CHAPTER 4

PROCEDURE

4.1 System Design

The development of expert system for power transformers diagnosis can be done by implementing knowledge acquisition from collecting knowledge on experienced repairing and maintenance experts, and the related technical documents from knowledge base domain sources and other related sources of reference such as power transformer manual, and etc. All knowledge will be analysed and transformed to settle the knowledge base and then the rules will be constructed by knowledge engineer to be rules for inference engine until the expert system can diagnose any problems completely and all problems can be solved completely as human experts. This is shown schematically in Figure 4.1.

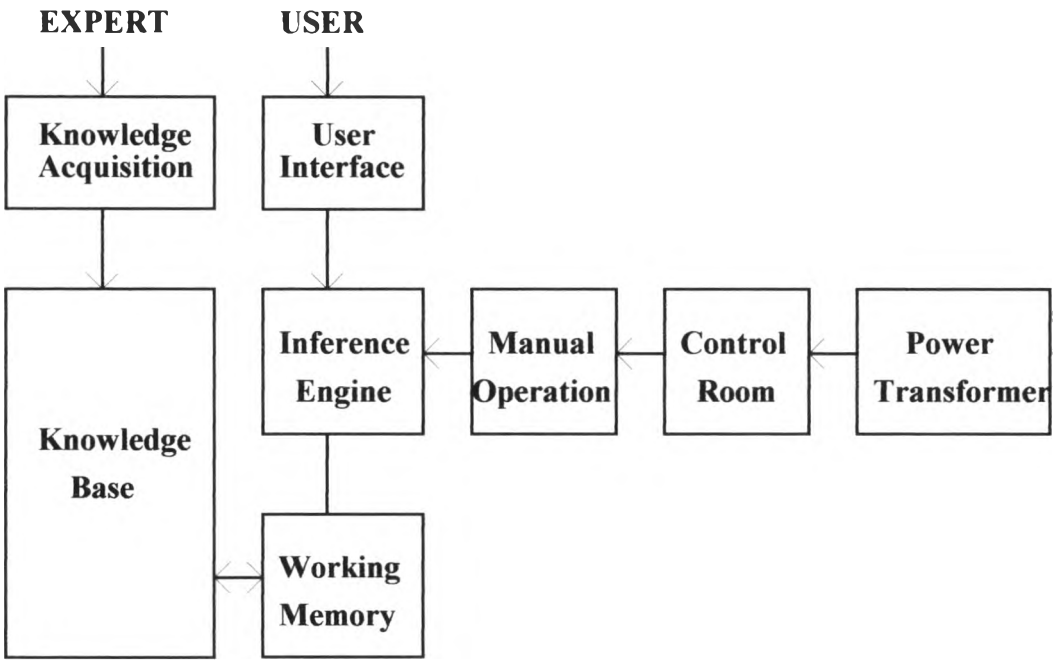

Figure 4.1 Diagram of Expert System for Diagnostic Power Transformers Fault

4.2 Data Description

The additional general information about power transformers for expert system design and implementation are as follows :

4.2.1 Location between power transformers and control room

Power transformers are normally installed outdoor in the switchyard of high voltage substation.

An example of outdoor location of power transformers is as shown in Figure 4.2.

The distance between control room of power plants or high voltage stations and external power transformers is usually around 100-200 metres. The annunciator cables and other cables from power transformers are located in trench between them and control room.

