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Transient stability improvement by using shunt FACT device (STATCOM) with Reference Voltage Compensation (RVC) control scheme

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ABSTRACT: This paper presents transient stability and power flow models of static synchronous compensator (STATCOM) and current Sourced Inverter (CSI) based Flexible AC Transmission System (FACTS) Controllers. A model of the static synchronous compensator (STATCOM), the application of the static synchronous compensator (STATCOM) in improving transient stability in power systems.MATLAB/SIMULINK is used to simulate the system under study. 'This paper presents a control block diagram of STATCOM for the transient stability improvement. The MATLAB/SIMULINK software package is used for simulation of test system. In this paper the STATCOM is connected to the 230KV line for a typical two machine transmission system. The study demonstrates that STATCOM not only considerably improves transient stability in steady stat. Due to its simplicity, robustness and ease implementation, proportional integral derivative (PID) controller along with auxiliary feedback signals are used to control the inverter firing angle and hence control the reactive power exchange between the AC system and the STATCOM.

Keywords: FACTS, STATCOM, transient stability.PID controller and PSS.

I. INTRODUCTION

Now a day's power transmission and distribution systems face increasing demands for more power, better quality and higher reliability at lower cost, as well as low environmental effect. Under these conditions, transmission networks are called upon to operate at high transmission levels, and thus power engineers have had to confront some major operating problems such as transient stability, damping of oscillations and voltage regulation etc [1]. While generator excitation controllers are helpful in achieving rotor angle stability or voltage regulation enhancement, with only excitation control, the system stability may not be maintained if a large fault occurs close to the generator terminal, or simultaneous transient stability and voltage regulation enhancement may be difficult to achieve [2]. The relatively recent development and use of FACTS family controllers static synchronous compensator (STATCOM) in power transmission systems has led to many applications of these controllers to can improvement smooth and rapid reactive power compensation to power systems, and therefore can be used to provide voltage support, increase transient stability and improve damping of power system. Several FACTS equipment is readily available or still under development, based on the solid state switch with conventional thyristors and on the voltage source inverter with GTO switches. All these equipment provide controllability to the AC transmission system by adjusting the reactive power in shunt and series impedance of transmission line, The STATCOM was proposed by several researchers to compensate the reactive current from or to the power system. This function is identical to the synchronous condenser with rotating mass, but its response time is extremely faster than of the synchronous condenser. This rapidity is very effective to increase transient stability, to enhance voltage support, and to damp low frequency oscillation for the transmission system. In this paper a design and tuning of PSS are crucial issues for researchers involved in the development of power systems control. It is because of inaccurate setting of PSS that not only it causes damping oscillations but it also contributes to the amplification of instability leading to the loss of synchronism. And this work introduces new technique namely the Reference voltage compensation (RVC) using PID control concept applied with STATCOM which reduces much the transient peak and settling time of the voltage and reactive power output which were still present after application of the STATCOM [3].

In this work the proposed Reference Voltage PID compensation has been used to damp out the oscillations of multi-machine power system and regulate the Bus Voltage at which the STATCOM is connected and maintain the reactive power.

The proposed method is implemented for a double machine and it is compared with an IEEE standard PSS. Simulation results show that the proposed PSS has a significantly better performance as well as satisfactory robustness compared to the standard PSS controller design and a simulation model development with the MATLAB/SIMULINK model are performed to improve the transient stability of AC transmission system [3].

II. STATCOM

A STATCOM is a controlled reactive-power source. It provides the desired reactive-power generation and absorption entirely by means of electronic processing of the voltage and current waveforms in a voltage source converter (VSC). A single-line STATCOM power circuit is shown in Fig. 1.(a), where a VSC is connected to a utility bus through magnetic coupling. In Fig. 1.(b), a STATCOM is seen as an adjustable voltage source behind a reactance meaning that capacitor banks and shunt reactors are not needed for reactive-power generation and absorption, thereby giving a STATCOM a compact design, or small footprint, as well as low noise and low magnetic impact. The exchange of reactive power between the converter and the ac system can be controlled by varying the amplitude of the 3-phase output voltage *Es*, of the converter, as illustrated in Fig. 1.(c). That is, if the amplitude of the output voltage is increased above that of the utility bus voltage, Et, then a current flows through the reactance from the converter to the ac system and the converter generates capacitive-reactive power for the ac system. If the amplitude of the output voltage is decreased below the utility bus voltage, then the current flows from the ac system to the converter and the converter absorbs inductive-reactive [1, 4].

