

Performance Evaluation of Voltage Profile Stability Under Dual Side Fault Condition Using Static var Compensator

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Abstract-A Static Var Compensator (SVC) is basically a shunt FACTS device, most often whose output is attuned to exchange capacitive or inductive current to the system. The voltage profile improvement is a process of improvement reactive power transfer or to provide better and stable voltage during transmission of power through transmission lines. This paper basically presents the performance evaluation of conventional PI controller based voltage regulator SVC system for voltage profile improvement.

Index terms: Voltage Stability, Three Phase Transmission system, Voltage Regulation, PI controller, SVC.

1. Introduction

The concept of Flexible AC transmission system has been proposed in 1995, which is called FACTS. The basic idea of FACTS is install the power electronic devices at the high-voltage side of the power grid to make the whole system by electronic means controllable. The advances achieve in high power semiconductor devices and control technology makes the basis of the development of FACTS. The FACTS devices are able to provide active and reactive power to the power grid quickly. The power reimbursement achieved by FACTS devices could adjust the voltage of the whole system and the power flow might be adequately controlled. Generally, the FACTS devices and technology could be divided into two generations:

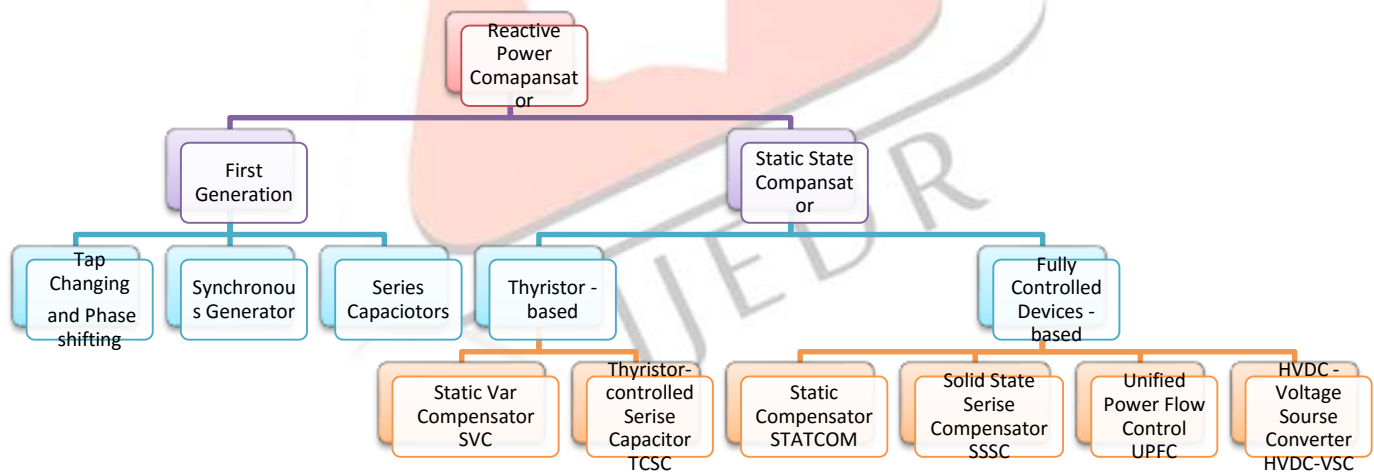


Figure1.The category of FACTS devices

- I. Dynamic devices and fixed capacitance devices. This is the first generation of the FACTS devices. In this period, the usual devices are including tap changing and phase changing transformer, synchronous generator and series capacitors. Apart from the series capacitors, which could also be called capacitor bank, others are dynamic devices. These devices are primarily controlled at the generation side of the power grid and the cost is typically expensive. When talk about the series capacitors, the disadvantage of this device could hardly be omitted. Since the device is made up of many fixed-capacitance capacitors, it could hardly be controlled to provide the real not-fixed capacitance to the grid.
- II. Static state compensator. This is the second generation of the FACTS devices. It could be classified into two categories: thyristor base devices and fully-controlled devices base compensator. The thyristor is called half-controlled device, as it can only be controlled to switch on but not to cut off. Static Var Compensator (SVC) and Thyristor-Controlled Series Capacitor (TCSC) are incorporated in this category. The fully controlled devices mainly involve GTO etc. The Static Compensator

(STATCOM), Solid State Series Compensator (SSSC), Unified Power Flow Controller (UPFC) and HVDC-Voltage Source Converter (HVDC-VSC) are incorporated in this group.

