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Modification and Analysis of Stabilizing Enhancement via Adaptive Neuro Fuzzy Interface UPFC with PSS Excitation System

Rakesh Kumar Nirmalkar Mr. Shailesh M. Deshmukh

M.Tech Student, Department of Electrical and Electronics Engineering, Disha Institute of Management and Technology, Raipur (India)

Head of Department, Department of Electrical and Electronics Engineering, Disha Institute of Management and Technology, Raipur (India)

ABSTRACT: An adaptive neuro- fuzzy inference system (ANFIS) based supplementary Unified Power Flow Controller (UPFC) with PSS Excitation system to superimpose the damping function on the control signal of UPFC is proposed. By using a hybrid learning procedure, the proposed ANFIS construct an input –output mapping based on stipulated input-output data pairs. The linguistic rules, considering the dependence of the plant output on the controlling signal are used to build the initial fuzzy inference structure. On the basis of linearized Philips-Hefron model of power system installed with UPFC, the damping function of the UPFC with various alternative UPFC with PSS Excitation system control signals are investigated. In the simulations under widely varying operating conditions and system parameters, ANFIS based controller yields improved performance when compared with constant gain controller, based on phase compensation technique. To validate the robustness of the proposed technique, the approach is integrated to a multi-machine power system and the nonlinear simulation results are presented.

KEYWORDS: Power System Stabilizer, Adaptive Neuro Fuzzy Interface, Unified Power Flow Controller, Automatic Voltage Regulator, Multi machine infinite bus, Excitation System.

I. INTRODUCTION

With the development of interconnection of large electric power systems there have been spontaneous system oscillations at low frequencies in the order of several cycles per minute. These low frequency oscillations are predominantly due to the lack of damping of mechanical mode of the system. Since power oscillation is a sustained dynamic event, it is necessary to vary the applied compensation to counteract the accelerating and decelerating swings of the disturbed machine. The concept of Flexible AC transmission system (FACTS) envisages the use of solid state controllers to achieve flexibility of power system by fast and reliable control of power system parameters affecting power flow in transmission line, namely voltage, impedance and or phase angle. Unified Power Flow Controller (UPFC), a multifunctional Flexible AC Transmission system (FACTS) Controller opens up new opportunities for controlling power and enhancing the usable capacity of present, as well as new and upgraded lines. A UPFC supplementary damping controller has been presented in the UPFC control system for damping the electromechanical mode oscillations. In systematic design of four alternative UPFC damping controllers are presented. However, these UPFC damping controller gains are designed on the basis of nominal operating conditions and remain independent of system operating conditions and line loadings. Also the controller gains and hence the control structure is different for the various choices of UPFC control signals. Since damping of low frequency oscillations may be one of the secondary functions of the multifunctional UPFC based on its other major control assignments, the widely varying control structure with respect to the choice of control signals makes the real time implementation inflexible. This work proposes an adaptive fuzzy inference system (ANFIS) based UPFC supplementary damping controller to superimpose the damping function on the control signal of UPFC for damping of power system electromechanical oscillations. The adaptive fuzzy controller is obtained by embedding the fuzzy inference system into the framework of adaptive networks. The proposed ANFIS based damping controller performance is examined for the four choices of UPFC control signals based on modulating index and voltage phase angle of UPFC series and shunt converters by simulations on a linearized Philips-Hefron model of a power system with UPFC. The effectiveness of this controller is supported by the results observed in simulations, which show the ability of the controller in damping oscillations over a wide range

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of loading conditions and system parameters with the four choices of alternative UPFC control signals when compared to constant gain damping controllers designed using phase compensation technique at selected operating point. Integrating this approach to a multi-machine power system and through non- linear simulation the robustness of the proposed controller is validated.

II. SYSTEM MODEL

In this Section, Power system consists of UPFC as shown in Fig 1. A Single Machine Infinite Bus (SMIB) system with synchronous generator provided with IEEE type-ST1A excitation system is considered. It is assumed that the UPFC performance is based on Pulse Width Modulation (PWM) converters. Here m1, m2 are the amplitude modulation ratio andδ1,δ2 are the phase angles of the reference voltage of each voltage source converter respectively.

