IMPROVEMENT OF POWER SYSTEM OPERATION USING SIMULINK MODEL OF UPFC

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ABSTRACT

This paper deals in a systematic approach for designing Unified Power Flow Controller (UPFC) based damping controllers for damping low frequency oscillations in a power system. Fuzzy logic is also incorporated to damp low frequency oscillation. Detailed study have been done and their simulink models are generated considering four alternative UPFC based damping controllers. The comparative study is also done with and without damping controller using simulink model.

1. INTRODUCTION

Power systems over the worldwide becoming complex day to day and continuous requirements are coming for stable, secured, controlled, economic and better quality power. These requirement become more essential when deregulation environment becoming more vital and important. Power transfer capacity in transmission system is limited due to various factor such as steady state stability limit, thermal limit, transient stability limit and system damping or even negative damping. The scenario of the magnitude of various limits are given in Figure 1.

Flexible AC Transmission System provides feasible and cost-effective solution to these problems and so these devices are required to use worldwide for improving performance of power system.

2. EXPERIMENT

(A) Basic Approach

The SMIB test system has been considered for evaluating the performance of developed controller. Firstly we will simulate the Heffron-Phillips model for SMIB without any controller, and then UPFC will be installed in that system to see the system behavior. Afterwards we will carry out simulation study of the damping controller for UPFC for enhancing the transient stability of the SMIB system.

(B) Single Machine Infinite Bus (Smib) System

We analyze the SMIB with and without UPFC. Initial condition and system data are given in Appendix A. To see the system performance, we have to build Heffron-Phillips model for SMIB. Using initial data condition and basic equation given in Appendix B, we calculate the K-constants (K₁, K₂, K₃, K₄, K₅ and K₆) [6] for above test system. Using these different calculated K-constant, make Heffron-Phillips simulation model using SIMULINK.
(C) SMIB System Without UPFC

Using given data, with input of step load perturbation and calculated K constant value, we form a simulation model shown in Fig. 2(b).

The output of this simulation model is taken as speed deviation ($\Delta w$) and angle deviation ($\Delta \delta$). So, the following response is formed for speed deviation ($\Delta w$) and angle deviation ($\Delta \delta$) against time from simulation model using SMIB system. The simulation process is carried for duration of 10 second. The time division scale is converted in to points i.e. 10s = 300 points.

From viewing response of the system we have, the variation in speed and angle is oscillatory in nature. Due to formation of these oscillations the system is unstable. To improve the system performance and getting the stable position we have to eliminate these oscillations. To eliminate these oscillations and improving system performance we install UPFC with this SMIB system.

(D) SMIB System with UPFC

As primary function of UPFC is not only the power flow control but also transient stability and damping the oscillation in power system. In this case UPFC is installed with in line, to damp the oscillation occurred due to load perturbation. The data for UPFC is also given in Appendix A. To see the performance of system installed with UPFC, the procedure is same for this case as described in case of without UPFC. We make a modified Heffron-Phillips model for SMIB system using UPFC. In this case we use the dynamics and linearized model of UPFC. In this case we are not only calculating the modified K-constants for Heffron-Phillips model, but also the constants for FACTS device which are installed in system i.e. $K_p$, $K_q$ and $K_v$. These constants are required to see the effect of FACTS devices on power system.

As we know that, the significant control parameters of UPFC are $m_E$, $\delta_E$, $m_B$ and $\delta_B$. By controlling $m_B$, the magnitude of series injected voltage can be controlled, therefore controlling the reactive power compensation. By controlling $\delta_E$ of series converter results in real power exchange.

By controlling $m_E$ the voltage at a bus where UPFC is installed is controlled through reactive power compensation. By controlling $\delta_B$ easier to regulates the dc voltage at dc link. Hence by taking consideration of individual control parameters of UPFC i.e. based on $m_E$, $\delta_E$, $m_B$ and $\delta_B$, we will investigate the performance of SMIB system.