This paper focus on the performance evaluation of conventional PI controller based voltage regulator for voltage profile improvement.

2. Basic operation of SVC

The static var compensator adjusts the voltage by controlling the reactive power amount absorbed from or injected into the power system. For instance, it generates reactive power by switching capacitor banks when the system voltage is low down or loads are inductive. Accordingly, the lagging load demanded the reactive power is supplied by the SVC relieve the distributing lines from delivering it. As a result, the voltage drops reduce and the voltage at the load terminals shall get better.

Similarly, the static var compensator absorbs reactive power when the system voltage is high or loads are capacitive. In this case, the SVC uses the reactors to consume the VARs from the system, thereby lower the system voltage.

2.1 Design and Configurations of SVC

There are three common configurations of static var compensators and each will be described below.

(i). Thyristor-controlled Reactors with Fixed Capacitors (TCR/FC)

This SVC design having two parallel branches connected on the secondary side of a coupling transformer. One of the branches is uses reactors that are controlled by AC thyristor switches. Additionally, the reactors are connected in delta for three-phase applications. The other branch could either be fixed capacitor banks or shunt filters.

The discrepancy of reactive power is achieved by controlling the thyristor's firing instants and, accordingly, the current that flows by the reactance.

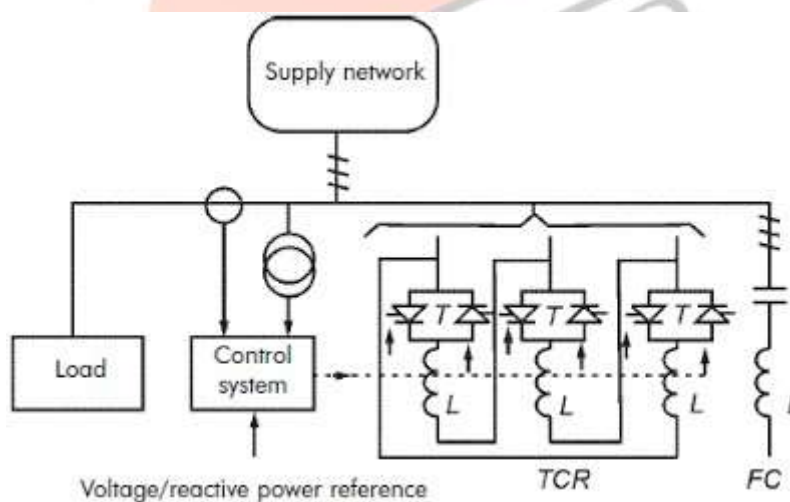


Figure 2 Thyristor-controlled Reactors with Fixed Capacitors (or Shunt Filters)

(ii). Thyristor switched capacitors (TSC)

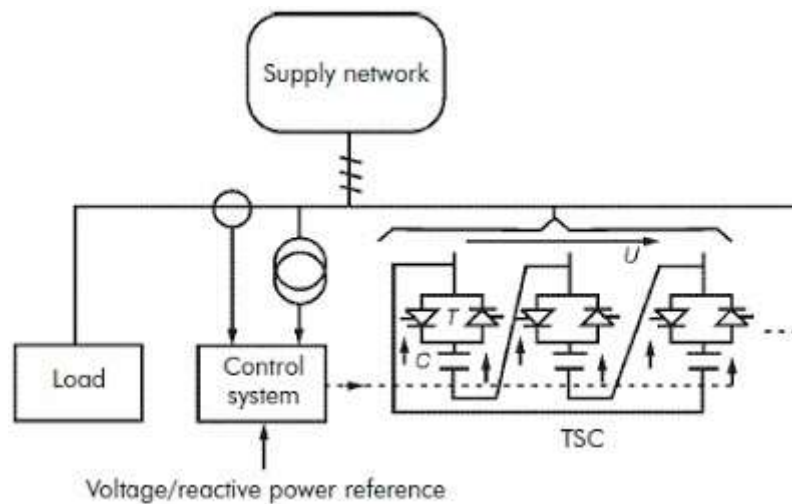


Figure 3 Thyristor-switched Capacitors (TSC)

