Expert systems

Their implications and applications for power systems

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Our dependency on the computer has been increasing ever since we recognized its tremendous potential. The ease of using numerical computations has proved a boon in designing complex power systems. Nevertheless, human experience and expertise cannot be incorporated in conventional programs. This has resulted in the emergence of "Artificial Intelligence" (AI), a tradition of research which attempts to emulate the reasoning mechanism in humans. This, in turn, has led to the field of "Expert Systems" (ES). The success of this venture has provided the replication of human reasoning though restricted to a narrow domain.

Formally speaking, we can define an expert system as a "set of programs which can emulate the reasoning and performance of a human expert in a narrow domain." There are crucial distinctions between an AI program and that of a conventional program. First, the conventional program is algorithmic in nature and needs a complete set of data to yield a unique solution to a problem. Or simply, the rules which go into building these programs are deterministic in nature. An AI program is heuristic in nature and is capable of producing several solutions with different confidence levels even when presented with incomplete data.

Second, an AI program needs flexibility of control as it calls for intelligent thinking. This is in contrast to the step by step algorithmic approach of a conventional one.

Thus, the nature of problems to be solved by the ES are different from the conventional method. This makes ES effective in problem areas of diagnosis, prediction and planning.

A potential advantage of an ES is the retention of knowledge when a human expert retires from the field.

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ES also seeks to relieve partially the burden of work for human experts. This way their energies can be devoted to more productive domains rather than routine work.

ES is also useful in situations where a critical judgment is called for in a very short time to prevent potential disaster. This is one of the features which makes it attractive for power systems applications. The commonly used languages for AI and ES development are LISP (list processing) and PROLOG (programming in logic) which use heuristics for symbolic data manipulation.

Human experts, when presented with a problem, use their expertise—facts about the problem, their specialized knowledge in the field. They then present to us a timely response which is sound as well as reliable.

For an ES to achieve the same,

1) it must have the capability to update knowledge easily, in order to keep pace with the latest information an expert acquires;

2) the control strategy employed must be flexible for intelligent information manipulation; and

3) the ES must have the capability to explain how it arrived at its conclusion.

An ES emulates the behavior of an expert essentially by four major components (Fig. 1):

- 1) knowledge base,
- 2) data base,
- 3) inference mechanism,
- 4) user interface.

Knowledge base

Essentially, the knowledge base is the medium through which a human expert's knowledge is made available to the computer. There are various schemes to this end, but the most common one is rule based systems.

The basic motivation in using rule based systems is that expertise can be coded as a set of rules of thumb or

"heuristics" in the AI jargon. A production rule contains knowledge in the form

IF < antecedent clause > THEN < consequent clause >

which simply means that if the antecedent clause is TRUE then a set of consequent logical conclusions is also TRUE.

A complicating factor, which arises here, is that of the confidence levels in the knowledge and hence in the deductions. For an ES to be reliable, there is a need to give sound judgment under

able control strategy. Some of the common ones are:

1) *Forward chaining*. Here, the mechanism compares information in the data base with the IF part of the knowledge base and generates the THEN part of the rule as its conclusion. This new state of the fact is added to the data base. The process continues until all the rules are exhausted. After that, the system scans the data base and informs us of its conclusion problem which involves more conclusions than facts.

The chaining involved is the logical

motion from one rule's consequent to another's antecedent. This has been found useful in power systems planning, distribution, design and load forecasting. The drawback is that the method has no grounds for following one path over another. Thus, the entire knowledge base might have to be searched to affect a logical conclusion.

2) *Backward chaining*. Here the mechanism starts by guessing a conclusion and attempts to prove its guess is

"TRUE" by finding a rule with a similar then part and establishing the "IF" condition which now is a sub conclusion.

This process continues until the problem is solved. Thus, this method is said to be goal driven. This approach is favorable only when the problem involves a larger number of facts than conclusions. This has been found useful in fault diagnosis, control and monitoring of power systems.

3) *User interface*. This is the component which actually brings about the interaction between the user and the system. This is usually assumed by a monitor which can be tailored for smooth user friendly interaction.

Why go the expert way?

With the growing complexity of power systems, minimization of interruption to customers and reliability of

Fig. 1 Structure of an expert system

uncertainty, because the real world data may be vague or uncertain. Thus, the knowledge base is designed to handle fuzzy or probabilistic data. This allows the user to be presented with the judgment along with a certainty factor.

