Comparison of Stability Improvement in Multimachine Power System by FACTS Devices

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Abstract: ***The machine dynamics response to any impact in the system is oscillatory. In past, the size of power system is smaller; therefore the period of oscillation was not much greater than one second. Today large capacity of generator and system interconnected with the greater system inertias and relatively weaker ties results in longer period of oscillation followed by perturbation. These are the situations in which dynamic stability is concern. The enhancement of dynamic stability becomes very important for reliability and continuity of power system. Now power electronic based FACTS (Flexible AC Transmission system) devices are established to enhance the power transmitting capacity and also mitigation of oscillatory period of system at the time of fault. The case study of two area system is taken for analysis. Fault is created for observation of different parameter of machine and transmission system like rotor angle waveform, settling time, voltage of machine, active power of machine and transmission voltage. The different fault analysis says that FACTS controllers help to improve dynamic stability.***

Keywords: FACTS controller, power system stability, UPFC, settling time

1. Introduction

Power system stability, in general term may be defined as its ability to respond to a perturbation from its normal operation by returning to a condition where the operating is again normal. Dynamic stability is the ability ifpower system to remain in synchronism after the initial swing (transient stability period) until the system has settle down to the new study state equilibrium condition. When sufficient time has elapsed after a perturbation, the governors of the prime mover will react to increase or decrease energy input as may be required, to reestablish a balance between energy input and the existing electrical load. This usually occurs in about 1 to 1.5 second after the perturbation. The period between the time the governor begins to react and the time that steady state equilibrium is reestablish in the period when dynamic stability characteristic of a system are effective.

Damping improvement in a SMIB system using STATCOM & SSSC was investigated using energy function approach. Classical Model was used for the synchronous machines and the FACTS devices were modeled as simple current and voltage sources. The proposed technique is then applied to a single-machine system and for some faults (local modes) in a multi-machine system to evaluate the additional damping provided by a STATCOM and a SSSC . This paper presents a comprehensive review on enhancement of power system stability such as rotor angle stability, frequency stability, and voltage stability by using different FACTS controllers such as TCSC, SVC, SSSC, STATCOM, UPFC, and IPFC in an integrated power system networks.

2. Problem Formulation

The stability of an interconnected power system is its ability to return to normal or stable operation after having been subjected to some form of disturbance. Conversely, instability means a condition denoting loss of synchronism or falling out of step. Stability considerations have been recognized as an essential part of power system planning for a long time. With interconnected systems continually growing in size and extending over vast geographical regions, it is becoming increasingly more difficult to maintain synchronism between various parts of a power system

3. Objective

Unified Power Flow Controller (UPFC) is the most widely used FACTS device to control the power flow and to optimize the system stability in the transmission line. The controller used in the control mechanism has an important effect on the performance of UPFC. This paper presents a comprehensive review on enhancement of power system stability such as rotor angle stability, frequency stability, and voltage stability by using different FACTS controllers such as TCSC, SVC, SSSC, STATCOM, UPFC, and IPFC in an integrated power system networks. Also this paper presents the current status of the research and developments in the field of the power system stability such as rotor angle stability, frequency stability, and voltage stability enhancement by using different FACTS controllers in an integrated power system networks

4. Facts Controller

The objective of incorporating FACTS is into the power system lines are similar to HVDC but greater flexibility are involved like improving real power transfer capability in the lines, prevention of sub- synchronous resonance (SSR)oscillations and damping of power swings

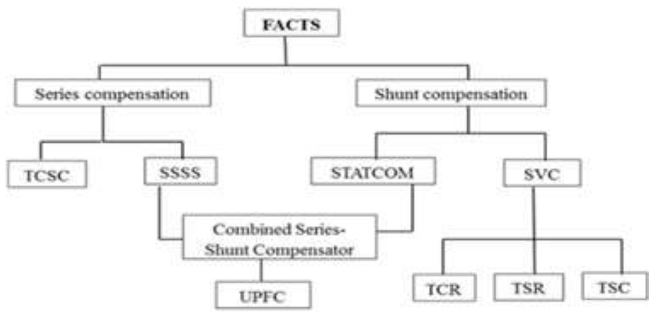

Figure 4.1: FACTS Diversification

Static VAR compensator
A shunt connected static VAR absorber whose output is adjusted to exchange capacitive or inductive current so as to control specific parameter of electrical power system. These comprised capacitor bank fixed or switched or capacitor bank and switched reactor bank in parallel. These compensator draw reactive power (leading or lagging) from the line regulating voltage, improve steady state or dynamic stability reduced voltage flicker. In HVDC system, compensator provides the required reactive power and damp out sub harmonic oscillation. It is also called static VAR switches.

STATCOM
Static synchronous compensator operated as shunt connected devices that are capacitive or inductive output current can be controlled independent of the ac system voltage. Its operation is counter part of SVC. It can be based of voltage and current sourced convertor. STATCOM can be designed to be an active filter to absorb harmonic of system.

