MFFN BASED IPFC FOR ENHANCEMENT OF POWER SYSTEM SECURITY

S.N. Dhurvey[1], V.K. Chandrakar[2], D.P. Kothari[3] and P.P. Ashtankar[4]
[1,4]Department of Electrical Engineering, Priyadarshini Institute of Engineering and Technology, India
[2]Department of Electrical Engineering, GH Raisoni College of Engineering, India
[3]Department of Electrical Engineering, Indian Institute of Technology Delhi, India

Abstract

ANN is the structure of neurons making transportation and communication of data. Instructing of neural network is capturing the unknown information. For optimizing the adoptability of the computational operation, MFFN (Multilayer feed forward network) controller is suggested which reduces execution time by providing more flexibility to identify the dynamic changes. For checking strength of 10-machine system, while designing, two signals: variation in voltage and variation in capacitor voltage are correlated. Competency of PI controller with MFFN has been analyzed under varying system conditions. Influence of additional suppression controller: POD is designed to get promising results. Recommended intelligent controllers are having proficiency of scrutinizing unique features of IPFC. Feasibility of different controllers subject to a three phase fault are studied and investigated on time domain basis in MATLAB software to verify the effectiveness of each controller.

Keywords:

FACTS, IPFC, MFFN, Damping of Oscillations

1. INTRODUCTION

These days, huge power transfer over long transmission lines have been increased as result of liberalism of global electrical energy markets. FACTS [1]-[5] are having potential of power transmission capability. Nowadays, several researchers presented put an endeavor on many nonlinear Voltage Source Convertor for advancement of power transfer capability. In the last decade, FACTS devices could facilitate secure operation of systems which have to be otherwise upgraded in order to relieve load on congested transmission lines or to optimize the system resources. From above classification of FACTS controller, among these, the series-shunt controller has proved the most popular. Among other VSC gadget, series-series controller is popular device by making overall compensating system more effective. FACTS devices like IPFC are regulated automatically. They can be placed anywhere in substations. Alteration of operation modes can be carried out casually. There is a perception for a high voltage power transfer network throughout the world to generate electrical energy eco-friendly and make available electrical energy according to the need. FACTS device like IPFC is the key to make this vision live.

So literature survey has concentrated on AI technique with nonlinear dynamic model of IPFC as well as linearized model of IPFC. In [6], the author adopted fusion of both intelligent techniques for IPFC and TCSC device. Potential of IPFC has been examined in [10]. NR power flow solution method has been carried out in [12]. Basic attributes of IPFC are figured out in [13] and proposed scheme to realize power flow control. Advance technique of PSO [20] for power flow analysis. Genetic optimization parameter for control of IPFC has been developed in [24].

Deep rooted fact is that work out of PI controller becomes worse when system conditions are deviated with nonlinear FACTS devices. Specialty of ANN is that it can guess the information hidden within the data. These efficient networks are used for modeling complex input-output relationships.

In [27]-[29], the authors have interpreted combined FLC series, shunt controllers by updating of performance of small and large systems in healthy and unhealthy situation. Radial Basis Function Network [RBFN] is the substitute to the conventional PI controllers. In [30] and [31], the authors have figured out impact of combined RBFNN based devices in small and large systems in both healthy and unhealthy situations.

VSC based FACTS devices are identified as the nonlinear devices. However, they have not included the linear or nonlinear model of IPFC with proposed scheme for transient stability and damping stability studies.

Since, Multilayer feed forward neural network (MFNN) shows good approximations with highly nonlinear and complicated network; it gives the reliable results in system identification and control. It provides superior dynamic performance than Fuzzy model. Rapid training, generality, and simplicity are the attractive feature of the MFFN network. Implementing this approach to a large system of conventional IPFC controllers satisfies the robustness of the proposed controller. In [32], the author has analyzed the performance of MFFN based SSSC for the improvement in transient stability. Although, they have not proposed same control strategy for IPFC device.

From the inspection of research work, this paper is projected towards advancement in long term strength and alleviation of power system oscillations.

2. SYSTEM MODEL

Adaptability of this device is that more than one SSSC can be connected in each line through dc link by providing multitask of compensation of transmission lines and also provides transportation of active power, making overall compensating system more effective as displayed in Fig.1.

