A Fault Diagnosis Expert System for Building Cooling Tower

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ABSTRACT

In many high-rise building and offices, air conditioning plays an important role in giving maximum comfort to the occupant as well as giving a comfortable working environment. This project describes the use of an expert system shell for building cooling tower. In air conditioning field, services and maintenances of cooling tower is expensive as depending heavily on human experts. Hence, the main objective of the developed system is to diagnose the problem for cooling tower. With the aid of expert system, process of diagnosis problem of cooling tower will be more standardized and more precise compared to the conventional way. The limited values for this developed expert system are based on the building cooling tower design and expert's experiences. A case study was conducted to verify the capability of the developed system.

Keywords: *Cooling Tower, Expert System, Fault Diagnosis*

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Introduction

Energy is the most important tool enables a nation to move forward as it is a vital component in this era of highly industry development. Energy created from limited resources such as fossil fuel will reach a limit border line in the future. In this project, energy is highlighted as air conditioning and mechanical ventilation (ACMV) consumed the most in energy consumption of a building [1, 2]. This is an accomplished phenomenon that human being is getting more reliable to air conditioning for comfort and cooling. Hence, a fault diagnosis expert system for a building cooling tower is developed.

Building air conditioning cooling tower maintenance and fault diagnosis are tasks required experienced technicians and engineers. Experts of cooling tower field may not always available all the time to advice and review on possible solution. It will be troublesome when cooling tower break down when there is no expertise around to deal with the scenario. Therefore, there will be lost of expert knowledge when human expertise is not around. Hence, expert system is playing an important role to keep all the expert knowledge and experiences and allows this valuable information to be applied by others.

An expert system is a computer that emulates the behavior of human expert within well-defined, narrow domain of knowledge [3]-[5]. The expert system will give guidance and recommendation according to the situation based on engineer knowledge and experiences. 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. Therefore, an expert system is developed with useful services and maintenance information related to building cooling tower. With the assistance of expert system, time for diagnosing the main factors of cooling tower system break down can be shorten and suitable service recommendation will be given. 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 [6].

The main purpose of this project is to give a solution and recommendation to the person in charge when experts are not around. The developed fault diagnosis expert system for building cooling tower will generate friendly prompts according to the user data. Friendly prompts will be shown as a recommendation to the user on how to tackle with the current situation. The recommendation prompts can be giving optimal advice on following steps or send back to factory for worst case scenario.

Air-Conditioning and Cooling Tower

Air conditioning and cooling tower has a strong relationship in order to provide thermal comfort in indoor environment especially to those living at hot season country. With these important reasons, air conditioning had become an important asset in each building or even housing area.

The basic operation of a cooling tower with air conditioning is shown in Figure 1. A cooling tower function is to reject heat into atmosphere. It represents a relatively inexpensive and dependable means of removing low grade heat from cooling water. Firstly, the warm water from the central unit is sprayed from the nozzles located at top of cooling tower. The warm water flows down through packaged of thin film. Through the process of flowing, the ambient air is induced through the fans. Heat is transfer from the warm water to the flowing air as sensible and latent heat. Finally, the cold water is accumulated at the bottom of cooling tower. The makeup water source is used to replenish water lost to evaporation. The cycles repeat over and over to ensure cooling system achieve in a satisfactory way [7].

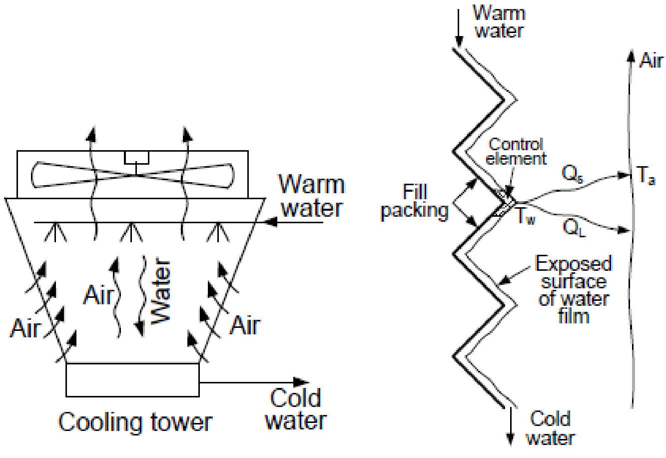

Figure 1: Heat transfer process of cooling tower [7]

The basic components of cooling tower are frame and casing, fill, cold water basin, drift eliminators, air inlet, louvers, nozzles and fans. Table 1 shows the components and its functions found in cooling tower whereas Figure 2 shows the parts and components in a real case study cooling tower which to be discussed.

