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INSTANTANEOUS POWER CONTROL AND POWER FACTOR IMPROVEMENT USING D -STATCOM AND SVC

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Abstract: The main aim of this paper is to represents a modified instantaneous power control scheme of D-STATCOM and SVC for power factor and harmonic compensation. The proposed control strategy has been introduced in order to enhance some steady state performances besides its functional elimination of power quality disturbances. Power factor and harmonic current of a controlled feeder section are two vital roles in steady-state power distribution system operation. Utilizing an already install D-STATCOM to achieve these additional control objectives can help system operators to maximize overall system performances. Otherwise D-STATCOM FACTS device are used for power quality enhancement and harmonic reduction in the power system but the proposed control strategy provides additional objectives for system performance improvement.

I. INTRODUCTION

Electric power distribution network have become more increasingly important and plays an essential role in power system planning. This type of power systems has a major function to serve distributed customer loads along a feeder line; therefore under competitive environment of electricity market service of electric energy transfer must not be interrupted and at the same time there must provide reliable, stable and high quality of electric power. To complete this challenge, it requires careful design for power network planning. There exist many different ways to do so. However, one might consider an additional device to be installed somewhere in the network. Such devices are one of capacitor bank, shunt reactor, series reactors, and automatic voltage regulators and/or recently developed dynamic voltage restorers, distribution static compensator (DSTATCOM), or combination of them. The DSTATCOM is a voltage source converter (VSC) based custom power technology which can perform as a reactive power source in power systems. The D-STATCOM can regulate magnitude of voltage at a particular AC bus, at the point where it is connected, via generating or absorbing reactive power from the system. From D-STATCOM literature, a majority of research works have been conducted in order to enhance electric power quality due to distribution voltage variations, e.g. voltage sags or swells. Apart from these voltage variations, the D-STATCOM is capable to enhance steady-state performances such as power factor and harmonic of a particular feeder portion. In this paper, a control scheme with constant power and sinusoidal current compensation is exploited. In order to correct the power factor additionally, a power factor control loop is required and therefore included in the control block.

II. D-STATCOM WORKING

Description of D-STATCOM Operation

A D-STATCOM consists of a two-level VSC, a dc energy storage device, controller and a coupling transformer connected in shunt to the distribution network. Figure-1 shows the schematic diagram of D-STATCOM.

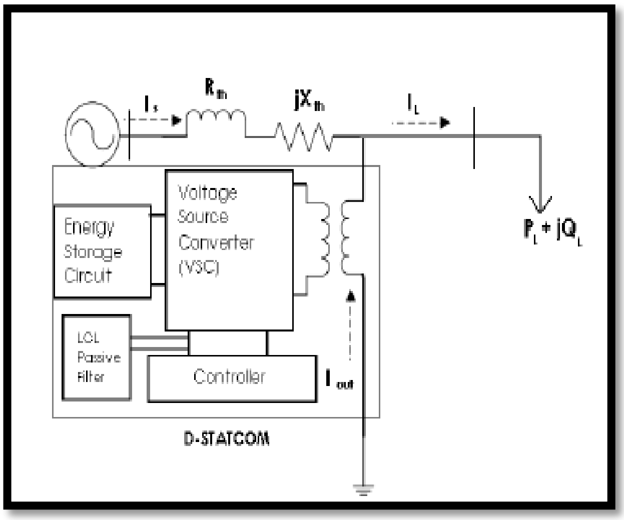

Figure: 1 Schematic diagram of a DSTATCOM

Overview of D-STATCOM

The Distribution Static Compensator (DSTATCOM) is a voltage source inverter based static compensator that is used for the correction of line currents. Connection (shunt) to the distribution network is via a standard power distribution transformer. The DSTATCOM is capable of generating continuously variable inductive or capacitive shunt compensation at a level up its maximum MVA rating. The DSTATCOM continuously checks the line waveform with respect to a reference ac signal, and therefore, it can provide the correct amount of leading or lagging reactive current compensation to reduce the amount of voltage fluctuations. The major components of a DSTATCOM are shown in Fig.1. It consists of a dc capacitor, one or more inverter modules, an ac filter, a transformer to match the inverter output to the line voltage, and a PWM control strategy. In this DSTATCOM implementation, a voltage-source inverter converts a dc voltage into a three-phase ac current that is synchronized with, and connected to, the ac line through a small tie reactor and capacitor (ac filter).

