Transient Stability Analysis of a Multi-Machine Power System with PSS and SVC

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Abstract: The Power System Stabilizer (PSS) is a control device which ensures maximum power transfer capability and thus the stability of the power system enhancement. The PSS has been widely used to damp electro-mechanical oscillations occur in power systems and which are due to disturbance. If no adequate damping is available, the oscillations will increase and it leads to instability. The Static Var Compensator (SVC) is also used to improve stability in the power system because its role is to reduce the reactive power in the power transmission lines. This paper presents an application of (SVC) in power transmission lines and PSS in two areas, multi generator test power system. Using Matlab software to designed and implemented control system and studied the effects of damping oscillations in stability power system after proposed faults in transmission lines of research model that used (PSS-generic and multiband) types and automatic voltage regulator (AVR).

Keywords: AVR, Power System, PSS, SVC, short Circuit, Transient Stability

I. Introduction

World is continuously growing so the generation, transmission and distribution of power should also increase simultaneously in same manner to fulfill the requirements. Power system stability broadly defined as, the property of a power system is to enable and remains in a state of equilibrium under normal operating conditions and to regain to its state of equilibrium after being subjected to a disturbance [1].Stability of the system needs to be maintained even when subjected to large low-probability disturbances so that the electricity can be supplied to consumers with high reliability. Certain system disturbances may cause loss of synchronism between a generator and the rest of the utility system, or between interconnected power systems of neighboring utilities. Various control methods and controllers are been developed in over time that has been used for this purpose. Recently, there is a interest in development and use of FACTS controllers in power system. These controllers utilize power electronics devices to provide more flexibility to AC power systems. The most popular type of FACTS devices in terms of application is the SVC [2]. This device is well known to improve power system such as steady state stability limits, voltage regulation, and damp power system oscillations [3]. The SVC is an electronic generator that dynamically controls the flow of power through a variable reactive admittance in the transmission network, and also the SVC regulates voltage at its terminals by controlling the amount of reactive power injected into or absorbed from the power system [4]. When system voltage is low the SVC generates reactive power (SVC capacitive). When system voltage is high, it absorbs reactive power (SVC inductive) [5].

It is known that PSS for generators and the supplementary controllers for flexible ac transmission system (FACT) devices are efficient tools for improving the stability of power systems through damping of low-frequency modes [6], where the frequency of these modes ranges from 0.2 to 2.5 Hz [7]. PSS devices are responsible for providing a damping torque component to generators for reducing fluctuations in the system caused by small perturbations [8].In some cases, when the use of PSS cannot provide sufficient damping for inter-area power swing, SVC damping controller is an alternative effective solution. The SVC supplemented with damping controller and PSS on synchronous generators are applied to increase the probability of stability [9].Generally, it is important to recognize that machine parameters changes with the loading make the machine behavior quite different at some different operating conditions. Since these parameters changes in a rather complex manner, a set of stabilizer parameters, which stabilizes the system under a certain operating conditions, may no longer yield satisfactory results when there is a radical change in power system, PSS should provide some degree of robustness to the variations in system parameters, loading conditions, and configurations [10, 11]. The basic structure of PSS is operating under typical control generator while the basic structure of SVC is operating under typical bus voltage control [13].

II. Multi-Machine Power System with SVC and PSS

The proposed power system works under abnormal system conditions and has the following characteristics see Fig-1.

- Two synchronous generators
- Two power transformers of 13.8 kV / 500 kV.
- Three bus bars.
- A transmission line of 500 kV and 700 km.
- Two PSS and two AVR (Automatic Voltage Regulator).
- The SVC characteristics: 200 Mvar.
- A purely resistive load of 5000 MW.

