RBFN Based IPFC for Enhancement of Power System Security

S.N. Dhurvey, V. K. Chandrakar, P.P. Ashtankar, P.R. Rothe

Abstract: Where the information is perverted by extreme noise level, an uncontrolled relationship between information and its yield. In that case, ANN is well known to solve this dilemma by giving fine result. Now, for specification and fine tuning of parameter, role of RBFN comes into picture. For optimizing the adaptability of the computational operation, Radial basis function (RBF) networks [10] 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 V & variation in Vdc are correlated. Competency of PI controller with RBFN 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.

Index Terms: RBFN

I. INTRODUCTION

Nowadays, several researchers presented an endeavor on many nonlinear Voltage Source Converter 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 classification of FACTS controller, among these, the series-shunt controller has proved the most popular. In the midst of 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 [12]-[15].

So literature survey [4-15] has been focused on the application of AI technique with nonlinear dynamic model of IPFC as well as linearized model of IPFC. Ref [4] adopted fusion of both intelligent techniques for IPFC and TCSC device. Basic attributes of IPFC are figured out in [6] and proposed scheme to realize power flow control.

Deep rooted fact is that work out of PI controller becomes worse when system conditions are deviated with nonlinear FACTS devices. Therefore, RBFN has dominance over the typical controllers. [9] 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; [10]-[11] have figured out impact of combined RBFNN based devices for betterment of transient stability of 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 RBFN for transient stability and damping stability studies.

From the inspection of research work, the main intention of this paper is to plan IPFC controller for advancement in long term strength.

II. SYSTEM MODEL

IPFC provides transportation of active power, making overall compensating system more effective as displayed in Figure 1. The nonlinear equations [2],[3] are -

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

(1)

\[ P_m = G_{m} E_{m}^{1/2} + E_{m}^1 \sum_{j=1}^{n} E_{qi}^j V_{m} \sin (\delta_j - \delta_j - \alpha_j) \]

(2)

\[ x_{i3} = \alpha_i \]

(3)

\[ x_{i3} = E_{qi}^1 A = \Pi r^2 \]

(4)

Considering VSC as a synchronous voltage source inserting sinusoidal voltage. This voltage is having controllable magnitude and angle as \( V_m \) and \( V_r \) 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 \( V_{se_{im}} \) \( V_{se_{im}} = V_{m} \angle \theta_{se_{im}} \) (n=q,r) and \( Z_{se_{im}} \) (n=q,r) are represented as insertion transformer impedance.
This is signified as shunt combination of $V_{se_{in}}$ and $I_{se_{in}}$.

Current source is as follows:

$$I_{se_{in}} = -j b s_{e_{in}} V_{se_{in}}$$

(5)

Apparent power inserted at $n^{th}$ bus can be stated as -

$$S_{inj,n} = V_n \left( I_{se_{in}} \right)^*$$

(6)

$$S_{inj,n} = V_n \left( -j b s_{e_{in}} V_{se_{in}} \right)^*$$

(7)

Bypassing series transformer resistance, equation can be written as:

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

(8)

Figure 2 (a)

Figure 2(a): Proportional Integral for modulation index (b) Proportional Integral for phase angle

IV. RBFN BASED IPFC

A. Details

Since opportunities and intricacy of operating system is always appealing, companies demands for exact evaluation of the project. Undoubtedly for both working group and clients, good operating system efforts become critical. Hence make plea for proposals, planning, inspection and finally compromise. Where the information is perverted by extreme noise level, causes complicated relationship between information and its yield. In that case, ANN is well known to solve this dilemma by giving fine result. Now, for specification and fine tuning of parameter, role of RBFN comes into picture.

The Radial basis function (RBF) networks offer replacement to the typical PI controllers. Owing to the tendency of hidden units, they are not affected by rotating information. Networks parenthesis is good.

B. Structure of RBF Networks

Single hidden layer behaves differently in RBF networks and back propagation networks. In RBF networks Gaussian function is used while in back propagation sigmoidal function is used.

As shown in Figure 3, RBFN [10] consist of three layers. They have no direct connections from input layer to output layer:

$$L_{in} \cap L_{out} = \phi$$

(9)

Only adjacent layers are connected, the entire set of connections is defined as:

$$C \subseteq \left( L_{in} \times L_{hid} \right) \cup \left( L_{hid} \times L_{out} \right)$$

(10)

B.1 Network Input Functions (Hidden Layer):

The space between the input vector and the weight vector is used as input function for each hidden neuron displayed in learning algorithm.

$$d : R^N \times R^N \rightarrow R^+$$

where $d$ denotes the distance function.