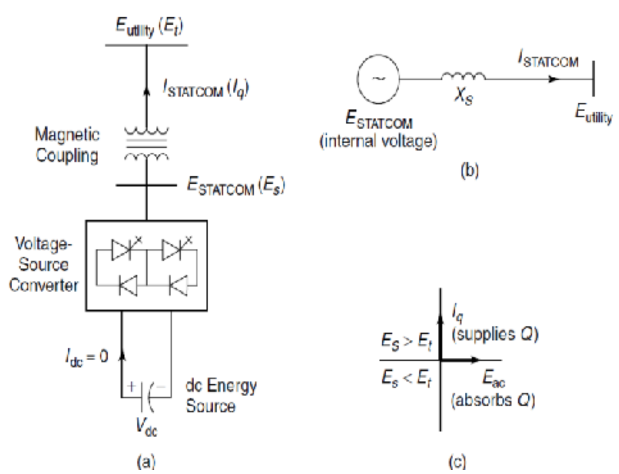

Fig. 1. The STATCOM principle diagram: (a) a power circuit; (b) an equivalent circuit; and (c) a power exchange power from the ac system.

III. THE V-I CHARACTERISTIC

A typical *V-I* characteristic of a STATCOM is depicted in Fig.1. As can be seen, the STATCOM can supply both the capacitive and the inductive compensation and is able to independently control its output current over the rated maximum capacitive or inductive range irrespective of the amount of ac-system voltage That is, the STATCOM can provide full capacitive-reactive power at any system voltage even as low as 0.15pu. The characteristic of a STATCOM reveals strength of this technology: that it is capable of yielding the full output of capacitive generation almost independently of the system voltage (constant-current output at lower voltages). This capability is particularly useful for situations in which the STATCOM is needed to support the system voltage during and after faults where voltage collapse would otherwise be a limiting factor [1,5].

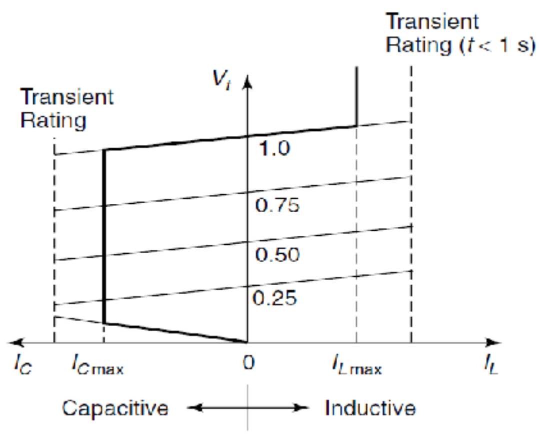

Fig. 2. The *V-I* characteristic of the STATCOM.

IV. MODEL OF STATCOM IN POWER SYSTEMS

Without losing generality, a three-bus STATCOM system shown in Fig. is employed to derive the model. It resembles the case where power is transmitted through an electrical transmission line connecting various generators and loads at its sending and receiving end. i t should be noted that except the STATCOM parameters, all the transmission network parameters are not known in practice.

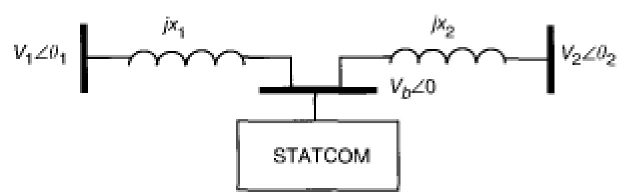

Fig. 3. Three bus system model with STATCOM.

V. POWER SYSTEM STABILIZERS (PSS)

Power system stabilizers (PSS) have been extensively used as supplementary excitation controllers to damp out the low frequency oscillations and enhance the overall system stability. Fixed structure stabilizers have practical applications and generally provide acceptable dynamic performance. There have been arguments that these controllers, being tuned for one nominal operating condition, provide suboptimal performance when there are variations in the system load. There are two main approaches to stabilize a power system over a wide range of operating conditions, namely robust control.
The block diagram for the designed conventional PSS is Shown in Fig.4

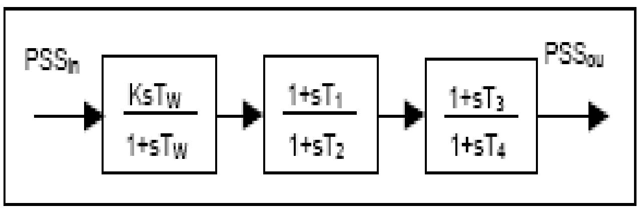

Fig. 4. Conventional Power System Stabilizer.

