptions

The long-duration voltage variation in which supply voltage falls to zero for a period of time in excess of 1 min is consider as sustained interruptions. Sustained interruptions are generally permanent and require human intervention to repair the system for restoration. The term sustained interruption refers to specific power system phenomena and has no relation to the usage of the term outage. To describe phenomena of similar nature for reliability reporting purpose, utilities use outage or interruption.

7. Transients

An undesirable and momentary variation in voltage or current or both is termed as transients. Transient can be also defined as that part of change in variable that disappears during transition from steady state operating condition to another. It is generally classified into two categories, impulsive and oscillatory.

Effects in motors

- Transients will cause the motor to run at high temperatures
- Equipment failure due to degradation in the insulation of the motors winding
- Increasing in the motor's losses and its operating temperature

Effects in electrical equipment

- Degrades the contacting surfaces of the protective devices
- Increasing in the hysteresis losses, transformer efficiency is reduced

Implusive transient

Impulsive transients is a sudden non power frequency change in the steady-state condition of current, voltages or both that is unidirectional in polarity. It is normally characterized by their rise and decay times, which can also revealed by their spectral content. For eg, a 1.2 X 50-μs 2000-volt (V) impulsive transient nominally rises from zero to its peak value of 2000 V in 1.2 μs and then decays to half its peak value in 50 μs.

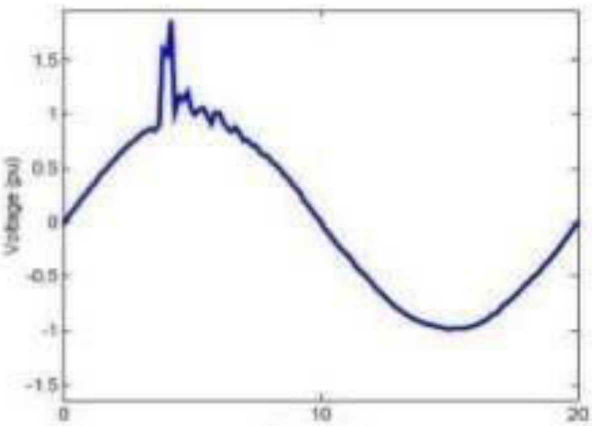


Fig.7 Impulsive transient

Lighting is the most general cause of impulsive transient. A current impulsive transient caused by lighting is shown in the figure 6. Due to the high frequencies involved, the shape of impulsive transient can be changed quickly by circuit components and may have significantly different characteristics when viewed from different parts of the system. When viewed from different parts of the electrical system, it may considerably have different characteristics (i.e. from one building to another). The high frequencies involved will allow damping of the impulsive transients through the resistive component of the system.

Oscillatory transient

The oscillatory transient is defined as the sudden non- power frequency change in the steady-state condition of current, voltage or both, and it also includes both positive and negative polarity values. Oscillatory transient consists of a voltage or current whose instantaneous values changes polarity rapidly. It is described by its spectral content, duration, and magnitude.

The spectral content subclasses into high, medium, and low frequency. High-frequency transients are oscillatory transient with primary frequency component greater than 500 kHz and a typical duration measured in microseconds. These transients are usually as a result of a local system response to an impulsive transient. A transient with a primary frequency component within 5 and 500 kHz with duration measured in the tens of microseconds are termed as a medium-frequency transient. Oscillatory transient currents in the tens of kHz caused by back to back capacitor are shown in figure 8.

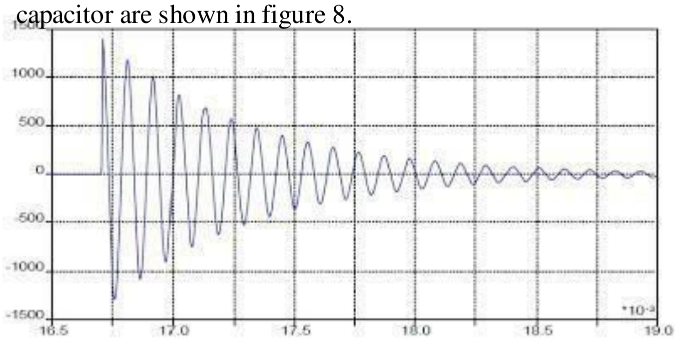


Fig.8 Oscillatory transient current caused by back to back Capacitor switching

A transient with primary frequency component less than 5 kHz, and duration from 0.3 to 0.5 ms, is termed as low-frequency transient. This category of phenomena is frequently encountered on utility sub transmission and distribution systems and is caused by many types of event. This category involves capacitor bank energization, which typically results in an oscillatory voltage transient with primary frequency between 300 to 900 kHz. The peak magnitude can approach 2 Pu, but is typically 1.3 to 1.5 Pu with duration of between 0.5 and 3 cycles depending on the system damping figure 9.

It is possible to categorize transients according to their mode. Depending on its appearance between line and neutral and ground, or between line and neutral, the transient in a three-phase system with a separate neutral conductor can be either common mode or normal mode.

