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Impact of Static Var Compensator (SVC) Installation in Power System Stability

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Abstract: Turbulences and faults in power systems pose adverse challenges. They include power swings, oscillations, loss of synchronism and outages. This circumstance causes power system problems of instability and even collapse. The large disturbances such as a three-phase fault decelerate loads and cause instability to generating units. Further still, continuous demand in electric power system network as well as heavy loading lead to system instability and straining of the thermal limits. Customarily, settled or mechanically switch shunt and series capacitors, reactors and synchronous generators were utilized to solve many problems. However, there are restrictions as to the use of these conventional devices. This paper presents the impact of Static Var Compensator (SVC) installation in power system stability. In this study, the modeling of SVC are developed with parameters: -100MVAR to 100MVAR, 220KV $V_{rms,\ L-L}$ for stability improvement in power system. The test system of this study is 220kV, 50Hz, and 100KVA base in long transmission line. Furthermore, the MATLAB/Simulink software is used to modeling the system in the normal condition with/without of SVC installation and the fault condition of test system. The results for normal condition, the value of voltage and active power are stable with range 0.98 p.u to 0.99p.u and 340MWatt to 600MWatt respectively. But for the faults condition, the results are negative for voltage at B2 and B3. When the SVC are installed at B2 and B3, the value of voltage and active power are the same with the normal condition. Based on the results, it demonstrates the effectiveness and robustness of the proposed SVC on stability improvement in power system.

Keywords: Static var compensator, FACTS devices, power system-, voltage stability, transmission line.

1. Introduction

Lately, the electrical power system faces a lot of difficulty due to increased operational complexity and their structure. The electrical power system is a complex system involving a wide range of generators, transmission lines, transformer and multiple loads. Bisen, P & Srivastasbe discuss the effect of the increase in electrical power supply demand, some transmission lines are more loaded than arranged when they are built [1]. Pariyar, K. R. (2002) explain that to improve the long transmission system, stability issues will be the main factor causing the transmission to be limited [2]. Next, Sahu, L (2011) discuss the transmission line that must have the ability to operate effectively in the high load demand [3]. In addition, the system should have the ability to operate in a lot of severe natural harassment,

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such as a short circuit on transmission lines or a damage of generator. To overcome this problem, an alternative in the technology of power electronics has given the opportunity to Flexibles AC transmission system (FACTS) device in terms of rapid growth, efficiency and flexibility for better exploit power system and improve dynamic behavior [4]. This device uses an electronic power to control power flow and voltage control on the power system. They are also able to increase temporary stability by increasing or reducing power transfer capacity. Wang e.t al (2000) discussed a design an optimal of PI controller to improve the transient stability using genetic algorithm (GA) method [5]. Farsing, Song and Lee (2004) proposed techniques to choose the information signals for FACTS devices in little and huge power systems [6]. Haque (2014) approaches a control technique using bang-bang method for FACTS devices to enhance the initial swing stability limit of straightforward power system [7]. Ciausiu and Eremia (2011) present a paper to investigate of identifying stability reserves and discovering better solutions for enhance available security margins in order that to be at safe space from a blackout is occurred. Calculation of the stability limits for power system either with or without FACTS devices are completed so as to show that the gain in power system stability and control by using these devices [8]. An investigation by Singh, Phunchok & Sood (2012) discussed the SVC and TCSC in the test system the IEEE-5 bus system has been utilized to improve power system by using PSAT tool box [9]. Vijayan and Padma (2013) published this paper to investigate the optimal location of FACTS devices in the power system to maintain bus voltage and increase the power flow through transmission lines [10].

The main objectives for this paper are to model power system a long transmission line 220KV, to simulate and analyze power system in a long transmission line without FACTS devices in normal condition and fault condition and to simulate and analyze power system long transmission line with Static Var Compensator (SVC) in normal condition and fault condition. The parameter of SVC in this paper are -100MVar to 100MVar with $220kV_{rms,\ L-L}$. The SVC is installed between at B2 and B3 or transmission line.