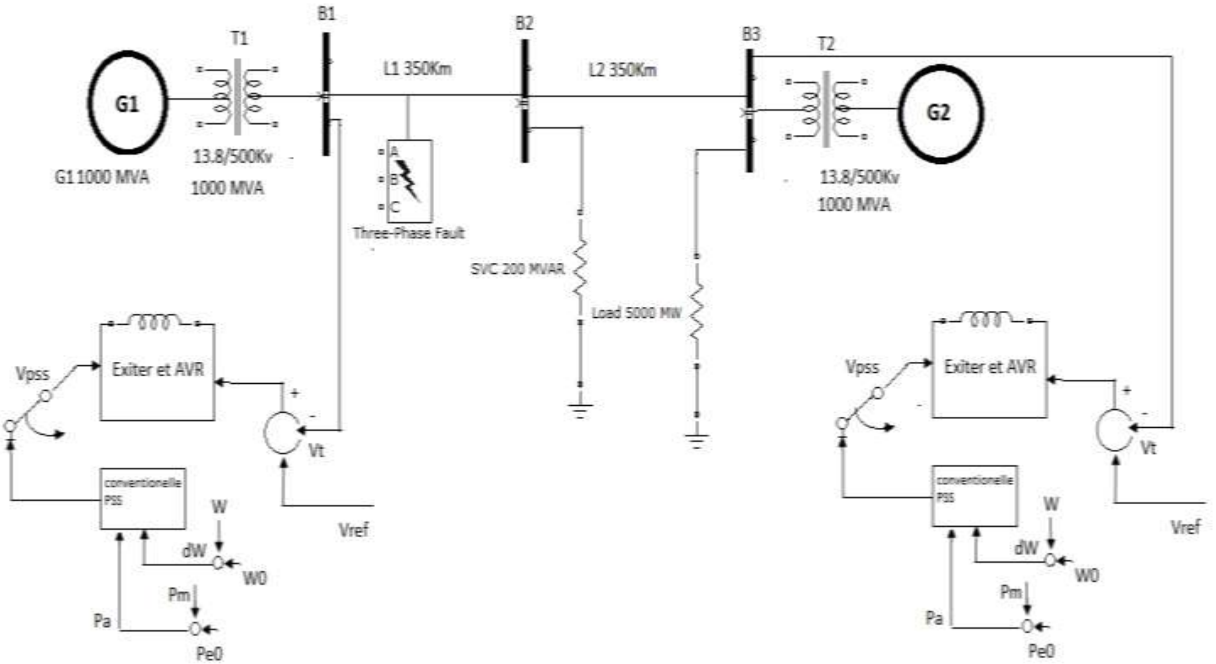

Fig.1: The Simplified Diagram of the Multi-Machine Power System with SVC and PSS

III.PSS Modeling and Damping Controller Design

The operating function of a PSS is to produce a proper torque on the rotor of the machine involved in such a way that the phase lag between the exciter input and the machine electrical torque is compensated [15]. The block diagram of the ith PSS with excitation system is shown in Fig:- 2, where (Δwi) is the deviation in speed from the synchronous speed which is the input signal. The output signal of the PSS is used as an additional input (Δvi) to the Excitation System block [16]. The three basic blocks of a typical PSS model are: The first block is the stabilizer Gain block, which determines the amount of damping. The second is the Washout block, which serves as a high-pass filter. The last one is the phase compensation block, which provides the desired phase-lead characteristic to compensate for the phase lag between the AVR input and the generator electrical (air-gap) torque [17].

