Adaptive Approach for Power Oscillation Damping using STATCOM

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Abstract: - In this paper we had described the designing of a Power Oscillation Damping (POD) controller for a Static Synchronous Compensator (STATCOM) equipped with Energy Storage System (ESS). Various adaptive techniques like fuzzy logic controller, PID controller, algorithm, etc. can be employed to achieve this allowing a fast and adaptive approximation of the low-frequency electromechanical oscillations from locally measured signals during power system disturbances. We developed an approach using variable DC voltage control and constant modulation index method; which are effective in increasing the damping of the system at the concerned frequencies and in case of system parameter uncertainties. A control policy that optimizes active and reactive power inoculation at various connection points of the STATCOM is derived using the simplified model in MATLAB Simulink using impower system toolbox. Signal analysis of the dynamic performance of the proposed control strategy is carried out. To verify the effectiveness of the proposed control method, we carried out simulations and found that the approach provides oscillation damping irrespective of the connection point of the device and also in the presence of system parameter uncertainties.

Key-Words: - Energy storage, frequency oscillation, power oscillation damping (POD), static synchronous compensator (STATCOM)

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1 Introduction

Modern electric power transmission system is facing many challenging problems due to ever increasing demand and due to the unstable voltage by increases in losses. The construction of new transmission lines is difficult due to economic, social and environmental problems. Due to these reasons, many FACT technologies have been developed. A typical FACT device, static synchronous compensator (STATCOM) has been developed and put in operation at distribution level to alleviate power quality and maintain voltage, power oscillation damping at transmission level by reactive power control and, thus, STATCOM has now become viable for steady state voltage control and purging of power system disturbances. By providing STATCOM with an energy storage system connected to the dc-link of the converter, a flexible control of the transmission system is realized. Low-frequency electromechanical oscillations (between that of 0.2 to 2 Hz) are a cause for apprehension regarding secure system operation, especially in a weak transmission system. FACTS controllers have been widely used to enhance stability of the power system. In case of STATCOM, POD and first swing stability can be achieved by controlling the voltage at the point of common coupling (PCC) using reactive power injection.

2 Literature Review

Static Synchronous is a key appliance for support of the strength in cooling control framework. This appliance has been connected each at dissemination level to alleviate control quality marvels and at transmission level for voltage control and power swaying damping (POD) [1]-[3]. Albeit usually used for responsive power infusion simply, by arming the STATCOM with a vitality storage related to the dc-connection of the device, a a lot of pliant control of the transmission framework is accomplished [4]-[5]. an institution of a STATCOM with vitality storage is as of currently found within the U.K. for power stream administration and voltage control [6]. The presentation of wind vitality and different seized era can harden a lot of vitality storage into the facility framework and helper soundness improvement capability is conceivable from the vitality sources [7]. Since infusion of dynamic power is used shortly amid transient, incorporating the stableness upgrade add frameworks wherever dynamic power infusion is basically used for various functions [8] is appealing. Low-recurrence mechanical device motions (ordinarily within the scope of zero.2 to two Hz) are traditional within the power framework and are a reason for concern with relation to secure framework operation, notably during a frail transmission framework [9]. In such manner, FACTS controllers, each in shunt and arrangement setup, are broadly speaking wont to improve soundness of the facility framework [10].

Within the explicit instance of shunt associated FACTS controllers [STATCOM and static power unit compensator (SVC)], initial swing strength and POD is accomplished by tweaking the voltage at the aim of basic coupling (PCC) utilizing responsive power infusion. In any case, one drawback of the shunt setup for this type of uses is that the PCC voltage should be managed within explicit points of confinement (regularly between 100 percent of the evaluated voltage), and this diminishes the live of damping which will incline by the compensator. additionally, the live of infused receptive power expected to balance the PCC voltage depends on upon the short out resistance of the framework seen at the association purpose. Infusion of dynamic power, then again, influences the PCC-voltage purpose (transmission lines are with success receptive) while not differing the voltage extent primarily. The control of STATCOM with vitality storage (named from now forward as E-STATCOM) for power framework solidness upgrade has been talked concerning within the writing [11]–[12].

