



## Mitigation of Transients in Hybrid Power Generation System Using Static Synchronous Compensator

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### ABSTRACT:

In this paper a hybrid power plant is proposed in order to provide a promising replacement of conventional power plant. Such power plants are efficient but due to excessive switching of power electronics devices and the other faults occur in transmission line they undergo power quality issues like voltage sag, voltage swell, transient instability in active and reactive power, power frequency disturbance etc. The proposed model is used in mitigating these issues by using combination of Static Synchronous Compensator (STATCOM) with Battery Energy Storage System (BESS). Such combinational system also enhance the flexibility of the power plant, improves the control over transmission and distribution system and provides dynamic decentralize active power. The MATLAB simulation with comparative analysis of system with and without STATCOM+BESS is presents to achieve compensation in system parameters are shown in the results.

**Keywords:** STATCOM, Battery Energy Storage System, power compensation, Hydro power plant, Wind power plant.

### I. INTRODUCTION

Renewable energy sources play an important role in power sector because of continuous increment in power demand. Such energy sources are abundant in nature and hence they are very good replacement of fossil fuels. But over this advantage a major disadvantage is that these renewable energy sources are weather dependent and hence are very intermittent by nature. Therefore, generating electricity by single source of renewable energy is somehow unreliable. To overcome such issues combination of different power plants i.e. hybrid power plant are used. By such action the intermittent nature of renewable energy is overcome by one another and hence system becomes more reliable. Such systems are efficient but due to excessive use of power electronics devices and other faults in the transmission line they undergo power quality issues. The proposed model is used to mitigating these issues by using combination of Static Synchronous Compensators (STATCOM) with Battery Energy Storage System (BESS).

The advantage of using STATCOM is that it increases the power transfer capability of the system under low-voltage condition and hence the fluctuation under fault conditions reduces. Shunt connected STATCOM improves the transient stability of the system simply by providing reactive power compensation at common point of connection. By increasing or decreasing the power transfer capability according to the increment or decrement of the machine angle, the reactive power compensation in transmission line is achieved. The following diagram shows the transmission line having STATCOM[9].

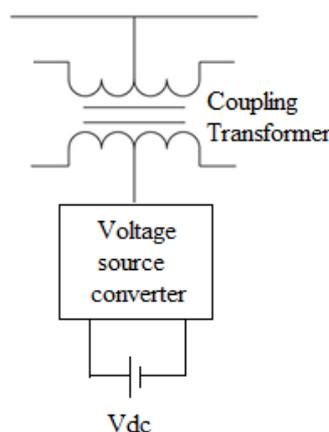


Figure 1: Transmission line having STATCOM

STATCOM operates in two modes, as per Fig 1, if the DC capacitor voltage  $V_{dc}$  is increased from its nominal value the STATCOM is operates in overexcited (or capacitive) mode and generates reactive power. While, if the voltage of the DC capacitor bank is decreased below the nominal value the STATCOM operates in under-excited (or inductive) mode and absorbs reactive power from the system[1]. And in such a way STATCOM provides reactive power compensation in the transmission line. The integration of BESS with STATCOM allows compensation of reactive as well as active power in the transmission line simultaneously.

In this paper application of STATCOM with BESS in hybrid power plant is presented with the help of MATLAB simulation modelling. The implemented model is use to analyse system under different fault conditions. The comparative analysis of system response under faulty conditions with and without STATCOM+BESS is shown in results.

### I. HYBRID POWER PLANT

Renewable energy sources are the future energy sources as their existence is abundant in nature. But due to uncertainty, intermittent nature and high installation cost, these energy sources are less competitive than conventional sources of energy like coal, petroleum etc. To overcome such issues combination of two or more power plants are used, which are commonly known as Hybrid power plant. Hybrid power plant consist of either combination of conventional energy source and renewable energy source power plants or combination of different types of renewable energy sources power plants. As per the present scenario wind power plant are very promising, and to overcome its intermittent nature hydro power plant as a secondary power source is efficient power plant combination.

