A Review on Efficient Mitigation Techniques for Issues in Power Quality

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Abstract - *In today's world the dependence on electrical power has increased a lot, due to which the power at quality is more essential. But there are a lot of problems facing due to disturbances in power quality, which arises the need to produce quality of electrical power. Telecommunication, computer networks, railway banking network, life system are few applications that just cannot function without electricity. At the same time these applications demand quality of electrical energy. From few decades, global energy consumption has been increased very rapidly because of the increase in the various manufacturing industries along with the use of automated systems and utilization of various appliances on both sending end andreceivingendofthe power system. Hence, maintenance of the quality of power is very important as per the stability concern. Power quality excursions not only affect customer equipment but also detrimental to the operation of the power utility. The dependence on the quality of electrical power has been increasing so, the focus on the mitigation techniques also increased. This paper reviews about the existing mitigation techniques and its improvements.*

***Key Words*:** power quality, mitigation techniques, corrective methods.

1. INTRODUCTION

The term power quality holds all the aspects associated with phase, frequency and amplitude of the voltage and current waveforms existing in the power circuit. Poor power quality occurs due to transient conditions in the power circuit or from the insertion of non-linear loads. Telecommunication and computer networks, railway banking network, post office, life support system are few applications that just cannot function without electricity. At the same time these applications demand qualitative of electrical energy. There is an increasing use of sensitive loads, such as communications, industrial drives, computers and medical equipment's. Nowadays, power quality has become more complex problem than in the past due to the new loads are not only sensitive to power quality, but also responsible for adversely affecting the power supply quality. Although, the distribution power systems may have an impact on the quality of power, it becomes significantly worse at the points where the loads are connected to the distribution grid. The electrical power system is polluted because of non-linear loads used in the system. Utilities are always looking for cost effective and improved power quality (PQ) solutions. Initially, the conventional method of passive filtering enriches to mitigate the PQ problems. The inadequate performance of the conventional passive filter techniques to mitigate PQ problems has affirmed to introduce advanced power electronic based topologies in the improvement of PQ. A single customer may cause significant depletion in power quality for other customers also. Understanding power quality issues is a good starting point for solving any power quality problem [3]. The following are the core terms and definitions that are used in association with power quality:

1.1 Voltage Sag

Voltage sag is defined as the reduction in voltage magnitude below 90% of nominal, but not a complete interruption. The typical duration varies from 3- 10 cycles, 50 to 167 milliseconds. Devices mostly affected are: Computers, programmable logic controllers, controller power supplies, motor starter contractor etc. [10].

1.2 Voltage Swells

A swell is defined as short duration increase in rms line voltage of 110 to 180 percent of the nominal line voltage for the duration of 0.5 cycles to 1 minute. Voltage swells when lasts longer than two minutes are categorized as over voltages. Voltage swells and over voltages are mostly caused by large change in the load and power line switching [14].

1.3 Interruption

Interruption occurs when voltage levels drop to zero. Interruptions are classified as momentary, temporary or long-term. Momentary interruptions occur when the service is interrupted, but then is automatically restored in less than two seconds. Temporary interruptions will occur when service is interrupted for more than two seconds, but it is automatically restored in less than 2 minutes. Long-term interruptions which lasts longer than two minutes and many require field work to restore the service [7].

1.4 Distortions

Distortion which occurs when harmonic frequencies are added to the 60 hertz voltage or current wave form, making the usually smooth wave appear jagged or distorted,

distortion can be caused by solid state devices such as rectifiers, adjustable speed controls, fluorescent lights and computers [2].

1.5 Transients

Transients will be sudden but significant deviations from normal voltage or current levels. Transients typically last from 200 million that of a second to half a second. Transients are typically caused by lightning, Electro static discharges and load switching [5].

1.6 Flicker

Flicker can be defined as small amplitude changes in voltage levels occurring at frequencies less than 25 Hertz. Flicker is caused by large, rapidly fluctuating loads such as arc furnaces and electric welders [14].

1.7 Voltage fluctuation

Voltage Fluctuations as defined by IEEE as systematic variations of the voltage waveform envelope, or a series of random voltage changes, the magnitude of which falls between the voltage limits. Causes are arc furnaces, frequent start/stop of electric motors (for instance elevators) and oscillating loads. Consequences are mostly common to under voltages. The most perceptible consequence is flickering of the lighting and screens, giving their impression of unsteadiness of visual perception [5] [14].

2. Importance of Power Quality

The users of electrical power are quite aware of power quality issues like interruptions, sags and switching transients. Hence the utilities are challenged by customers to improve the quality of the power delivered. Not only electric utilities but also end users of electric power are more concerned about the quality of electric power. The increased interest in power quality is mainly as a result of the following factors:

- Equipment has become extra sensitive to voltage disturbances.
- Some equipment causes voltages disturbances.
- A growing need for the standardization and the performance criteria.

In order to be competitive, utilities will be forced to deliver a good product [3].