In any case, the result of the realm of the E-STATCOM on its dynamic execution is generally not treated. At the purpose once dynamic power infusion is used for POD, the realm of the E-STATCOM considerably affects its dynamic execution. Also, the typical control procedure of the appliance for POD accessible within the writing is just like the one used for power framework stabilizer (PSS) [13], wherever a progression of wash-out and lead-slack channel connections are used to supply the control input signals. this type of control technique is compelling simply at the operating purpose wherever the setup of the channel connections is improved, and its speed of reaction is strained by the return of the mechanical device motions. during this paper, an effect procedure for the E-STATCOM once used for POD are going to be explored. owing to the selected neighborhood flag amounts measured within the framework, the control technique streamlines the infusion of dynamic and responsive energy to allow uniform damping at completely different areas within the power framework. it'll be incontestable that the actualized control calculation is powerful against framework parameter vulnerabilities. For this, associate adjusted algorithmic minimum sq. (RLS)-based mostly estimation calculation as represented in [14] are going to be used to separate the specified control signals from in camera measured signs. At long last, the adequacy of the planned control procedure is going to be approved by suggests that of reenactment confirmation.

Flexible ac transmission systems (FACTS)[15] device like static synchronous Compensator (STATCOM) applications [16] are increasing in power systems. this is often as a result of their ability to stabilize the transmission systems [17]-[18] and to enhance power quality in distribution systems. STATCOM is popularly accepted as a reliable reactive power controller. This device provides reactive power compensation, active power oscillation damping, flicker attenuation, voltage regulation, etc. Generally, in dynamical applications, power unit compensation is achieved using structure inverters. These inverters encompass an oversized range of dc sources that are typically realized by capacitors. But, as a result of mate in conductivity and shift losses of the shift devices, the capacitors voltages are unbalanced. reconciliation these voltages could be a major analysis challenge in structure inverters. Static synchronous compensator (STATCOM) could be a key device for reinforcement of the soundness in associate ac installation. This device has been applied each at distribution level to mitigate power quality phenomena and at transmission level for voltage control and power oscillation damping (POD) [19].

Although usually used for reactive power injection solely, by militarization the STATCOM with associate energy storage connected to the dc-link of the device, a lot of versatile control of the gear [20]can be achieved. Low-frequency mechanical device oscillations] (typically within the vary of zero.2 to two Hz) are common within the installation and are a cause for concern relating to secure system operation, particularly during a weak gear. The control of STATCOM with energy storage (named hereafter as E-STATCOM) [21]-[22] for installation stability sweetening has been mentioned within the literature [23]. However, the impact of the placement of the E-STATCOM on its dynamic performance is often not treated. once active power injection is employed for POD, the placement of the E-STATCOM contains a important impact on its dynamic performance. Moreover, the standard control strategy of the device for POD on the market within the literature is analogous to the one used for installation stabilizer (PSS), wherever a series of wash-out and lead-lag filter links are wont to generate the control input signals. this type of control strategy is effective solely at the operational purpose wherever the planning of the filter links is optimized, and its speed of response is proscribed by the frequency of the mechanical device oscillations. In this paper, an effect strategy for the E-STATCOM once used for POD are going to be investigated. The control strategy optimizes the injection of active and reactive power [24] to produce uniform damping at numerous locations within the installation. it'll be shown that the enforced control algorithmic rule is strong against system parameter uncertainties. For this, a changed Recursive Least Sq. (RLS) [25] based mostly estimation algorithmic rule as delineate are going to extract the specified control.

2.1 Principle of Operation of STATCOM

The generation of reactive power and its absorption is provided by STATCOM by processing the voltage and current waveforms in a voltage-source converter (VSC) [26]. In Fig. 1.1(a), a STATCOM power circuit is shown where a VSC is connected to a utility bus through magnetic coupling. STATCOM is seen as an adjustable voltage source in Fig. 1.1(b). where capacitor banks and shunt reactors are not needed for reactive-power generation and absorption. Hence, STATCOM have a compact design, having low noise and low magnetic impact [27]-[28].