In this type of static var compensator device, the capacitor banks are linked phase-to-phase, with each section switched by thyristors. Thus, a distinct variation of the reactive power can be attained but not a continuous alteration similar to that of a TCR. On the other hand, by given that a suitably large number of small sections, the required resolution of reactive power alteration for a single step can be achieved. Synchronization of switching and initial pre-charging of the capacitors limits the [transients](#) usually linked with capacitor switching. Generally, the reaction time for symmetrical operation does not exceed 20 ms.

(iii). Thyristor-controlled Reactors and Thyristor switched capacitors (TCR/TSC)

Fundamentally, this is the grouping of TCR and TSC. In this configuration, the control of the static var compensator is depends on measuring the reactive component of load current at the instantaneous of voltage zero. Subsequently, the measured current is used to obtain the firing angle so that the SVC absorbs or injects the amount of reactive power requisite for compensation.

However, there is a time interval between the instant of measuring the reactive component (in one half-cycle) and the firing instant (the next half-cycle). This natural delay of its operation mode is one of its major limitations.

3. Methodology

3.1 AC lines Voltage Regulation using Conventional Static var compensator

The Static Var Compensator (SVC) is a shunt scheme of the Flexible AC Transmission Systems (FACTS) family to regulate the power flow and improve transient stability on power grids. The SVC controls the voltage at its terminals by adjusting the amount of reactive power inserted into or absorbed from the power system. When voltage is low, the SVC produces reactive power (SVC capacitive). When voltage is high, it grips reactive power (SVC inductive). The variation of reactive power is executed by switching three-phase capacitor banks and inductor banks coupled on the secondary side of a coupling transformer. Each capacitor bank is switched on and off by three thyristor switches (Thyristor Switched Capacitor or TSC). Reactors are either switched on-off (Thyristor Switched Reactor or TSR) or phase-controlled (Thyristor Controlled Reactor or TCR). Fig.4 shows a single-line diagram of a static var compensator and a streamlined block diagram of its control system.

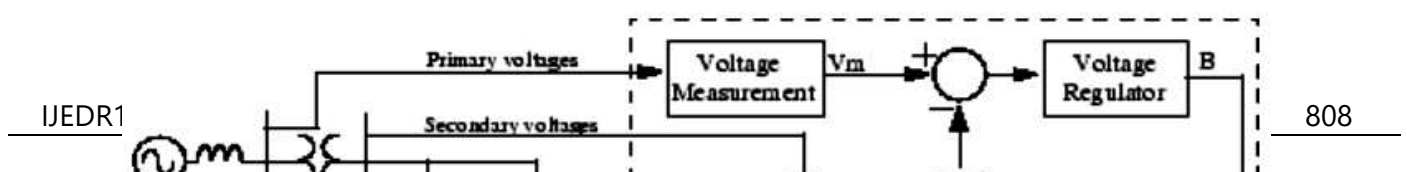


Figure 4. Single line voltage regulation using SVC.

The control system of conventional SVC consists of:

- A measurement system determining the positive-sequence voltage to be controlled. A Fourier-based dimension system using an average of one-cycle running is used.
- A voltage regulator that uses the voltage error (difference between the measured voltage V_m and the reference voltage V_{ref}) to find out the SVC susceptance B_{SVC} needed to keep the system voltage constant.
- A distribution unit that decides the TSCs (and eventually TSRs) that must be switched in and out, and computes the firing angle α of TCRs.

A synchronizing system using a phase-locked loop (PLL) synchronized on the secondary voltages and a pulse generator that send suitable pulses to the thyristors. SVC with the voltage regulation unit accepts measured voltage from the line V_m and reference voltage V_{ref} to generate the controlled SVC susceptance B_{SVC} needed to keep the line voltage constant.

