

Damping Power System Oscillation with STATCOM

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Abstract--- In their early years electric power systems did not reach far from the generating station. Since then power systems have been inter-connected to cover first regions and later nations. Today they extend over entire continents and contain a huge number of components that together serve to supply electric energy to the customers. The aim is to maintain the voltage and the frequency at their nominal values. To improve reliability both design and operation of power systems involve safety margins to the cost of some profit. Much effort today is spent on control and supervision that can reduce these margins, which also has environmental aspects. "Environmental and economic aspects make it difficult to build new power lines and to reinforce existing ones. The continued growth in demand for electric power must therefore to a great extent be met by increased loading of available lines. A consequence is that power system damping is reduced, leading to a risk of poorly damped power oscillations between the generators. This thesis proposes the use of controlled active loads to increase damping of such electro-mechanical oscillations. The focus is on structural aspects of controller power system damping by fact device Statcom."

I. INTRODUCTION

The STATCOM (or SSC) is a shunt-connected reactive-power compensation device that is capable of generating and/ or absorbing reactive power and in which the output can be varied to control the specific parameters of an electric power system. It is in general a solid-state switching converter capable of generating or absorbing independently controllable real and reactive power at its output terminals when it is fed from an energy source or energy-storage device at its input terminals.

II. PRINCIPLE OF OPERATION OF 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.(a) where a VSC is connected to a utility bus through magnetic coupling. In Fig.(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, E_s , of the converter, as illustrated in Fig.(c). That is, if the amplitude of the output voltage is increased above that of the utility bus voltage, E_t ,

then a current flows through the reactance from the converter to the ac system and the converter generates capacitive-reactive

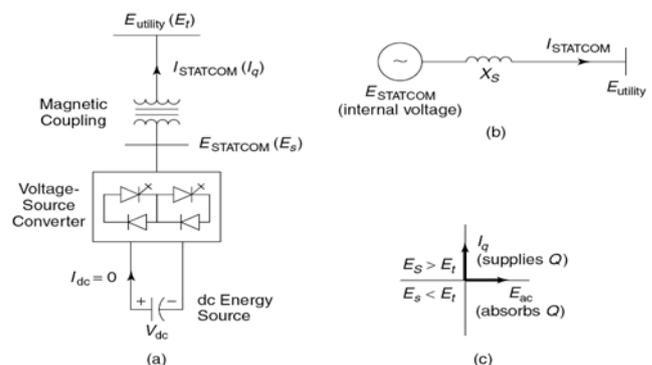


Fig. 1: Basic circuit arrangement of the STATCOM

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. 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. Adjusting the phase shift between the converter-output voltage and the ac system voltage can similarly control real-power exchange between the converter and the ac system. In other words, the converter can supply real power to the ac system from its dc energy storage if the converter-output voltage is made to lead the ac-system voltage. On the other hand, it can absorb real power from the ac system for the dc system if its voltage lags behind the ac-system voltage.

A STATCOM provides the desired reactive power by exchanging the instantaneous reactive power among the phases of the ac system. The mechanism by which the converter internally generates and/ or absorbs the reactive power can be understood by considering the relationship between the output and input powers of the converter. The converter switches connect the dc-input circuit directly to the ac-output circuit. Thus the net instantaneous power at the ac output terminals must always be equal to the net instantaneous power at the dc-input terminals.

III. THE V-I CHARACTERISTIC

A typical V-I characteristic of a STATCOM is depicted in Fig. 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 0.15 pu.

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

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.

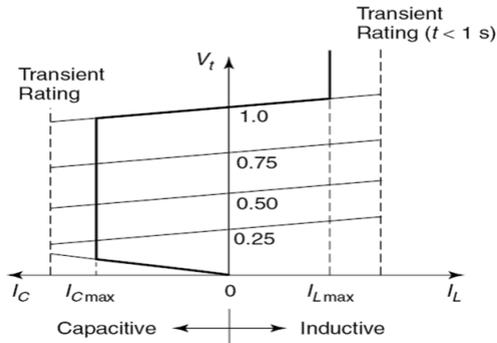


Fig. 2

Figure 2 also illustrates that the STATCOM has an increased transient rating in both the capacitive- and the inductive-operating regions. The maximum attainable transient over current in the capacitive region is determined by the maximum current turn-off capability of the converter switches. In the inductive region, the converter switches are naturally commutated; therefore, the transient-current rating of the STATCOM is limited by the maximum allowable junction temperature of the converter switches