Fig. 1.1(c) illustrates the exchange of reactive power between the converter and the ac system which can be controlled by changing the amplitude of the 3-phase output voltage, Es, of the converter.

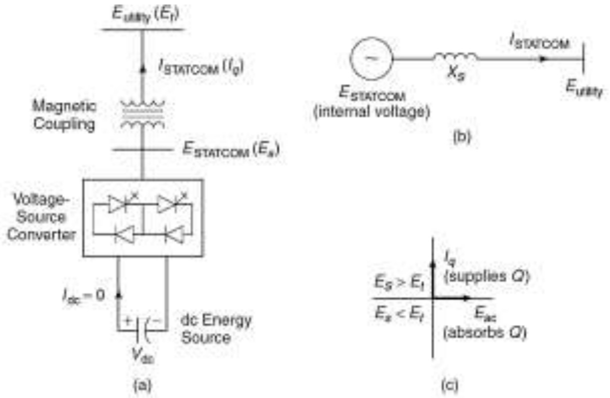

Fig. 2.1. STATCOM: (a) a power circuit; (b) an equivalent circuit; (c) a power exchange

The reactive-power exchange becomes zero if the output voltage equals the ac system voltage [29]. In such a case the STATCOM is said to be in a floating state [30]-[31].

2.2 Integration of FACTS with Energy Storage System (ESS):

The integration of ESS into FACTS devices leads to a more economical and supple transmission control. The enhanced performance will have greater application by providing proven solutions to the problems of uneven active power flow, sub-synchronous oscillations, transient and dynamic stability, and power quality issues using active power control [32]-[35]. A schematic diagram of the mentioned application in the supply of energy is portrayed in Fig. 2.2.

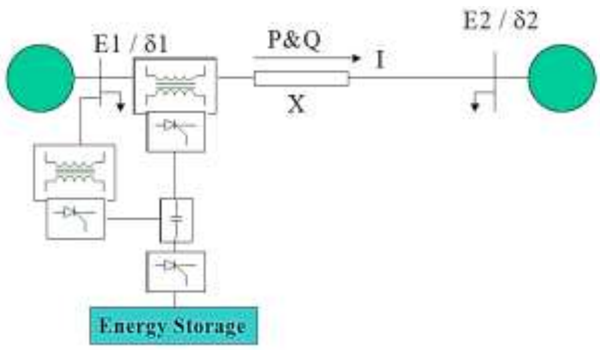

Fig. 2.2. Configuration of energy storage system integrated to FACTS

The STATCOM does not employ capacitor or reactor banks to harvest reactive power. An equivalent circuit for the STATCOM is shown in Fig. 2.3.

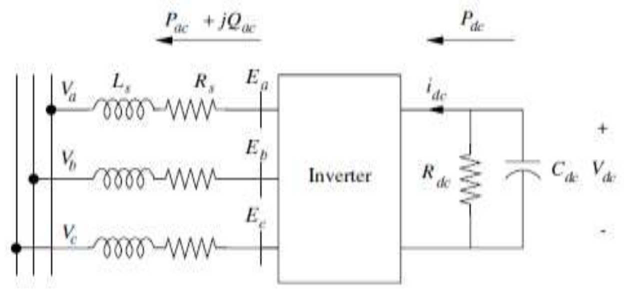

Fig. 1.3. Equivalent circuit of the STATCOM

3 MATLAB Simulation Model for Power Oscillation Damping Using STATCOM

This section gives the detail description of the MATLAB Simulation models for the proposed approach. The MATLAB model of the overall system is initially represented followed by the essential building blocks of the proposed system [36]-[40]. These blacks include:

- Direct axis and quadrature axis current calibrated MATLAB subsystem
- PI Controller for governing switch pulses MATLAB subsystem
- Two level space vector controller subsystem for gate pulses generation
- Multiport switches subsystem model
- STATCOM controller subsystem model
- Sector selector subsystem model

The complete MATLAB simulation model designed for damping power oscillations using STATCOM with energy storage is shown in Fig. 3.1.

