A Knowledge-Based Expert System Using MFM Model for Operator Supporting

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1. Introduction

In this paper, a knowledge-based expert system using MFM (Multi-level Flow Modeling) [1] is proposed for enhancing the operators' ability to cope with various situations in nuclear power plant. There are many complicated situations, in which regular and suitable operations should be done by operators accordingly. In order to help the operator to assess the situations promptly and accurately, and to regulate their operations according to these situations, it is necessary to develop an expert system to help the operator for the fault diagnosis, alarm analysis, and operation results estimation for each operation. Many kinds of operator supporting systems focusing on different functions have been developed. Most of them used various methodologies for single diagnosis function [2-5], or operation permission function [6-8]. The proposed system integrated functions of fault diagnosis, alarm analysis and operation results estimation by the MFM basic algorithm [9] for the operator supporting.

2. System Construction

The knowledge-based system is described in the Figure 1.The proposed system composes three core databases: MFM model database, Operating procedure database and MFM algorithm (rules) database. By integrating three databases, the system could perform fault diagnosis, alarm analysis and operation regulation in general or emergency situations in nuclear power plant.

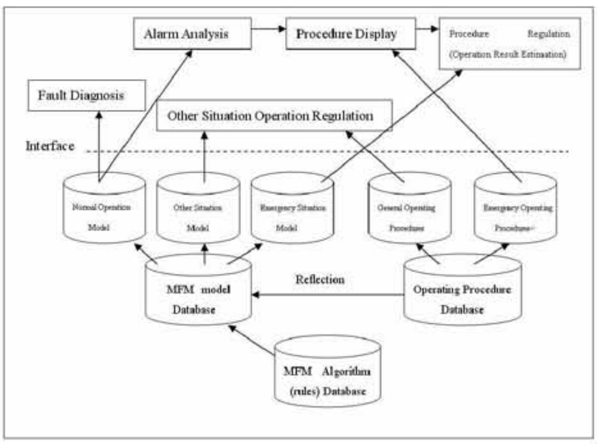

Figure 1. System Overview

2.1 MFM Modeling

There are great numbers of components in complex systems, e.g. nuclear power plant. M. Lind established MFM for modeling the complex systems based on the ideas of different levels of means-end and part-whole abstraction as the abstraction hierarchy [10]. The complexity and integrality of the MFM model directly influences the accuracy and efficiency of the algorithm implementation.

In this work, the Westinghouse type 900MW nuclear power plant is the target plant for system modeling. The MFM model of main parts of the plant, including the reactor coolant system and nuclear steam supply system in normal operation is given in the Figure 2. The main goal (G0) of the power plant in normal operation is to generate power, which is achieved by the energy flow structure 1. The Structure 2 and Structure 3, which both are mass flow structure, are constructed for the goals: G1 and G2 (G1: Transfer the energy though the primary loop; G2: Transfer the energy though the secondary loop). The goal of the structure 4 is keeping the pressurizer water level and pressure constant and under the preset value. Tr13, One of the functions of the structure 2, has the condition-achievement relation with the structure 5, which is abstraction of the Feedwater Pump energy supply with the goal G4. As the sub-goals of the G0, the G1, G2 and G3 are its conditions. Also, G3 and G4 are the sub-goal of the G1. Other goals (G5, G6…) are the similar to the G4 that are the sub-goals of the higher level goals. The goal tree structure of the system is established (Figure 2), which could be used for fault diagnosis and alarm analysis.

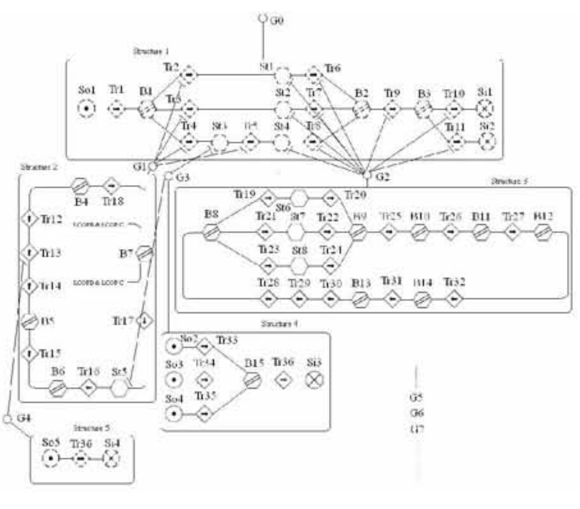

Figure 2. MFM Model for Normal Operation

2.2 Dynamic MFM

The MFM propagation algorithm for diagnosis has already been clarified and used [7]. However, in the real time environment, MFM should not only consider the functions rules but also take sequences of the functions establishment and goals achievement into account. The question: which goal should be achievement according to its importance, should be answered in the real time environment. In this work, dynamic MFM [11], which specified for the real time system, was used for the functions and goals implementation. In the dynamic MFM, all the goals have three states:

Immediate achievement: goals are already achieved.

Future achievement: goals will be achieved.

Soundness of achievement: all the needed functions are ready. But referring to the priority, goals will not be achieved at the present time.

And all the functions have two states:

Enable: functions are ready but not work at the present time.

Established: functions work for the achievement of the goals.

After the real time property are implemented in the MFM model, the priority for the all the goals established. The dynamic MFM is primarily important in the function: emergency operation regulation because the sequences of the goals are vital in this case.

2.3 Operating Procedure Database

Each procedure in the operating procedure database not only has the function of display procedures for operator, but also has the reflection on the functions in the MFM model. A simple example is given: Manual Turbine Trip is the one of the operating procedures in the database. Its reflection is the function B11 and B14 in the structure 3 (Figure 2). When the operator chooses this procedure, the operation would reflect it in the MFM model and goal G2 would be possibly destroyed. Because the sub-goal would affect sup-goal in the model, in this example, the G1 would be influenced by the G2 and the result of it would be given after the MFM model refers to the algorithm (rules) database.

2.4 System Operation

Most of the functions of the system are for emergency situation, even though they still could be used in other operation situation, e.g. reactor coolant system filling and venting. In the case of alarms happening, the alarm analysis function of the system would be performed to find out the root alarm. Then, the system comes to procedure display function. In this phase, the suitable procedures according to the operating procedures would be displayed. The operator needs to choose and confirm the operation. If the operation is following the emergency operating procedure, it would be permitted. Otherwise, the procedure's reflection on the MFM model would be executed, and conclusion that if the operating would worsen the situation would be obtained. Whether Operation is permitted or not is base on the conclusion.

3. Conclusion

A design concept of a multifunctional expert system was proposed for operator supporting. The system could be used in the general and emergency operational environment for the fault diagnosis, alarm analysis and operation regulation. The system used the dynamic MFM instead of the traditional one for solving goals priority problem existed.

Although the MFM basic algorithm for diagnosis has already explicitly clarified and listed [7] [9], its feasibility and reliability has not been definitely tested in nuclear engineering system. The further system establishment and improvement would focus on the algorithm testing improvement.

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