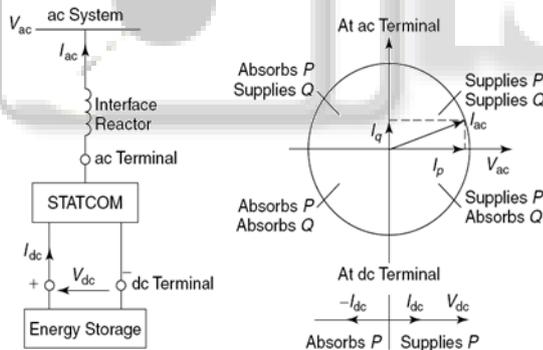


Fig. 3

The reactive- and real-power exchange between the STATCOM and the ac system can be controlled independently of each other. Any combination of real power generation or absorption with var generation or absorption is achievable if the STATCOM is equipped with an energy-storage device of suitable capacity. With this capability, extremely effective control strategies for the modulation of reactive- and real-output power can be devised to improve the transient- and dynamic-system-stability limits.

IV. ELECTRO-MECHANICAL OSCILLATIONS

The problem treated in this is damping of electro-mechanical oscillations in power systems. During such oscillations, mechanical kinetic energy is exchanged between synchronous generators as electric power flows through the network. The oscillations can be seen in many

variables, where the rotor velocities of the generators and the power flows in the network are the most important. The rotor velocity variation causes strain to mechanical parts in the power plant and should be limited. The power flow oscillations may amount to the entire rating of a power line. As they are superimposed on the stationary line flow, they limit the transfer capacity by requiring increased safety margins. Given certain conditions torsional dynamics of the turbine-generator shaft can interact with for example the network, leading to sub synchronous oscillations. Such oscillations are not considered in this work.

The term synchronous generator stems from the fact that this electrical machine is synchronized to the network. This makes the shaft speed connected to the frequency of the voltage in the network. At any point in the network the mains frequency is thus determined by the rotor velocity of nearby generators. A consequence worth to mention is that electromechanical oscillations can be detected in the mains frequency as a variation around the nominal 50 or 60 Hz.

A. SMIB WITHOUT FACTS DEVICES

Figure shows the single line diagram of Single Machine Infinite Bus (SMIB) system without a STATCOM and the corresponding equivalent circuit is shown in fig.

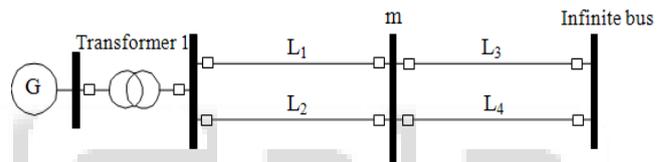


Fig. 3: Schematic diagram

Here X_1 is the equivalent reactance between the machine internal bus and the bus m and X_2 is the equivalent reactance between bus m and the infinite bus

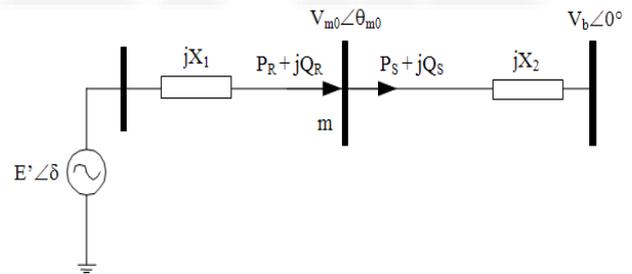


Fig. 4: Equivalent circuit

The generator is represented by a constant voltage source (E') behind transient reactance (X_d'). The active power balance at bus m is given by

B. MATHEMATICAL MODEL OF SMIB WITHOUT FACTS DEVICES

Figure shows the single line diagram of Single Machine Infinite Bus (SMIB) system without a STATCOM. In SMIB first ambition is improvement in damping. main parameters are synchronous machine, Three phase transformer, transmission line, three phase measurement, source, load, electromechanical power, electromagnetic power in SMIB to measure average power and voltage measurement