UPFC
A combination of static synchronous compensator (STATCOM) and Static series compensator (SSSC) connected via DC link to pass flow of real power between the series output terminal of SSSC and shunt output terminal of STATCOM. Also controlled the flow real and reactive without an external electrical energy source.

SSSC
Static Series Synchronous Compensator is operated without an external electric energy source as a series compensator whose output voltage is an quadrature with and controllable independently of, the line current for the purpose of increasing or decreasing the overall reactive voltage drop across the line and controlling the transmission power. SSSC operating like STATCOM but its output voltage is in series with the line. Thus its controlled the voltage across the line and hence its impedance.

5. Performance Analysis

A Critical Clearing
Angle by Analytical Method In paper a generator deliver a power 420MW taken as a Reference value. A fault takes place reducing the maximum power 200MW. Before the fault, power is 420MW. After the clearing of the fault, it is 460MW. So by equal area criteria critical clearing angle is found.

Pm = 420MW= 1 PU
Pre fault Pm1 = 420MW =1PU
During fault Pm2 = 200MW =0.476 PU
Post fault Pm3 = 460MW =1.095 PU.

$$\partial_0 = \sin^{-1}\frac{P_m}{P_{m1}} \quad (1)$$

$$\partial_0 = \sin^{-1}\frac{1}{1} \quad (2)$$

$$\partial_0 = 1.57rad \quad (3)$$

$$\partial_{max} = \pi - \sin^{-1}\frac{P_m}{P_{m3}} \quad (4)$$

$$\partial_{max} = \pi - \sin^{-1}\frac{1}{1.095} \quad (5)$$

$$\partial_{max} = 1.99rad \quad (6)$$

$$\cos\partial_{cr} = \frac{P_m(\partial_{max}-\partial_0)P_m\cos\partial_0 + P_{m3}\cos\partial_{max}}{P_{m3}-P_{m2}} \quad (7)$$

$$\partial_{cr} = 87.67^0 = 88^0 \quad (8)$$

So by analytical method has obtained the Value of Critical Clearing Angle is 88 from equation (8). And value obtained by simulation modeling withoutFACTS controller is 105.

b. Waveform of Simple Model without FACTS Controller

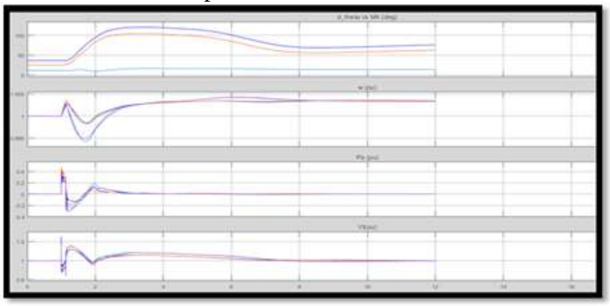

Figure 6.1: Rotor angle, power Vs Time without FACTS Controller

First wave shape of fig. 6.1 indicate rotor perspective of synchronous machine verses time. Maximum peak of waveform is105. And settling time at post fault situation is 12 sec.

c. Waveform of SVC Connected FACTS Controller

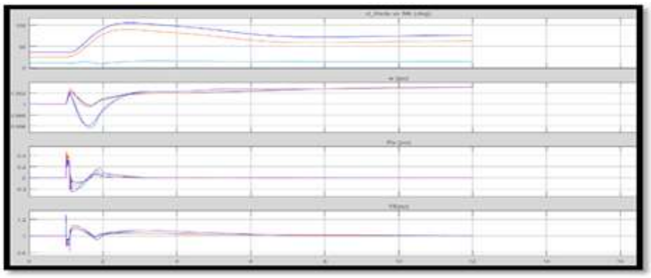

Figure 6.2: Rotor angle, power Vs Time with SVC FACTS Controller

To start with wave type of fig.6.2 demonstrate rotor angle of synchronous machine verses time. Most extreme peak of waveform is 105 .And settling time at post blame condition is 6 sec.

d. Waveform of STATCOM Connected FACTS Controller.

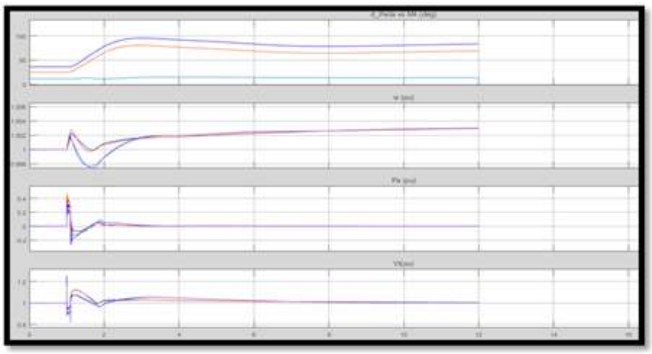

Figure 6.3: Rotor angle, power Vs Time with STATCOM FACTS Controller

First wave form of fig.6.3 indicate rotor angle of synchronous machine verses time. Maximum peak of waveform is 100. And settling time at post fault condition is 5.9 sec.

