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A FAULT DIAGNOSIS EXPERT SYSTEM FOR WATER COOLED PACKED UNIT

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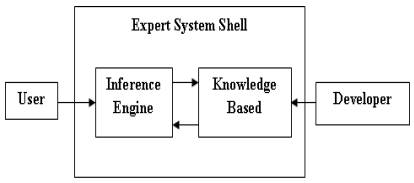
Graphical abstract



Abstract

Air conditioning plays an important role in giving maximum comfort working and leisure environment to the occupant as well as to reduce the indoor temperature. This project describes the use of an expert system shell for air conditioning air handling unit. For air handling unit, the services and maintenances of machine are expensive due to heavily dependent on experts. Hence, the main goal of the developed system is to diagnose the problem of air handling unit. With the assistance of expert system, the diagnosis process for air handling unit can be shorten up by 566.5% and standardized compared to the conventional way. The developed system is restricted by the expert's experiences and knowledge. A case study was conducted to verify the capability of the developed system.

Keywords: Air conditioning, air handling unit, case study, expert system fault diagnosis

Abstrak

Unit pendingin hawa memainkan peranan yang penting dalam memberi keselesaan maksimum untuk suasana bekerja dan persekitaran yang santai di samping mengurangkan suhu dalaman. Projek ini menerangkan penggunaan sistem pakar untuk unit pengendalian pendingin hawa. Perkhidmatan dan penyelenggaran untuk unit pengendalian pendingin hawa adalah mahal kerana tugas tersebut bergantung kepada tenaga pekerja yang mahir dan pakar. Oleh itu, matlamat utama sistem yang dibangunkan adalah untuk mendiagnos masalah unit pengendalian pendingin hawa. Dengan penggunaan sistem pakar, proses diagnosis untuk unit pengendalian pendingin hawa boleh dipercepatkan dengan 566.6% dan lebih seragam jika dibandingkan dengan cara konvensional. Namun, sistem yang dibangunkan ini adalah terhad kepada pengalaman dan pengetahuan pakar. Satu kajian kes telah dijalankan untuk mengesahkan keupayaan sistem tersebut.

Kata kunci: Pendingin hawa, unit pengendalian pendingin hawa, kajian kes, sistem pakar, diagnosis masalah

1.0 INTRODUCTION

Energy is an important element to move a nation forward as it is highly demanded in industry development. Nowadays, our earth fossil fuel is decreasing at an alarming rate to meet human basic needs and energy the consumed the most in a building is air-conditioning [1]. Since human is so highly depending in this high energy cooling device, it is time for us to save up this limited resources energy

for our upcoming generation. As a result from the above, a fault diagnosis expert system for a air handling units is developed as building air conditioning is always dominating the energy consumption in a building [2]-[4].

Maintenances and services of water cooled packed unit (WCPU) required highly skills and experiences from technicians and engineers. Expert from this field might not be always available all the time when the units break down. In another words, there will be lost of expert knowledge when human expertise is not around. Hence, to keep all the information and data of a field permanently, an expert system comes to a role. An expert system is a computer that emulates the behavior of human expert within well-defined, narrow domain of knowledge [5]-[8]. The expert system will give guidance and recommendation according to the situation based on engineer knowledge and experiences.

A knowledge based expert system is computer software that can overcome problems with expert solution [9, 10]. Therefore, an expert system is developed with useful information related to air handling unit. With the assistance of expert system, time for diagnosing the main factors of unit breaks down can be shorten and suitable recommendation will be given. In addition, expert system is one of the artificial intelligence (AI) technologies that were developed from research and it is able to simulate the human cognitive skills for problem solving [11].

An expert system called Kappa-PC Software is been used as a software system to provide a standardized methodological approach to solve important and complex problem normally done by human experts [12]. So, the main purpose of this project is to give a solution and recommendation to the person in charge when experts are not around. The system will generate friendly prompts according to the user data. Friendly prompts will be shown as an advice to the user on how to tackle with the current situation. The recommendation prompts can be giving optimal advice on what to do in the next following steps or even send back to factory for service for worst scenario.

