ARTIFICIAL INTELLIGENCE APPLICATIONS TO POWER SYSTEM

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ABSTRACT

In recent years, artificial intelligence techniques have attracted considerable attention of power system experts as a potential choice for computational system due to the variety of advantages they offer over the conventional systems. Today the main computational intelligence techniques found in the power system applications are artificial neural network (ANN), evolutionary computation, fuzzy system and expert systems. Artificial Intelligence tool have been useful for solving power system problems when there is good match between the problem characteristics and those of the AI tool. This paper describes an overview of various intelligent system applications to power systems. Restructuring or deregulation will probably the primary force driving the long term future of Artificial Intelligence applications to power systems especially under the uncertainty in the Input data, market forecasts and complexity of operation.

Key Words : Artificial neural networks, expert systems, fuzzy logic, fuzzy set, heuristic search and Intelligent system.

1. INTRODUCTION

One of the primary concerns of the power systems is to maintain services of prescribed quality to its consumers under all circumstances [1]. Today, the electric power industry is continuously searching for methods to improve the efficiency and reliability with which it supplies energy. Though the fundamental core technologies of the power industry, i.e., the power generation, transmission and distribution change quite slowly, the power industry has been quick to explore the new technologies that might assist its search and to wholeheartedly adopt those that show benefits. Artificial intelligence is an area that deals with fundamental issues such as knowledge representation, search techniques, probabilistic or heuristic reasoning and machine learning. It refers to the study of how to make computers to solve problems which at the moment, man does better [6]. If man is more intelligent than computers and artificial intelligence tries to improve the performance of computers in activities that people do better, then the goal of artificial intelligence is to make computers more intelligent. Artificial intelligence areas include expert systems, fuzzy logic, artificial neural network (ANN), and genetic or evolutionary algorithms.

For decades, many efforts have been devoted to the development of Artificial Intelligence (AI) systems. Since the 1980's, a number of power engineering applications has been proposed so far. The activities started primarily in the area of expert systems, followed by applications in artificial neural networks, fuzzy logic and genetic algorithm. Earlier, computer applications in power engineering have been focused on numerical computation. To name a few, we solve power flow equations, integrate swing equations, minimize the fuel costs and maximize the transfer capabilities. All these are computation intensive applications that help to improve the efficiency and quality of power system planning and operation. The power system computer applications, however, should not be limited to numerical computations. A number of practical power system problems require logic reasoning, heuristic search, perception, and/or the ability to handle uncertainties, AI tools can be part of their solution. For example, the design of a distance/ impedance relays is based on a logic, e.g., if the impedance viewed by a relay falls with in its designed reach, the relay sends a tripping signal to that associated circuit breaker. For complex situation that involves possible multiple faults and multiple malfunctioning devices, many relays have to be analyzed to determine the causes of the problem. This analysis clearly requires logical reasoning based on the data and information available and the principles of protective system design and power system as a whole. Voltage and current waveforms, if available, can be very useful information for diagnosis. Neural networks as signal processing tools can be used to recognize the fault type based on the waveforms. The resulting computer application area, referred to as fault diagnosis has proved to be a promising AI application. The fault diagnostic tools are required by the industry and this technology is maturing for development of these tools.

The representation of knowledge is an important issue. If the knowledge acquired from experts is represented by rules or If- Then structures, the resulting system is called a rule based expert system.

2. Artificial Intelligence in Power Systems

AI tools are useful for solving power system problems when there is a good match between the problem characteristics and those of AI tools. For example, one aspect of power system problems that the previous description omits, but which is highly significant for AI applications, is the non-linear behavior of the various components and of the entire system. The non linearities are of three basic types: near linear, continuous non-linear, and discrete. In normal operation many problems can be treated as near-linear, and many numerical applications take advantage of this to minimize solution times. As the power system becomes more stressed by larger loads and power transfers, for example non linearities become too large to ignore, and control limits start to appear. In either the near linear or non linear case, the power system routinely encounters planned and unplanned discrete changes caused by switching operations, either automatic or manual [4]. On one hand, non linear component behavior means that even an application that addresses one component at a time will be nontrivial. One the other hand, non linear problems are precisely of the type that AI tool can address [8].