Iout = IL – IS =IL – ((Vth - VL)/Zth) …………………………….(1)

Iout < γ = IL < (-θ) – (Vth/Zth) < (δ-β) + VL/Zth < (-β) ………………………….(2)

Iout =Output current
IS = Source current
IL = Load current
Vth = Thevenin voltage
VL = Load voltage
Zth = Impedance

Referring to the equation (1), output current, Iout will correct the voltage sags by adjusting the voltage drop across the system impedance, (Zth =R+jX). It may be mentioning that the effectiveness of D-STATCOM in correcting voltage sags depends on:

a) The value of Impedance, Zth = R+jX
b) The fault level of the load

Static VAR Compensator (SVC)
The FACTS are controllers based on solid states technologies, whose two main objectives are: the increase of the transmission capacity and the control of the power flow over designated transmission routes. On this way, the Controllers FACTS can be classified into four categories: Series Controllers, Shunt Controllers, and Combined series-series Controllers, Combined series-shunt Controllers. The SVC is the most widely employed FACTS Controller. It is a shunt-connected static Var generator or absorber whose output is adjusted to exchange capacitive or inductive current so as to maintain or control specific parameters of the electrical power system (typically bus voltage). The general configuration of the SVC is essentially a controllable inductor in parallel with a switchable capacitance. In order to prevent the thyristor valves from being subjected to excessive thermal stresses the maximum inductive current in the overload range is constrained to a constant value by an additional control action.

The SVC fall into Shunt Controllers category and it function as fast generators or as a fast absorber of reactive power, with the purpose so as to maintain or control specific parameters of the electric power systems (typically bus voltage).

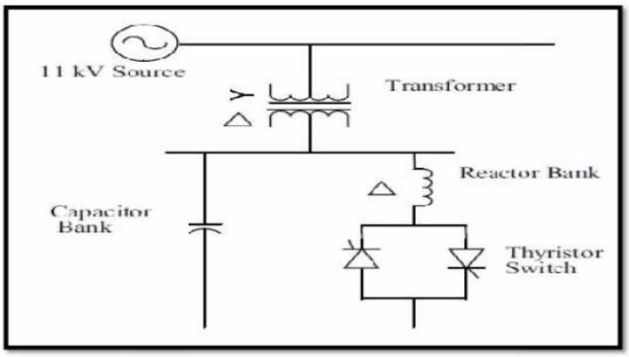

Fig.2 The SVC diagram of exchange power from the ac system

In order to investigate the impact of SVC on power systems, appropriate SVC model is very important. In this section, SVC and its mathematical model will be introduced. SVC is built up with reactors and capacitors, controlled by thyristor valves which are in parallel with a fixed capacitor bank. It is connected in shunt with the transmission line through a shunt transformer and thus, represented in Figure-2 and Figure-3 shows the equivalent circuit at which SVC is modeled [2].

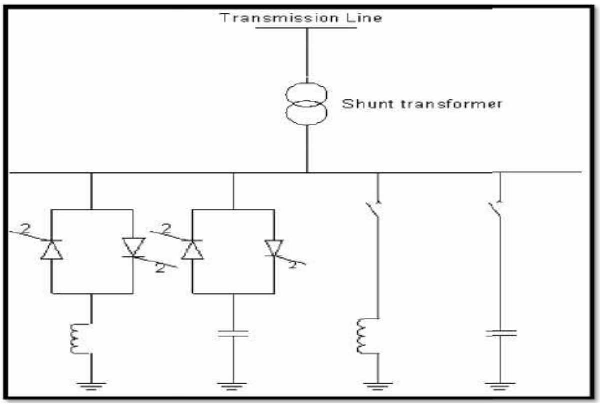

Figure-3 Functional diagram of SVC

III. MODELLING AND SIMULATION

Modeling of 3-phase system without D-STATCOM
In the 3-phase system the power factor and active, reactive power parameters are very important as discussed in the above sections of this project. Now in the proposed system first of all we take a 3-phase system in which we create the 3-phase fault and check the values of power factor, line voltage, and line current and also check the effect on active and reactive power values. This is shown in the fig 4 below with the simulation results.