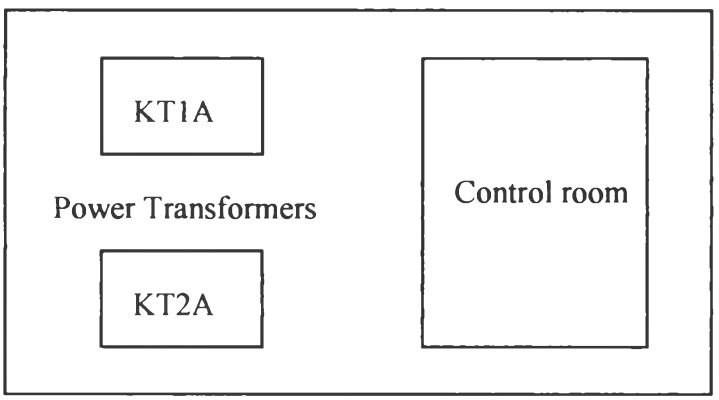

Figure 4.2 Location of Control Room and Power Transformers

4.2.2 Power transformer annunciator in control room

Any abnormal events of power transformers will be shown at control panel at a side of those power transformers and also at annunciator panel board in control room to acknowledge operators in order to be ready to make determination on abnormal event characteristics of power transformer in re-energising of power transformer to power system or cutting power transformer circuit out of power system.

The detailed signals at the control panel of power transformers will be summarised by their own category and shown in control room annunciator panel board as shown in Figure 4.3 :

KTxA Lockout Operated	Major Trouble	Minor Trouble	Winding Temp Alarm Stage 1	Winding Temp Alarm Stage 2

Figure 4.3 Annunciator panel board of power transformer in control room

All signals from power transformer will be grouped in their category to 5 groups which will be mentioned descriptively as follows :

4.2.2.1 Major Trouble

Major Trouble is a signal group showing operating of protective equipment from important abnormal events which needs to be checked immediately. Major trouble has 2 subcategories as follows :

4.2.2.1.1 Trip is a violent signal when trouble which needs to cut power transformer out of power system, the signals are as shown :

1. Transformer Pressure Relief Device Trip
2. Diverter Switch Pressure Relief Trip
3. Buchholtz Trip
4. Fault Pressure Relay Trip
5. LTC Pressure Relay Trip or Oil Flow Relay Trip

4.2.2.1.2 Alarm is a quite violent signal when trouble or need of instant repairing for power transformers but the operation of power transformer is still performed., the signals are as shown :

1. Buchholtz Alarm
2. Oil temperature
3. AC. Supply Failure
4. DC. Supply Failure
5. AC. Control Failure
6. FAN Therm Relay Stg. 1
7. FAN Therm Relay Stg. 2
8. Fan Bkr. Stg. 1
9. Fan Bkr. Stg. 2
10. DC. Trip Circuit Failure

4.2.2.2 Minor Trouble

Minor Trouble is a nonviolent signal when trouble is happened to the power transformers but the operation of power transformer is still performed., the signals are as shown :

1. Tx. Oil level
2. Div. Sw. Oil level
3. Rubber bag rupture
4. AC. Regulating failure
5. AC. Control failure
6. LTC overcurrent during tap change
7. Tap change delay
8. Tap diff.
9. LTC. drive motor Bkr.
10. Hot line Oil filter trouble

4.2.2.3 KTxA Tx Lockout Operated

The lockout signal will be alarmed at the same time with the trip signal which means power transformer is already cut out of power system.

4.2.2.4 Winding Temp. Alarm Stage 1

Winding Temperature Alarm Stage 1 will be alarmed when the winding temperature reaches on the first limited temperature rating. Load and temperature control of cooling fan are needed to be careful and ready to reduce load.

4.2.2.5 Winding Temp. Alarm Stage 2

Winding Temperature Alarm Stage 2 will be alarmed when the winding temperature reaches on the second limited temperature rating. Contemporary load and temperature of power transformers under controlling of cooling fan are needed to be very careful, some parts of load must be shedded and temperature control of cooling system needs to be monitored closely.

4.2.3 Relay

Relay is an protective equipment for preventing damages of power transformer, power supply, and other related equipment from both external faults and internal faults. Relay signal can be grouped in 2 subcategories as follows and the annunciator of relay at control room is as shown in Figure 4.5 :

KTxA Relay Operated	KTxA Low Side OC/OCG Relay Operated	KTxA Tertiary OCG Relay Operated	87K51-51G OC. Supply Fail
KTxA High Side OC Relay Operated	KTxA Relay Lockout Operated	87K51-51G Converter Fail	-

Figure 4.5 Relay Annunciator Panel Board in Control Room

4.2.3.1 Protective Relay

The function of protective relay is to protect power transformers and related equipment from both internal and external faults as mentioned descriptively in section 2.6.

