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Power Oscillation Damping in Three Phase A.C. Transmission Lines Using Static VAR Compensator with Fuzzy Logic Controller

Roopesh Kumar[1], Ashish Choubey[2]

[1]Research scholler J.E.C. Jabalpur
[2]Assistant professor of J.E.C. Jabalpur

Abstract**: With the increase in nonlinearity in power system, Voltage sag, voltage swell and generation of harmonics that may cause system instability. To compensate all these problems in transmission system svc is used. Static VAR Compensator (SVC) has been used as a supplementary controller to improve transient stability and power oscillation damping of the system. This paper presents modeling and simulation of SVC with FUZZY logic controller in MATLAB/Simulink. The aim of svc with fuzzy logic controller is to make it more compatible with prevailing load demand so as to maintain the system stability under heavy load condition or light loading conditions.**

Keywords: **FACTS, fuzzy logic, reactive power, SVC, voltage stability.**

I. INTRODUCTION

SVCs can be very effective in controlling voltage fluctuations at rapidly varying loads. Unfortunately, the price for such flexibility is high. Nevertheless, they are often the only cost-effective solution for many loads located in remote areas where the power system is weak. Much of the cost is in the power electronics on the TCR. Sometimes this can be reduced by using a number of capacitor steps. The TCR then need only be large enough to cover the reactive power gap between the capacitor stages. Most of a.c. appliance have induction motor as their main drive which works at lagging power factor and the mostly contribute for lagging power factor of system. SVC provides capacitive var which helps to improve the power factor and compensate reactive power demand.

The main objective of using static var compensator with supplementary controller is to improve the power factor in distribution system during normal as well as abnormal condition and also to improve the voltage stability of system during fault condition so that to meet continuity of supply. The ultimate objective of compensation is to increase transmittable power. This may required to improve the KW capacity of transformer and alternators, to improve the regulation of line and to decrease overall cost per units. [1]

II. STATIC VAR COMPENSATOR

The SVC is a shunt type of FACTS devices family using power electronics to regulate voltage, control power flow and improve transient stability in power system. The SVC regulates voltage at its terminals by controlling the amount of reactive power injected into or absorbed from the power system. The SVC will generates reactive power (capacitive mode) when the system voltage is low and will absorbs reactive power (inductive mode) when the system voltage is high. The variation of the reactive power can be controlled by switching three-phase capacitor banks and inductor banks which are connected on the secondary side of a coupling transformer. Each capacitor bank is switched on and off by three Thyristor Switched Capacitor (TSC). Reactors are either switched on-off by Thyristor Switched Reactor (TSR) or phase-controlled Thyristor Controlled Reactor (TCR). [2]

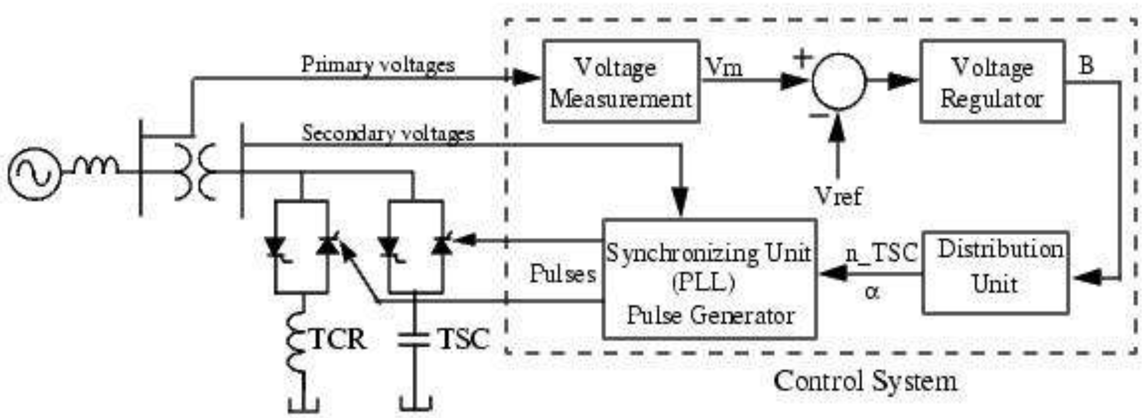

Fig.1. Schematic diagram of SVC

Fig.1 shows Schematic Diagram of SVC. Svc is simulated in MATLAB by using phasor simulation, it consists of three phase power system together with generators, turbine models, motors and dynamics load to perform dynamic stability. It also consists of stepdown transformer, TCR (Thyristor switched capacitor), TSC (thyristor switched reactor), voltage regulators and phase locked loop (PLL). The control system consists of followings:

[1]. A measurement system for measuring the positive-sequence voltage to be controlled.