2. FACTS Devices

The FACTS devices are one of equipment based on a power electronic ability to change parameters such as voltage magnitude, line impedance and transmission phase angle. The purposes of FACTS devices are to increase the power flow through transmission line, reduce the heavily loaded on transmission lines, improve power flow transfer capability during transmission systems, enhance voltage regulation and damping electromechanical power system oscillations [11 -13].

2.1 Static Var Compensator (SVC)

Zhang, Rehtanz and Pal (2012) mentioned that the SVC is defined as a shunt-connected static VAR generator or absorber reactive power. The output of this device is in sync to conversation a capacitive or an inductive current in order to switch a specific factors of the electrical power system. The purpose of SVC such as the thyristor valve which is a stack of series connected anti-parallel thyristors to provide controllability, air core reactors and high voltage AC capacitors [14]. It is connected to the transmission line through a power transformer and includes a thyristor-controlled reactor for leading VAR and thyristor switched capacitor for lagging VAR [14]. Jumaat S.A., Musirin I & Baharun M.M (2017) discussed the SVC regulating a voltage by controlling the amount of reactive power injected into or absorbed from the power system. When the system voltage is low, the SVC generates reactive power such as a capacitive and when the system voltage is high, it absorbs reactive power such as an inductive [15]. Ciausiu and Eremia (2011) also discussed the SVC in providing a fast reactive shunt compensation. Nest, the SVC is dynamic to control a voltage for the power system through its utilization of high-speed thyristor switching/controlled reactive devices [8]. Fig. 1 shown the circuit diagram of SVC with the main components [16].

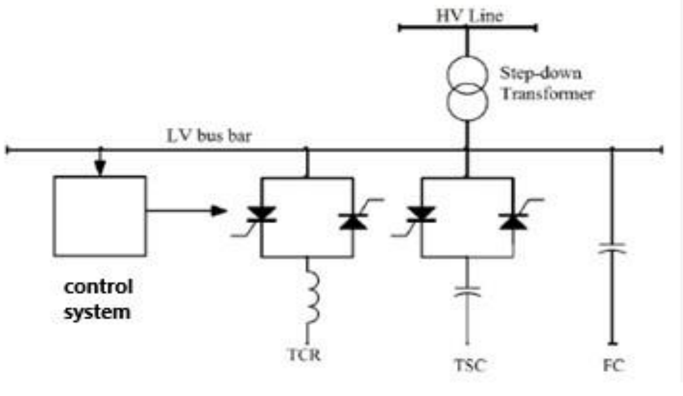

Fig. 1 - Circuit diagram of static Var compensator (SVC)

Figure 2 shown the operating principle of SVC with the main components of operating process are TCR/FC. Sabai, N., Maung, H. N. & Win, T. (2008) explained the function of SVC is to sustain the desired voltage at a high bus voltage. In steady- state condition, the SVC has ability to control the voltage, therefore controlling the power to maintain at the highest voltage bus. If the bus voltage starts decreasing below the set point range, the SVC will inject reactive power (Q_{net}) into the system within the control limits. If the bus voltage increases, the SVC will inject less (or TCR will absorb more) reactive power and the result will be able to realize the desired the bus voltage [16].

