World Academy of Science, Engineering and Technology
International Journal of Electrical, Computer, Energetic, Electronic and Communication Engineering Vol:1, No:6, 2007

Application of Neural Networks in Power Systems; A Review

M. Tarafdar Haque, and A.M. Kashtiban

Abstract—The electric power industry is currently undergoing an unprecedented reform. One of the most exciting and potentially profitable recent developments is increasing usage of artificial intelligence techniques. The intention of this paper is to give an overview of using neural network (NN) techniques in power systems. According to the growth rate of NNs application in some power system subjects, this paper introduce a brief overview in fault diagnosis, security assessment, load forecasting, economic dispatch and harmonic analyzing. Advantages and disadvantages of using NNs in above mentioned subjects and the main challenges in these fields have been explained, too.

Keywords—Neural network, power system, security assessment, fault diagnosis, load forecasting, economic dispatch, harmonic analyzing.

I. INTRODUCTION

NEURAL networks have been used in a board range of applications including: pattern classification, pattern recognition, optimization, prediction and automatic control. In spite of different structures and training paradigms, all NN applications are special cases of vector mapping [1]. The application of NNs in different power system operation and control strategies has lead to acceptable results [2-4].

This paper is an overview of application of NNs in power system operation and control. The comparison of the number of published papers in IEEE proceedings and conference papers in this field during 1990-1996 with them during 2000-2005 has showed that the following fields has attracted the most attention in the past five years:

1-load forecasting
2-fault diagnosis/fault location
3-economic dispatch
4-security assessment
5-transient stability

Considering this fact, this paper has focused on the above-mentioned subjects.

M. Tarafdar Haque is with Department of Electrical and Computer Engineering, Tabriz University, Tabriz, Iran (e-mail: tarafdar@tabrizu.ac.ir).
A.M. Kashtiban is with Department of Electrical and Computer Engineering, Tabriz University, Tabriz, Iran (e-mail: atabak_mashhadi@ee.iust.ac.ir).

TABLE I
ARTIFICIAL INTELLIGENT IN POWER SYSTEMS-SURVEY OF PAPERS 1990-1996 AND 2000 – APRIL 2005

	no. of published papers 1990-1996	no. of published papers 2000-April 2005
Power system subject	ANN	ANN
Planning		
-Expansion		
Generation	-	1
Transmission	-	1
Distribution	-	-
-Structural		
Reactive Power	1	-
-Reliability	-	1
Operation		
(i) plant		
-Generation scheduling	-	4
-Economic dispatch, OPF	1	14
-Unit commitment	-	-
-Reactive power dispatch	1	1
-Voltage control	4	3
-Security assessment		
Static	7	3
Dynamic	6	9
-Maintenance scheduling	3	1
-Contract management	-	-
-Equipment monitoring	4	3
(ii) System		
-Load forecasting	12	23
-Load management	-	-
-Alarm processing/Fault diagnosis	13	20
-Service restoration	-	2
-Network switching	-	-
-Contingency analysis	1	2
-Facts	-	-
-State estimation	4	2
Analysis / Modeling		
-Power flow	4	4
-Harmonics	-	3
-Transient stability	5	9
-Dynamic stability/ Control design	13	7
-Simulation/operators	-	1
-Protection	7	4

I. GROTH RATE OF APPLICATION OF NNs IN POWER SYSTEMS

Table I summarizes the number of published papers about application of NNs in power system operation and control topics in two time intervals. The first time interval is from 1990 to 1996 [2], while the second one is from 2000 to 2005. These papers are published in IEEE proceedings and conferences. It seems that the comparison of two columns can be used as a proof of successful or unsuccessful operation of NN in related power system operation field. Fig. 1 shows the percentage of the number of published papers during 2000-2005 in a circle form. This figure shows that some fields such as load forecasting,, fault diagnosis/fault location, economic dispatch, security assessment and transient stability. The following parts of paper is a review of why and how to apply the NNs in these power system operation and control strategies.