[2]. A voltage regulator that uses the voltage error (difference between the measured voltage Vm and the reference voltage Vref) to determine the SVC susceptance B needed to keep the system voltage constant.

[3]. A distribution unit that determines the TSCs (and eventually TSRs) that must be switched in and out, and computes the firing angle α of TCRs

[4]. A synchronizing system using a phase-locked loop (PLL) synchronized on the secondary voltages and a pulse generator that send appropriate pulses to the thyristors.[2]

III. FUZZY LOGIC CONTROLLER

Mamdani type membership rule is adopted for fuzzy logic interfacing. Load voltage and load current taken as input to fuzzy system. To get the linearity triangular membership function is taken with 50% overlap. The output of fuzzy controller is taken as the control signal. The Fuzzy Logic is a rule based controller, where a set of rules represents a control decision mechanism to correct the effect of certain causes coming from power system. In fuzzy logic, the five linguistic variables expressed by fuzzy sets defined on their respective universes of discourse. The output of fuzzy controllers' works as a control signals for pulse generator and according to this firing angle is changed. [3]

Fuzzy logic is new control approach with great potential with real time applications .Due to simplest structure, easy designing and low cost, PI controller is used in SVC as voltage regulator in most industries. But its drawback is that due to highly nonlinearity, or uncertainty it is not able to control. Hence we need to design svc with fuzzy controller. There are two types of fuzzy controller which are Mamdani and Takagi-Sugeno. The difference between them is that the output membership function (MF) of Takagi-Sugeno is either linear or constant value [4].

Error in voltage and change in error is taken as two input of fuzzy logic controller. The output of fuzzy controller decides the control signal which supplied to firing angle control units .According to control signals the TSC and TCR is triggered. A fuzzy logic is rule base control mechanism which decides the control mechanism to correct the effect of certain causes coming from power system. In fuzzy logic seven linguist variable expressed by fuzzy sets. The structure of fuzzy logic controller is shown in fig.2

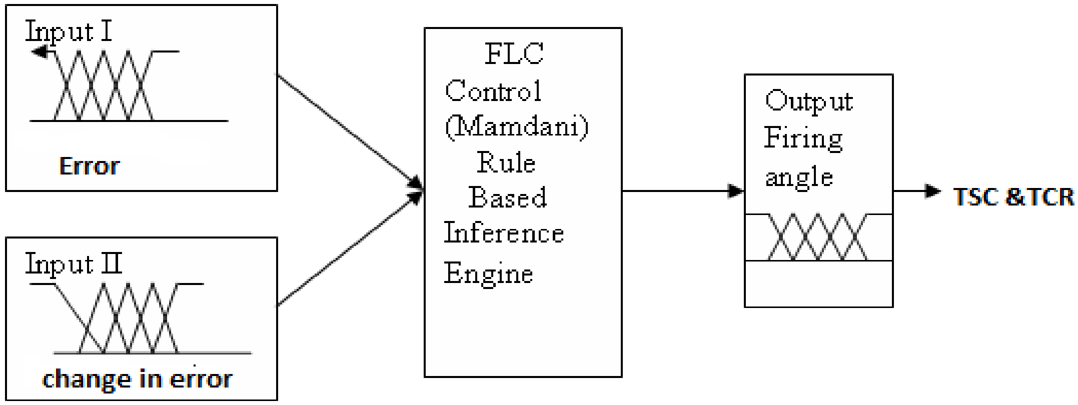

Fig. 2 The structure of fuzzy logic controller

Table.1 Membership rules for controller

E / ΔE	NB	NM	NS	ZE	PS	PM	PB
NB	NB	NM	NM	NS	NS	NS	ZE
NM	NM	NM	NS	NS	NS	ZE	PS
NS	NM	NM	NS	NS	ZE	PS	PM
ZE	NB	NM	NS	ZE	PS	PM	PM
PS	NS	NS	ZE	PS	PS	PM	PM
PM	NS	ZE	PS	PS	PS	PM	PM
PB	ZE	PS	PS	PM	PM	PB	PB

IV. MATLAB SIMULATION AND TRANSMISSION SYSTEM DESCRIPTION

A test system consists of 2 machines with 3 buses is considered. Plant 1 (M1) is a 1000 MW hydraulic generation plant is connected to a load centre through a long 500 kV, 700 km transmission line. The load centre is represented as a 5000 MW resistive load and supplied by the remote plant 2 (M2) consists of a 1000 MVA plant and a local generation of 5000 MVA.