The various kinds of protective relay are as shown :

1. Differential Relay

2 Overcurrent relay for High side, Lowside, and tertiary side of power transformer.

- Phase overcurrent relay
- Ground overcurrent relay

4.2.3.2 Self Protection Relay

Self protection relay is installed at power transformers, the function of self protection relay is to send alarm signal, to protect power transformers from internal faults and to stop power transformer operation when damages such as Buchholtz relay, fault pressure relay, sudden oil flow relay, and etc.

4.3 Knowledge Acquisition

Knowledge base can be established from representation of gathered data which consists of facts and rules.

Facts can be simply collected by inspection at the substation and power transformers.

The domain knowledge used in the expert system mainly gathered and collected from experiences and skills of human experts in the meetings. The experts were usually being in the same working environment and knowledge principles, so their experiences and skills are similar, an example of domain expert conversation dialogue is as shown in Figure 4.5.

The other sources of knowledge are secondary sources which are power transformer manual, training manual, operating memo, case study notes, and etc.

Gathered data consists of wide view of structured models of each kind of the fault characteristics and detailed condition for each determination steps and final results.

KE "When the major trouble happens at control room,
what will you do next ?"
EX "Check what kinds of protective relay are operated ?"
KE "If the KTxA Lockout is operated, what will you do next ?"
EX "Check which trouble alarms are showed ?"
KE "If Buchholtz trip and Buchholtz alarm showed. "
EX "Check at Buchholtz inspection window on
accumulated gas and float falls down"
KE "If there is no gas ?"
EX "Check MW, MVAR for power swing"
KE "If MW / MVAR Swing ?"
EX "It shows fault happened in distribution system of
MEA, or PEA"
KE "What will you do next ?"
EX "Check oil temperature gauge not to exceed 50°C"
KE "If not exceed ?"
EX "Determine to re-energize power transformer and it is
possible to trip again"
KE "If trip ?"
EX "The conclusion is that fault happens inside the
Transformer, Do not re-energize."
"Maintenance by checking DGA of power transformer as
soon as possible"
KE "If not trip ?"
EX "The conclusion is that the power transformer is normal
but the buchholtz relay is too sensitive."
"Making the power transformer maintenance by checking relay"

Figure 4.5 Examples of an Dialogue Question for Interviewing Domain Experts (KE : Knowledge Engineer, EX : Domain Experts)

Most of the gathered knowledge derived from the power transformer troubleshooting manuals and expert opinions, comments, and agreements which can be substituted by tree diagrams in the form of rules easily, their actions of each determination condition, and reasoning sections describe the action, causes of problem and comments from experts for extending the understanding of users.

4.4 Knowledge Representation

The collected data was analysed, interpreted, and represented into knowledge models as tree diagrams which are easy to creating knowledge base, checking, and validation from significant models. The collected data was separated into groups in the form of tree structure respectively by fault types.

The knowledge models of power transformer faults are attached in appendices A and an example of them is as shown in Figure 4.6 :

