

Power Quality Issues and Their Mitigation Techniques

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Abstract— *With the increased use of sophisticated electronics, high efficiency variable speed drive, power electronic controllers and also more & more non-linear loads Power Quality has become an increasing concern to utilities and customers. This paper presents the problems associated with the power quality or power quality issues and their mitigation techniques. A practical system is considered for analyzing different cases of power quality issues such as voltage sags, harmonics and transients and with and without compensation devices and are simulated by using Mi Power Software.*

Keywords— *DSTATCOM, Filters, Harmonics, Power Quality, SVC, Transients, Voltage sag.*

I. INTRODUCTION

The term Power Quality has become one of the most prolific buzzword in the power industry since the late 1980s. Both electric utilities and end users of electrical energy are becoming increasingly concerned about the quality of electric power. Electrical Power Quality is the degree of any deviation from the nominal values of the voltage magnitude and frequency. Power Quality problems concerning frequency deviation and voltage magnitude deviations because of the presence of harmonics and voltage fluctuations other voltage problems are the voltage sags, short interruptions and transient over voltages. In this paper, main focus is made on the following problems and their mitigation. The demarcation of the various Power Quality issues defined by IEEE Std. 1159-1995, are described in The power quality issues such as voltage sags, swells, harmonics ,transients and their mitigation techniques those are suitable for different types of voltage sags , filter deign for reducing harmonic distortion and Surge arrester sizing for location of transients.

The main objective of this paper is:

- i) To investigate the suitable mitigation techniques.
- ii) The power quality mitigation analysis is made by using MI Power Software.
- iii) Observe the effectiveness of Static VAR Compensator (SVC), Distribution Static Compensator (DSTATCOM), Passive harmonic filter and surge arrester. This paper organized into four sections: Section II shows the solution of the different power quality problems in the form of custom power devices harmonics filters and surges arresters, the Section III shows the Simulation Results and the Section IV shows the Conclusion. The following factors that are serious concerns in Power Quality are:
 - i. Newer generation load equipment, with microprocessor based controls and power electronic devices, is more sensitive to Power Quality variations, then was equipment used in the past.
 - ii. The increasing emphasis on over all power system has resulted in continued growth in the application of devices such as high efficiency, adjustable speed motor drives and shunt capacitors for power factor correction and to reduce losses. This is resulting in increasing harmonic levels in power systems and has many people concerned about the future impact on system capabilities.
 - iii. End users have an increased awareness of Power Quality issues. Utility customers are becoming better informed about such issues as interruptions, sags, and switching transients, and are challenging the utilities to improve the quality of power delivered.
 - iv. In industries many things are interconnected in a work. Integrated process means that the failure of any component has much more important consequences.

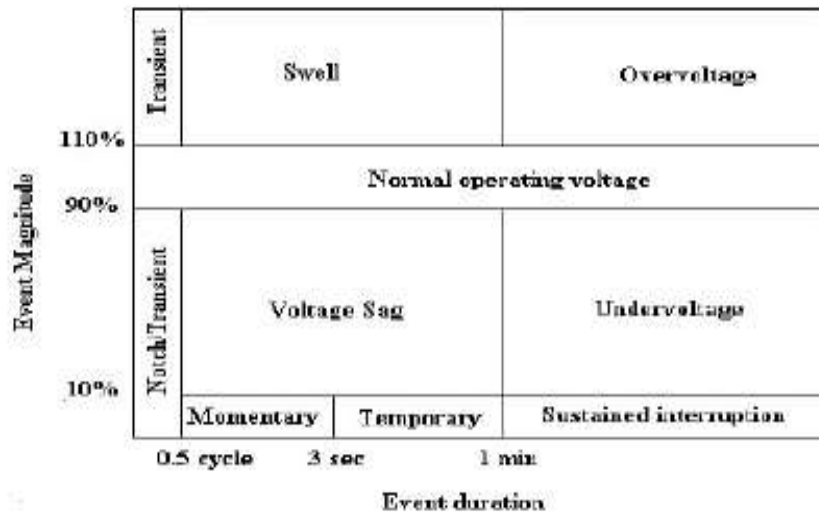


FIGURE 1: Demarcation of the various Power Quality issues defined by IEEE Std. 1159-1995.