1.1 Air Conditioning and Air Handling Unit

ASHRAE [13] defines air-conditioning as the "Treatment of air so as to control simultaneously its temperature, humidity, cleanliness and distribution to meet the essential of the conditioned space". For better comfort in a room, the air must be cooled and heated, humidified or dehumidified, purified and circulated. The general comfort temperature zone ranged from 22.1 degree Celsius to 26.7 degree Celsius which is difference of 10-15 degree Celsius of body temperature.

Relative humidity is defined as the ratio of the water vapor in the air to the maximum amount of water vapor that can exist in the air at the same temperature. Relative humidity has a significant effect on comfort and hence the relative humidity in Malaysia is set around 60 %. The air movement in a room should be in the range of 0.15-0.50 m/s (29.5-98 fpm). In recent issues, many illness have been diagnosed which resulted from poor quality indoor air such as contamination of dust and microfiber.. Thus, one of the main functions expected from air conditioning equipment is to filter up the circulation air in a confined room [13].

As the definition demonstrates, the imperative activities involved in the operation of air conditioning system are [13]:

- Control of Temperature
- Control of Humidity
- Air Cleaning, Filtering and Purification
- Movement and Circulation of Air

Air handling unit are intended for central preparation for air and allow all basic functions including heating, cooling, filtration, humidification, dehumidification, heat recovery and regeneration [13].
Advantages of air handling unit as follows:

- Wide range of application
- Friendly installation
- Low energy consumption
- Long life span
- Variety choices of air handling units

There are many developed families of air handling units in the market for selecting an optimal unit concerning purpose, place of installation, assembly of functional units and building characteristics.
There are:

- Horizontal air handling unit
- Two-stage air handling units
- Parallel air handling units
- Vertical air handling units
- Combined air handling units upon agreement

The availability of choices is mainly depending on the room size of air handling unit to be placed and horsepower required [13].

1.2 Water Cooled Packed Unit

Water cooled packed unit (WCPU) is used to feed cold air into the office area, retail, lift lobby and common area as corridor. The main and branch duct covered with insulation from WCPU to general office and retail area. The supply air and return air grilled are provided for each unit complies with insulated flexible duct as drawing specified.

The heat gain from general office/retail area is then transferred from the refrigerant in WCPU to the condenser water. The condenser water is piped to the cooling tower located roof top level. The evaporative cooling process releases the heat to the atmosphere and cools the condenser water. Figure 1 shows a WCPU placed in AHU room.

Figure 1 A WCPU placed in AHU room

2.0 METHODOLOGY

Kappa-PC is a knowledge based expert system shell that helped in developing an expert system [15]-[18]. The main menu of the developed Kappa-PC system is shown in Figure 2. The tools in the main menu of Kappa-PC software is as shown in Table 1.

Table 1 Tools and function in Kappa-PC software

Tools	Function
Object Browser	Object can be created and edited in this function.
Session	In this function, session window can create or edit a graphical resource editor which will forming a user-interface in the expert system
Edit Tools	This function including invoking the editors of classes, instances, function, rules and goals.
KALView Debugger	This is a tool use for debugging KAL code.
Find/Replace	This is use for searching and replacing text in the knowledge base
Rule Relations	This shows the relationships of the graphical tool and the rules created in the knowledge base.
Rule Trace and Inference Browser	The display of graphical traces of the rules and you can step in the inference process.