Again, In this case also, we see the response of system for speed deviation and angle deviation against time. The value of FACTS device constant ($K_p$, $K_q$ and $K_v$) is different for each control parameters of UPFC i.e.
based on $m_p$, $\delta_p$, $m_e$ and $\delta_e$. The simulation model of SMIB system with UPFC is shown in Fig. 4. The response of system with individual control parameter of UPFC is shown in figures below.

![Figure 4: Simulation Model for SMIB with UPFC](image)

![Figure 5: Response of System from $m_b$ Based UPFC](image)

![Figure 6: Response of System from $\delta_b$ Based UPFC](image)

![Figure 7: Response of System from $m_e$ Based UPFC](image)
In this case also, the formation of damping controller is based on control parameter of UPFC i.e. $m_{\beta r}$, $\delta_{\beta r}$, $m_{E}$, and $\delta_{E}$. The corresponding gain and phase compensation constant is different for every control parameter based UPFC. To see the performance of SMIB system, output is taken as in terms of angle deviation i.e. $\Delta \delta$. The response of system is formed by using $m_{B}$ based damping controller for UPFC is shown in Figure 10.

(F) SMIB System with Fuzzy Controller for UPFC

As the response of SMIB system with damping controller is shown in Fig. 10. In this subsection we install a fuzzy damping controller for UPFC. The input given to fuzzy damping controller is $\omega$ and its integral. The output formed from fuzzy logic controller is given as input to UPFC. Here also, the formation of fuzzy controller depends on $m_{\beta r}$, $\delta_{\beta r}$, $m_{E}$, and $\delta_{E}$ parameter based UPFC. The simulation model is shown in Figure 11. For designing purpose of fuzzy damping controller, in preprocessing state a gain and signal washout is used whose values can be tuned depending upon which type of UPFC (based on control parameter) is used. In this simulation model a MATLAB function code is introduced which works as fuzzy logic controller. The value of controller gain variable and constant used in fuzzy logic controller are adjustable.

The following response of system is formed using $m_{\beta r}$, $\delta_{\beta r}$, $m_{E}$, and $\delta_{E}$ based UPFC using fuzzy controller.
3. CONCLUSION

The response of SMIB using UPFC with damping controller and fuzzy controller are shown in Fig 10 and Fig. 12 respectively. In comparison of both compensation technique and fuzzy technique based controller, the response of fuzzy based controller is better. Looking at Fig. 10 and 12, it is evident that peak overshoot in angle of machine with fuzzy damping controller is negligible where as it has a visible high value in range of 13-15% with compensation based damping controller. Thus it can be concluded that system is stabilized quickly and efficiently with fuzzy damping controller.

APPENDIX A

The nominal parameters and the operating conditions of the SMIB system are given below (all value in pu):

**Generator:**
- \( H = 4 \)
- \( M = 2H \)
- \( D = 0.0 \)
- \( Td_o' = 6.0 \) s
- \( X_d = 1.0 \)
- \( X_q = 0.6 \)
- \( X_d' = 0.3 \)

**Excitation System:**
- \( T_a = 0.01 \) s
- \( K_a = 100 \)

**Transformer:**
- \( X_{TE} = 0.1 \)
- \( X_E = 0.1 \)
- \( X_B = 0.1 \)

**Transmission Line:**
- \( X_{BV} = 0.3 \)

**Operating Condition:**
- \( V_t = 1.0 \)
- \( V_b = 1 \)
- \( P_t = 0.2 \)
- \( f = 50 \) Hz

**UPFC Parameters:**
- \( m_B = 0.0789 \)
- \( m_E = 0.4013 \)
- \( \delta_B = -78.2174^\circ \)
- \( \delta_E = -85.3478^\circ \)

**Parameters of DC link:**
- \( V_{dc} = 2 \)
- \( C_{dc} = 1 \)

REFERENCES


