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USING EXPERT SYSTEMS FOR FAULT MANAGEMENT IN ELECTRICAL POWER SYSTEMS

Syed Bader Anwar
Associate Professor, E.E.E. Department, Ayaan College of Engineering & Technology, Moinabad, Ranga Reddy District, Telangana State, India.

ABSTRACT

Expert Systems are extensively being used in power system fault managements and it has become an area of strong research interest in the past few years. This paper is primarily concerned with applications that relate to the overall power system monitoring, control, operation, protection and planning with emphasis on protective relaying, substation control and related monitoring functions. It gives both a survey of the present research efforts and a discussion of future possibilities and trends in this area.

Keywords: *Fault Management, Expert systems etc.*

I. INTRODUCTION

Fault Management in Electrical Power systems has received a lot of theoretical and practical attention in the recent past. Fault Diagnosis is a complex reasoning activity where Expert Systems have been successfully applied.
An expert system is a computer system that emulates the decision-making ability of a human expert. Expert systems are designed to solve complex problems by reasoning about knowledge, represented primarily as if–then rules rather than through conventional procedural code. The first expert systems were created in the 1970s and then proliferated in the 1980s. Expert systems were among the first truly successful forms of Artificial Intelligence software.

An expert system is divided into two sub-systems: the inference engine and the knowledge base. The knowledge base represents facts and rules. The inference engine applies the rules to the known facts to deduce new facts. Inference engines can also include explanation and debugging capabilities.

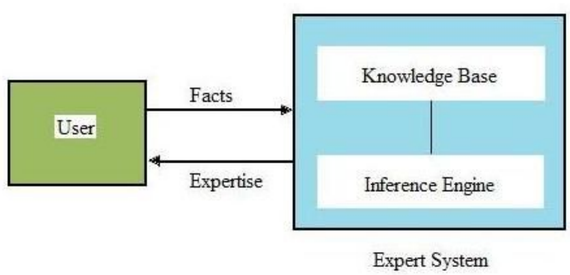

Fig 1. The basic architecture of an Expert System.

II. CHARACTERISICS

2.1 FUNCTIONAL CHARACTERISICS

In order to be able to classify the existing expert system applications a discussion is needed of the response time, dependability / selectivity and equipment allocation requirements of the protection, control and monitoring functions. There are a number of protection, control and monitoring functions that are implemented in an electrical power system.

2.1.1 Response time

One of the main characteristics for almost all of these functions is a very short response time. This may be related to the reaction time, if the function is a closed-loop real-time control such as protective relaying. On the other hand, this time may be associated with the execution time if an open-loop operator-initiated function such as substation switching. Finally, the time response may denote the database update time if data acquisition functions such as alarm and status monitoring are considered. A brief overview of the time constraints associated with the main groups of protection, control and monitoring functions is given in Table 1.

Table 1.

Response Time Requirements

I - Protection:	
a) Line	milli seconds
b) Bus	milli seconds
c) Transformer	milli seconds
d) Out of step machines etc.,	milli seconds
II – Control:	
a) Switching	seconds
b) V / VAR control	seconds
c) Load Shedding	seconds
d) SCADA	seconds
III – Monitoring:	
a) Fault Location	minutes
b) Sequence of events (SOE) recording	minutes
c) Disturbance recording	minutes

Given the state of the art of expert systems, it is unlikely that they could operate in the short time required for protective relaying. However, a protective relay which implements an expert system can be programmed in such a manner that the expert system recognizes when to turn over the relaying function to an extremely fast operating algorithm. Expert systems also offer potential for improving system operations by identifying more complex situations which happen slowly (such as the loss of the transmission network). It may be difficult for a human to determine the action needed in time to prevent the loss of a transmission system. On the other hand, an expert system could determine the necessary actions in time to prevent power system breakup as the loss of a transmission system happens over tens of seconds or minutes.

2.1.2. Dependability/selectivity

The dependability and selectivity of protective relays describe the ability of the relay to identify events correctly and take action based upon the information available to the relay. The dependability and selectivity of protection relays have been limited in the past by conventional approaches and limitations of the implementation technology. This has been widely recognized as an inability of the relaying scheme to adapt to the changes in the power system operating conditions.

With the advent of expert systems, it is now possible to implement protection systems which can analyze data in a more complex fashion and maintain or surpass the high degree of dependability and selectivity previously available with conventional approaches. This ability implies that the circuits and systems which are protected by the new relay designs can be operated at higher loading capacity and higher efficiency and reliability.

Finally, expert system applications may require a brand-new approach to equipment designs which would combine the functions of several existing types of equipment with the addition of some new functions. The ICPS design is an example of such an approach.

2.2. Expert system characteristics

2.2.2. Languages

An expert system can be developed utilizing any computer language. Some languages, such as Lisp and Prolog, have features which strongly support the development of expert systems. These languages were developed for symbolic processing, and commonly rely upon interpreters to interface the language to the actual computer machinery where they are executed. Other languages, such as C, Fortran, and Pascal, have few or no special constructions for symbolic processing, however these special constructions can be developed in these languages. It may be more difficult to develop or modify expert systems in this latter set of languages. However, since they tend to be compiled languages, they will have faster execution times.

