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Design of an Adaptive Power Oscillation Damping (POD) Controller for a Static Synchronous Compensator (Statcom) Equipped with Energy Storage.

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Abstract: This project deals with a custom power oscillation dumping (POD) controller design for a stable Synchronous Reporter (STATCOM), which is embedded with energy storage. This is achieved using a signal assessment method based on the least square (RLS) algorithm that has been revised to be revised, which allows a faster, constructive and positive approximation of low frequency electronic tendencies from locally measured signals during electrical disruptions. In the case of the parameter uncertainty of the system and the various connection points of the limit, the proposed method efficiently works to increase the system's dumping at interest frequencies. First, an analysis of the effectiveness and effect of reactive power injection in the energy system is maintained using a simple two-machine system model. A control strategy that optimizes active and reactive power injections at various connection points of STATCOM is generated using a simplified model. The small-signal analysis of the dynamic performance of the proposed control strategy is undertaken. The effect of the proposed control method to control the device's connection point and system parameter uncertainties in the presence of the uncertainties is demonstrated by simulation and experimental results.

I. Introduction

STATIC Synchronous Component (STATCOM) is a key tool for stabilizing an AC power system. The device has been used to reduce the transmission level for power quality phenomena and voltage control and power oscillating dumping (POD) [1] - [3]. Although more commonly used for reactive power injection, STATCOM can be achieved more flexible control of the transmission system, with an energy pool connected to the DC-link of the conversion [4], [5]. The installation of STATCOM with energy storage has already been detected in U.K for power flow management and voltage control [6]. Wind energy and other distributed wave introduction lead to greater energy storage in the energy system and functional stability improvement function from power sources is possible [7]. Since the injection of active energy is temporarily used temporarily, active energy injection mainly consists of a stability improvement function in attractive systems that use other purposes [8]. Low-frequency electromagnetic oscillations (usually within 0.2 to 2 Hz) are common in the power system and are associated with a safe system operation, especially in the weak transmission system. [9] In this regard, FACTS controllers have been widely used to improve the stability of the power system in the shunt and array configuration [1]. FACTS controllers [STATCOM and Static Composter (SVC), connected to the shunt by modifying the voltage during normal combustion using the reactive power injection (PCC), can achieve the first swing stability and specific case of POD. However, a defect of shunt configuration for such applications is that the PCC voltage should be regulated at specific limits (usually between 10% voltage voltage), and it reduces the dumping amount offered by compensation. In addition, the injection reactive power required to modulate the PCC voltage depends on the grid's short circuit impedance found at the whole connection point. On the other hand, the injection of active force affects the PCC-voltage angle (transmission lines are effectively reactive) voltage levels do not change significantly.

Discussion in energy literature (STATCOM, named E-STATCOM) in literature [10] - [12] was discussed. However, the impact on its dynamic performance of E-STATCOM is generally not treated. When active electrical injection for POD is used, the position of E-STATCOM will have a significant effect on its dynamic performance. Furthermore, the general regulation strategy of the device for POD available in literature is similar to that used for the electrical system stabilizer (PSS) [9] where the wash-out and lead-lag filter links

control input signals. This type of control strategy is effective only at the optimized operating point of the filtering design, and its reaction speed is limited to the frequency of electromechanical oscillations.
In this project, a control strategy for E-STATCOM used for POST is investigated. Measured in the system thanks to the selected local signal sizes, the control strategy optimizes the projection of active and reactive energy to provide uniform bumper in different places in the energy system. This shows that the implemented algorithm is against the parameter uncertainty of the system. For this, the last recursive square (RLS)-based estimation algorithm as described in [13], [14] will be used to extract the required control

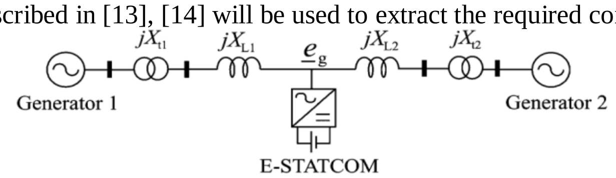

Fig. 1.1. Simplified two-machine system with E-STATCOM.

