Proceedings of the 5th WSEAS/IASME Int. Conf. on SYSTEMS THEORY and SCIENTIFIC COMPUTATION, Malta, September 15-17, 2005 (pp206-212)

Minimal Radial Basis Function Network Based Bus Protection System using OCT

Zahra Moravej
Moshanir Co.
Protection & Control Division
Tehran-IRAN
E-mail: moravej.zahra @gmail.com
z_moravej@hotmail.com

Abstract:
This paper presented the Minimal Radial Basis Function Network (MRBFN) approach busbar protection. The Optical Current Transducer (OCT) is used to solve the magnetic saturation so as to improve the reliability of the system. Performance of this model is compared with Feed Forward Back Propagation Neural Network (FFBP). The proposed model is more accurate in prediction with few numbers of hidden neurons. Performance analysis shows its distinguishing advantages over the traditional busbar protection.

Key-words: Minimal Radial Basis Function Network, Optical Current Transducer, Bus Protection.

1. Introduction

Protection of busbar demand high standards. Failure to trip on an internal fault, as well as false tripping of a busbar during load service, or in case of an external fault, both have disastrous effects on the stability of power systems, and may even cause complete blackouts. A further important point to consider is through fault stability with current transformer saturation.
For the traditional principle of the protection, it is necessary to lead the secondary current of all the CTs to a central differential relay, so that the complicated wiring of the secondary CT circuit is needed.

The magnetic saturation of the electromagnetic current transformer is the key problem, which reflects the reliability of system.

In order to eliminate the weakness of the traditional bus-bar protection, a new ANN bus protection system using OCT is proposed in this paper.
The OCTs are used to eliminate the mal-operation problem due to magnetic saturation of the electromagnetic current transformer, so as to increase reliability. Compared with traditional current transformer, OCT possesses a lot of advantages [1-3]: resistance to electromagnetic interference and noise, simpler, more reliable insulation, very wide dynamic measure range, small and light, no saturation regarding large current, no saturation regarding current with large dc component time constants.
Especially, OCT possesses the feature of no core – saturation, which is very useful for protective relaying. Researches on OCT show: although accuracy of OCT couldn't

satisfy the requirement of metering, but with excellent dynamic characteristic practical OCTs employed in problem field performed well [1].

In this paper the MRBFN based approach detected normal and external fault current based on recognizing their wave shapes, more precisely, by differentiating their wave shapes from the fault current shapes.

It gives a trip signal in the case of internal fault current only, and exercise restraint under healthy and external fault current conditions. This differential relay can be realized using MRBFN with far fewer hidden neurons where the learning process is made sequential and the optimum number of hidden neurons is chosen with a pruning strategy [4].

2. Optical current transducer

2.1. Principle

OCT including light source, optical sensor and detector as shown in figure 1.Optical fibers are used to connect sensor, light source and detector. The sensor is based on the Faraday effect. The plane of polarization of linearly polarized light is rotated in proportion to the magnetic field associated with the measured current and the optical path length through the Faraday cell. The Faraday effect may be written as: [5]

$$I = § \ H.dl , \qquad \theta_a = \mu\nu I$$
$$\theta_a = \mu\nu § Hdl = \mu\nu_\alpha I \qquad (1)$$

where: θ_α is the rotation of polarization azimuth

μ is the relative permeability

ν is the verdet constant (rad/A)

H and dl are the components in the direction of propagation

I is the current

α is the constant dependent on the relative position of light path and conductor

$\alpha = 1$ when a close optical path surrounds the conductor.

The rotation angle is not a directly detectable parameter. Analyzer transfers the rotation to optical power, which is converted into electric signal by the photo detector, then the signal is amplified and calculated to achieve the current information measured.

The plane of the polarizer is parallel with X-axis as shown in fig.1.

The detection is most sensitive when polarizer and analyzer are arranged at an angle of $\pi/4$.

The output light power is given in terms of the input power by:

$$P_0 = ½ P_i (1 + \sin 2\theta_a) \qquad (2)$$

The output can be normalized by computing the ratio M of the ac to the dc components as follows :

$$M = P_{ac} / P_{dc} = \sin 2\theta_a \qquad (3)$$

The equation (1) is inserted into equation (3)

$$M = \sin 2(\mu\nu\alpha I)$$

Obviously, the computation is nonlinear.

2.2 Sensor Selection

To construct the sensor usually four methods can be used:

A. Sensing fibers are wound around the conductor. However birefringence reduces the sensitivity and accuracy.

B. A piece of sensor only is placed adjacent to a conductor, which is sensitive to the disturbance by other phase currents.