2.1 Causes and Effects of Electrical Power Quality Problems

Power quality is defined as "Any power problem which makes modification in the voltage, current, or frequency deviations that result in the failure or disoperation of customer equipment's". Power systems, ideally, should provide their customers with an uninterrupted flow of energy at smooth sinusoidal voltage at the contracted magnitude level and frequency [3][8][9] Table 1 clearly explains the power quality problems, causes of the problem and their effects.

Table -1: PQ problems, causes and its effects

Problem	Causes	Effects
Harmonics	Electromagnetic interference from appliances, machines, radio and TV Broadcasts.	Continuous distortion of normal voltage, Random data errors.
Voltage Sags/ Swells	Major equipment start-up or shut down, short-circuits (faults), undersized electrical wiring, temporary voltage rise or drop.	Shut down of equipment, errors in data, dim or bright lights, shrinking the display screens, loss in memory
Interruption	Operator Switching, attempt for isolation of electrical problem and maintain power for power distribution area.	Trips off Equipment, loss of programming, disk drive crashes.
Flicker	Arc furnace, voltage fluctuations on, utility transmission and distribution systems.	Visual irritation, introduction of many harmonic components in the supply power and their associated equipment.
Transients	Lightning, turning major equipment on or off, utility switching.	Tripping, processing errors, data loss, burned circuit boards.

3. Mitigation Techniques:

Power quality excursions not only affect customer equipment but also detrimental to the operation of the power utility. The Adverse impacts of disturbances of the power system components include the following:

1) Mal-operation of remote controls
2) Overheating of cables.
3) Increased losses in transformers.
4) Incorrect operation of protective devices.
5) Errors in energy metering [1].

Electric power quality is very important aspect for power engineers which has been established from the beginning of power systems. However, the topics in power quality have a raised to forefront ever since the introduction of high-power semiconductor switches and networking of

transmission and sub transmission systems. The development in modern power engineering have been to extricate the most from the existing installed system, and this too has placed stress on issues of sinusoidal waveform fidelity, absence of high and low voltage conditions, and other ac waveform distortion [4]. It is reasonable and desirable that the consumers are provided with distinguished levels of power quality according to their types and demands so that they have the flexibility to adjust their required quality level and to reduce the total operation cost consequently [12]. Fig 1 shows the solutions of power quality improvement in power system [6].

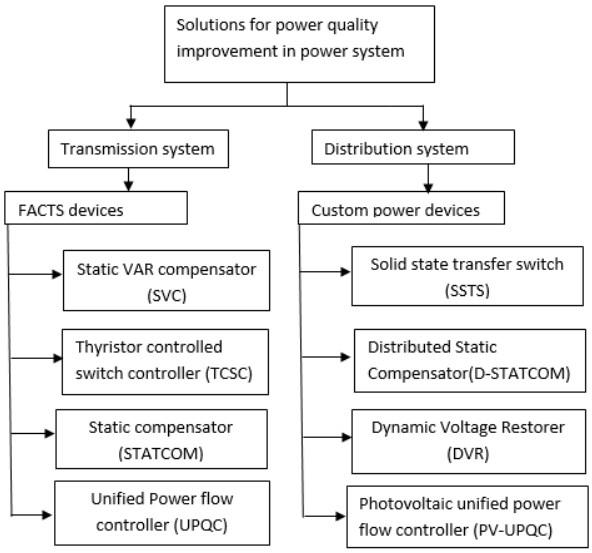

Fig - 1: Solutions for power quality improvement in power systems

The solutions for power quality improvement in power systems are catergorized into two types FACTS devices and custom power devices. In FACTS devices, SVC's are used for protection against transients, TCSC's are used in power system for dynamically control of the reactance of a transmission line to provide sufficient load compensation, STATCOM is installed to support electricity networks which are having poor power factor and poor voltage regulation, UPFC is used for providing fast acting reactive power compensation on high voltage transmission network. In custom power devices, SSTS is a Solid-State Transfer Switch is used for protection of sensitive loads from system side faults by transferring the load on to a healthy back up feeder line, if any problem appears on main feeder line, a D-STATCOM has been used for reactive current compensation, harmonic current mitigation and load balancing are necessary in distribution system, DVR's are used to mitigate voltage sag problems, although DVR are mainly depends upon its control techniques, PV-UPQC's are that consists of the PV array, DC/DC converter and UPQC for compensating the voltage interruption.

From few decades, global energy consumption has been increased very rapidly beacause of the increase in the manufacturing of various industries along with the use of automated systems and hence due to the utilization of various appliances on both sending end and receiving end of the power system. Hence, maintenance of the quality of power is very important as per the stability concern. Due to variation in availability of natural resources, penetration of such sources to generate electricity is the big challenge in the existing electrical power system without changing the quality and flow of power. Hence, it is a challenge to maintain generation, distribution and transmission system as a healthy, realiable and extra smart [18].

In current era the operation of power electronic devices in power system is enormous to enhance the utilization of electric power in an interconnected distribution system, to increase the reliability of sophisticated lifestyle of deregulated electricity market, which alarms the power system engineers about the impact of power quality issues and the need for improving the quality of electric power supplied to the consumers. The effects produced by the interconnected power system having renewable energy based electric power generating systems and non-linear loads cause harmonics, voltage variations in the system [19].