The nonlinear Eq.(1)-Eq.(5) of multi-machine system are described as follows-

$$E_{qi} = E_{qi}^{1} + \left(x_{di} - x_{di}^{1}\right) I_{di} \tag{1}$$

$$P_{ei} = G_{ii} E_{qi}^{1\,2} + E_{qi}^{1} \sum_{\substack{j=1 \\ j \neq i}}^{n} E_{qj}^{1} y_{ij} \sin\left(\delta_i - \delta_j - \alpha_{ij}\right) \tag{2}$$

$$x_{i2} = \omega_i \tag{3}$$

$$x_{i3} = E_{qi}^{1} A = \Pi r^2 \tag{4}$$

Considering VSC as a synchronous voltage source inserting sinusoidal voltage. This voltage is having controllable magnitude and angle as V_a, V_b and V_c at the buses p, q and r respectively can be written as: $V_m \angle \theta_m$ ($m = p$, q and r). This voltage is outlined as ($m = p,q$ and r).

Complex series inserted voltage source is symbolize as: Vse_{in} $Vse_{in} = Vse_{in} \angle \theta se_{in}$ ($n=q,r$) and Zse_{in} ($n=q,r$) are represented as insertion transformer impedance.

This is signified as shunt combination of Vse_{in} and Ise_{in}. Current source is as follows:

$$Ise_{in} = -jbse_{in}\, Vse_{in} \tag{5}$$

Apparent power inserted at nth bus can be stated as -

$$S_{inj,n} = V_n(Ise_{in})^* \tag{6}$$

$$S_{inj,n} = V_n(-jbse_{in}\, Vse_{in})^* \tag{7}$$

Bypassing series transformer resistance, equation can be written as:

$$\sum_{m=x,y,z} P_{inj,m} = 0 \tag{8}$$

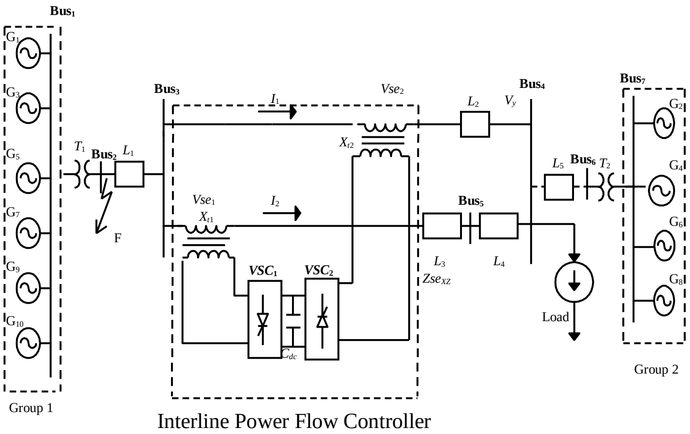

Fig.1. Ten machine system with IPFC

3. PI IPFC

Proportional and Integral Gain [27] is recommended for suppression of oscillations with the input of variation of voltage and output of Modulation Index outline in Fig.2(a). In general, trial and error method is opted for their selection. For enhancement in suppression of oscillations, in addition to PI controller, another tool POD can be connected. The block diagram is to monitor modulation switching of the VSC.

Divergence in V_{dc} commands over the phase angle of VSC [30]. Constants proportional and integral gain of the DC voltage regulators are opted through cut and try method. Change in Voltage (V_{dcref} -V_{dc}) has been given to PI controller and output is Phase angle. Output of Fig.2(a) and Fig.2(b) are utilized for firing of two VSCs.

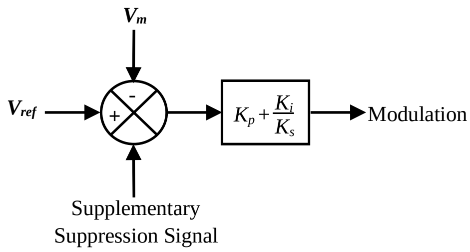

Fig.2(a). Proportional Integral for modulation index

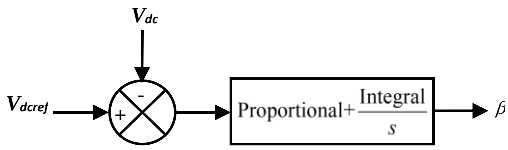

Fig.2(b). Proportional Integral for phase angle

4. MFFN BASED IPFC

ANN works beyond biological revelation. Instructing of neural network is capturing the unknown information. Two main instructions occur: supervised and unsupervised. In supervised instructions, neural network knows the target. It makes estimated and desirable target very nearest by fine tuning of weight coefficients. In unsupervised instructions, system is unknown from its target. In repetition of cycles, it will work out for a fixed pattern.

For optimizing the adoptability of the computational operation, MFFN (Multilayer feed forward network) controller [32] is suggested which reduces execution time by providing more flexibility to identify the dynamic changes. In this paper, supervised training is implemented. Each neuron in the network receives the information and for movement dispatches an output signal.

