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RBFN Based IPFC for Enhancement of Power System Security

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Abstract: 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. For optimizing the adoptability 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 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 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].

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

(2)

$$x_{i2} = \omega_i$$

(3)

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

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*). 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-

$$Ise_{in} = -jbse_{in}Vse_{in}$$

(5)

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

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

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

Bypassing series transformer resistance, equation can be written as-

$$\sum_{m=x,y,z} P_{inj,m} = 0 \quad (8)$$

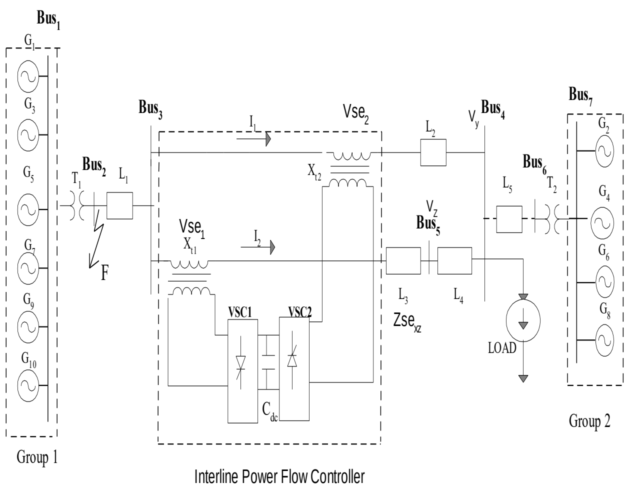

Figure 1: Ten machine IPFC

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_{dcref} -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.

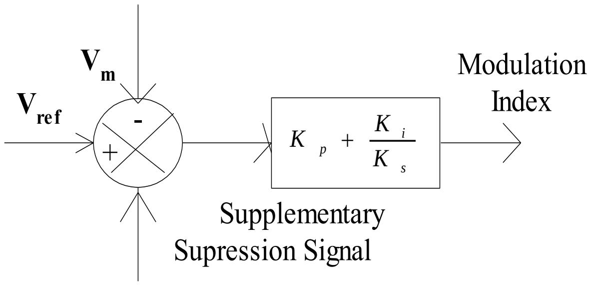

Figure 2 (a)

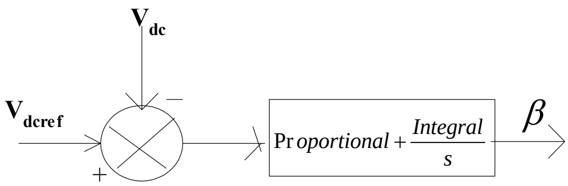

Figure 2(a): Proportional Integral for modulation index (b) Proportional Integral for phase angle

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:

$$L_{in} \cap L_{out} = \phi \quad (9)$$

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

$$C \subseteq (L_{in} \times L_{hid}) \cup (L_{hid} \times L_{out}) \quad (10)$$

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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.

$$where\ d : R^N \times R^N \longrightarrow R_0^+$$ denotes the distance function.

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

$$d_k(w,x) = \left(\sum_{i=0}^{N-1} |w_i - x_i|^k\right)^{\frac{1}{k}}, with\ k \in \{1,2,.....\infty\} \quad (11)$$

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.

$$f_{act}^{(l)} : R \rightarrow [0,1]\ with\ f_{act}^{(l)}(0) = 1\ and \lim_{x\to\infty} f_{act}^{(l)}(\infty) = 0,\ for\ all\ l \in L_{hid} \quad (12)$$

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

$$f_{act}^{(l)}(y_{net}^{(l)}, \theta^{(l)}) = \beta y_{net}^{(l)} - \theta^{(l)},\ for\ all\ l \in L_{out} \quad (13)$$

B.3 Training Network Parameters

3) The update terms for the connection weights are:

$$\Delta w^{(l,m)} = \frac{-\gamma_3}{2}\frac{\partial e^{(m)}}{\partial w^{(l)}} = \gamma_3\left(y_{ref}^{(l,m)} - y_{out}^{(l,m)}\right)x^{(l,m)},\ for\ all\ l \in L_{out} \quad (14)$$

As activation function the Gaussian function is often employed:

$$f_{act}(y_{net}^{(v,m)}, \theta^{(v)}) = \exp\left(\frac{-1}{2}\left(\frac{y_{net}^{(v,m)}}{\theta^{(v)}}\right)\right) \quad (15)$$