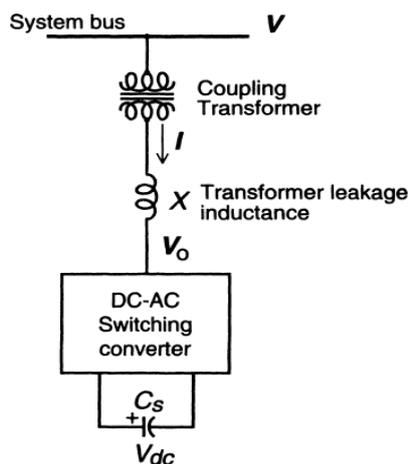
In proposed model, combination of wind power plant and hydro power plant are used as a hybrid power system. Wind power plant is the primary (main) power plant of the system whereas hydro power plant acts as a secondary power plant, which is used to compensate intermittent nature of wind power plant. Both the power plants are complimenting each other and hence the overall efficiency of the power plant increases adequately. But using renewable energy source based power plant large power electronic based devices are incorporate with the system which increase system complexity. The excessive switching of power electronic devices and the faults in the transmission line may result in power quality issue and hence the quality of generated power reduces, means system may experience issues like voltage sag, voltage swell, transient instability in active and reactive power, power frequency disturbance etc. Such issues adversely affect the system parameters and may reduce the system efficiency. Hence compensation devices like Flexible AC transmission system (FACTS) are used.

### II. FLEXIBLE AC TRANSMISSION SYSTEM

In a large power transmission system, power electronic based controllers which are commonly known as Flexible AC transmission system (FACTS) are used. These flexible networks have ability to exchange power between neighbouring utility in order to fulfil the large power demand and hence reduce the need of new power plants and transmission lines to overcome the increased demand for power.

FACTS consist of the power electronic devices which are used to provide additional level of controllability over high voltage side of the network by introducing inductive as well as capacitive power in the network. FACTS have ability to increase the power transfer capability of the transmission system and hence stabilised the system. Basically there are 4 types of FACTS controllers: series controller, shunt controller, series-series controller and series-shunt controller. Series controllers are variable impedance device which consist of capacitors and inductors. They are used to reduce the inductive effect of the transmission line by injecting voltage in it. Typical examples of such controllers are Thyristor Controlled Series Capacitor (TCSC), Thyristor Switched Series Capacitor (TSSC), and Static Synchronous Series Compensator (SSSC). Another type of FACTS controller is shunt controller these controllers inject current in series with the transmission line in order to reduce the capacitive effect of the transmission line. Static Synchronous Compensators (STATCOM), Static Var Compensator (SVC), Thyristor Switched Capacitor (TSC), and Thyristor Switched Reactor (TSR) are some of the examples of shunt type FACT controller. The third type of controllers are series-series controller such controllers consist of integration of two series controller in order to maintain series current and real power of the transmission line with in its specified limits. Interline Power Flow Controller (IPFC) drop into this category of fact controller. The fourth and the last type of FACT controllers are shunt-series type FACT controller. As name implies such controllers are the combination of shunt and series controller which are used to compensate the current and the voltage of the transmission line. UPFC i.e. Unified Power Flow Controller is one of the example of such controller[1,3].

In this paper, STATCOM controller which is a shunt type FACT controller is used to provide reactive power compensation to the power system. A STATCOM unit consist of a charged capacitor, a dc-to-ac converter unit and a coupling transformer. The charged capacitor  $C_s$  provides dc input voltage to the dc-to-ac converter unit. Converter unit produces a set of controllable three-phase output voltages with the frequency of the ac power system as its output. The controllable three-phase output voltage is in phase and coupled to the corresponding ac system voltage via tie reactance. By comparing the amplitude of converter output voltage  $V_o$  with the amplitude of the system voltage  $V$ , the reactive power flow in the ac system can be controlled. If  $V_o$  is greater than  $V$  that means system operates in over-excited mode and as a result leading current is obtained and the machine is seen as a capacitor by the ac system. Similarly if  $V_o$  is less than  $V$ , the system operates in under-excited mode and produces a lagging current and hence in such case machine is seen as a reactor (inductor) by the ac system[1,9].