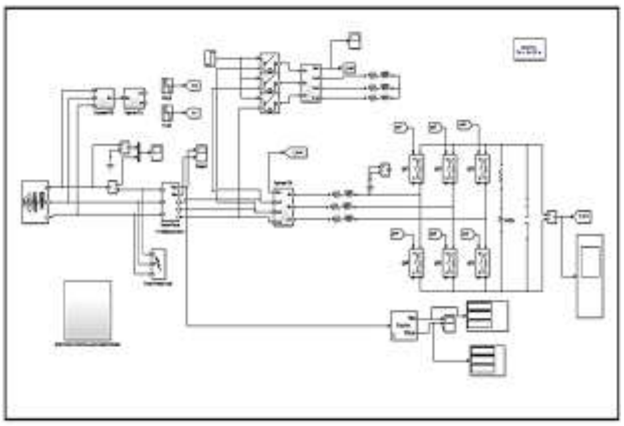

Fig. 3.1: MATLAB Simulink model of power system with STATCOM and energy storage device

3.1 Direct axis and quadrature axis component subsystem

Figure 3.2 shows Direct axis and quadrature axis current calibrated MATLAB subsystem of the proposed approach.

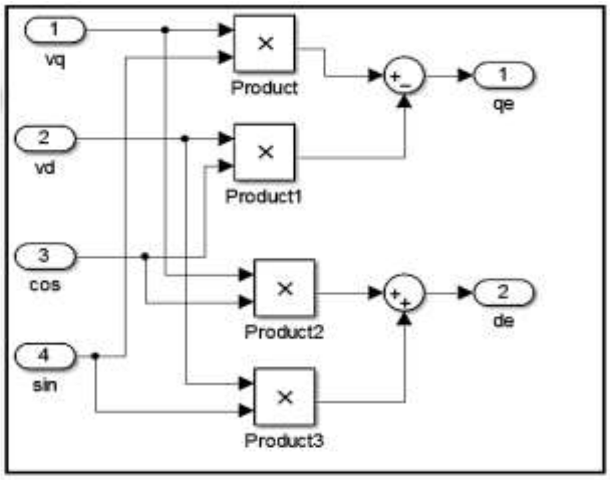

Fig. 3.2: Direct axis and quadrature axis current calibrated MATLAB subsystem

3.2 PI Controller subsystem

PI controller block is shown in Figure 3.3.

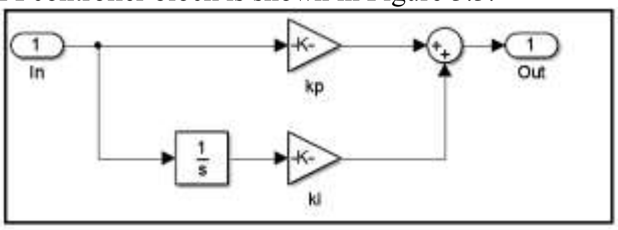

Fig. 3.3: PI Controller for governing switch pulses MATLAB subsystem.

3.3 Two level space vector subsystem

Two level space vector controller subsystem is shown in Figure 3.4. This subsystem is developed so as to generate gate pulse

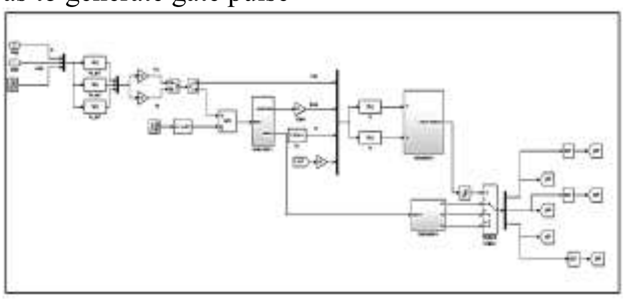

Fig. 3.4: Two level space vector controller subsystem for gate pulses generation.