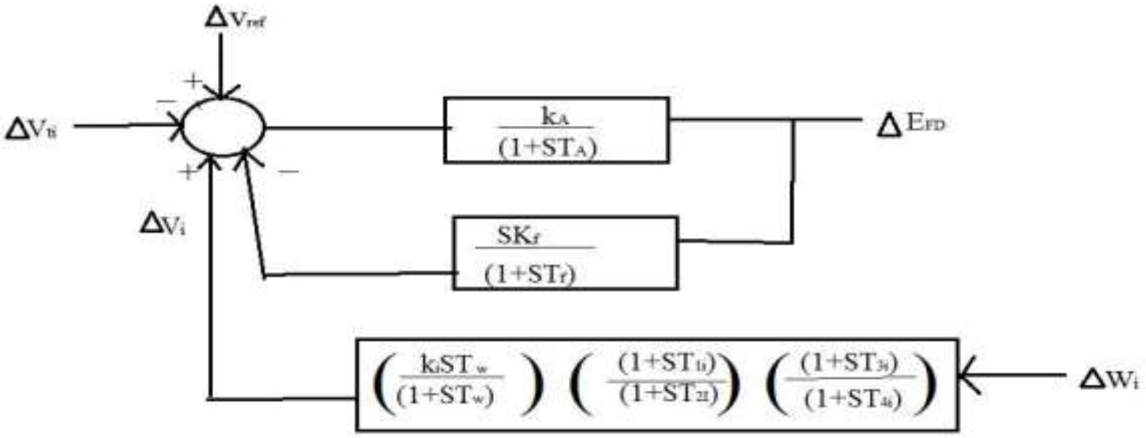

Fig. 2: Block diagram of ith PSS with excitation system

IV.SVC modeling and damping controller design

A Static Var Compensator (SVC) is composed of a fixed capacitor in parallel with a thyristor controlled reactor (FC-TCR), this model consists of a harmonic voltage source in series with a variable source admittance [18]. The SVC adjusts the susceptance in each phase by controlling the conducting angles of the thyristor controlled reactor [19]. Also it can control the unbalanced loads more effectively and can enhance the transient stability of the system by inserting or absorbing instantaneous currents to or from the system [20].

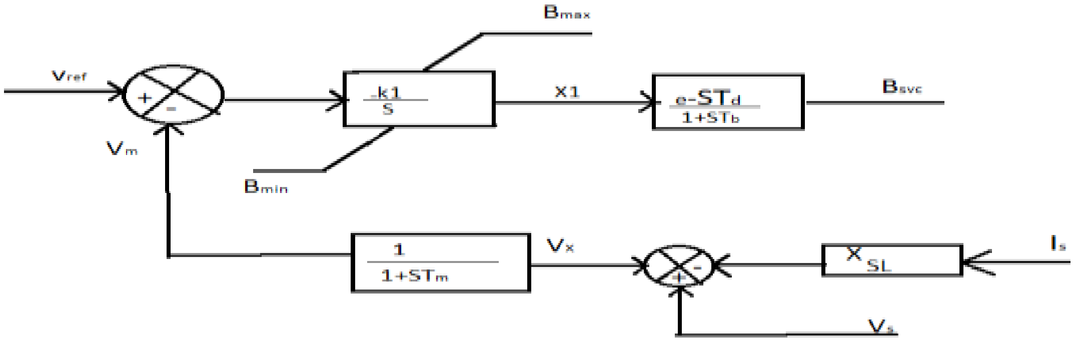

Fig.3: SVC Control Model

The equations describing the SVC controller are:

$V_m = 1/T_m(V_x - V_m)$ (1)

$X1 = -V_e K1$ (2)

$B_{svc} = 1/T_b(X1 - B_{svc})$ (3)

$V_e = V_{ref} - V_m$ (4)

$V_x = V_s - X_{sl}.I_s$ (5)

$X1 = B_{min};\ X1 < B_{min}$

$X1 = B_{max};\ X1 > B_{max}$ (6)

V.Simulation Results and Discussion

This simulink modeling of a simple transmission system containing two hydraulic power plants. A Static Var Compensator (SVC) and Power System Stabilizers (PSS), In order to observe the impact of PSS and SVC on the power system stability a single-phase to ground fault and a three-phase fault have been applied on the first section of the line (L1) see Fig:- 4