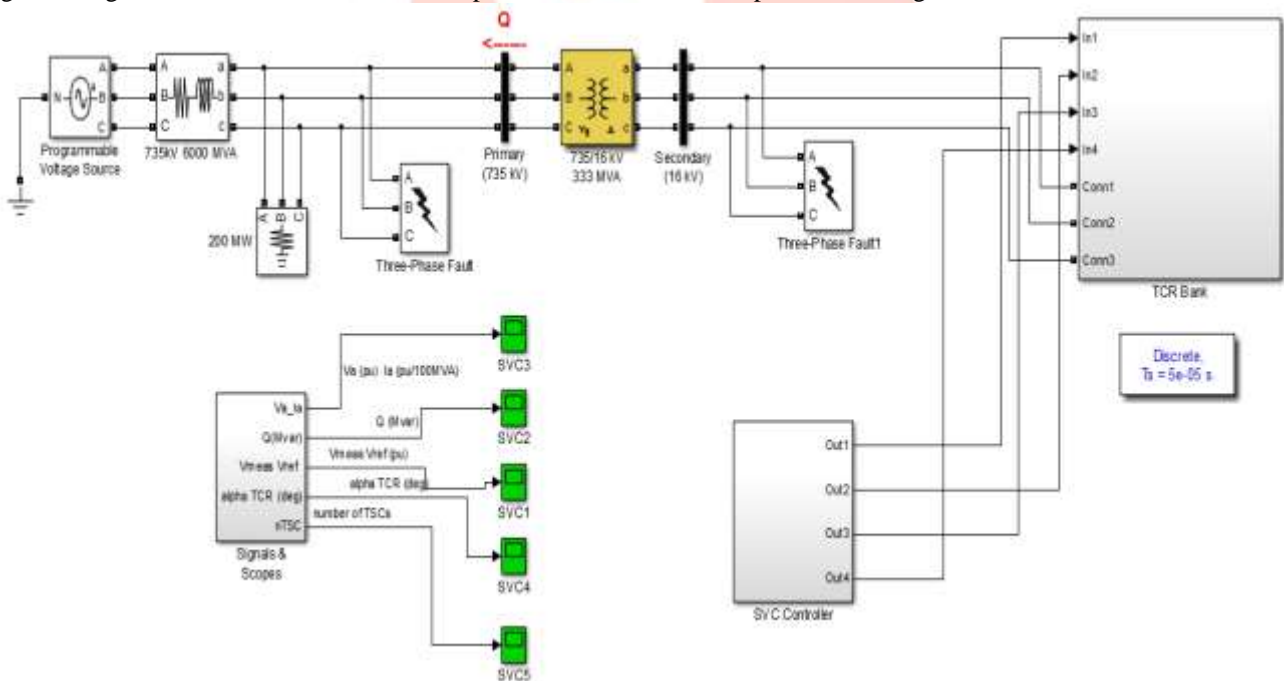


Figure 5. Simulation Diagram for SVC Regulated three phase system

The SVC controller subsystem consist of PI controller based voltage regulator which controls the susceptance of SVC by differences of signals V_m and V_{ref} to maintain the vottage constant during the fault condition. The sub-system are as follows

