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Minimization of Low Frequency Oscillatios in the Power System Using PSS and UPFC

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Abstract

The characteristics of integrated power system under normal operating conditions express full reliability of power supply. But due to fault conditions and sudden variation in loads, the power system causes the low frequency oscillations. They greatly affect the power system characteristics, the transmission line transfer capability and power system stability. The unwanted frequencies are reduced with help of FACTS controller and Power System Stabilizer (PSS). The effect of Unified Power Flow Controller (UPFC) on the system under various fault conditions and disturbances are examined using simulink software.

Keywords: FACTS, low frequency oscillations, PSS, Fault, UPFC.

1. Introduction

The power system is an interconnection of generating units to load centers through high voltage electric transmission lines and in general which is mechanically controlled. The FACTS technology that provides the need correction of the transmission functionality in order to fully utilize the existing transmission facilities and thus reducing the difference between the thermal limit and stability limit. The power system parameter namely terminal voltage, line impendence and phase angle is controlled by using FACTS device like UPFC control the real and reactive power flow control in the network and power system stabilizing control. The main objective of the paper is

1. To analyze the UPFC based PSS,
2. To evaluate the approximate effectives of modulating UPFC and PSS parameters, and
3. To examine the performance of UPFC based PSS for 6-bus system. Under LG, LLG, LLLG fault conditions and system parameters.

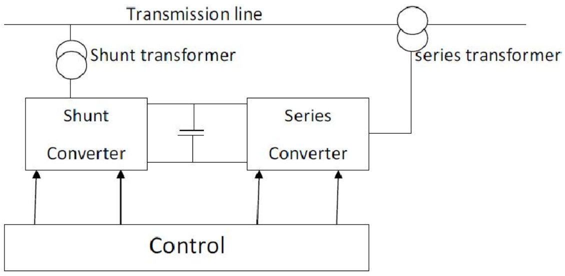


Fig.1: Practical implementation of UPFC.

2. UPFC operation under various operating conditions

The UPFC can be investigated under the following conditions

1. Operation Under Steady state condition,
2. Operation Under power system oscillations,
3. Operation Under line conditions.

2.1 UPFC Operation under Steady state condition

During the steady-state operating it neither absorbs nor injects real power with respect to the system, the voltage of the DC capacitor remains constant at the prespecified value "V_{dc}". Hence, under steady state conditions the losses are neglected and the two sources are mutually decent.

2.2 Operation Under power system oscillations

The main factors for power system oscillations are

(a) Loading of the generator or tie line,

(b) Disturbances on the line.

The UPFC operation under power system oscillation can analyze with help of swing block equation. To initiate a oscillation in the simple system model, a fault was applied for duration of several cycles through impedance to ground at the "V_r" bus as shown in Fig2. The rate of change of the differential phase angle between the sending end and receiving end buses ($d\partial/dt$) is sensed and fed into the real power command P_{real}, for the UPFC with the correct polarity and an appropriate gain can control the power flow through the line which helps in generating source to relieve from sudden loads and reduces system oscillations.

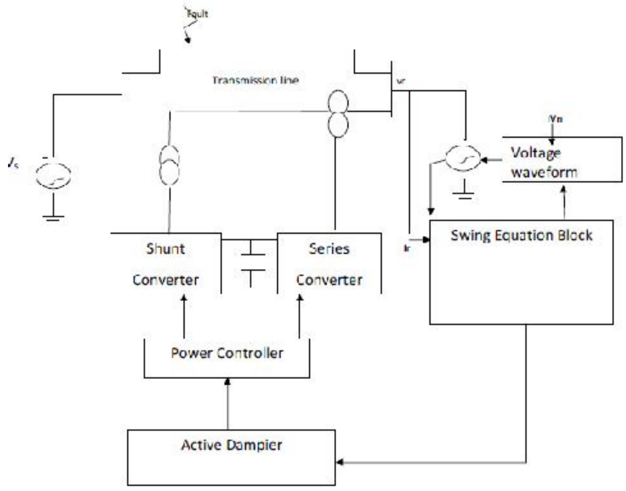


Fig. 2: Block diagram showing the "swing block" and UPFC.