Data base

The ES gathers facts about problems both by user supplied information and information deduced by the system's inference mechanism. These facts constitute the data base of the system which grows with the user system interaction.

Inference mechanism

This literally constitutes the "brain of the ES." Inference is the process by which programs can deduce logical conclusions by manipulating facts from the data base and knowledge from the knowledge base by employing a suit-

service assume paramount importance. The means to achieve this is by designing and operating an intelligent protection scheme which demands expertise and skill both of the operator as well as the designer.

Setting relay parameters demands appreciable knowledge and ingenuity of relay engineers and often is a time consuming process. A substation may consist of a variety of relays such as distance relays, overcurrent relays, synchronism relays, etc.

Effects of faults can be minimized only if there is a proper coordination of all these relays. This means looking up a lot of relay charts and routine work involving a large amount of data.

Furthermore, faults have a myriad of possibilities to their locations and causes. Fault section estimation could become very difficult when, a) relays fail to operate, b) there are multiple faults at the same time.

Under such cases, the operator is burdened by a lot of alarms. He or she might be at a loss to explain the exact causes for malfunction of relays and circuit breakers.

Fault diagnosis done by station operators is based on the behavior of the relaying system and a judicious selection of a course of action. This demands appreciable skill and expertise from the operator.

As the complexity of power systems and relaying schemes increases, fault diagnosis in the real time frame becomes almost impossible. There is a need to design an optimal switching strategy to affect an energy efficient system restoration following a fault.

In the event of high impedance faults (HIF) usually marked by a high degree of randomness, a) There may be numerous electrical parameters which give an indication of a HIF, which may also be active for switching events; b) So, the amount of data available is insufficient to draw a deterministic conclusion.

Keep in mind that any improper judgment and delay on the part of the operator could result in system damage of catastrophic proportions. Under these circumstances, a well designed ES may prove a beneficial on-line consultant to

Expert systems can help operators make better informed decisions in pressure situations.

Fig. 2 Sample system

assist power system operators working in a SCADA (Supervisory Control And Data Acquisition) environment.

For instance, consider the sample system shown in Fig 2. A rule base for on-line fault estimation is created in the form of small modules of information.

IF < B5,B6,B9 operate > THEN < fault is on bus 3 >

IF < B2,B3 > operate > THEN < fault is on line 1 >

A typical rule base may consist of hundreds of such rules. Acquiring this knowledge from experts forms a major part in building a successful expert system.

An "expert" approach to solve the problem of on-line fault estimation proceeds by utilizing the information obtained by real time phasor measurements along with relay's and breaker's status. A digital relaying scheme obtains the optimal estimates of the fundamental frequency components from the corrupted voltage and current waveforms following a fault (Fig. 2).

The pre-fault data stored in the memory of digital relays compute the pre-fault current and voltage with the same reference as the post fault date. The obtained pre fault and post fault data of current and voltage waveforms, along with the relay's and breaker's status is communicated to the main computer managing the ES.

The inference engine of the ES then performs the task of intelligent information manipulation to conclude about the

nature of the systems following the fault. So, the operator is freed from the trouble of looking at maps, feeder diagrams and device locations because all these are stored in the data base of the ES.

A report generated by the ES can inform us about the identification of the faulted section, correct and incorrect operation of relays and breakers. The report can also tell possible causes to their failure and suggest a suitable course of action.

Expert systems are also useful in distribution system design. Unlike generation and transmission system design, the need for distribution system design arises quite frequently. Possible designs generated by a combination of different pat-

terns are quite large. So, heuristic and experience based design engineering reduces the search space very quickly as only promising proposals are examined guaranteeing elegant design in a short time.

Current research

Of late, expert systems have found widespread use in alarm processing, short term load forecasting, power system planning, economic dispatch and contingency analysis. Expert systems currently employed need a precise description of the power system using a lot of consistent rules. Research going on in this field is aimed at making the ES adaptive by making it learn from new experiences. This challenge could possibly be met by embedding ES with neural networks. With research in the field of evolutionary computations, the prospects for expert systems seem bright. If these ventures are successful, we will probably have much more efficient and reliable power systems. Thus, expert systems seem to be promising for power systems.

About the author

K. G. Rajesh has his Bachelor of Engineering from Visvesvaraya Regional College of Engineering-Nagpur. He worked as a design engineer for GEC ALSTHOM Technology Development Center in Bangalore for one year. He is currently working towards his MSEE at the Indian Institute of Science, Bangalore, India.