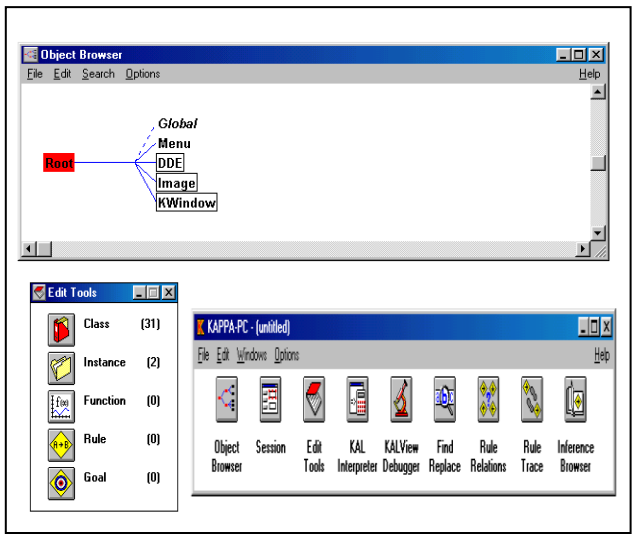


Figure 2 Main menu of Kappa-PC software

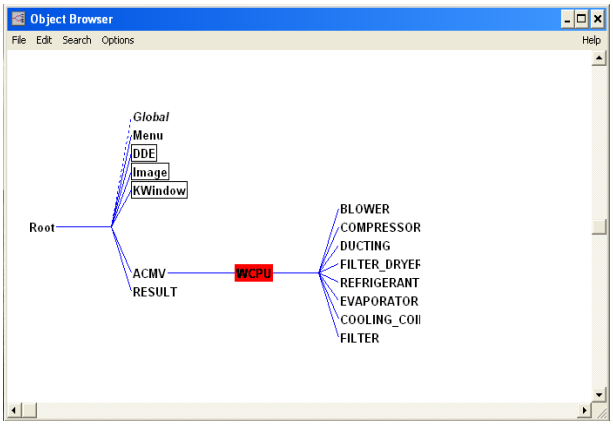


Figure 3 The hierarchy chart

The hierarchy chart in Figure 3 shows the "sub-class" from "class" WCPU. As shown in Figure 4, an expert system consists of a knowledge base and inference engine. The knowledge base is used to store the knowledge from the expert. The inference engine is used to interpret the information in the knowledge base [19]. The user interacts with the expert system shell via the inference engine [19]-[23]. The knowledge base will be retrieved to give the right solution to the user.

Figure 5 shows the main layout session of the software where user is needed to click on the button according to the situation of air handling unit problems. Developer can always customize the window with own graphics and design, creating an interface that simplifies the end user of interacting with the application. Figure 6 shows the goal editor of the developed system. Goal is to show user with the final output that user wanted from this expert system. In this expert system, the goal is generated through backward chaining method. On the other hands, Figure 7 and Figure 9 show the function editor while Figure 8 shows the rule editor of Kappa-PC software.