2.3UPFC operation under line faults

Whenever the UPFC senses the over current on faulted phases, it immediately activates the electronic bypass to protect the series converter. During the fault the shunt converter may, if desired, remain operational to supply reactive compensation. A simplified schematic of power system installed with UPFC during fault condition as shown in Fig3. Depending on the line impedance of the line, the location of the fault and line current during faults may reach a magnitude which would for exceed the converter rating. Under this condition the UPFC would typically assume a bypass operating mode for the contingency of delayed fault clearing

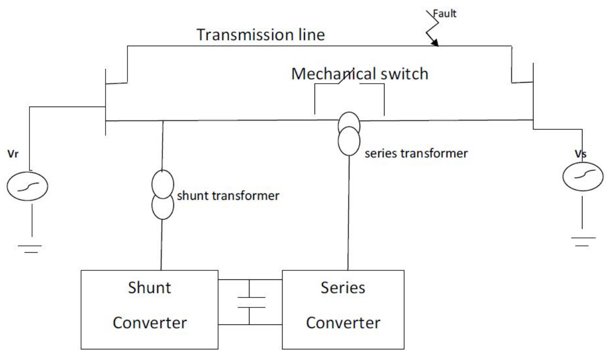


Fig. 3: Simplified schematic of power system.

3. Power System Stabilizer

The dynamic stability of a system can be improved by providing suitable tuned PSS on selected generators to provide damping of low frequency oscillations. In a practical interconnected power system consist of various modes of oscillations such as inter-plant mode (Range of 1.5 to 3.0 Hz), local mode (Range 0.8 to 1.8 Hz) and inter area oscillation frequencies (Range of 0.2 to 0.5 Hz). The PSS will introduce a component of electrical torque in phase with the generator rotor speed deviations resulting in damping of low frequency power oscillations in which generators are participating. The PSS is designed mainly to stabilize local and inter area modes.

3.1. Structure of PSS

The structure of a PSS as shown in Fig.4. The PSS consists of washout block, dynamic compensator block and limiter. It is to be noted that the major objective of providing PSS is to increase the power transfer in the network, which would otherwise limited by oscillatory instability.

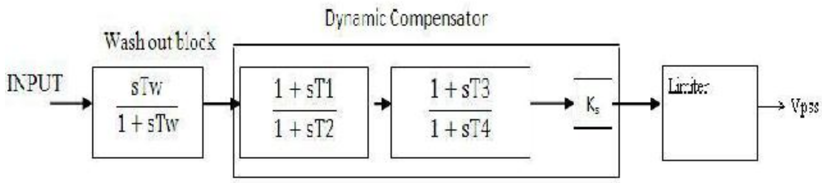


Fig.4: The Structure of PSS

3.1. A. Wash out block: serves as a high-pass filter, with the time constant T_W high enough to allow signals associated with the oscillations in ω_r to pass unchanged, which modify the terminal voltage. It allows The PSS to respond only to changes in the speed.T_W may be in the range of 1 to 20seconds.

3.1. B. The Dynamic compensator: It is used in industries have two lead lag stages and it is shown in the above Fig4. Where K_s is the amount of damping introduced by the PSS. Ideally, the gain should be set at a value corresponding to maximum damping however it is often limited by other considerations. Time constants T_1 to T_4 are chosen to provide a phase lead for the input signal in the range of frequencies that are interest.

3.1. C. Limiter: It is designed to pass the swing mode frequency signal while allowing from any variation in this frequency from system conditions. It rejects frequencies associated with non-power swing modes, such as sub synchronous tensional oscillations and modes relating to noise signals that override the auxiliary control signals. In some cases, this noise may be within the bandwidth of the power swing frequencies.