Table 1: Components of Cooling Tower

Part	Function
Frame and Casing	Acts as a structural frame that gives support to the exterior closures, motors, fans and others components.
Fill	Most cooling tower employ fills (can be wood or plastic) to facilitate the heat transfer by maximising water with air contact.
Cold water basin	Located at bottom of tower, receives cooled water that flows through the tower and fills.
Drift Eliminators	Capture water droplets entrapped in the air stream that otherwise would be lost to the atmosphere.
Air Inlet	A point of entry for the air entering a tower. The inlet may be entire side or bottom of a tower cross flow design.
Louvers	A cross flow towers have inlet lovers. It functions as to equalize the air flow into the fill and retain the water within the tower.
Nozzles	This provides the water sprays to wet the fill. Uniform water distribution at the top of the fill is essential to achieve proper wetting of the entire fill surface. Nozzle can be either fixed in place and have either round or square patterns or can be part of a rotating assembly as found in some circular cross section towers.
Fans	Can be either axial (propeller type) and centrifugal fans.

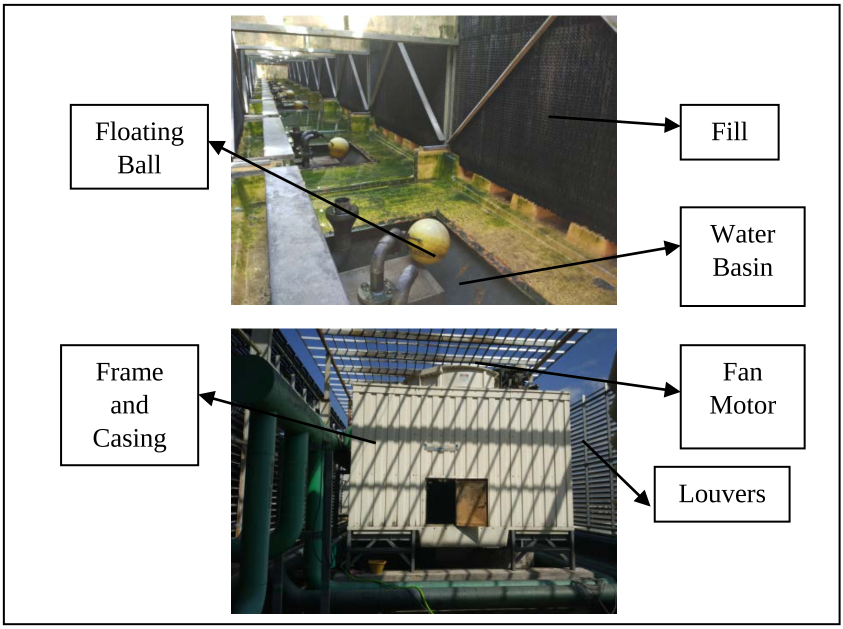

Figure 2: Parts and Components of Cooling Tower

Overall Description of the Fault Diagnosis System for Building Cooling Tower

A knowledge based expert fault diagnosis system for cooling tower involves multi-stages development. As shown in Figure 3, these includes knowledge based and rule based, inference engine, knowledge acquisition, explanation unit, user interface, and user. The knowledge base is used to store the knowledge from the expert. In the knowledge based group, there are few important components in it which are the equipment, method and man. The inference engine is used to interpret the information in the knowledge base which allows the user to interact with the expert system shell, via the inference engine [8, 9]. The knowledge base will be retrieved to give the right solution to the user. Hence, Kappa-PC is suitable to develop fault diagnosis building cooling tower expert system. Figure 5 shows the framework design of the expert system.