Vijayakumar Gali *et al.* [11] have proposed Active Power Filter (APF) which is best for various mitigation problems among various power quality improvement techniques using FACTS devices. The electrical power system polluted because of non-linear loads used in the system. Utilities always looking for cost effective and improved power quality (PQ) solutions. The conventional method of passive filtering enriches to mitigate the PQ problems. The inadequate performance of the conventional passive filter techniques to mitigate PQ problems has affirmed to introduce advanced power electronic based topologies in the improvement of PQ. Shunt Active Power Filter is well established to mitigate PQ problems like current harmonics, reactive power demand and poor power factor in the distributed electrical power system.

M. Chindris *et al.* [13] proposed UPQC as the best solution to improve power quality in low voltage weak distribution networks. The extensive use of power electronic devices and non-linear or unbalanced loads has continuously degraded PQ in LV distribution networks. The power system faces some challenges in order to ensure the reliability and quality of the power supply, especially in low voltage (LV) rural and sub-urban grids. The best way to manage the PQ problems is to mitigate all disturbances at the PCC so that, all loads connected to the grid are provided with clean power. The solution is to install in PCC a combination of both series and shunt APFs known as a unified power-quality conditioner (UPQC).

Eklas Hossain *et al.* [15] described about the power quality issues for distributed generation systems based on renewable energy sources, such as solar and wind energy. A thorough discussion about the power quality issues is conducted. A comprehensive study of power quality in power systems, including the systems with dc and renewable sources analyzed. The methods of mitigation of these problems using custom power devices, such as D-STATCOM, UPQC, UPS, TVSS, DVR, etc., are proposed for micro grid systems. For renewable energy systems, STATCOM can be a potential choice due to its several advantages, whereas spinning reserve can enhance the power quality in traditional systems.

Andrey V. Shalukho *et al.* [16] have proposed solution for the violation cases of power quality so as to reduce the negative impact of distributed generation on the power quality in the microgrid. The power quality indicators, such as voltage fluctuations, frequency deviation, non-sinusoidal were studied for three operation modes. *Ding Kai et al.* [17] proposed the comprehensive evaluation indicator system for LVDC power distribution system, adopts the comprehensive weighting method combined with analytic hierarchy process (AHP) and entropy weight coefficient method, and applies grey relational analysis (GRA) in the comprehensive evaluation of power quality. The discussion about the development of low-voltage DC (LVDC) power distribution system become more and more strict requirements on power quality of consumers, it has been important to give a power quality comprehensive evaluation method for LVDC power distribution system. However, the existing comprehensive method of power quality, which focuses on AC power system, is not applicable to DC power distribution system.

Arun Kumar Puliyadi Kubendaran *et al.* [18] have proposed that UPQC mitigates voltage variations such as sag/swell and harmonics present in an interconnected distribution system and improve the electric power quality supplied to the consumers as per IEEE standard 519-1992. The entire system has been modeled using MATLAB SIMULINK environment. It discusses about the performance comparison between two different control techniques adopted in the design of UPQC namely synchronous detection method (SDM) and instantaneous direct and quadrature (i_d-i_q) method. The effects produced by the interconnected power system having renewable energy based electric power generating systems and non-linear loads cause harmonics, voltage variations in the system, which can be mitigated with the help of Unified Power Quality Conditioner (UPQC).

Komal D. Thakur *et al.* [19] has proposed DFIG based wind power system which having two converters of respective sides such as GSC and RSC with gearbox connected to the grid. The variable speed wind turbine uses a doubly fed induction generator, i.e. DFIG in which RSC provides the rotor winding while the stator winding is connected to the grid. It also uses vector control devices to decrease flicker. power electronics switching devices use in order to reduce the impact of fluctuation and variations of output power. A STATCOM can also be used to prevent from voltage fluctuations and to improve the quality of power. It is commonly used FACTS device used to reduce the output power of the interconnected power system. Konala Kalyan *et al.* [20] has proposed a method in which series active filters are used for voltage and power quality improvement to the system and harmonic content on load voltage reduces. FFT analysis is done with help of series active power filter. The results show that proper tune active power filter provides best outputs for the imaginary power compensation and power factor developments.

4. CONCLUSIONS

The demand for electric power is increasing at an exponential rate and at the same time the quality of power delivered became the most prominent issue in the power sector. Thus, to maintain the power quality the problems affecting it should be treated efficiently. The FACTS devices are connected to the power network are the point of interest to protect the critical loads. These devices also have other advantages like harmonic reduction and power factor correction. Poor power quality causes serious effect on the power system like over loading condition, generation of harmonics, voltage fluctuation, waveform distortion and overheating in system equipment etc., therefore these PQ issues have to be mitigated. This paper gives an idea about various definitions, terms and importance of power quality (PQ). The PQ problems and their mitigation techniques to the existing devices and the improvements in mitigation techniques are also discussed.

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