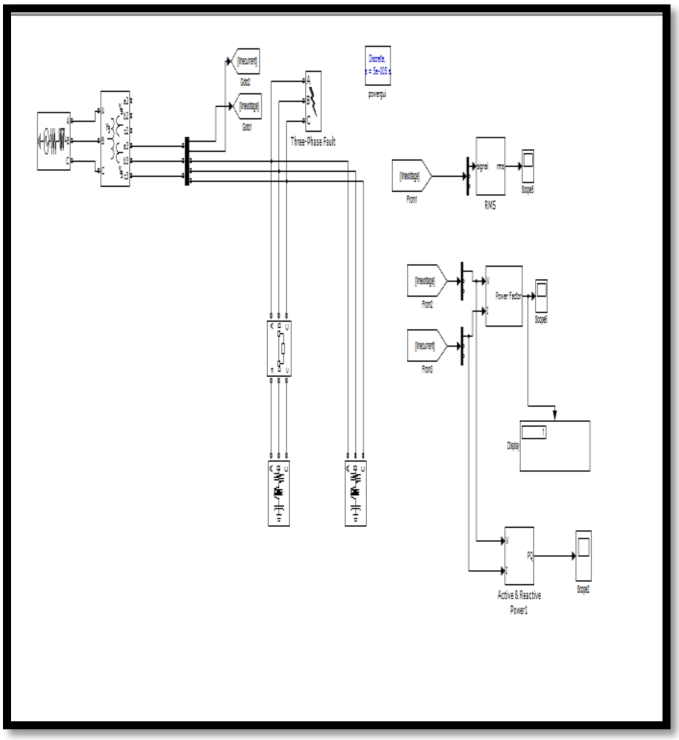

Fig 4 -three phase system with the 3-phase fault and measurements block

Simulation Results:-
The simulation results in these sections shows the fluctuation in the value of power factor and it also shows the distortion and effect on active and reactive power also.

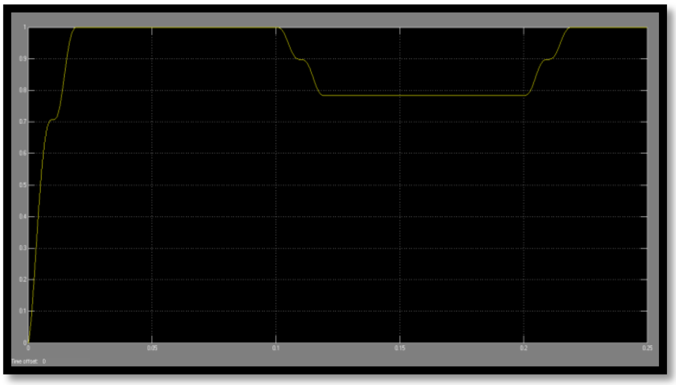

Fig 5-Distortion in line voltage Value

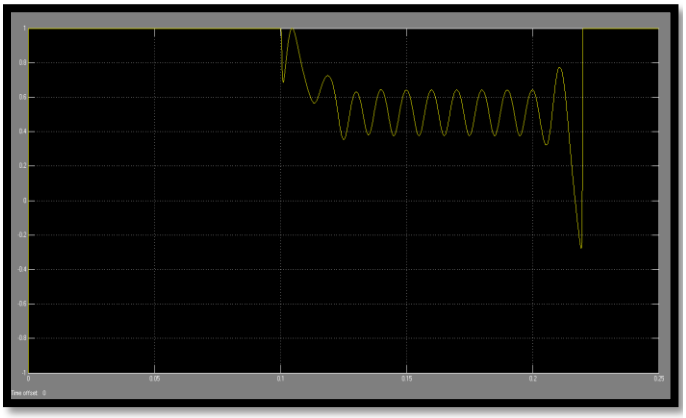

Fig 6-Fluctuation in power factor value

Modeling of 3-phase system with D-STATCOM

Now we will provide D-STATCOM in the above proposed system with PI control strategy which will mitigate the distortion and fluctuation from the proposed system. Fig 7 below shows the 3-phase system with D-STATCOM and Control strategy of the proposed system with instantaneous power control theory which improves power factor and also provides control for active and reactive power value in the system.

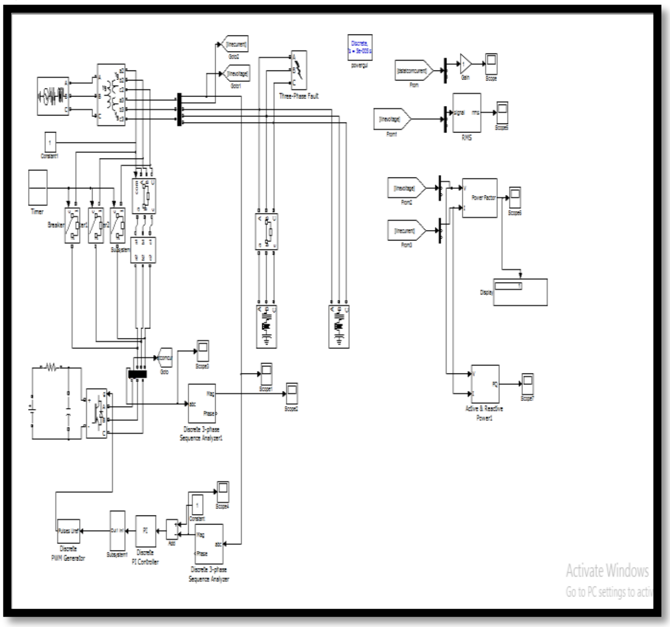

Fig 7-Proposed System with D-STATCOM connected

Simulation results after connection of D-STATCOM

Now after the proposed control strategy and simulation the D-STATCOM improves the power factor value and also shows that distortion and fluctuation are remove from the system. These are shown in the simulation results of fig bellows:-

