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Modelling of SVC for Voltage Profile Improvement in Electric Traction System

Ms. Yamini Chaudhari[1], Prof. Rachna J. Patel[2]

[1]P.G Scholar, Electrical Department, LDCE, Ahmedabad, Gujarat, India

[2] Assistant Professor, Electrical Department, LDCE, Ahmedabad, Gujarat, India

Abstract: Operating multiple locomotives under a section of traction transmission line not only degrades the voltage profile and causes excessive flow of current which triggers the relay without any fault on line. To overcome dip in voltage, traction transmission line is compensated with SVC connected in shunt at proper location. The research work presented in this paper proposes a compensation scheme to overcome voltage fluctuation on traction transmission line due to uncertainty in operation of locomotive loads under a section of traction transmission line fed by local substation. Sudden loading of multiple locomotive loads on traction line yields to dip in voltage and voltage across locomotive motor may drop beyond its rated voltage and inefficient operation of motor takes place. Due to excessive load on a section of traction line of finite length may trips the circuit breakers without any fault on line. Application of Static VAR Compensator (SVC) in shunt with transmission line can effectively overcome the dip in voltage. Extensive simulations have been done to study the effect of multiple loads on section of traction transmission line.

Keywords: SVC, Traction, Voltage Profile, Simulink,etc.

I. INTRODUCTION

Nowadays, AC electrified railway transportation systems are developing around the world. Among the variety of electrical railway structures, co-phase traction system eliminates neutral sections between output phases of the traction transformer. Therefore, electric trains would be able to reach their maximum practical speed. However, power quality problems including system unbalance, low power factor (PF), and harmonics are a major concern for upstream power grids. Various techniques have been used in the literature to overcome these problems. Since negative sequence current (NSC) of the grid-side is a major issue, especially balanced transformers e.g., Scott, Leblanc, Roof-delta, Modified Wood-bridge etc. have been utilized to obtain balanced three-phase grid currents. Due to dynamic, time varying and nonlinear locomotives, having symmetry in three-phase grid currents is practically impossible, especially in co-phase traction system of an unloaded output phase.[2][1]
However, V/v transformer is widely used in electric railway systems due to its low complexity and high utilization factor. Compared to passive devices, active compensations methods can provide fast dynamic response and more satisfactory performance. Static VAR compensators (SVC) and its next-generation static synchronous compensator (STATCOM) have been commonly used in the traction power system with reactive power compensation goal. Since nonlinear locomotive loads also inject a significant amount of harmonics into the system, these compensating devices are ineffective for harmonic contents mitigation.

Locomotive loads with converters are the real sources of harmonics and degrades the power quality of entire traction transmission line. It is always difficult to limit the number of locomotives suddenly come under a section of traction line fed by a local substation. Operation of multiple locomotive loads under a finite traction line causes a sudden dip in voltage below the rated voltage of traction motor and inefficient operation of traction motor takes place.[2] Operating multiple locomotives under a section of traction transmission line not only degrades the voltage profile and causes excessive flow of current which triggers the relay without any fault on line. To overcome dip in voltage, traction transmission line is compensated with SVC connected in shunt at proper location. Here, we propose an SVC operation method to minimize the power loss in an electrified railway traction system. A power flow calculation method considering SVCs in a railway traction system is proposed. Nevertheless, to upgrade the railway system is obviously critical. Technically, many related approaches have been taken into account. The replacement of feeding cables or substation transformers is one of many possible solutions to increase power-feeding capacity but this inevitably interrupts the services. The other approach that is widely applied to typical railway systems is the use of additional reactive power sources, e.g. SVC. Although these installations can improve system performance, they require spacious installing areas and are also costly. The development of a new upgrading technique in order to minimise cost while maximising system performance therefore challenges railway system engineers for the 21st century. There are differentiae approaches to control this type of issues. [7]

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The exceptionally well known path for this is to view an extra device as introduced some place in the system. Such devices are one of capacitor bank, shunt reactor, arrangement reactors, and programmed voltage controllers as well as of late created dynamic voltage restorers, static compensator (STATCOM), Static Var Compensator (SVC), and so on. STATCOM and SVC devices are able to improve steady state performance, for example, Power factor and harmonic of a specific feeder portion.[7][5]

II. SVC OPERATION

Static var compensators as the first FACTS device have been used in North American transmission systems since late 1977 in western Nebraska. SVC device was installed to provide automatic, continuous voltage control. There are a lot of transmission SVCs around the world and many transmission SVC applied in North America. SVC are also applied at the distribution level to compensate for voltage fluctuation due to industrial load.[1]

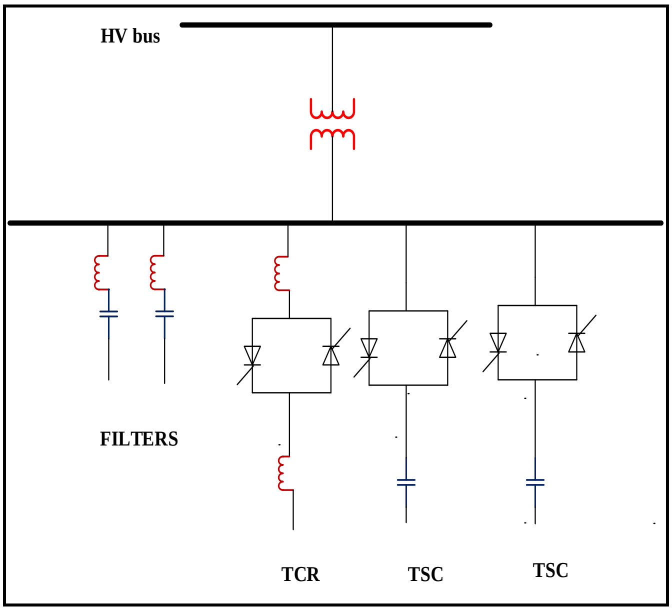

Fig-1 Schematic Diagram of SVC

The SVC is an A.C power semi-conductor switch known as the Thyristor valve that is used in principle to replace mechanical switches to achieve rapid and in some causes continuous control of the shunt susceptance at a location in a transmission system by an inductor and a capacitor. The fixed capacitor in parallel with a Thyristor controlled reactor the valve continuously and control the reactor to achieve is varied to maintain the transmission system voltage to a desired value. [4]

SVC in Power system

It is variable impedance device where the current through a reactor is controlled using back to back connected Thyristor valves. A SVC has no compared to synchronous condensers and can be extremely fast in response 2-3 cycles.
This enables the fast control of reactive power in the control range. Ideally It should be located at the electrical center of the system or midpoint of a transmission line.