3.4. Multiport switch subsystem

Multiport switches subsystem model is shown in Figure 2.5 followed by: STATCOM controller subsystem model shown in Fire 2.6.

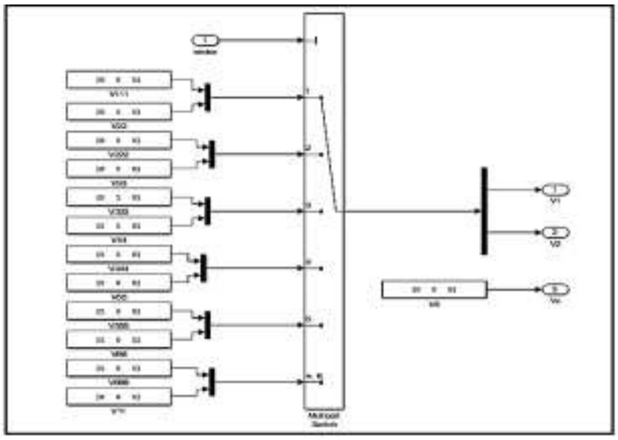

Fig. 3.5. Multiport switches subsystem model.

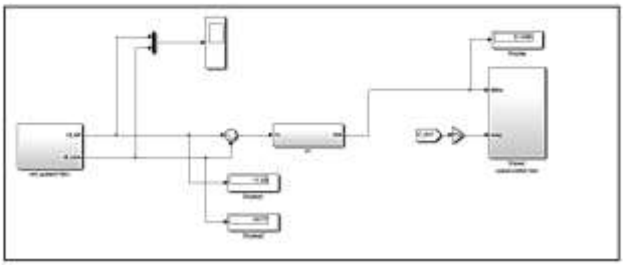

Fig. 3.6: STATCOM controller subsystem model.

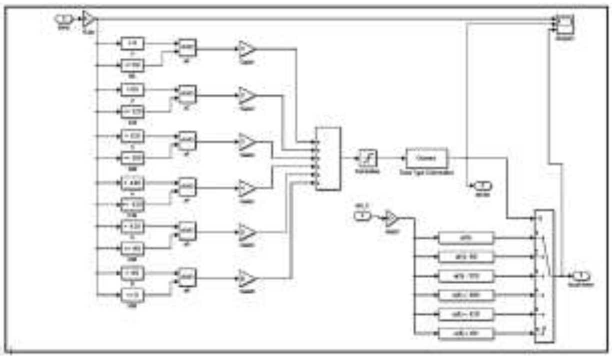

Fig. 3.7: Sector selector subsystem model.

4 MATLAB Simulation Results

4.1. Results showing STATCOM without energy storage device

In this section, we have presented the simulation results of the proposed MATLAB Simulink Model.

4.1.1. Normal condition with inductive

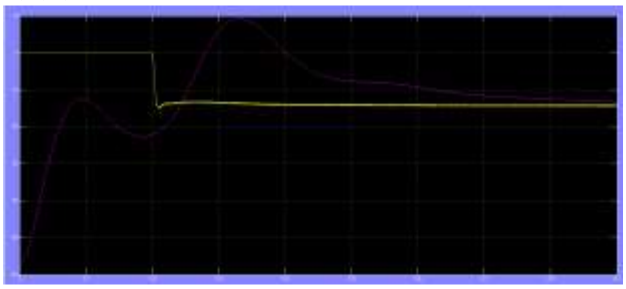

Fig. 4.1: Direct axis reference current and direct axis power system current waveform

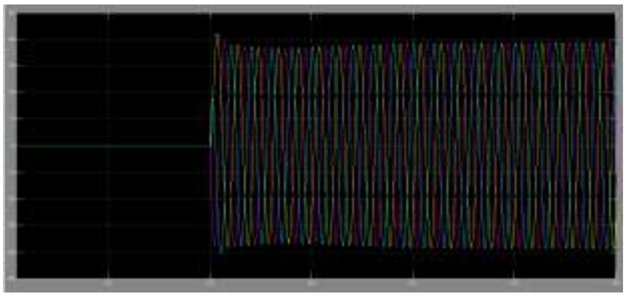

Fig. 4.2: Inductive load current when load connects with power system at 0.2 second.