To investigating that which characteristics of a power system problem are suited to AI tools, the power system problems can be classified by the time frame into real time control, operations, operations planning and planning.

2.1. Real Time Control

This category deals with those processes occurring too fast for human intervention or those subjected to local, autonomous control. Most often both characteristics apply. Local controls distributed in the power system must often be coordinated so that many autonomous controls work together in response to a system condition. Real time control involves both discrete and continuous control systems. Many real time controls are quite simple in their individual operation, but their co-coordinated effect on the power system and their interaction through the power system can become quite complex.

Generator exciters, which control the reactive power and terminal voltage of the generating units are important real time continuous control systems that play a major role in maintaining the power system's stability. The exciter control system portions that deals exclusively with stability are called power system stabilizers.

Capacitor switches sometimes have local controllers that switch based on local voltage and time of the day. Continuous changes in reactance can be supplied by Static VAR Compensators (SVCs) that switch thyristors every cycle.

Protection, a discrete control, is perhaps the most ubiquitous of the real time controls. Protection must correctly classify the power system state as normal or faulted. It also must isolate the faulted portion of the power network in tens of milliseconds to prevent equipment damage and to continue delivery of power in the rest of the system. Protection controls are usually coordinated by controlling their relative operating times.

Load Shedding is another form of discrete control. The loss of a power system component, such as a generator or transmission line, can instantaneously change the amount of load the system can apply. When loads exceed this supply capacity, the load must quickly be reduced to avoid widespread blackouts. Such excessive loads are indicated by dropping frequency or voltage. A load shedding relay is used to sense voltage or frequency, and de-energizes its assigned feeder to reduce load when it classifies the system state as one of the generation/load imbalance.

On load tap changers are local controllers that change transformer turn ratios by small discrete increments to maintain the voltage on one side of the transformer at a nearly constant value while the voltage on the other side changes, or sometimes to control real power flows.

2.2. Operations

This category includes real time human decision making in time frames ranging from a few minutes to several hours. Most utilities have a control centre with an energy management system, a large process control computer system. The measurements from all over the system are telemetered to the EMS, and control signals are sent through the EMS to the power system components. These functions are called Supervisory Control and Data Acquisition (SCADA). Operators, often called dispatchers, view the power system through the EMS, issue manual controls, and establish set points and operating modes for centralized real time control applications. Other applications in the EMS assist the dispatchers by analyzing or optimizing the power system in various ways. The main operating functions are monitoring the power system's health and diagnosing the cause or location of abnormal conditions through the telemetered values from the SCADA system.

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.

2.3. Operations Planning

This category deals with operating strategies for time frame ranging from a day to a year into the future. Operations planning occur in the 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. Short term load forecasting predicts loads for up to two weeks, using historical data. Longer term load forecasts depend more on economic forecasts.

The unit-commitment problem involves scheduling generator start-ups and shut-downs to meet predicted loads at minimum cost [7]. Generator start-up costs and minimum up-and-down times make this a complex problem that can benefit from heuristic search techniques.

The complex problems in load forecasting, the heuristics used in large non-linear optimization problems and the knowledge intensive tasks associated with operations planning are all areas of potential AI application [5].

2.4. Planning

The primary concern in power system planning is decision making for capital projects with lifetimes 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 or generation and 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. These restoration plans require coordinating the generation, transmission and distribution systems in abnormal operation to identify available generation capacity, transmission paths and loads to pick up, all subject to numerous constraints. The preparation of a restoration plan involves heuristic search, rules and prioritizing.

3. Applications of Artificial Intelligence to Power Systems

Various AI techniques have found numerous applications to power systems. These techniques conveniently fall into four categories: expert systems, artificial neural networks, fuzzy sets and heuristic search.

