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Mitigation of Power Quality Problems Using FACTS Devices: A Review

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Abstract

The power quality issue will take new dimension due to power system restructuring and shifting trend towards distributed generation. Huge loss in terms of time and money have made power quality problems a major anxiety for modern industries with non-linear loads in electrical power system. Power quality consists of a large number of disturbances such as voltage sags, swells, harmonics, notch, flicker, etc. Power quality problems can be mitigated by many methods but most appropriate solution to mitigate these problems are FACTS devices. In this paper a brief survey of FACTS devices are presented which are used to mitigate power quality problems.

Keywords: Power Quality, Restructuring, Distributed Generation, Sag, Swell, Harmonics, Notch, Flicker, FACTS.

1. Introduction

Power quality issues is an issue that is becoming increasingly important to electricity consumers at all levels of usage. PQ related issues are of most distress because of the extensive use of electronic equipment. In arrears to this, various PQ issues arises like voltage sag or dip, very short and long interruptions, voltage spike, voltage swells, harmonic distortion, voltage fluctuation, noise, voltage unbalance and altered our power system. Power quality problems have been attracting the eye of researches for decade. The presence of voltage disturbances at the point of common coupling (PCC) results in malfunction of sensitive industrial instrumentality, that turn out grid part failures, such as transformers, and economical losses. FACTS devices are the possible answer to shield sensitive loads against the most significant voltage disturbances, voltage harmonics, imbalance and sags [1]. Definition of power quality may vary from person to person because we cannot define what is power quality we only define what is good or bad power quality as we can see that two identical devices or pieces of equipment might react differently to the same power quality parameters due to differences in their manufacturing or component tolerance [2]. According to institute of Electrical and Electronic Engineers (IEEE) Standard power quality is defined as a, “the concept of powering and grounding sensitive electronic equipment in a manner suitable for the equipment”. The focus of this survey is on the use of FACTS devices in mitigation of PQ problems.

2. Main Sources, Causes And Effects Of Electrical Power Quality Problems

Power Quality is “Any power problem manifested in voltage, current, or frequency deviations that results in failure or disoperation of customer equipments”. Power systems, ideally, should provide their customers with an uninterrupted flow of energy at smooth sinusoidal voltage at the contracted magnitude level and frequency [3-4].

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, Sort circuits(faults),Undersized electrical wiring, Temporary voltage rise or drop.	Memory loss, Data errors, Dim or bright lights, Shrinking display screens, Equipment shutdown
Interruption	Switching Operator, Attempting to isolate electrical problem and maintain power to power distribution area.	Equipment trips off, Programming is lost, 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.

Some of the primary sources of distortion can be identified as below:

- Non–Linear Loads
- Power Electronic Devices
- IT and Office Equipments
- Arcing Devices
- Load Switching
- Large Motor Starting

- Larger capacitor bank energies
- Embedded Generation
- Electromagnetic radiations and Cables
- Storm and Environment Related Causes

3. Mitigation Echniques Using Facts Devices

The dynamic voltage restorer (DVR) has become popular as a cost effective solution for the protection of sensitive loads from voltage sags and swells. The control for DVR based on dqo algorithm was discussed in [5]. Rosli Omar *et. al* [5] have described the problem of voltage sags and swells and its severe impact on nonlinear loads or sensitive loads. The proposed control scheme was simple to design. Simulation results carried out by Matlab / Simulink verify the performance of the proposed method. S. Sadaiappan *et. al* [6] have used a series compensator (SC) to improve power quality was an isolated power system investigated. The role of the compensator is not only to mitigate the effects of voltage sag, but also to reduce the harmonic distortion due to the presence of nonlinear loads in the network. In this proposed method, a series compensator was proposed, a method of harmonic compensation is described, and a method to mitigate voltage sag was investigated by S. Sadaiappan [6].