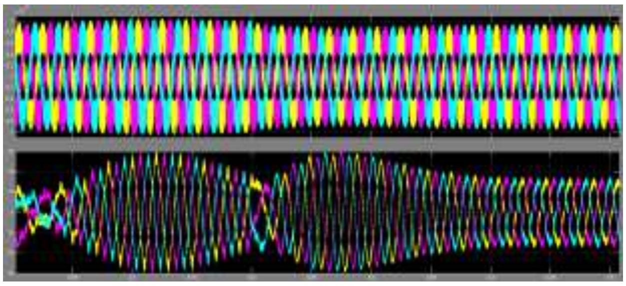

Fig. 4.3: Power system three phase voltage and current waveform during normal condition and inductive load

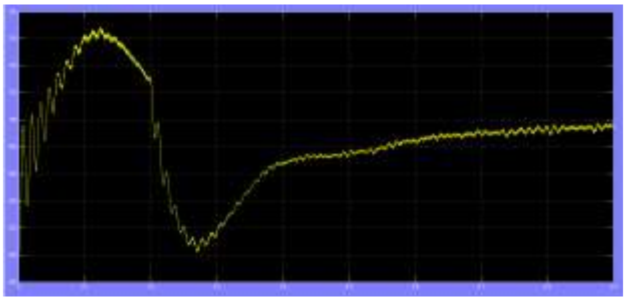

Fig. 4.4: DC link voltage of STATCOM during power system voltage and current control.

4.1.2. LG fault with inductive load

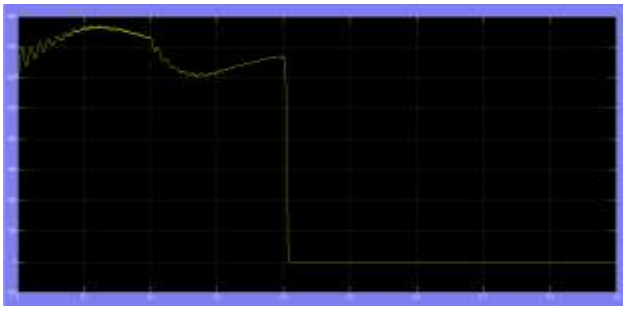

Fig. 4.5: DC link voltage of STATCOM during power system voltage and current control when LG fault and inductive load presents.

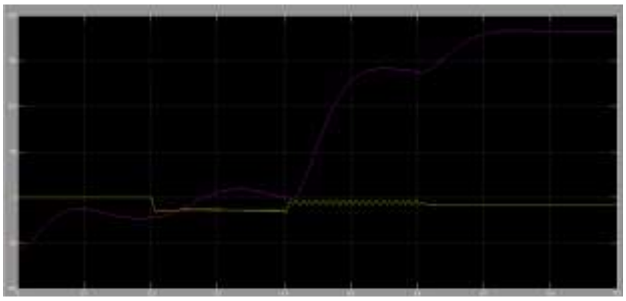

Fig. 4.6. Direct axis reference current and power system current waveform when line to ground fault and inductive load on power system

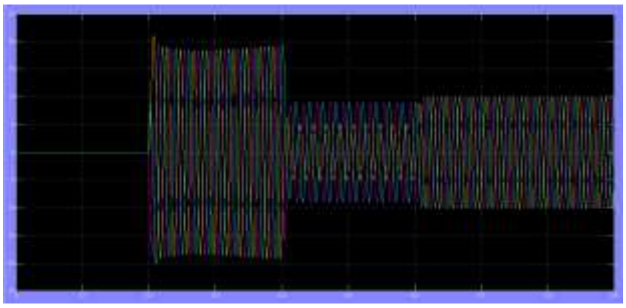

Fig. 4.7: Inductive load current when load connects with power system at 0.2 second when LG fault and inductive load on power system.