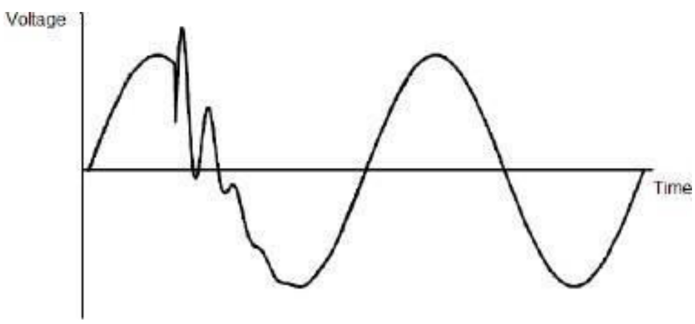


Fig.9 Low frequency oscillatory transient caused by

capacitor bank

8. Power Factor Variation

Power factor is the very important term in the electrical power system. It means that defined as the ratio of real power to apparent power. Apparent power refers as the product of voltage and current. Semiconductor devices are used in various the electrical power systems because of it will distorted the wave form it is called the nonlinear load. According to this nonlinear load is not giving perfect sinusoidal and also lot deviations in the voltage and current wave form. In this situations the apparent power is greater than the real power it gets low power factor. Once the level of power factor will be increased we must face a lot of problems in the load side along with entire circuit. Poor power factor has various consequences such as increase the load current, larger KVA rating of the equipment, greater conductor size, larger copper loss, poor efficiency, and poor voltage regulation. In case of the power factor is very low the current flowing in the circuit is more than load. In case the high power factor the useful power is transferred the electrical system. When we will get a poor factor we required a cost of the equipment and also large wires in the system.

9. Waveform Distortion

A steady state deviation from ideal sine wave of power frequency is termed as waveform distortion. The following are primary types of wave distortion.

DC Offset

The presence of a dc current or voltage in an ac power system is termed as dc offset. DC offset can occur as the result of asymmetry or geomagnetic disturbance of electronic power converters. Incandescent light bulb life extenders, consisting of diodes to reduce the rms voltage supplied to the light bulb by half-wave rectification are also sources of dc offset. Direct current in ac networks has harmful effect on biasing transformer cores, they saturate transformer in usual operation. This causes extra heating and loss of transformer life. DC might also cause the electrolytic erosion of connectors and grounding electrodes.

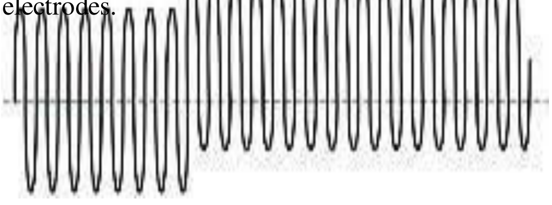
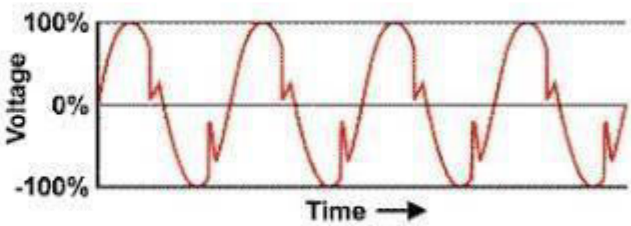


Fig.10 DC offset

Inter-harmonics

Inter-harmonics are defined as the voltage or current having frequency components that are not integer multiple of the frequency at which supply system is designed to operate. The main sources of inter-harmonics waveform distortion are static frequency converters, cycloconverters, induction furnaces and arcing devices. Carrier signals in power line are also considered as inter-harmonics.



International Journal of Scientific Research in Engineering and Management (IJSREM)
Volume: 05 Issue: 06 | June - 2021 ISSN: 2582-3930

The varying inter-harmonics frequency might with natural frequencies of the system resulting quite severe resonances. They effect power-line-carrier signaling and induce visual flicker in fluorescent and other arc lighting as well as in computer display devices.

Notching

Periodic disturbance in voltage caused by the usual operation of power electronics devices when current is commutated from one phase to another is defined as notching. Notching can be distinguished through the harmonic spectrum of the affected voltage since it occurs continuously. The effects due to notching are loss of system data, system halts etc. Figure 11 shows an example of voltage notching from three-phase converter that produce dc current.

Fig.11 Notching

Noise

Unwanted electrical signal with broadband spectral content lower than 200 kHz superimposed upon the power system current or voltage in neutral conductor or phase conductor or signal lines is termed as noise. Loads with arcing devices equipment, solid-state rectifiers, switching power supplies, power-electronics devices etc.., are the major causes of noise in power system. Noise problems may become more intense with improper grounding which fails to conduct noise away from the power system. Noise also disturbs electronic devices such as microcomputer and programmable controllers.