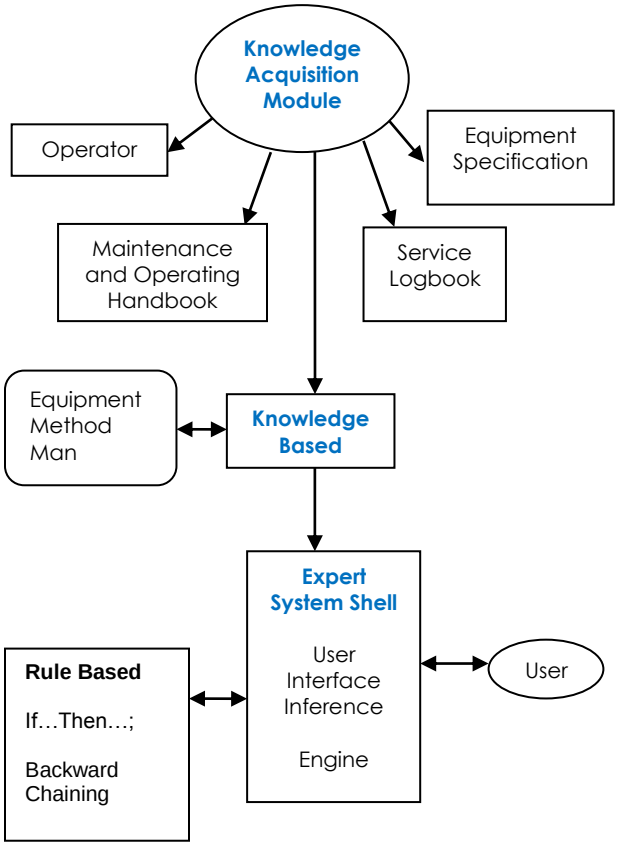


Figure 4 The framework design for developed system

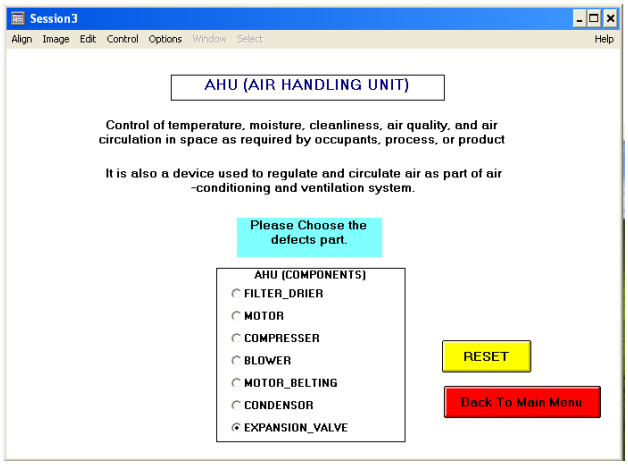


Figure 5 The session of the developed system

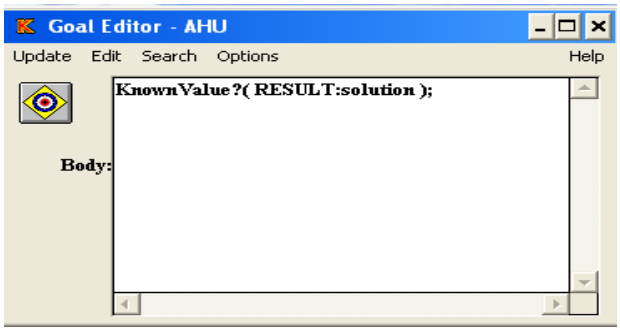


Figure 6 The goal editor

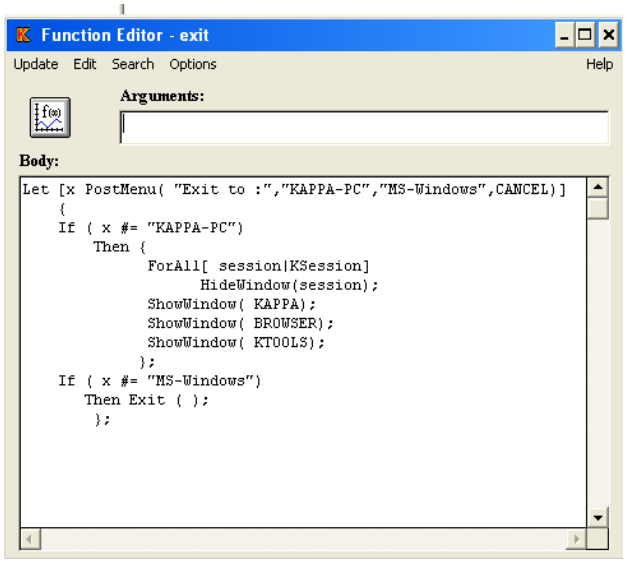


Figure 7 The function editor of the developed system

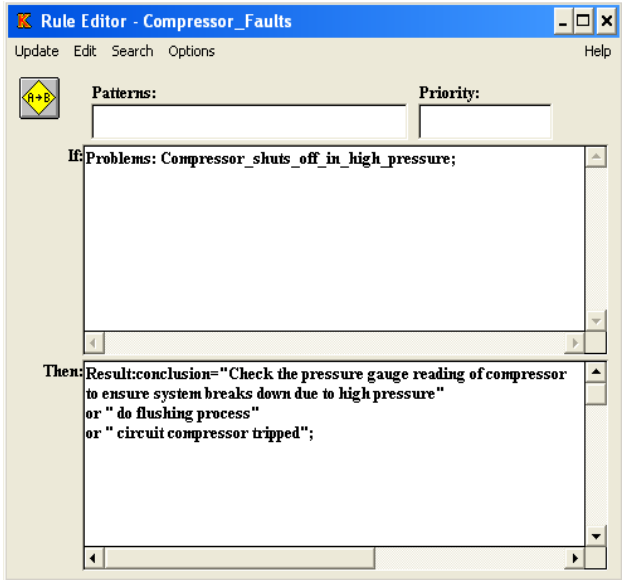


Figure 8 The rule editor of the developed system

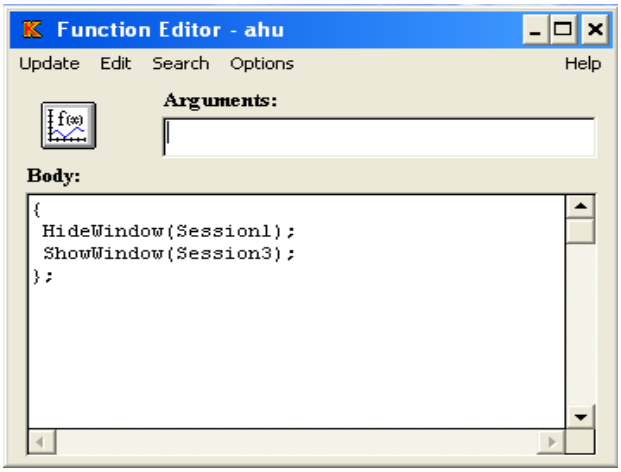


Figure 9 The function editor of the developed system

3.0 RESULT AND DISCUSSION

A case study has been conducted at the main building of Tower PJD at Jalan Tun Razak, Kuala Lumpur, Malaysia. Currently, the building is occupied by Malaysia Public Work Department as their second building administration office. Tower PJD consists of 28 storeys and inclusive of 13 floors of commercial podium with total floor area of 47,968 m^2. Since Tower PJD has a big area and many occupants in it, it must have many water cooled packed unit to sustain the cool temperature for the whole building.

The air conditioning system of this building, which operates from 0700 to 1730 every working day. The building is equipped with 60 water cooled packed units that run continuously to ensure the occupant comfort. Due to long working period, the probability of water cooled packed unit to break down is high. Whenever this situation occurs, technicians have to call upon external expert or air-conditioning contractor to diagnose the root cause and repair it. The frequent breakdown of WCPU will increase building management cost. The specifications of the water cooled packed units installed in every floor are different (Table 2).

According to the service and maintenance logbook, there are 7 items needed to be highlighted during the maintenance of WCPU. As refer to Table 3, some of the components need to be checked every month while others need to be checked once in two months. Figure 10 shows how the rule reasoning of a compressor. Figure 11 shows the regular maintenance on the WCPU compressor by technician.