A load flow has been performed on this system with M1 generating 950 MW and M2 generates 4046MW. The line carries 944 MW which is close to its surge impedance loading (SIL = 977 MW). A 200 MVAR SVC is implemented at the centre of the transmission line to maintain the system stability after faults occurrence. The two machines are equipped with a hydraulic turbine and governor (HTG), excitation system, and PSS. [2]

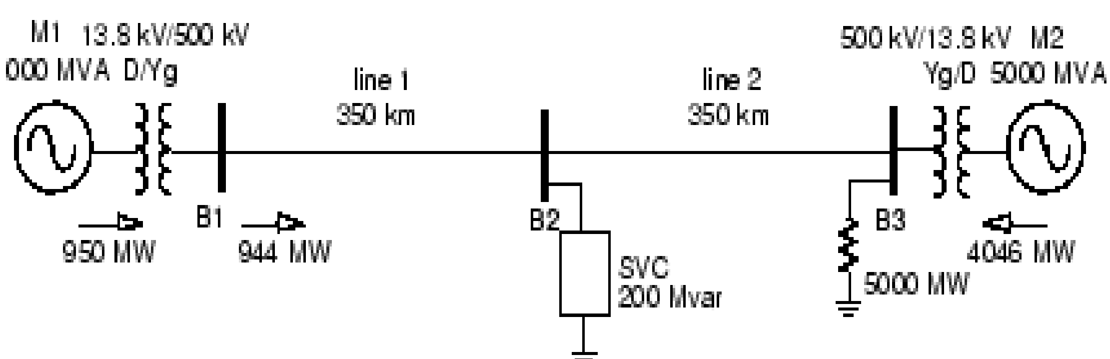

Fig.3 Test system line diagramme

V. SIMULATION RESULTS

Fig.4 shows simulation mode without any fault and without fuzzy svc controller.Fig.5 shows positive sequence voltages at buses B1,B2,and B3.Without any controller and pss even there is no fault in line has local oscillation. Without Fuzzy- SVC controller in power system oscillation damping after fault in two machine system is examined. Fig.4 shows simulink model of two machine power system.

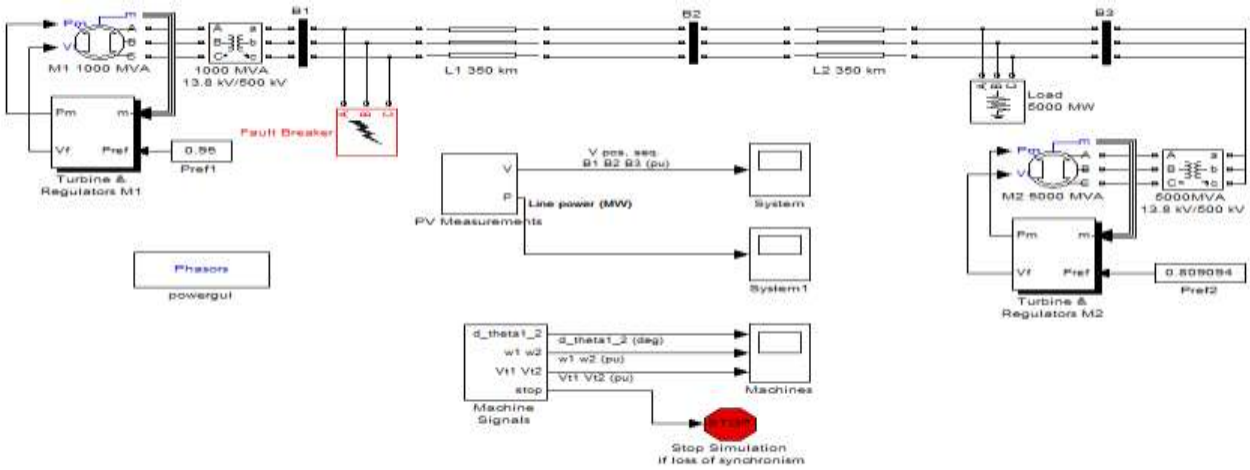

Fig. 4 Simulink model without any fault.