Harmonics

Harmonics is defined as the integer multiple of the fundamental frequency. In a linear load the current drawn is a perfect and also giving pure sinusoidal wave. There is no deviation in this type of load. In a nonlinear load the current voltage drawn is not perfectly. Current deviations are there. Harmonic distortion occurs in the nonlinear characteristics of devices and loads in the power system. Harmonic distortion levels are causes many problems such as insulating materials in motors, degrading of the conductors; transformers faced a lot of problems. Once the level of harmonics increases it will affect the loads associated with other equipment. The problems created like equipment failure, equipment heating, create an electromagnetic interference between communication circuits.

In the early days of power electronics, thyristors were the dominating valves. With these semiconductors, very low order harmonics are generated due to the mechanism for commutating current flows. With introduction of self- commutated valves such as transistors, generation of emission has been shifted to high frequency. With rapid growth of electronics and energy saving equipment in our home the emission in higher frequencies, are expected to increase.

High frequency range of 2-150 kHz is known as super harmonics. Active power-electronics use switching frequencies starting above 1 kHz. This results in the emission at frequencies above the classical harmonic range. Some examples of devices that have been found to emit super harmonics are:

- Industrial-size converters (9–150 kHz)
- Oscillations around commutation notches (up to 10 kHz)
- Street lamps (up to 20 kHz)
- EV chargers (15–100 kHz)
- PV inverters (4–20 kHz)
- Household devices (2–150 kHz)
- Power line communication for automated meter reading (9–95 kHz)

IV.CONCLUSIONS

Power quality is the important and very critical or crucial matter in the modern society. Most of the electrical equipment is failed by the power quality problems. Many sectors can be accepted or satisfied the quality of the utility powers. But some of the consumers more demanding getting the proper functioning of the electrical equipment along with quality of the power. To prevent this problems better way to restoring the technologies, distributed generation, selecting the less sensitive equipment and also using the interface devices.

The power quality problems are voltage sag, voltage swell, voltage fluctuations, voltage dips, voltage unbalance, flicker, and harmonics distortions, frequency variations, very long interruptions, and very short interruptions, electrical noise, under voltages. Harmonics is one of the major power quality issue and is defined as the integer multiple of the fundamental frequency. With introduction of self-commutated valves such as transistors, generation of emission has been shifted to high frequency. With rapid growth of electronics and energy saving equipment in our home the emission in higher frequencies, are expected to increase.

Disturbances of super-harmonics are becoming an increasing concern in the industry, especially with the growth of distributed and embedded generation. Super-harmonic emission and its importance are studied in the ongoing research work.

REFERENCES

[1] Sarah Rönnberg, Math Bollen *"Power quality issues in the electric power system of the future"*. The Electricity Journal 29 (2016) 49–61

[2] Styvaktakis,M., Bollen, H.J. , Gu, I.Y.H. , *"Classification of power system events: Voltage dips,"* 9th International conference on Harmonics and Quality of Power, Orlando,
Florida USA, Vol. 2, pp. 745- 750, 2000

[3] M. Bollen, *"Understanding Power Quality Problems– Voltage Sags and Interruptions"*, IEEE Press Series on Power Engineering – John Wiley and Sons, Piscataway, USA (2000).

[4] Alexander Kusko, Marc T. Thompson, *"Power Quality in Electrical Systems "*, McGraw-Hill, New York, 2007

[5] Anurag Agarwal, Sanjiv Kumar, Sajid Ali, "*A Research Review of Power Quality Problems in Electrical Power System*". *MIT* International Journal of Electrical and Instrumentation Engineering, Vol. 2(2), pp. 88-93, 2012.

[6] Roger. C Dugan, Mark .F.Mc Granaghan, Surya Santoso, H.Wayne Beaty. *"Electrical Power Systems Quality*" third edition

[7] Shazma Khan, Balvinder Singh, Prachi Makhija "*Review on Power Quality Problems and its Improvement Techniques*".

[8] Bingham,"SAG and SWELL", New Jersey: Dranetz-BMI, 1998

[9] Blanco, A.M., Stiegler, R., Meyer, J., 2013. *"Power quality disturbances caused by modern lighting equipment (CFL and LED)"*. PowerTech (POWERTECH), 2013. IEEE, Grenoble, pp. 1–6.

[10] J. Arrilaga and N. R. Watson, *Power System Harmonics*.
New York: Wiley, 2003

[11] Mahesh Singh and Vaibhav Tiwari, "*Modeling analysis and solution of Power Quality Problems,*" SSCET Bhila INDIA, (2013).

[12] Marty Martin, "*Common power quality problems and best practice solutions,*" Shangri-la Kuala Lumpur, Malaysia 14. 1997

[13] "*Power Quality*", Schneider Electric Cahier Technique no. 199, September 2000

[14] Sudarshan Govindarajan , Sai Shankar Balakrishnan "*Analysis and Interpretation of Power Quality Issues With Suitable Corrective Measures"*

[15] Domijan, A. Heydt, G.T., Meliopoulos, A.P.S., Venkata, S.S., West,S., "*Directions of research on electric power quality,*" IEEE Transactions on Power Delivery, Vol. 8, pp. 429-436, 1993.