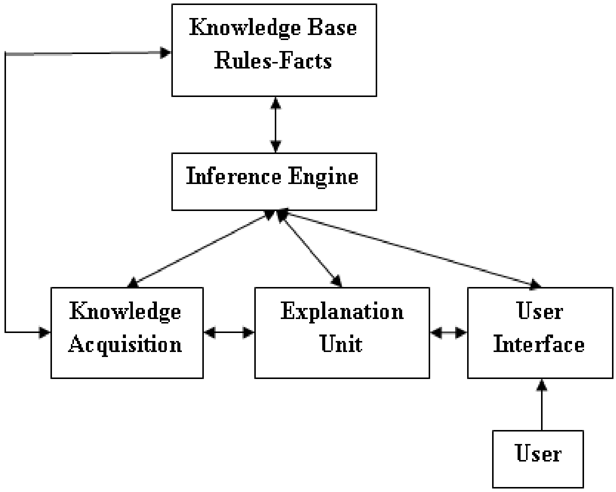

Figure 3: Structure of an expert system [10]

Kappa-PC

Kappa-PC is a knowledge based expert system shell that helped in developing an expert system [11]-[13]. The main menu of the developed Kappa-PC system is shown in Figure 4.

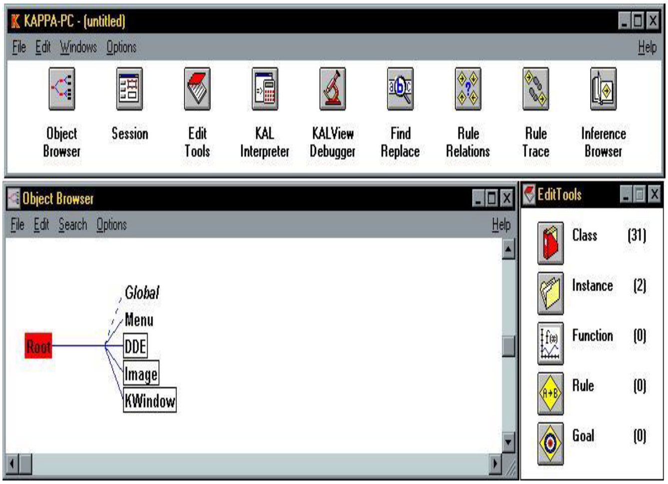

Figure 4: Main menu of Kappa-PC software

The tools in the main menu of Kappa-PC software is as shown in Table 2.

Table 2: 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 5 shows the hierarchy tree where it shows a graphical representation of the object browser hierarchy. In the hierarchy tree, shown that the parts of cooling tower been studied are from ACMV (class) , into cooling tower (sub-class) and finally splits into fan motor, belts and pulley, floating ball, fan blade, fill and fan bearing as the sub-instances.

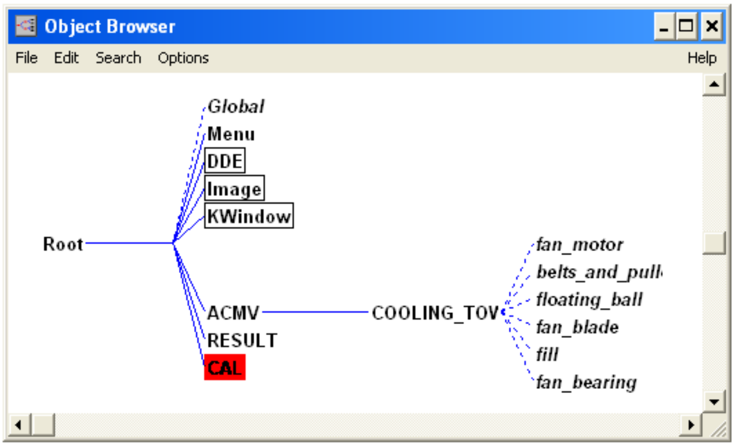

Figure 5: The hierarchy tree

Figure 6 shows the structure of framework of the system. The main layout session of the software where user can choose according to the situation of cooling tower problem is as shown in Figure 7. The user interface window can always be customized with own graphics and design, to allow creating an interface that simplifies the interaction with the end user.