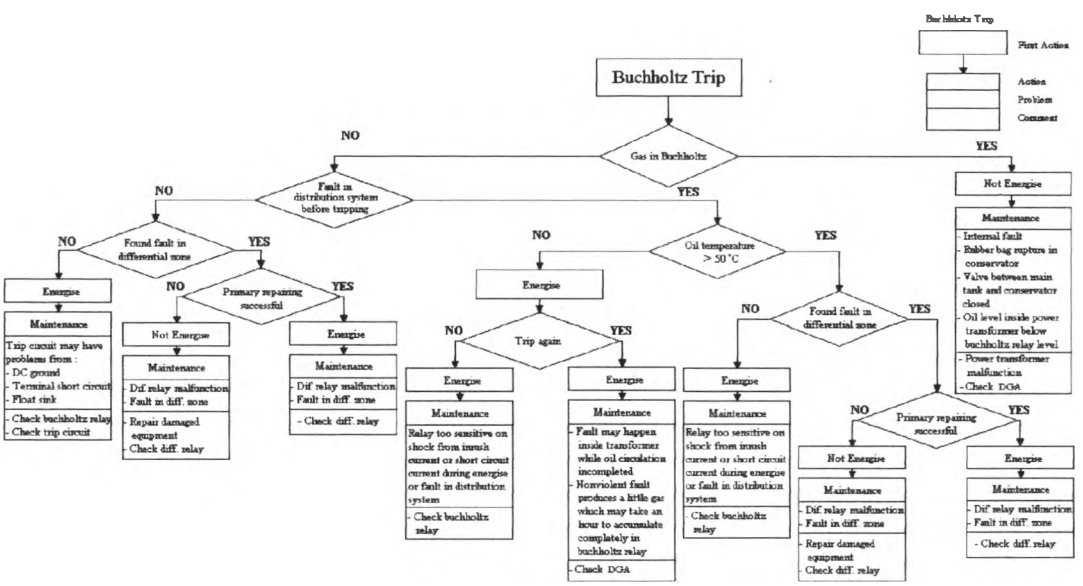

Figure 4.6 Knowledge Representation

4.5 Knowledge base

The developing tools for creating expert system are MS.Visual Basic 4.0 for inference engine and user interface parts and MS.Access 4.0 for knowledge base management in order to be easy to add or modify rules of the knowledge base.

Knowledge base is the logical knowledge representation as natural-language rules which the expert system developing tools can be understood.

In the inference process both forward and backward chaining, rules will be represented in the form of :

if ... then ... then do ... else do ...

An example of the substitution of rule in knowledge representation is as shown in Example in Figure 4.7 below :