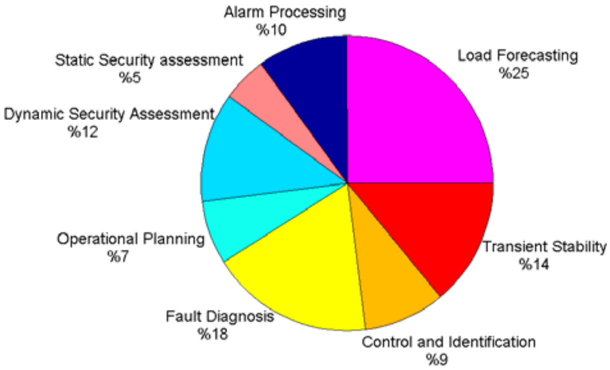

Fig. 1 Neural networks applications in power systems; 2000-April 2005

II. Various NNs Application in Power System Subjects

A. Load Forecasting

Commonly and popular problem that has an important role in economic, financial, development, expansion and planning is load forecasting of power systems. Generally most of the papers and projects in this area are categorized into three groups:

- Short-term load forecasting over an interval ranging from an hour to a week is important for various applications such as unit commitment, economic dispatch, energy transfer scheduling and real time control. A lot of studies have been done for using of short-term load forecasting [11-14] with different methods. Some of these methods may be classified as follow: Regression model, Kalman filtering, Box & Jenkins model, Expert systems, Fuzzy inference, Neurofuzzy models and Chaos time series analysis. Some of these methods have main limitations such as neglecting of some forecasting attribute condition, difficulty to find functional relationship between all attribute variable and instantaneous load demand, difficulty to upgrade the set of rules that govern at expert system and disability to adjust themselves with rapid nonlinear system-load changes.

The NNs can be used to solve these problems. Most of the projects using NNs have considered many factors such as weather condition, holidays, weekends and special sport matches days in forecasting model, successfully. This is because of learning ability of NNs with many input factors.

- Mid-term load forecasting that range from one month to five years, used to purchase enough fuel for power plants after electricity tariffs are calculated [15].
- Long-term load forecasting (LTLF), covering from 5 to 20 years or more, used by planning engineers and economists to determine the type and the size of generating plants that minimize both fixed and variable costs[16]. Figure 6 shows the percentages of load forecasting after 2000. Main advantages of NNs that has increased their use in forecasting are as follows:

1- Being conducted off-line without time constrains and direct coupling to power system for data acquisition.

2- Ability to adjust the parameters for NN inputs that hasn't functional relationship between them such as weather conditions and load profile [17,18,19]. Fig. 2 shows the percentage of number of published papers during last five years in different load forecasting types.

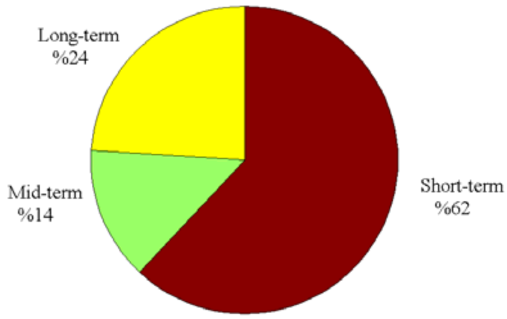

Fig. 2 Types of load forecasting that done with NN

B. Fault Diagnosis\Fault Location

Progress in the areas of communication and digital technology has increased the amount of information available at supervisory control and data acquisition (SCADA) systems [3,4]. Although information is very useful, during events that cause outages, the operator may be overwhelmed by the excessive number of simultaneously operating alarms, which increases the time required for identifying the main outage cause and to start the restoration process. Besides, factors such as stress and inexperience can affect the operator's performance; thus, the availability of a tool to support the real-time decision-making process is welcome. The protection devices are responsible for detecting the occurrence of a fault, and when necessary, they send trip signals to circuit breakers (CBs) in order to isolate the defective part of the system. However, when relays or CBs do not work properly, larger parts of the system may be disconnected. After such events, in order to avoid damages to energy distribution utilities and consumers, it is essential to restore the system as soon as possible.

Nevertheless, before starting the restoration, it is necessary to identify the event that caused the sequence of alarms such as protection system failure, defects in communication channels, corrupted data acquisition [5].

The heuristic nature of the reasoning involved in the operator's analysis and the absence of an analytical formulation, leads to the use of artificial intelligence techniques. Expert systems, neural networks, fuzzy logic, genetic algorithms (GAs), and Petri nets constitute the principal techniques applied to the fault diagnosis problem [6].

