Investigation of the Effect of Different Facts Devices on Stability in Case of Asymmetric and Symmetrical Fault Condition in Two-Machine System

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***Abstract* – Many methods have been developed for the control and stability of electrical energy systems. As a result of the researches, more complex systems are produced for electricity generation, transmission and distribution. New modern systems are developed which are capable of changing power flow parameters such as voltage, impedance, power angle, frequency, and power transmission capacity in transmission systems. In this context, the effects of static elements to be connected in parallel or in series to the stability of power system stability studies is one of the most important fields of study of electrical science. In this study, the effects of STATCOM and SVC, one of these shunt flexible AC devices, on the stable operation of the system in case of symmetrical or asymmetric fault situations that may occur in the transmission system are examined in matlab / simulink environment. This study showed that STATCOM provides superior control than SVC and maintains the stability of the system in case of any failure.**

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1. Introduction

With human needs increasing day by day, electricity has been an indispensable part of our daily life since the late 19th century when its production began. For this reason, it has to be delivered in the desired quality and reliability until it reaches the end user from where it is produced. If the factors such as system voltage collapses, active and reactive power changes, power factor improvements are not taken into account, these problems may cause power losses in lines, disruption of synchronization or failure of consumers' devices [1]. Especially in systems operating at medium and high voltages, due to the large damages that may occur because of the losses or an electrical fault, flexible alternative transmission system (FACTS) devices made with semiconductor power electronics elements have been developed. The main goal of FACTS technology is to regulate the power transfer by keeping the system under control and to increase the carrying capacity within certain limits. Today, power systems are large and mechanically controlled. FACTS technology is a technology comprising of microelectronics, communication and advanced control applications consisting of various power electronics circuit elements based on high power electronics. With the FACTS devices, the magnitude and phase angle of the selected bus can be controlled. The flow of power can be continuously monitored by the control centre [2]. FACTS devices are basically power electronics based devices, which are aiming to increase the capacities of systems and transmission lines [3]. Nowadays, researchers have made use of different algorithms like IPGSA and MFOA to provide small signal stability in large capacity power systems in order to maintain general power system stability [4], [5]. It has been observed that [6] SVC systems, which used to ensure voltage stability in long transmission lines, can cause electromagnetic oscillation under certain frequencies. The research results show that with the increase in the length of the transmission line, the frequency of the electromagnetic oscillation has decreased. In reference [7], the system quality has been improved by using a fuzzy method-based SVC based on the reduction in voltage and power fluctuations, reduction in harmonic currents and improvement on the system stability. When FACTS devices are used in two machine and multi area systems, it has been observed that [8], [9] the angular and voltage stability of the system has been positively affected as well as harmonic current reducing impact seen. In addition, a novel FACTS device called PV-STATCOM [10] is proposed for power oscillation damping.

In this paper, the effects of SVC which consists of TCR and TSC structure and STATCOM on the angular and voltage stability of the system in case of symmetrical and asymmetric fault occurring in a long transmission line with 2 machine system were examined. According to the simulations studies, STATCOM has shown better performance than SVC. The system answer is given separately in the conclusion section.

2. Static VAr Control Systems

The design and implementation of static VAr compensation systems emerged as a necessity and its foundation dates back to 1970s [11]. The first static VAr compensator was commissioned in western Nebraska, USA in 1977 [12]. It is problematic to correct the power factor of unbalanced and fast switching loads with conventional electromechanical compensation devices. One reason for this is that conventional compensation systems cannot meet the required capacitive reactive power from the compensation system and the load cannot immediately respond to the sudden reactive power demand. On the other hand, in the case of unbalanced loading, three-phase systems do not have a chance to respond to the needs of each phase. With static VAr compensation systems, instant compensation of unbalanced loads, such as elevators, spot welding machines, port cranes and arc furnaces can be done quickly. SVC can effectively suppress power system fluctuations and improve the stability of power systems in voltage control circuits. An ideal SVC is defined as a controller that does not have active and reactive power loss, whose voltage is equal to the reference voltage, does not change and can respond very quickly by maintaining control of the connected bus's either absorbed or injected reactive power [13], [14], [15], [16].