4. System Investigated

A multimachine system having 6-bus with UPFC shown in Fig6. The system investigated for two synchronous generators, one equivalent 3-phase source and a load which is connected to bus bar 3. Generator 1 is connected to bus1 and generator 2 is connected to bus 4. Initially the UPFC is not connected to 6-bus system and the performance of system during various disturbances is studied and after that UPFC is placed between bus 3 and bus 6.

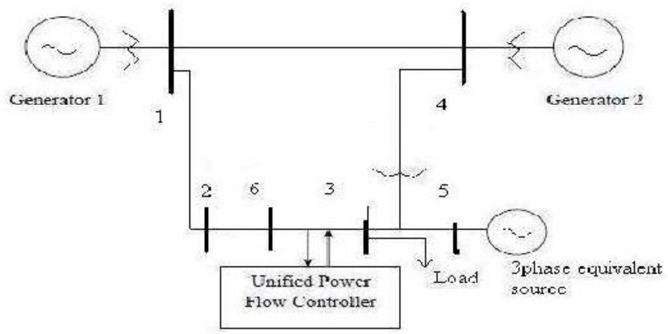
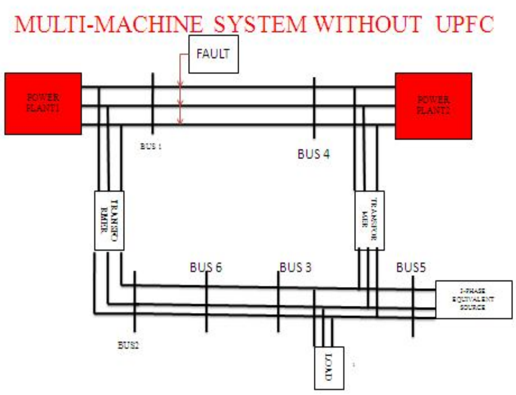


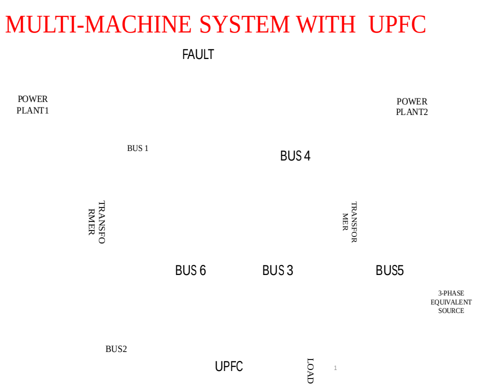
Fig. 5: UPFC Installed in Multimachine system having 6-bus.

5. Modeling of system

The two generators are connected to two transformers which are connected to a transmission system 500KV/230KV.the 6 buses are connected in loop configuration through the transmission lines (L_1, L_2, L_3) and two transformer banks 500KV/230KV. The two power plants generate a total power of 1500MW which is located on the 230KV system and transmitted to 500KV 15000MVA equivalent and to a 200MW load connected to bus1. The power plant model consists of a speed regulator, an excitation system as well as PSS. The system specifications of the multimachine system as following ratings.

1. Two Generators of 13. 8 KV, 1000 MVA, rotor type: salient pole each with mechanical input is 0.5 P.U.
2. Two Transformers connected in Delta / Star fashion along the generator side, and in main network Star / star fashion with 230 KV / 500 KV respectively.
3. Line L_1, L_2, L_3 each of 100 KM.
4. Three phase VI measurement blocks B_1, B_2, B_3, B_4, $B_{5,}$ B6 of base voltage of 230 KV, and base power of 100 MVA respectively.
5. Three phase voltage source in series with R-L branch having phase to phase rms voltage of 500 KV and X/R ratio of 10.
6. Three phase parallel RLC load of voltage 500 KV and power of 200 MW.