**Figure 2: Reactive power generation by voltage source converter**

The above diagram shows the reactive power generation by voltage source converter[1]. The operating principle of STATCOM in order to provide reactive power compensation is somehow same as the conventional rotating synchronous machine. Hence the reactive current  $I$  drawn by the voltage source converter is determined by the magnitude of system voltage  $V$ , converter output voltage  $V_o$  and circuit reactance  $X$ .

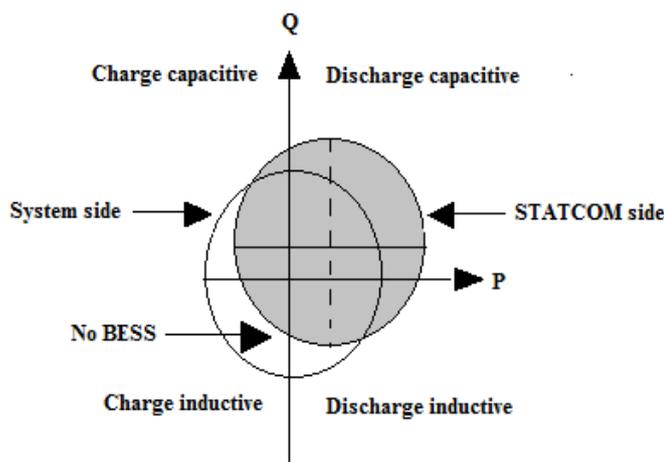
$$I = \frac{V - V_o}{X}$$

The corresponding reactive power exchange between ac system and converter unit is given by

$$Q = \frac{1 - \frac{V_o}{V}}{X} V^2$$

### III. INTEGRATION OF STATCOM AND BESS

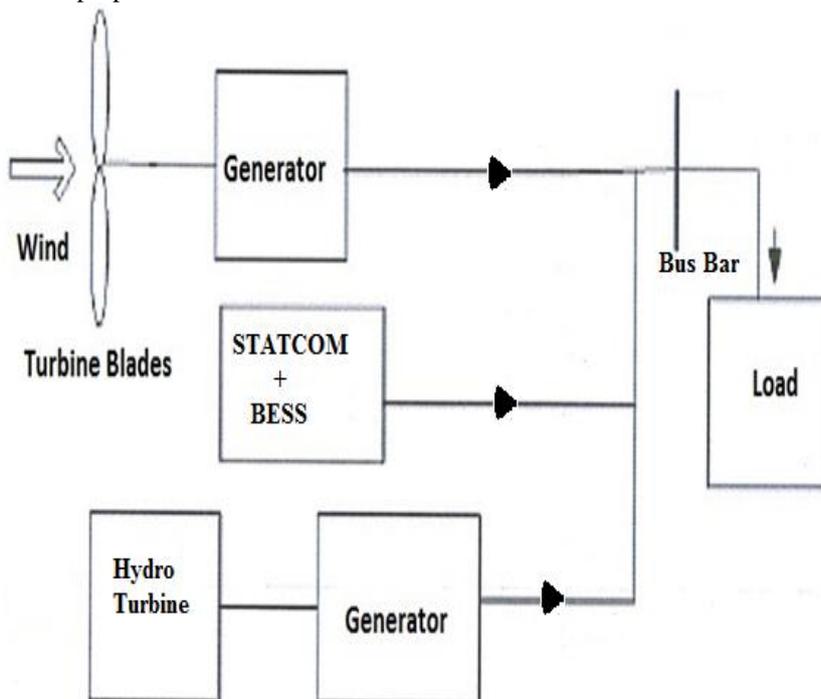
Although STATCOM have ability to improve power system performance, they are unable to adjust in steady state independently due to lack of active power compensation capability. Hence for complete control over power flow capability in a transmission line and to improved power system performance parameters, an integrated STATCOM with Battery Energy Storage System (BESS) is proposed. Unless the traditional STATCOM modes of operation in such combinational system under steady state are extended to all four quadrants. These modes of operation are reactive (inductive) with DC charge, reactive (inductive) with DC discharge, capacitive with DC charge, and capacitive with DC discharge. Practically the operating modes represents quasi-steady state as the combined STATCOM+BESS system cannot be operated infinitely in one of the four modes (i.e., the battery cannot continuously discharge). The charging and discharging profile of the battery storage is sufficient to provide enough energy that maintains the stability of the power system operation until another long-term energy sources may brought on-line[1,9].