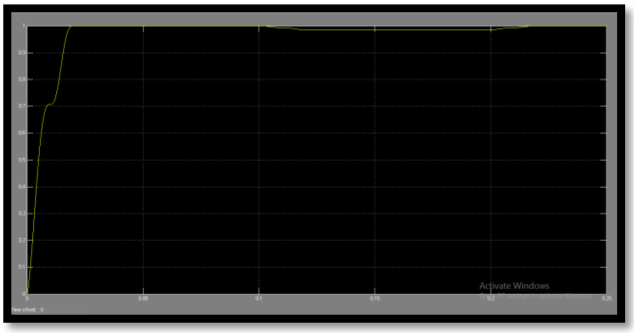

Fig 8-Line Voltage after D-STATCOM connection

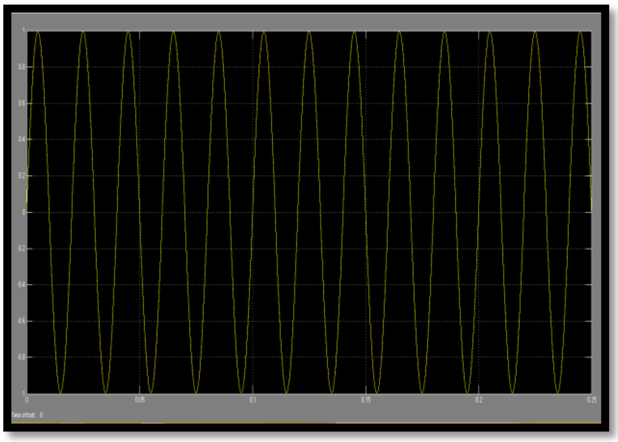

Fig 9-D-STATCOM current pure sinusoidal

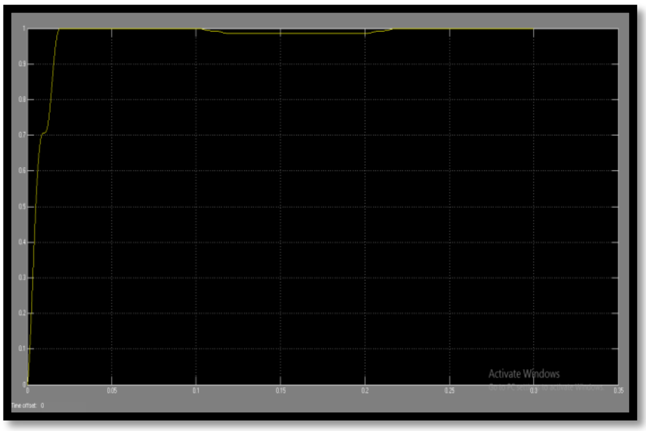

Fig 10-Improvement in power factor

Modeling and Simulation of SVC for Power factor Enhancement

Now we will connect SVC in the proposed system with ANN control strategy which will mitigate the distortion and fluctuation from the proposed system. Fig 11 below shows the 3-phase system with SVC and Control strategy of the proposed system with instantaneous power control theory which improves power factor and also provides control for active and reactive power value in the system.