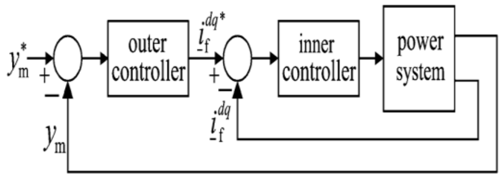

Fig. 1.2. Block diagram of the control of E-STATCOM.

II. Active Power Compensation of Statcom with Energy Storage Systems

A STATCOM is a second generation FACTS controller based on a self-commutated solid-state voltage source inverter. It was used with great success to improve reactive power / voltage control and temporary stability. A STATCOM, however, can only absorb reactive power, and thus limits the size of freedom and continuous action, in which the power grid (Chen 1996) helps. Strength addition additionally allows STATCOM to introduce and / or realize active and reactive power simultaneously, thus providing additional advantages and improvements in the system. The STATCOM's voltage source inverter front-end is easily connected with an energy storage source. This practical technology applies to high power consumption and protection applications. With Energy Storage Systems (ESS), STATCOM can provide a ride through collapse and voltage collapse (Aso and others 2003). VC can work as a backup power supply if DC power capacity is available, and development of energy storage components reduces voltage quality problems for voltage sags and disruptions. Electrical oscillation occurs when transmitting lines, loss of waves and large changes in electrical load. Advantages of ESS integration into a STATCOM

Compulsory active load changes for voltage phase fluctuations in weak networks Compensation of a cyclical load to improve the quality of power at the PCC

2.1. Energy Storage System

Recent developments and advancements in energy storage and electrical electronics technologies implement a viable solution for modern energy applications for energy storage technologies. Viable storage technologies include batteries, flywheels, ultra capacitors and superconducting energy storage systems. These technologies are now seen as an instrument for improving system stability, the power transfer and the power quality improvement in the power system (Boes 2000, Paul Butler and others 2002). ESS increases high reliability and dynamic stability, improves the quality of the power and increases the transmission capacity of the transmission grid in a high power application (Panda and Patel 2007). For a higher energy application, the short-term (seconds-to-seconds) power consumed with the FACTS controller can provide different advantages: Provide system dumping, provide extra dumping in 169 conditions when continuous voltage after disruption Dynamic reactive power provided by traditional FACTS controllers is not enough. Alternatively, it offers low cost delays at low cost, giving the power to maintain the speed of induction motors locally connected to the electrical system as an excellent ESS application by sharing the actual amount of virtual energy with each other. This prevents voltage collapse in areas where voltage sag relaxation techniques have specific distillation motors to investigate through the above mentioned works. This work instead demonstrates regulation strategies with ESS to provide higher strategic and reactive power control for STSS's STSS and to improve electric current in a line with cyclical loads. The study focuses on voltage fluctuations due to sudden changes in connected loading at PCC. STATCOM capacitor or reactor banks have not produced reactive power but are used to maintain a fixed DC voltage to allow the operation of the voltage source converter.

III. Interface between ESS and the DC Link of the VSC

DC Link bus is a bridge between ESS and VSC. You can model the DC link system as shown in Figure 4.12. For traditional STATCOM configuration, the DC Link Capacitor is required for an unbalanced system operation and harmonic absorption.

For STATCOM with ESS, DC Link Capacitor DC can reduce the current character from ESS to ESS and thus use a small DC-link capacitor. Controlling the chopper removal can be controlled to change the relationship between storage size and the relative limit on the DC side of VSC. Energy in SMES is stored in a large lossless sphere.

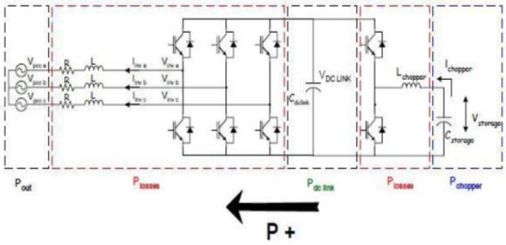

Figure 3.1. DC link regulator

The shunt converter DC side energy storage device size can be calculated by Eshunt = Sload T cos (4.22), the MVA protected load rating in sload, cosDuration of disturbance in protected load and T power factor seconds. Eshunt KJ has storage power. The ESS should be a constant state of active energy, not connected to the converter's DC side. In practice, however, take some active force from the AC network to compensate for losses at transformer and values. The active and reactive power of the AC bus is given, the phase shift cone is adjusted to the small positive value through the control of the view. Vinv can change if changed. V Constant (4.25)Vinv = Vac then = 0. If the AC bus bar voltage is assumed to be the coefficient of the cyanusidol and DC voltage is tight, here is the Voltage Fourier analysis in the converter phase of the VF (1) VSC production voltage. DC Capacitor dimension A term constant () Name ½ CVdc 2N Rated DC voltage Storage power VSC Current Void and SN Converter are largely dependent on nominal clear power. The purpose of the inter-phase inductors is to allow a balanced current partnership for each chopper stage. It reduces current waves to produce chopper in order to guarantee the work life of the ESS.