II. POWER QUALITY ISSUES AND MITIGATION TECHNIQUES

There are different solutions to mitigate Power Quality problems. The solution adopted will be tailored specifically to the problem and site. The measures used in this paper to deal with Power Quality disturbances are:

- 2.1. Static VAR Compensator (SVC)
- 2.2. Distribution Static Compensator (DSTATCOM)
- 2.3. Passive harmonic filters
- 2.4. Surge arresters

2.1. Static VAR Compensator (SVC):

SVC is a shunt device, which is a family member of flexible AC transmission system (FACTS) uses power electronics equipment to control reactive power flow. The term static is used to differentiate SVCs from rotating var compensators (synchronous motors or generators). The SVC regulates the voltage at its terminals by controlling the amount of reactive power injected into or absorbed from the power system. When the system voltage is low, the SVC generates reactive power (capacitive behavior). In this manner, the demand of reactive power of the load is provided by the SVC and the feeding lines are relieved. As a result, the voltage drop decreases and the voltage at the load terminals increase. Similarly, when the system voltage is high, the SVC absorbs reactive power (inductive behavior) [5]. There are two types of SVC:

2.1.1. Fixed Capacitor-Thyristor Controlled Reactor (FC-TCR)

2.1.2. Thyristor Switched Capacitor – Thyristor Controlled Reactor (TSC- TCR).

The second one is more flexible than the first one, requires smaller rating of the reactor, and consequently generates fewer harmonics. The schematic diagram of a TSC- TCR type SVC is shown in Fig 2. It shows that the TCR and TSC are connected on the secondary side of a step-down transformer. Tuned and high pass filters are also connected in parallel, which provide capacitive reactive power at fundamental frequency. Using a potential transformer, the voltage signal is taken from the high voltage SVC bus. The TSC is switched in using two thyristor switches (connected back to back) at the instant in a cycle when the voltage across valve is minimum and positive. This results in minimum switching transients. In steady state, TSC does not generate any harmonics. To switch off a TSC, the firing pulses are blocked and the thyristors turns off when the current through the thyristors less than the holding currents. When the voltage rating of a thyristor is not sufficient for the required voltage level, then the several pairs of thyristors are connected in series to improve the voltage rating. However the voltage ratings of valves for

a SVC are much less than the voltage ratings of a HVDC valve as a step down transformer is used in the case of SVC. To limit di/dt in a TSC it is necessary to provide a small reactor in series with the capacitor.

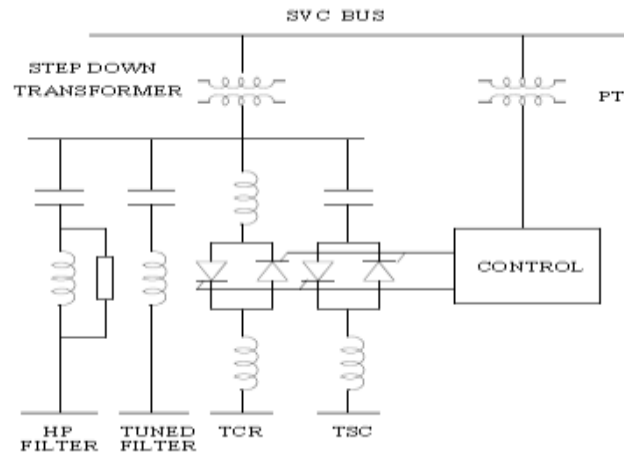


FIGURE 2: Typical static var system.

2.1.1.1 Modeling of Static VAR Compensator

A functional block diagram representation of the SVC is shown in fig.

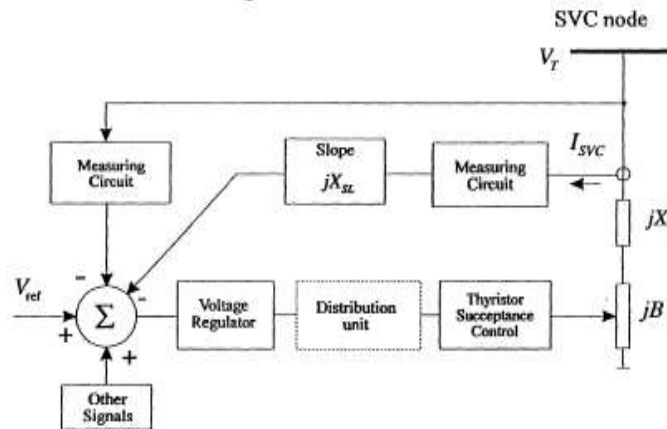


FIGURE 3: Basic SVC model

2.2. Distribution Static Compensator (DSTATCOM):

The Distribution Static Compensator (DSTATCOM), previously referred to as a static condenser (STATCOM) or advanced static VAR compensator (ASVC) or self-commutated static VAR compensator is a shunt connected reactive compensation equipment which is capable of generating and/or absorbing reactive power whose output can be varied as to maintain control of specific parameters of the electric power system. The term static indicates that it is based on solid-state power electronic switching devices with no moving or rotating Components. The terms synchronous and compensator indicate that it is analogous to an ideal synchronous machine generating a balanced set of 3 sinusoidal phase voltages at fundamental frequencies.