From Table I, we see that the major effort to detect and rectify power system faults in 90's, concentrate on expert system methods. Its main defect is the incapacity of generalization and the difficulty of validating and maintaining large rule-bases. Recently, using model-based systems including temporal characteristics of protection schemes based on expert systems and NNs developed.

The main advantage of neural network is its flexibility with noisy data and its main drawback is long time required for training feed forward network with backpropagation training algorithm, especially when dimension of the power network is high. To short the training time using these substitute methods proposed: the general regression neural network (GRNN) in feed forward topology, the probabilistic neural network (PNN), adaptive neurofuzzy methods and the selective backpropagation algorithm [7].

C. Economic Dispatch

Main goal of economic dispatch (ED) consists of minimizing the operating costs depending on demand and subject to certain constraints, i.e. how to allocate the required load demand between the available generation units [20, 21]. In practice, the whole of the unit operating range is not always available for load allocation due to physical operation limitations.

Several methods have been used in past for solving economic dispatch problems including Lagrangian relaxation method, linear programming(LP) techniques specially dynamic programming(DP), Beale's quadratic programming, Newton-Raphson's economic method, Lagrangian augmented function, and recently Genetic algorithms and NNs. Because of, economic dispatch problem becomes a nonconvex optimization problem, the Lagrangian multiplier method, which is commonly used in ED problems, can not to be directly applied any longer. Dynamic programming approach is one of the widely employed methods but for a practical-sized system, the fine step size and the large units number often cause the 'curse of dimensionality'.

Main drawbacks of genetic algorithm and tabu search for ED are difficulty to define the fitness function, find the several sub-optimum solutions without guaranty that this solution isn't locally and longer search time.

Neural networks and specially the Hopfield model, have a well-demonstrated capability of solving combinational optimization problem. This model has been employed to solve the conventional ED problems for units with continuous or piecewise quadratic fuel cost functions. Because of this network's capability to consider all constrained limitation such as transmission line loss and transmission capability limitations, penalty factor when we have special units, control the unit's pollutions and etc., caused increasing the paper proposed recently.

Recently attractive tools for ED are neural network based on genetic algorithm and fuzzy systems. Figure 3 shows the percentage of these methods applications in the interval 2000-april 2005 papers. The main drawback of Hopfield neural network is low converging speed. This shortcoming can be alleviated by decreasing the limitations, but in nonlinear cases this method not suggested.

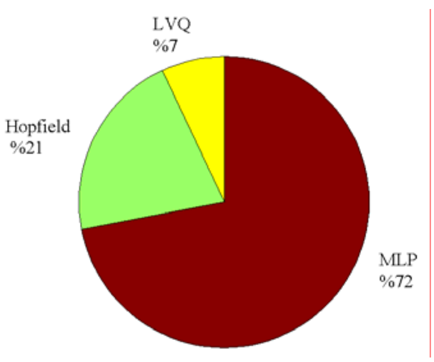

Fig. 3 Proportional usage of various methods in economic dispatch

D. Security Assessment

The principle task of an electric power system is to deliver the power requested by the customers, without exceeding acceptable voltage and frequency limits. This task has to be solved in real time and in safe, reliable and economical manner.

Figure 4 show a simplified diagram of the principle data flow in a power system where real-time measurements are stored in a database. The state estimation then adjusts bad and missing data. Based on the estimated values the current mathematical model of the power system is established. Based on simulation of potential equipment outage, the security level of the system is determined. If the system is considered unsafe with respect to one or more potential outages, control actions have to be taken.