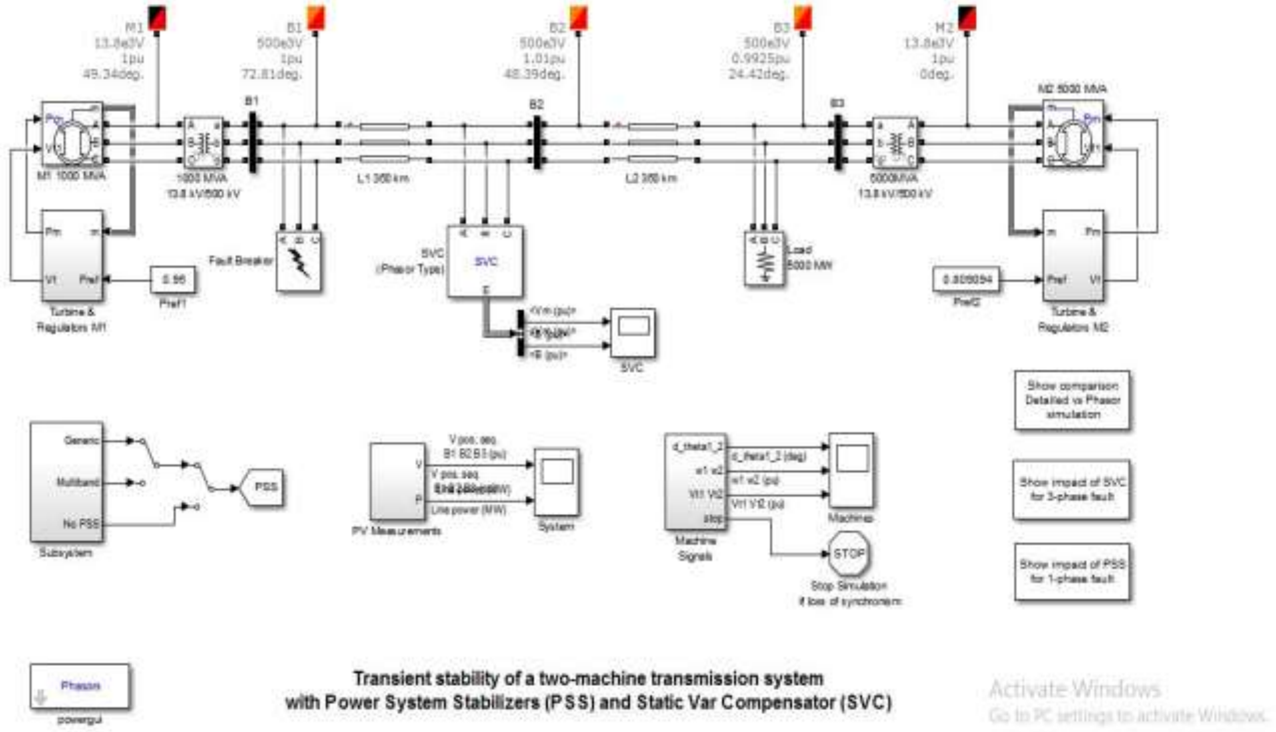

Fig. 4: Matlab simulation circuit

Single-Phase Fault - Impact of PSS –Without SVC

In this part the SVC is set to operate in fixed susceptance mode with (Bref=0) this is equivalent to putting the SVC out of service. Also a single-phase to ground fault have been applied at t=0.1 s and eliminated at t=0.2 s.

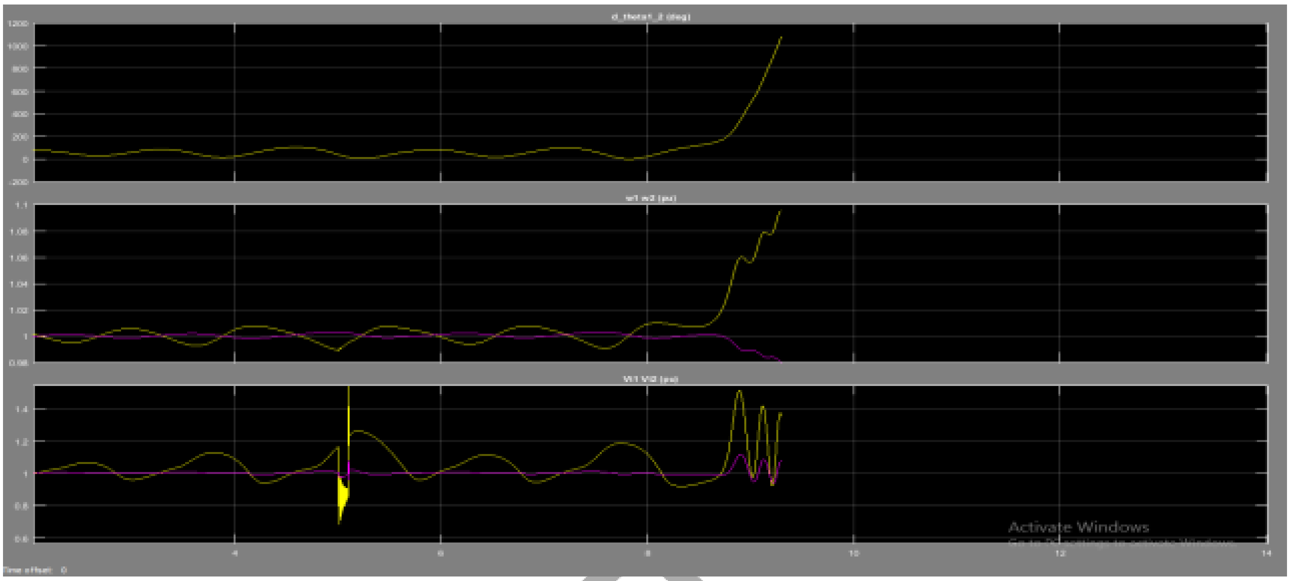

Fig.5: Impact of PSS – Without SVC

Stability analysis of the system without PSS

Fig. 6 shows the obtained graphs without the impact of the PSS, if a single-phase fault is applied, immediately the system tends to support the oscillations, then these oscillations increased more and more, so that the system loses its steady state.