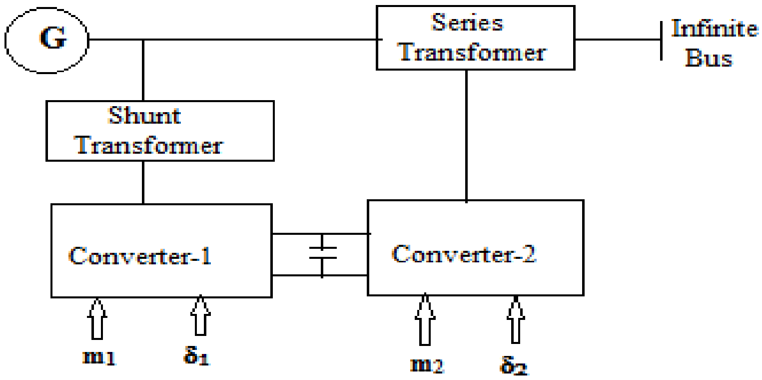

Fig 1 UPFC connected to SMIB

The basic components of UPFC are two voltage source inverters (VSIs) sharing a common dc storage capacitor which is connected to the power system through coupling transformers. One of the VSI is connected to power system via a shunt transformer, while the other one is connected in series through a series transformer. A basic UPFC functional diagram is shown in Fig. 1. The series inverter is operated to inject a symmetrical three phase voltage system (Vse), of controllable magnitude and phase angle in series with the line to control active and reactive power flows on the power system. So, this inverter will exchange active and reactive power with the line. The shunt inverter is operated in such a way that it demands the dc terminal power (positive or negative) from the line keeping the voltage across the storage capacitor Vdc constant. So, the net real power absorbed from the line by the UPFC is equal only to the losses of the inverters and their transformers. The remaining capacity of the shunt inverter can be used to exchange reactive power with the line so as to provide the voltage regulation at the connection point. The two VSI's can work independently of each other by separating the dc side. In this case the shunt inverter is operates as a STATCOM that generates or absorbs reactive power to regulate the voltage magnitude at the connection point. On the other hand the series inverter is operates as SSSC that generates or absorbs reactive power to regulate the current flow, and hence the power flow on the Power system. The UPFC has many possible operating modes. In particular, the shunt inverter operates in such a way that it injects a controllable current, I_{sh} into the transmission line. The shunt inverter can be controlled in two different modes.

A.VAR Control Mode: The reference input is an inductive or capacitive VAR request. The shunt inverter control translates the var reference into a corresponding shunt current request and adjusts gating of the inverter to establish the desired current. For this mode of control a feedback signal representing the dc bus voltage, Vdc, is also required.

B. Automatic Voltage Control Mode: The shunt inverter reactive current is automatically regulated to maintain the transmission line voltage at the point of connection to a reference value. For this mode of control, voltage feedback signals are obtained from the sending end bus feeding the shunt coupling transformer.

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C. Direct Voltage Injection Mode: The reference inputs are directly the magnitude and phase angle of the series voltage. The series inverter controls the magnitude and angle of the voltage injected in series with the line to influence the power flow on the line. The actual value of the injected voltage can be obtained in several ways.

D. Phase Angle Shifter Emulation Mode: The reference input is phase displacement between the sending end voltage and the receiving end voltage.

E. Line Impedance Emulation mode:The reference input is an impedance value to insert in series with the line impedance.

F. Automatic Power Flow Control Mode: The reference inputs are values of P and Q to maintain on the transmission line despite system changes.

III. METHODOLOGY

A Controller is adaptive neuro-fuzzy controller. In this section, we will present the procedure of designing of the adaptive neuro-fuzzy controller. In this research, the neuro fuzzy controller has 2 inputs that are $\Delta\delta$ and $\Delta\omega$ and it has 1 output that is $f \in \{\Delta mE, \Delta\delta E, \Delta mB, \Delta\delta B,\}$. For each input 7 membership functions and also 49 rules in the rules base is considered. Fig.2 demonstrates the structure of adaptive neuro-fuzzy controller for a sugeno fuzzy model with 7 inputs and 49 rules.

