FUZZY CO-ORDINATION OF UPFC FOR DAMPING POWER SYSTEM OSCILLATION

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ABSTRACT

In this paper the parameters of facts controller are optimized and a hybrid fuzzy logic controller for the coordination of facts controller is present. This coordination method is well suitable for series connected facts devices like a UPFC.

Index Terms: Damping Power System, FACTS devices, Fuzzy Logic Controller, UPFC

I. INTRODUCTION

Nowadays, FACTS devices can be used to control the power flow and enhance system stability. They are playing an increasing and major role in the operation and control of power systems. The UPFC (Unified Power Flow Controller) is the most versatile and powerful FACTS device. The parameters in the transmission line, i.e. line impedance, terminal voltages, and voltage angle can be controlled by UPFC. It is used for independent control of real and reactive power in transmission lines. Moreover, the UPFC can be used for voltage support and damping of electromechanical oscillations.
In this study, the linearized Phillips-Heffron model of a power system equipped with UPFC and demonstrates the application of the model in analyzing the damping effect of the UPFC and designing UPFC based stabilizer to improve power system oscillation stability. A comprehensive approach to the design of UPFC based stabilizer (power flow control, DC-voltage regulator and damping controller) is presented. In this case, the multi-machine power system with UPFC is studied and an example of power system is presented. It is shown that the DC voltage contributes negative damping to power system oscillations, which is confirmed by both eigen value computation and nonlinear simulation. To counterattack the negative damping effect due to the DC voltage regulator, UPFC based stabilizer is designed and its effectiveness is demonstrated by both eigen value computation and nonlinear simulation. Then the effects of UPFC and PSS on power systems are compared. Simulation results show that the performance of UPFC based stabilizer on damping of power system is better than PSS. In this case, the multi-machine power system with UPFC is studied and it has been shown that the DC voltage contributes negative damping to power system oscillations, which is confirmed by both eigen value computation and nonlinear simulation[1]-[3]. The use of the supplementary controller of a unified power flow Controller (UPFC) to damp low frequency oscillations in a weakly connected system is investigated. The potential of the UPFC supplementary controllers to enhance the dynamic stability is evaluated. Two different objective functions are proposed in this work for the controller design problem. The first objective is eigen value-based while the second is time domain-based objective function. The UPFC controller design problem is solved using particle swarm optimization (PSO) technique. The effectiveness of the proposed controllers on damping low frequency oscillations is tested and demonstrated through non-linear time simulation. In addition, a comparison between the objectives is carried out. It can be concluded that the time domain-based design improves greatly the system response under fault disturbances [4]-[6]. The Unified Power Flow Controller (UPFC) is the most versatile and complex power electronic equipment that has emerged for the control and optimization of power flow in electrical power transmission system. This paper presents real and reactive power flow control through a transmission line by placing UPFC at the sending end using computer simulation. When no UPFC is installed, real and reactive power through the transmission line cannot be controlled. This paper presents control and performance of UPFC intended for installation on that transmission line to control power flow. A control system which enables the UPFC to follow the changes in reference values like AC voltage, DC voltage and angle order of the series voltage source converter is simulated. In this control system, a generalized pulse width modulation technique is used to generate firing pulses for both the converters. Installing the UPFC makes it possible to control an amount of active power flowing through the line. Simulations were carried out using MATLAB and PSCAD software to validate the performance of the UPFC [7]. While the controllability of the line power flow by unified power flow controller (UPFC) has been recognised, only very limited information is available concerning the quantitative control of the UPFC to provide additional damping during system oscillations. This paper presents a current injection model of UPFC which is suitable for use in power system stability studies. To use the current injection model on dynamic stability studies, a proper control method is necessary. It is proposed that the shunt compensation of UPFC is controlled to maintain the system bus voltage and the two components of UPFC
series voltage, which are in phase and quadrature with the line current, are controlled in coordination by Strip Eigen value Assignment method. The eigen value analysis and time domain simulation results show that the proposed model and control method can substantially improve the dynamic stability of the power system [8]. In this case, an adaptive tuning of parameters of a power oscillation damping (POD) controller for FACTS devices are discussed. The FACTS devices considered here are the Thyristor Controlled Series Compensator (TCSC) and the Unified Power Flow Controller (UPFC). A residue method is applied to the linearized power system model to determine the best siting for FACTS devices as well as for the selection of measured signals. Information available from a higher control level, e.g. from a wide-area monitoring and control platform, is used for a fine tuning of the POD controller in case of changing operating conditions[5]. With increased power transfer, transient stability is increasingly important for secure operation. Transient stability evaluation of large scale power systems is an extremely intricate and highly non-linear problem. An important function of transient evaluation is to appraise the capability of the power system to withstand serious contingency in time, so that some emergencies or preventive control can be carried out to prevent system breakdown. In practical operations correct assessment of transient stability for given operating states is necessary and valuable for power system operation. Static VAR Compensator is a shunt connected FACTS devices, and plays an important role as a stability aid for dynamic and transient disturbances in power systems. UPFC controller is another FACTS device which can be used to control active and reactive power flows in a transmission line. The damping of power system oscillations after a three phase fault is also analyzed with the analysis of the effects of UPFC on transient stability performance of a power system. A general program for transient stability studies to incorporate FACTS devices is developed using modified partitioned solution approach [9].