3.1. Converter control for ACTIVE POWER EXCHANGE

Figure 4.13 describes the four-pulse VSI connectivity scheme with four-pulse basic VSIs. The four inverters are DC-side and are connected to the AC side through shipping transformers. Thus the capacitors for the balance filter can be created with an equivalent 48-pulse inverter, removing the use of large banks, by combining two 24-pulse VSIs, stage-change 7.4 ° from each other. The output voltage wave of 48-pulse VSI is not expected to be downstream and the exact sign wave of the sine wave. However, the multi-pulse converter AC system, combining current organism transformer by tie reactance, supplies almost syunoxaid power. As a result, the net has three volumes of volatile power (VA) 48-pulse inverter satisfaction for high power utility applications at the VSC output terminal.

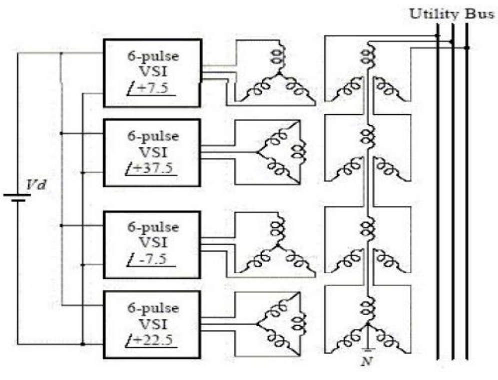

Figure 3.2. 24-pulse VSI

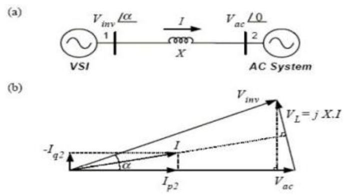

Figure 3.3 (a) Single-phase equivalent circuit of a STATCOM/ESS and utility system (b) Phasor diagram

The interaction of VSI with the AC system is shown in Figure 4.14 (a). Faser diagram equations (4.29) and (4.30) can be expressed for the primary frequency operation shown in 4.14 (b) respectively, with the active and reactive power exchanges transmitted through the STATCOM productive terminal per stage. Using equations above the real and reaction forces, VSC voltage is the size and phase angle of VVSC, active state control of active and reactive power. However, DSC's dynamic control is not explained. From these equations, the reactive power exchange between the input and the AC system is fundamentally controlled based on the spread of the three-stage output voltage. Because the practical step-shift ratings are in the range of ± 10 º, the effect of the equation (4.29) of this variable is less than ± 1.4%. Similarly, the active power switch between the inverter and the AC system is primarily controlled by step-shift. The effect of inverter voltage variations in the AC voltage is not greater than 4%. For the following set equations, the inverter performs an effective control voltage source, ignoring the effects of the current melody. In the analysis, the capacitor filter will be ignored because the filter flow represents a small part of the current part of the inverter. Then the characteristics of the system can be represented in Figure 4.15.

A three-step scheduling reference to the simplicity and simplicity of the transition tasks required to synthesize the control system are written in reference. The instant three-step variables are represented by vector representations, orthogonal co-ordinates and rotating instructions in Figure 4.15. A balanced three phase voltages (V1, V2, V3) can align in a constant two axis (d-q) coordinate system and d-q axis components
These equations represent the dynamic dq model of VSC, in the referenced frame of reference at the angular speed of F. In this model f, iqf, idf, iqf and Vdf state variables and Vcqf and Vcdf inputs. Because the current components are not decoded, the dynamics of these items interfere with each other. By active electrical compensation, the bus voltage magnitude is likely to decrease the difference and phase jump. If the active load is 3-stage symmetry, the current measurement is more straightforward than the load power load. The measured load is taken from the current PLL using the angle from the dq plane and the active current (q component) is taken in reference to active electricity.