2.2.3. Knowledge source

The acquisition of the domain-specific knowledge for the expert system can be the most difficult part of the development. In addition, the ability to check the knowledge base for correctness, conciseness, and thoroughness, in other words the verification of the knowledge base, can be very difficult, depending upon the source of knowledge. For example, the source of knowledge could be a set of manuals, a single human expert, or several human experts. The verification of heuristic knowledge in these three examples can be seen as totally different processes.

2.2.4. Knowledge representation

Rules, frames, or logic, the common methods for representing knowledge in an expert systern, are discussed in many texts and articles. Acknowledging that a field of engineering has emerged involving the acquisition and representation of knowledge, the tradeoffs between knowledge representations for the knowledge domain can be complex to evaluate. The choice of knowledge representation can have major effects on the development time, cost, performance, and ultimate success of the expert system design.

2.2.5. Inference engines

Whatever the knowledge representation chosen, the inference process involves comparing current conditions with the knowledge base. In some problems the best direction is to view the facts and see what kind of conclusions are indicated in the knowledge base. This is forward chaining. In other applications it may be more important to get goals and subgoals and then find or facilitate the facts which support these goals. This is backward chaining. In still other applications, the combination of the two techniques is desirable. In either forward or backward chaining, matches between the current conditions and the knowledge base are searched for. One may choose to study one branch of options as extensively as possible until one succeeds or is forced to abandon this train of thought and move to another branch. This is a depth-first search. On the other hand, it may be more advantageous to study all possible branches in equal depth and only proceed to deeper levels in the more promising branches. This is breadth-first searching. Again, it may be advantageous to combine, or switch, from one technique to another within a given problem.

2.2.6. Shells

On top of many languages, knowledge representations and inference strategies, empty shells have been developed for expert systems. These shells require only the domain-specific knowledge base to become functional expert systems. Shells usually provide easier user interfacing for the development and execution of an expert system.

2.2. 7. Hardware

The performance of the expert system will be greatly affected by the choice of hardware. The following characteristics make expert systems particularly burdensome on the hardware: (1) the extensive use of memory for program storage and execution space; (2) the vast number of memory accesses for the symbolic comparisons and searches. All of this usually represents execution speed bottlenecks. Some special computer architectures have been developed to support languages such as Lisp or Prolog more effectively. However, demand for these special architectures has not been great enough to manufacture them at a cost comparable with conventional architectures.

III. SURVEY OF THE PRESENT APPLICATIONS

3.1. Functional description

It is well recognized that, in general, an expert system is ideally suited for diagnostic function implementation. This impression has been reflected in the power field as well. One relatively broad area of application is monitoring of the power system equipment and diagnostics of the abnormal regimes of operation. These activities are directly related to prevention of damages that may result from undesirable equipment conditions.

3.1.1. Substation control

One of the most common control functions in a substation is the switching function. This function is normally carried out by the operators, but it can also be automated. The approaches proposed so far have enabled data validation, execution of switching sequences and final status verification steps to be automated so that the operator is fully assisted in carrying out such a complex task. Expert system applications have also concentrated on supporting operators in making their decisions more reliable and secure. The recent approaches have suggested that overall substation operation can be guided by an expert system. One other area of interest for expert system application for substation control purposes is in distribution automation systems. Preliminary results in this field have been reported and initial implementation efforts undertaken in the area of feeder monitoring and protection.

3.1.3. Protective relaying and related functions

Owing to the stringent time-response requirements, there are very few applications of expert systems in the implementation of protective relaying functions. The only known application is in the area of high impedance fault detection. High impedance faults have eluded the application of any conventional techniques for detection. Such faults appear to mimic normal load conditions experienced on a given feeder. Substantial research in recent years has shown that it is necessary to implement very sophisticated approaches to identifying what with conventional approaches have been seen as very subtle changes. Using expert system techniques, small differences become obvious changes which are unique to the high impedance downed-conductor fault. This approach provides for reliable, accurate and secure detection.

One area of interest is the relay setting coordination function. Some preliminary research has been reported in the past, and one of the activities has produced a prototype system. Similar activities for selection and coordination of fuses in an industrial customer environment have also been reported .

Yet another application of expert systems is to aid selection of appropriate algorithms for fault location. A hybrid expert system has been proposed to carry out the fault location function using a combination of known fault location algorithms and expert system support for algorithm classification and utilization. Finally, expert systems are also proposed for digital fault recorder (DFR) signal analysis. Some preliminary results indicate that a combination of digital signal processing algorithms and expert system techniques will have to be used to solve this type of fault analysis problem.

As a conclusion, it has also been recognized that integrated control and protection systems may benefit from expert system applications.

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