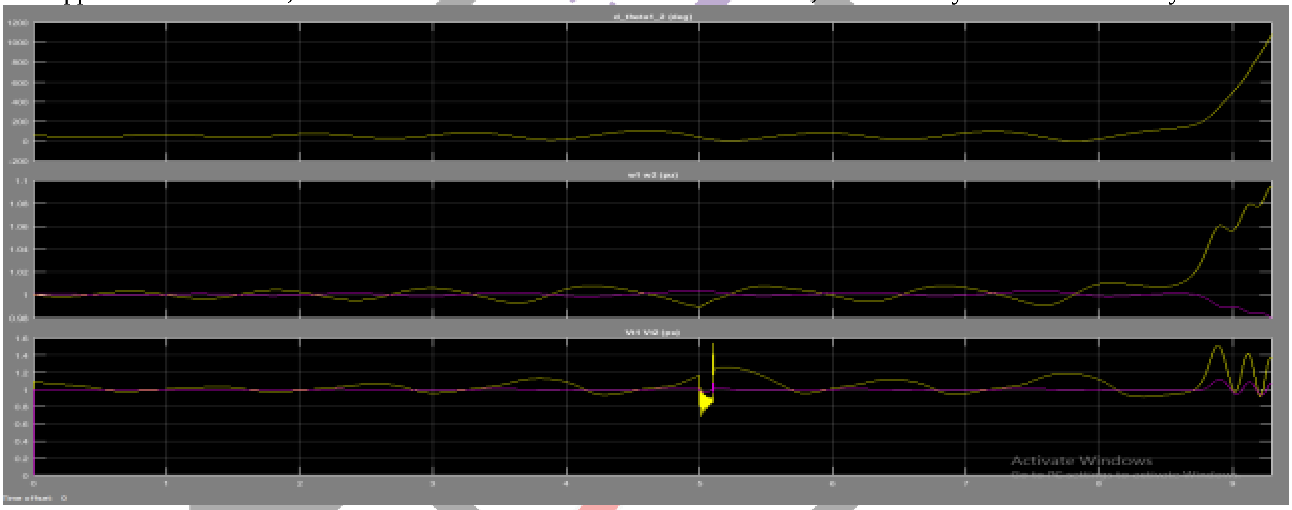

Fig. 6: Impact of PSS for 1-phase fault (without PSS)

Generic Band type With PSS

Fig.7 shows the impact of PSS with Generic band type, if a single-phase fault is applied, Fig:- 5(a) shows the Rotor angle difference d_theta1_2 between the two machines, it is found that the angle is approximately (50°) at the fault clearing time, Fig:- 5(b) shows that machine speeds (W1, W2) for G1 and G2 respectively. Fig:- 5(c) shows that the voltage at SVC-bus is constant.