The gap in input and the weight vector is represented according to:

Figure 3

III. PI IPFC

Proportional and Integral Gain [9] is recommended for suppression of oscillations with the input of variation of voltage and output of Modulation Index outline in Figure 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 [10]. Constants proportional and integral gain are opted through cut & try. Change in Voltage ($V_{dc_{ref}} - V_{dc}$) has been given to PI controller and output is Phase angle. Output of Figure 2(a) and Figure 2(b) are utilized for firing of two VSCs.
B.2 Network Functions (Hidden and Output Layer):
As activation function so-called radial function is decreasing function and is used for each hidden neuron.

\[ f_{act} : R \rightarrow [0,1] \text{ with } \lim_{x \to \infty} f_{act}(x) = 0, \text{ for all } l \in L_{hid} \]

A linear function as activation function is used for each output neuron:

\[ f^{(l)}_{act}(y^{(l)}_m, \Theta^{(l)}) = \beta y^{(l)}_m - \Theta^{(l)}, \text{ for all } l \in L_{out} \]

B.3 Training Network Parameters

3) The update terms for the connection weights are:

\[ \Delta w^{(l,m)} = \gamma \frac{\partial \mathcal{E}}{\partial w^{(l,m)}} = \gamma \left( y^{(l,m)}_{ref} - y^{(l,m)}_{net} \right) x^{(l)} \text{, for all } l \in L_{out} \]

As activation function the Gaussian function is often employed:

\[ f_{act} (y^{(l,m)}_{net}, \Theta^{(l)}) = \exp \left( -\frac{1}{2} \frac{\left( y^{(l,m)}_{net} \right)^2}{\Theta^{(l)}} \right) \]

V. SIMULATION RESULTS OF NONLINEAR MODEL OF IPFC

System is examined for 3-φ fault at bus 2 of 0.05sec.interval. Strength of the controllers are scrutinized on the system to validate the controller performance for:

a. Without IPFC
b. With PI
c. With RBFN

under sudden disturbance are presented in Figure 5, 6 and 7. Realization of the proposed PI and RBFN controller’s performances are implemented in 10 machine system. Time domain attainment for all modes has been displayed in Table 1.

C. Simulation Result for Group 1-

Evaluation for speed of local mode 1 in atypical situation is delineated in Figure 5 It is observed that the peak overshoot is minimum with RBFN based IPFC. Outcome of the RBFN based IPFC greatly promote large disturbance stability, system is more responsive.

D. Simulation Result for Group 2-

Thus further analyses are done with respect to speed of local mode 2 in Figure 6 depicts that RBFN based IPFC shorten 1’st crest and clears in 1.2 sec. In short, large disturbance stability of the large system is recovered with RBFN based scheme.

E. Simulation Result for Inter-area oscillations of Group 1 and Group 2-

Simulation studies are done on the system for inter area oscillations shown in Figure 7 which indicates that with RBFN combined action trims the first crest from \(2 \times 10^{-2}\) to \(-0.5 \times 10^{-2}\).
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![Figure 5: Time Domain Analysis for Group 1](image1)

![Figure 6: Time Domain Analysis for Group 2 for three cases](image2)

![Figure 7: Variation in response for Group 1 and Group 2 for three conditions](image3)

Table I: Time domain attainment for all modes

<table>
<thead>
<tr>
<th>Name of Controller</th>
<th>Group 1</th>
<th></th>
<th>Group 2</th>
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<th>Inter area mode</th>
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<tr>
<td>Without IPFC</td>
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<td>0.00</td>
<td>1.00</td>
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</table>

VI. CONCLUSION

For multi-machine system, RBFN based controller has been suggested for up gradation of the network. RBFN has been devised considering features of minimization of large disturbance fluctuation, augmentation in suppression of oscillations. The controller’s approaching work out in updating transient stability is exhibited. Examining simulation results inference can be drawn that RBFN controller is showing superior performance than PI based controller. RBFN controller easily correlates with damping strategy and establishes the robust performance.

REFERENCES


16. Appendix -
17. For large system-
18. For Group 1 machine-
19. Rating of Equivalent Generator for Group1: [13.8kV, 60Hz., 6x350MVA]
20. For Group 2 machine-
21. Rating of Equivalent Generator for Group2: [13.8kV, 60Hz., 4x350MVA]
22. Rating of Equivalent Transformer for Group 1 - 2100MVA, 43.8kV/500kV
23. Rating of Equivalent Transformer for Group 2 - 1400MVA, 13.8kV/500kV

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