3.3. Simulatin of POWER SYSTEM RESPONSE to enforce POWER version

To illustrate the effectiveness of STATCOM / ESS on cyclic loads, simulation studies are performed and the results are displayed in the following sectors. Cyclic loads vary in power over time. A particle accelerator utilizes a simple cyclical load, which uses an active reactive and active force with a powered power factor. Fast magnetization and demagramization of major magnets require a slight increase and fall times of energy during each power cycle. A cyclic load model used in this study is shown in figure 4.16, to show dynamic performance with an SMES coil of STATCOM.

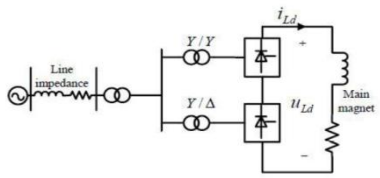

Figure 3.4. Cyclic load model

Although the voltage magnitude disturbance in the PCC is caused mainly by the pulsating reactive power, the active charge power also plays a role. The pulsed active power will be exchanged mainly between the cyclic load and the converter, whereas the network will only need to supply the average active power to the load. The charge model of a main particle accelerator magnet supplied from a 48-pulse VSC is simulated in the Matlab / Simulink environment. The first load is initially synchronized with the grid. The second charge comes on after 0.5 sec. The total load capacity is 395 MVA. The accelerator consumes active and reactive cyclic energy. Rapid magnetization of the main magnet requires a short rise time of the load current. When the acceleration is completed, the main magnet must demagnetize rapidly, requiring a short time of current drop. In the cyclic load control system implemented in Matlab, the outer loop controls the load current and gives the DC output references of the converter. The internal load voltage control loop controls the output voltage of the drive and delivers the drive angle command of the drive. To obtain the sinusoidal voltage with low harmonic content the STATCOM is modeled with a VSC of 48 pulses of 3 levels that is constructed. Four 12-pulse 3-level converters are connected in series on the primary side of the coupling transformer to form an equivalent converter of 48-pulse voltage source, as shown in Figure 4.17. Two ordinary three-phase transformers have their secondary windings connected in delta and the other two in ungrounded star. The required transformer connections and trigger pulse logics are modeled to obtain the 48 pulse operations.

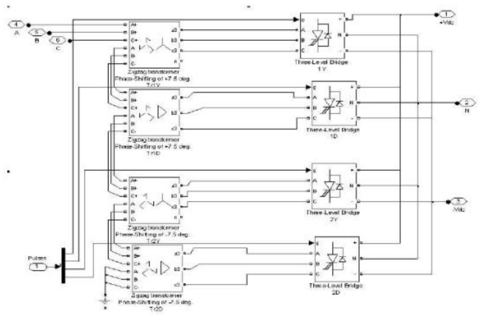

Figure 3.5. 48-pulse voltage source inverter

The 48-pulse VSC can be used in high-voltage, high-power applications without the need for AC filters because of its low THD content on the AC side. The output voltage has normal harmonics n = 48k + 1, where k = 0,1,2 ... .etc. This converter is used in the STATCOM VSC block by replacing the DC source with the energy storage device and connecting it to the bus through the appropriate interface inductor. Two 24-pulse GTO converters, offset 7.5 ° from each other, can provide full 48-pulse converter operation. Using a symmetrical displacement criterion, the 7,5 ° is provided as follows: phase displacement winding with -3,75 ° in the two coupling transformers of a converter of 24 pulses and + 3.75 ° in the others two transformers of the second 24-pulse converter.

IV. Results and Analysis

The implemented system is rated 20/230kV, 900 MVA, total series reactance of 1.665 p.u. P=400 MW and inertia constants $H_{g1} = H_{g2} = H_{g3} = H_{g4} = 6.5s$ .Leakage reactance of transformers 0.15 p.u. and transient impedance of generators 0.3 p.u. By creating a three phase fault at transmission line and E-STATCOM is connected at various points and simulation results were carried out by using simulink/MATLAB software. The simulation results for both PI and E-STATCOM are discussed in this section.