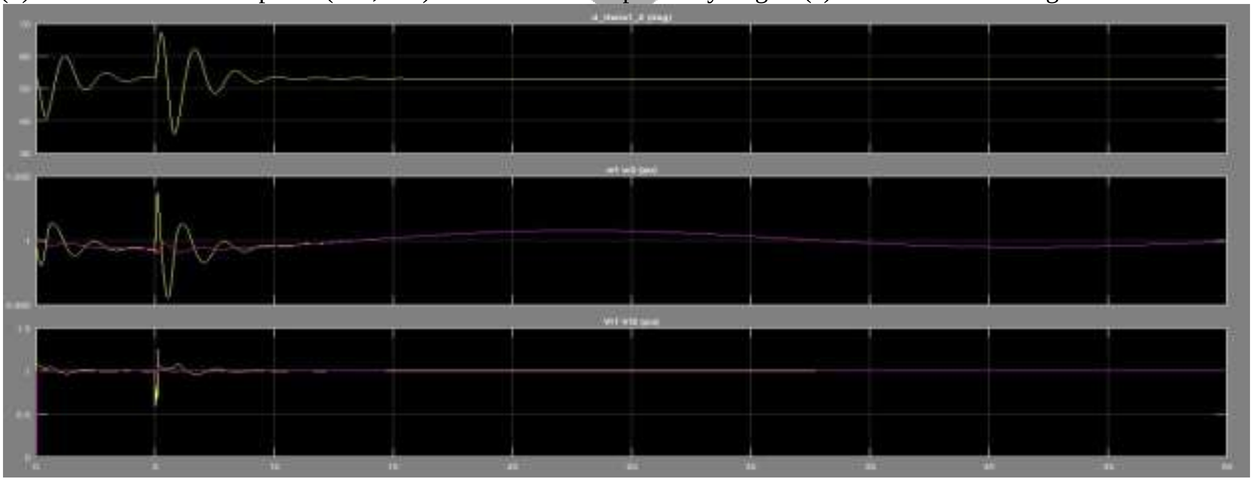

Fig.7: Impact of PSS for 1-phase fault (with PSS Generic type)

Multi-Band type with PSS

Fig.8 shows the impact of PSS Multi-Band type, if a single-phase fault is applied, the same results shown above with PSS Generic type have been drawn, however the Multi-Band type can attenuate not only the frequencies of 0.8Hz but also 0.025Hz .

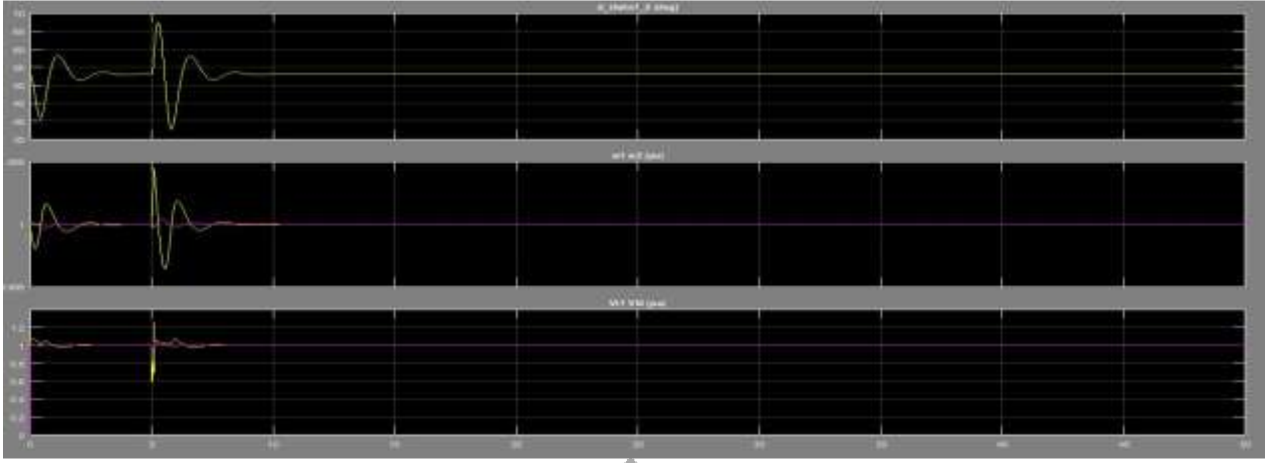

Fig.8: Impact of PSS for 1-phase fault (with PSS Multi-Band type)

Now the results have been assembled in the same graph to allow comparison between a various cases (without PSS, with PSS Generic type and with PSS Multi Band type. The first trace of Fig-8 shows the rotor angle difference d_theta1_2 between the two machines.

Three-Phase Fault - Impact of SVC

This part contains two tests, in the first one the SVC is set to operate in fixed susceptance mode with (Bref=0) this is equivalent to put without SVC. The second one, the SVC is set to operate in voltage regulator mode; however, the PSS Generic type has been maintained in service.