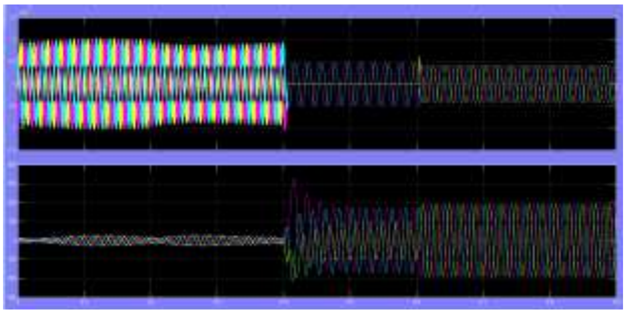

Fig. 4.8: Power system three phase voltage and current waveform during LG fault condition and inductive load on power system.

4.2. Results showing STATCOM with energy storage device

4.2.1. Normal condition with inductive load

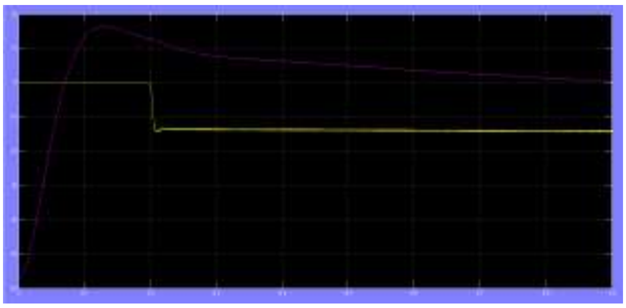

Fig. 4.9: Direct axis reference current and direct axis power system current waveform when normal condition and inductive load on power system with energy storage based STATCOM.

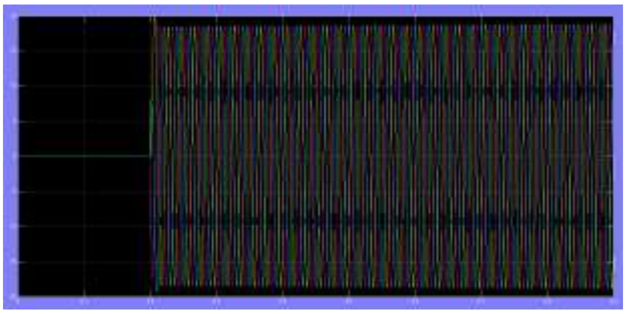

Fig. 4.10: Normal system load current when load connects with power system at 0.2 second when system normal and inductive load on power system with energy storage based STATCOM

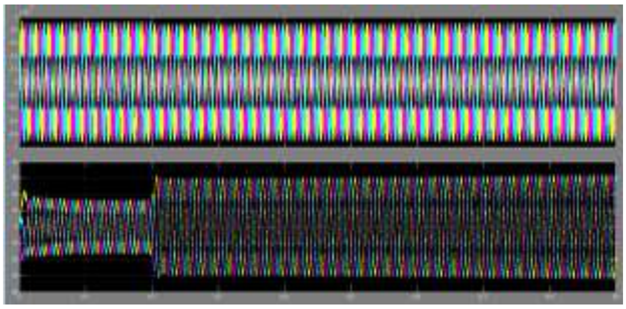

Fig. 4.11: Power system three phase voltages and current waveform during normal condition and inductive load on power system with energy storage device based STATCOM.

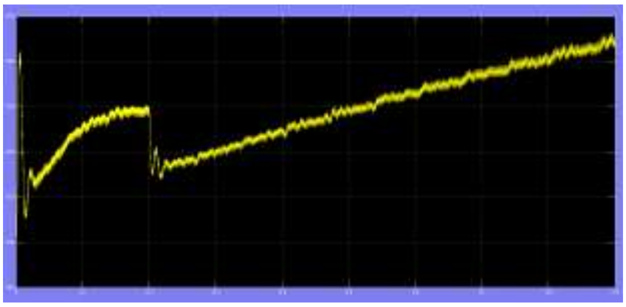

Fig. 4.12: DC link voltage of STATCOM during power system voltage and current control when power system normal and inductive load presents with energy storage device based STATCOM