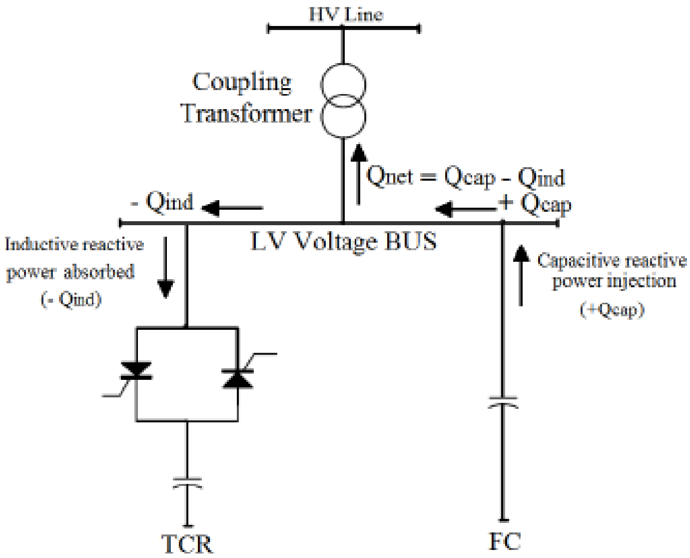

Fig. 2 - Schematic diagram of TSC-TCR

3. Results and Analysis

In this paper, the simulation was done using a MATLAB/ Simulink software with and without the SVC for the purpose of clarifying the effect of device on the test system. There are two main effects of SVC on the power system. The first one is the ability of these devices to control the flow of power performance at normal operation. The second one is the ability of these devices on damping oscillation at fault condition. The test system of the research is 220 KV, 50 HZ and 100KVA base. The single line diagram of a two-machine power system is shown in Fig. 3.

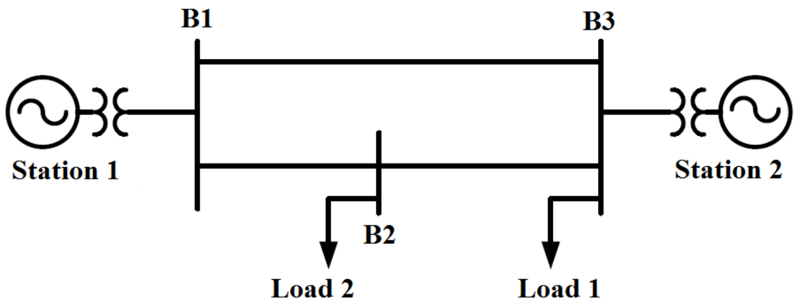

Fig. 3 - Single line diagram for the test system

3.1 Test System at Normal Condition

The test system in this research consists of two generators, two transformers, three bus bars and three transmission lines. The system operates on the 220 KV, frequency 50 HZ and 100 KVA base. It consists of three-phase load of 750 MW at B3 and the three-phase load of (200MW + 50 MVAR) at B2. The generator M1 has a rating of 850 MVA and the generator M2 has a rating of 500 MVA.

In this condition, the test system is without installation of SVC as shown in Fig. 4. In the same figure, the results of voltage output on busbar No -B1, B2 and B3 are 0.98, 0.93 and 0.97 p.u. respectively. Next, the value of active power is 570.73 MW at busbar no -B1, 316.31 MW at B2 and 334.68 MW at B3, respectively as shown in Fig. 4.

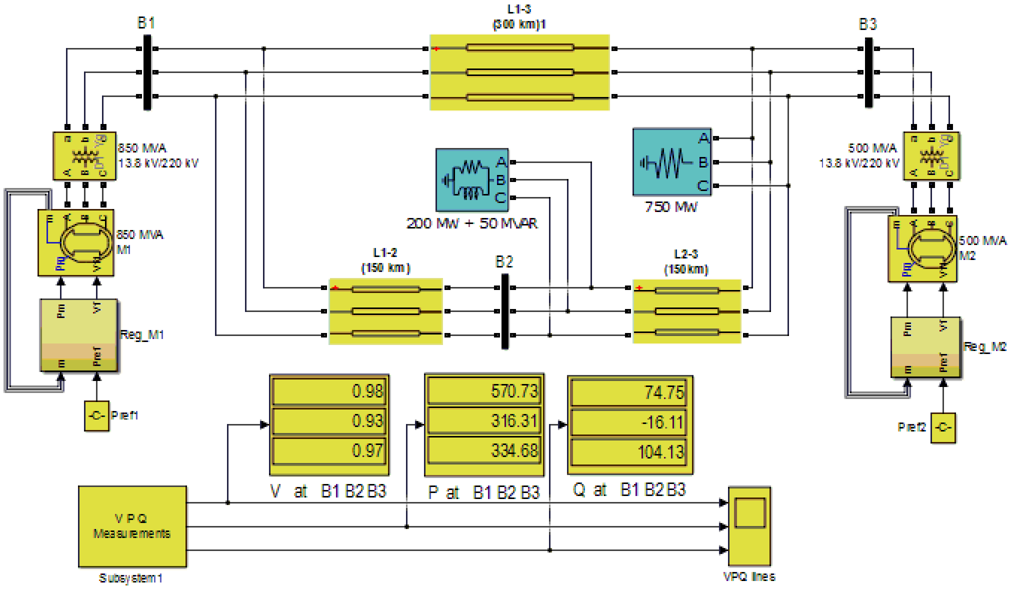

Fig. 4 - The test system at normal condition without SVC installation

In this case, the SVC are added to the system with parameters are tabulated in Table 1. Then, the voltage and the power are measured for each bus bar, to check the ability of these devices of controlling the voltage and the flow of power in normal operation without any fault. SVC is connected to B2 in the system as shown in Fig. 5. The SVC has reactive power limits (100 MVAR to -100 MVAR) and drop reactance of 0.03 p.u/phase.

