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Power Oscillation Control in Power System by ANFIS based Unified Power Flow Controller along with Stabilization: Review

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Abstract

Now a days electrical power consumption has been increased and increasing drastically. So it must be supplied to all the consumers with high reliability and quality. Since the load is unpredicted but only estimated the generation must be equal to load all the times. But due to variations in load there is effect on the power system whether the load is switched on or off suddenly which causes low frequency oscillations in the entire system [3]. Low frequency electromechanical oscillations are inevitable characteristics of power systems and they greatly affect the transmission line transfer capability and power system stability. Power system stabilizers (PSS) along with FACTS devices can help in damping these low frequency oscillations. The objective of this paper is to design an advanced PSS and UPFC damping controller using Swing equation. This paper presents a control scheme, comprehensive analysis and result obtained for the dynamic control of power transmission, damping of oscillations with Unified Power Flow Controller (UPFC) on the basis of theory and computer simulations through MATLAB software. In this paper UPFC is not designed but its controller is designed and the effect of UPFC on the system under the fault condition, disturbances is being verified [1].

Key words: UPFC damping controller, PSS, Low frequency oscillations. FACTS.

Introduction

The Power transfer in an integrated power system is constrained by transient stability, voltage stability and small signal stability. These constraints limit a full utilization of available transmission corridors. These constraints limit a full utilization of available transmission corridors. Flexible ac transmission system (FACTS) is the technology that provides the needed corrections of the transmission functionality in order to fully utilize the existing transmission facilities and hence, minimizing the gap between the stability limit and thermal limit. A unified power flow controller (UPFC) is a multi-functional FACTS controller with the primary function of Power flow control plus possible secondary duties of voltage support, transient stability improvement and oscillation damping i.e. a UPFC can control power, line impedance and phase angle which can be used for power system stabilizing control [4]. In view of the main objectives of the research work presented in the paper are:

- To present a systematic approach for designing UPFC based damping controllers.
- To examine the relative effectiveness of modulating alternative PSS & UPFC control parameters
- To investigate the performance of the alternative damping controllers, following wide variations in loading conditions and system parameters in order to select the most effective damping controller.

Unified Power Flow Controller

A Unified Power Flow Controller (or UPFC) is an electrical device for providing fast-sensation on high-voltage electricity transmission networks. It uses a pair of three-phase controllable bridges to produce current that is injected into a transmission line using a series transformer. The controller can control active and reactive power flows in a transmission line. The UPFC uses solid state devices, which provide functional flexibility, generally not attainable by conventional thyristor controlled systems. The UPFC is a combination of a static synchronous compensator (STATCOM) and a static synchronous series compensator (SSSC) coupled via a common DC voltage link. The UPFC concept was described in 1995 by L. Gyugyi of Westinghouse. The UPFC allows a secondary but important function such as stability control to suppress power system oscillations improving the transient stability of power system compensation without an external electric energy source [1]. The UPFC, by means of angularly unconstrained series voltage injection, is able to control, concurrently or selectively, the transmission line voltage, impedance and angle or alternatively, the real and reactive power flow in the line. The UPFC may also provide independently controllable Shunt reactive compensation. Viewing the operation of the UPFC from the standpoint of conventional power transmission based on reactive shunt compensation, series compensation and phase shifting, the UPFC can fulfill all these functions and thereby meet multiple control objectives by adding the injected voltage V_{Bt} with appropriate amplitude and phase angle, to the terminal voltage V0. The Unified Power Flow Controller (UPFC) is the most versatile of the FACTS controllers envisaged so far. It not only performs the function of STATCOM, TCSC, and the phase angle regulator but also provides additional flexibility by combining some of the functions of above controllers. The main function of UPFC is to control the flow of real and reactive power by injection of a voltage in series with transmission line. Both the magnitude and the phase angle of the voltage can be varied independently. Real and reactive power flow control can allow for power flow in prescribed routes; loading of transmission lines closer to their thermal limits and can be utilized for improving transient and small signal stability of the power system [2]. The schematic of the UPFC is shown in Fig. 1.