**Figure 3: Output power characteristics of STATCOM+BESS**

Under steady state, the output voltage of the standalone STATCOM is one dimensional only, and must lie along the dashed line, whereas the output voltage of a STATCOM+BESS can take any value within the circle. Hence the STATCOM+BESS acquire an extended degree of operating freedom that enhanced performance of the power system[8,9]. The maximum and minimum output voltage angles of the STATCOM+BESS dependent upon the system voltage, equivalent impedance and the maximum current limit of the STATCOM+BESS. Further the maximum current limit of the STATCOM+BESS is determined by the maximum transformer current, the maximum device current, and the maximum output current of the BESS[7,6].

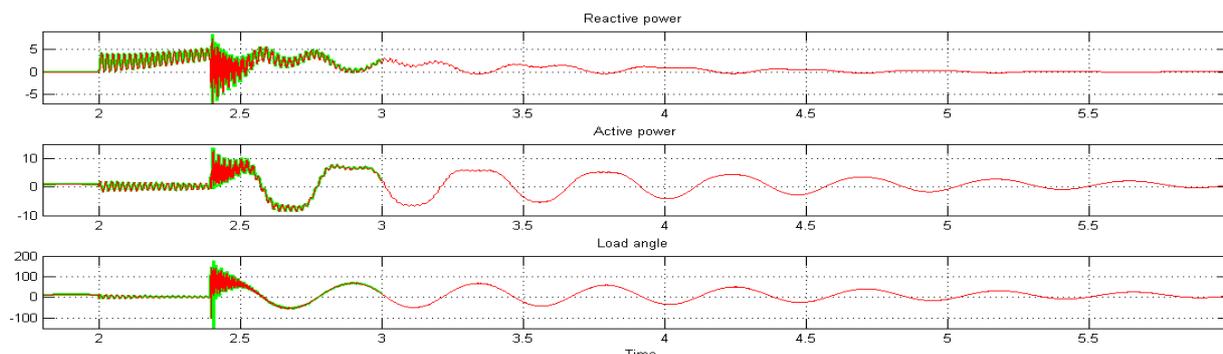
In Figure 3, the active and reactive power characteristics under constant terminal voltage of STATCOM side (converter side of the transformer) and the system side are shown. The circles represent the possible output power of the STATCOM side (shaded region) and the system side. The dashed lines represent the possible output power of the standalone STATCOM. It is evident that on the system side of the standalone STATCOM (dashed line), the active power is always negative, because the STATCOM will always draw active power to compensate system losses. Ideally, the STATCOM+BESS can be operated anywhere within the circle. And hence improve the power transfer capability, system stability and reliability adequately. Fig 4 shows the block diagram of proposed model.



**Figure 4: Block diagram of proposed model**

#### IV. SIMULATION RESULTS

In this section the designed power system is analysis under different fault conditions in order to check the stability of the power system. Power, voltage, frequency etc. of hydro power plant, wind power plant and STATCOM are taken into consideration and effect of STATCOM+BESS in power system is determined on the basis of the waveform obtained from the MATLAB simulation. Firstly three phase faults are applied to the power system and the impact of these faults on the transmission line, with and without STATCOM+BESS is studied. After that phase-to-ground faults impact are studied. The results shows that the transient of the power system are mitigated up to some extend after using combination of STATCOM+BESS and hence the overall system becoming comparatively stable.



**Figure 5: Characteristics of SG during 3 phase faults (without STATCOM+BESS-green and with STATCOM+BESS-red)**

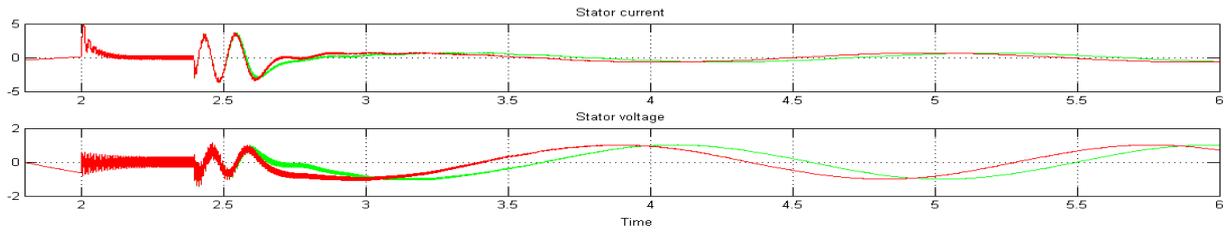


Figure 6: Characteristics of IG during 3 phase faults (without STATCOM+BESS-green and with STATCOM+BESS-red)