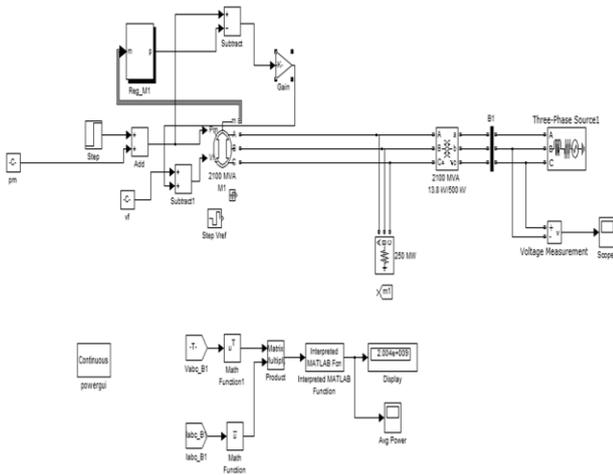


Fig. 5

In SMIB input are V_f , difference between electromechanical power and electro-magnetic power to connect source synchronous machine

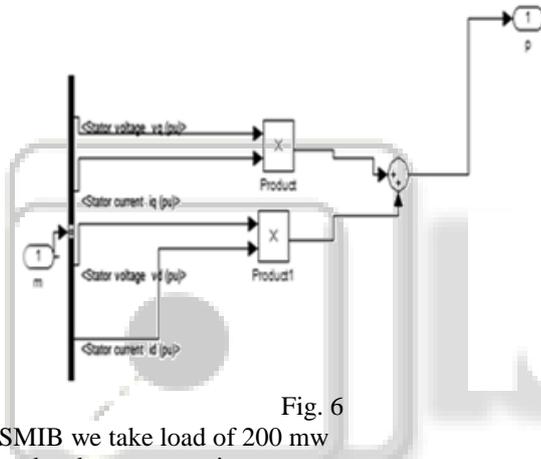


Fig. 6

In SMIB we take load of 200 mw
We take electromagnetic power
 $P_e = V_d I_d + V_q I_q$
We can improvement damping without fact devices

V. SIMULATION SINGLE MACHINE INFINITE BUS (SMIB) SYSTEM WITHOUT A STATCOM

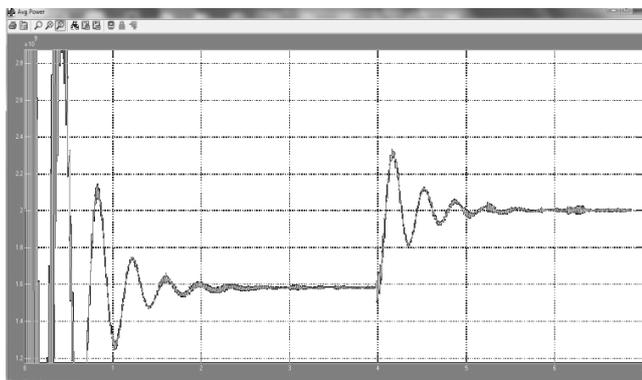


Fig. 7

Single machine infinite bus system without fact devices (average power)

Single machine infinite bus system without fact devices to improve damping (average power)

A. SINGLE MACHINE INFINITE BUS (SMIB) SYSTEM WITH A STATCOM

STATCOM is a shunt connected reactive power compensation device that is capable of generating and observing reactive power and which the output can be varied to control the specific parameters of an electrical power system. it is in general a solid-state switching converter capable of generating and observing independently controllable reactive power as its output terminal

$$I_s = I_s e^{j(\delta_m \pm \pi/2)}$$

$$\delta_m = \tan^{-1} \left(\frac{E'X_2 \sin \delta}{VX_1 + E'X_2 \cos \delta} \right)$$

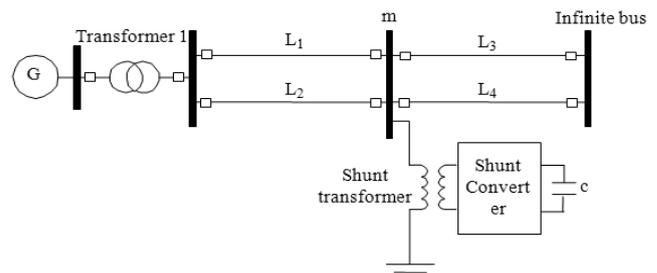


Fig. 8: schematic diagram

With the STATCOM the output Power P_e of the machine can be written as

$$P_e = P_{max} \sin \delta + f_1(\delta) I_s$$

WHERE

$$f_1(\delta) = \frac{E'X_2}{X_1 + X_2} \sin(\delta - \delta_m)$$

For enhanced of power system damping the shunt reactive current can be modulated in proportion to the rotor speed deviation w . with this control signal is can be express as

