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"COMPARATIVE STUDY FOR DAMPING OF POWER SYSTEM OSCILLATIONS USING FACTS DEVICES"

Jayendra Prajapati*, Navita and Neha Rana*****

Abstract: The demand of electricity is increasing day by day. To fulfill the demand of electricity, power system becomes more complex and unstable. Power quality is the major issue at the present time. Power oscillations are the main problem in the power system. Losses are increasing in the system and transmittable power is reducing due to power oscillation. This paper presents the damping of power oscillations of a two area system, using a STATCOM and UPFC. The performance of the system is compared with STATCOM, with UPFC and without any FACTS devices. The simulation results of proposed system with FACTS devices show the damping of power oscillations in the system.

Key Words: FACTS, STATCOM, UPFC, MATLAB/simulation, two area system, power system oscillation, power system stabilizers (PSS).

1. INTRODUCTION

The power system becomes more complex and bigger to provide more power to the consumers. Due to increase in complexity, power system becomes less secure and unstable against faults and disturbances [3]. Power system stability can be referred as the capability of the system to maintain steady state condition under any fault and disturbance in the system. Due to any fault and disturbance in the system, load angle oscillate around normal operating condition or steady state value[1]. Power transmit also oscillates near steady state value at natural frequency, due to oscillation of the load angle. The power oscillations are occurring in the range of .1 Hz to 2Hz [5]. The power oscillation is defined as local mode and inter- area mode. In local mode, an oscillation is occurring in the range of 1Hz to 2Hz and in which one generator is oscillating against rest of the system [4].

In earlier time, power system stabilizers (PSS) are used for damping of power oscillations. There are many problems in using of PSS. PS only damps out local mode of electromechanical oscillations. It can produce large variation in voltage profile under any fault. Loads are also affected by power oscillations [2]. Power electronic devices are used to damp out these oscillations.The recent development in power electronic is used to improve the power quality. FACTS devices are used to secure and stable the complex power system. There are many FACTS devices like SVC, STATCOM and UPFC that are used in damping of power oscillations [7].First

* Electrical and Electronics Engineering Lovely Professional University Near Vankhandi mandir NH8, Behror, Alwar Rajasthan-301701. Email: jayendraparjapati@gmail.com

** Electrical and Electronics Engineering Lovely Professional University 200 V.N Park, Magsudan Jalandhar city, Punjab -144008 Email: Navita.17119@lpu.co.in

*** Electrical and Electronics Engineering Lovely Professional University Email: rananeha102@gmail.com

generation FACTS devices is Static VAR Compensator (SVC) that is used for improving voltage profile and reactive power compensation. Inter-area mode of oscillations is more effectively damp out by using STATCOM. UPFC is a versatile FACTS device which is also used for damping of oscillations [6].This paper investigates the damping of power oscillations in two area system. Two area system model has been developed using MATLAB/Simulinkwith STATCOM and UPFC. The result of UPFC is compared with STATCOM.This paper is structured as follow: section II presents about power system oscillation; section III presents about STATCOM and UPFC; section IV presents simulations and results and section V concludes the paper.

2. POWER SYSTEM OSCILLATION

When any fault and disturbance occur in the system, rotor angle oscillate near the steady state or normal operating value. Due to oscillation of the load angle, power generated by synchronous generator also oscillates near the steady state or normal operating value. The power oscillations are occurring in the range of .1 Hz to 2Hz [4]. The power oscillation is defined as local mode and inter- area mode. In local mode, an oscillation is occurring in the range of 1Hz to 2Hz and in which one generator is oscillating against rest of the system. In inter- area, an oscillation is occurring at a frequency of .1Hz and less, in which generator of one area oscillate with the ones in another area [1].

Reasons of Power System Oscillations

1. Due to dynamic loading.
2. Due to sub synchronous resonance.
3. Due to fault in the system.
4. Due to insufficient synchronizing torque.
5. Due to insufficient damping torque [8].

Effects of Power System Oscillations

1. It may be the limiting factor for the transmittable power.
2. It may also affect the load that is connected.
3. It reduces the thermal capacity of the line.
4. Low frequency power swing increases [4].