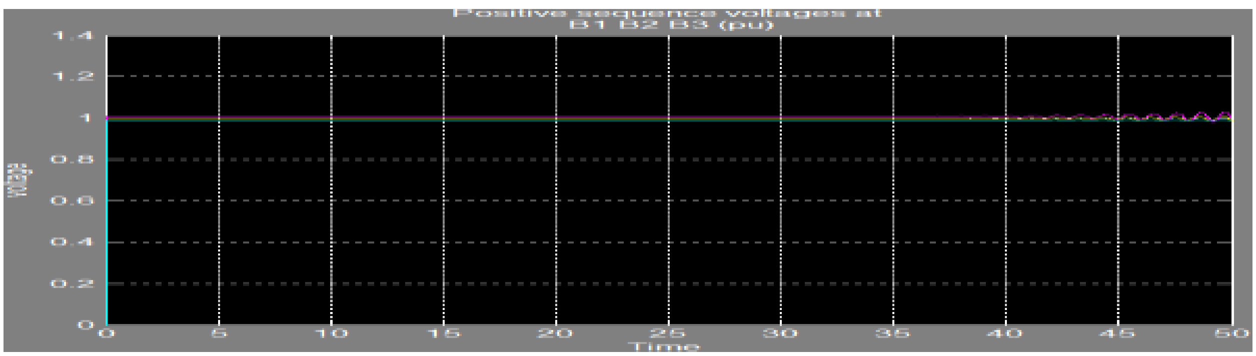

Fig.5 Positive sequence voltages at buses without fault and without controller

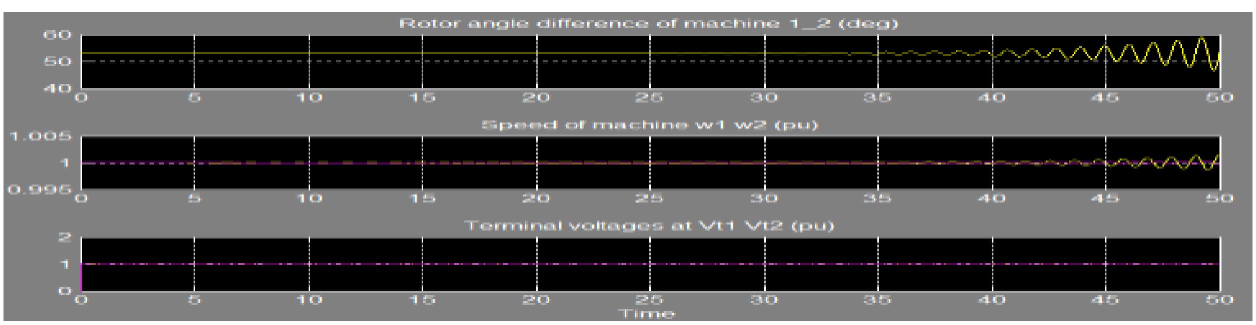

Fig.6 Rotor angle, speeds and terminal voltages without any fault.

L-L fault occurred at bus at Bus 1 for 0.1 second from t1=5.1s to t2=5.2s. Fig.7 shows positive sequence voltages at bus B1,B2 and B3 oscillates system with respect to time. Fig.8 shows Rotor angle difference, speeds and terminal voltages with L-L fault and without F-SVC controller. It is observed that as fault occurred between Bus 1 and Bus 2, terminal voltage Vt1 is also affected. Observation from Fig. 8 Vt1 is less oscillated and stabilized faster with the FUZZY-SVC controller used in the system.