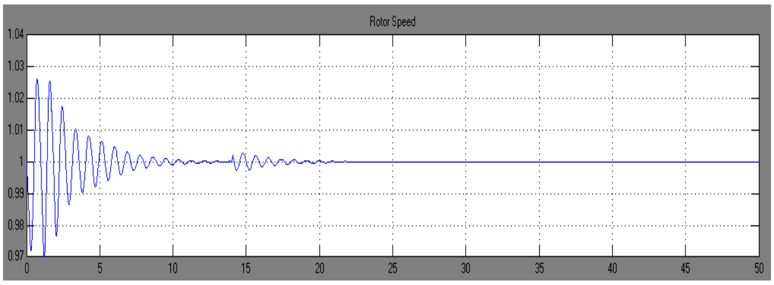
6. Simulation results and analysis

The system is examined under various conditions such as oscillations and fault conditions. Here the fault is created at t=14 sec and is cleared at t=14.1 sec. The systems tested under various LG, LLG, LLLG conditions are:

Case1: LG fault condition

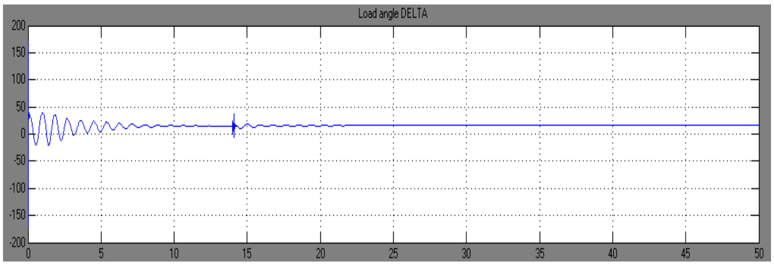
1.1Simulation results of multimachine system without PSS, UPFC and fault:

(A). The Rotor speed (Wm) with respect time response:



In this case, at 14sec the LG fault is created and it's cleared at 14.1 sec and the time taken to stabilize the system is of approximately at 25.4 sec.

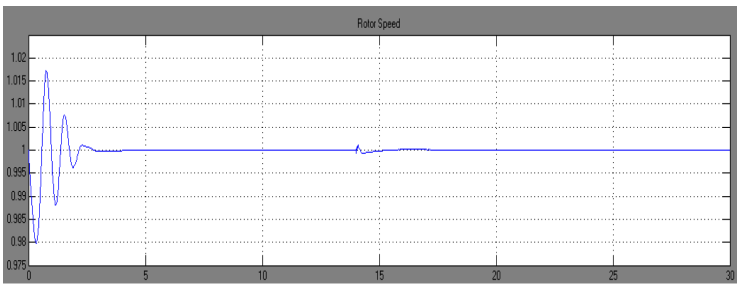
(B). load angle (∂) with respect to time response:



In this case, at 14sec the LG fault is created and it's cleared at 14.1 sec and the time taken to stabilize the system is of approximately at 18.1 sec.

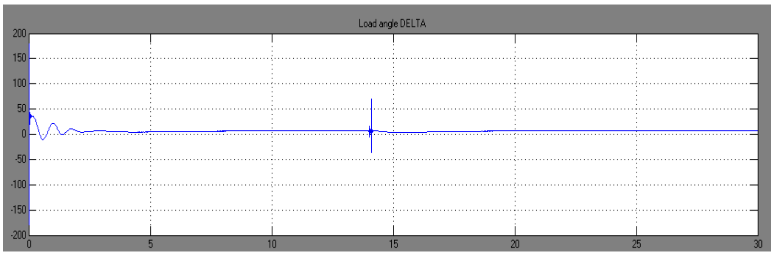
1.2Simulation results of multimachine system with PSS, UPFC and fault:

(A). The Rotor speed (Wm) with respect time response:



In this case, the system is analyzed with UPFC. At 14sec the LG fault is created and it's cleared at 14.1 sec and the time taken to stabilize the system is of approximately 15.4 sec.