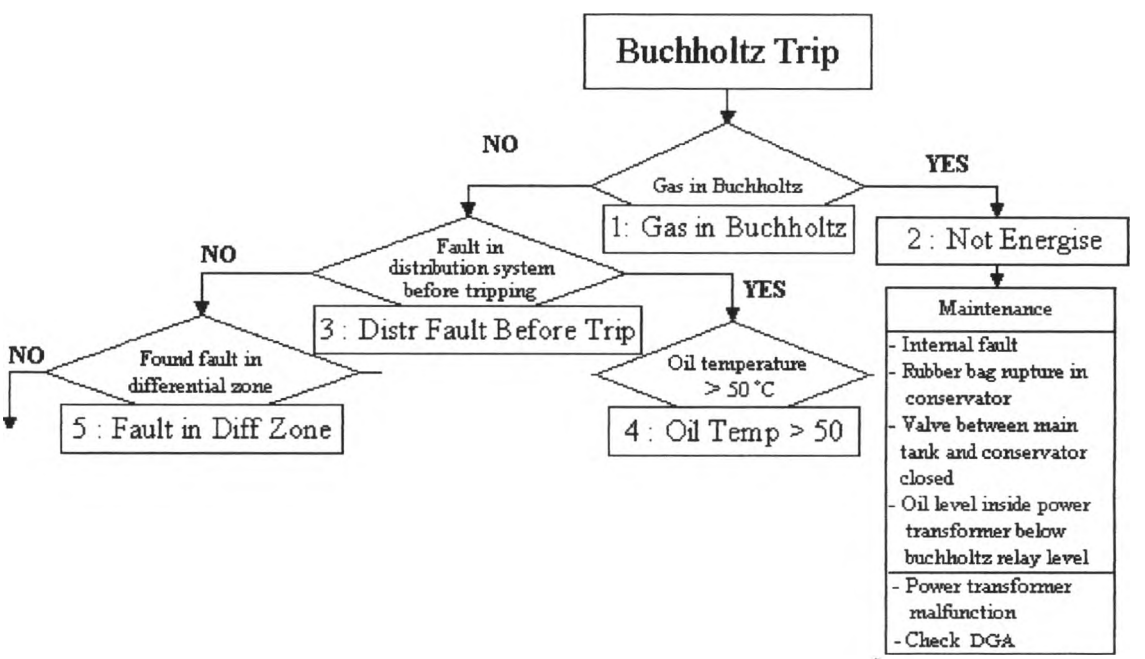

Figure 4.7 An Example of Expert System Condition

and the condition will be transformed into rules as shown in Figure 4.8 below :

```
Rule BuchTrip1
        If 1: Gas in Buchholtz = Yes      then 2 : Not Energise
                                          else 3 : Distr Fault Before Trip

Rule BuchTrip2
        If 3 : Distr Fault Before Trip = Yes  then 4 : Oil Temp > 50
                                              else 5 : Fault in Diff Zone
```

Figure 4.8 An Example of Rules in Knowledge Base

4.6 User Interface

The interaction between computer and users, the expert system will ask the operators and give recommendation and suggestion in natural language sentence form which can enable the expert system to be easy to use and easy to understand.

The expert system may need additional information as off-line system. So, the answers are needed for system determination by simple answering 'Yes' or 'No' with the assisting of instructing explanation for answering the questions, the procedures will resume automatically until the conclusion screen is appeared.

Expert system can be started by doubleclicking on expert system icon which will make the main screen appear firstly. Figure 4.9 shows main screen of the expert system.

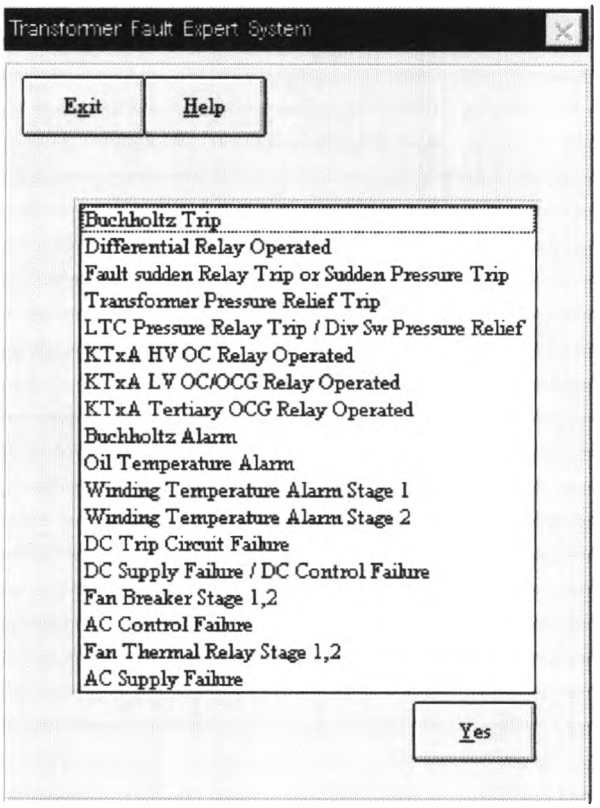

Figure 4.9 Main Screen of The Expert System

The demonstration of the expert system will be presented as follows in an example of fault case.

For example, when the buchholtz relay is operated, operators can be acknowledged from the signals of annunciator showing at control room 'KTxA lockout operated' and 'Major trouble' and the signal of annunciator showing at the side of power transformer 'Buchholtz trip'. So, the operators can access the expert system by starting the program and select the Buchholtz relay trip statement from the list on the main screen, the result from selecting is as shown in Figure 4.10.