Thanks to the static VAr compensators based on the thyristor switching method, the number of switching in and out is almost unlimited, and the switching time can be precisely controlled. Thyristor is used to connect capacitors, reactors and other equipment to the power system with switching by eliminating the inrush currents without arc situation. With a switching time of approximately 0.01 - 0.02 seconds dynamic response time, operational difficulties and the effect of the inrush currents are greatly reduced. In this way, the power factor is kept at optimum value at any time. Thus, dynamic reactive power compensation is realized, power quality is improved and voltage fluctuations are reduced. In Figure 1., SVC V-I curve is given. Considering this curve, it is seen that the voltage will be regulated to (reference voltage) as long as the SVC susceptance oscillates between capacitor and reactor capacities.

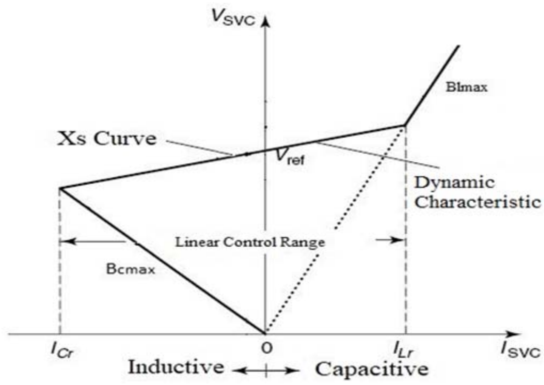

Figure 1. SVC V-I curve [17]

The location of an SVC strongly affects the controllability of oscillation. In general, the best location is at the point where voltage fluctuations are greatest. Normally, the midpoint of a transmission line between the two areas can be considered the optimal area [18]. While industrial type SVC systems generally fulfils the constraints related to power quality and phase angle, taking into account harmonic and flicker distortions, transmission type SVC plants mainly work on system stability (angle, frequency, voltage) and voltage control.

3. Static Synchronous Compensator Systems

STATCOM is one of the flexible alternating current transmission system (FACTS) devices used in power systems to improve power flow, ensuring transient stability and regulation of the voltage magnitude on connected bus. It is a voltage source converter (VSC) type shunt device [19], [20]. These devices make the voltage regulation in the bus which they are connected to by reacting power to the system by absorbing or creating reactive power. When the voltage on the bus drops, STATCOM supplies reactive power to the system and compensates the voltage on the bus. When the voltage in the bus rises, they absorb reactive power from the system and provide compensation. STATCOM has a structure consisting of IGBT and GTO. Since this structure is fed from the DC capacity inside STATCOM, active power consumption will be very low [21]. In Figure 2., the STATCOM V-I curve is given.

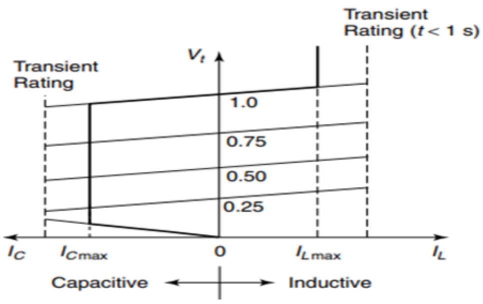

Figure 2. STATCOM V-I curve [17]

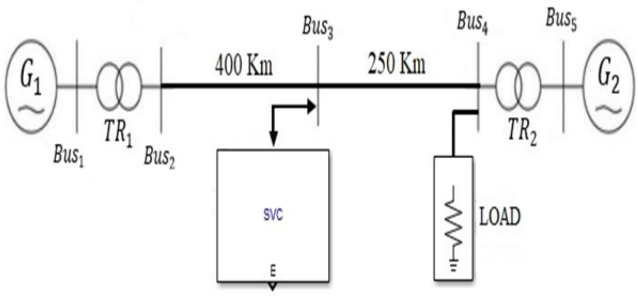

Figure 3. Two machine system with SVC

4. Simulation Studies

In simulation studies, G_1 represents a hydraulic turbine-governor system set up as 1000MW PV production generator. This generator and together with 5000MW capacity G_2 generator which set as oscillation bus feeds a load of 5000MW, totally ohmic, at 650 Km away.