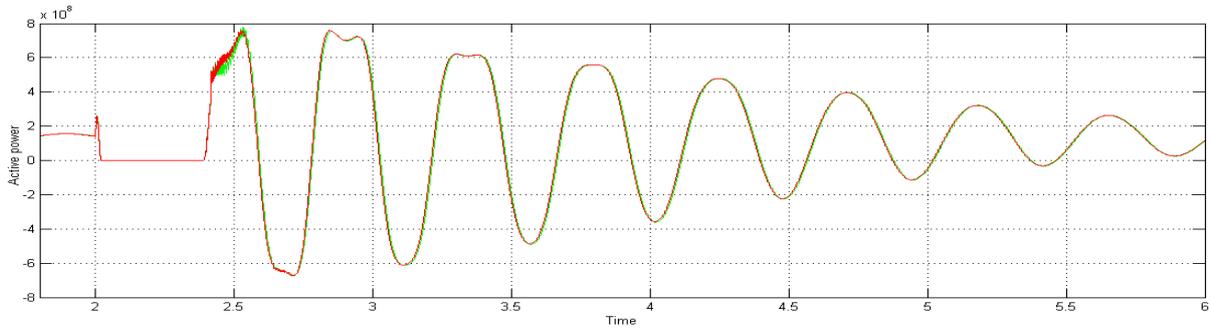


Figure 7: Bus active power during 3 phase fault (without STATCOM+BESS-green and with STATCOM+BESS-red)

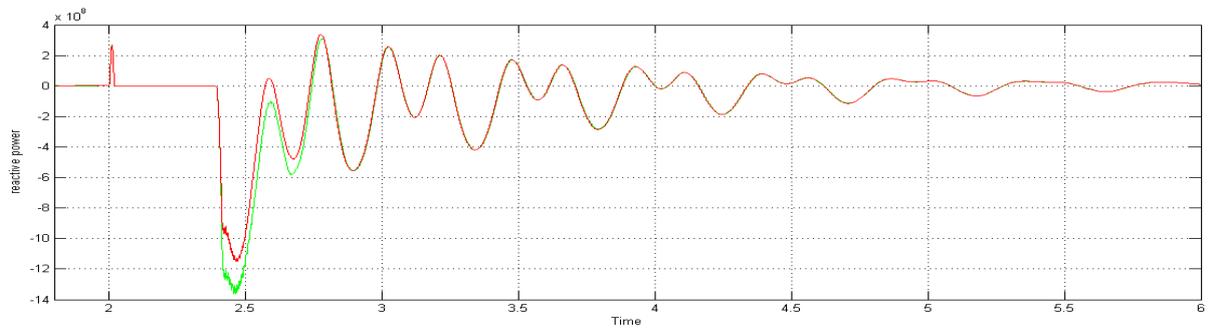


Figure 8: Bus reactive power during 3 phase fault (without STATCOM+BESS-green and with STATCOM+BESS-red)