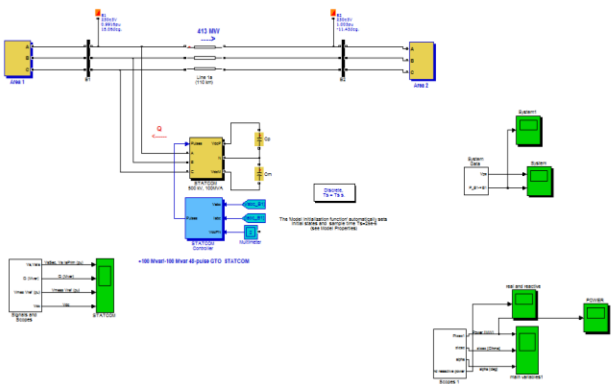

Figure 4.1. Simulation Block Diagram For The System With E-Statcom

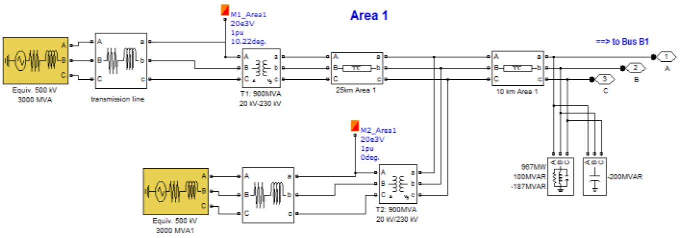

FIG:4.2.Simulation block diagram for the AREA 1

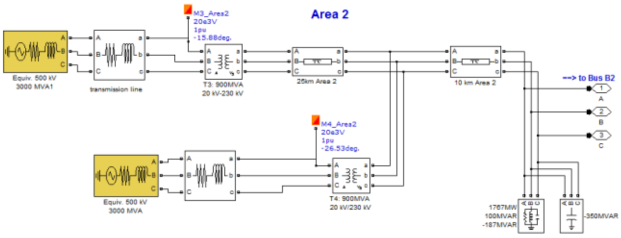

FIG:4.3.Simulation block diagram for the AREA 2

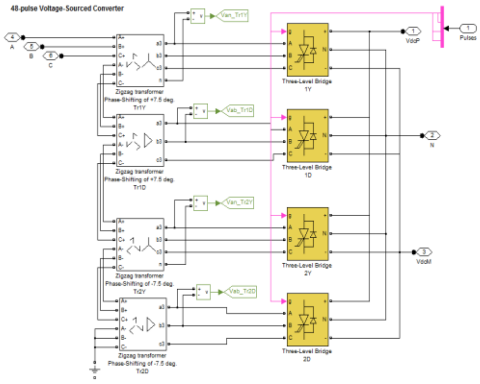

FIG:4.4.Simulation block diagram for the E-statcom 48-pulse voltage source inverter