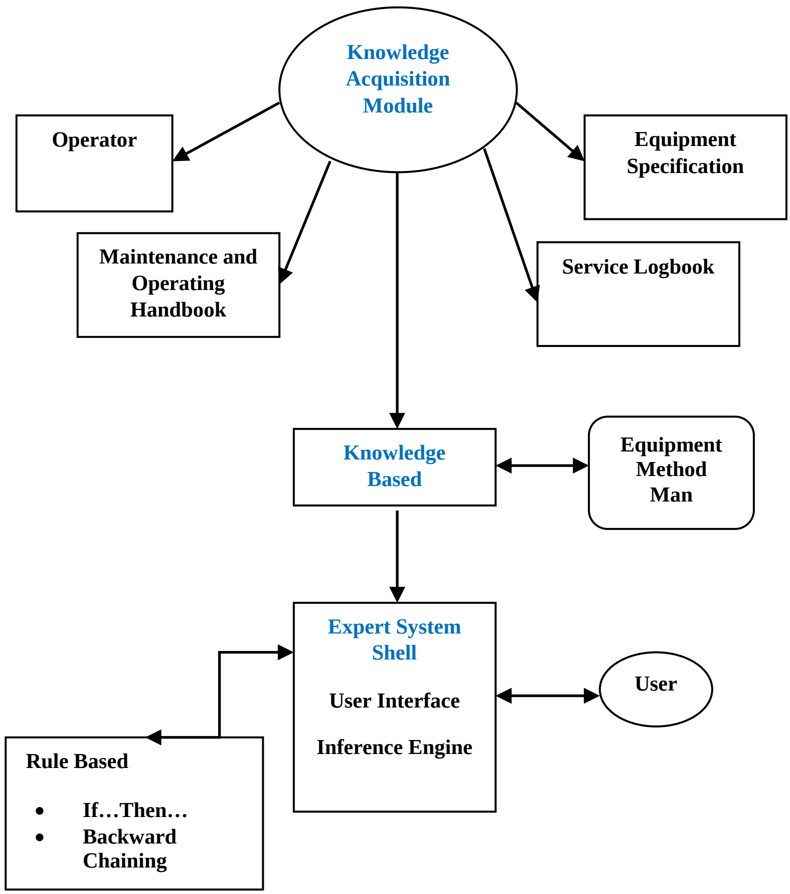

Figure 6: The framework design of the expert system

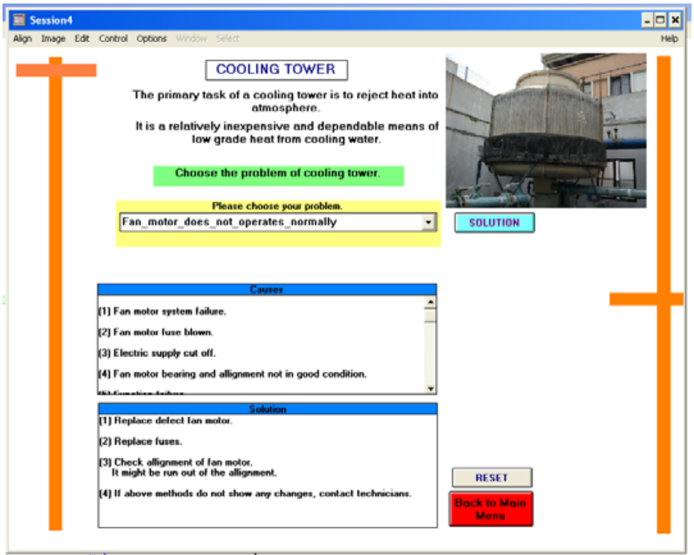

Figure 7: The main session layout mode of Kappa-PC Software

Figure 8 shows the rules set by the user for program developing. The rule based system is the important tool in the fault diagnosis cooling tower process. For each fault component of classes, several rules have been created. There are chained by using backward chaining with goal-driven reasoning [14].

The rule is in the form of:

```
{
        If
            (Condition);
        Then
            (Conclusion);
};
```

If the condition of rule is satisfied, then the conclusion of the rule will be the result. The selected results are listed according to causes and recommendation and will be stored and displayed at the transcript images. Transcript image is a form of empty boxes for possible results to be displayed. Figure 9 shows the rule system for the case study.

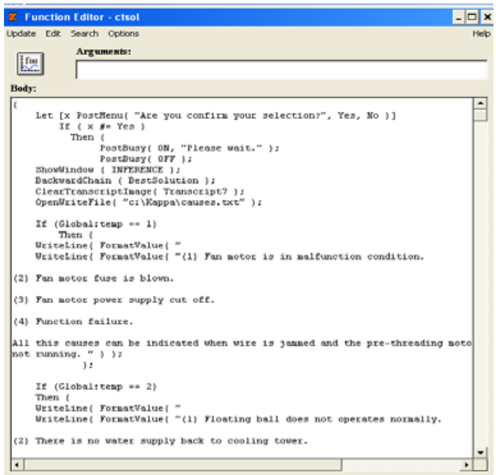

Figure 8: The rule function written by the user

Q: Cooling tower fan does not operate normally.

Yes

Q: Is the fan motor able to start up?

→ ***Yes***

AD: Check fan motor bearing and belt.