5. System Design

Simulation studies has been done for the system, which is given a single line diagram in Figure 3. and Figure 4. The effects of symmetrical and asymmetrical failure situations occurring at different times on the operation and stability of the two-machine system were examined in detail and the effects of STATCOM and SVC on the system were observed. FACTS devices, which are connected to the system with shunts, have been added to ensure that generator synchronization is not disrupted in case of symmetrical and asymmetrical faults applied and consequently system stability can be maintained.

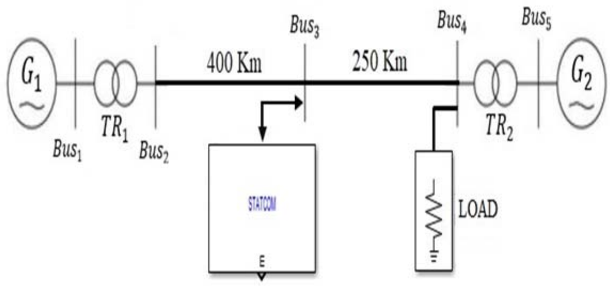

Figure 4. Two machine system with STATCOM

In the load flow analysis made with matlab/powergui block, the power transfer capacity of the system was found approximately 950MW.

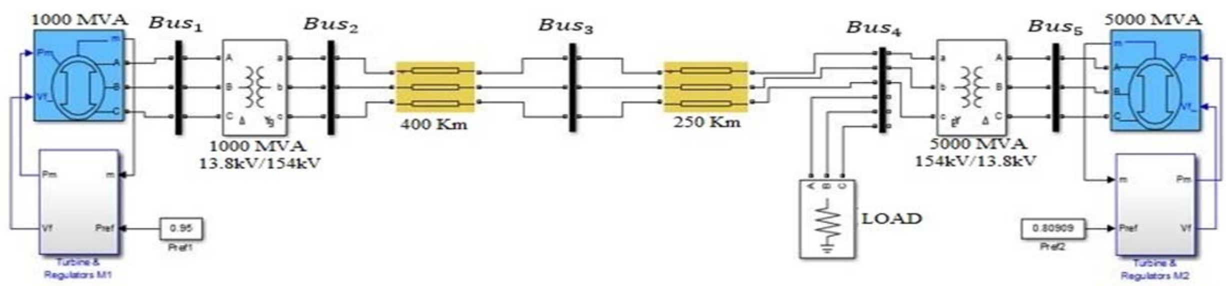

Figure 5. Simulink model of designed system [23]

Asymmetric and symmetrical faults occurring between the and on the two machine transmission lines shown in Figure 5., have been examined.

In order to minimize the effects of these faults and ensure power system stability, the effects of the FACTS devices connected to the system are analysed separately.

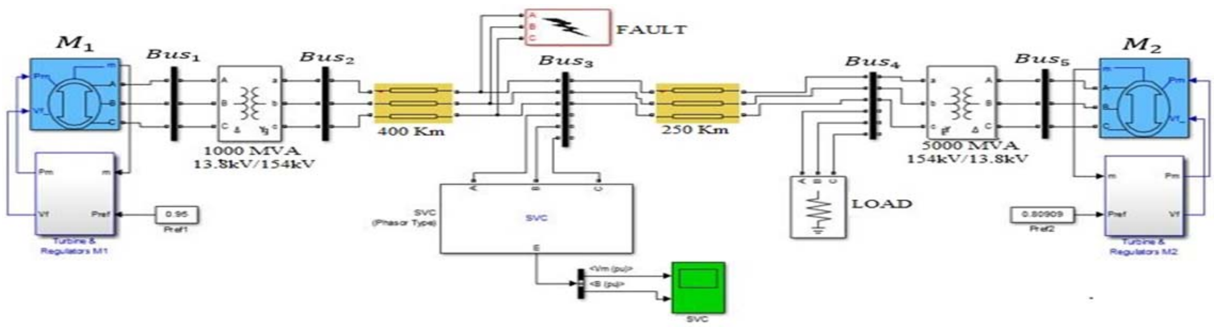

Figure 6. System block diagram with SVC during asymmetric and symmetric fault

In the system shown in Figure 6., asymmetric and symmetrical faults are simulated and their results have been discussed. In this system, the effective compensation area of SVC has been adjusted to have ± 100 MVAr capacity.