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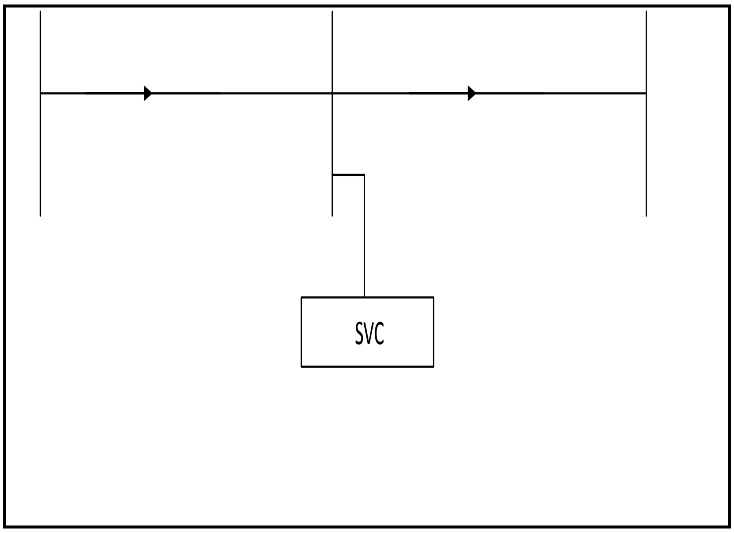

Fig-2 a transmission line with SVC connected at midpoint

SVC always connected in shunt with the line system and its circuit input is adjustable using inductive and capacitive to control the parameters of the electrical power system. It will be used for the bus voltage control.[4][8]

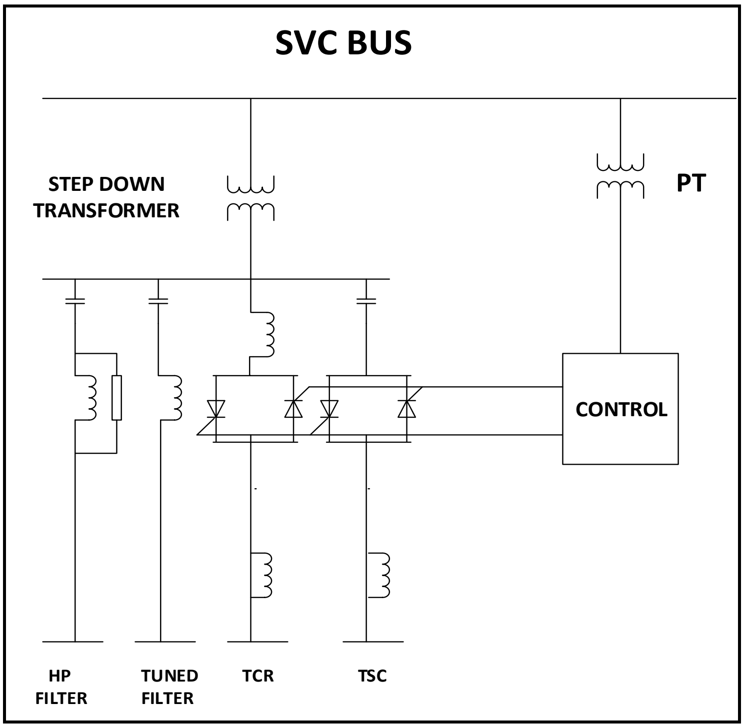

Fig-3 SVC Configuration

When system voltage is low the SVC inject reactive power, When system voltage is high the SVC absorb reactive power. The three phase capacitor banks and inductor banks connected on the secondary side of coupling transformer.

There are two configuration of SVC i) FC-TCR (fixed capacitor thyristor control reactor.) ii) TSC-TCR (thyristor switch capacitor thyristor control reactor). TSC-TCR can quickly operate to disconnected capacitor from the compensator during voltage swing compare FC-TCR.

SVC V-I Characteristics

SVC can be operate in two different modes: i) Voltage regulation mode. ii) Var control mode.

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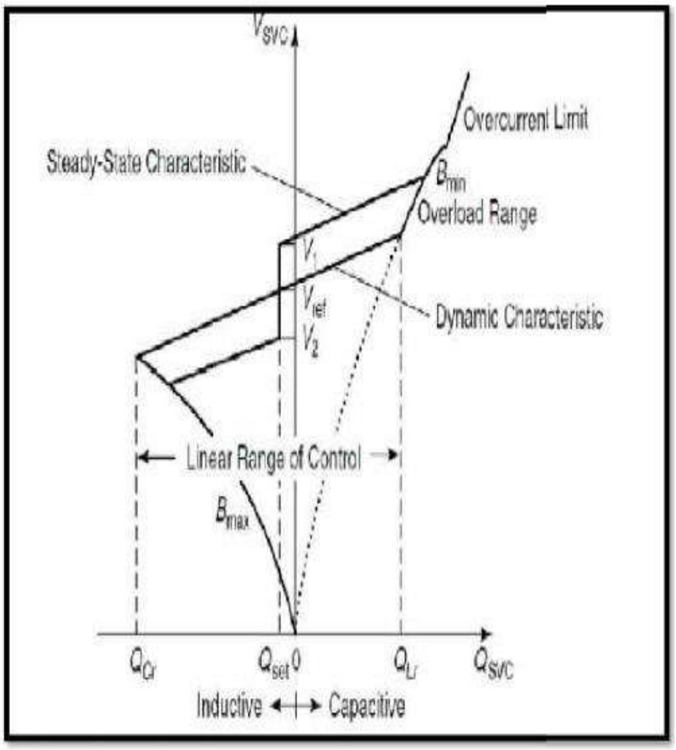

Fig-4 SVC V-I Characteristics

The SVC susceptance stays within maximum and minimum values imposed by the total reactive power of the capacitor banks and reactor banks the voltage is regulated at the reference voltage. A voltage droop is normally used and V-I characteristics has the slop Xs.[10][11]

Voltage Regulation Mode

The Voltage control of the SVC in the voltage regulation mode range is describe as:
Vsvc=Vref.+ XsIssvc.
Vsvc= Positive sequence Voltage.
Vref= Reference Voltage
Xs= Slope Reactance.

Var control Mode

The SVC is operating as a fixed susceptance device. It is absorb or inject an amount of reactive power into the system.
When SVC is fully inductive V= I/Blmax
Blmax= Maximum inductive susceptance.
When SVC is fully capacitive V=-I/Bcmax
Bcmax= Capacitive susceptance maximum.

Application

- Increase power transfer in long lines.
- Improve reliability fast acting voltage regulation.
- Damp low frequency oscillation due to swing modes.
- Control dynamic overvoltage.