2.2.1. V-I characteristics of Distribution static compensator:

The DSTATCOM is essentially an alternating voltage source behind a coupling reactance with the corresponding V-I characteristics as shown in Fig 4.

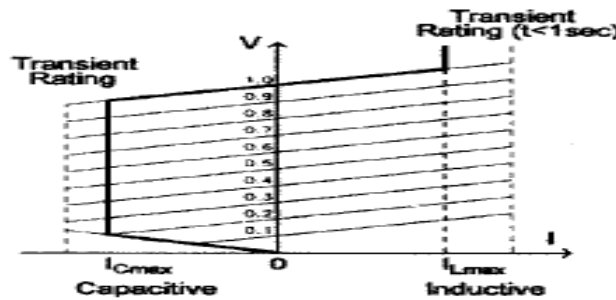


FIGURE 4: V-I characteristics of DSTATCOM

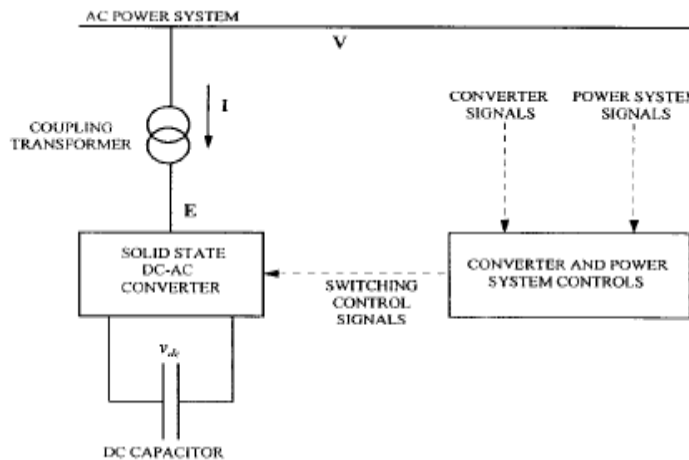


FIGURE 5: Typical DSTATCOM overview

2.3. Harmonic Filters:

One of the most common methods of controlling harmonic distortion is to place a passive shunt harmonic filter close to the harmonic producing load(s), which is a source of harmonic current. The objective of the harmonic filter is to shunt some of the harmonic current from the load into the filter, thereby reducing the amount of harmonic current that flows into the power system. The simplest type of shunt harmonic filter is a series inductance/capacitance (LC) circuit.

2.5. Surge Arrester:

Arresters and TVSS (Transient Voltage Surge Suppressers) devices protect equipment from transient overvoltage by limiting the maximum voltage. However, TVSSs are generally associated with devices used at the load equipment. A TVSS will sometimes have more surge-limiting elements than an arrester, which most commonly consists solely of Metal Oxide Varistors (MOV) blocks. An arrester may have more energy-handling capability. Overvoltage protection devices or surge protectors protect facilities and equipment against transient voltage surges produced by lightning (μ s), electrostatic discharges (ns), switching (ms) or long voltage deviations at power frequency(s). They limit or eliminate voltage surges up to acceptable limits, blocking or shorting them to earth.

III. SIMULATION AND RESULTS

Consider the study system is a 20-bus industrial power system. The system taken has 6 generators and connected to grid. In the system taken there is an industry connected at 66kV. The industry has a motor load connected at 11 kV, and arc furnace load connected to bus-603. These are the instigators of the Power Quality issues viz., voltage sags because of motor starting and

harmonics & time varying load (cyclic load) because of the arc furnace Separate cases of these major power quality issues are analyzed with and without the compensating devices and simulated by using Mi-Power. Different power quality cases are simulated and their results are presented.

CASE I: Voltage dip due to motor starting

The system taken has a motor load, connected at 11 kV and the motor data is given in Table 1. The voltage at the 11kV motor bus and reactive power taken by the motor during starting is as shown in Fig.6 and Fig.7 respectively.

3.1 Motor data

| | Connected to bus No | MVA Rating | MW Rating | kV Rating | Inertia |
|--------------|---------------------|------------|-----------|-----------|---------|
| Motor | 5 | 4.6875 | 3.6 | 11 | 500 |