The system was simulated for 50 seconds. Asymmetric and symmetrical faults were applied to the system starting from 10 seconds.

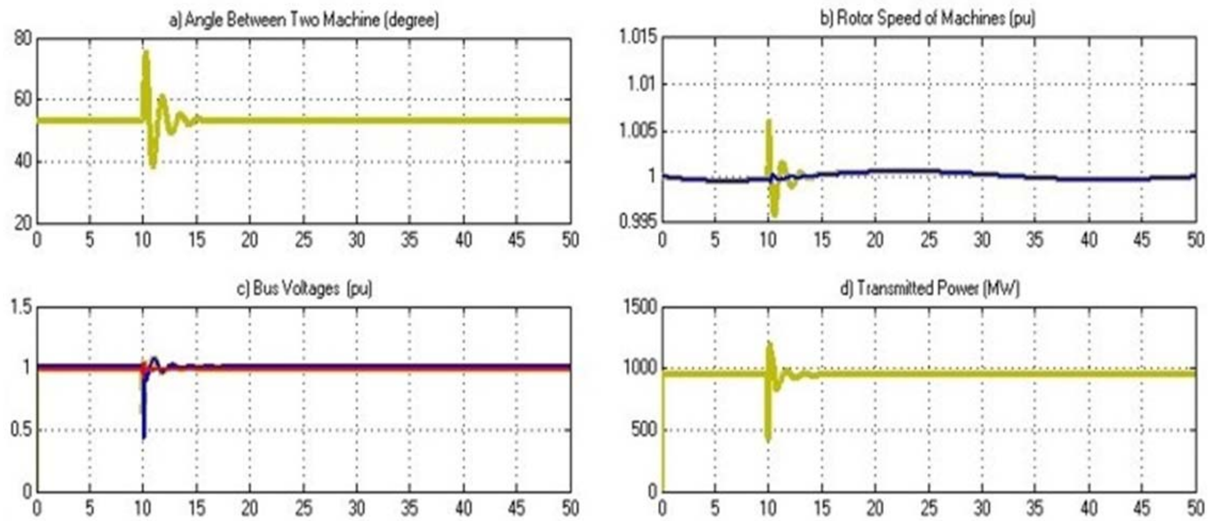

Figure 7. Effect of SVC on the system in case of asymmetric fault a) angle difference of generators b) rotor speeds of generators c) bus voltages d) power transmitted in the system