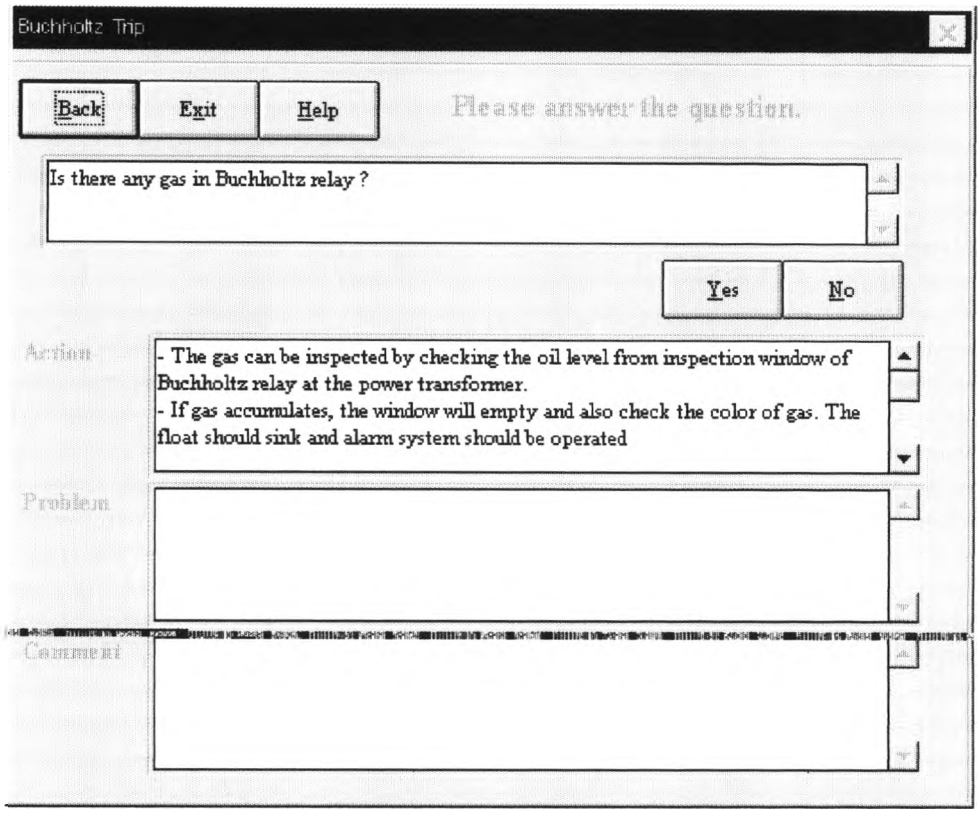

Figure 4.10 An Example of a Question from User Interface of Expert System

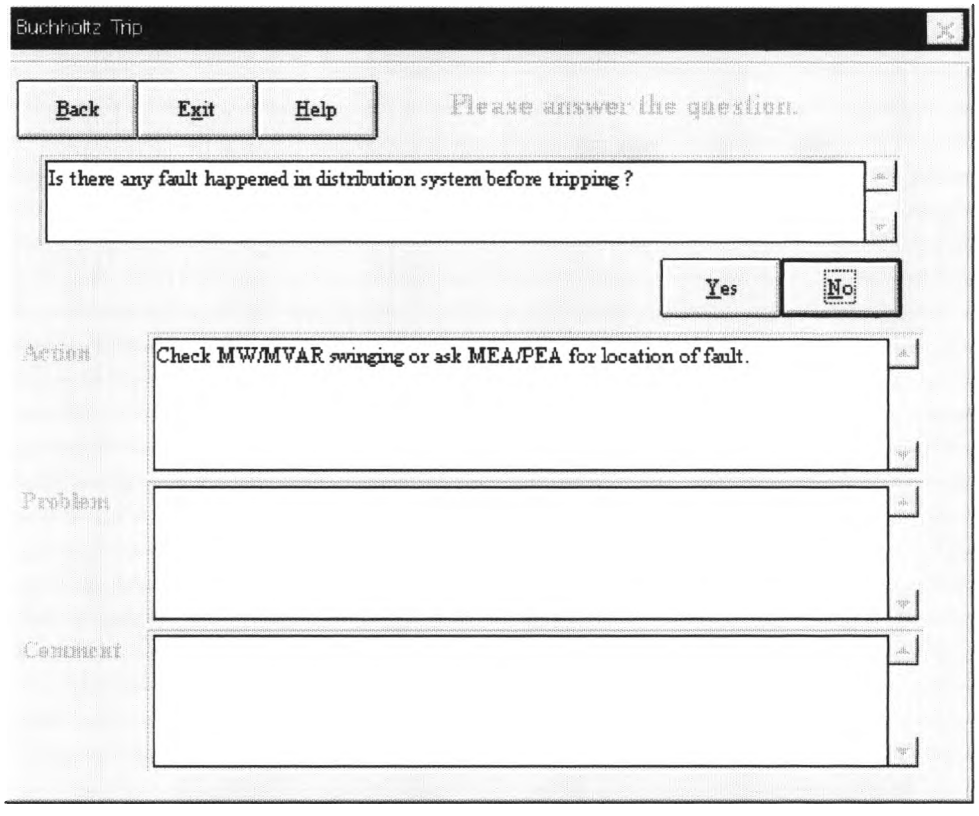

Figure 4.11 Shown Examples of a Question from User Interface of Expert System

After selecting the buchholtz relay trip, the next screen will ask the question about gas in Buchholtz relay which must be inspected following recommendation of the expert system for answering the question. The example case will assume that there is no gas seen in inspection window and the answer for the expert system will be 'No' and the next screen will be displayed as shown in Figure 4.11.

After clicking the answer, the next screen as shown in Figure 4.11 will ask the question about fault happening in distribution which needs to be proved by checking from the MW / MVAR records or asking from MEA /PEA as described in action frame of the sample screen for gathering the additional information to be analysed for the next step. The example case will assume that there was no any fault happened before tripping so the answer for the expert system will be 'No' and the next screen will be displayed as shown in Figure 4.12.