AD: Fan belt may be loosen or need adjusting to the right position.

AD: Check the rotation.

→ ***No***

AD: Return fan motor for fully service.

No

Q: Is the fan operating?

→ ***Yes***

AD: Call up electrician for fuses and wiring checking.

AD: Call up electrician for motor starter and overloads checking.

→ ***No***

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

Note:

Q = Question

AD =Advice

Figure 9: The rule for case study

Case study

Using the developed fault diagnosis expert system, a case study has been conducted at the main building of Tower PJD at Jalan Tun Razak, Wilayah Persekutuan, Kuala Lumpur, Malaysia and it is currently occupied by Malaysian 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 47968.39 m^2. Since Tower PJD has a big area and many occupants in it, it must have a strong cooling tower to sustain the cool temperature for the whole building.

According to the management, air conditioning system of this building will be operating from 7am to 5.30 pm (Monday to Friday). There are 12 cooling tower (9 cooling towers at Block A whereas 3 cooling towers at Block B) which placed at the roof top running continuously to ensure the cooling cycle runs smoothly. Therefore, the probability of cooling tower to break down is high. Whenever this situation occurs, technicians have to call upon outsourcing expert or air-conditioning contractor to diagnose the root problem and repair it. This indirectly burden up the management expenses as air –conditioning is just part of the important asset of a building not included others as well as fire system, lighting system, lift system and security system.

With the present of expert system, technician of the company can diagnose the problem and make services according to the recommendation given by it. Through case study, it shows that the developed system can cut down a huge amount of expenditure for getting expertise for cooling tower. Table 3 is the detail specification of cooling tower for purpose of case study.

Table 3: Specifications of Cooling Tower

Model	Nihon-Spindle CTA250-UK-9
Type	Crossflow
Cooling Capacity	2250 HRT
Circulating Water Flow Rate	1197.9 m^3/hr
Evaporation Loss	0.97 %
Drift Loss	0.02% below
Fan Type	Axial-Flow
Drive System	V-belt & Pulley Drive
Fan Diameter	2000mm
Number of Fan Blade	4 pieces
Width (W) x Length (L) x Height (H)	21150mm x 3870mm x 3676mm
Dry Weight	11790 kg
Operating Weight	26640 kg
Water Storage Capacity	15.12 m^3

Field Testing

Ten participants (8 males and 2 females) were invited to participate in the validation experiment. Participants were asked to use the expert system to trouble shoot the building cooling towers. The system was deployed at the rooftop of PJD tower where cooling towers were placed. The age of participants ranges from 19 to 48 years. The professions in the experimental group include 4 technicians, 1 worker, and 5 engineers. The participants were the workers in the PJD tower.

A professional cooling tower technician Mr Wong was invited to provide onsite service and explanation on cooling tower during the experiment. The author provided technical support on the developed expert system. During the field test, there was a defect where the floating ball of bottom cooling tower no longer connected, and this defect is rarely happened in cooling tower. The expert fault diagnosis system was improved by adding in "loosen float ball" and the knowledge base is modified.

Table 4 shows the fifth of the field testing cooling tower fault diagnosis results and respective validation. The developed system is deployed and validated with the real world problem. The developed expert system has the ability to diagnose the root problem to different type of situation and gives a precise recommendation. The main objective of the expert system is to determine whether the expert system meets the actual cooling tower fault.

Table 4: Case Study Result

No	Problems	Actual Root Cause	Expert System Results	Match
1	Fan is not turning	Fan motor spoilt.	Check for the fan motor.	YES
2	Fan motor is not operating normally	Fuses of the electric motor. Belt of the motor and fans is broken.	Check wiring and fuses. Check condition of fan belt.	YES
3	Basin cool water does not flow back	The float ball located at bottom of cooling tower does not show exact location of water level. Loosen float ball.	Check the float ball.	YES
4	Basic cool water still in high temperature	The fill sheets need to be checked. Fan is not operating.	Check the condition of the fan.	YES

5	Cooling tower displaced slightly in position	Alignment of the fan not in proper condition.	Check for the alignment of fan.	YES

Conclusion

An expert system on building cooling tower has been developed by using Kappa-PC software. The developed system consists of inference engine, a user interface and knowledge acquisition module. The developed system can helps technicians or engineers with lack of knowledge and experiences by providing them with the right information and best solution.

A major achievement of this expert system is that it can provide useful suggestion and recommendation of 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 where it can be upgraded to enhance the system.

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