(B). load angle (∂) with respect to time response:

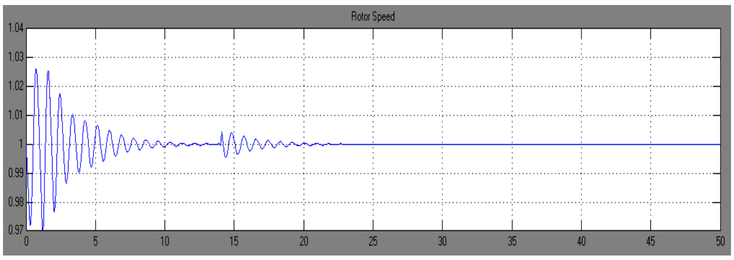


In this case, the system is analyzed with UPFC. At 14sec the LG fault is created and it's cleared at 14.1 sec and the time taken to stabilize the system is of approximately 14.8 sec.

Case2: LLG fault condition

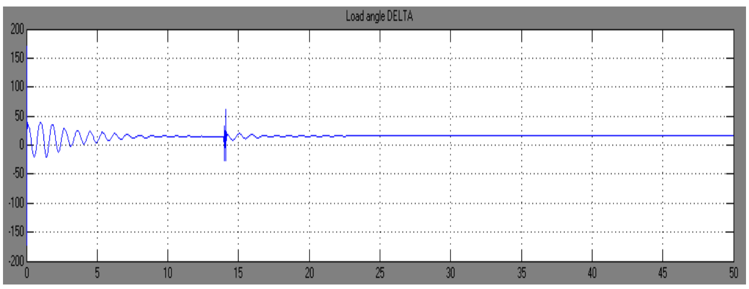
2.1Simulation results of multimachine system without PSS, UPFC and fault:

(A). The Rotor speed (Wm) with respect time response:



In this case, at 14sec the LLG fault is created and it's cleared at 14.1 sec and the time taken to stabilize the system is of approximately at 26.2 sec.

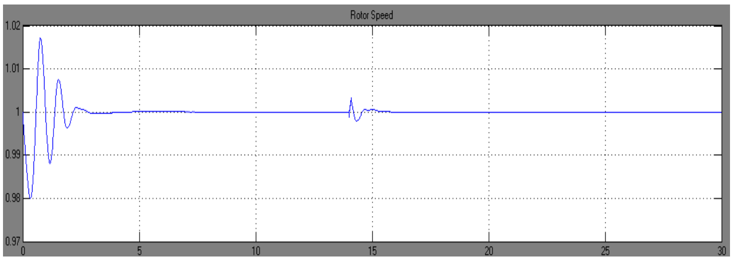
(B). load angle (∂) with respect to time response:



In this case, at 14sec the LLG fault is created and it's cleared at 14.1 sec and the time taken to stabilize the system is of approximately at 19 sec.

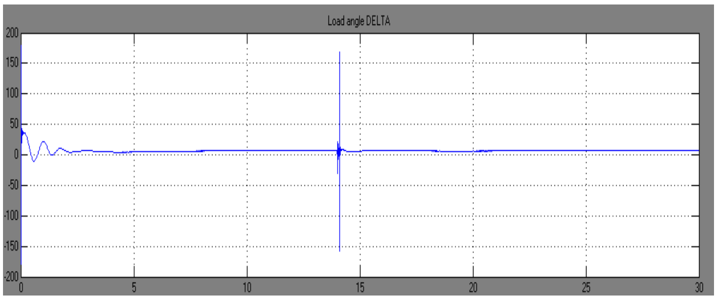
2.2Simulation results of multimachine system with PSS, UPFC and fault:

(A). The Rotor speed (Wm) with respect time response:



In this case, the system is analyzed with UPFC. At 14sec the LG fault is created and it’s cleared at 14.1 sec and the time taken to stabilize the system is of approximately 16 sec.