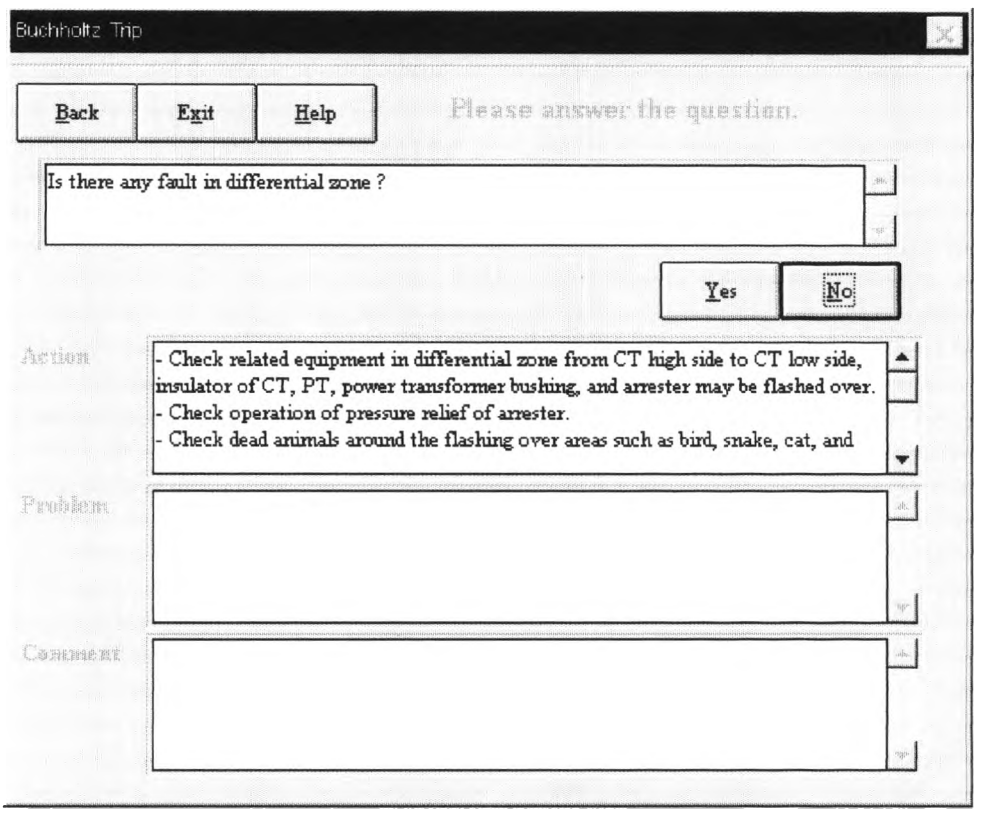

Figure 4.12 An Example of a Question from User Interface of Expert System

The next question wants to know the additional information about the fault happening in differential zone so the answer for the example will be assumed that there is no fault happened in differential zone as described in action frame of the sample screen. When clicking 'No', the next screen will be displayed as shown in Figure 4.13 :

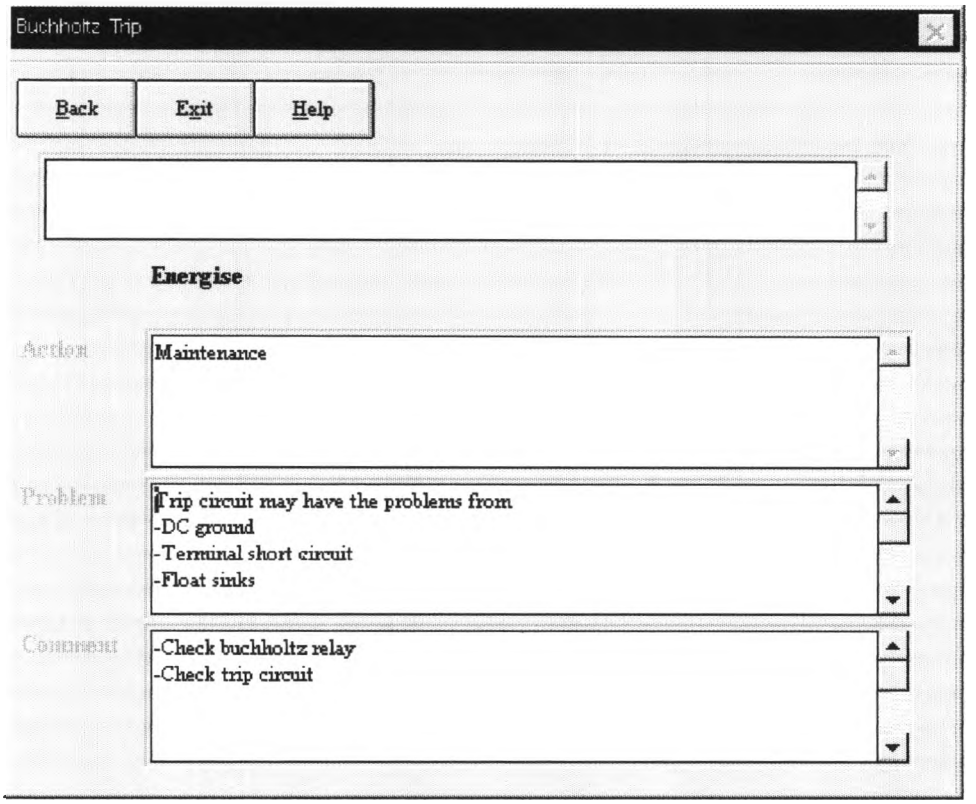

Figure 4.13 Diagnosed Recommendation from Expert System

When the expert system gathers all complete additional information, the diagnosed conclusion screen will be shown. The recommendation from the expert system shows that the power transformer can be re-energised after tripping from abnormal of Buchholtz relay or trip circuit as shown in problems frame but the activities for maintenance and checking on Buchholtz relay and trip circuit are still needed to be performed as informed in comment frame of the sample screen.