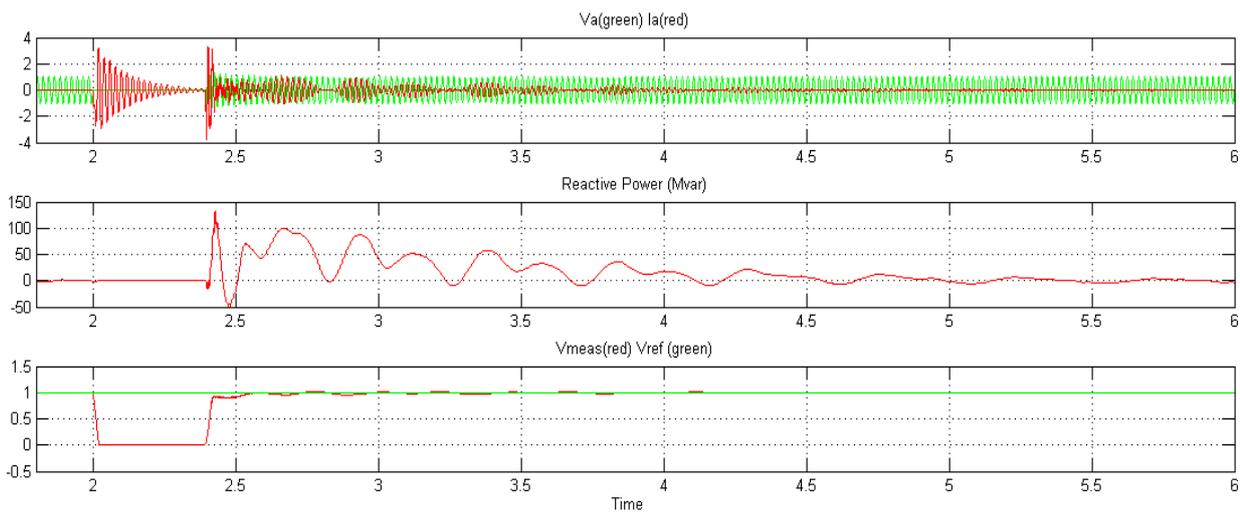
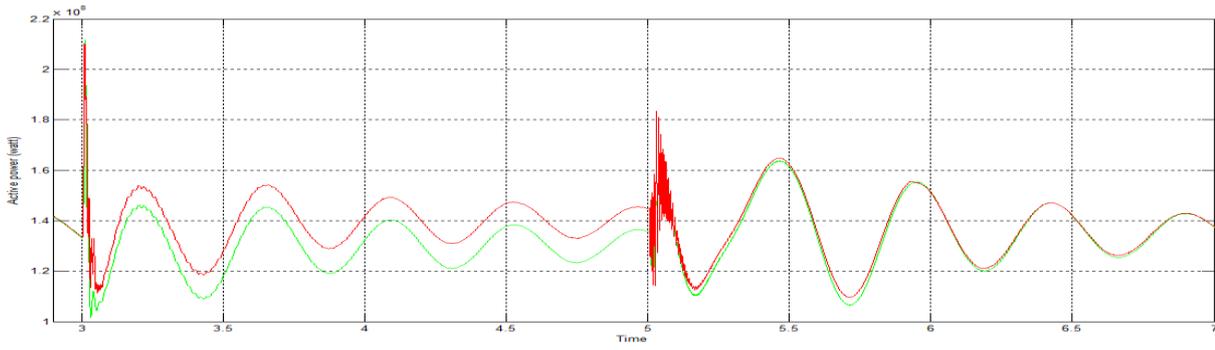
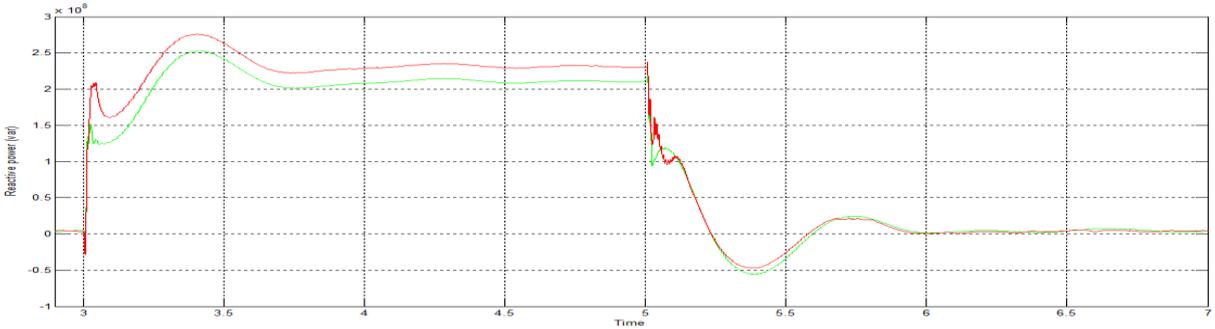