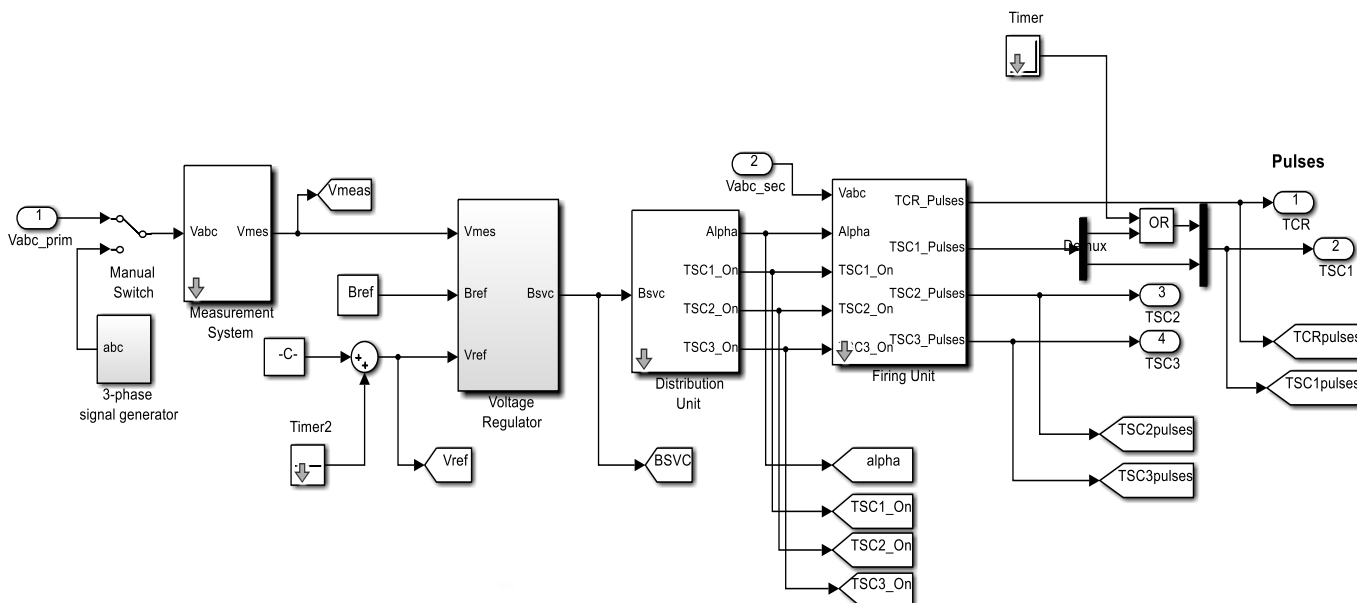


Figure 6. Subsystem for SVC controller

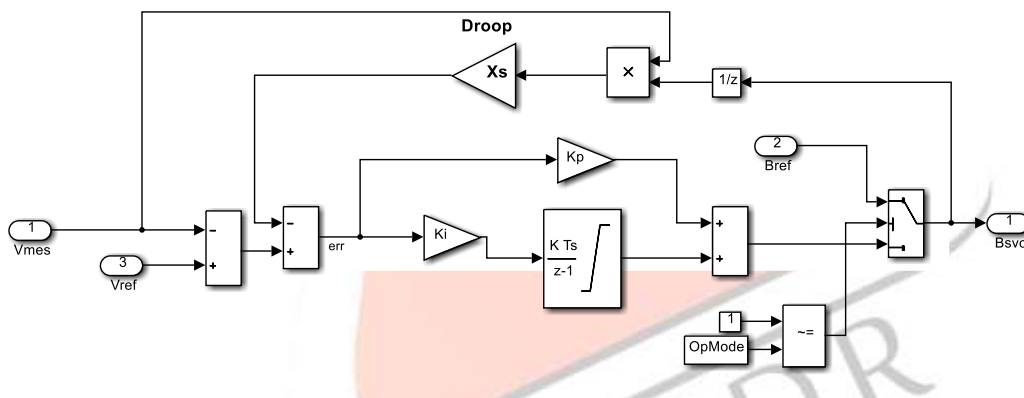


Figure 7. PI controller for Voltage Regulation

4. Parameter for Modeling

Three Phase Programmable Voltage Source

This block implements a three-phase zero-impedance voltage source. The common node (neutral) of the three sources is accessible via input 1 (N) of the block.
 Amplitude ($V_{rms} \text{ Ph-Ph}$) – 735×10^3 , Phase (deg.) – 0, Freq. (Hz) – 60

Three Phase Series RL Branch

Implements a three-phase series RL branch having $R = 9.0038$ (ohm), $L = 0.23895$ (h).

Three Phase Series RLC Load- $V_{RMS} = 735 \times 10^3$, Power rating $P = 200 \text{ MW}$

Ratings of TCR and TSC

TCR = 109 Mvar TSC1 = TSC2 = TSC3 = 94 Mvar

4. Performance Evaluation of PI controller based voltage regulator for voltage profile Improvement

This section presents the details of performance evaluation performed to analyze the conventional PI controller based voltage regulator for its voltage profile improvement capability.