e. Waveform of SSSC Connected FACTS Controller

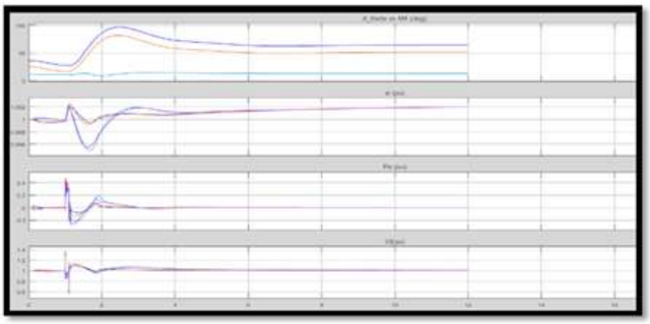

Figure 6.4: Rotor angle, power Vs Time with SSSC FACTS Controller

To start with wave type of fig. 6.4 demonstrate rotor angle of synchronous machine verses time. Most extreme peak of waveform is 80 .And settling time at post fault condition is 6 sec.

f. Waveform UPFC Connected FACTS Controller.

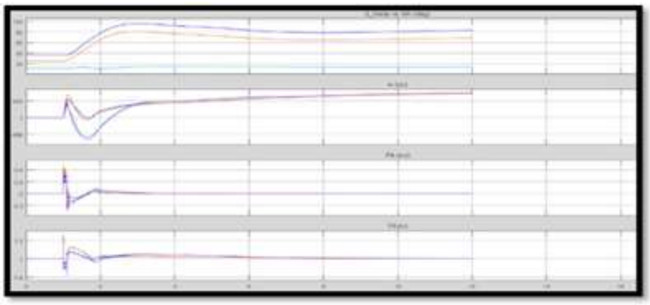

Figure 6.5: Rotor angle, power Vs Time with UPFC FACTS Controller

To begin with wave type of fig. 6.5 demonstrate rotor angle of synchronous Machine verses time. Extreme peak of waveform is 95. In addition, settling time at post fault condition is 5.5 sec.

TABLE I. Difference between FACTS Devices for dynamic Stability Enhancement in multi machine control system

Two area power system	Power system stability enhancement	Settling time in post fault period(sec)
UPFC	YES	5.5
STATCOM	YES	5.9
SVC	YES	6
SSSC	YES	6
Without FACTS	NO	12

Observation of FACTS controller is given by this paper and after effect of that is analyses in table I. This table is designed of diagram acquired between rotor point verses time of fault condition. In this table four FACTS controller are giving Settling time at post fault condition. Time required for settle down the system at new steady period is 5.5 sec for UPFC, while in other FACTS controller like STATCOM it is 5.9sec, In SVC and SSSC it is 6 sec. What's more, without FACTS time required is 12 sec. Therefore, UPFC is best FACTS controller as stability perspective.

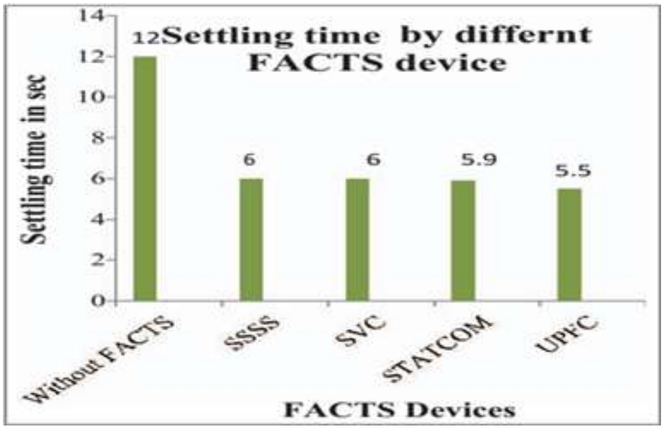

Figure 6.6: Settling time of Different FACTS devices

Graphical representation of settling time for special FACTS controllers as cited in desk I is represented with the aid of fig.6.3.6. Therefore, specific FACTS controller is as compared and fined that STATCOM is better than SVC and UPFC is better than SSSC. Time required for relax the device is 5.5 sec by connecting UPFC FACTS controller. This time is smaller as comparisons with different FACTS controller. So later UPFC is best FACTS controller as evaluate to other stabilizer as stability factor of view.

6. Conclusion

The performances are analyzed for different FACTS controller with application of fault. First two area system is considered where fault are created and observations are made for settling time. The same type of fault is applied with FACTS controller. The results of settling time for different FACTS controller are compared. In shunt connected FACTS device STATCOM is more reliable at stability point of view. The settling time of STATCOM is small as compare to SVC in shunt connected FACTS controller. UPFC is combined shunt and series connected FACTS stabilized, so overall performance of UPFC is much faster than other FACTS controller. This performance analysis is done with the help of MATLAB Simulink modeling.

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