4.1 PRINCIPLE OF OPERATION

Simplest neural structure is one having single information and product layer. The Fig.3 describes the network consists of single-layer feed forward neural network, information A_0, A_1, A_2 directed towards product layers C_0 and C_1. Perceptron use activation functions, g_0 and g_1 to generate final products B_0 and B_1. Adding hidden layers save the execution time.

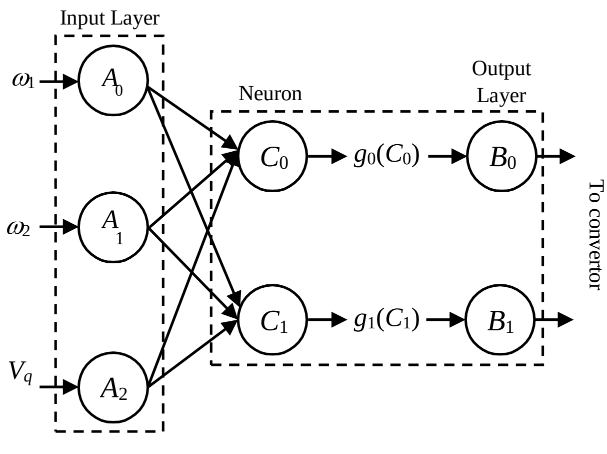

Fig.3. Three layers of a feed forward neural network

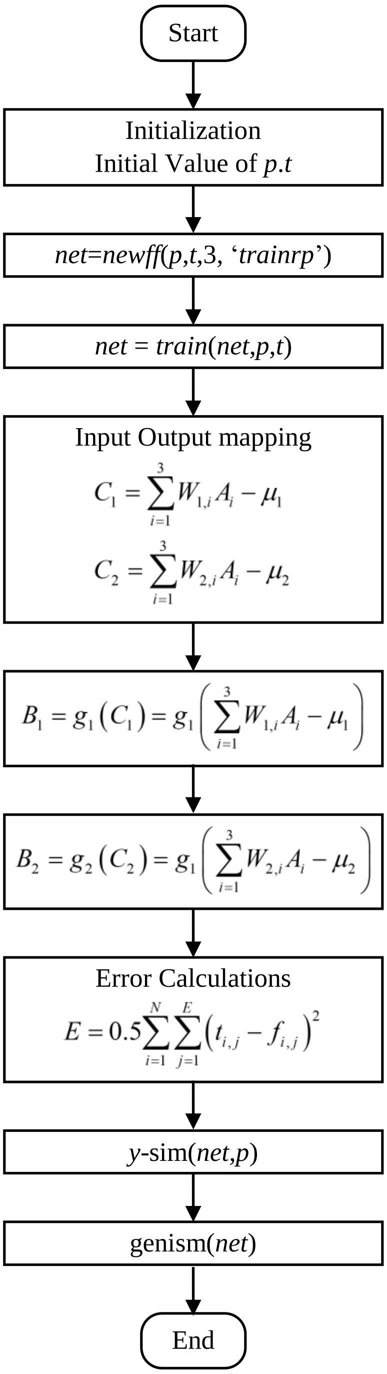

Fig.4. Training for MFFN based IPFC

To prepare a unique set of network model, and weights based upon a training dataset is the elementary objective of network training. Back-propagation attribute to the method used for calculating the gradient of the network during network training. Many have been researched for estimating these weights. Sum-of-squared errors are the most commonly used error function.

The Fig.4 illustrates the training for MFFN based IPFC [32] which gives the complete sequence of initialization, training, input-output mapping and error calculations. In error calculations, the total numbers of training cases are indicated by N and C is the no. of network products. t_{ij} is the noticed product for the i^{th} training and the j^{th} product and $\hat{t}_{ij}$ is the network's prognosis.

5. SIMULATION RESULTS

For verifying the topology of system for local and inter-area modes, 10-machine power system is considered. System is proved powerful by applying 3-φ fault at bus 2 of duration 0.05sec.

Nonlinear simulation is performed on the system with different situations like: a) without IPFC, b) with PI based IPFC, c) with MFFN based IPFC to validate the controller performance under sudden disturbance are presented in Fig.5(a), Fig.5(b) and Fig.5(c).

5.1 SIMULATION RESULT FOR GROUP 1

The Fig.5(a) displays the comparative analysis of speed for local mode 1. The generator 1 is considered as swing bus. It is observed that the peak overshoot is minimum with MFFN trims spike as shown Table.1.

