Potential of Artificial Intelligence (AI) Techniques for WAPDA Grid System in Deregulated Environment

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Abstract: *This paper discusses the Potential of Artificial Intelligence Tools with reference to application for Power System in general and for WAPDA Grid System in particular in the senior of deregulation. Very brief description of AI tools has been given. Problem in Power System suited for AI tools have been explored. The potential for AI Tools for WAPDA grid system has been presented. Lastly the experience of AI based solution for selected problem has been given.*

Keywor : *Artificial intelligence, Power system, Short term load forecasting, Economic dispatch, Artificial neural networks.*

1. INTRODUCTION

Electric Power Systems are among the most complex man made systems in the world. These Systems have emerged at century's end as most critical infrastructure in the sense that they enable all other infrastructures. One of the main problems in power system is to arbitrate between economy and security. At the start of the new millennium the lot debates are going on for the "Power System of Future". New goals are being set for the working philosophy of individual utilities and the priorities for the modernization of their power system in the next 20 years. The Power System of future should enable the utilities to:

- Be more competitive with overall strategies.
- Provide better service.
- Better manage their assets.
- Extend equipment life.
- Improve diagnostics.
- Develop reliability-centered maintenance.

In this paper efforts have been made to develop brief survey on the potential of AI Techniques for WAPDA Grid System. The paper is organized as follows: Section I deals with brief introduction of AI Tools. The Artificial Intelligence Techniques in the senior of Privatization & Restructuring is introduced in Section II. Section III covers very briefly the areas of Power System suited for AI Techniques. Section IV presents the potential of AI Tools for WAPDA Grid System. Section V gives the experience of selected case studies of WAPDA System Problem based on AI Tools. Lastly there is conclusion.

2. Artificial Intelligence Tools

"Intelligence" is commonly considered as the ability to collect knowledge and to reason with this knowledge in order to solve problems. Artificial intelligence is a discipline with two strands: science and engineering. The scientific strand attempts to understand the requirements and mechanisms enabling intelligence of various kinds in humans, other animals, and information processing machines and robots. The engineering strand attempts to apply such knowledge in designing useful new kinds of machines and helping us to deal more effectively with natural intelligence. There are many ways to define the field of Artificial Intelligence. However, two definitions are given below:

"Artificial Intelligence is the science of making machines do things that require intelligence if done by men."--Marvin Minsky, MIT)

- "The goals of Artificial Intelligence can be defined to make computers more useful and to understand the principles that make intelligence possible."---Patric Winston, MIT).
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Figure 1 gives time line of major AI events. The tools for Artificial intelligence (AI) may be listed as:

1. Artificial Neural Network (ANN)
2. Expert Systems
3. Evolutionary Computation
4. Fuzzy Logic
5. Hybrid Approaches

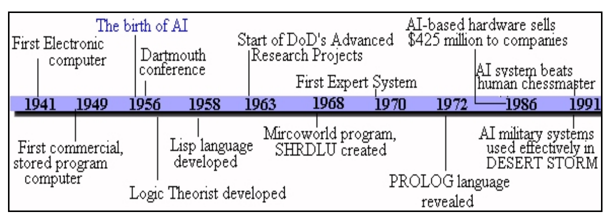

Figure 1: Time line of major AI events

3. ARTIFICIAL INTELLIGENCE TOOLS IN THE SENIOR OF PRIVATIZATION & RESTRUCTURING

The new technologies, concepts and tools are being evolved to the challenges for the power system of future. Intelligent systems are expected as new methodology for solving difficult problems in Power Systems. Artificial Intelligence (AI) techniques are extensively being used independently and in conjunction with conventional techniques in the area of Power System. The power industry has seen the extensive application of AI techniques to a wide range of power system problems. Deregulation will probably be the primary force driving the long-term future of AI applications to power systems. Three principal features of deregulation seem likely to provide motivation for increased efforts to apply AI Techniques to power systems.

- First, uncertainty in the input data will increase. Market forecasts will be required, and there is no reason to believe that electrical energy markets will exhibit any more predictability than do other markets.
- Second, the complexity of operations will increase dramatically, as energy transactions under the purview of a control center increase by an order of magnitude, each requiring technical analysis, approval, oversight, and accounting.
- Finally, the time pressures associated with competitive markets seem likely to appear in power systems operations and operations planning. This is certainly true for generators, who will have to market their power, and probably also true for the transmission system, which will be pressured to make rapid decisions on the suitability of various sales.

The need for fast answers to complicated problems with uncertain and incomplete data will undoubtedly grow as deregulation progresses. This situation presents an enormous opportunity for AI applications to solve the challenging problems looming in the future of power systems.

4. AI TOOLS IN POWER SYSTEM

Modern power systems are required to generate and supply high-quality electrical energy to consumers. The electric power industry is continuously searching for ways to improve the efficiency and reliability with which it supplies energy. Although the fundamental technologies of power generation, transmission, and distribution change quite slowly, the power industry has been quick to explore new technologies that might assist its search and to wholeheartedly adopt those that show benefits.