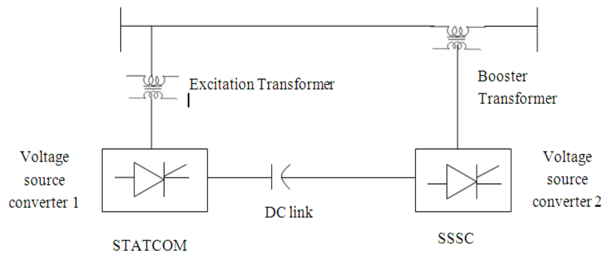

Fig-1: Schematic diagram of UPFC

3. Basic Operating Principle

The basic components of the UPFC are two voltage source inverters sharing a common dc storage capacitor, and connected to the power system through coupling transformers. One VSI is connected to in shunt to the transmission system via a shunt transformer, while the other one is connected in series through a series transformer [1]. The series inverter is controlled 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 transmission line. So, this inverter will exchange active and reactive power with the line. The reactive power is electronically provided by the series inverter, and the active power is transmitted to the dc terminals. The shunt inverter is operated in such a way as to demand this 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 to provide a voltage regulation at the connection point.

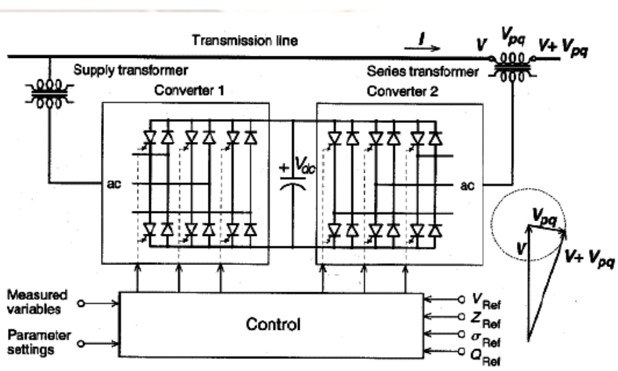

Fig-2: Implementation of UPFC by two back-to-back VSI

The two VSI‟s can work independently of each other by separating the dc side. So in that case, the shunt inverter is operating as a STATCOM that generates or absorbs reactive power to regulate the voltage magnitude at the connection point. Instead, the series inverter is operating as SSSC that generates or absorbs reactive power to regulate the current flow, and hence the power low on the transmission line [2]. The UPFC has many possible operating modes. A basic UPFC functional scheme is shown in Fig. 2 In the presently used practical implementation, the UPFC consists of two voltage-sourced converters, as illustrated in Figure. These back-to-back converters, labeled "Converter I" and "Converter 2" in the figure, are operated from a common dc link provided by a dc storage capacitor. As indicated before, this arrangement functions as an idea! AC-to-AC power converter in which the real power can freely flow in either direction between the terminals of the two converters, and each converter can independently generate {or absorb) reactive power at its own ac output terminal. Converter 2 provides the main function of the UPFC by injecting a voltage **Vw** with controllable magnitude **VM** and phase angle **θ** in series with the line via an insertion transformer. This injected voltage acts essentially as a synchronous ac voltage source. The transmission line current flows through this voltage source resulting in reactive and real power exchange between it and the ac system. The reactive power exchanged at the ac terminal (i.e., at the terminal of the series insertion transformer) is generated internally by the converter. The real power exchanged at the ac terminal is converted into dc Power which appears at the dc link as a positive or negative Real power demand.

Design of ANFIS Based UPFC Damping Controllers

UPFC is one of the famous FACTs devices that is used to improve power system from dynamic oscillation.. It is assumed that the UPFC performance is based on adaptive neuro fuzzy interface system. In figure 3 *me*, *mb* and *δe*, *δb* are the amplitude modulation ratio and phase angle of the reference voltage of each voltage source converter respectively. These values are the input control signals of the UPFC [3].