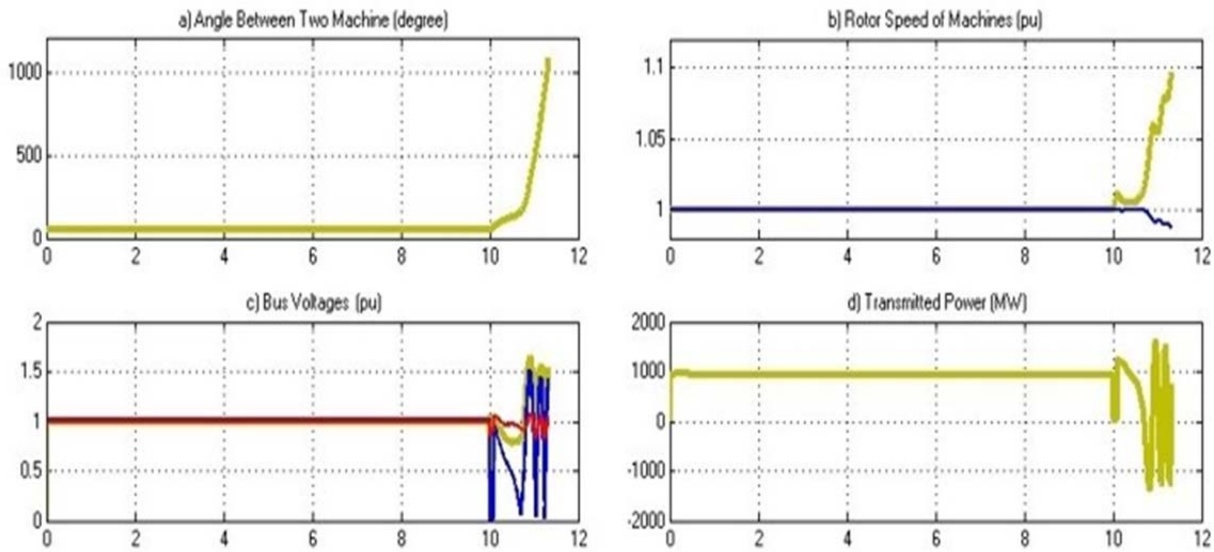

Figure 8. Effect of SVC on the system in case of symmetrical fault a) angle difference of generators b) rotor speeds of generators c) bus voltages d) power transmitted in the system

When the system made with SVC is examined, as seen in Figure 7c, in the case of asymmetric fault, even though bus voltages and transmitted power collapses, synchronization was not disturbed and power transmission continued. However, when Figure 8. is examined, it was seen that the synchronization between the generators disappeared and the rotor speeds increased by 10% within 1 second after the occurrence of the error and exceeded the nominal values as seen at the bus voltages in Figure 8c. It is seen that the voltage oscillates excessively in the B_1 and B_2 bus close to the point where the fault occurs.

There was an oscillation varying between 0-1 pu at bus B_1, and an oscillation varying between 0.8-1.6 pu at bus B_2. As a result of these values, it is understood that synchronization is lost in the system. As a result, it has been observed that static VAr compensators consisting of TCR and TSC structures help maintain the stability of the system in asymmetrical fault situations. However, it has been found that the system with the SVC is insufficient in symmetrical fault situations.

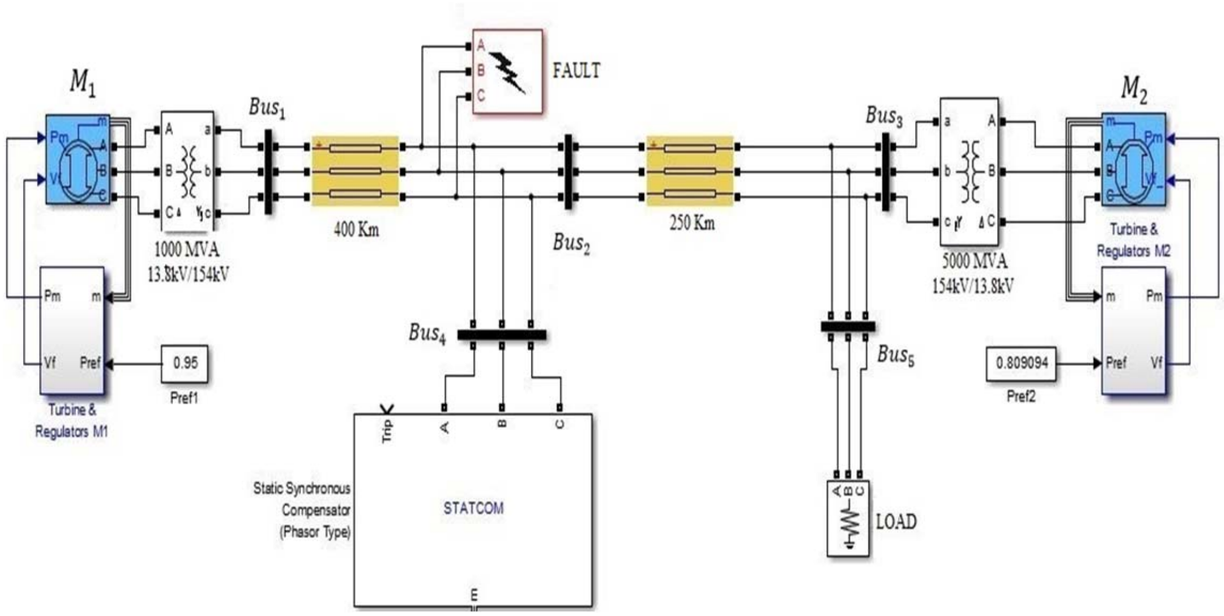

Figure 9. STATCOM system block diagram in case of asymmetrical and symmetrical fault [23]

The parametric values of STATCOM used in the two-machine system which are shown in Figure 9. are given in Table 1. The system was run for 50 seconds and the results were examined.