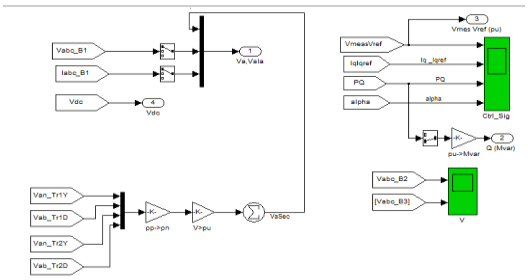

FIG:4.4.Simulation block diagram for the control signal and voltage

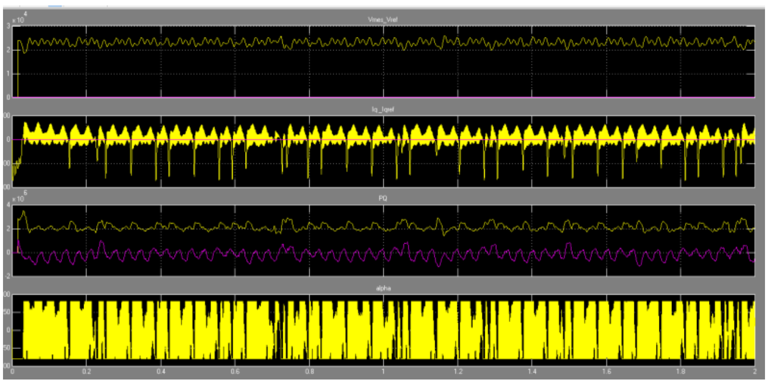

FIG:4.6. Simulation Results For The control signal

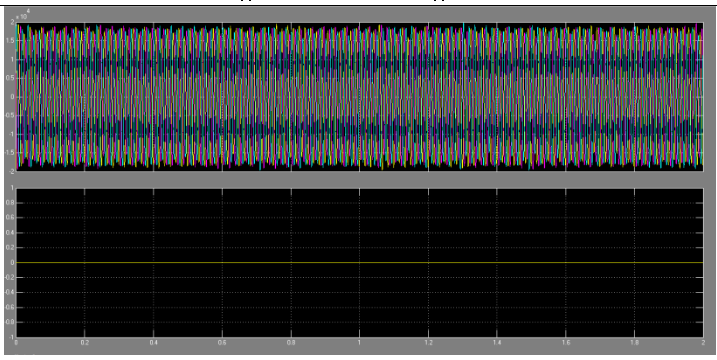

FIG:4.7. Simulation Results For The voltage

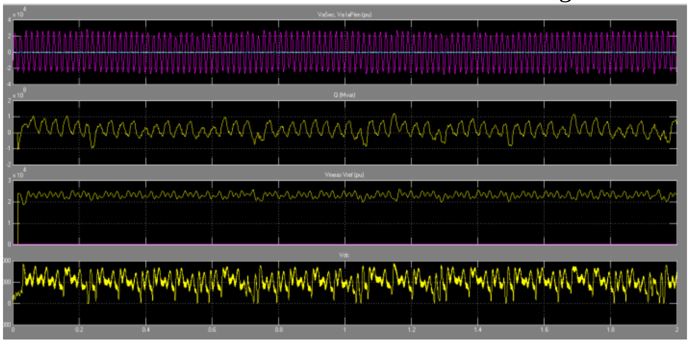

FIG:4.8. Simulation Results For The E-statcom

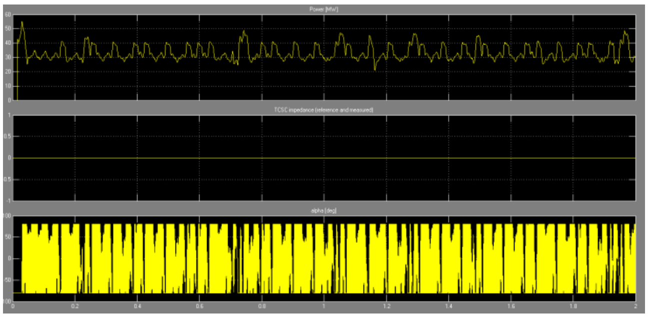

FIG:4.9. Simulation Results For The main variables

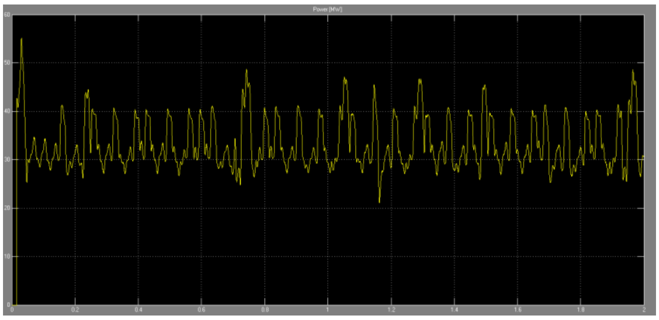

FIG:4.10. Simulation Results For The power

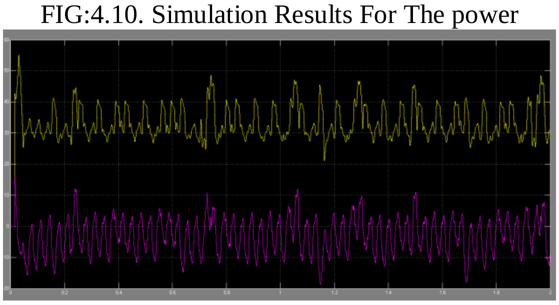

FIG:4.11. Simulation Results For The Real and active

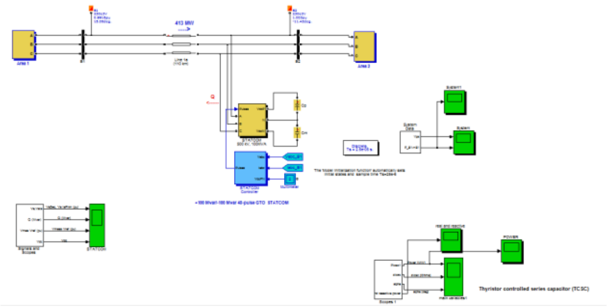

Figure 4.12. Simulation Block Diagram For The System With E-Statcom using pi controller