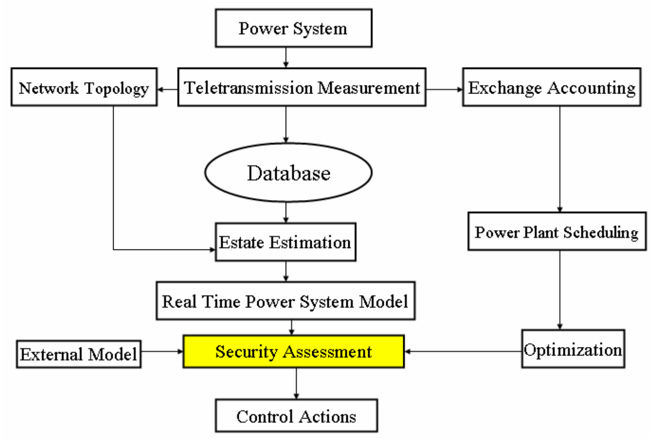

Fig. 4 Data flow in power System Operation

Generally there are two types of security assessments: static security assessment and dynamic security assessment [8, 9]. In both types different operational states are defined as follows:

Normal or secure state: In the normal state, all customer demands are met and operating limit is within presented limits.

Alert or critical state: In this state the system variables are still within limits and constrain are satisfied, but little disturbance can lead to variable toward instability.

Emergency or unsecure state: the power system enters the emergency mode of operation upon violation of security related inequality constraints. For a 3-bus-3-line power system that is shown in Fig 5, considering limitations, operating and constrained space illustrated in Fig 6.

In practical power systems the dimension of the operating system is very high. To overcome this "curse of high dimensionality", three main approaches can be followed:

Restrict the number of contingences and characterization of the security boundaries. This is for example done with supervised NNs like MLP.

Reduce the dimension of the operating vector; this is for example done with unsupervised NNs like Oja-Sanger networks.

Quantify of the operating point into a reduced number of classes, this is done with clustering algorithms for instance the nearest neighbor or the k-means clustering algorithms

Commonly NN that satisfies these conditions is multi-layered perceptron(MLP) with backpropagation training algorithm. The reason for this is on-line learning capability. There are two problems with using MLP, selecting of input data and overtraining. A good method for first problem is using some of the security indicators presently calculated by the energy management system (EMS) as inputs to the ANN. To overcome the latest problem using the backpropagation with selective training algorithm proposed [10].

From Table I we see that the number of papers about dynamical security case has increased in recent years. One of the reasons for this event is the dynamical and nonlinear behavior of power networks. With the growth of power system and energy demand and to have more reliable and secure energy, in most cases we see high dimensional problems with many limitations and constraints. To have the state of system quickly, in addition to MLP network, nowadays hopfield network has been used. Figure 7 shows the types of NNs used for security assessment.

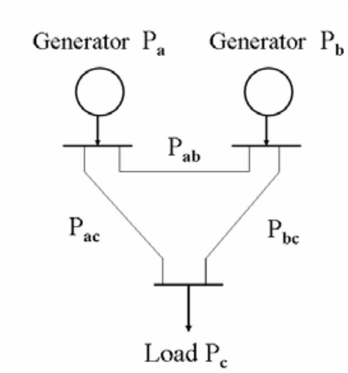

Fig. 5 Three bus-three line power system

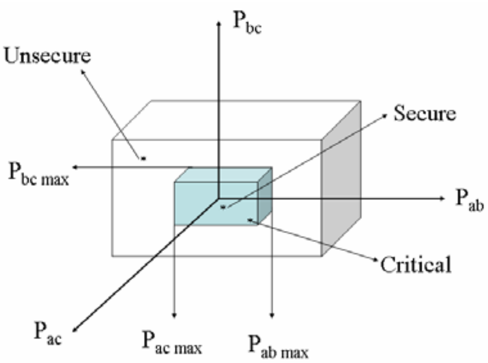

Fig. 6 Constraints and operating space for considered system in Fig 3

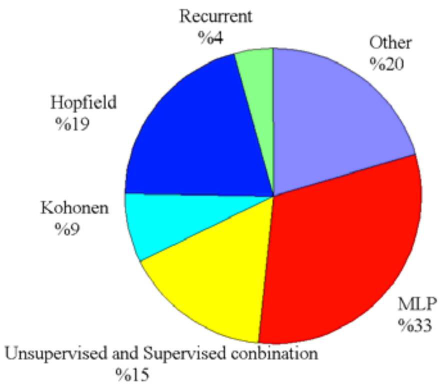

Fig. 7 NNs types used for security assessment

III. Other Applications

Due to the best ability of other AI techniques such as expert systems, evolutionary computing, fuzzy systems and hybrid system technique of these methods, and widely utilization of these techniques in power systems [27,28,29,30], in this section we introduce some of these applications and techniques. Because of best capability of genetic algorithm to optimize of process, optimal distribution and structural subject such as unit commitment always can be done with this method [31]. Also genetic algorithm can be used to provide a good set of initial weights for the NN, or can be used to fully train the NN or to find the optimal network structure.