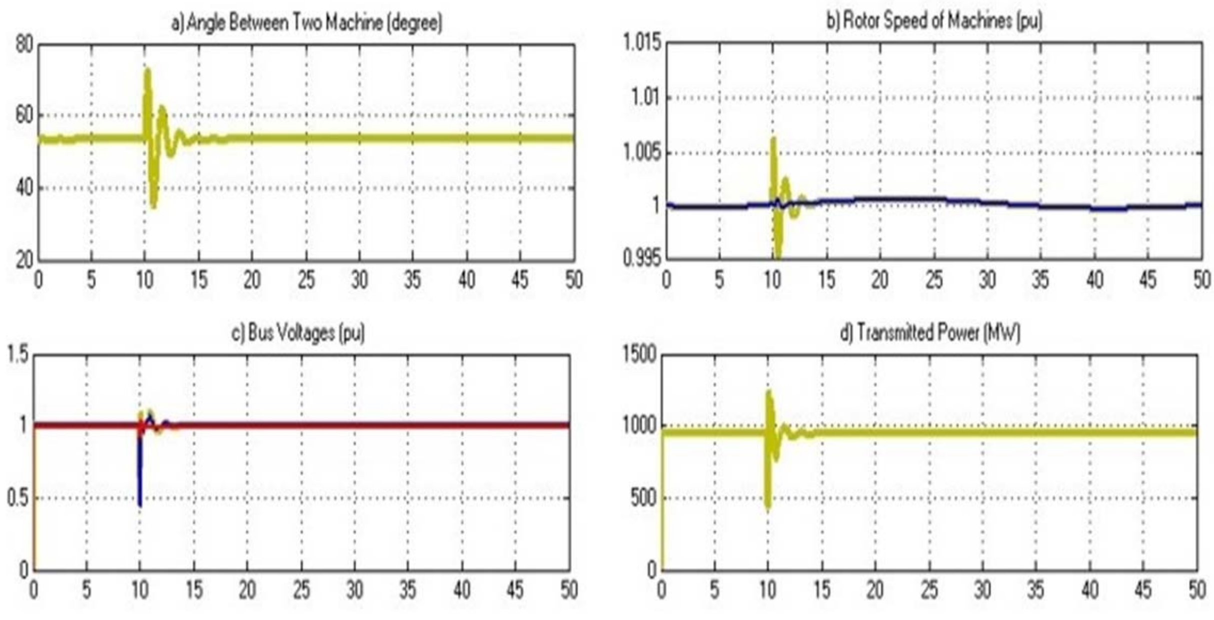

Figure 10. Effect of STATCOM on the system in case of asymmetric error a) angle difference of generators b) rotor speeds of generators c) bus voltages d) power transmitted in the system

Table 1. Statcom parameters

Converter Capacity	**Dc Voltage**	**Capacitor**	**Converter Impedance**
100 MVA	35 KV	350 $\boldsymbol{\mu f}$	0,0073-0,22$\boldsymbol{h}$

When Figure 10. a, b, c graphs are examined, in case of asymmetric error, although the difference between rotor angles oscillates, it is fixed at nominal value of 54^0 approximately 5 seconds after the error and rotor speeds of the generator are at the nominal value of 1 pu, 5 seconds after the error. Although the voltage in B_1 bus dropped to 0.8 pu, it was observed that bus voltages recovered 3 seconds after the error and reached 1 pu approximately. Along with these results, it can be said that STATCOM has a positive effect on stability in case of an asymmetrical error.