III. PROPOSED WORK

The research work presented in this paper proposes a compensation scheme to overcome voltage fluctuation on traction transmission line due to uncertainty in operation of locomotive loads under a section of traction transmission line fed by local substation. Sudden loading of multiple locomotive loads on traction line yields to dip in voltage and voltage across locomotive motor may drop beyond its rated voltage and inefficient operation of motor takes place. [3]

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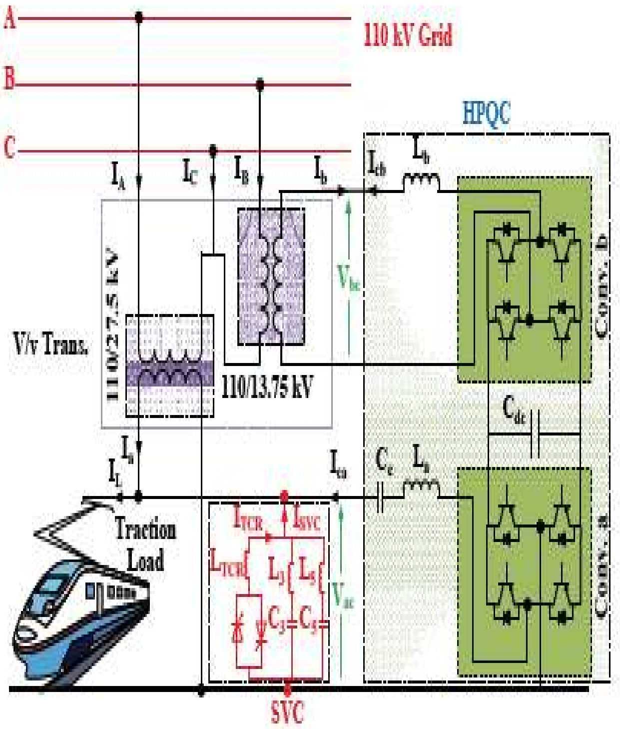

Fig-5 Proposed co-phase traction power system

Due to excessive load on a section of traction line of finite length may trips the circuit breakers without any fault on line. Application of Static VAR Compensator (SVC) in shunt with transmission line can effectively overcome the dip in voltage. Extensive simulations have been done to study the effect of multiple loads on section of traction transmission line. The proposed configuration is shown in Fig. 5. In this structure, the three-phase three-wire system is transformed into two single-phase outputs (Vac and Vbc) via V/v transformer. [2][13]
The output supply phases are the equal magnitude with 60-degree differences. As known, in the co-phase traction system, one output phase is intentionally maintained unload (Vbc) while the other output phase (Vac) supplies the traction loads directly. Therefore, the neutral sections between phases are omitted and trains are able to operate at a high-speed velocity. The HPQC consists of two single-phase converters including four legs and two IGBT switches in each leg with common DC-link voltage. It is connected throughout Vac and Vbc while SVC is installed across the Vac phase to compensate load reactive power. Since harmonics caused by SVC are injected into the grid, two shunt low-order filters are adapted to suppress 3rd and 5th harmonics effectively.[13]

Basic model of SVC

Choice of input signals to SVC to provide controllability depends up on the problems associated with system. Frequency of AC Voltages, current or power flow on major lines and voltage magnitude are the several possibilities to be input signals of SVC. To improve voltage profile of traction system, voltage magnitudes are the input signals, firing angle and SVC currents injected into the system are function of change in line voltage.

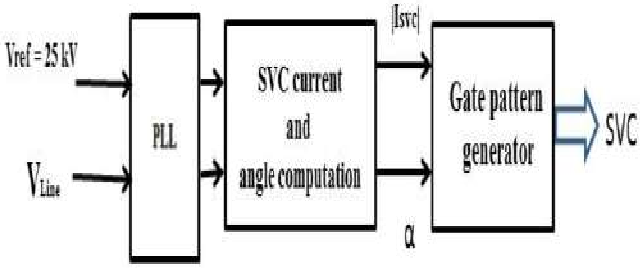

Fig-6 Basic block diagram of SVC with input signals to control reactive power to be injected into the system

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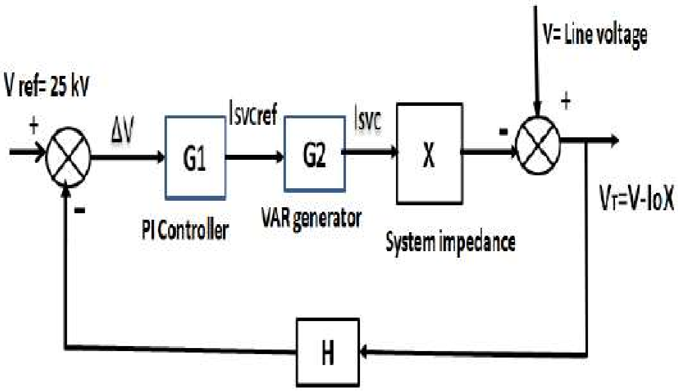

Fig-7 SVC controller loop block diagram

Compensation can be obtained by some specific variation in the amplitude of the terminal voltage with time or with some other variable, then an appropriate correcting signal, derived from the auxiliary inputs is summed to the fixed reference Vref in order to obtain the desired effective signal as shown in fig-7.[6]