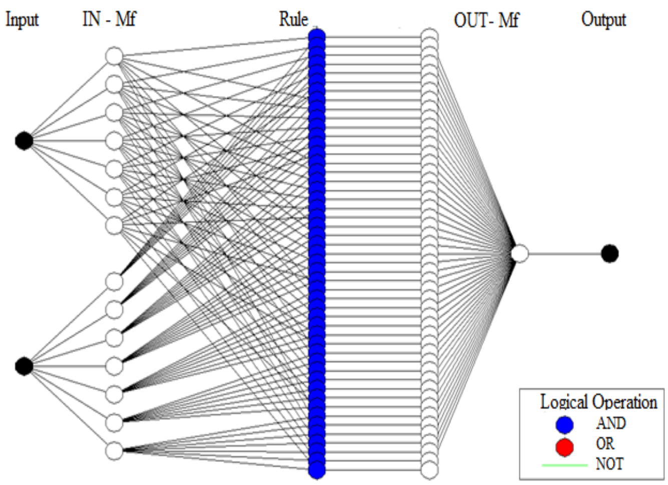

Fig.2 ANFIS architecture for a two-input Sugeno fuzzy model with 49 rules

In Figure 2, a Sugeno type of fuzzy system has the rule base with rules such as follows:
1. If $\Delta\delta$is A1 and $\Delta\omega$ is B1 then $f1=p1\ \Delta\delta+q1\ \Delta\omega+r1$.
2. If $\Delta\delta$is A2 and $\Delta\omega$ is B2 then $f2=p2\ \Delta\delta+q2\ \Delta\omega+r2$.

μAiand μBiare the membership functions of fuzzy sets Ai and Bi for i=1,…,49. In evaluating the rules, we choose product for T-norm (logical and). Now Hybrid learning algorithm can be applied to obtain values of parameters. Hybrid learning algorithm is combination of linear and nonlinear parameters learning algorithm. Description for learning procedure can be found in [49].

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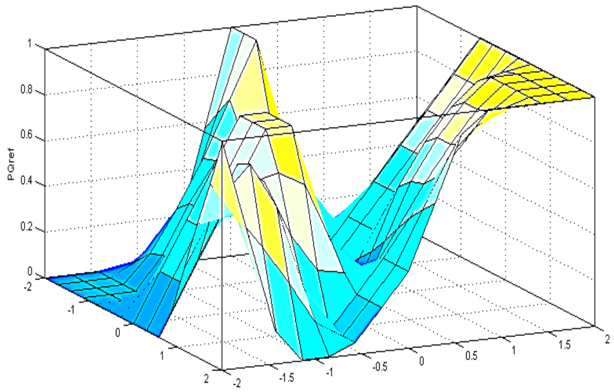
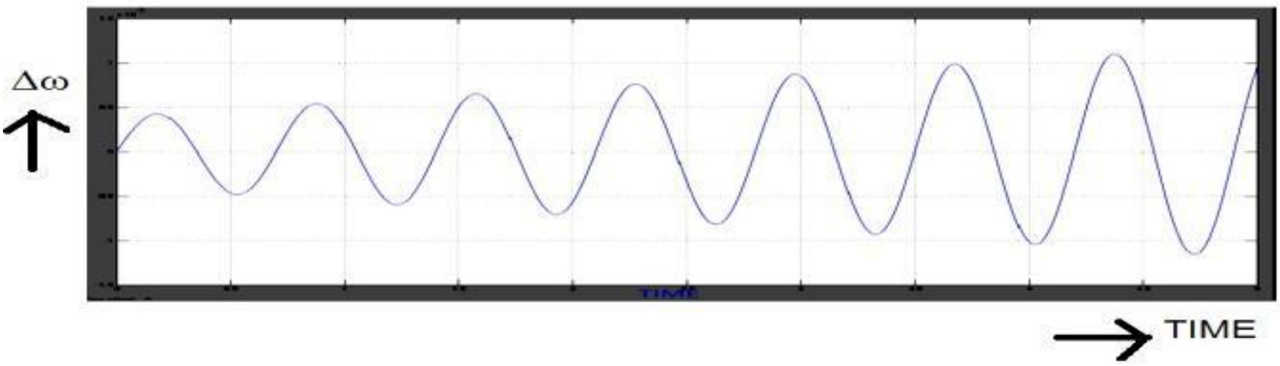