In this paper, a multimachine system with UPFC is simulated. Damping of electromechanical oscillations between interconnected synchronous generators is necessary for secure system operation. A well-designed FACTS controller can not only increase the transmission capability but also improve the power system stability. A series of approaches have been made in developing damping control strategy for FACTS devices. The researchers are mostly based on single machine system. However, FACTS devices are always installed in multi-machine systems. The coordination between FACTS controllers and other power system controllers is very important. Fuzzy-coordination controller is presented in this paper for the coordinated of traditional FACTS controllers. The fuzzy logic controllers are rule-based controllers in which a set of rules represents a control decision mechanism to adjust the effect of certain cases coming from power system. Furthermore, fuzzy logic controllers do not require a mathematical model of the system. They can cover a wider range of operating conditions and they are robust.

This paper on the optimization of conventional power oscillation damping (PI) controllers and fuzzy logic coordination of them. By using fuzzy-coordination controller, the coordination objectives of the FACTS devices are quite well achieved.
II. CONVENTIONAL CONTROLLERS

A. PI Controller

It is well known the integral part of the PID controller produces a signal that is proportional to the time integral of the input of the controller. Figure 1 shows the block diagram of a feedback control system that has a plant with transfer function $G_p(s)$, and a controller with proportional-integral (PI) components.

![Figure 1 Feedback control system with PI Controller.](image)

B. PID Controller

PID is one of the most popular control algorithms used in the industry, power grid, etc. to control the variables involved in an industrial manufacturing process, for the proper operation of the process. If the set point changes, the PID algorithm can quickly bring the process back under control. To achieve a stable and responsive process control, it is very important to select the proper PID parameters. Experienced users can estimate good starting values for these parameters and later tweak them to optimize the PID loop performance. This is called as the manual tuning of the process.

C. POD Controller (power system oscillation damping controller)

Commonly the POD controllers involve a transfer function consisting of an amplification link, a washout link and two lead-lag links. A block diagram of the conventional POD controller is illustrated in Fig.2.

![Figure 2 POD Control.](image)

III. PROPOSED SYSTEM

The UPFC (Unified Power Flow Controller) is the most versatile and powerful FACTS device. The parameters in the transmission line, i.e. line impedance, terminal voltages, and voltage angle can be controlled by UPFC. It is used for independent control of real and reactive power in transmission lines. Moreover, the UPFC can be used for voltage support and damping of electromechanical oscillations. Damping of electromechanical oscillations between interconnected synchronous generators is necessary for secure system operation. With all the encompassing
capabilities of voltage regulation, series compensation and phase shifting, it can independently and very rapidly control both real and reactive power flows in a transmission line. In a power system installed with UPFC, the three control aspects become available in-phase voltage control, quadrature voltage control aspects control and shunt compensation. It is very important to quantify the effectiveness of these three control actions in the best possible way to utilize the available ratings of the UPFC. A shunt series connected FACTS controller that can control the various electrical parameter (voltage, real power flow and reactive power flow) either individually or simultaneously is known as Unified Power Flow Controller. It is combination of STATCOM and SSSC, coupled via a common dc link, to allow bi-directional flow of real power between the series and shunt terminals. The UPFC may also provide independently controllable shunt reactive compensation. The UPFC consist of two solid-state voltage source converters, which are connected through a common dc link capacitor. The first voltage source converter known as STATCOM injects an almost sinusoidal current, of variable magnitude, at the point of connection. The second voltage source converter is known as SSSC, injects an almost sinusoidal voltage, of variable magnitude, in series with the transmission line. The injected voltage can be at any angle with respect to line current. The exchanged real power at the terminals of the inverter with the line flows to the terminals of the other inverter through the common dc link capacitor. In addition, each inverter can exchange reactive power at its terminal independently. A well-designed FACTS controller can increase the transmission capability but also improve the power system stability. A series of approaches have been made in developing damping control strategy for FACTS devices. The future hope of this project is to design the Unified Power Flow Controller (UPFC) coordinated with the Fuzzy Controller to damp the power system oscillations. The advantage of this project is to increase the stability of the power system. Using fuzzy based controller instead of conventional PID controller, the nonlinearity has been rectified.