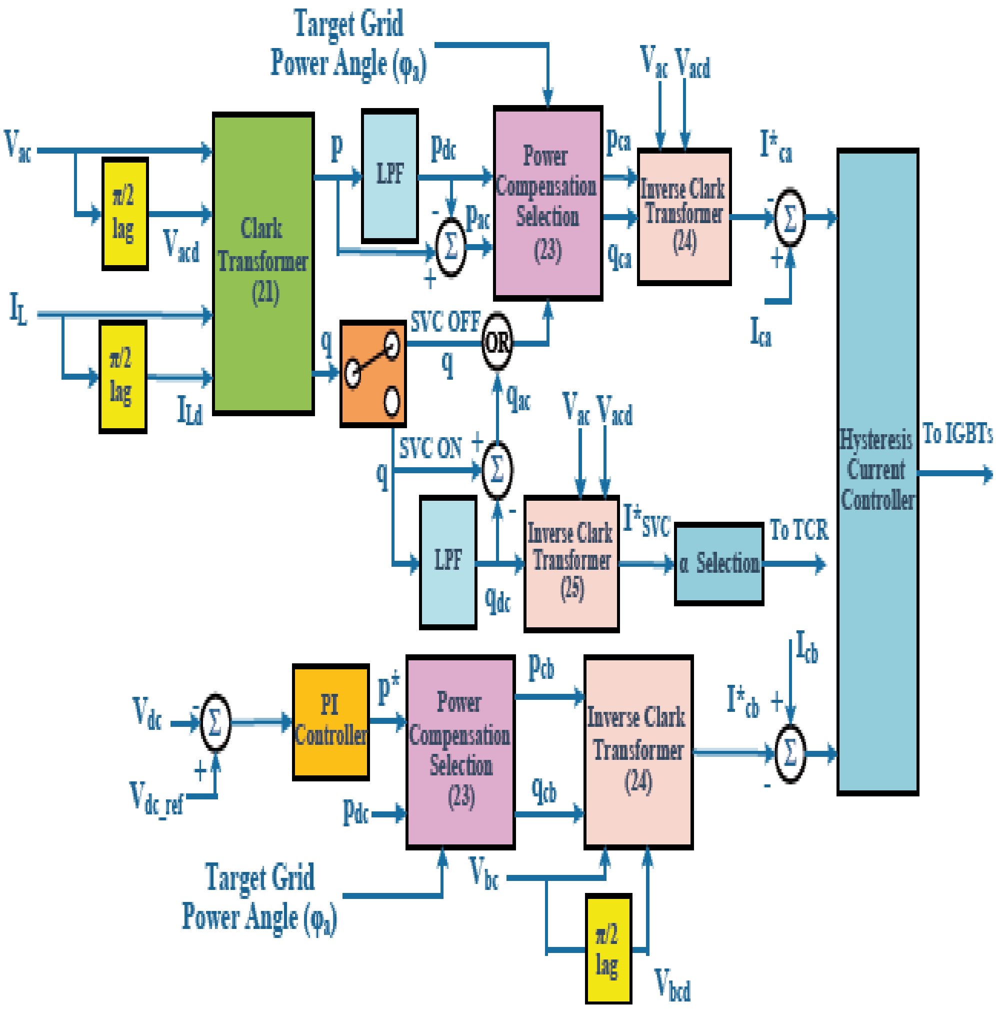

Fig.-8 Control block diagram of the HPQC in PCT considering SVC

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IV. SIMULATION AND RESULTS

Matlab Simulation of Proposed System without Control

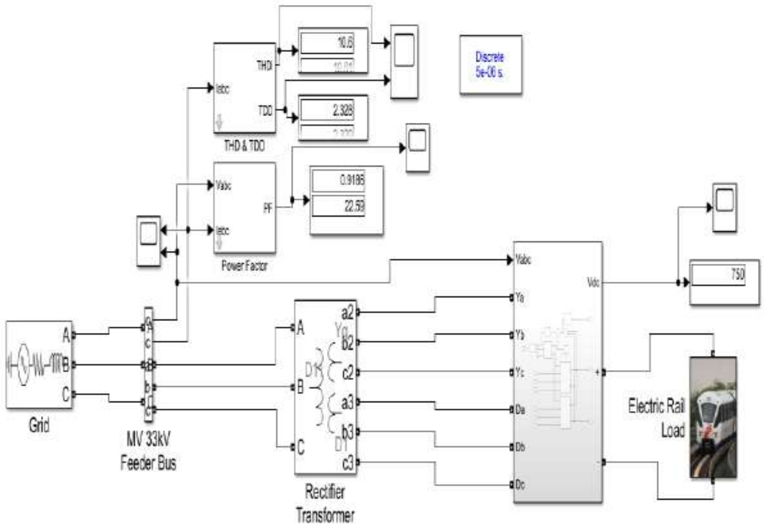

Fig 9- Matlab Simulation of Proposed System without control

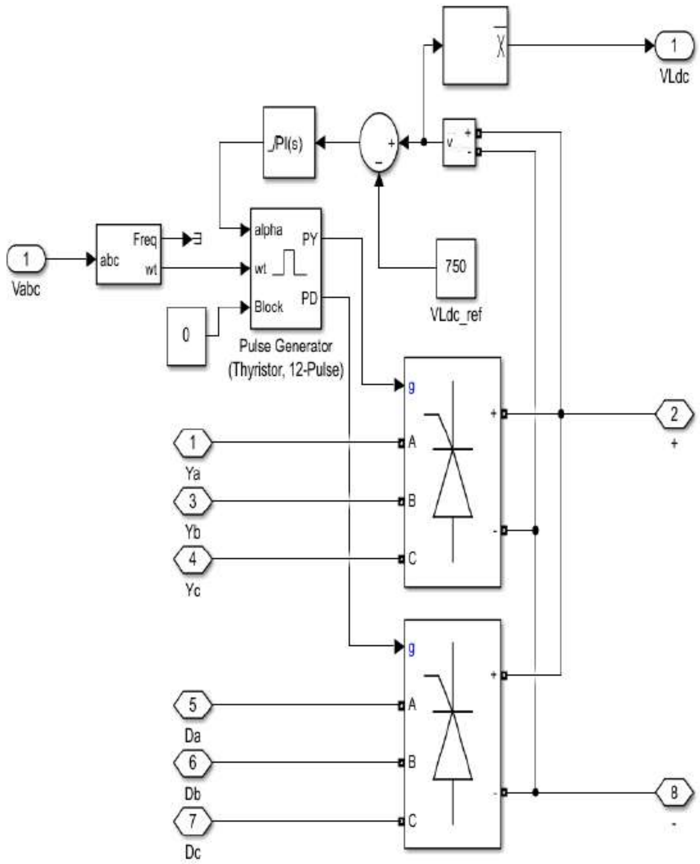

Fig 10- Simulation model of 12-pulse Rectifier controlling

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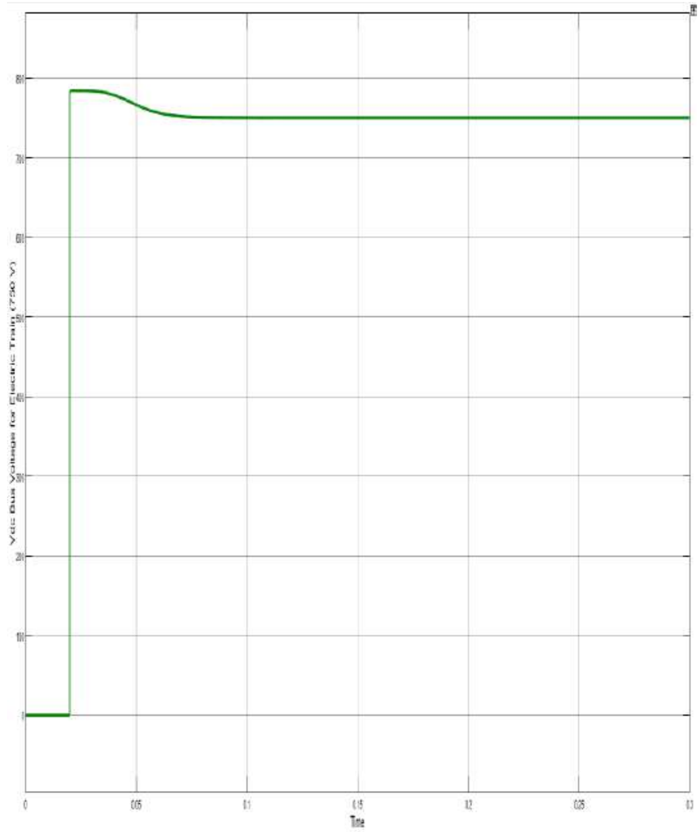