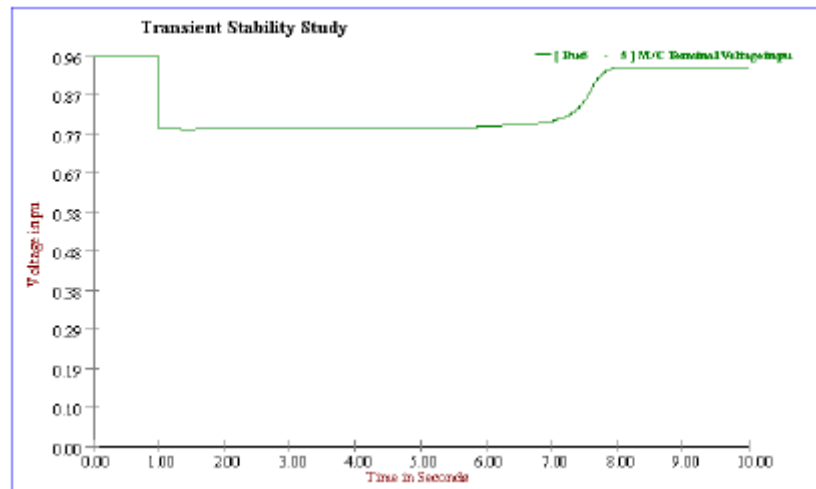


FIGURE 6: Voltage at the 11 kV bus (motor is started after 1 sec)

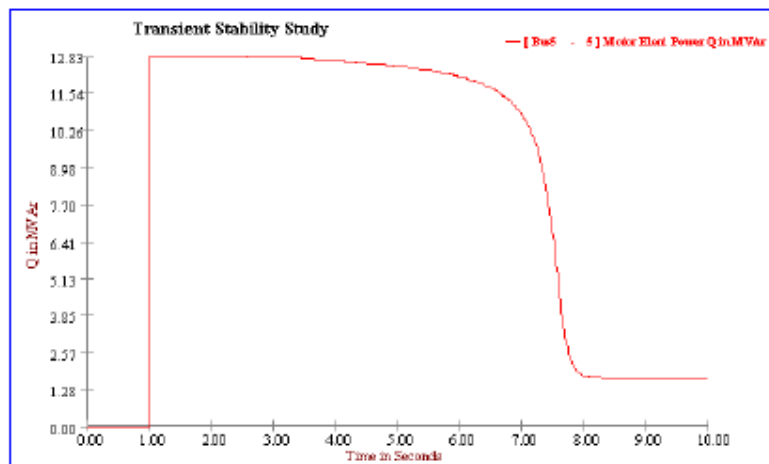


FIGURE 7: Reactive power taken by motor (motor is started after 1)

3.2 SVC model

There are mainly two types of models used for SVC, one is integral type and the other one is proportional type. Proportional type is used in this system study, as shown in Fig.8.

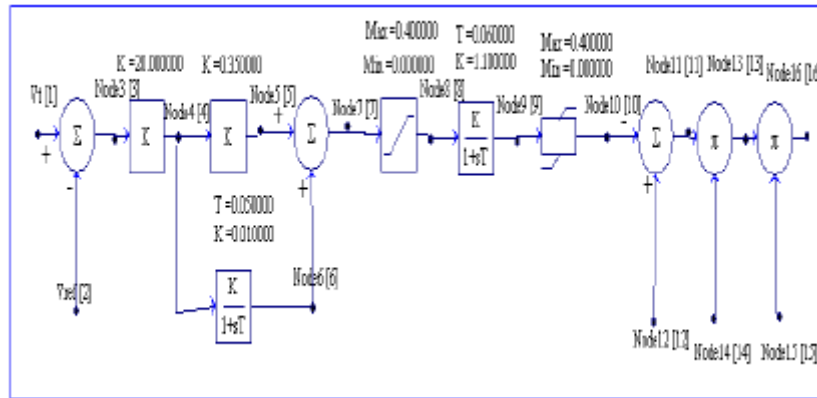


FIGURE 8: SVC Model designed using FPB

Transient stability analysis is carried on the system for the motor starting using SVC. The voltage characteristic of the system with SVC is as shown in Fig.9.

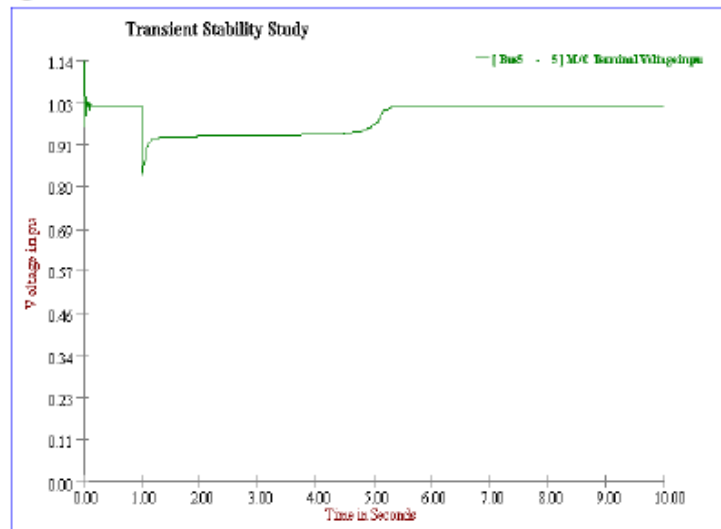


FIGURE 9: Voltage at the 11 kV bus – by using SVC

3.3 DSTATCOM Model

A DSTATCOM is said to have superior performance during low voltage condition as the reactive current can be maintained constant compared to SVC because in a SVC the capacitive reactive current drops linearly with the voltage at the limit of capacitive susceptance. To validate this fact, the same motor starting study was performed with DSTATCOM. The DSTATCOM is designed using FPB (Free Programmable Block) in Mi Power. DSTATCOM is designed by using sensitivity based simulations and DSTATCOM parameters were finely tuned based on system requirement.