Benefits of Power Oscillation Damping

1. It increases the thermal capability of the line.
2. There is no damage on the load side.
3. Power transfer capacity is increased [4].

3. FACTS CONTROLLER

Generally FACTS devices are used for controlling the impedance, phase angle and voltage. Some brief introduction is given of FACTS devices which are used in the system model.

Static Synchronous Compensator (STATCOM)

It is connected in parallel with line. It is based upon voltage and current source converter. It works in both capacitive and inductive regions [8]. The voltage source converter’s output voltage is controlled according to the reactive current required into the line through capacitor which is worked as voltage source for converter [8].

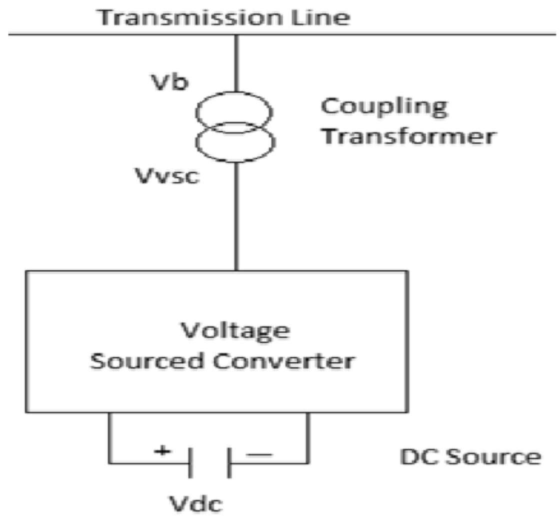

Figure 1 STATCOM connected to a line

Unified Power Flow Controller (UPFC)

UPFC is the most versatile FACTS device. It can control all the three parameters (voltage, impedance and angle) simultaneously. It can control both real and reactive power in the system. UPFC has two converters which are connected with one common dc link [8]. One of the converter is connected in series with line through series transformer. Another converter is connected in parallel with line through supply transformer. The real power is exchanged through dc link. The reactive power compensation is done by both the converters separately [8].

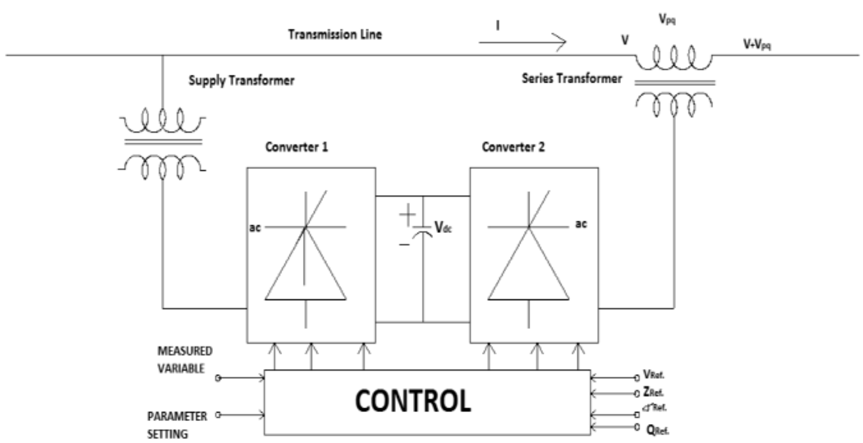

Figure 2 UPFC connected to a line

4. SYSTEM MODELING

Consider a two- area power system (area-1 and area-2). These areas are connected with FACTS devices, connected by a single circuit long transmission line as shown in figure 3 as the single line diagram.