Fig 11- Simulation results of DC voltage of 750V for Electric Railway

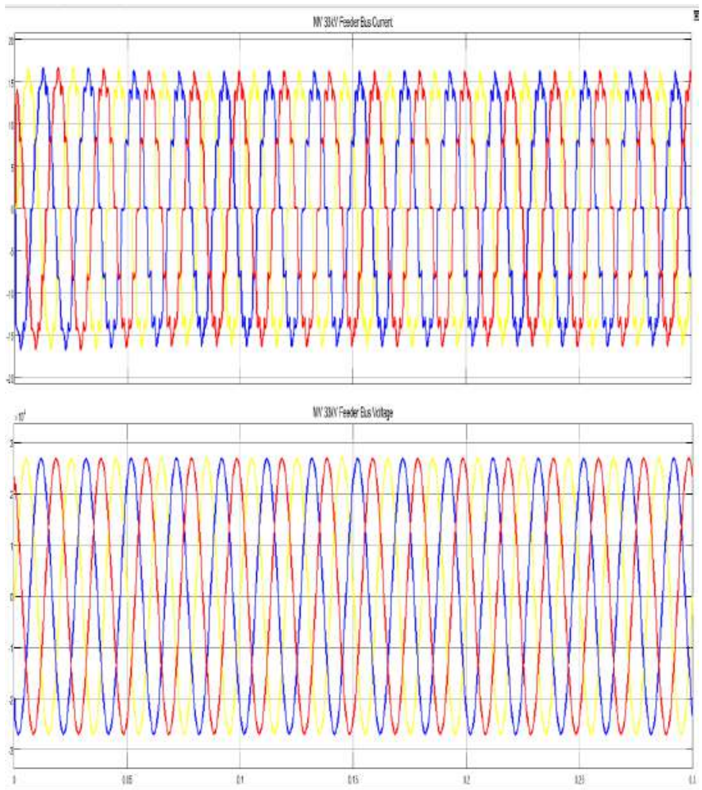

Fig 12- Simulation Waveforms of Feeder Line Voltage and Current

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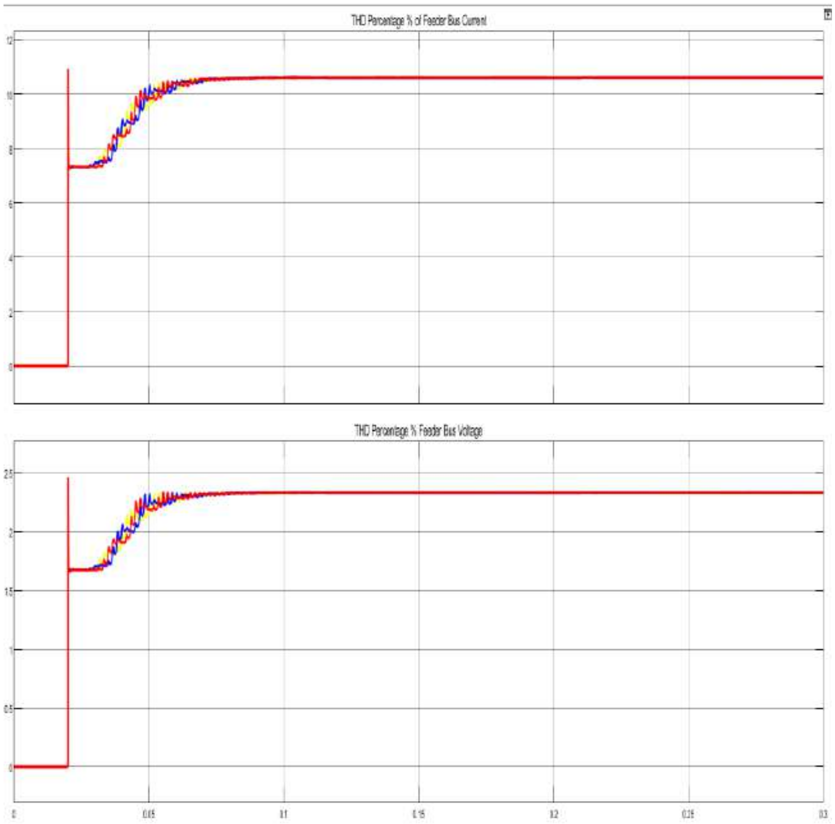

Fig 13- Simulation Result of THD % for Voltage and Current

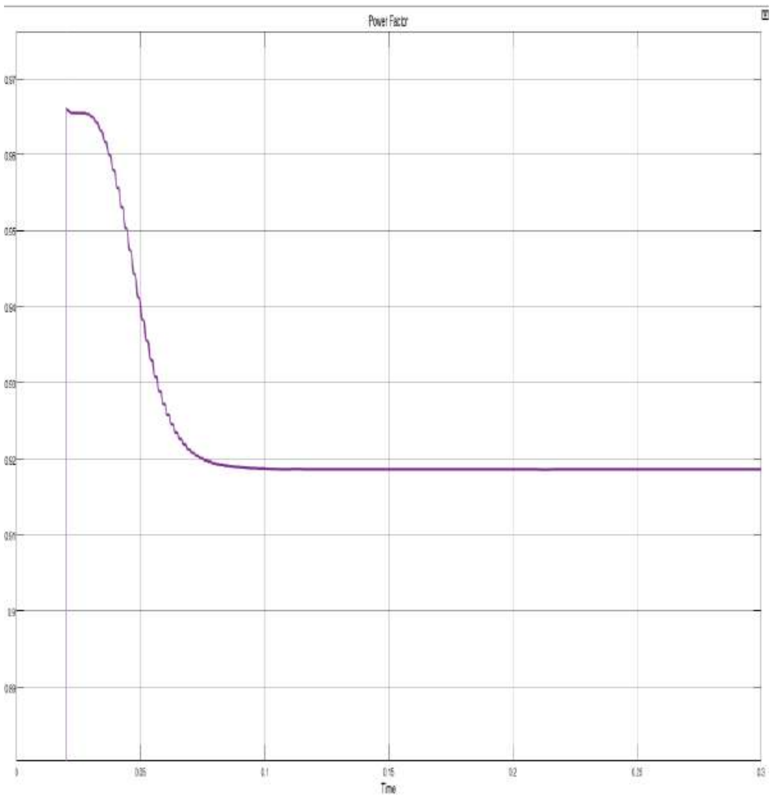

Fig 14- Simulation Results of PF without Control

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Matlab Simulation of Proposed System with Single Tuned Passive Filter