Table 1 - Parameters of Static Var Compensator (SVC)

Item	Value
$V_{rms\ L\text{-}L}$ (KV)	220
Frequency (Hz)	50
Power (MVA)	150
Reactive Power Q_C (Var)	150
Reactive Power Q_L (Var)	-150
Average time delay , T_d (ms)	5

After the SVC was installed, the voltage has been improved on all buses and voltage values on B1, B2 and B3 are 0.99, 0.98 and 0.99 p.u respectively as shown in Fig. 5. Based on the results, the active power increased to 597.48 MW at B1, 340.24 MW at B2 and 350.44 MW at B3 as shown in Fig. 5.

From Table 2, it can be observed that the voltage is unstable at the normal operation on B2. The voltage value at B2 around 0.93 p.u when it should be at least 0.95 p.u to keep the system stable. In case of SVC, the voltage increased at all buses and the active power also improved for all buses.

Table 2 - Comparison Results with and without SVC Installation for Normal Condition

Item	Without SVC	With SVC
Voltage B1(p.u)	0.98	0.99
Voltage B2(p.u)	0.93	0.98
Voltage B3(p.u)	0.97	0.99
Active Power at B1 (MW)	570.73	597.49
Active Power at B2 (MW)	316.31	340.24
Active Power at B3 (MW)	334.68	340.68