The first case study is performed by taking phase AB to ground fault for both the primary and secondary side. The three phase voltage waveform obtained for this case is shown in figure (8).

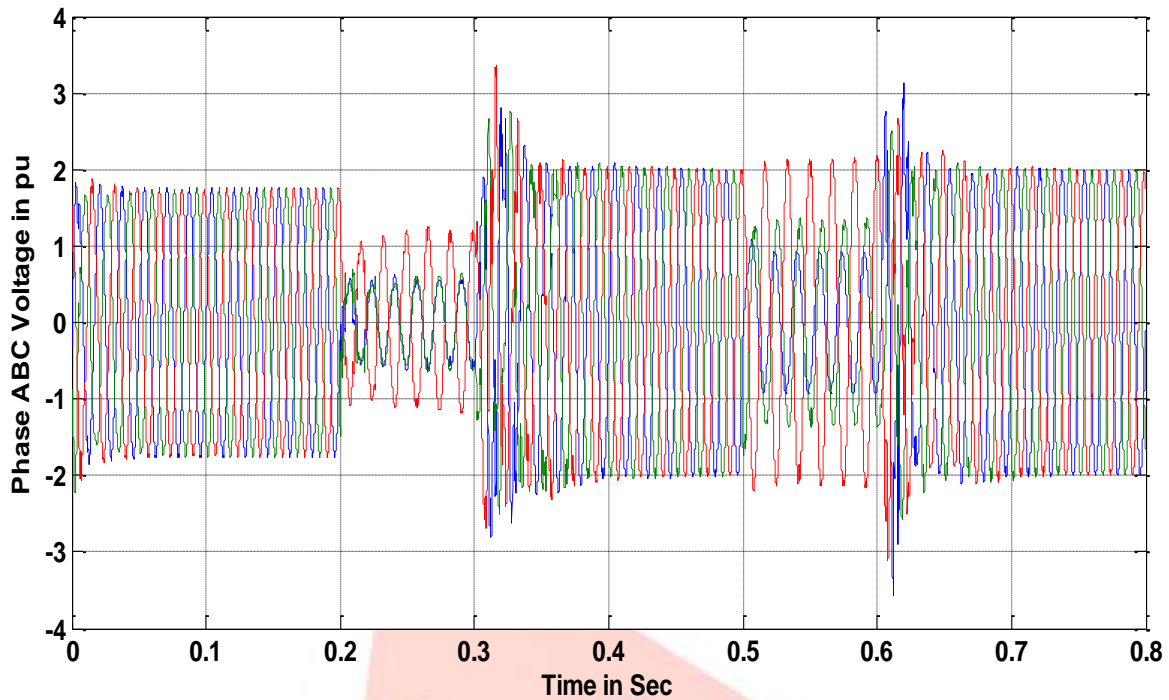


Figure 8. phase AB to ground fault effect on the transmission line voltage profile

The above figure clearly indicates that there are two fault conditions on phase A and phase B on two different time spans. The first fault is occurred here for .1 sec from $t = 0.2$ sec to $t = 0.3$ sec while the second fault is occurred for again .1 sec from $t = .5$ sec to $t = .6$ sec.

Now the results obtained after restoration of the means voltage for the conventional SVC based system is shown in figure (9).

From the above figure it is clear that, during the fault timing the means voltage dropped to very low values but after the clearance of fault the conventional SVC settles the voltage within the tolerance range of .1 pu, which indicates the 90 percent efficiency of the conventional SVC to recover and provide voltage stability.