(B). load angle (∂) with respect to time response:

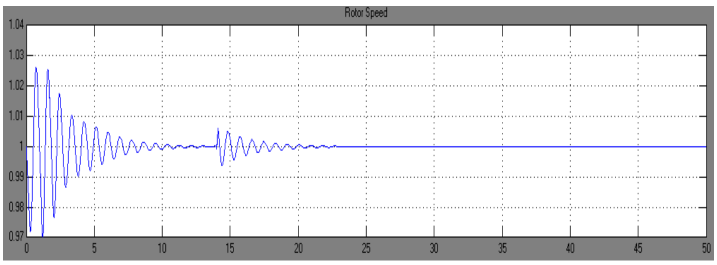


In this case, the system is analyzed with UPFC. At 14sec the LLG fault is created and it’s cleared at 14.1 sec and the time taken to stabilize the system is of approximately 15.2 sec.

Case3: LLLG fault condition

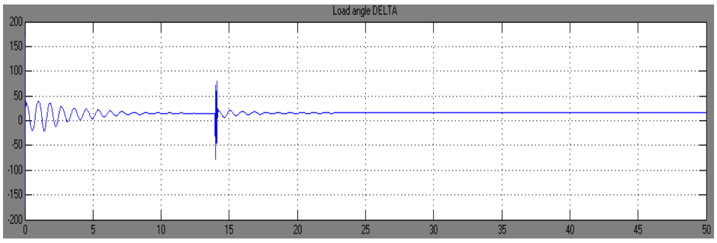
3.1 Simulation results of multimachine system without PSS, UPFC and fault:

(A). The Rotor speed (Wm) with respect time response:



In this case, at 14sec the LLLG fault is created and it’s cleared at 14.1 sec and the time taken to stabilize the system is of approximately 32 sec.

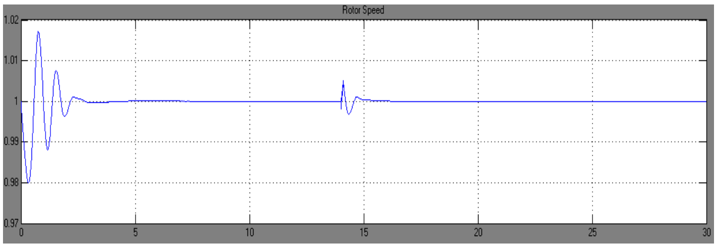
(B). load angle (∂) with respect to time response:



In this case, at 14sec the LLLG fault is created and it's cleared at 14.1 sec and the time taken to stabilize the system is of approximately 26.1 sec.

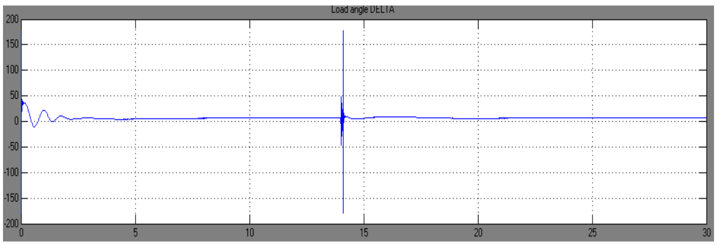
3.2 Simulation results of multimachine system with PSS, UPFC and fault:

(A). The Rotor speed (Wm) with respect time response:



In this case, the system is analyzed with UPFC. At 14sec the LLLG fault is created and it's cleared at 14.1 sec and the time taken to stabilize the system is of approximately 16.1 sec.

(B). load angle (∂) with respect to time response:



In this case, the system is analyzed with UPFC. At 14sec the LLLG fault is created and it's cleared at 14.1 sec and the time taken to stabilize the system is of approximately 18 sec.

7. Conclusion

The combination of PSS and UPFC controller minimize the low frequency electromechanical oscillations presents in the power system during various disturbances and loading conditions. In this paper the position of UPFC is kept constant at the midpoint of the transmission lines. The combination of PSS and UPFC not only reduces the system oscillations but also reduces the oscillations presents in the real and reactive power and phase voltage that is it maintains the constant power flow after the fault.

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