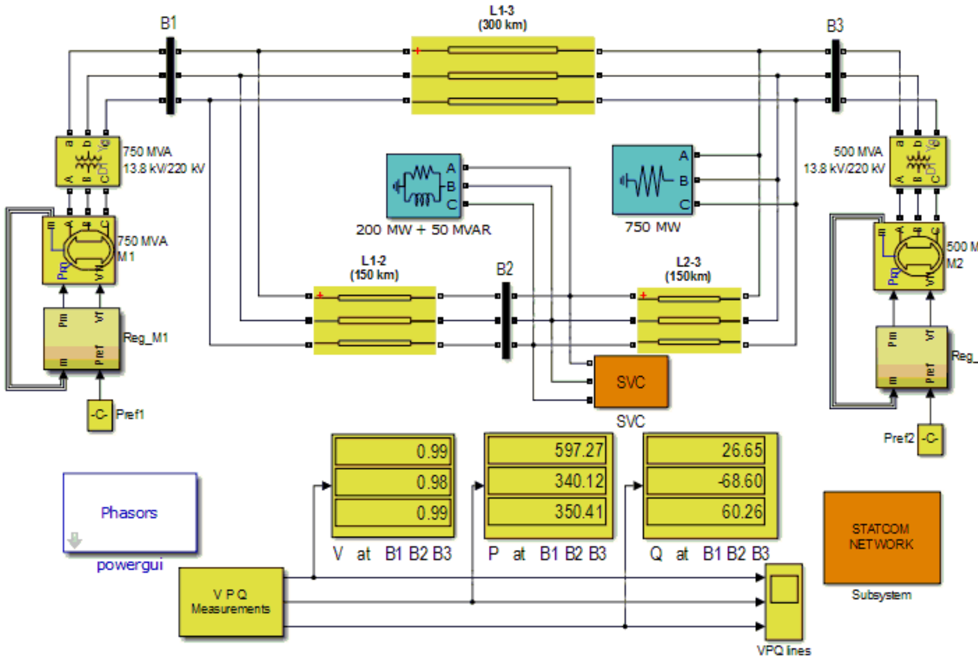

Fig. 5 - The test system at normal condition with SVC

3.2 The Test System at Fault Condition

In this situation, the ability of FACTS device to control damping oscillations for the system due to a three-phase fault is tested. As known, the three-phase fault is the greatest fault that occurs in the system. So, the FACTS devices can be used to help the unstable system by increasing the voltage and current. In this system, three-phase fault is applied on B1 with duration of 0.348 s. Fig 6 illustrates the system and the location of the fault. The fault is at transmission line 300km between B1 and B3. After running the system simulation, the oscillation that occurs due to a three phase fault at B1 after 1.5 seconds is shown in Fig. 6. This oscillation causes many problems in the system if it is not damped in short time. From the figure, the value of voltage is reduced to 0.77 p.u at B2 and B3. Meanwhile, the value of active power are negative at B1 and B2 respectively.

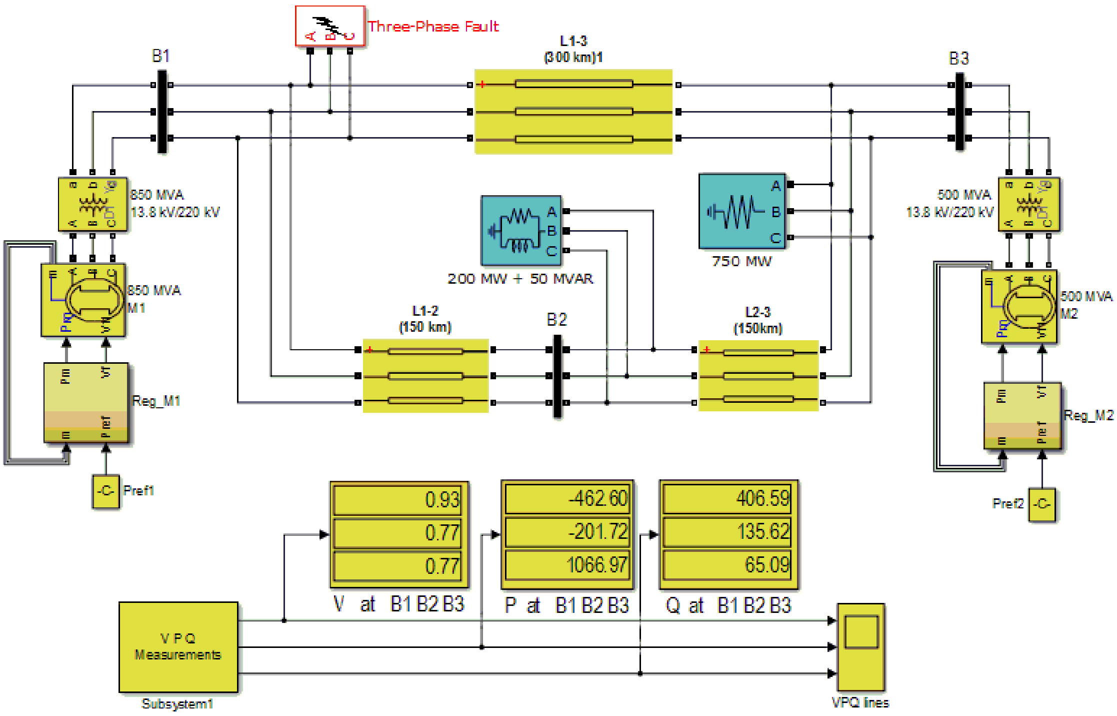

Fig. 6 - The test system at fault condition before install SVC

In this case, the FACTS are added to the system then measure the voltage and the power for each bus bar. After that, check the ability of these devices of controlling the voltage and the flow of power in a fault condition. The effect of SVC for damping oscillation when SVC model is added in the system at B2 is studied in this section, as illustrated in Fig. 10. After running simulation of the system in this case, SVC damped and controlled the three-phase fault after 3 seconds of the time fault occurred. From the simulation results, it is clear that the voltage and the active power are improved at B1, B2 and B3. The value of voltages increases to 0.98 at B2 and 0.99 at B1 and B3.