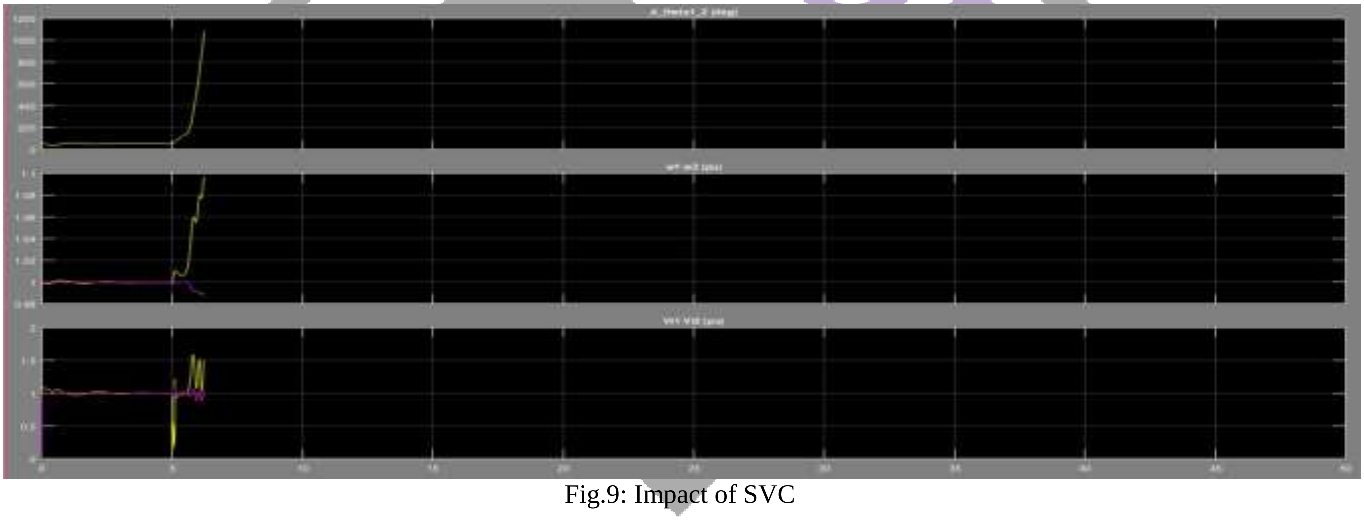

Fig.9: Impact of SVC

Stability analysis of a system without SVC

Fig.10 shows the obtained graphs with PSS Generic type in service and without the impact of the SVC (fixed susceptance mode Bref=0), if a three-phase fault is applied, immediately the system tends to support the oscillations, then these oscillations increased more and more, so that the system loses its steady state.