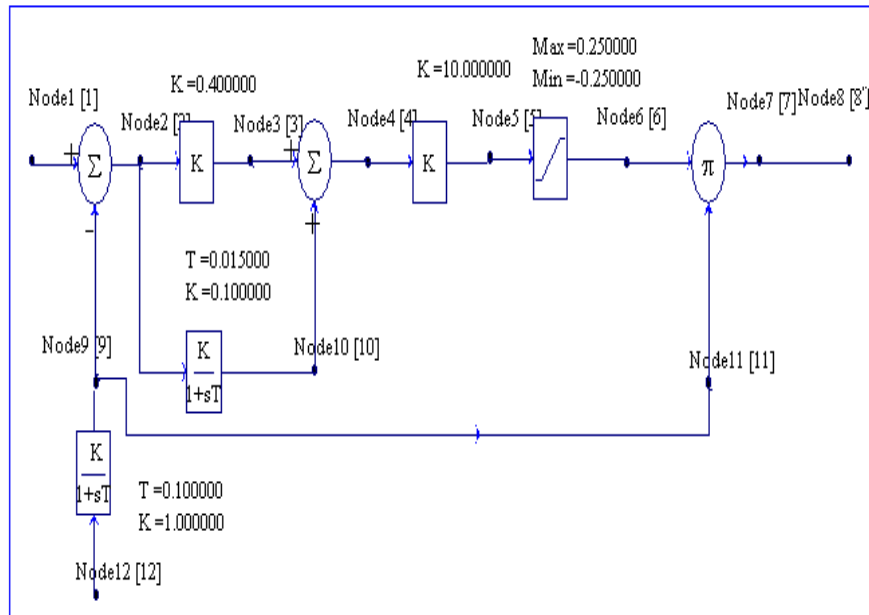


FIGURE 10: DSTATCOM Model designed using FPB

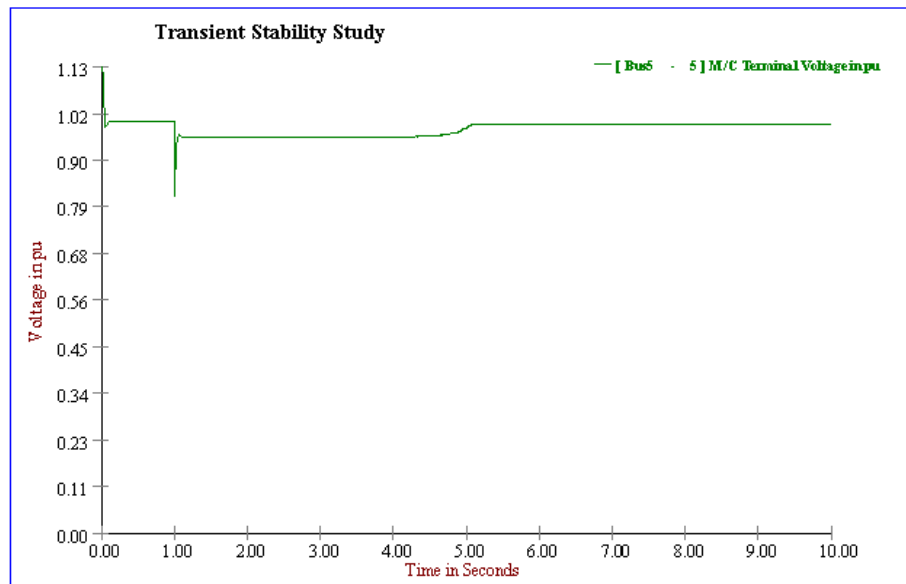


FIGURE 11: Voltage at the 11 kV bus – by using DSTATCOM

CASE II: Voltage dip due to LG Fault and 3-phase fault: Single line-to-ground faults (SLGF) on the utility system are the most common cause of voltage sags in an industrial plant. The utility attempts to clear the fault by opening and closing the faulted circuit using reclosers, which can require from 40 to 60 cycles. The power line experiences voltage sags or total loss of power for the short duration it takes to clear the fault. So, to mitigate the voltage dip due to these faults SVC and DSTATCOM can be used. During the LG fault a voltage dip of about 0.3 p.u. V is observed as shown in Fig.12.

