FUZZY LOGIC APPLICATION IN POWER SYSTEM FAULT DIAGNOSIS

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Abstract

Fuzzy logic allows a convenient way to incorporate the knowledge of human experts into the expert systems using qualitative and natural language-like expressions. Recent advances in the field of fuzzy systems and a number of successful real-world applications in power systems show that logic can be efficiently applied to deal with imprecision, ambiguity and probabilistic information in input data. Fuzzy logic based systems with their capability to deal with incomplete information, imprecision, and incorporation of qualitative knowledge have shown great potential for application in electric system fault detection.

Key words:-Fuzzy logic, Power System , Fault diagnosis

Introduction

The major use of artificial intelligence today is in expert systems, AI programs that act as intelligent advisors or consultants. Drawing on stored knowledge in a specific domain, an inexperienced user applies inferencing capability to tap the knowledge base. As a result, almost anyone can solve problems and make decisions in a subject area nearly as well as an expert. Expert System can be defined as a computer program that models the reasoning and action processes of a human expert in a given problem area. An expert system has three main components: a *knowledge base*, an *inference engine*, and a *man-machine interface*. The knowledge base is the set of rules describing the domain knowledge for use in problem solving. The prime element of the man-machine interface is a working memory which serves to store information from the user of the system and the intermediate results of knowledge processing. The inference engine uses the domain knowledge together with the acquired information about the problem to reason and provide expert solution. All AI software is knowledge-based as it contains useful facts, data, and relationships that are applied to a problem. Expert systems, however, are a special type of knowledge based system, they contain heuristic knowledge. Heuristics are primarily from real world experience, not from textbooks.

1.Desirable Features of Expert System

Expert systems are far more useful if they have some additional features. These include an explanation facility, ease of modification, transportability, and adaptive learning.

1.1 Explanation Facility

Expert systems are very impersonal and get right to the point. Many first time users are surprised at how quickly the expert system comes up with a recommendation, conclusion, or selection. The result is usually stated concisely, and sometimes very curtly, using rule clauses. A natural language interface will help improve this situation, but that's not the main problem. A more important issue is that often users have difficulty in "buying" the output decision. They question it or perhaps don't believe it. Users frequently want to know how the expert system arrived at that answer. Most of the better expert systems have a means for explaining their conclusion. Typically, this takes the form of showing the rules involved in the decision and the sequence in which they were fired. All of the information is retained in the data base for that purpose. When users want to know the expert system's line of reasoning, they can read the rules and follow the logic themselves. Some rule formats permit the inclusion of an explanation statement that justifies or elaborates on the need for or importance of the rule. The explanation facility is important because it helps the user feel comfortable with the outcome. Sometimes the outcome is a surprise or somewhat different than expected. It is difficult for an individual to follow the advice of the expert in these cases. However, once the expert system explains itself, the user better understands the decision and feels more at ease in making a decision based upon it.

1.2 Ease of Modification

As indicated earlier, the integrity of the knowledge base depends upon how accurate and up to date it is. In domains where rapid changes take place, it is important that some means be provided for quickly and easily incorporating this knowledge. When the expert system was developed using one of the newer development tools, it is usually a simple matter to modify the knowledge base by writing new rules, modifying existing rules, or removing rules. The better systems have special software subsystems which allow these changes to be made without difficulty. If the system has been programmed in LISP or Prolog, changes are much more difficult to make. In examining or evaluating an expert system, this feature should be considered seriously in context of the modification.

1.3 Transportability

The wider the availability of an expert system the more useful the system will be. An expert system is usually designed to operate on one particular type of computer, and this is usually dictated by the software development tools used to create the expert system. If the expert system will operate on only one type of computer, its potential exposure is reduced. The more different types of computers for which the expert system is available, the more widely the expertise can be used. If possible, when the expert system is to be developed, it should be done in such a way that it is readily transportable to different types of machines. This may mean choosing a programming language or software development tool that is available on more than one target machine.

1.3 Adaptive Learning Ability

This is an advanced feature of some expert systems that allows them to learn their own use or experience. As the expert system is being operated, the engine will draw conclusions that can, in fact, produce new knowledge. New functions stored temporarily in the data base, but in some systems they can lead to the development of a new rule which can be stored in the knowledge base and used again in the problem. The more the system is used, the more it learns about the domain and more valuable it becomes. The term learning as applied to expert systems refers to the process of the expert system new things by adding additional rules or modifying existing rules. On the other hand, if the system incorporates the ability to learn it becomes a much more powerful and effective problem solver. Today few expert systems have this capability, but it is a feature that is sure to be further developed into future systems.

2. Expert System Applications

Expert systems are ideal when it is necessary for an individual to select the best alternative from a long list of choices. Based on the criteria supplied to it, the expert system can choose the best option. In power systems, many promising applications have been reported in the broad field of system control, alarm processing and fault diagnosis, system monitoring, decision support, system analysis and planning. An excellent review of the popular application areas can be found in [1].