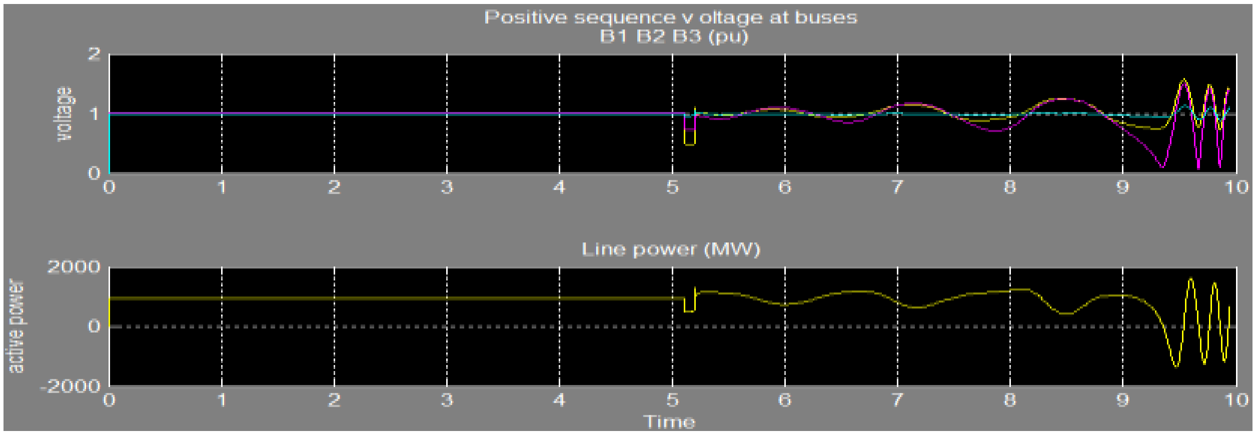

Fig.7 Positive sequence voltage and line power with L-L fault and without F-SVC controller

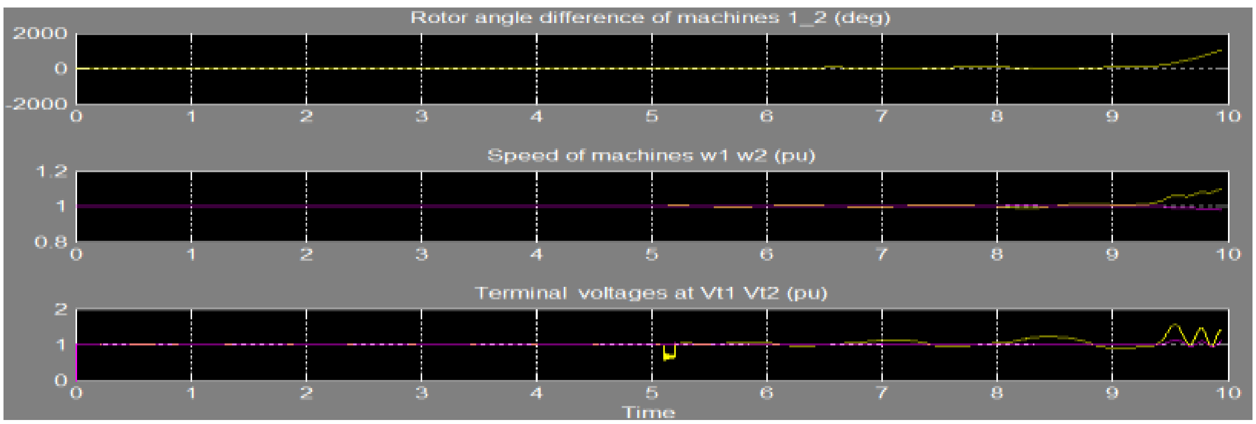

Fig.8 Rotor angle difference, speeds and terminal voltages with L-L fault and without F-SVC controller