Expert systems with complete gather a set of engineering and statistical and historical rule of projects can be used in monitoring of equipment and operational projects. Using the neural expert system hybrids may be increased the speed of recognition. Five different strategies have been developed for integrate neural network and expert systems: stand-alone models, transformational models, loosely coupled models, tightly-coupled models and fully-integrated models [32].

IV. Conclusion

In this paper the application of NNs in power system subjects and advantages and drawbacks of using NNs and other conventional methods have been reviewed. Main advantages of using NNs are

- Its capability of dealing with stochastic variations of the scheduled operating point with increasing data
- Very fast and on-line processing and classification
- Implicit nonlinear modeling and filtering of system data

However, NNs for power system should be viewed as an additional tool instead of a replacement for conventional or other AI based power system techniques. Currently NNs rely on conventional simulations in order to produce training vectors and analysis the training vectors, especially with noisy data. There are some remain major challenge to be tackled using NNs for power system: training time, selection of training vector, upgrading of trained neural nets and integration of technologies.

References

[1] M. T. Vakil, N. Pavesic, *A Fast Simplified Fuzzy ARTMAP Network*, Kluwer Academic Publisher, pp. 273-316, July 2003.

[2] K. Warwick, A. Ekwure, R. Aggarwal, *Artificial Intelligence Techniques in Power Systems*, IEE Power Engineering Series 22, Bookcratt Printed, pp. 17-19, 1997.

[3] G. Rolim, J.G. Zurn, *Interpretation of Remote Backup Protection for Fault Section Estimation by a Fuzzy Exper System*, IEEE PowerTech Conference, pp. 312-315, June 2003.

[4] R. Lukomski, K. Wilkosz, *Power System Topology Verification Using Artificial Neural Network Utilization of Measurement Data*, IEEE PowerTech Conference, pp. 180-186, July 2003.

[5] T.T. Nguyen, *Neural Network Load Flow, IEEE Trans. of Distribution, Generation and Transmission Conference*, pp. 51-58, January 1995.

[6] M. Vasilic, M. Kezunoric, *Fuzzy ART Neural Network Algorithm for Classifying the Power System Faults*, IEEE Trans. Power Delivery, pp. 1-9, July 2004.

[7] J.P. Park, K. Ganesh, *Comparison of MLP and RBF Neural Networks Using Deviation Signals for Indirect Adaptive Control of a Synchronous Generator*, IEEE Trans. of Power Delivery, pp. 919-925, March 2004.

[8] K.W. Chan, A.R. Edward, A.R. Danish, *On-Line Dynamic Security Contingency Screening Using Artificial Neural Network*, IEEE Trans. Power Distribution System, pp. 367-372, November 2000.

[9] G. Chicco, R. Napoli, *Neural Network for Fast Voltage Prediction in Power System*, IEEE Power Tech Conference, pp. 312-316, September 2001.

[10] M.T. Vakil, N. Pavesic, *Training RBF Network with Selective Backpropagation*, Neurocomputing Elsevier Journal, pp. 39-64, July 2004.

[11] H.S. Hippert, C.E. Pedreira, R.C. Souza, *Neural Networks for Short-Term Load Forecasting: A Review and Evaluation*, IEEE Trans. on Power System, VOL. 16, NO. 1, pp. 44-53, Februrary2001.

[12] W. Charytoniuk, M.S. Chen, *Neural Network Design for Short-Term Load Forecasting*, IEEE International Conference of Deregulation of Power System Technologies, pp. 554-551, April 2000.

[13] A.K. Sinha, *Short Term Load Forecasting Using Artificial Neural Networks*, IEEE Trans. On Power System Distribution, pp. 548-553, 2000.

[14] G. Chicco, R. Napoli, F. Piglone, *Load pattern clustering for Short-Term Load Forecasting of anomalous days*, IEEE Trans. on Power Tech, pp. 550-556, September 2001.