Chong Han *et al.* [7] have proposed a method in which an electrical arc furnace (EAF) is a major flicker source that causes major power quality problems. In this proposed method, flicker mitigation techniques by using a CMC-based STATCOM was presented and verified through a transient network analyzer (TNA) system. The required STATCOM capacity was first studied through a generalized steady-state analysis. Second, the STATCOM control strategy for flicker mitigation is introduced, and simulation results are given. Finally, a TNA system of the STATCOM and an EAF system are designed and implemented.

K. A. Schwabe *et al.* [8] have described the derivation of an analytical model and simulation for the unified series-shunt compensator (USSC) for investigating power quality in power distribution system. The USSC simulation comprises of two 12-pulse inverters which were connected in series and in shunt with the system. A generalized sinusoidal pulse width modulation (SPWM) switching technique was developed in the proposed controller for fast control action of the USSC. Simulations were carried out using the PSCAD/EMTDC electromagnetic transient programs to examine the performance of the USSC model. Simulation results from the proposed model demonstrated the performance of the USSC and its effectiveness for voltage sag compensation, flicker reduction, voltage unbalance mitigation, power flow control and harmonics elimination.

S. Rahmani *et al.* [9] have proposed a new combination of a three-phase Shunt Hybrid Power Filter (SHPF) and a Thyristor Controlled Reactor (TCR) for compensating harmonic currents and reactive power. The task of reactive power and harmonic compensation is shared by the combination of the SHPF and the TCR. The tuned passive filter and the TCR form a shunt passive filter (SPF) to compensate reactive power and consequently the SHPF is used to eliminate harmonic currents. The control of the SHPF is based on a nonlinear control technique method. The proposed combination provides the reactive power and harmonic currents required by the nonlinear load, thereby achieving sinusoidal supply currents in phase with supply voltages under dynamic and steady state conditions.

Tejas Zaveri *et al.* [10] have proposed a Distribution STATIC COMPENSATOR (DSTATCOM) for balancing source currents, power factor correction and harmonic mitigation in three-phase, three-wire distribution system supplying delta connected load under various source voltage conditions. The control strategy applied to the DSTATCOM play a major role in its performance. A novel approach based on an improved instantaneous active and reactive current component (IARCC) theory is proposed for generation of three-phase reference currents for DSTATCOM. A three-phase voltage source converter with a dc bus capacitor is employed as DSTACOM, which will track the reference currents in a hysteresis band scheme. The performance of DSTATCOM is evaluated under sinusoidal, unbalanced sinusoidal and unbalanced distorted source voltage conditions. The performance of the DSTATCOM using the proposed control strategy is demonstrated using simulation results in MATLAB/SIMULINK software. Simulation results demonstrate the feasibility of proposed scheme for the control of DSTACOM. According to Mohammad H. Moradi *et al.*[11] different methods for voltage sag source location (upstream or downstream) based on various criteria such as energy, impedance, voltage or current is simulated and compared with each other. In this method the current (pre sag and during sag) is the only variable measured by relay/power quality (PQ) monitor. The performance of proposed method along with the mentioned methods above will be compared under symmetrical and asymmetrical faults on a sample network. This network is a large-scale real regional network including transmission and sub-transmission levels, which was modeled by using PSCAD/EMTDC. The output data are processed via MATLAB codes. The results determine the accuracy and validity of each method and show good performance of the proposed method and its unique applicability in cases where only currents are recorded. This study will help utilities in operation and network planning.

E. Najafi *et al.* [12] have proposed a new current mode controller to overcome the mentioned problem. The approach uses a fixed frequency current controller to maintain voltage levels in voltage sags (dips). This proposed was also simple and can be easily implemented by digitally. It has superior performance over conventional methods in terms of harmonic reduction in STATCOM output current. Another important factor for STATCOM effectiveness in sag mitigation is its sag detection method. This paper also introduced sag detection method based on Goertzel algorithm, which was both effective and simple for practical applications. The simulation results presented illustrate the superiority of the proposed controller and sag detection algorithm to be utilized in the STATCOM. Tejas Zaveri *et al.* [13] have discussed the mitigation of power quality disturbance in low voltage distribution system due to voltage swells using one of the powerful power custom devices namely Dynamic Voltage Restorer (DVR). The DVR normally installed between the source voltage and critical or sensitive load. The new configuration of DVR has been proposed using improved d-q-o controller technique. The simulations are performed using Matlab/Simulink's SimPower Toolbox. The proposal is then implemented using 5KVA DVR experimental setup. The simulation and experimental results demonstrate the effective dynamic performance of the proposed configuration.