Fig.3 the Rules Surfaces

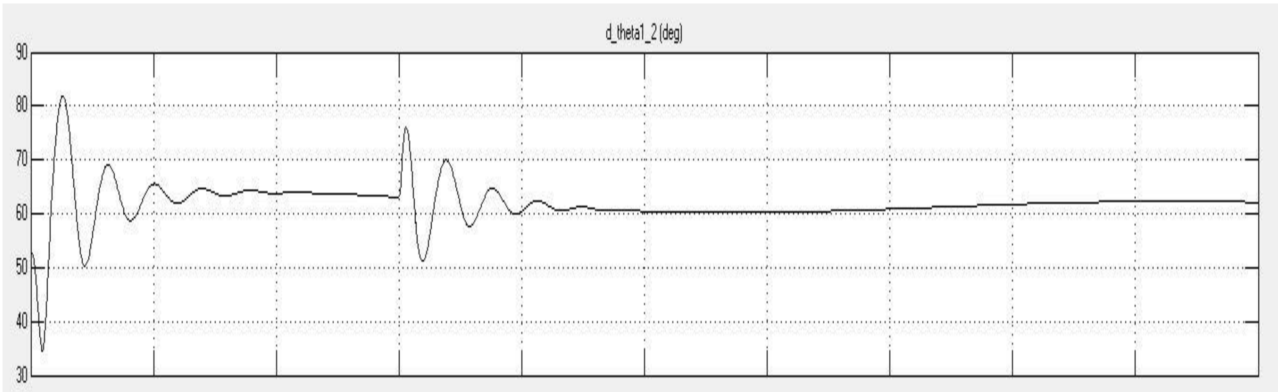
This network is called adaptive by Jang and it is functionally equivalent to Sugeno type of a fuzzy system. It is not a unique presentation. With regard to the explanations presented and with the help of MATLAB software, adaptive neuro-fuzzy controller can be designed. The rules surface for designed controller is shown in fig. 3.
One of the advantages of using neuro-fuzzy controller is that we can utilize one of the designed controllers for instance Δ*me*controller in place of the other controllers. While if we use conventional lead-lag controller, for each controls parameters, a controller must be designed.

IV. SIMULATION RESULTS

A. Dynamic responses for Δω12 considering a 5% step increase in Power flow(ref) without any controller



B. Dynamic responses for Δω12 considering a 5% step increase in P flow(ref) with only UPFC Fuzzy Controller



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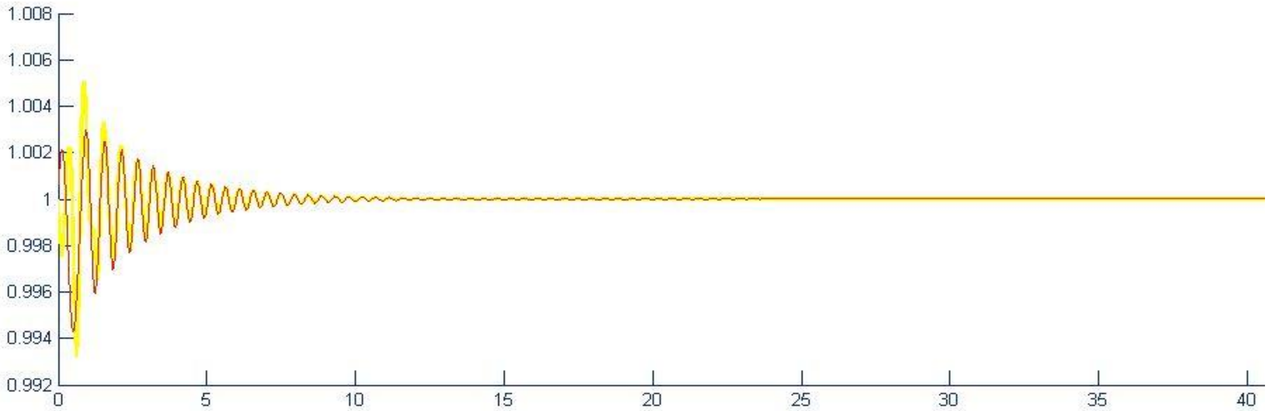
C. Dynamic responses for Δ P flow considering a 5% step increase in P flow(ref) with UPFC with PSS Neuro Fuzzy Controller



V. CONCLUSION

In this paper, A comprehensive approach for optimum design of UPFC controllers (i.e. STATCOM control andSSSC control) has been presented for a single machine system. The adverse interaction between PSS and SSSC control has been compensated, by providing UPFC based damping controller and UPFC capability in transient stability improvement and damping LFO of power systems, an adaptive neuro-fuzzy controller for UPFC was presented. The controller was designed for a single machine infinite bus system. Then simulation results for the system including neuro fuzzy controller were compared with simulation results for the system including conventional UPFC controller. Simulations were performed for different kinds of loads. Comparison showed that the proposed adaptive neuro-fuzzy controller has good ability to reduce settling time and reduce amplitude of LFO.

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