C. A block of optically active material encloses the conductor exactly once, which is expensive and difficult to manufacturer.

D. A piece of sensor is placed in a gap of a concentrator with high permeability arranged around the conductor, which is less sensitive to disturbance, simple and economic [2].

Because more elements are needed in busbar protection system, by taking into consideration of both measuring accuracy and the economic factor, the sensor with magnetic concentrator is chosen. The saturation of the iron core can be suppressed by adjusting the gap length [3].

3. Differential busbar protection

The differential busbar protection ensures the protection of the electric nodes, band on laws such as kerchief, the impedance variation, the admittance variation, in order to distinguish internal faults of the electric node from the external faults [6].

A double busbar system as shown in fig.2 is considered in this paper for evaluating the performance of proposed relay. There are three protective zones in the selected system.

The protection for this system is achieved by MRBFN based algorithm.

Fig. 3 shows the percentage differential characteristic. Where I_D is the vector summation and $\Sigma|I|$ is the scalar summation of the feeder current.

If the requirements of the equation

$|I_D| > k_1 \Sigma|I| + k_0$ ………… (1)

are met for a set predefined period, the percentage differential element will operate. Where k_0 and k_1 are constants that relate to the operating value and bias value respectively. This calculation is achieved using the differential value $|I_D|$ and the restraining value $\Sigma|I|$.

.

4. Simulation of Training Cases

To test the MRBFN based algorithm and to evaluate the performance of proposed relay the EMTP/ATP program [7] is used to simulate the different operational conditions i.e normal, external and internal fault of the system.

The protective device has to trip only for internal fault and to exercise restraint under healthy and through fault conditions.

5. Network Architecture and Training

Various architectures and combinations of input sets have been attempted to arrive at the final configuration with a goal of maximum accuracy.

Recently in [4] it has been shown that a compact network structure can be obtained for RBF neural network. In this strategy the network start with no hidden units are added based on novelty of the data. A new pattern is considered novel if the input is far away from the existing centers, error between the desired output and network output is large and rms error is also significant. If the data set does not satisfy the above criteria no hidden neuron is added and the parameters of the existing network, such as the weights, centers and spreads are updated using Extended Kalman Filter (EKF).

In the above sequential learning process, some hidden units though active initially, may be contributing very little to the network output subsequently. To overcome this problem a pruning strategy can be incorporated that detect and removes units, which consistently contribute little to the network output.

A set of 210 training cases (180 sets for training and 30 sets for testing purpose) generated by the

EMTP package has been used to train and test the neural network.

A network with 8 neurons has been found suitable for this work. Hence, the final architecture consists of 16 input nodes, a single hidden layer with 8 neurons and one output. A binary output is sufficient to indicate whether the measured current is a normal, external or an internal fault. In this work the value of 0 indicates either normal current or external fault current and 1 indicates an internal fault current. Thus a single output of value 1 indicates an internal fault and 0 as no fault (could be one of normal or external fault condition).

The network tends to converge with MSE=0.0016 after 8 epochs, with fixed η= 0.001 for the training sets. After nets performance convergence, then tested the network with the testing sets and MSE = 0.0019 has been obtained.

6. Network Numerical Result

After the training the net has been tested with different sets of data and the network respond adequately performing the discrimination and classification of normal, external and internal fault currents.

This section presents some of the comparisons between the MRBFN model and the more commonly used FFBP model [8].

Table 1 shows the performance of different architectures with training and testing error.

Table 2 and 3 shows the testing and training output of both the model.

The actual and predicted output is also shown in these tables. Based on the training and testing results, the model for this problem showed superior performance when the number of hidden nodes was equal to 8. The training time for the MRBFN model is much less than for the FFBP model, and the architecture is simple, local minima problem has not been seen during training of MRBF. The test results based on unseen data attained through MRBFN are either close to unity or zero.

In this work the proposed busbar protection possesses good discrimination and also fast response time (< 20ms) to the internal fault.

The differential protection criterion is formed by software. It is not necessary to lead the CT secondary cables to a central differential relay, so the new system is well adaptable to any bus operation mode.

The proposed bus protection system is shown in fig.4.

7. Conclusion

A more efficient and less complex MRBFN for protection of busbar is presented in this paper.

Using this new network, the number of training patterns and training time are drastically reduced and internal fault detection accuracy improved. No auxiliary CTs is necessary. Fibers disconnect high voltage part and low potential part, which simplify secondary circuit and are resistance to electromagnetic interference.