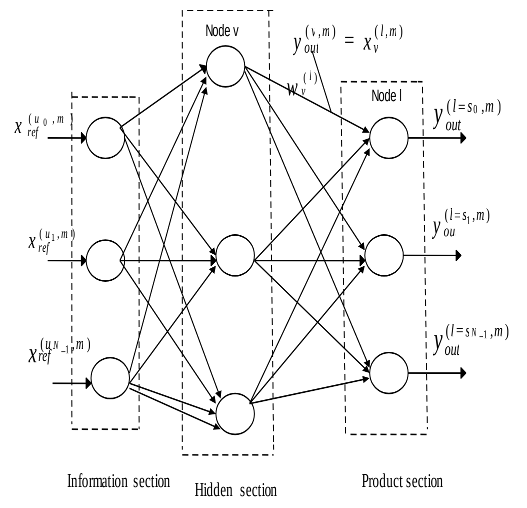

Figure 3: RBF with three layers

The Training for RBFN based IPFC is as shown in **Figure 4** where p denotes the input function and t denotes the output function. Input-output mapping [11] between input and output function is made by objective function net. The optimization starts with preselected values of input output function. Then RBFN algorithm iteratively adjusts the parameters till the objective function equation is minimized.

net=newff(p,t) (16)

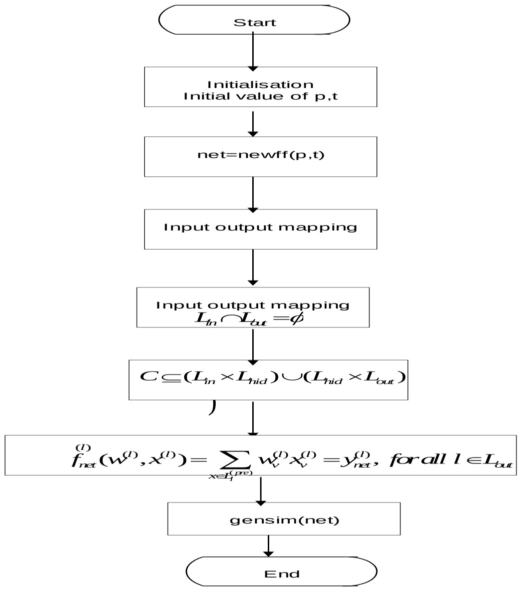

Figure 4: Training for RBFN based IPFC

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 I**.

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 2×10^{-3} -0.5×10^{-3}.

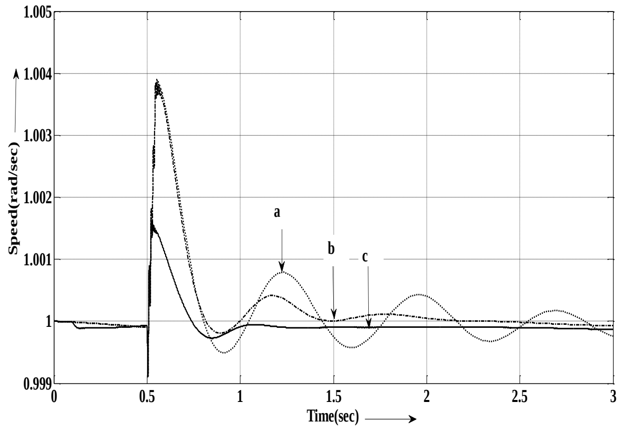

Figure 5: Time Domain Analysis for Group 1

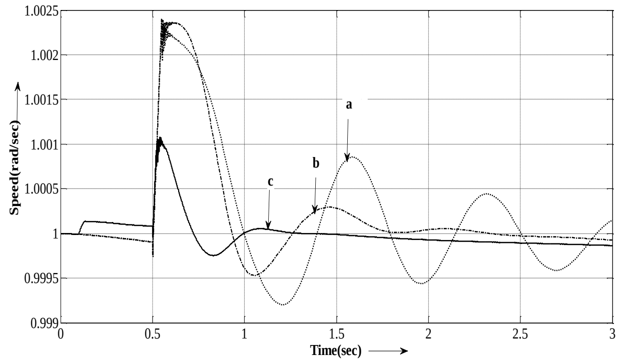

Figure 6: Time Domain Analysis for Group 2 for three cases

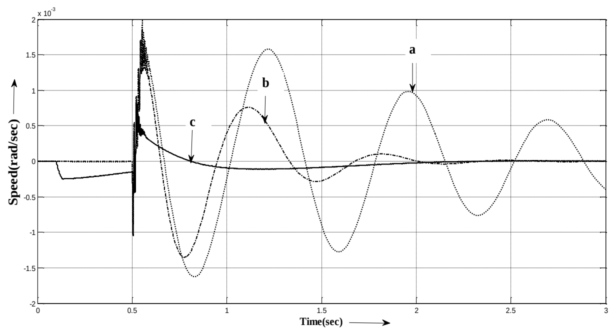

Figure 7: Variation in response for Group 1 And Group 2 for three conditions

Table I: Time domain attainment for all modes

Name of Controller	Group 1			Group 2			Inter area mode		
	No. of Oscillation s	Peak overshoot Mp (rad/sec)	T_s (sec)	No. of Oscillations	Mp (rad/sec)	T_s (sec)	No. of Oscillation s	Mp (rad/sec)	T_s (sec)
Without IPFC	4	1.0038	Infinity	4	1.002	Infinity	4	0.002	Infinity
With PI	3	1.0038	2.1	3	1.002	2.2	3	0.0017	2.1
With RBFN	1	1.0015	1	2	1.001	1.2	1	0.005	1.9