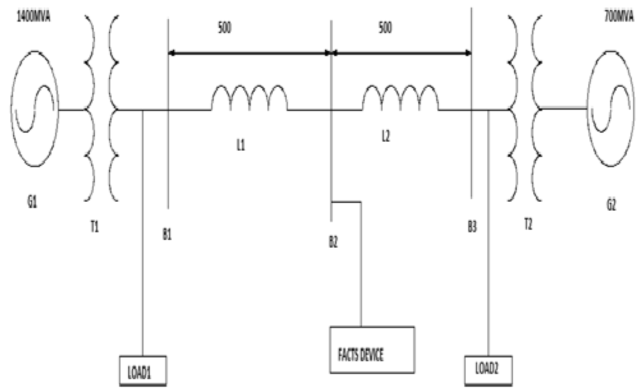

Figure 3 Single line diagram of two machine system with FACTS device

The two area system is modeled with two hydraulic generating units. In which one of the unit is of 1400MVA and another is of 700 MVA, respectively. It is two machine three bus models. This model is made in the MATLAB/Simulink environment. The length of each transmission line is 500Km. Two machines are connected with a hydraulic turbine and governor (HTG), excitation system. These components are included in blocks of subsystem-1 and subsystem-2, accordingly.

5. SIMULATIONS AND RESULTS

In basic model of two machine system, initial power output of the first generator is P_1=0.9 p.u. and the second generator initial power output is P_2 =0.9 p.u. The excitation system and a hydraulic turbine and governor (HTG) are used in both the generators. The rating of first generator is 1400MVA and rating of second generator is 700MVA. The rating of step up transformer is 13.8kV/500kV and it is used in both the sides. Both transformers have same rating which is 700MVA. Two transmission lines of equal length which is 500km are connected between three buses. All three buses have same rating. For analysis of power oscillation damping, a three phase fault is created in the system. After occurrence of the fault, we analysis the variation in the rotor angle. We created the fault in the system during 0.0167 to 0.0833 seconds. There is large variation in the rotor angle during this time duration. These oscillations are damped out using different FACTS devices. In this, we use STATCOM and UPFC to damp out the power oscillations from the system.