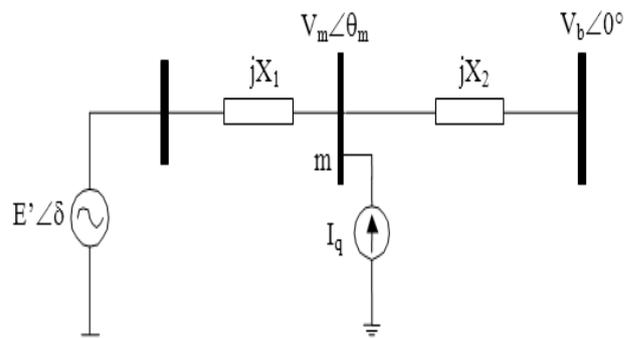


Fig. 9: Equivalent circuit

Here X_1 is the equivalent reactance between the machine internal bus and the bus m and X_2 is the equivalent reactance between bus m and the infinite bus. The generator is represented by a constant voltage source (E') behind transient reactance (X_d).

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Figure shows the single line diagram of Single Machine Infinite Bus (SMIB) system with a STATCOM

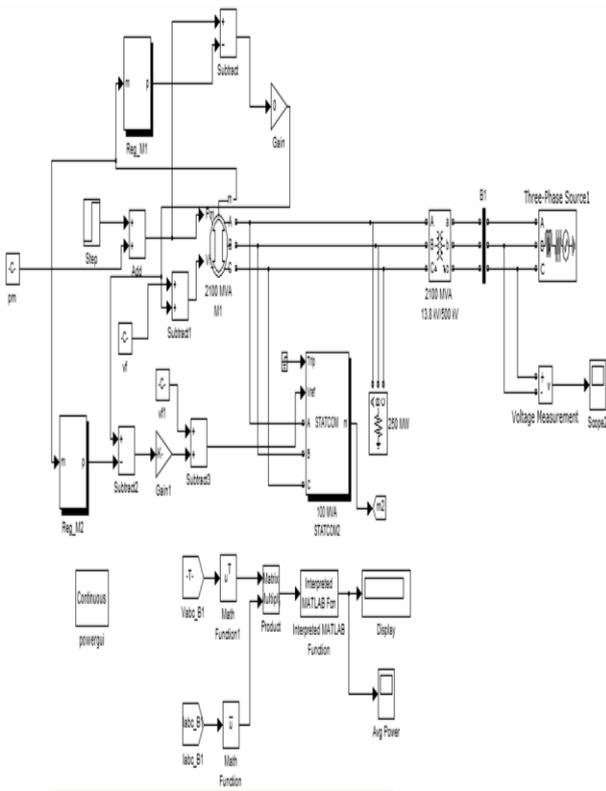


Fig. 9

In SMIB with statcom first ambition is improvement in damping main parameters are synchronous machine, Three phase transformer, transmission line, Three phase voltage measurement, source, load, electromechanical power, electromagnetic power in SMIB to measure average power and voltage measurement

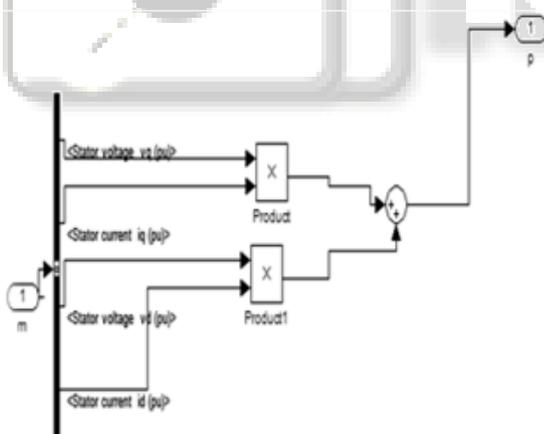


Fig. 10

In SMIB we take load of 200 mw
We take electromagnetic power
 $P_e = V_d I_d + V_q I_q$
We can improve damping with fact devices

In SMIB input are V_f , difference between electromechanical power and electromagnetic power to connect source synchronous machine In SMIB we take load of 200 mw