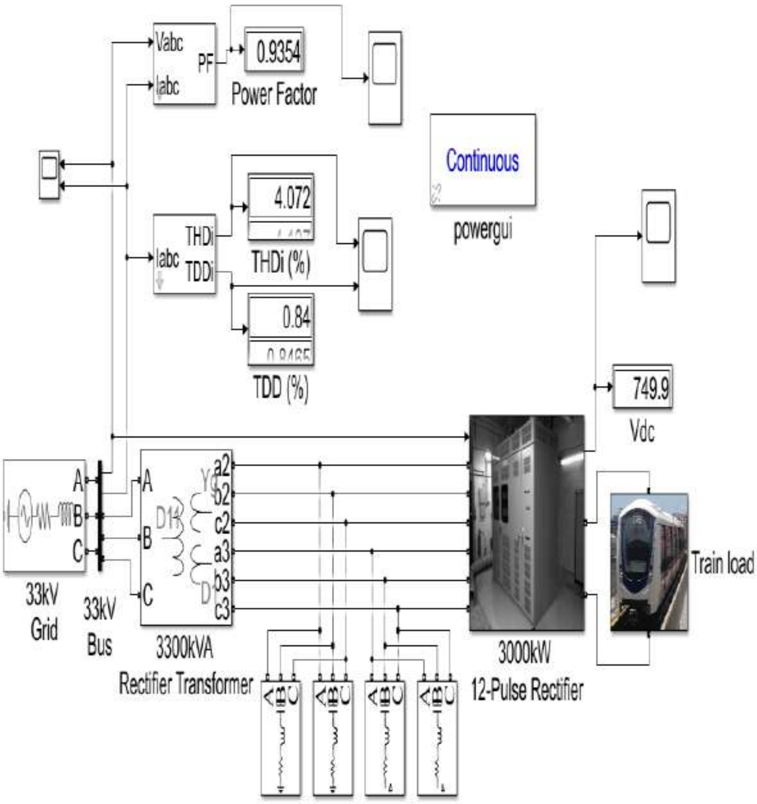

Fig 15- Simulation Proposed system with Single Tuned Passive Filter

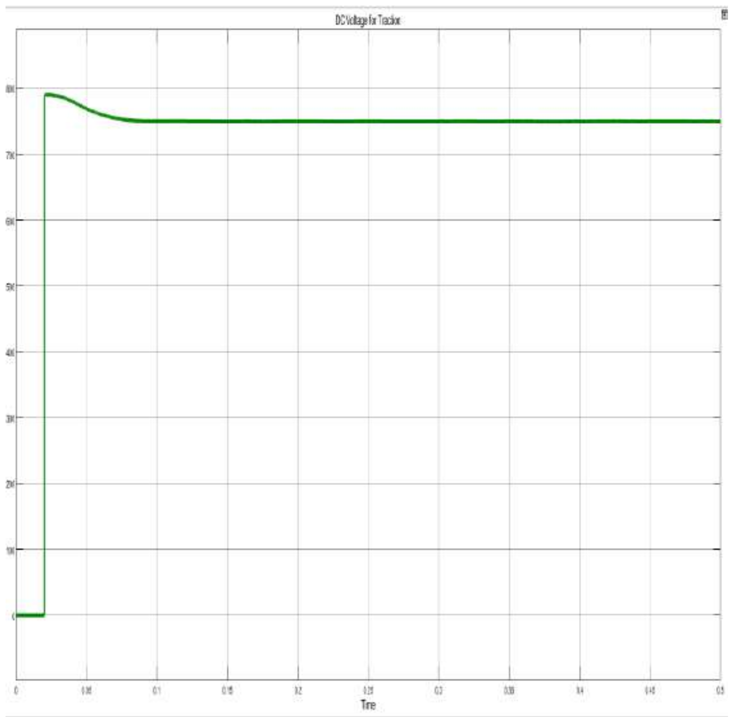

Fig 16- Simulation Waveform of DC Bus Voltage with Filter Control

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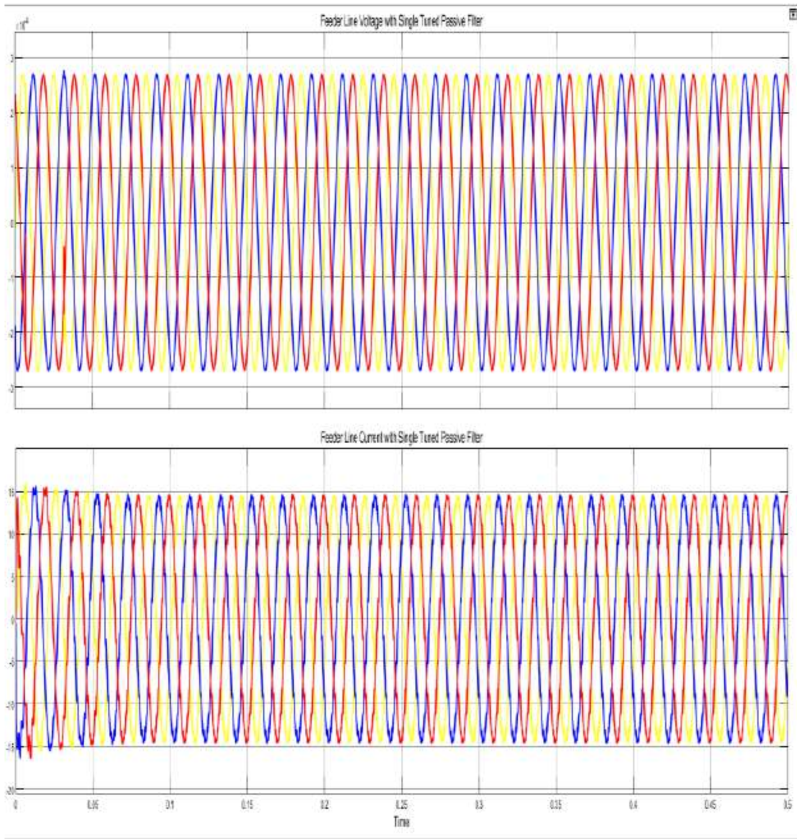

Fig 17- Simulation Results of Feeder Line Voltage & Current using Filter Control

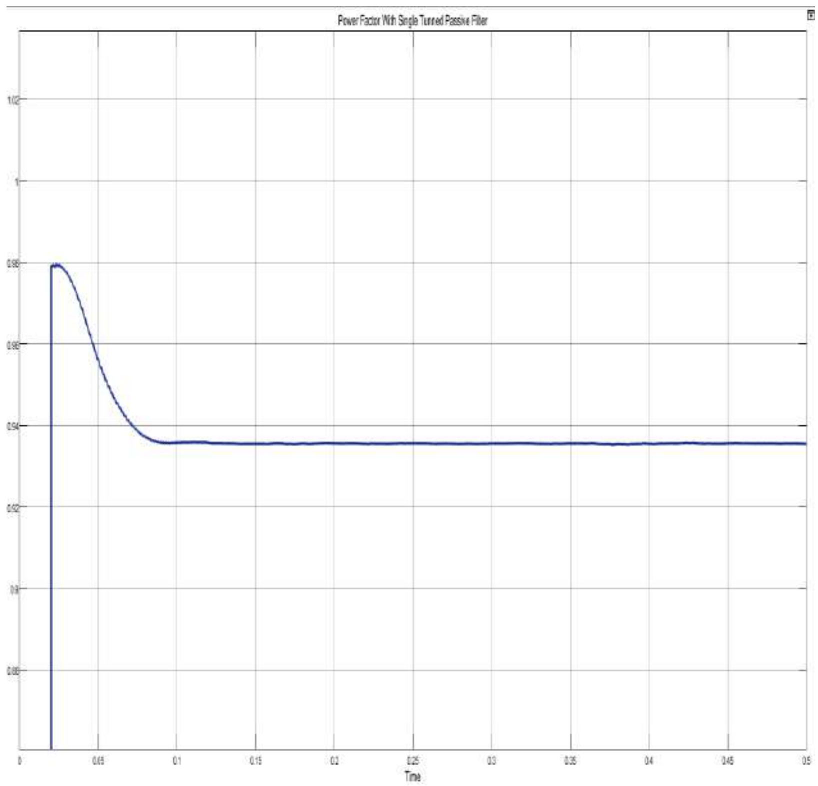

Fig 18- Simulation Result of PF with Filter Control

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Matlab Simulation of Proposed System with SVC Control