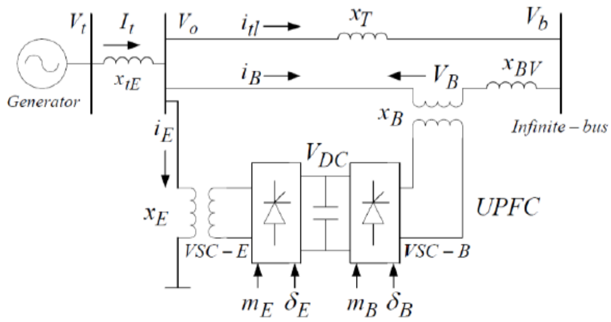

Fig.3 Power system connected to infinite bus with UPFC

As it mentioned previously, a linearized model of the power system is used in dynamic studies of power system. In order to consider the effect of UPFC in damping of LFO, the dynamic model of the UPFC is employed; In this model the resistance and transient of the transformers of the UPFC can be ignored.

Adaptive Neuro-Fuzzy Controller Design

Another 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 ΔP and ΔQ and it has 1 output that is PQ_{ref} {PB PM PS ZE NS NM NB}. For each input 7 membership functions and also 49 rules in the rules base is considered. Fig.4 demonstrates the structure of adaptive neuro-fuzzy controller for a sugeno fuzzy model with 2 inputs and 49 rules.

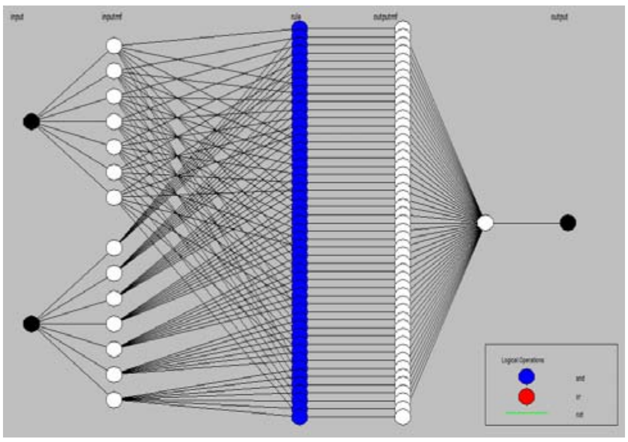

Fig.4. structure of adaptive neuro-fuzzy controller

The above relation is linear with respect to *Pi*, *Qi*, PQ_{ref} *i* and *i*=1,…,49. So parameters can be categorized into 2 sets: set of linear parameters and set of nonlinear parameters. Now Hybrid learning algorithm can be applied to obtain values of parameters [4]. Hybrid learning algorithm is combination of linear and nonlinear parameters learning algorithm. 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 figure 5.

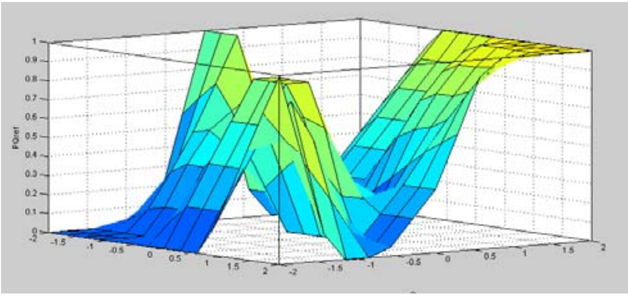

Fig.5. The rules surface

One of the advantages of using neuro-fuzzy controller is that we can utilize one of the designed controllers for instance Δ*PQ* controller in place of the other controllers. While if we use conventional lead-lag controller, for each controls parameters, a controller must be designed.

Conclusions

With regard to UPFC capability in transient stability improvement and damping LFO of power systems, an adaptive neuro-fuzzy controller for UPFC was presented in this paper. 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 lead-lag controller [6]. 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. Also we can utilize advantages of neural networks such as the ability of adapting to changes, fault tolerance capability, recovery capability, High-speed processing because of parallel processing and ability to build a DSP chip with VLSI Technology.

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