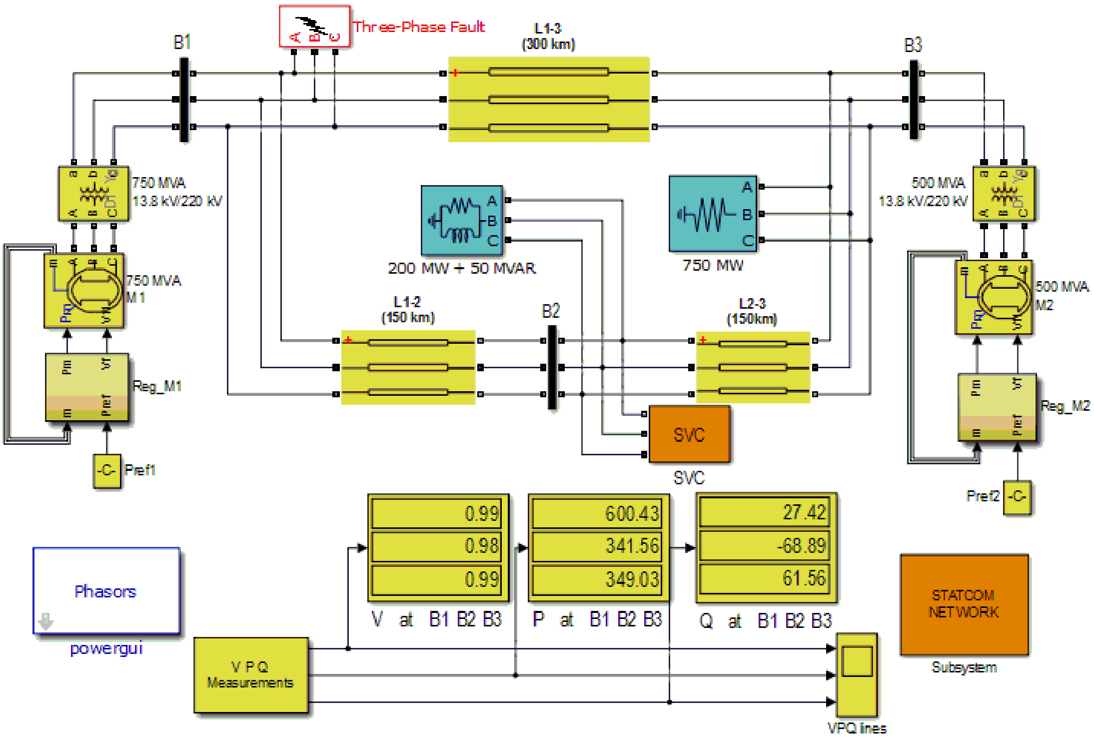

Fig. 7 - The test system at fault condition with SVC

From Table 3, it can be seen that the system is unstable at all buses at fault condition with the value of voltage are 0.93 p.u. at B1, 0.77 p.u at B2 and B3 respectively. At the same time, the value of active power are negative values: -462.60MW at B1 and -201.72MW at B2. In case of SVC, the voltage increased at all buses and the active power also improved for all buses.

Table 3 - Comparison Results with and without SVC Installation for Fault Condition

Item	Without SVC	With SVC
Voltage B1(p.u)	0.93	0.99
Voltage B2(p.u)	0.77	0.98
Voltage B3(p.u)	0.77	0.99
Active Power at B1 (MW)	-462.60	600.43
Active Power at B2 (MW)	-201.72	341.56
Active Power at B3 (MW)	1066.97	349.03

4 Conclusion

The main objectives of this paper are to model power system of a long transmission line 220KV, to simulate and analyze power system of a long transmission line without FACTS devices in normal condition and fault condition and to simulate and analyze power system of long transmission line with SVC in normal condition and fault condition. Based on the results, the SVC is a type of shunt FACTS device that can control the power flow through the transmission line and voltage. The function of the SVC is to control the voltage drop on bus 2 and increase the power flow through the transmission line at all buses. Besides, it can improve the transient behavior of the system during a large scale fault, such as three-phase short circuit. As a conclusion, it shows the possibility of controlling the voltage and power flow through the transmission line. Furthermore, the advantages of FACTS devices is to control the electromechanical oscillation when the fault happens, which will lead to the stability of the entire system and the access to a security system with high reliability.

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