5.2 SIMULATION RESULT FOR GROUP 2

The Fig.5(b) shows further analyses with respect to speed for local mode 2. Here, the generator 2 is taken as swing bus. Under 3 different circumstances MFFN trims spike as shown in Table.1. The simulation results have proved that MFFN has more competent results.

6. SIMULATION RESULT FOR GROUP 1 AND GROUP 2

Simulation studies are done on the system for inter area oscillations as displayed in Fig.5(c). MFFN reduces the speed deviation and damps the oscillations quickly as shown in Table.1.

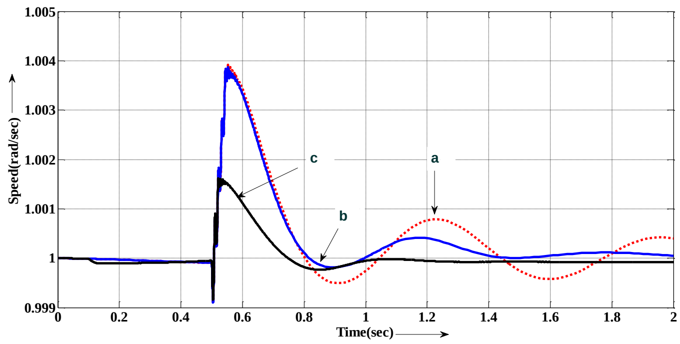

Fig.5(a). Time Domain Analysis for Group 1

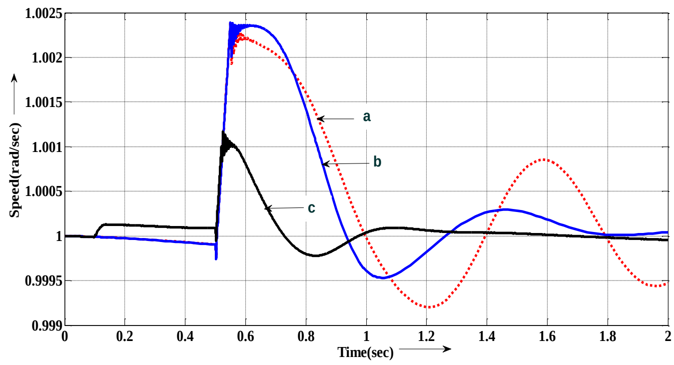

Fig.5(b). Time Domain Analysis for Group 2

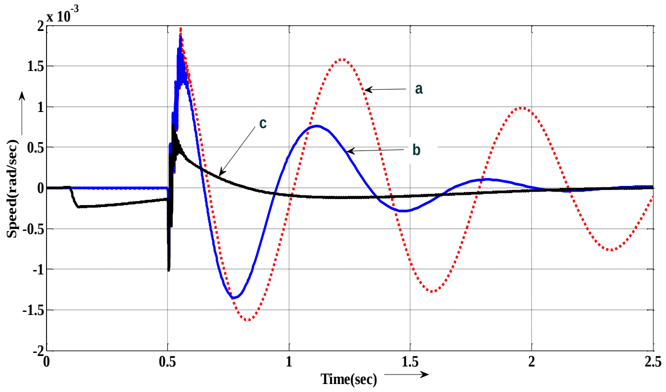

Fig.5(c). Time Domain Analysis for Inter area mode

Table.1. Time domain attainment for all modes

Name of the Controller	Group 1		
	No. of Oscillations	M_p (rad/sec)	T_s (sec)
Without IPFC	4	1.004	Infinity
With PI	3	1.004	2.1
With MFFN	1	1.002	1
Name of the Controller	**Group 2**		
	No. of Oscillations	**M_p (rad/sec)**	**T_s (sec)**
Without IPFC	4	1.002	Infinity
With PI	3	1.002	2.2
With MFFN	2	1.001	1.2
Name of the Controller	**Inter area mode**		
	No. of Oscillations	**M_p (rad/sec)**	**T_s (sec)**
Without IPFC	4	0.002	Infinity
With PI	3	0.002	2.1
With MFFN	1	0.005	1.8

7. CONCLUSIONS

In this paper, a PI based IPFC performance deteriorates under varying system conditions in large complex system. To upgrade power system performance, MFFN based controller designed and tested under various system conditions for large system. Dynamic performance has been checked in local mode of oscillations (Group 1 and Group 2) and inter area mode of oscillations (ω_1-ω_2). The MFFN have been framed out to avoid spikes in sudden disturbances. Comparative performance terms of dynamic situation and oscillations damping is demonstrated. Examining the simulation results it is pointed out that recommended MFFN displays superior execution.

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