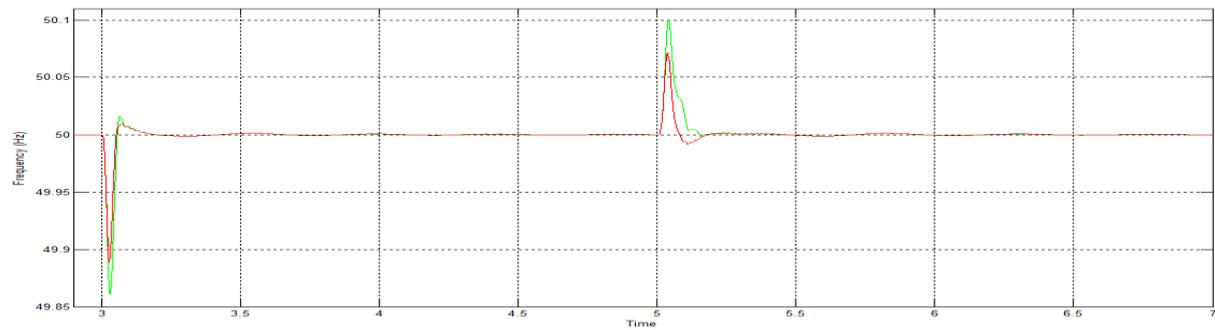
Figure 9: STATCOM characteristics during 3 phase faults



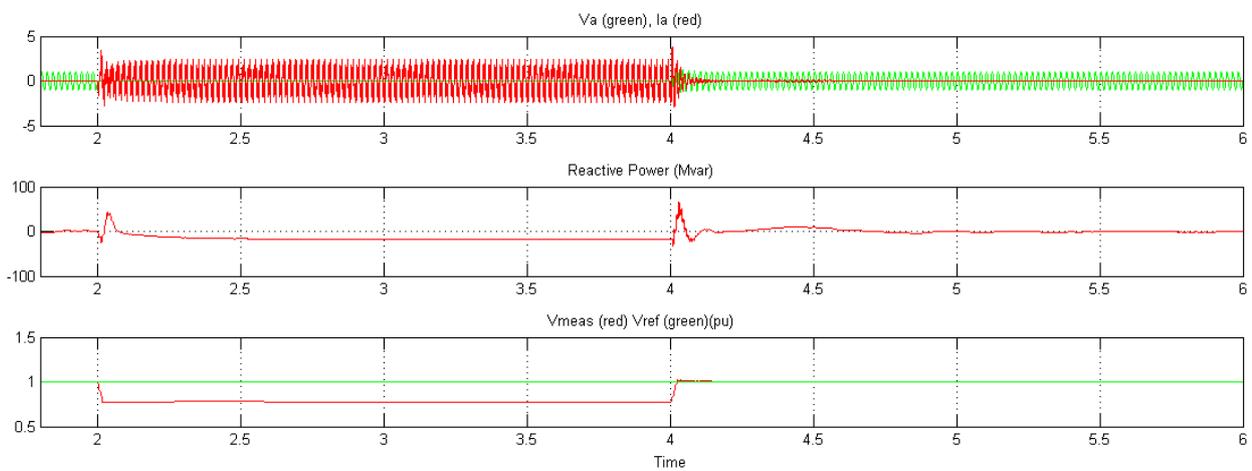
**Figure 10: Bus active power during phase-to-ground fault (without STATCOM+BESS and with STATCOM+BESS)**



**Figure 11: Bus reactive power during phase-to-ground fault (without STATCOM+BESS and with STATCOM+BESS)**



**Figure 12: Frequency of generated power during phase-to-ground fault**



**Figure 13: STATCOM characteristics during phase-to-ground faults**

#### V. CONCLUSIONS

The designed hybrid power plant reduced considerably amount of power fluctuations. The combination of STATCOM+BESS fulfill its purpose and hence provides better transient stability and mitigates power quality issues like voltage sag, voltage swell, fluctuation in active and reactive power etc. at reasonably good amount. With the help of MATLAB simulation the comparative results are analyses and stability of power system is discussed.

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