B. SUBUDHI
and
A. K. SWAIN

An expert system approach for fault diagnosis in a sub-system of power plant

This paper describes a simplified method for development of an expert system for fault diagnosis in the sub-system of a power plant. A most powerful approach for system reliability evaluation is fault tree or fault diagram analysis, which is basically a systematic analysis of different component failure events. This logic diagram is translated into an equivalent rule based expert system. Then, this has been used to determine the sub-system failure that has caused the breakdown of the plant. This knowledge based system for fault diagnosis has been implemented in C language under MS-DOS environment on an IBM PC-AT.

Introduction

With the increasing complexities of modern power plants, the use of expert system is gaining popularity. A number of expert systems have been reported in various problem domains. Some of these are MYCIN [1] and MDX [2] for medical diagnosis, EL [3] for analysis of electrical circuits, and R1 [4] for computer configuration. In the recent years there have been growing interests in the application of expert systems to power system protection. This rule based expert system queries the user, and gives the result.

Power plant is an electro-mechanical system. Hence, there are faults associated with electrical and mechanical sub-systems of the power plant. The electrical faults are diagnosed by automatic relay protection schemes. So, these faults do not require much frequent human interference. However, mechanical systems require frequent maintenance, which are mostly carried out by human intervention. The mechanical faults can cause the reaction loop failure resulting in even complete shut down of the plant. The sub-system failure modes are associated with boiler, pump system, and heat exchanger. In this work two motor valve units are taken into consideration for the operation of boiler. Similarly, two pumps are used in the pump system. The heat exchanger could be an internal heat exchanger or an external heat exchanger.

Prof. B. Subudhi and Mr. A. K. Swain, Department of Electrical Engg., Indira Gandhi Institute of Technology, Sarang (Talcher) 759 146.

Fault tree representation and categorization of faults

A fault tree represents system conditions symbolically, and includes all the basic fault events that may occur or are expected to occur in the system. The mechanical system of the plant consists of cooling system, heat exchanger, and boiler, etc. The different possible events that could occur in the plant can be categorised as primary failure, compound failure and reaction loop failure. Fig.1 represents the different possible fault modes of the power plant.

Expert system architecture

Expert system can be defined to be problem solving computer programs which can reach a level of performance comparable to that of human expert in some specialized problem domain. Fig.2 shows the architecture of the expert system (ES), which consists of interface between the user and ES, knowledge base, inference engine, and rule adjuster.

User friendliness is an inherent feature of any expert system. It allows the user interacting to be performed at a higher level and in an interactive manner. In the process the system can guide an user to present the proper formulation of problem, and to provide any other information required. The user supplied information can also be validated by the system.

The primary expert interface during development is a knowledge engineer. In later stages of knowledge base development, some experts can interact effectively with both the knowledge base and the inference engine. When the knowledge base becomes operational, user can easily interact directly with both the inference engine in an interactive mode, if required. The knowledge base is the data or knowledge used to make decisions. Knowledge acquisition is the most difficult task, frequently constituting a bottleneck during expert system construction. The knowledge base consisted of different production rules.

Expert system can explain, the decisions and actions taken to the user.

Development framework

Specific information regarding the various plant conditions are to be incorporated into the knowledge base of the expert