[15] M. Gavrilas, I. Ciutera, C. Tanasa, *Medium-Term Load Forecasting With Artificial Neural Network Models*, IEE CIRED Conference, pp. 482-486, June 2001.

[16] M.S. Kandil, S.M. El-Debeiky, N.E. Hasanien, *Long-Term Load Forecasting for Fast Developing Utility Using a Knowledge-Based Expert System*, IEEE Trans. on Power Systems, Vol. 17, No. 2, pp. 491-496, May 2002.

[17] T. Senjyu, P. Mandal, K. Uezato, *Next day load curve forecasting using recurrent neural network structure*, IEEE Trans. on Power Distribution System, pp. 388-394, March 2003.

[18] T. Saksornchai, W.J. Lee, M. Methaprayoon, J. Liao, *Improve the Unit Commitment Scheduling by Using the Neural Network Based Short Term Load Forecasting*, IEEE Trans. Power Delivery, pp. 33-39, June 2004.

[19] H. S. Hippert, C.E. Pedreira, *Estimating temperature profiles for short-term load forecasting: neural networks compared to linear models*, IEE Trans. on distribution and Generation Conference, pp. 543-547, January 2004.

[20] N. Kumarappan, M.R. Mohan, S. Murugappa, *ANN Approach to Combined Economic and Emission Dispatch for Large-Scale System*, IEEE Power Distribution system, pp. 323-327, March 2002.

[21] K. P. Wong, *Computational Intelligence Application in Unit Commitment, Economic Dispatch and Power Flow, IEEE Conference in Advance in Power System Control*, Operation and Management, pp. 54-59, November 97.

[22] J. Moreno, A. Esquivel, *Neural Network Based Approach for the Computation of Harmonic Power in Real Time Microprocessor-Based Vector for an Induction Motor Drive*, IEEE Trans. on Industry Application, pp. 277-282, January 2000.

[23] J. R. Vazquez, P. R. Salmeron, *Three Phase Active Power Filter Control Using Neural Networks*, 10th Mediterranean Electrotechnical Conference, Vol 3, pp. 924-927, 2000.

[24] A. G. Bahbah, A. A. Girgis, *New Method for Generator's Angles and Angular Velocities Prediction for Transient Stability Assessment of Multi Machine Power Systems Using Recurrent Neural Network*, IEEE Trans. of Power System, Vol 19, pp 1015-1022, May 2004.

[25] L. L. Lai, E. Vaselcar, H. Subasinghe, *Fault Location of a Teed-Network With Wavelet Transform Neural Networks*, IEEE International Conference of Deregulation of Power System Technologies, pp 505-509, April 2000.

[26] H. K. Siu, H. W. Ngan, *Automatic Power Quality Recognition System Using Wavelet Analysis*, IEEE International Conference of Deregulation of Power System Technologies, pp 311-316, April 2004.

[27] M. Fanabashi, A. Maeda, Y. Morooka, K. Mori, *Fuzzy and Neural Hybrid Systems: Synergetic AI*, IEEE Expert, pp. 32-40, 1995.

[28] J. A. Momoh, X. Ma, K. Tomsovic, *Overview and Literature Survey of Fuzzy Set Theory in Power System*, IEEE Trans. Power Systems, pp. 1676-1690, 1995.

[29] K. Tomosovic, *A Fuzzy Linear Peogramming Approach to the Reactive Power/Voltage Control Problem*, IEEE Trans. Power Systems,(1992), pp. 87-293.

[30] A. A. El Desouky, M. M. El Kateb, *Hybrid Adaptive Technique for Electric Load Forecast Using ANN and ARIMA*, IEE Proceeding in Distribution Conference, pp 213-217, July 2000.

[31] T. Saksomchai, W. J. Lee, K. Methaprayoon, J. Liao, *Improve the Unit Commitment Scheduling by Using the Neural Network Based Short Term Load Forecasting*, IEEE, pp. 33-39, July 2004.

[32] P. Ansarimehr, S. Barghinia, N. Vafadar, *Short Term Load Forecasting for Iran National Power System Using Neural Network and Fuzzy Expert System*, IEEE, pp. 1082-1085, July 2002.