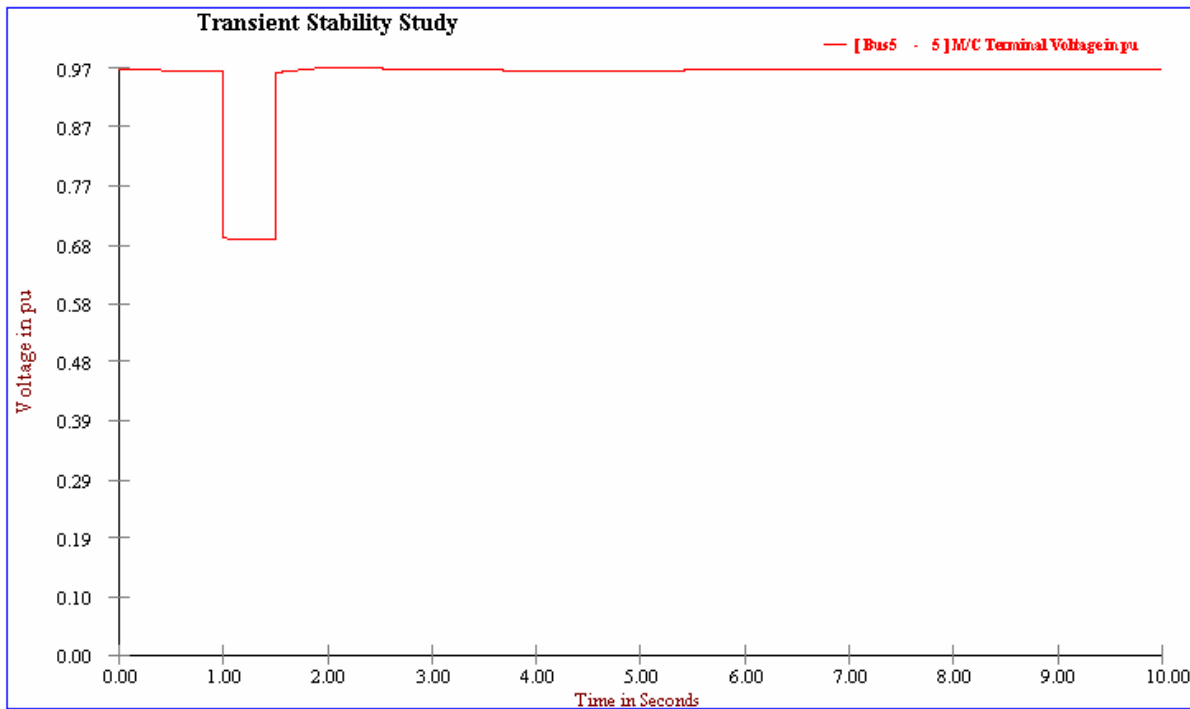


FIGURE 12: Voltage at 11 kV bus when SLG fault applied

By using SVC, the dip is reduced to 0.22 p.u. V is as shown in Fig.12.