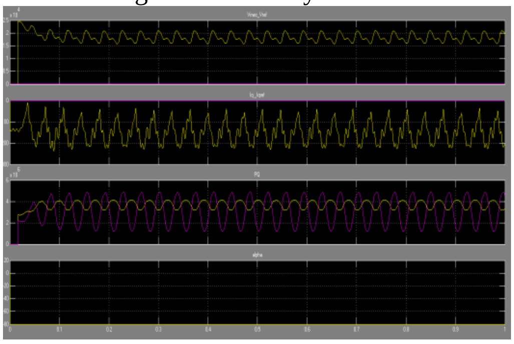

FIG:4.13. Simulation Results For The control signal

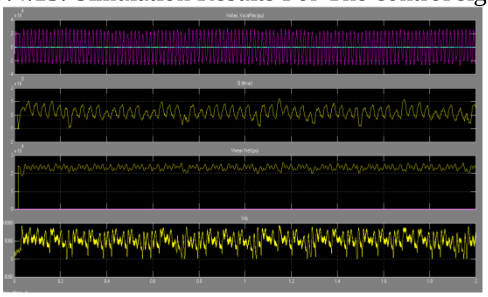

FIG:4.14. Simulation Results For The E-statcom using pi

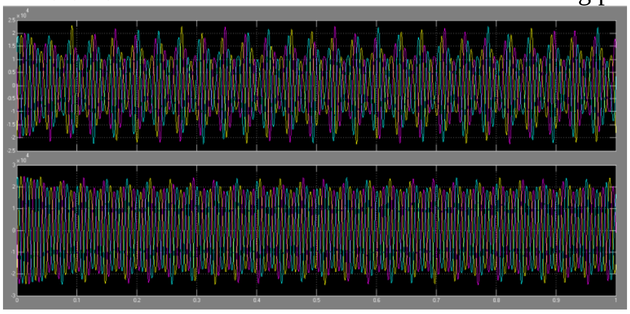

FIG:4.14. Simulation Results For The voltage

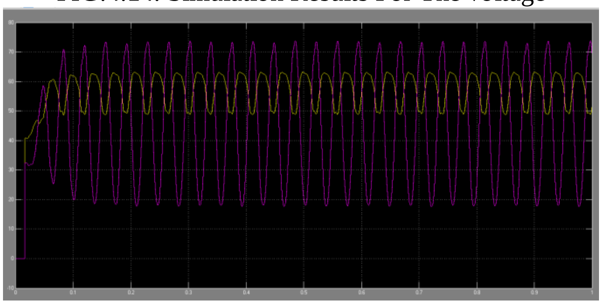

FIG:4.16. Simulation Results For The Real and Reactive

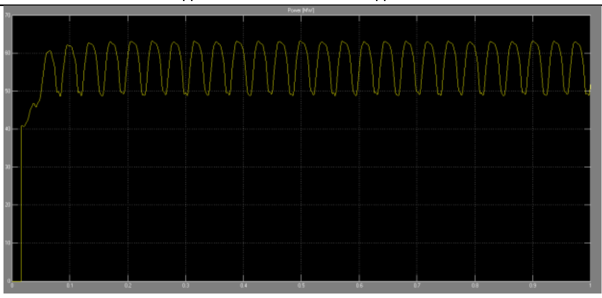

FIG:4.17. Simulation Results For The power

V. Conculsion

With the POD controller structure the performance of the E-STATCOM following the fault at three different locations, This low oscillation frequency highlights the importance of the adopted estimation method, since the classical approaches based on filters would require low bandwidth, resulting in a reduction in the estimation speed. The small-signal analysis for two-machine system, when moving closer to the generator units, a better damping is achieved by active power injection. With respect to reactive power injection, maximum damping action is provided when the E-STATCOM is connected close to the electrical midpoint of the line and the level of damping decreases when moving away from it. Because of a good choice of signals for controlling both active and reactive power injection, effective power oscillation damping is provided by the E-STATCOM irrespective of its location in the line.

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