4.2.2. LG fault with inductive load

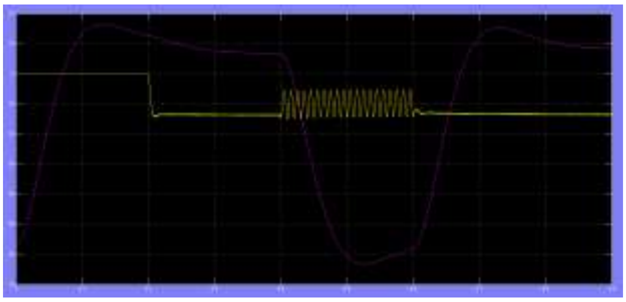
Fig. 4.13: Direct axis reference current and direct axis power system current waveform when line to ground fault and inductive load on power system with energy storage based STATCOM

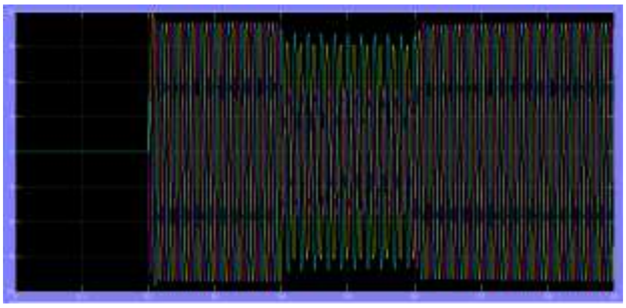
Fig. 4.14: Inductive load current when load connects with power system at 0.2 second when line to ground fault and inductive load on power system with energy storage based STATCOM.

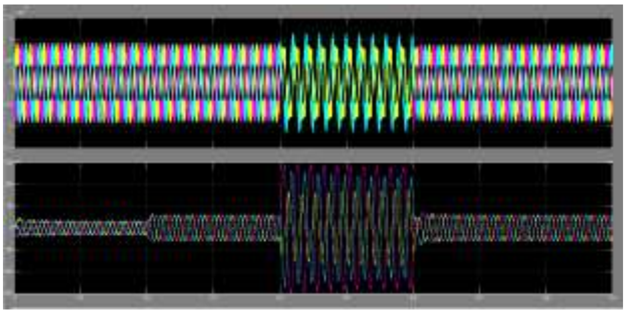
Fig. 4.15: Power system three phase voltages and current waveform during LG fault and inductive load on power system with energy storage device based STATCOM.

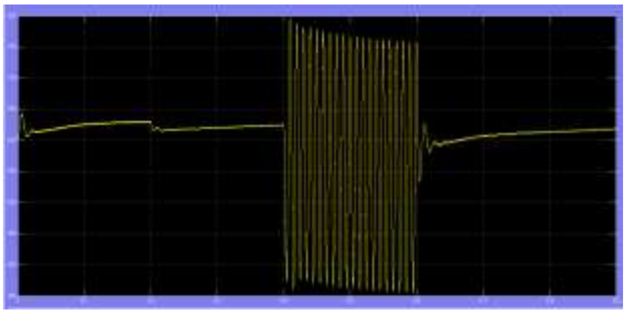
Fig. 4.16: DC link voltage of STATCOM during power system voltage and current control when LG fault and inductive load presents with energy storage device based STATCOM.

4 Conclusion

An adaptive approach for power oscillation damping has been developed in this paper. We have designed a power oscillation damping (POD) controller for STATCOM equipped with energy storage. We have carried out the simulation of damping oscillation model for analysis of STATCOM performance. For this purpose, we have used constant modulation index and variable dc bus voltage based STATCOM. Various waveforms of STATCOM for normal conditions and faulty condition with and without energy storage device are obtained and it is found that using STATCOM controller we can smoothly control the power system damping during normal condition and fault condition with inductive or capacitive load on power system.

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