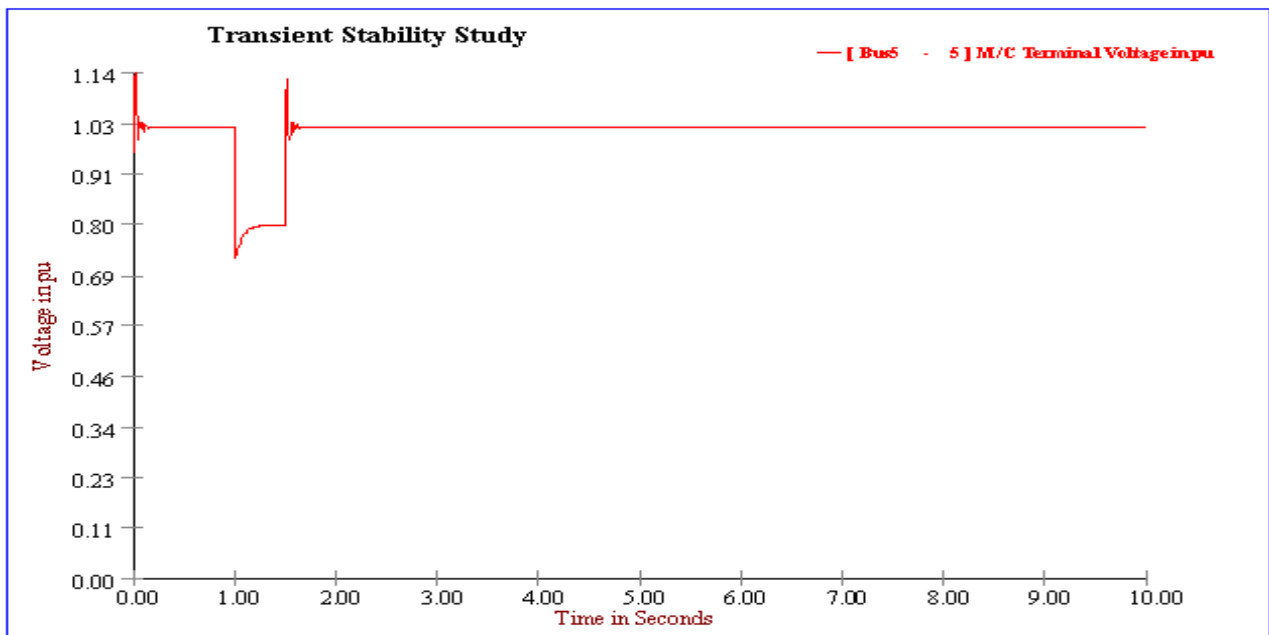


FIGURE 13: Voltage at 11 kV bus when SLG fault applied & SVC connected

By using DSTATCOM, the dip is reduced to 0.13 p.u. as shown in Fig.14.

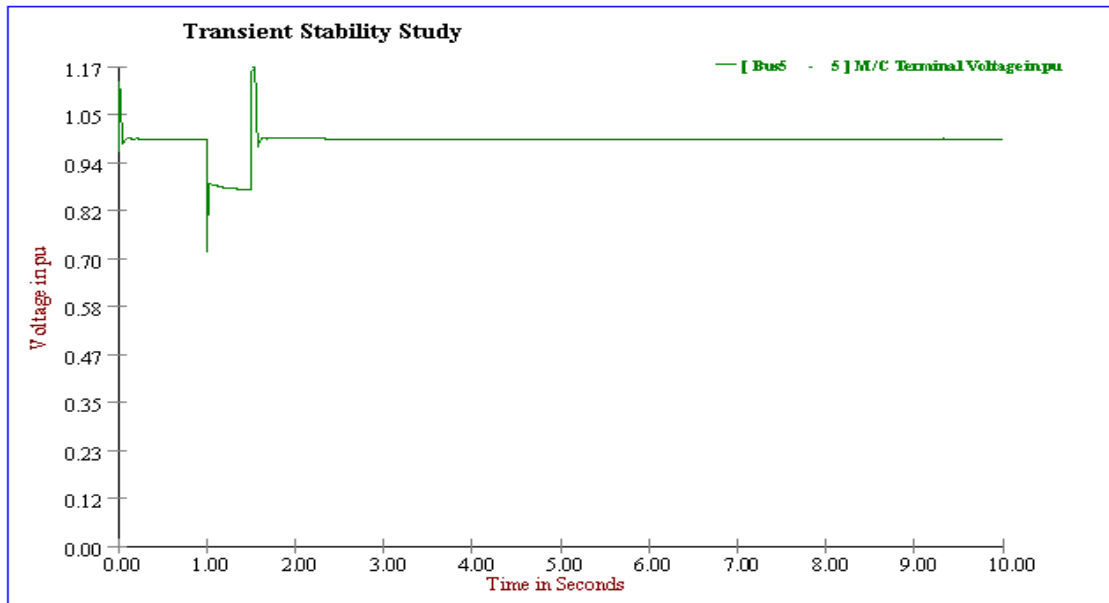


FIGURE 14: Voltage at 11 kV bus when SLG fault applied & DSTATCOM connected

The DSTATCOM has superior performance compared to SVC during low voltage condition as the reactive current can be maintained constant and is independent of the system voltage, the voltage dip is reduced considerably. To test the working of these two devices a 3 phase fault is applied at 11 kV bus, and the voltage characteristics is as shown in Fig.14

Transient stability analysis is carried out on the system for the motor starting using DSTATCOM. The voltage characteristic of the power system with DSTATCOM is as shown in Fig.16. By using the DSTATCOM, the voltage dip is reduced to 0.96 p.u. (0.94 p.u. in case of SVC) and the starting time of the motor is marginally reduced.