3.1. Expert Systems

These systems are computer programs that possess expertise in a given area. This expert knowledge is normally stored separately from the procedural part of the program and might be stored in the many of the one forms including rules, decision, trees, models and frames. Many areas of applications in electric power systems match the expert system abilities- i.e., decision making, archiving knowledge and solving problems by reasoning, heuristic or judgment. Expert systems are particularly useful for these problems when a large amount of data must be processed in a short time period [11].

Expert Systems appeal to many power system operators and engineers. These systems can consistently apply knowledge gained from years of human experience to simplify complex power system problems and make high level operating, planning and design decisions. These systems find applications in real time control, operations, and operations planning and planning.

The control applications include generator voltage regulators, power plant operations and control of SVC's. The security applications classify the system's security or select critical contingencies for further numerical analysis, based on extracted heuristics or learned knowledge [3].

3.2. Artificial Neural Networks

Artificial neural networks (ANN) are neurons and are biologically inspired systems that transform a set of into a set of outputs through a network of neurons. A neuron can be described by its input output relationship. The output of an ANN is a weighted sum of the neuron outputs. The network learns these weights during training, which can be supervised or unsupervised. A wide Variety of network connections and training techniques exist. Power system problems regarding classification or the encoding of an unspecified non linear function are well suited for ANN's.

ANN's applications to the power system can be categorized under three main areas: regression, classification and combinatorial optimization. Applications involving regression include transient stability analysis, load forecasting, contingency screening and harmonic evaluation. Application involving classifications include static and dynamic security analysis. The area of combinatorial optimization includes unit commitment and capacitor control.

3.3. Fuzzy Set Theory

Fuzzy logic is a technique to handle uncertainties. The traditional probabilistic approaches are based on rigorous probability theories [5]. A fundamental element of fuzzy logic is the membership function which describes the degree of participation with a value between 0 and 1.

For power system applications, fuzzy sets are appropriate in many areas where the available information involves uncertainties. One of the examples is power system stabilizer. The majority of the real time fuzzy control applications implement fuzzy logic. The restoration of power system and load forecasting applications also use fuzzy logic [2]. Fuzzy sets find application in monitoring and diagnosis of faults and equipment. They also determine a fuzzy assessment of system security and represent uncertainty in generation expansion planning.

3.4. Heuristic Search

Genetic algorithms are search methods that emulate the evolution of a population. Starting with an initial population, each string is assigned a fitness value. The crossover and mutation may alter the strings randomly during reproduction. The selection process is expected to result in a population with higher fitness values that (hopefully) contains the optimal solution. Genetic algorithm and simulated annealing are two forms of heuristic search, which solves optimization problems by randomly generating new solutions and retaining the better ones [9].

The recent area of application of heuristic search to power system is deregulation as it involves complexity of power system operation subjected to a number of constraints. Firstly, uncertainty in input data will increase [12]. Market forecasts will be required and there is no reason to believe that electric energy markets will exhibit anymore predictability than do other markets.

Secondly, complexity of operation will increase dramatically, as energy transactions under the purview of a control centre increase by an order of magnitude, each requiring technical analysis, approval, oversight and accounting.

Thirdly, the time pressures associated with competitive market seem likely to appear in power system operations and operations planning. This is certainly true for the 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 [10].

Therefore heuristic search algorithms have potential applications in operations planning and planning.

4. Conclusions

The power industry has seen the extensive application of AI techniques to a wide range of power system problems. In this paper, various AI techniques and their applications to power system area has been explained. The successful application of a particular AI technique to a power system problem is a challenging field. It is challenging to develop ANN, fuzzy logic and evolutionary algorithm applications to real problems in the practical world. It is important to keep in mind that AI techniques designed for specific tasks finally are to be supported by decisions of human engineers and managers.

Restructuring or deregulation will probably be the major thrust in future for AI applications to power system. The three basic features of deregulation are likely to spur the increased efforts to apply AI to power systems. The first one is uncertainty in input data, which will require market forecasts. The second one is the complexity in operation due to large number of market participants and third one is about the time pressures associated with competitive market structure. The requirement of faster solutions to complicated problems with uncertain and incomplete data will definitely grow as deregulation proceeds. There is potential opportunity for AI applications to solve the complex problems of power systems.

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