IV. SIMULATION RESULTS AND DISCUSSIONS

Fig.3 without UPFC Simulation Circuit
Delay Time

Figure 4 Without UPFC waveform

The output waveform of without UPFC was drawn between power angle and delay time. The oscillations to be minimized at the time of 0.087 sec.

Figure 5 with UPFC Simulation Circuit

Figure 6 With UPFC waveform.
The output waveform of without UPFC was drawn between power angles and delay time. By using UPFC in the power line the oscillations to be minimized at the time of 0.045 sec.

![Figure 7 Output Waveform of Fuzzy Co-ordination of UPFC](image)

The output waveform of without UPFC was drawn between power angles and delay time. By using Fuzzy controller coordination of UPFC the oscillations to be minimized at the time of 0.041 sec.

![Figure 8 Comparison waveform of with & Without UPFC and Fuzzy Coordination](image)

**TABLE I: COMPARISON OF WITH UPFC, WITHOUT UPFC AND FUZZY COORDINATION**

<table>
<thead>
<tr>
<th>Sl.No</th>
<th>Type of Controller</th>
<th>Delay Time in seconds</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Without UPFC</td>
<td>0.087</td>
</tr>
<tr>
<td>2</td>
<td>With UPFC</td>
<td>0.045</td>
</tr>
<tr>
<td>3</td>
<td>Fuzzy Co - Ordination Of UPFC</td>
<td>0.041</td>
</tr>
</tbody>
</table>
V. CONCLUSION

This paper presents conventional controller and UPFC for the FACTS devices in a multi-machine power system to damp the electromechanical oscillations. The unified power flow controller is designed based on the conventional POD controllers. The amplification part of the conventional controller is modified depends upon the power system conditions. The performance of the proposed method is simulated over a wide range of operating conditions and disturbances and its robustness is proved. Both inter-area and local modes oscillations are quite damped using this new controller. The proposed control scheme adopts the advantages of the conventional PI controller and it is not only robust but also simple and being easy to be realized in power system. The parameters in the transmission line, i.e. line impedance, terminal voltages, and voltage angle can be controlled by UPFC. It is used for independent control of real and reactive power in transmission lines. Moreover, the UPFC can be used for voltage support and damping of electromechanical oscillations.

APPENDIX

Appendix 1: Power System Model

Base Value:
\[ V_B = 220KV; \quad S_B = 100MVA; \]

Generators:
\[ 2H_1 = 2H_2 = 8s; \quad 2H_3 = 10; \]
\[ D_1 = D_2 = D_2 = 0.0; \]
\[ T_{d01} = T_{d02} = 4.49s; \quad T_{d03} = 6s; \]

\[ X_{d1} = X_{d2} = 1.56(p.u.); \quad X_{d3} = 2(p.u.); \]
\[ X_{q1} = X_{q2} = 1.06(p.u.); \quad X_{q3} = 1.9; \]
\[ X_{d1} = X_{d2} = 0.17(p.u.); \quad X_{d3} = 0.25(p.u.). \]

Transformers:
\[ X_{T1} = X_{T2} = X_{T3} = J0.305\ (p.u.) \]

Transmission Lines:
\[ Z_{l1} = Z_{l2} = Z_{l3} = 0.0 + J0.25\ (p.u.) \]

UPFCs:
\[ V_{oper} = 220KV; \quad V_{semax} = 0.1V_{oper}; \quad V_{semin} = -0.1V_{oper} \]

Loads:
\[ L_1 = L_2 = L_3 = 0.05\ (p.u.); \quad L_4 = 0.65\ (p.u.) \]

Appendix 2: Parameter optimization

<table>
<thead>
<tr>
<th>Parameter Value</th>
<th>K</th>
<th>Tw</th>
<th>[ T_1 = T_2 ]</th>
<th>[ T_3 = T_4 ]</th>
<th>V_{max}</th>
<th>V_{min}</th>
</tr>
</thead>
<tbody>
<tr>
<td>Initial</td>
<td>0.5</td>
<td>3.0</td>
<td>0.05</td>
<td>0.05</td>
<td>0.1</td>
<td>-0.1</td>
</tr>
<tr>
<td>Optimized</td>
<td>1.82</td>
<td>3.0</td>
<td>0.02</td>
<td>0.15</td>
<td>0.1</td>
<td>-0.1</td>
</tr>
</tbody>
</table>
Appendix 3: Fuzzy-coordination Controller

\[ K = 0.7, N = 0.2 \]

REFERENCES