Table 2 The specification and quantity of WCPU according to type

No	Model (York)	Compressor Type	Type of Refrigerant	Capacity Tons/ HP	Quantity
1	EWS 0280, 0300	Scroll type	R22	7.5 hp	15
2	EWS 0450	Scroll type	R22	15 hp	17
3	EWS 0520, 0610	Scroll type	R22	15 hp	23
4	EWS 0720	Scroll type	R22	10 hp	2
5	EWM 0840	Scroll type	R22	10 hp	1
6	EWM 1060	Scroll type	R22	15 hp	2

Table 3 The maintenance description for the water cooled packed unit

No	Description	Maintenance Frequent		
		Monthly	Every 2 Month	Quarterly
1	Check and clean filters.	■		
2	Inspect fan motor.	■		
3	Check fan shaft bearing and motor bearings, lubricate if necessary.		■	
4	Check and clean the cooling coil and drain pan when necessary.		■	
5	Purge air trapped in cooling coil when necessary.		■	
6	Check the operation of refrigerant gas control valves and thermostat control.		■	
7	Check the operation of condensing unit and coil cleaning.	■		

Q: Compressor shuts off.

Yes

Q: Compressor shuts off at high pressure (>255 psig).

Yes

AD: Check the compressor pressure. To determine it is low or high pressure.

AD: The incoming pressure towards the compressor is high. Compressor will automatically stop operating when it detects over pressure. Over pressure can be due to contamination or dirt which accumulates at the incoming channel to compressor. Flushing may need to carry out.

No

AD: Check the compressor pressure. To determine it is low or high pressure.

AD: The incoming pressure to compressor is too low (<250 psig) beyond its desired specification to run continuously. Low pressure can be due to leakage of gaseous. Welding / Refill of refrigerant may be needed.

No

Q: Is the electric circuit for compressor tripped.

Yes

AD: Call up electrician for fuses and wiring checking/overload checking.