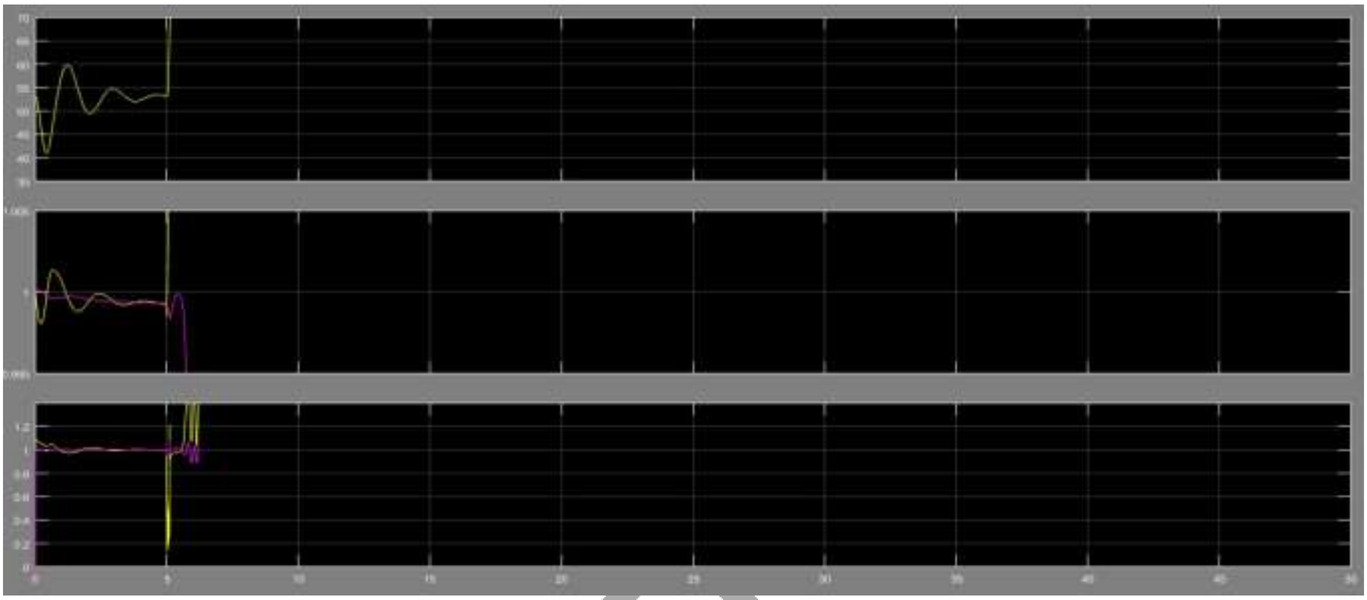

Fig.10: Impact of the SVC for 3-phase fault. (without SVC)

Stability analysis of a system with SVC

The rotor angle difference d_theta1_2 between the two machines, it is found that the angle is approximately (70°) at the fault clearing time and that machine speeds (W1, W2) for G1 and G2 respectively converge to 1 Pu .

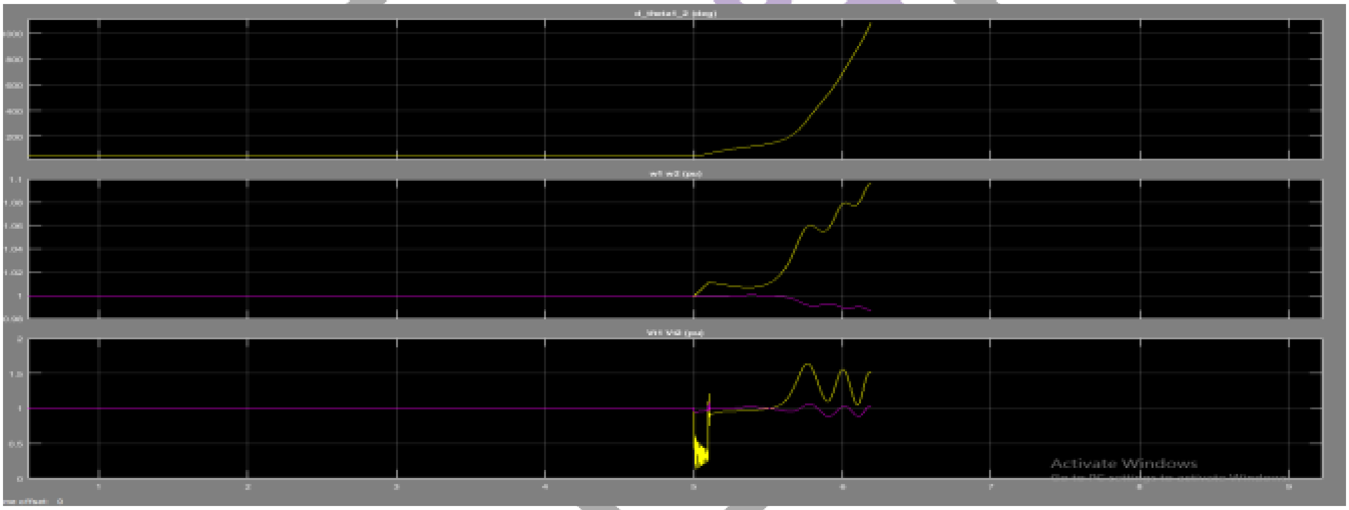

Fig. 11: Impact of the SVC for 3-phase fault. (with SVC)

Now, the results have been assembled in the same graph to allow comparison between the two tests (without SVC and with SVC).Here we show that if there is three-phase transient fault than without SVC, both PSS are not able to maintain the stability. Now the SVC is set to operate in voltage regulation mode. The results of these studies show that the SVC has an excellent capability in damping power system oscillations and enhances greatly the dynamic stability of the power system. We also observed that the stabilization time is less.

VI. Conclusion

The model is oscillatory and instable with absence effects of (PSS) and SVC.The selective of (PSS) are capable of proving sufficient damping to the steady state oscillation and transient stability voltages performance over a wide range of operating conditions and various types of disturbances of the system used in proposed model. If there is Single line to ground fault than the PSS able to sustain the stability, but using SVC the angle deviation is reduced. If there is three phase transient fault then without SVC both PSS are not able to maintain the stability. Compare working two types of (PSS), the multiband type oscillation is quickly damped than generic type.

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