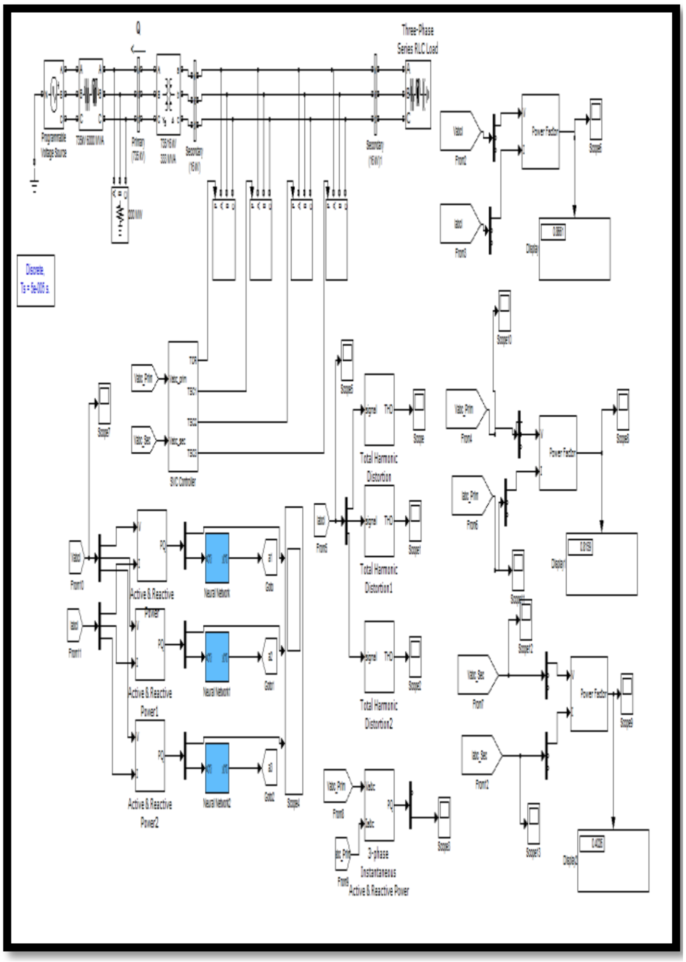

Fig 11- Three Phase system with SVC

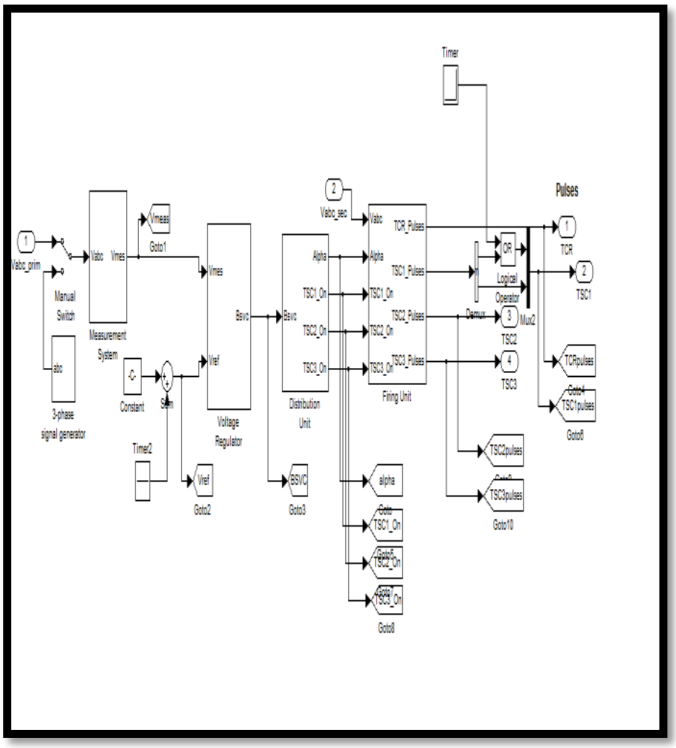

Fig 12-Subsystem of SVC Controller

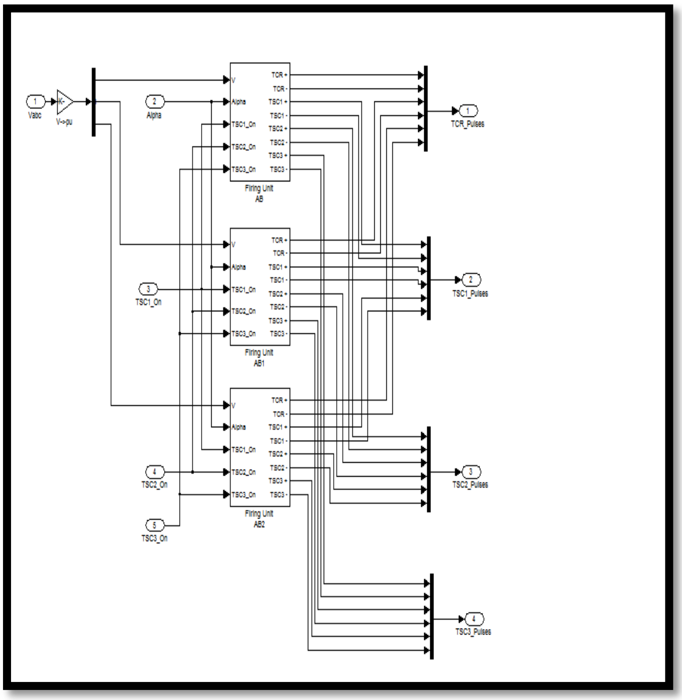

Fig 13- SVC Firing angle circuit

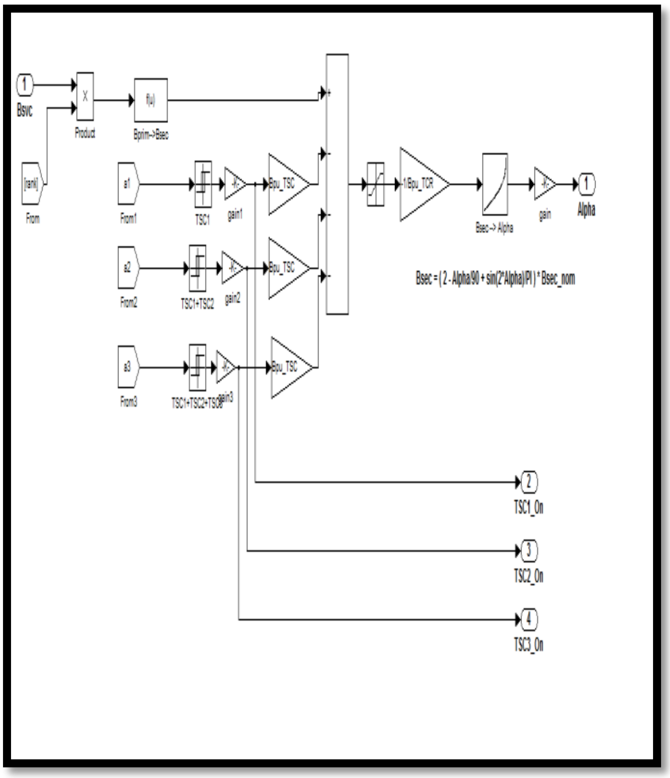

Fig 14- Distribution control circuit

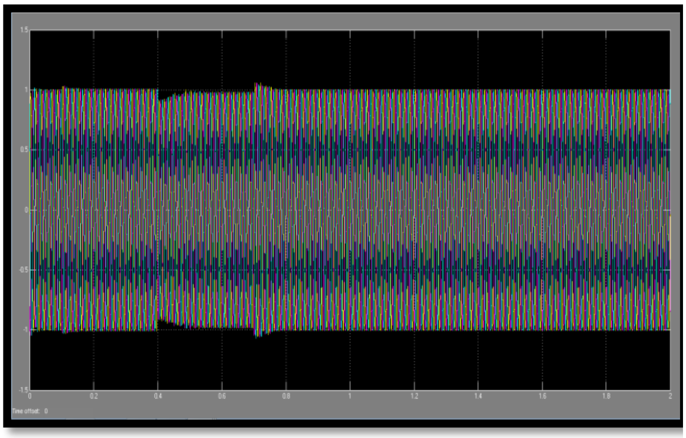

Fig 15-Primary Side voltage

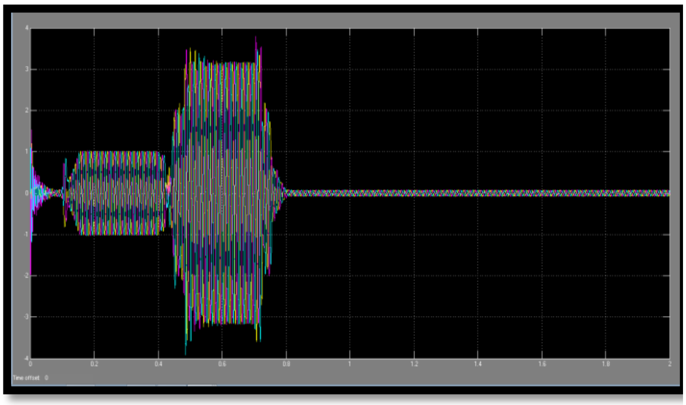

Fig 16- Primary side current

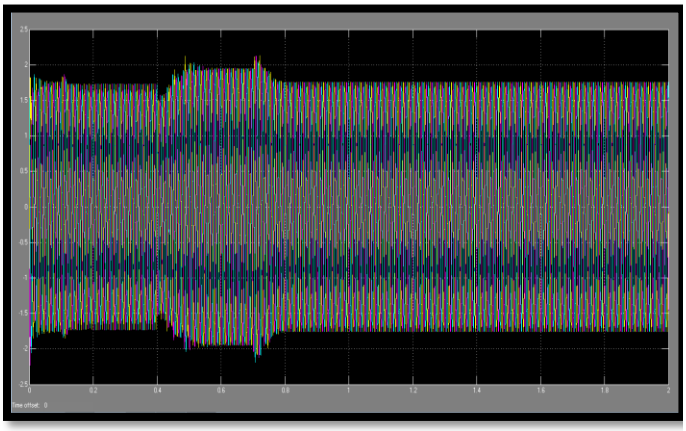

Fig 17- Secondary side voltage

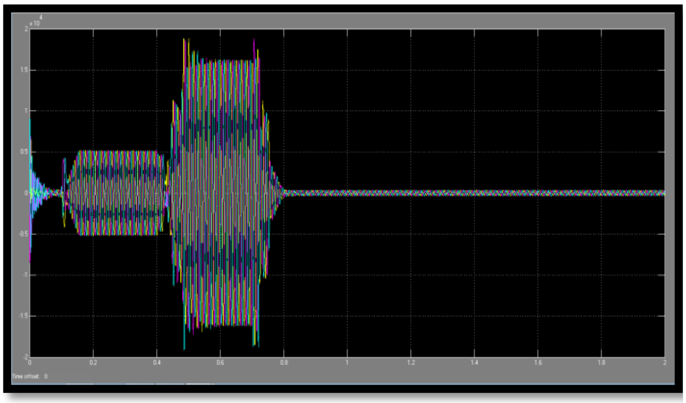

Fig 18- Secondary side current

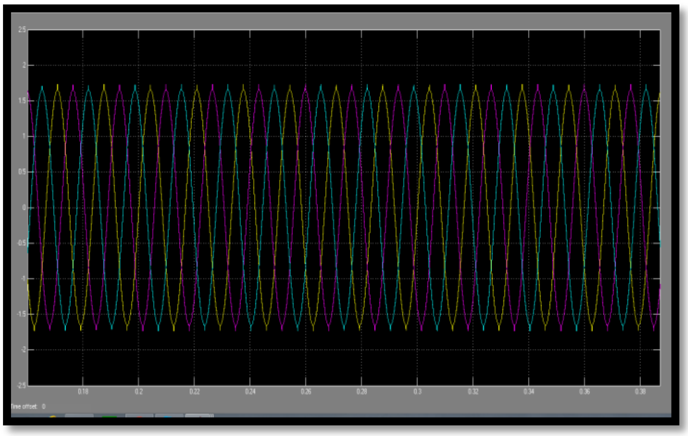