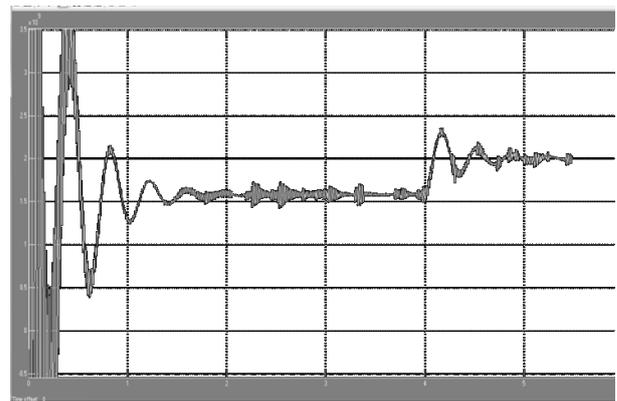


Fig. 11: Average Power

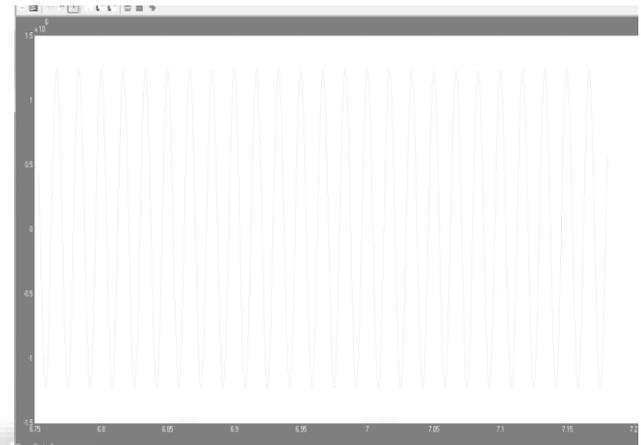


Fig. 12: voltage measurement

$$P_R = P_S \tag{1}$$

HERE

$$P_R = \frac{E'V_{m0}}{X_1} \sin(\delta - \theta_{m0}) \tag{2}$$

AND

$$P_{S1} = \frac{V_{m0}V_b}{X_2} \sin(\theta_{m0}) \tag{3}$$

After some mathematical manipulations of Eq. 1- Eq. 3, the voltage angle at bus m of the system without STATCOM is given by

$$\theta_{m0} = \tan^{-1} \left(\frac{E'X_2 \sin \delta}{E'X_2} \right) \tag{4}$$

$$Q_R = Q_S \tag{5}$$

HERE

$$Q_R = \frac{E'V_{m0}}{X_1} \cos(\delta - \theta_{m0}) - \frac{V_{m0}^2}{X_1} \tag{6}$$

AND

$$Q_S = \frac{V_{m0}^2}{X_2} - \frac{V_{m0}V_b}{X_2} \cos \theta_{m0} \tag{7}$$

After some mathematical manipulations of Eq. 5-7, the voltage magnitude at bus m of the system without STATCOM is

$$V_{m0} = \frac{E'X_2 \cos(\delta - \theta_{m0}) + X_1 V_b \cos \theta_{m0}}{X_1 + X_2} \quad (8)$$

It can observe from the Fig. 1b and 2a-c that the STACOM doesn't effect on the active power balance and then the voltage angle equation at bus doesn't change written by

$$\theta_m = \theta_{m0} = \tan^{-1} \left(\frac{E'X_2 \sin \delta}{E'X_2} \right) \quad (9)$$

However, the STATCOM effects on reactive power balance given by

$$Q_{inj} = -V_m I_q$$

(9)
HERE

$$Q_R = Q_S + Q_{inj} \quad (10)$$

After some mathematical manipulations, the voltage magnitude at bus m of the system with a STACOM is given by

$$V_m = \frac{E'X_2 \cos(\delta - \theta_m) + X_1 V_b \cos \theta_m + X_1 X_2 I_q}{X_1 + X_2} \quad (11)$$

From Eq. 8 and 12, the voltage magnitude at bus m of the system with a STATCOM is given by

$$V_m = V_{m0} + C I_q \quad (12)$$

HERE

$$C = X_1 X_2 / (X_1 + X_2)$$

VI. CONCLUSION

After this analysis in Research paper I conclude that transient stability of power system will improve by using STATCOM. STATCOM is most versatile device than other facts devices. Simulation Of Power Swing Damping Controller With STATCOM Is Presented.

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