VI. TRANSIENT STABILITY

The double machine three bus systems qualitatively important characteristics of the behavior of machine system, it is extremely useful to describe the general concepts of power systems stability and is relatively simple to study [1]. Shown in Fig.6 is thus used to show the effect of STATCOM in improving system transient stability [2]. The compensation capacitor is omitted during this investigation. During the fault the transmitted electrical power decreases significantly while mechanical input power to generator remains constant, as a result, the generator continuously accelerates as can be seen in the generator speed and power angle shown in Fig.7 (With STATCOM) respectively. When the fault is cleared, the speed is continuously increasing and system is not able to retain stability due to the lack of damping. During the fault, the generator terminal experiences voltage sag of more than 90% without the STATCOM as shown in Fig.7. This voltage is not recovered after the fault clearance due to the lack of reactive power support, the shaft sections of the turbine generator set are subjected to high torsional oscillations and force as seen in the electromechanical torques [6,7].

When the STATCOM is connected to the midpoint terminals, reactive power controller adapts the value of the inverter firing angle according to system requirements. As shown in Fig.7. STATCOM firing angle, the firing angle should remain zero at normal operating conditions and there is no reactive power exchange between the system and the STATCOM. When the fault occurs, the firing angle is changed instantly and the reactive power is supplied by the STATCOM to the system. When the fault is cleared, the firing angle is reduced to zero again and the STATCOM back to the idle condition [6]. The impact of reactive power modulation using STATCOM on system performance can be seen in Fig.7.Connecting the STATCOM to the midpoint terminals will maintain the rotor speed and the power angle at their nominal values even during the fault. The voltage sag at the generator terminals will be reduced substantially. The shaft oscillations and torsion forces will be reduced to almost the normal steady state condition [1,2,4].

VII. EXPERIMENTAL TEST MODEL

For the purpose of studying the transient phenomena and obtaining more practical results, the proposed MATLAB/ SIMULINK control scheme in computer hardware and software designed specifically for the solution of power system electromagnetic transients. Because real time operation can be achieved, it can be applied in areas traditionally reserved for analogue simulators, e.g. testing of protective relays and testing of system controller.

Double machine three bus model of a power system for evaluating the proposed design method is considered. Using this model, we consider a typical two 500MVA, 11KV, 50Hz synchronous generator to connect with a 500MVA, 11/230KV two transformers and two transmission lines are 230KV, 300KM connected to three buses. Single line diagram of the model is shown in Fig.

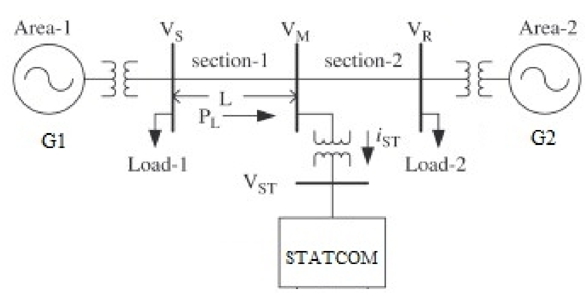

Fig.5. Single line diagram of two generating station with STACOM.

Fig. 6 shows a generation unit consisting of a synchronous generator, a turbine, a governor, an excitation system, an automatic voltage regulator (AVR) and a PSS.

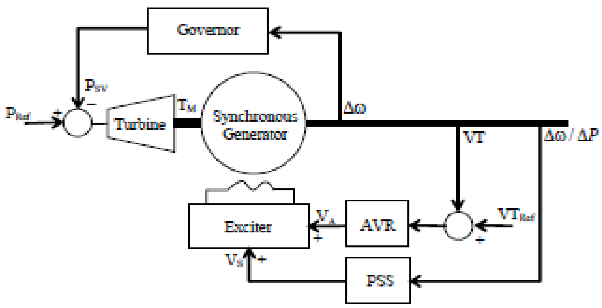

Fig. 6. Generation unit diagram.