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

1. Y.H. Song and A.T. Johns, Flexible AC Transmission systems, IEE Power and Energy series 30, London, (1999), 577 pages.
2. K.R. Padiyar, Power System Dynamics Stability and Control, Interline Bangalore, (1996).
3. Tariq Masood, D. P. Kothari, Centralized/Decentralized FACTS Controllers in Electric Grids, New Age International Publishers, New Delhi, 2019.
4. Mishra S., Dash P.K., Hota P.K., Tripathy M., "Genetically optimized neuro-fuzzy IPFC for damping modal oscillations of power system", IEEE Transactions on Power Systems, Volume: 17(4) ,2002, pp.1140 – 1147.
5. Parimi A.M., Sahoo N.C., Elamvazuthi I, Saad N., "Interline Power Flow Controller Application for Low Frequency Oscillations Damping", WSEAS Transactions on Systems, Volume 9, 5, May 2010, pp.512-527.
6. Jianhong Chen, Lie, T.T. ; Vilathgamuwa D.M., "Basic control ,of interline power flow controller", *IEEE Power Engineering Society Winter Meeting*, 2002, pp.521 – 525.
7. Gomathi V., Ramachandran, Kumar C.V., "Simulation and state estimation of power system with Interline Power flow Controller", *Universities Power Engineering Conference (UPEC), 45th International, Universities Power Engineering Conference (UPEC)*, Cardiff, Wales, Aug. 31st-Sept. 3rd 2010, pp.1 – 6.
8. Menniti D. , Pinnarelli A., Sorrentino, N., "Fuzzy logic controller for interline power flow controller model implemented by ATP-EMTP", *International Conference on Power System Technology, PowerCon* , Vol.3, 2002, pp.1898 – 1903.
9. S.N.Dhurvey, V.K.Chandrakar, "Performance Evaluation of IPFC By Using Fuzzy Logic Based Controller", *IEEE Fourth International Conference on Emerging Trends in Engineering & Technology, ICETET 2011*, Mauritius, 16th-18th Nov. 2011, pp.168-173.
10. V.K. Chandrakar, A.G.Kothari, "Comparison of RBFN and Fuzzy based STATCOM Controllers for Transient Stability Improvement", *IEEE Aegean Conference on Electric Machines Powers and Electromotion*, Bodrum,Turkey, 10th-12th Sept.2007, pp.520 – 525.
11. Chandrakar V.K. and Kothari A.G., "RBFN based Static Synchronous Series Compensator (SSSC) for Transient Stability improvement", ICARCV, 2006, pp.1-7.

12. S.N.Dhurvey,V.K.Chandrakar, Performance Comparison of UPFC In Coordination with Optimized POD and PSS On Damping of Power System Oscillations", *International Journal of WSEAS Transaction on Power System*, 5, 2008, pp.
13. S.N.Dhurvey,V.K.Chandrakar,"Optimized POD in coordination with UPFC for damping of power system oscillations", *Universities Power Engineering Conference*, 2008. UPEC 2008.
14. S.N.Dhurvey,V.K.Chandrakar, "Improvement of Power System Performance Using Fuzzy Logic Based Interline Power Flow Controller [IPFC]", *Journal of Power and Energy Engineering*, 4, 2016, pp.67-77.
15. S.N.Dhurvey,V.K.Chandrakar, **"**Performance Comparison of PI and Fuzzy Logic Based IPFC on Damping of Power System Oscillations", *Journal of Power and Energy Engineering*, 4, 2016, pp.78-90.

16. **Appendix -**
17. **For large system-**
18. *For Group 1 machine-*
19. **Rating of Equivalent Generator for Group1:** [13.8kV, 60Hz.,6×350MVA]
20. *For Group 2 machine-*
21. **Rating of Equivalent Generator for Group2:** [13.8kV, 60Hz., 4×350MVA]
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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Dr. S.N. Dhurvey has done Ph.D. from Nagpur University, India. Currently she is associated with Priyadarshini Institute of Engg. & Technology, Nagpur, India. Her area of research is Power system, FACTS, Artificial Intelligence Technique.

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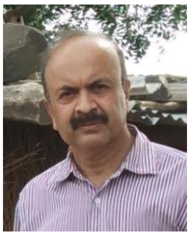

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