This new architecture of the RBF network is expected to be suitable for real time application

References :

[1] Emerging Technologies working Group, “Optical Current Transducers for Power Systems : A Review” , IEEE Transaction on power Delivery , vol.9, No.4 , pp 1778-1788, Oct. 1994.

[2] T.sawa, K . Kurosawa ,T.Kaminishi, T.Yokota “ Development of Optical Instrument Transformers” , IEEE Transaction on Power Delivery, Vol.5 , No.2, pp 884-891, April 1990.

[3] Y.Yoshida, S.Kawazoe , K. Lbuk , K.Yamada , N.Ochi, “New fault locating system for air insulated substations using optical current detector” , IEEE Transaction on Power Delivery , Vol .7 , No.4 , pp 1805-1812 , Oct.1992.

[4] Lu Yingwei, Narashiman Sundarajan and P.Saratchandran, “ Performance Evaluation of Sequential Minimal Radial Basis Function (RBF) Network Learning Algorithm”, IEEE Transaction on Neural Network, Vol.9 , No.2 , March 1998, pp 308-318.

[5]Qiufeng Shang , Yincheng Qi, Zhiyuan Xie,”A New Digital Bus protection System Using OCT and DSP”, ICSP 2002 IEEE, pp. 1731-1734.

[6]H.Watanabe , I.Shuto , K.Igarashi , P.Beaumont,K.Okuno,” An Enhanced Decentralized Numerical Bus bar protection Relay Utilizing Instantaneous Current Values From High Speed Sampling”, Development in Power System protection, Conference publication No. 479 IEE 2001, pp.133-136.

[7] D.Van Dommelen and H.W.Dommel,”PC – EMTP User Manual, Alternative Transients,” Program Rule Book, Vol.7, No.2, 1987.

[8] Z.Moravej, “ANN based novel fault detector for busbar protection”, 38th International Universities Power Engineering Conference Proceeding, Vol. 2, pp. 677-680, 2003.

Table 1 . Performance of MRBFN with variable hidden layer

ANN topology	Training Error	Prediction Error	Performance	Remarks
16-6-1(MRBF) 16-10-1(FFBP)	0.027216 0.085211	0.020231 0.073315	Not good	Not selected
16-7-1(MRBF) 16-11-1(FFBP)	0.010341 0.025310	0.012367 0.035412	Not good	Not selected
16-8-1(MRBF) 16-12-1(FFBP)	0.001621 0.003546	0.001956 0.004134	Good	Selected

Table 2. Comparison of two ANN models test output

Type of Cases	**Output**			
	Test (FFBP) 16-12-1		**Test (MRBFN)** 16-8-1	
	P	**A**	**P**	**A**
Normal	0.003104	0	0.002234	0
External fault	0.002067	0	0.001089	0
Internal fault	0.982130	1	1.198224	1

Table 3. Comparison of two ANN models trained output

Type of Cases	**Output**			
	Trained (FFBP) 16-12-1		**Trained (MRBFN)** 16-8-1	
	P	**A**	**P**	**A**
Normal	0.004321	0	0.002342	0
External fault	0.003216	0	0.001223	0
Internal fault	0.995320	1	1.058201	1

A=Actual, P=Prediction

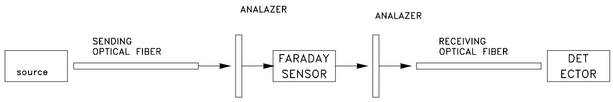

FIG. 1 OCT BASIC STRUCTURE

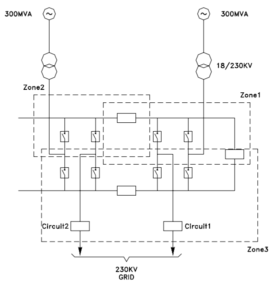

Fig. 2 Double busbar system

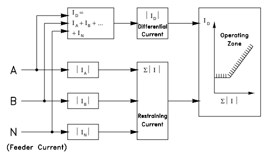

Fig.3 Percentage Differential characteristic

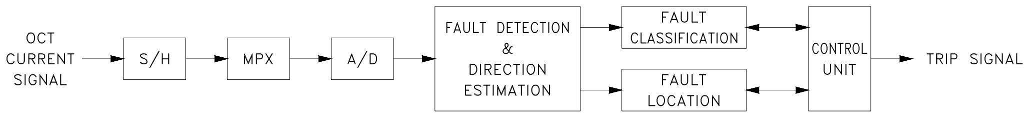

Fig.4 PROPOSED BUSBAR PROTECTION