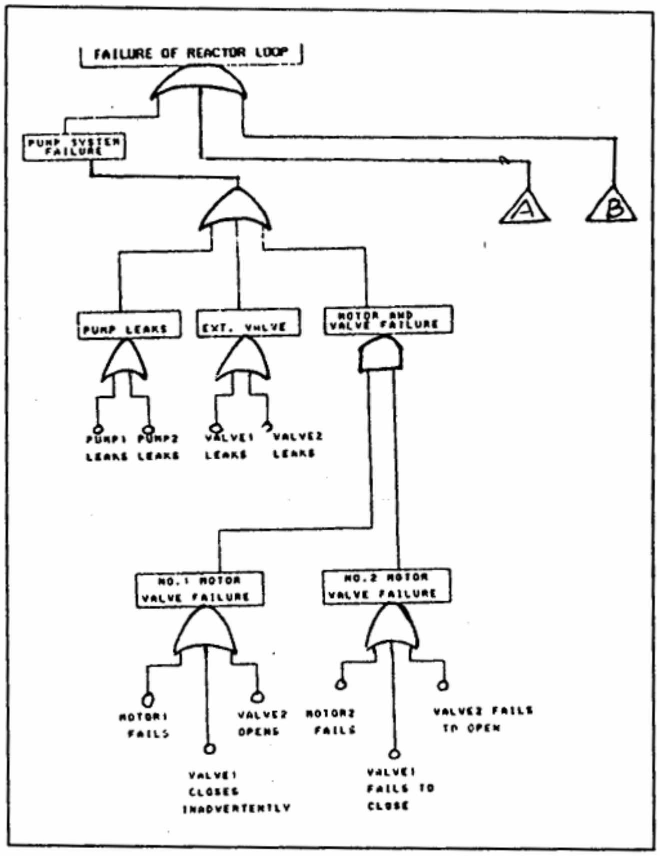

Fig.1(a) Fault tree representation

system. In a real system this could be the sensor outputs. From the sensor outputs, and the experience there of, it is possible to make adjustments regarding the type of fault. However in this system the user is queried about the information. It interacts with the user by putting questions. The user has to reply by inputting "Y" for yes and "N" for no. This interaction is described below.

Is there external leakage in boiler 1 ?

Enter : Y/N Y = yes, N = no

We use a rule based formalism to capture human expert knowledge and experience. These expertise are stored in the knowledge base (KB). The knowledge captured are in the form of IF THEN rules.

IF (systems) THEN (type of fault).

Appendix 1 illustrates the information contained in the rule base. In developing knowledge base it is essential to interact with the inference engine.

Search strategies used in traversing the inference net are fundamental for the operation of inference engine. In this work data-driven or forward chaining or production rules [5-7] method is used for inferencing. The inference engine (IE) matches the input from the user with the premises of the rules, and if there is a match the corresponding failure mode is concluded, also using AND/OR fault tree, IE finds out the possibility of occurrence of the compound failure. Also, during the process some intermediate conclusions may be obtained. This has been illustrated as

If [(I1) or (I2) or (I3)] Then [NO.1 motor valve failure] where I1, I2 and I3 are symptoms, and the message within the braces is the conclusion.

The outputs of the expert system are pump system failure, heat exchanger failure or boiler failure. Results obtained by the interaction of the inference mechanism, and knowledge base and user queries is the conclusion about a particular subsystem failure.

The character variables representing the various symptoms provided by the user are assigned appropriate values in the previous part of the software. These