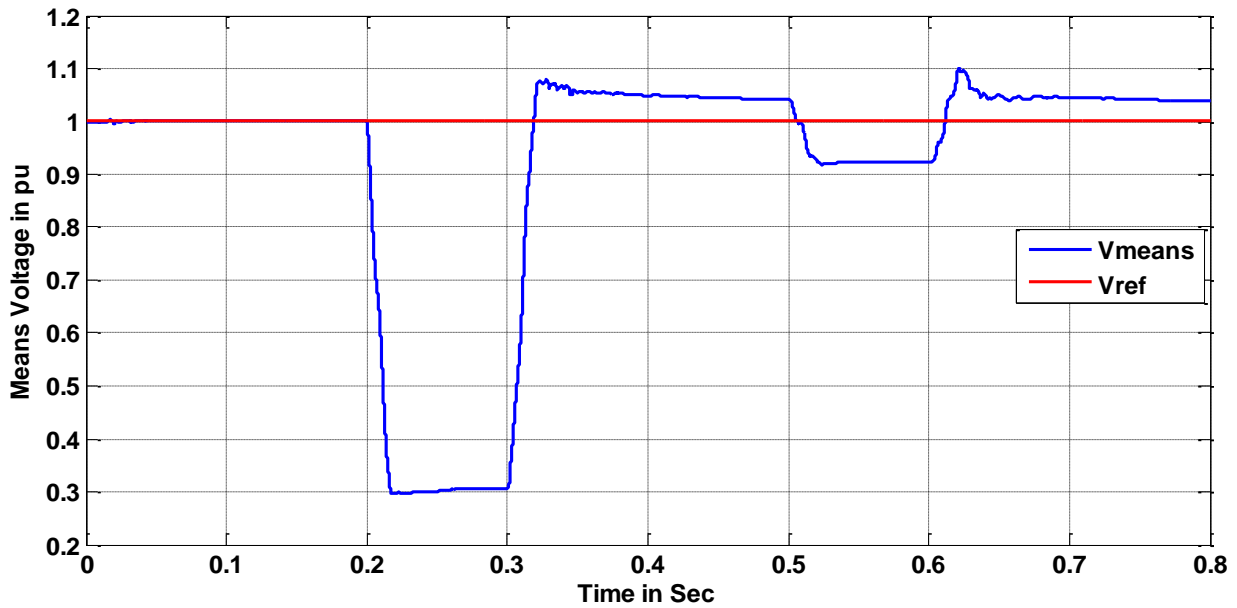


Figure 9. The line voltage regulation response of SVC system

The second case study is performed by taking phase ABC to ground fault for both primary and secondary side. The three phase voltage waveform obtained for this case is shown in figure (10).

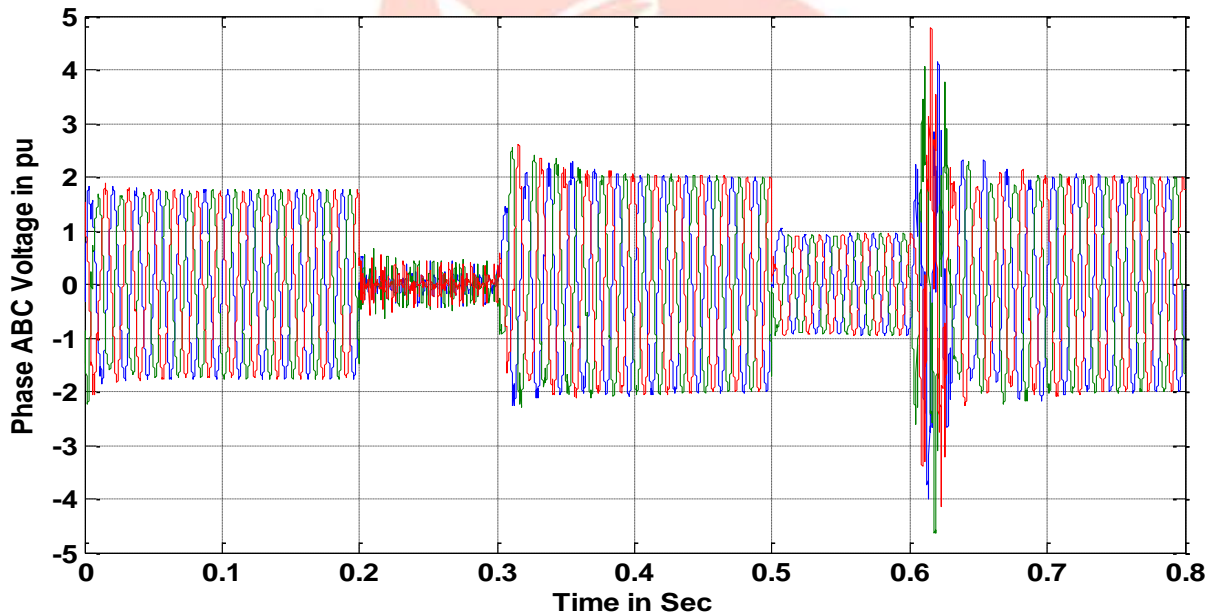


Figure 10. Phase ABC to ground fault effect on the transmission line voltage profile