3.Reasoning with Uncertainty in Rule Based Expert Systems

One of the important feature in expert systems is their ability to deal with incorrect or uncertain information. Traditional algorithmic software simply cannot deal with incomplete information. If the data is incorrect**,** the answer will be incorrect. This is where artificial intelligence programs, particularly expert systems, are particularly useful. When the inputs are ambiguous or completely missing, the program may still find a solution to problem. The system may qualify that solution, but at least it is an answer that can in many cases be put to practical use. Thus, in the design of expert systems, there has been a focus on methods of obtaining approximate solutions to a problem when there is no clear conclusion from the given data. Logically, as expert system problems become more complex, the difficulty of reaching a conclusion with complete certainty increases, so in some cases, there must be a method of handing uncertainty. In [2,3], researchers have reported that a classical expert system gave incorrect results due to the sharpness of the boundaries created by the if-then rules of the system; however, once a method for dealing with uncertainty (in these two cases fuzzy set theory) was used, the expert system reached the desired conclusions. The expert knowledge takes the form of heuristics, procedural rules and strategies in nature. It inherently contains vagueness and imprecision. Uncertainty in rule based expert systems occurs in two forms. The first form is linguistic uncertainty which occurs if an antecedent contains vague statements such as the level is high" or "the value is near 20". The other form of uncertainty, called evidential uncertainty, occurs if the relationship between an observation and a conclusion is not entirely certain. This type of uncertainty is most commonly handled using conditional probability which indicates the likelihood that a particular observation leads to a specific conclusion. The study of making decisions under either of these types of uncertainty will be referred to as plausible or approximate reasoning in this work. Several methods of dealing with uncertainty in expert systems have been proposed, including

- Subjective probability
- Certainty factors
- Fuzzy measures
- Fuzzy set theory

The first three methods are generally used to handle evidential uncertainty, while the last method, fuzzy set theory is used to incorporate linguistic uncertainty. [4]. As expert assessments of the indicators of the problem may be imprecise, fuzzy sets may be used for determining the degree to which a rule from the expert system applies to the data that is analyzed.

4.Fuzzy Logic

Another method of dealing with imprecise or uncertain knowledge is to use fuzzy *logic.* Fuzzy logic is a system conceived by Zadeh for dealing in inexact or unreliable information. In this method, an attempt is made to assign numerical ranges with a possibility value between zero and one to concepts and elements with values that are hard to pin down. It allows you to work with ambiguous or fuzzy quantities such as large or small, or data that is subject to interpretation.

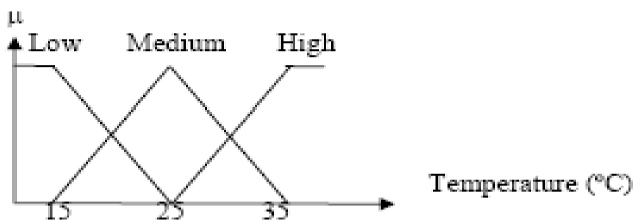

FIG 1. Fuzzy Sets for representation of uncertainity

5. Fault Diagnosis

In the past few years, great emphasis has been put in applying the expert systems for transmission system fault diagnosis. However, very few papers deal with the unavoidable uncertainties that occur during operation involving the fault location and other available information. This paper shows a method using fuzzy sets to cope with such uncertainties.

5.1 Problem Statement

To reduce the outage time and enhance service reliability, it is essential for dispatchers to locate fault sections in a power system as soon as possible. Currently, heuristic rules from dispatchers' past experiences are extensively used in fault diagnosis. The important role of such experience has motivated extensive recent work [5-11] on the application of expert system in this field. A few papers have described and dealt with uncertainties involving the fault location and other information available [12-15]. These uncertainties occur due to failures of protective relays and breakers, errors of local acquisition and transmission, and inaccurate occurrence time, etc. An effective approach is thus necessary to deal with uncertainties in these expert systems. Fault diagnosis in electric power system is a facet operation. Every signal and step contain some uncertainties, which can be modeled by membership functions. Fuzzy set theory is used to determine the most likely fault sections in the approach presented here. Membership functions of the possible fault sections are the most important factors in the inference procedures and decision making. In this example, the membership function of a hypothesis is used to describe the extent to which the available information and the system knowledge match the hypothesis. They are manipulated during inference based on rules concerning fault sections.

5.2 Structure of the Fault Diagnosis System

The fuzzy expert system structure is shown in Fig. 2. Its database contains the power system topology, and the status of all breakers and protective relays after the fault.