The replacement of feeding cables or substation transformers is one of many possible solutions to increase power-feeding capacity but this inevitably interrupts the services. The other approach that is widely applied to typical railway systems is the use of additional reactive power sources, e.g. SVC. Although these installations can improve system performance, they require spacious installing areas and are also costly. The development of a new upgrading technique in order to minimise cost while maximising system performance the simulation SVC connection with proposed system is shown in below section.

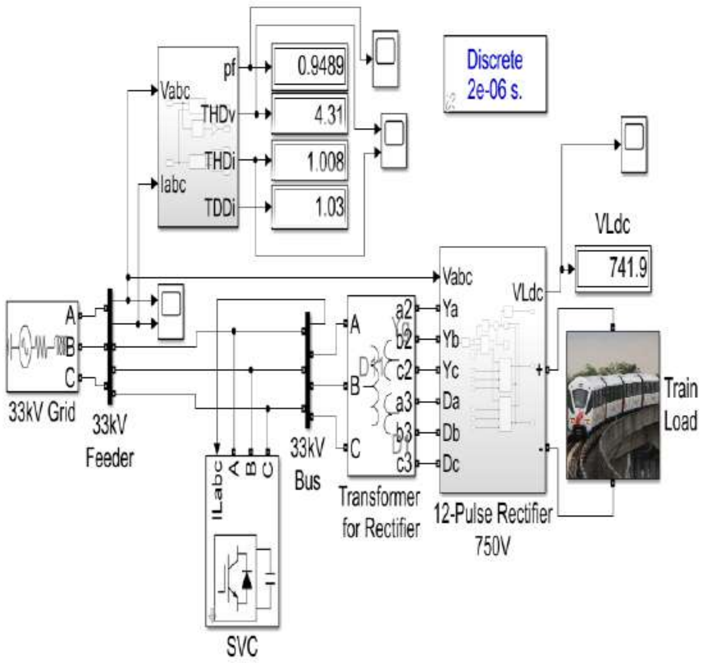

Fig 19- Matlab Simulation of Proposed system with SVC controlling

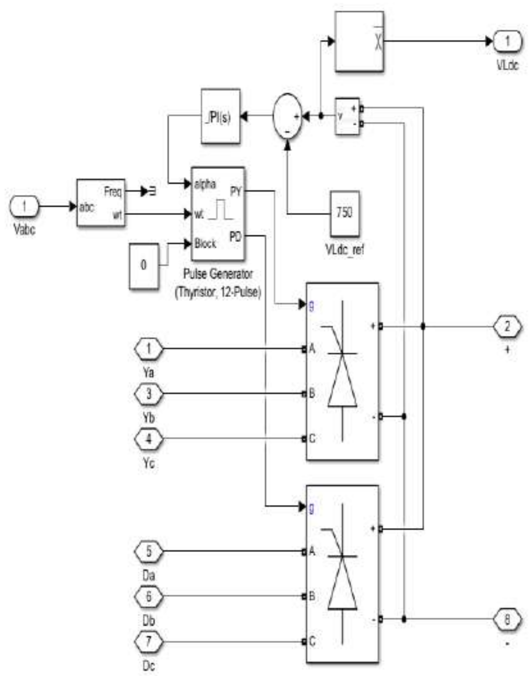

Fig 20- Simulation model of 12-Pulse Rectifier Control

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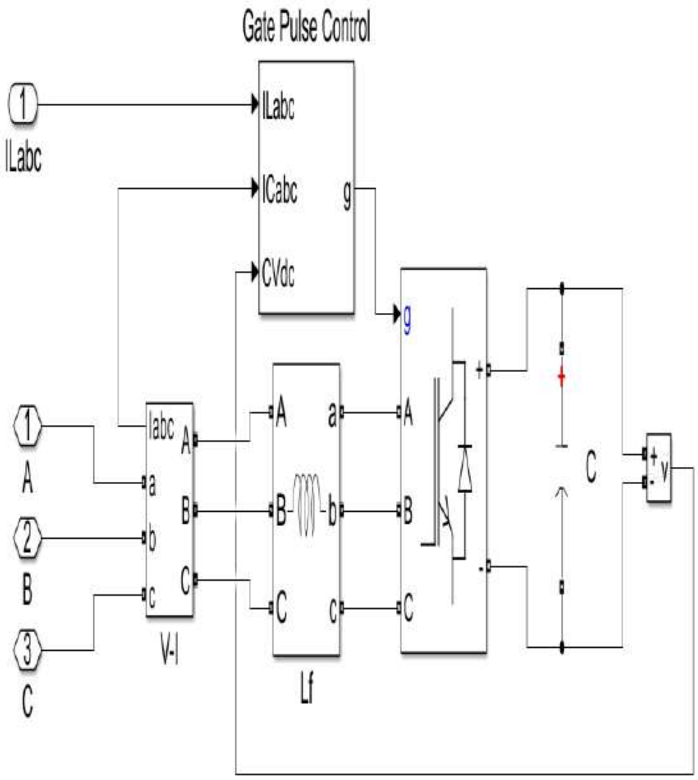