N. Sudhakar *et al.* [14] have proposed a method in which the effect of power system deregulation on the power quality problems is investigated. Identifying the high priority research areas related to electric power quality in deregulated power systems and investigating the advances made in this area over the last decade constitutes the main goal of this paper. The paper addresses the definition of deregulated environment, the different mitigation techniques implemented to improve the system power quality. Moreover, the advances in research on using modern signal processing techniques like wavelet transform in developing automated recognition of power system disturbances is pointed out.

T. K. Abdel-Galil *et al.* [15] have proposed a technique in which FACTS devices, power electronic devices and their switching control schemes are used for improving the power flow in the transmission network and hence improve the power quality and reliability of the low-voltage distribution network. The Distributed Static Compensator or DSTATCOM was a type of FACTS controller and has the function of reactive power compensation and harmonic mitigation. This paper discussed the use of synchronous detection algorithm for implementation of DSTATCOM for mitigation of harmonics.

In literature, large number of reported articles are present which used large number of feature sets. Feature set are the strength of any mitigation system. This leaves a question that how these features will perform when applied to events. Therefore, it is important to investigate the discriminative power of each PQ identification feature proposed in the literature before one may use it for the purpose. In view of this, a comprehensive analysis is desirable. However, results reported were quite encouraging on most occasions, which were obtained using only a selected number of events in experimental study.

4. Key Issues and Challenges In Mitigating Power-Quality Problems

- Use of Large number of energy efficient devices in public and private sectors.
- A new design which incorporates a superconducting magnetic energy storage module as a DC voltage source to mitigate voltage sags and enhances power quality of a distribution system based on DVR.
- The dynamic voltage restorer (DVR) has become popular as a cost effective solution for the protection of sensitive loads from voltage sags and swell
- Data compression becomes a significant issue. Methods like WT offer this added advantage, however, prime matters such as estimation correctness needs to be improved.
- For techniques based on ANN, it is difficult to collect sufficient training signal patterns for practical applications because the highly time-varying behaviour of

nonlinear loads may be unexpected. There is a need for dynamical adjustment of the size of the neural network to effectively search for the minimum estimation errors of the measured signal.

5. Conclusion

In this paper, we have reviewed the mitigation techniques using FACTS devices of various PQ issues like voltage sag or dip, very short and long interruptions, voltage spike, voltage swells etc. Power system and its equipment is badly affected to this PQ issues like breakdown of information technology equipment or may be stoppage of all equipment, circuit breakers trip without being overloaded, automated systems stop for no apparent reason, electronic systems work in one location but not in another location. Most of the research highlight on product innovation and cost reduction. But few of them focuses on studying the PQ related issues are of most distress because of the extensive use of electronic equipments. Here I have intended to propose a proper change in perspective of PQ. The information obtained in the current study will be helpful to understand the mitigation techniques using FACTS devices of power quality problems in the electrical network.

6. Directions for Future Research

This paper contain the topic means compensate power quality problem have good scope as our power system is most affected by power quality problems because now a days there is no any technology available which is able to compensate or protect power qualities problem totally or fully, we only compensate certain part of power quality problem that’s why at time to time researchers, research on this topic to how to compensate power quality problems. Now a days nonlinear loads are frequently used in our power system, it is also the major source of power quality issues. This paper focus on to compensate voltage variation (sag, swell, etc.). It can also mitigate voltage dips and over-voltages, compensate reactive power of the load, unbalance in currents, and can compensate unbalance in load voltages. In future cost-effective mitigation techniques can be developed to mitigate multiple power quality problems simultaneously.

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