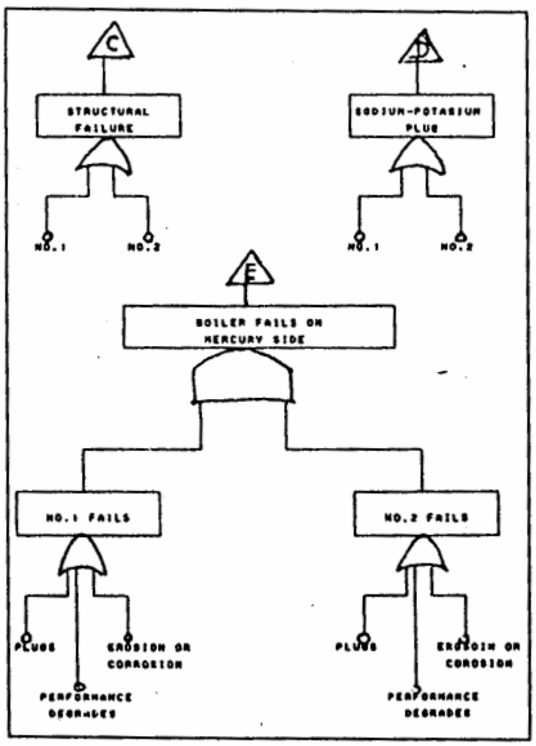

Fig. 1(b) Fault tree representation

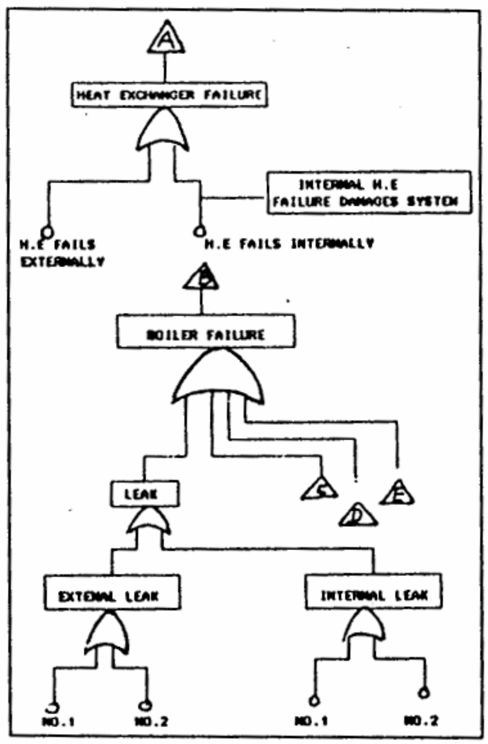

Fig. 1(b) Fault tree representation

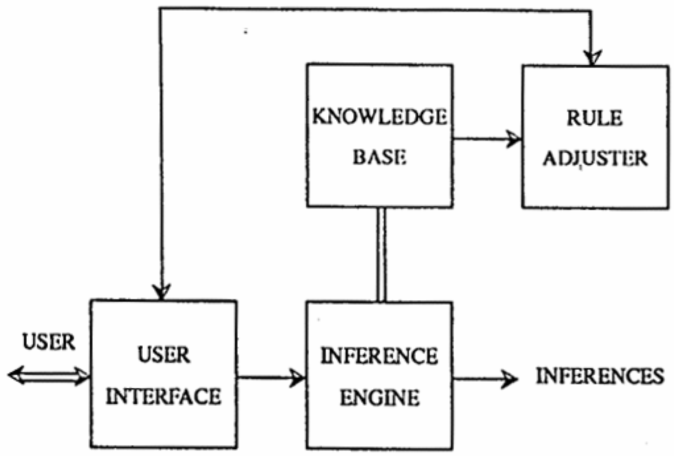

Fig.2 Architecture of expert system

integer variables assigned with particular valid integer value are used by the inference engine to draw conclusion about the type of fault. In this process it uses the AND/OR rules as described below. For example I33 = I10 || I11 = 33 is assigned the result of the ORING of I10 with I11 which are obtained by the program I33 represents the external leakage of boiler during the fault.

To take care of the addition of rules at a later instant of time and to have better understanding, maintaining, and validating, rules are organised into groups. Each group is ordered based on the conclusion attributes. Appendix 1. gives a block of rules, that has been used for knowledge representation for the ES [8,9].

Results and discussion

During the development of ES, we investigated several fault conditions diagnosed by the ES. We achieved fast response time by selecting those concepts that can be implemented quickly as Appendix 2 shows.

The maximum expertise experiment (Appendix 3) implemented all the concepts we investigated. The rule capacity for the maximum expertise experiment was slightly reduced compared to the speed experiment, even though the memory size is doubled.

Conclusion

Our effort focussed on developing a prototype knowledge based power system fault diagnosis system. Multiple failures have been considered in the design of ES. The software can be further expanded to incorporate additional knowledge into its rule base. This is possible because all the similar rules are grouped together. The certainty assumptions has been made, i.e., all the events are assumed to be certain. Probabilistic considerations have also been dealt with.

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APPENDIX 1. A RULE BLOCK

1.	IF [(I1) OR (I2) OR (I3)]	THEN	[No.1 motor valve failure].
2.	IF [(I4) OR (I5) OR (I6)]	THEN	[No.2 motor valve failure].
3.	IF [(I5) OR (I6) OR (I7)]	THEN	[No.3 motor valve failure].
4.	IF [(I8) OR (I9) OR (I10)]	THEN	[No.4 motor valve failure].
5.	IF [(I9) OR (I10) OR (I3)]	THEN	[No.1 motor valve failure].
6.	IF [(I4) OR (I5) OR (I6)]	THEN	[No.2 motor valve failure].
7.	IF [(I5) OR (I6) OR (I7)]	THEN	[No.3 motor valve failure].
8.	IF [(I8) OR (I9) OR (I10)]	THEN	[No.4 motor valve failure].

APPENDIX 2 RESULTS WITH EMPHASIS ON MAXIMUM SPEED

Computer	32 bit Intel 80286, 256 memory
Max. number of rules	About 500 (200 actually used)
Response time	0.25 -0.5 (KB part only)
Sophistication	Moderate

APPENDIX 3. RESULTS WITH EMPHASIS ON MAXIMUM EXPERTISE

Computer	32 bit Intel 80286, 256 memory
Max. number of rules	About 400 (100 actually used)
Response time	1-10 s (KB part only)
Sophistication	Maximum