Fig 19- Load side voltage

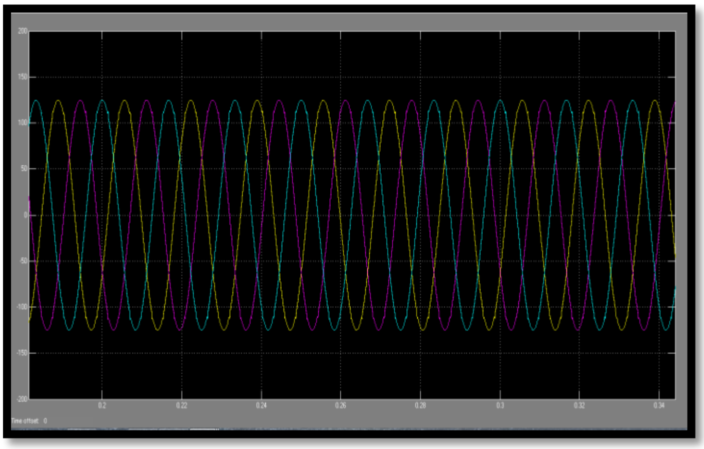

Fig 20- Load side current

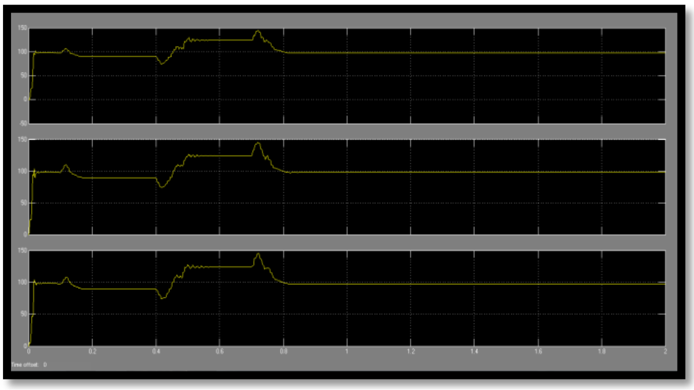

Fig 21- Active Power variations after use of SVC

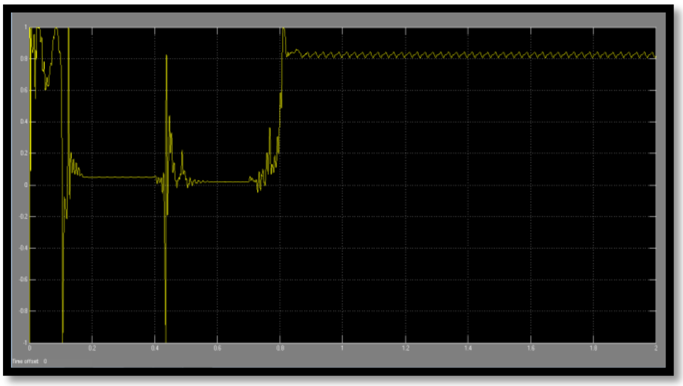

Fig 22- Power factor variation before SVC connected

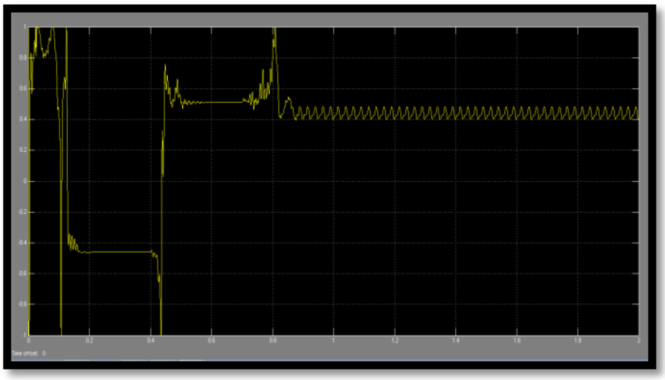

Fig 23- Power factor variation before SVC connected at secondary side

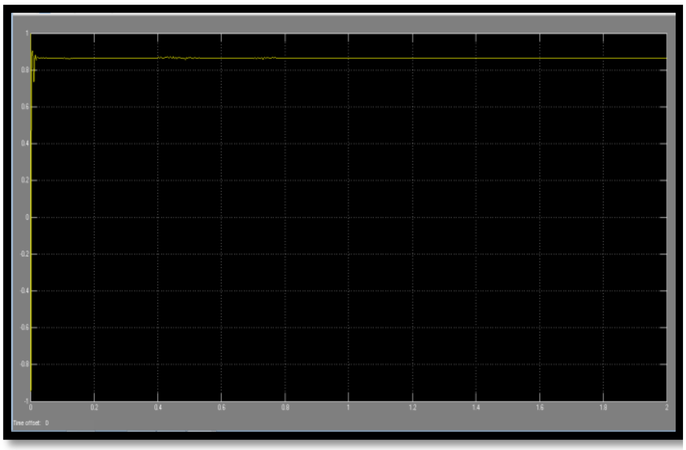

Fig 24- Constant Power factor after the use of SVC

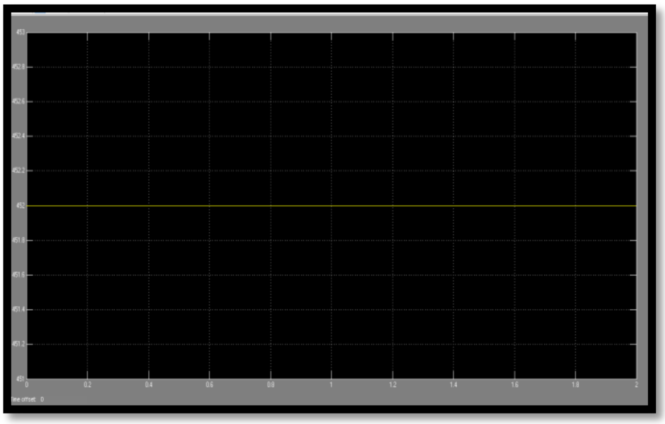

Fig 25- Constant power at load side after the use of SVC

IV. CONCLUSION

This paper presents a modified control scheme to compensate a distribution feeder loading with non-linear loads. The compensation consists of three main objectives that are i) regulation of real powers delivering to loads, ii) regulation of DC link voltage to ensure PWM converter operation, and iii) correction of power factor. Modification of the control scheme made in this paper is to add the reactive power regulation into the control loop. With zero reactive power reference, unity power factor can be achieved. As a result, the modified control scheme can regulate DC link voltage and real power delivery at specified level while reactive power drawn from the load was cancelled by that injected from D-STATCOM. The results proved the theoretical assumptions and the SVC system operates correctly. It is able to compensate a low power factor (both lagging and leading) in each phase independently and automatically within a very short time period (depending on the type of load and system conditions). In the future, the created model can be extended by various improvements and utilities and it can be used for demonstration of the basic operation principle of FACTS controllers, power factor correction or for science and educational purposes.

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