Since beginning of last decade of previous century, the researchers in the power engineering community have been studying the feasibility and application of new information processing techniques for efficient problem solving of complex power system problems. With the advent of artificial intelligence tools, alternative strategies have been identified, proposed and developed for the solution of ill-structured and complex problems in power systems. The acceptance of these techniques by the power engineering community, both in the academic institutions and industry, has paved way for basic research into the identification of new methodologies in artificial intelligence and machine learning, and in an attempt to understand the basic concept of problem solving and its application to power systems [1-3].

The dual questions of which problem to attack with AI techniques and which AI technique to use for a particular problem are abiding ones in the power industry, as they are in many other industries.

4.1 Opportunities for AI in Power Systems

The typical utility's electric power system consists of generation, transmission, and distribution systems. Generators produce electric power. The transmission system moves it in bulk, often over large distances, and the distribution system delivers it to individual customers. Even this simplified sketch of a utility illustrates several important characteristics of the problems that appear. First, problems can appear as either component or system problems. Secondly many system problems exhibit combinatorial complexity. Applications that address system-level problems must be able to deal with the number of components in the typical power system, either directly or by reducing the problem size to a manageable level without losing too much accuracy in the result. Thus power system is highly complex and nonlinear system to be solved and operated. Time scales involved for various activities in power system planning, operation and control varies from second, minutes, hours, months and years.

AI tools have been useful for solving power system problems when there is a good match between the problem characteristics and those of the AI tool. One aspect of power system problems, which is highly significant for AI applications, is the nonlinear behavior of the various components and of the entire system.

4.2 Problems suited for AI Tools

To investigate which characteristics of power system problems are suited to AI tools, we can categorize the problems by time frame into real-time control, operations, operation's planning, and planning. The brief description is as follows:

Real-Time Control
Real-time control involves both *discrete and continuous control* systems. *Many real-time controls are quite simple in their individual operation, but their coordinated effect on the power system and their interactions through the power system can become quite complex*

Discrete Control	Load Shedding, Protection, Transformer, Capacitor Switches
Continuous Control	Generator exciters

Operations
This category includes real-time human decision making in time frames ranging from a few minutes to several hours. SCADA provides the fuel for EMS in Control Centre. Issues to be dealt may be: Alarm Processing, AGC, Short Term Optimization, and Security.

Operations Planning

This category deals with operating strategies for time frames ranging from a day to a year into the future. Operations planning occur in interactive environments using either the EMS or off-line processing. The three principal focuses are ***economics, security, and maintenance scheduling.*** All require a forecast of the loads on the power system.

Planning

The primary concern in power system planning is decision making for capital projects with life times measured in tens of years. Each alternative is evaluated for its security and economic impacts on the existing system. Although driven by technical issues such as load growth and generation or transmission capacity, major planning decisions dealing with new generation or new transmission lines tend to be dominated by political and financial considerations. Planning also occurs to develop procedures for shorter time frames. For example, power system blackouts occur occasionally, and generic plans are developed off line for restoring the power system

4.3 Opportunities for AI in Power System Problem

Real-Time Control

The power system's rich diversity of distributed real-time control functions provides many opportunities for AI applications. These opportunities occur both directly in the controllers to classify monitored conditions and execute desired logic or heuristics and indirectly in solving problems complicated by the interaction of real-time controls at the system or component level

Operations

The EMS, with its automatic data collection, computational facilities, interface to humans in the operations control loop, and complex real-time tasks, is an attractive environment for AI tools. They can augment existing applications or provide new applications beyond the scope of traditional numerical control, analysis, and optimization applications.

Operations Planning

The complex problems in load forecasting, the heuristics used in large nonlinear optimization problems, and the knowledge-intensive tasks associated with operations planning are all areas of potential AI application.

5. POTENTIAL FOR AI TOOLS IN WAPDA SYSTEM

The AI Tools may be applied for various problems in WAPDA Grid system. However, few applications may be listed as:

Expert Systems

Monitoring & Diagnosis, Restoration, Security, Load Forecasting, Voltage Control.

Artificial Neural Networks

Load Forecasting, Unit commitment, Economic Dispatch, Security

Evolutionary Computation

Unit Commitment, Economic dispatch, Security

Hybrid Approaches

Economic dispatch, Unit commitment

6. AI TOOLS APPLICATION IN WAPDA SYSTEM

Three case studies have been presented in this section to highlight the experience of using AI Tools with WAPDA System problems.

Economic Dispatch Using Analytic Hopfield Neural Network

Case Study I

Economic Dispatch Problem (EDP) has been solved using Analytic Hopfield Method [5]. Both λ iteration and Analytic Hopfield Models have been programmed in Visual C environment Table 1 gives the comparison for the three machine test system [6] Comprehensive discussion on ANN based advances in Economic dispatch can be referred in [7]. EDP of simplified WAPDA system has also been carried out. Table 2 lists the results.