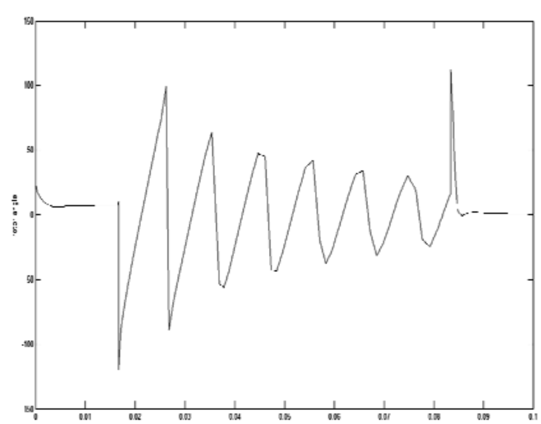

Figure 4: Variation of rotor angle with three phase fault

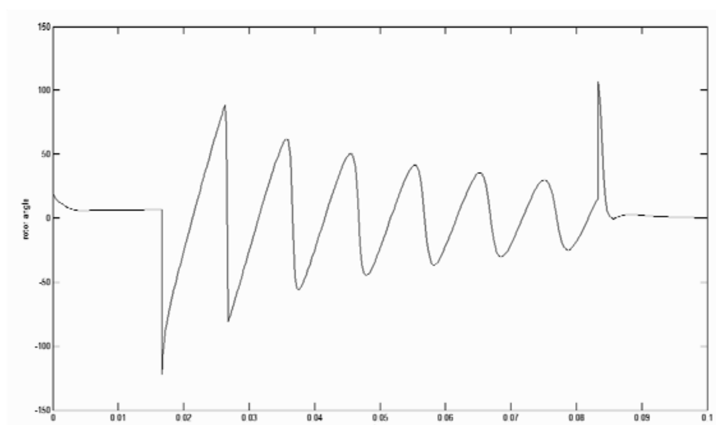

Figure 5: Variation of rotor angle with STATCOM in two machine system

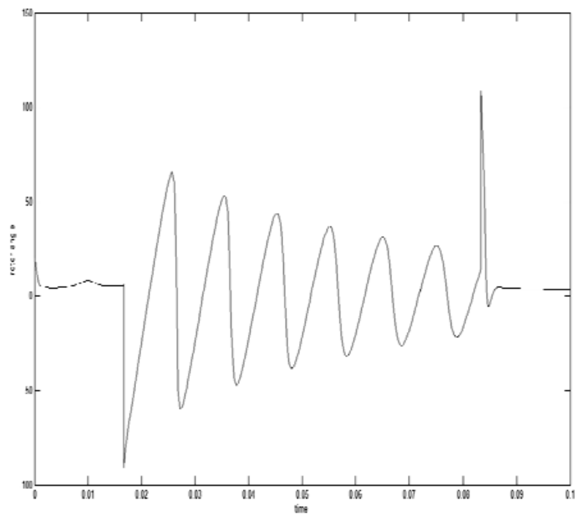

Figure 6: Variation of rotor angle with UPFC in two machine system

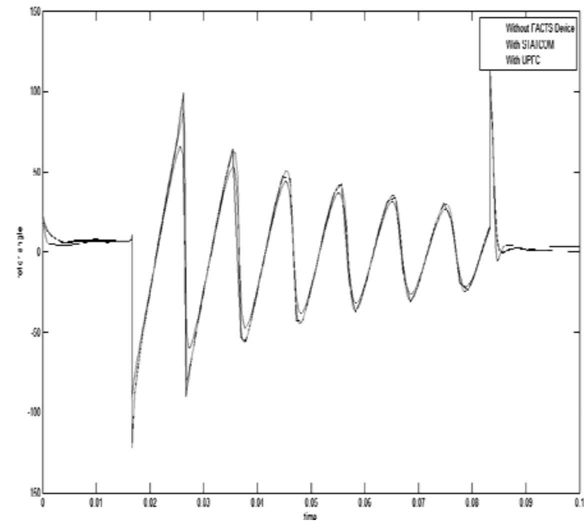

Figure 7: Comparison of results

From the above simulation results, we conclude that:

1. First peak overshoot is decreases, when we use FACTS devices.
2. Settling time is also reduced.
3. Waveform becomes more sinusoidal.

6. CONCLUSION

In this study, two-machine model is used for analysis of power oscillations. A MATLAB simulation of the system is used for studying the effect of oscillations on the power system and methods for damping these oscillations. It has been observed that oscillations are damp out by use of FACTS devices. Power oscillations are damped out from the system, power quality is improved. UPFC is better than STATCOM in damping of power oscillations.

The work done so far can be summarized in the following points:

(a) Oscillations are occurs in the system due to faults in the system.

(b) These oscillations are damp out by using STATCOM.

(c) Damping of oscillations is improved by using UPFC rather than STATCOM. Settling time is also reduced.

(d) Better results can be achieved in future by using different controllers.

(e) Due to these oscillations, power quality is decreases and life of the equipments is reduced.

7. APPENDIX

The data which is used in MATLAB model is given as

Generator parameters

M_1 = 1400MVA, M_2 = 700MVA, V = 13.8 kV, F= 60 Hz, X_d = 1.305Ω, X_d^1 = 0.296Ω, X_d" = 0.255Ω, X_q = 0.474Ω, X_q = 0.243Ω, X_l = 0.18Ω

Transformer parameters

T_1 = 1400MVA, 13.8/500 kV, T_2 = 700MVA, 13.8/500 kV, R_2 = 0.002Ω, L_2 = 0.12H, R_m = 500Ω

Transmission Line parameters

Number of phases = 3, F= 60Hz, Line Length = 500 Km, R_1 = 0.1755Ω, R_0 = 0.2758Ω, L_0 = 0.8737mH, L_1 = 3.22mH, C_1 = 13.33μF, C_0 = 8.279μF

STATCOM parameters

System nominal voltage = 500 kV, F = 60Hz, STATCOM ranting = 100MVA, R = 0.0073Ω, L = 0.22H, C = 325μF

UPFC parameters

System nominal voltage = 100kV, F = 60Hz, Shunt converter rating = 100MVA, R_1 = 0.0073Ω, L_1 = 0.22H, C = 325μF, Series converter rating = 100MVA, R_2 = 0.0053Ω, L_2 = 0.16H

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