The system is employed in the experiment to evaluate the proposed control scheme. The parameters of the example system are given as follows

Generator:
S=500MVA, V=11 kV, ω_0= 314.159rad/s, D=5.0 pu., H= 4.0s, X_d= 1.863 pu, X'_d = 0.657pu, X''_d=0.245pu, T'_{d0} = 6.9s T''_{d0}= 0 .03s , X_q= 0.657 pu. , X_q'' = 0.27pu, T''_{d0}= 0.06s, X_{ad}=1.712pu, $\boldsymbol{k_c}$= 1, and Max [Ef(t)] = 6.Opu.

Transformer:
S = 500 MVA, winding 1(Y) = 22 kV, winding 2(Δ) = 230 kV, and X_T= 0.127 pu.

Transmission line:
Length =300km, X_{L1} = X_{L2} = 0.24265 pu, R_{L1}= RL2 = 0.016pu and f= 50Hz

STATCOM:
220MVAR, R_s=0.01 pu., L=0.1 pu, C_{dc}= 100OpF, snubber circuit: *Rb* = 5000 **Ω,** and *C*, = 0.05 µF.

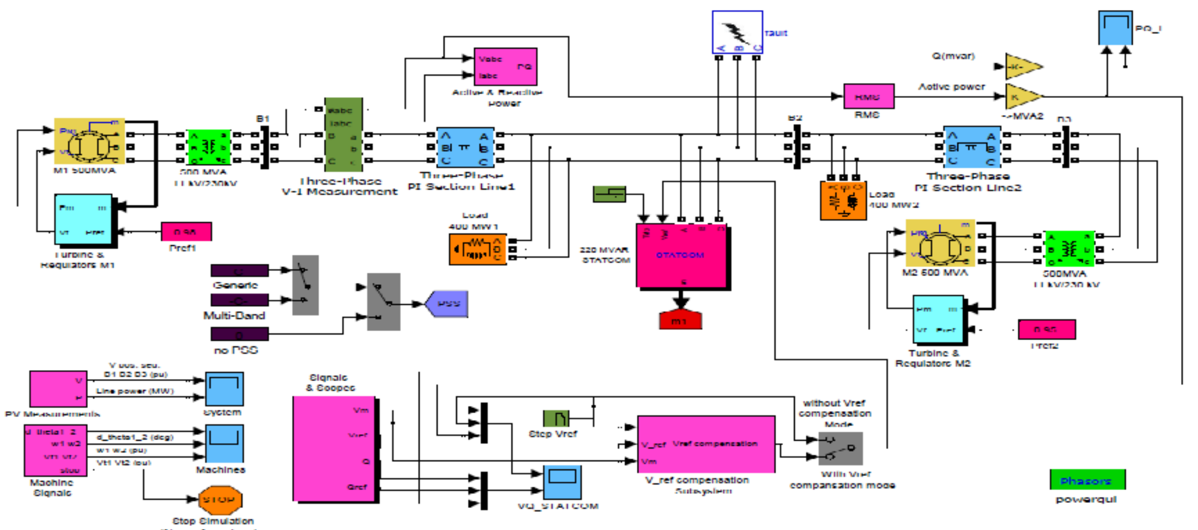

Fig. 7. MATLAB experiment model for transient stability test system.

VIII. SIMULATION AND RESULTS

In this model, performance of controller is evaluated conventional PSS from IEEE standard. The simulations carried out using MATLAB/ SIMULINK environment for power system Fig.7 for evaluating robustness of proposed PSS stabilizations of these PSSs is simulated of disturbances.

1. Without STATCOM- Shows d_theta angle instability of synchronous generator, angular velocity ω1 and ω2 and terminal voltage unstable due to occurs single phase fault on a generator bus. When no compensation allows-

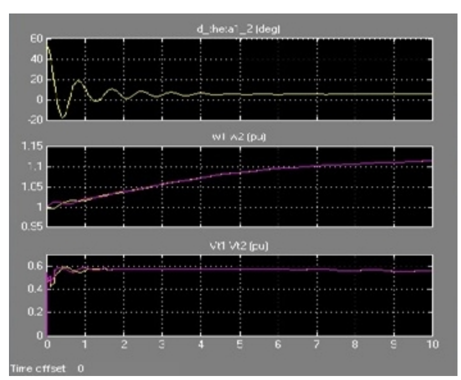

Fig. 8. d_theta angle of without STATCOM.