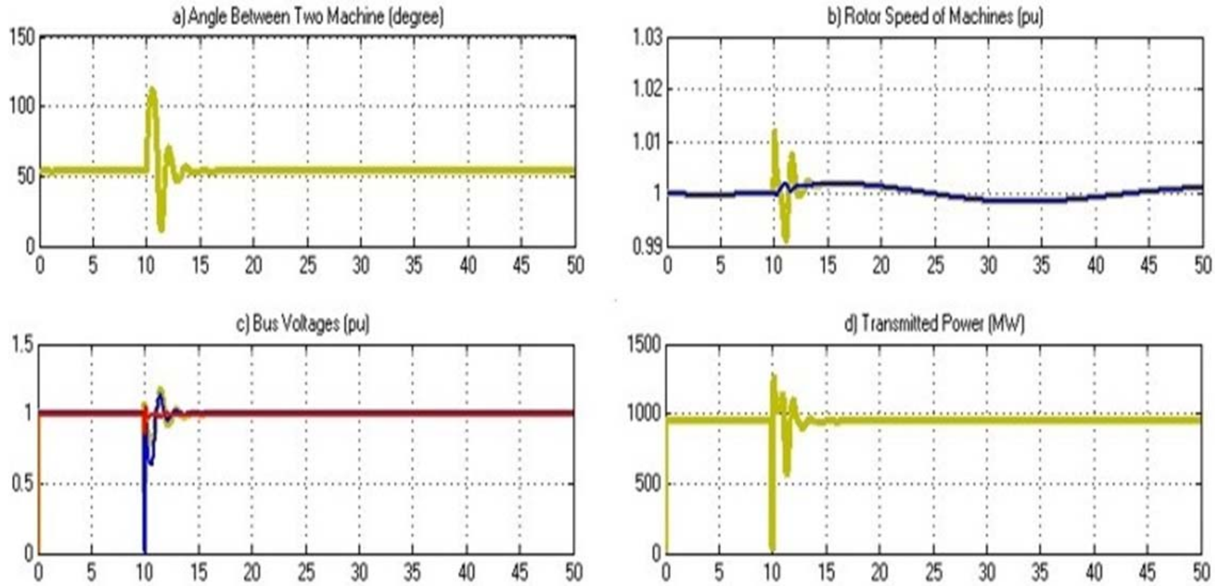

Figure 11. Effect of STATCOM on the system in case of symmetrical fault a) angle difference of generators b) rotor speeds of generators c) bus voltages d) power transmitted in the system

When the graphs of Figure 11. a, b, c, d are examined, it is seen that the system continues to work steadily in case of symmetrical error even though oscillations are observed at the time of the error. According to the results obtained from simulation studies, STATCOM superior to SVC, and it can perform the necessary compensation in order to remain stable in both asymmetrical and symmetrical fault situations [22].

6. Conclusion

In this study, the effect of SVC and STATCOM, one of the shunt FACTS devices, on power flow and stability has been studied. Matlab / Simulink Simscape ToolBox was used in simulation studies. Asymmetric and symmetrical faults were applied to the system as a disturbing effect from the outside and system behavior was observed. In case of unbalanced (asymmetrical) error, both FACTS devices were found to have a positive effect on the stability of the system. In addition, in the case of asymmetric error, it was observed that bus voltages oscillate between 0.7 and 1.1 pu values in studies conducted with SVC system. Similarly, in studies with STATCOM, bus voltages were released between 0.8 and 1.05. According to these values, it can be said that STATCOM performs better than SVC. In the case of symmetrical error, it was seen that SVC system could not maintain stability and machine synchronizations were broken. Although the bus voltages oscillate between 0 and 1.2 pu in the STATCOM system, it was observed that the system recovered and stabilized. As a result of these comparisons, it can be said that STATCOM is a better compensator. While evaluating how to compensate the system in energy transmission studies in two-machine systems, it has been observed that it is imperative to take into account the effects on the system in case of balanced and unbalanced errors.

In this paper, it was emphasized that the systems to be used while making the selection of the most economical and optimal FACTS device should be taken into account in the overall system stability.

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