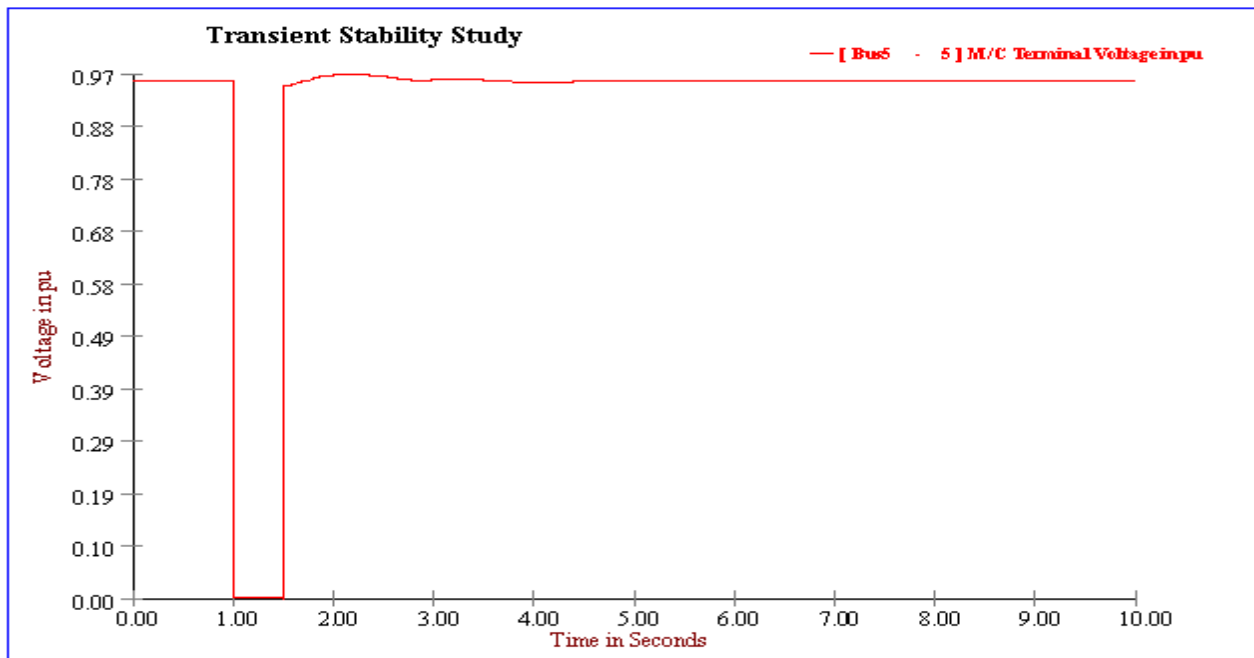


FIGURE 15: Voltage at 5th bus when 3-phase fault applied & SVC connected

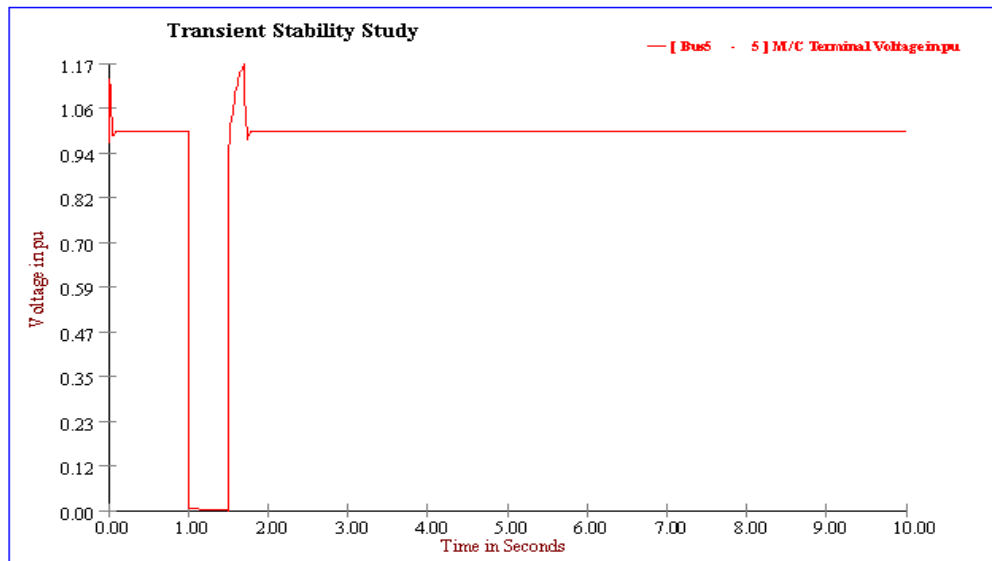


FIGURE 16: Voltage at 11 kV bus when 3-phase fault applied & DSTATCOM connected

IV. CONCLUSION

The associated problems of Power Quality that a customer may encounter 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. In this paper, it is focused on these major issues. Therefore, in this paper, it is investigated to use mitigation technique that is suitable for different type of voltage sags source, voltage fluctuations, harmonics and transients. The simulation is carried out using MiPower software and the mitigation techniques that using such as Static VAR Compensator (SVC), Distribution static compensator (DSTATCOM), passive Harmonic Filters, and Surge arrester.

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