2. With STATCOM- Shows d_theta angle stability of synchronous generator, angular velocity ω1 and ω2 and terminal voltage stable single phase fault on a generator bus. When RVC compensation allows-

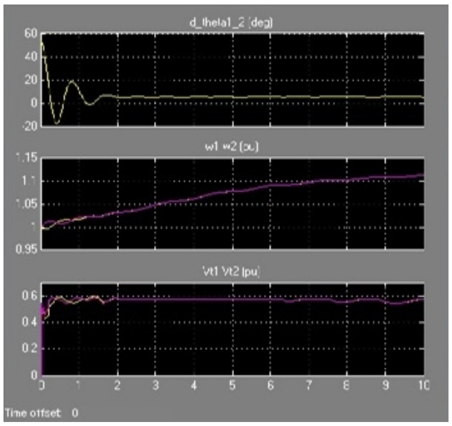

Fig.9. d_theta angle of with STATCOM.

3. This simulation result shows that line power fluctuation and bus voltage fluctuation Without STATCOM.

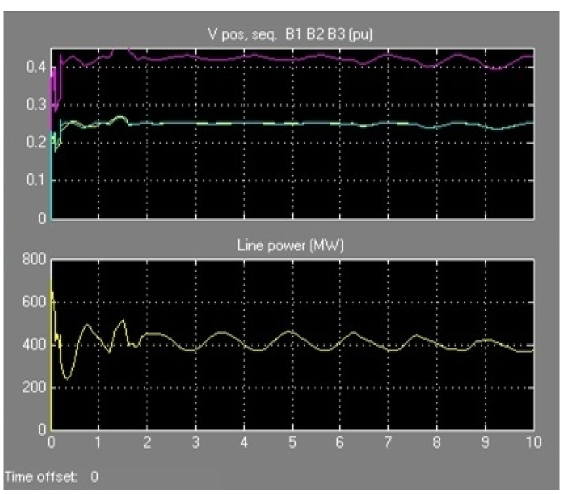

Fig. 10. Line power (MW) and bus voltage without STATCOM.

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4. This simulation result shows that line power fluctuation and bus voltage fluctuation With STATCOM.

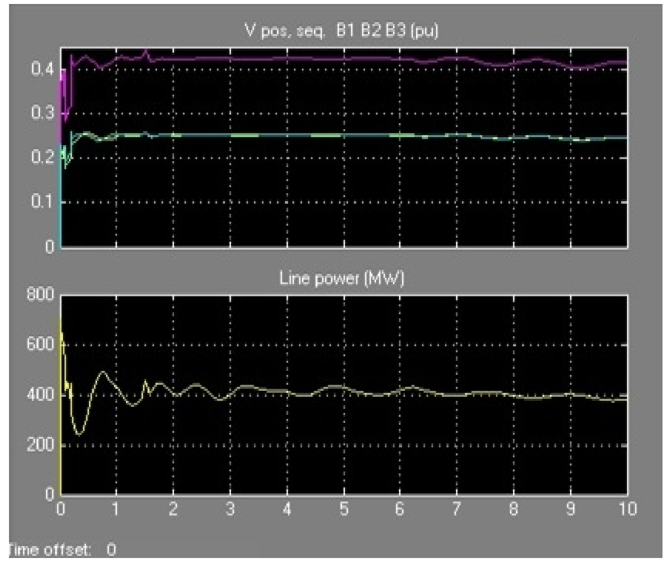

Fig. 11. Line power (MW) and bus voltage with STATCOM.

IX. CONCLUSION

This paper has investigated the transient characteristic of STATCOM, and then summarized the switch strategy of internal and external fault based on two generating station. The simulation result shows: STATCOM considered in transmission line can damp power oscillation efficiently, and different switch modes result different effect especially when internal fault. The bypass mode reaches the best effect in the three modes when internal fault, and also avoids the impulse voltage and current. The effects on power compensation and damping low-frequency oscillation of STATCOM for the three-phase short-circuit of the same line were studied and compared based on the simulation.

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