The above figure shows that the again there are two fault conditions on phase A, phase B and phase C on two different time spans. The first fault is occurred here for .1 sec from $t = 0.2$ sec to $t = 0.3$ sec while the second fault is occurred for again .1 sec from $t = .5$ sec to $t = .6$ sec.

Now the results obtained after restoration of the means voltage for the conventional SVC based system is shown in figure (11).

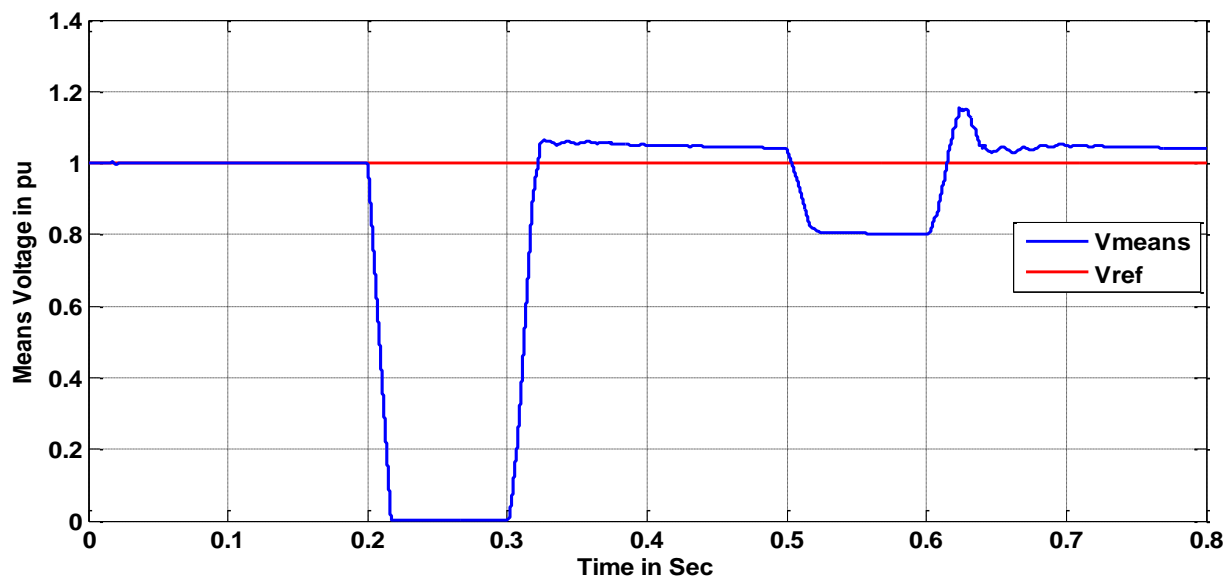


Figure 11 The line voltage regulation response of SVC system

5. Conclusions

In this paper a complete performance evaluation of conventional PI controller based voltage regulation for analyzing the voltage profile improvement have been successfully implemented and simulated in MATLAB 2012 (b) Simulink. It is observable from the results obtained that conventional PI controller based voltage regulation SVC system can able to provide stable voltage in the transmission lines up to a good extent but not able to control the reactive power completely in transient part where the line voltage fluctuates.

In addition to this the obtained results also indicates that, the conventional PI controller based voltage regulation SVC system is good enough to maintain constant voltage in steady state part after fluctuations occurred. Hence this system is able to provide good power stabilization in steady state part during power transmission.

To develop more fine results, the presented work of this paper can be further extend with the modification of the control mechanism of SVC voltage regulation system by using advance control structures like fuzzy controller, neural network controllers and adaptive neural fuzzy controllers to replace conventional PI controllers used in the TCSC.

6. Reference

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