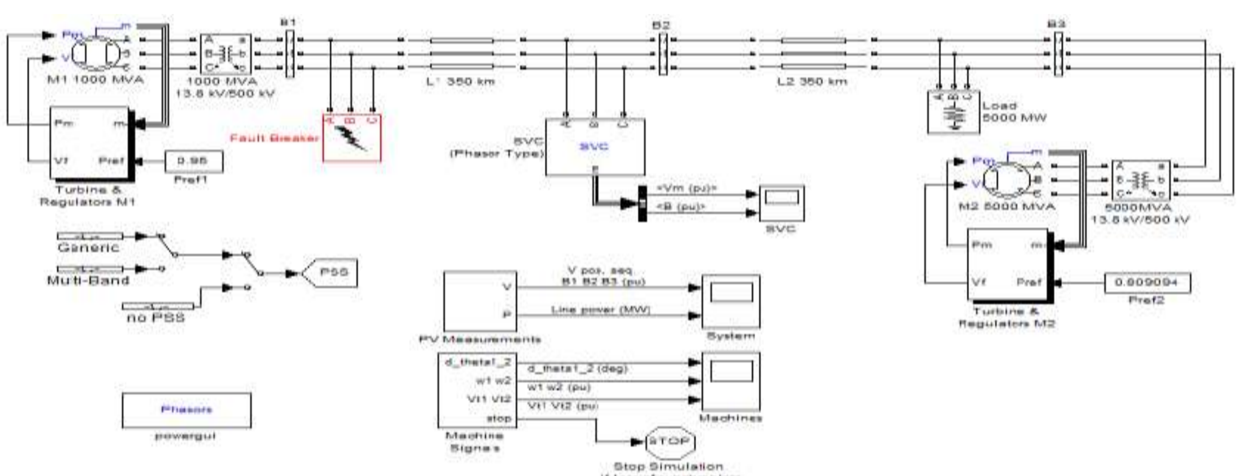

Fig.9 Simulink model with L-L fault and F-SVC controller

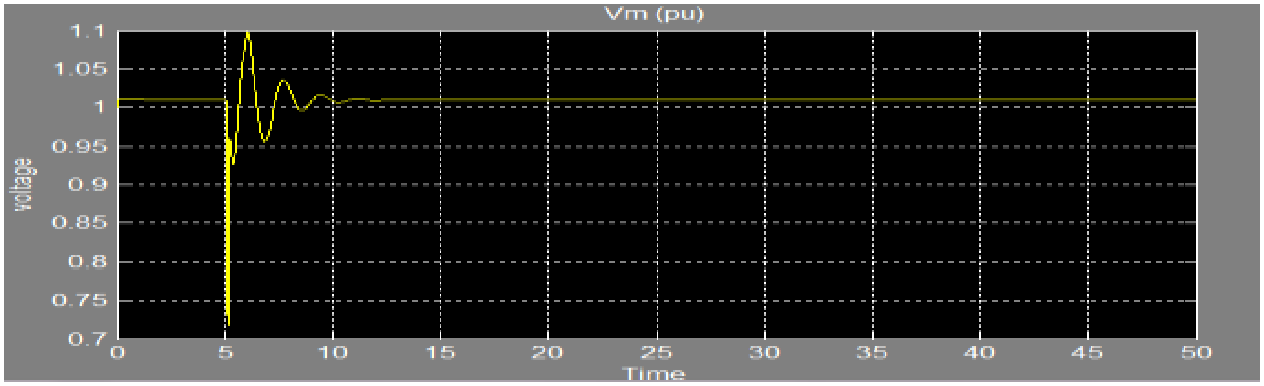

Fig.10 Voltage Vm of system with F-SVC

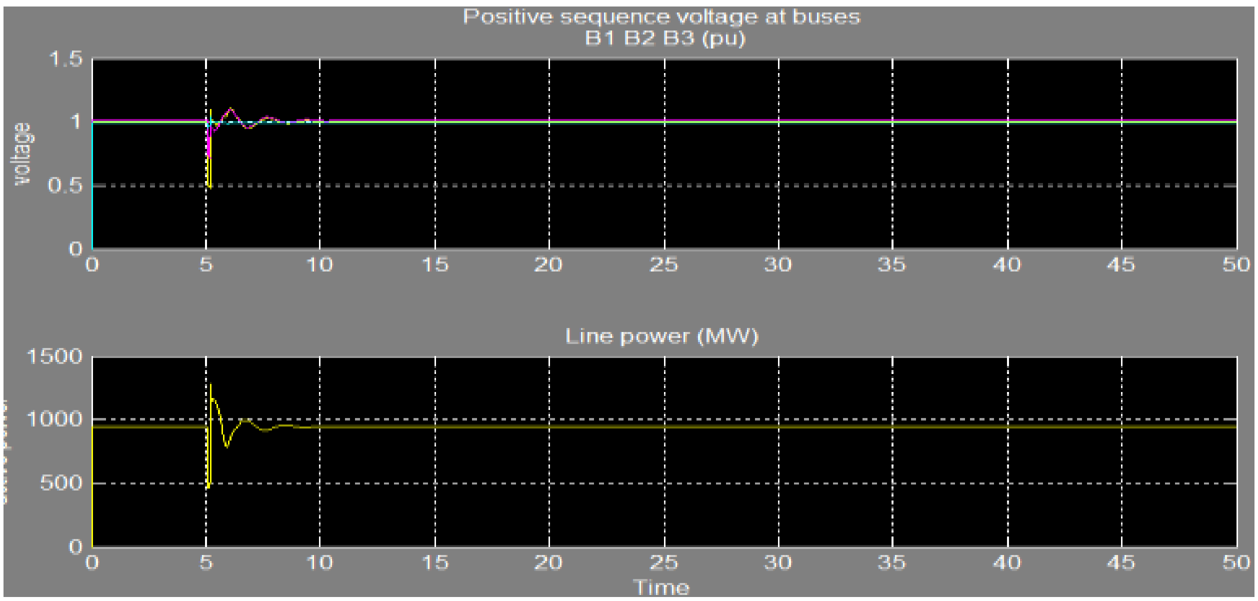

Fig.11 Positive sequence voltage and line active power with L-L fault and F-SVC

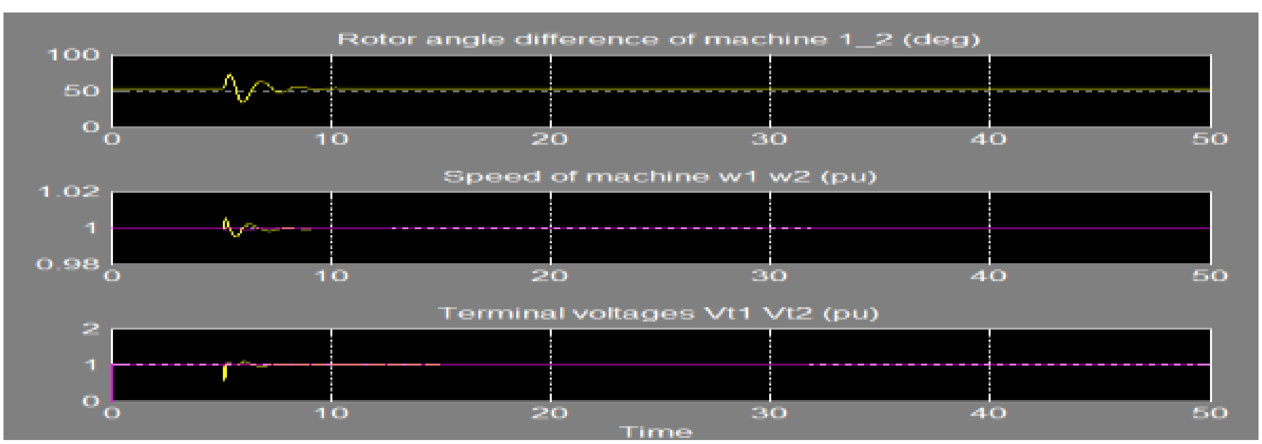

Fig: 12 Rotor angle, speeds and terminal voltages with LL fault with F-SVC controller

The effectiveness of the SVC with fuzzy logic controller is been observed. Fig. 10-12 shows the Fuzzy-SVC modelled in Simulink/MATLAB. After the fault occurred, the SVC will try to support the voltage by injecting reactive power on the line when the voltage is lower than the reference voltage (1.009 pu).

VI. SIMULATION RESULT & DISCUSSION

L-L fault-impact of PSS-F-SVC in services: In this section the simulation is carried out with L-L fault in presence of PSS and F-SVC. It Verify that the PSSs (Generic Pa type) are in service and that a 6-cycle single-phase fault is programmed in the Fault Breaker block (Phase A checked, fault applied at t = 5.1 s and cleared at t = 5.2 s). For this type of fault the system is stable without F-SVC. After fault clearing, the 0.6 Hz oscillation is quickly damped. This oscillation mode is typical of inter area oscillations in a large power system. First trace on the Machines scope shows the rotor angle difference between the two machines. Power transfer is maximum when this angle reaches 90º.This signal is a good indication of system stability. If angle 1_2 exceeds 90º for too long a period of time, the machines will lose synchronism and the system goes unstable. Second trace shows the machine speeds. Notice that machine 1 speed increases during the fault because during that period its electrical power is lower than its mechanical power. By simulating over a long period of time (50 sec) it will also notice that the machine speeds oscillate together at a low frequency (0.025 Hz) after fault clearing. The two PSSs (Pa type) succeed to damp the 0.6 Hz mode but they are not efficient for damping the 0.025 Hz mode. Fig.4-12 shows the simulation model and the result of simulation for single line to line fault.

VII. CONCLUSIONS

The SVC with fuzzy logic controller has been tested in a 2-machines 3-bus power system where several parameters including the difference of rotor angle between the machines, speed of the machines, terminal voltage and the transmission line active power have been observed. The performance of the system implemented with the FUZZY-SVC controller .The system implemented with the Fuzzy-SVC controller show better performance in damping oscillations, maintain terminal voltage and control the power after the system is subjected to disturbance.

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