Case Study -II

Short Term Load Forecasting for WAPDA System Using Artificial Neural Network

In order to apply the ANN to Wapda System Short Term Load Forecasting problem, back propagation algorithm has been programmed in C++ language. Real data of Wapda system for the years 1091-92 & 1999-2000 has been used to train the network and then forecast was made for the year 1993 & 2003 respectively. The forecasted results then compared with the real and actual load of the Wapda system for the same period. The methodology adopted is as follows:

1. The whole year has been divided into three seasons --- **Summer** (From May – September) **Winter** (From November – February) **Spring** (From March – April)
2. **Target:** Prediction of peak load over the day
3. **Inputs:** Three inputs --- Previous day peak load in MW, Previous week peak load in MW Previous month peak load in MW

Tables 3, 4 & 5 list the result of summer season 1993, winter season 2001 & spring season 2001 (with η as momentum and α as learning rate) respectively.

7. CONCLUSION

In the deregulated environment quick decision making is a vital parameter. The AI tools can be exploited for the solution of the various problem of WAPDA Grid System. The case studies highlight the experience with WAPDA system. AI Tool based solution could be effective and useful option in the new millennium for WAPDA Grid System.

Table 1.EDP Comparison of Analytical Hopfield Neural Network with Lambda Iteration

	Analytic HFNN with Pm = 0.01	Lambda Iteration	
		Δλ Specified	Δλ Gradient Method
P1	393.1653	393.4365	393.1696
P2	334.6000	334.4128	334.6036
P3	122.224	122.1496	122.226
Total Power Generated	849.99	849.999	849.999
Power Mismatch	0.009	0.001	0.0003
No. of Iteration	1	147523	02
Lambda	---	9.137	9.148
Total Cost of Generation	8189.126	8194.0237	8194.3561

Table 2.EDP of WAPDA System Comparison of Analytical Hopfield Neural Network with Lambda Iteration

	Analytic HFNN with Pm = 0.01	Lambda Iteration	
		Δλ Gradient Method	Δλ Specified
P1	200	200	200
P2	200	200	200
P3	100	100	100
P4	50	50	50
P5	200	200	200
P6	537.837	537.838	537.837
P7	500	500	500
P8	200	200	200
P9	512.162	512.162	512.162
P10	800	800	800
P12	500	500	500
P13	2200	2200	2200
Total Power Generated	6000	6000	6000
Power Mismatch	0.001	0.000	0.00
No. of Iteration	10	6	821892
Lambda	-	20.21892	20.21891
Total Cost of Generation	64133.493	64133.5135	64133.494

Table 3 Actual & Forecast Load for Winter Season 2001 for WAPDA System with η = 0.24 & α = 0.6

Forecast Date	Actual load	Forecast load	% Error
28.9.1993	6414	6833	6.5
21.9.1993	6544.7	6484	0.92
14.9.1993	5979.7	5987	0.12
7.9.1993	6061.5	6137	1.2
31.8.1993	5813.1	6594	0.13
24.8.1993	6265.5	6133	2.11
17.8.1993	6203.5	6306	1.6
10.8.1993	6259.1	6242	0.27
3.8.1993	6006.8	6274	4.4
27.7.1993	6320.7	6477	2.4
20.7.1993	6176.7	6202	0.40
13.7.1993	6233.1	6237	0.06
6.7.1993	6237.5	6308	1.13
29.6.1993	6030.4	5998	0.53
22.6.1993	5835.9	5933	1.6
15.6.1993	5502	5108	7.16
8.6.1993	6137	5946	3.11
1.6.1993	5669	5698	0.51
25.5.1993	5868	6146	4.73
18.5.1993	5735	5722	0.22
11.5.1993	5557.9	5673	1.71
4.5.1993	5863.3	5872	0.14

Average percentage error = 1.86%
Maximum percentage error = 6.53%
Minimum percentage error = 0.06%

Table 4 Actual & Forecast Load for Winter Season 2001 for WAPDA System with η = 0.27 & α = 0.96

Forecast Date	Actual load	Forecast load	% Error
27.2.2001	7832	7615	2.77
20.2.2001	7616	7533	1.08
13.2.2001	7822	7592	2.94
6.2.2001	7904	7637	3.37
30.1.2001	7792	7590	2.59
23.1.2001	8085	7706	4.68
16.1.2001	7793	7578	2.75
9.1.2001	8256	7756	6,05
2.1.2001	7947	7690	3.23

Average percentage error = 3.27
Maximum percentage error = 6.05
Minimum percentage error = 1.08

Table 5 Actual & Forecast Load for Spring Season 2001 for WAPDA System with η = 0.25 & α = 0.97

Forecast Date	Actual load	Forecast load	% Error
25.4.2001	8719	8275	5.09
19.4.2001	7302	7414	1.5
11.4.2001	8494	8283	2.48
4.4.2001	7767	7856	1.14
28.3.2001	7228	7605	5.21
21.3.2001	8011	8185	2.17
14.3.2001	8241	8150	1.10
7.3.2001	7192	7397	2.85

Average percentage error = 2.65
Maximum percentage error = 5.09
Minimum percentage error = 1.5

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