Fig 21- Simulation model of SVC control for proposed system

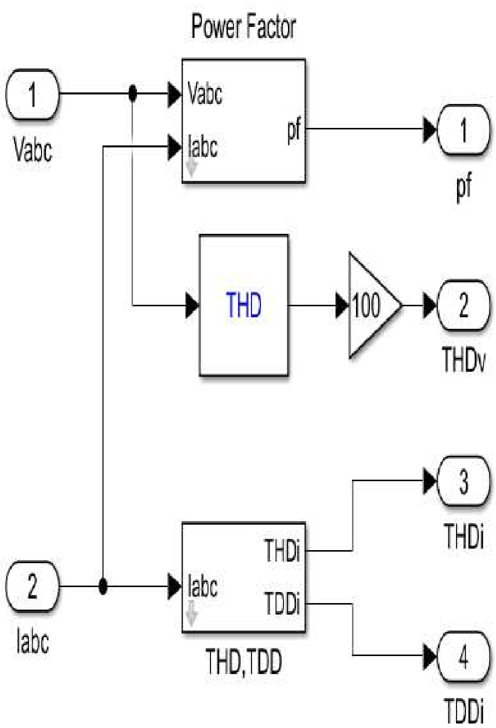

Fig 22- Modelling of PF & THD Calculation

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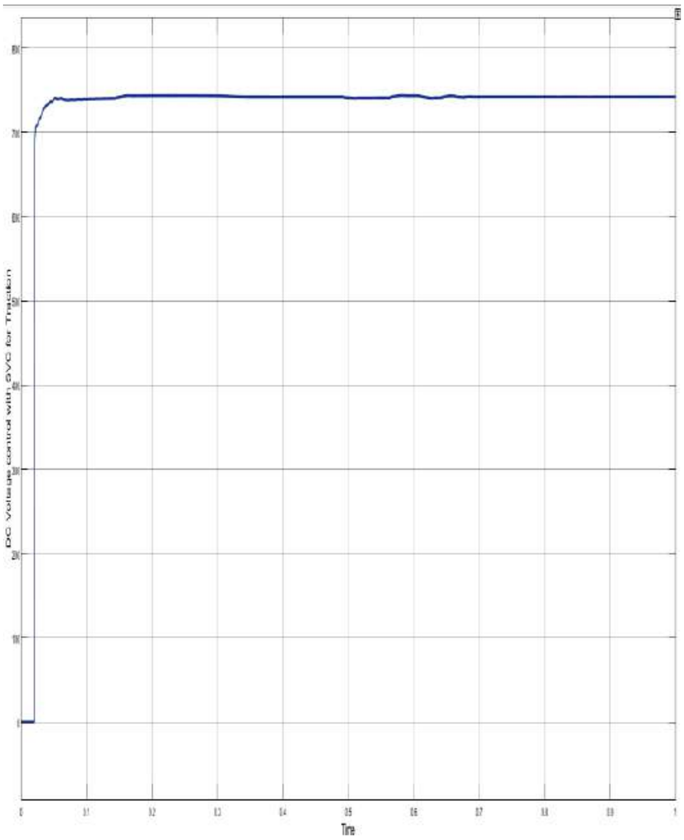

Fig 23- Simulation Result of DC Voltage using SVC Control

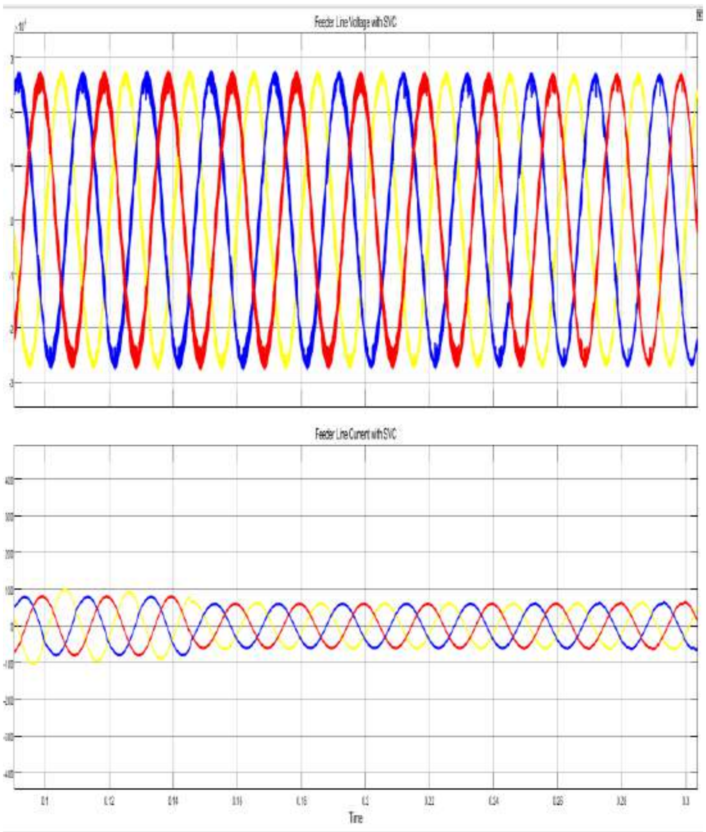

Fig 24- Simulation Waveforms of Voltage & Current with SVC control

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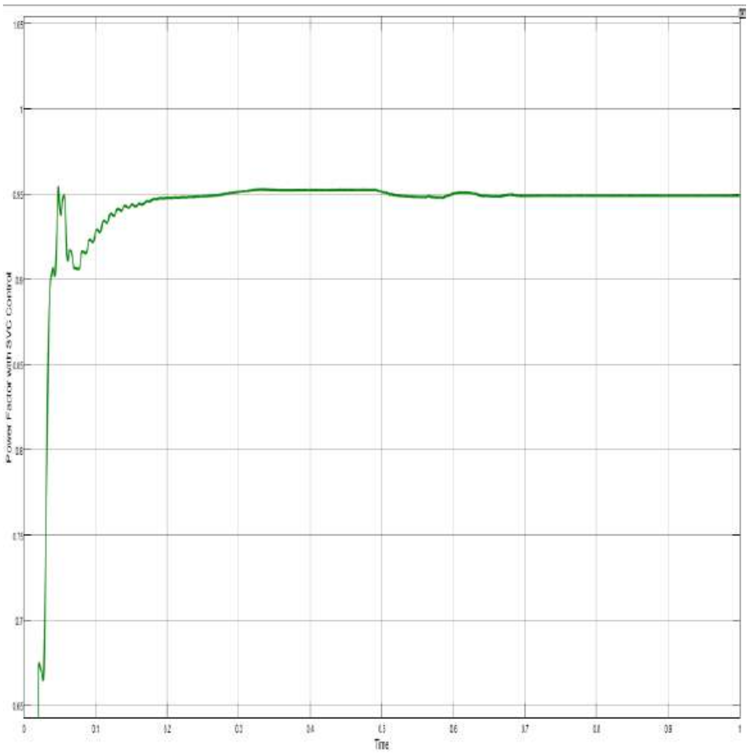

Fig 25- Simulation Results of PF with SVC control in proposed system

V. CONCLUSION

The research work presented in this paper proposes a compensation scheme to overcome voltage fluctuation on traction transmission line due to uncertainty in operation of locomotive loads under a section of traction transmission line fed by local substation. Sudden loading of multiple locomotive loads on traction line yields to dip in voltage and voltage across locomotive motor may drop beyond its rated voltage and inefficient operation of motor takes place. Due to excessive load on a section of traction line of finite length may trips the circuit breakers without any fault on line. Application of Static VAR Compensator (SVC) in shunt with transmission line can effectively overcome the dip in voltage. Extensive simulations have been done to study the effect of multiple loads on section of traction transmission line. The Matlab Simulation of Proposed system without control, with Filter control and with SVC control is successfully shown in this paper.

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