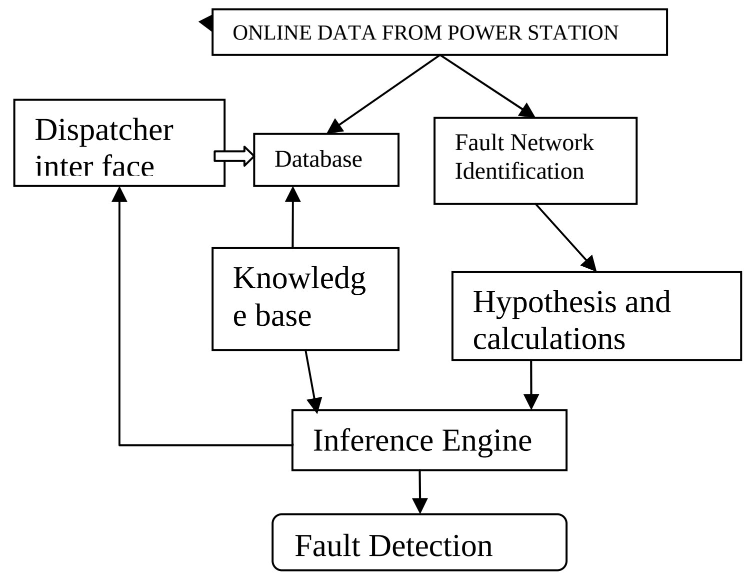

FIG 2 Fuzzy expert system structure

The knowledge base of the fuzzy expert system contains all the data of the protection system. The information is based on known statistics of protection performance used in the system. If these data are not available when a fault occurs, the fuzzy expert system asks the dispatcher to provide them and then saves them in the database for future use. Models for estimation of possible faults, and heuristic rules about the relay characteristics for actual fault determination are also included here.

5.3 Island Identification

When a fault occurs in a power system, the relays corresponding to the fault sections should trip the circuit breakers to isolate the fault sections from being extended. Thus the power system is separated into several parts named sub networks after the operation of protective relays and circuit breakers. Generally, only a few subsections are formed from the faults. Since the fault sections are confined to these sub networks, The magnitude of the problem can be reduced greatly. An expert system is developed to identify the island by using the real-time information of circuit breakers and adopting the real-time network topology determination method [17]. The framework of this efficient method is described as follows:

- Initializing the network: The expert system identifies the power system pre-fault status as the normal operation state by using the real-time network topology determination method [17]. When a fault occurs, the power system status would be changed by the operation of relays and circuit breakers.
- Healthy sub network identification: The next step is to identify the network topology of the healthy part of the post-fault power system by using the real-time network topology determination method [18]. The healthy sub network is called set Shealthy.
- Island identification: By comparing the initial network topology with the healthy subnetwork topology, the differences between them are identified as the island. This sub network is called Sisland. This method was proven in a case study that consists of 43 substations, 523 sections, 412 circuit breakers, 107 busbar, 23 three-winding transformers and 77 transmission. The simulating results are quite satisfactory [17]. The required processing time to identify the island is less than 2 seconds in a 486 micro-computer in all the simulated cases.

5.4 Fault Section Identification

When a fault occurs, the change in breaker status activates the fuzzy expert system. It then classifies the breakers into two sets: no-trip status set and tripped status set. a fault hypothesis Fi is formed as follows:

$$F_i = F_i(CB) \cup F_i(RL) \text{ --------- } (1)$$

$$= \{(C_i, \mu_{P_{fault}}(C_i) | C_i \in S_{island}\}$$

$$P_{fault} = \{F_i\} \text{ -----------} (2)$$

$$F_i(CB) = \{C_i, \mu^{CB}_{P_{fault}}(C_i)\} \text{ ---------} (3)$$

$$F_i(RL) = \{C_i, \mu^{RL}_{P_{fault}}(C_i)\}$$

where Ci is one of the possible fault sections being considered; Pfault is the fuzzy set which contain all the possible fault sections and their membership functions; Fi(CB) is the fuzzy subset by considering only the tripped circuit breakers; Fi(RL) is the fuzzy subset by considering only the operated relays.

5.5. *Conclusion*

Generally, a conventional rule-based expert system for bulk power system needs several hundreds of rules. It is time consuming in inference procedures to search for suitable rules during inferencing. On the other hand, fuzzy set based expert systems tend to be much faster compared to traditional rule-based expert systems for most of the rules are replaced by the calculation of the membership functions of the applicable rules . Only a few rules or functions are used in the inference engine. The fuzzy set approach for uncertainty processing in expert systems offers many advantages to compared other approaches to deal with uncertainty.

Small memory space and computer time: The knowledge base is very small because there are only a few rules needed during inference. The computation time is therefore also small.

- *Small number of rules*: With properly designed linguistic variables and level of granularity, only a few fuzzy rules are needed for each situation.
- *Flexibility of the system*: Membership functions representing the parameters can be changed dynamically according to the situation. It is also possible to develop a self-learning module that modifies the grades of membership automatically according to changing situations.

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