No

AD: Call up electrician for compressor checking. Repair or replace if defective no necessary.

Note
Q = Question
AD =Advice

Figure 10 The rule reasoning for compressor

Figure 11 The maintenance checking of compressor

3.1 Field Testing

The developed system is deployed and validated with the real world problem. Table 4 below shows one of the WCPU detailed specification.

Table 5 shows the case study result. The developed expert system has the ability to diagnose the root problem to different type of situation and gives a precise recommendation.

10 technicians were asked to use the expert system to trouble shoot the building cooling towers and Table 4 shows the validity of the expert system. The main objective of the expert system is to determine whether the expert system meets the actual requirements.

Table 4 Specification of WCPU

Model	York Water Cooled Unit
Part Number	463M00061-102
Series Model	EWS 0610 T/D N/S R22 AL
H.P	7.5
Power Supply	380-415V / 3PH / 50 Hz
Number of System	4
Fan Pulley	2-SPA 236*2
Motor Pulley	2-SPA 140*2

Table 5 Case study Result

No	Problems	Actual Root Cause	Expert System Results	Match
1	Fan is not turning	Fan motor spoilt. Fan motor circuit tripped.	Check for the fan motor. Check for the control panel indication light for motor trip.	**YES**
2	Compressor is not functioning.	Compressor circuit tripped. Incoming over/ below pressure.	Check electronic circuit and pressure value for the compressor. Check all seal pipe lines connecting to compressor.	**YES**
3	AHU not functioning.	Check for wiring.	Check for the wiring/fuses. Or call technician.	**YES**
4	Fan motor is not running.	The motor bearing may be away from the alignment. Wiring of motor is loosening.	Check the condition of the motor.	**YES**
5	A loud noise is produced.	Alignment of the fan not in proper condition. Bad fan belt condition.	Check for the alignment of fan and the fan belt.	**YES**

This Inference Browser as shown in Figure 12 allows viewing the rules that the inference engine invokes in the form of a graphical network. In the browser there is clearly seen that how the system arrived at its conclusions by examining its lines of reasoning once the reasoning process is complete.

The Inference Browser graphically displays the chaining relations among rules. It is a graphic display that is used after reasoning is complete. Among the considered rules, only some apply. Applicable rules have solid lines leading from them toward the facts (pairs), which they mention in their premise. At the inference browser almost have three different colours that is green, blue and red. The colours in the inference browser are interpreted as following

- Blue: Unknown
- Red: False (not satisfying rule criterion)
- Green: True (satisfying rule criterion)

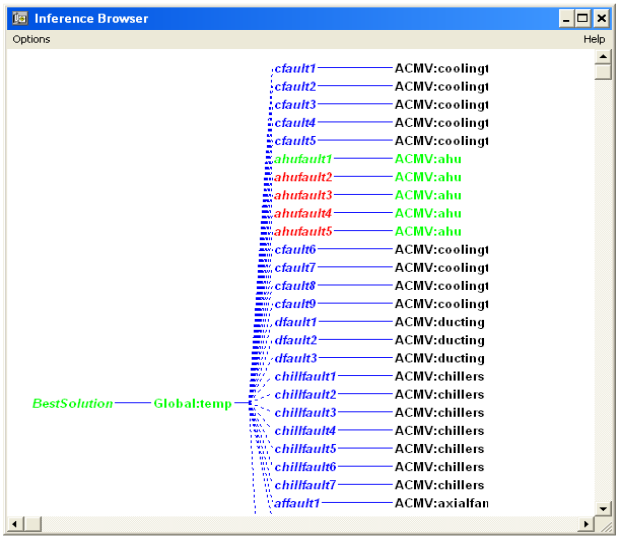


Figure 12 The inference browser of WCPU in the developed system

4.0 CONCLUSION

An expert system on water cooled packed unit has been developed by using Kappa-PC software. The developed system can helps technicians or engineers with lack of knowledge and experiences by providing them with the correct information and solution. A major achievement of developed expert system is to provide useful suggestion and recommendation for the user. With the present of this system, time for diagnosing problem could be shortening up when expertise is not around. The system was flexible and modular type where it can be upgraded to enhance the system in more comprehensive way.

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