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A Fault Diagnosis Expert System for Building Chillers

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Abstract – *Building air conditioning is a demanding trend nowadays. It gives maximum comfort working and leisure environment to the occupant as well as it reduces the indoor temperature. This project describes the use of an expert system shell to develop a fault diagnosis system for building chillers. For the building chiller, services and maintenances of the machine are heavily depending on human expertise, which is costly and critical. Hence, the main goal of the developed system is to diagnose the problems of building chillers. With the developed system, the diagnosis process for building chillers is standardized, precise and faster compared to the normal way. The developed system is useful for the inexperienced staff as a training module as well. The constraint values for this developed expert system are based on building chiller design data and expert's experiences. A case study was also conducted to verify the capability of the developed system.*

***Keywords**: Building, Chillers, Expert System, Fault Diagnosis*

I. Introduction

Energy is considered an important element in this era of industrial development and population growth. The energy generated from fossil fuel will finish soon. Hence, as humans, we should save this precious energy for the coming generations. According to a study by Vakiloroaya. V [1], more than 50% of the electricity bill is consumed by the air conditioning system of commercial building. It also shows that the occupants of the building highly rely on air–conditioning for better comfort and hence the demand of a better occupant experience would require sustainable building cooling system. A building chiller fault diagnosis expert system able to reduce the down time and hence to better manage the occupant experience, definitely needs to be developed. Building chillers maintenance and fault diagnosis are generally accomplished by experienced technicians or engineers. Building chillers experts normally are not available all the time to advice and review possible references and data [2]. An artificial expert system, a computer that emulates the behavior of human experts within well-defined narrow domains of knowledge [3], is important in keeping the expert knowledge and allows this invaluable fault diagnosis knowledge being applied by the building chillers maintenance team. The fault diagnosis expert system will provide guidance and suggestions according to the knowledge coming from experienced engineers.

A knowledge based expert system is a computer software that can overcome important problems with expert solutions [4], [5]. Therefore, the knowledge-based expert system could be used to assist engineers or experts by providing them with useful information related to building chiller diagnosis.

Developing an expert system by using the KAPPA-PC software system will be able to provide a standardized methodological approach to solve important, fairly complex problem tasks that normally require human expertise [6]. The main purpose of this paper is to provide a suitable solution and recommendation to the person in charge whenever building chillers experts are not available. Building chillers diagnosis knowledge is gathered in various forms such as data, rules of thumb, facts, and judgements gathered from experts or experienced engineers that has been analysed and compiled into sets of logic working rules of the IF-THEN concept.

The proposed building chiller fault diagnosis expert system will generate friendly prompts according to the given user chiller issues. The system will then provide experts with some advice on recommended diagnosis actions or send back to the factory for service in the worst cases. The system is sufficiently flexible, as its knowledge base can be extended and modified whenever new technologies are developed and old facilities are discarded.

II. Overall Description of Expert Fault Diagnosis System

Air conditioning and mechanical ventilation (ACMV) systems can play an important role in reducing the environment impact of buildings. Providing comfort to the occupants by varying heating and cooling loads all the time is always the ultimate mission of a good ACMV design. An efficient scheme should be implemented so that the ACMV can always run in an efficient way with minor heat losses in the surrounding. The basic chiller plant operation of an ACMV is shown in Fig. 1.

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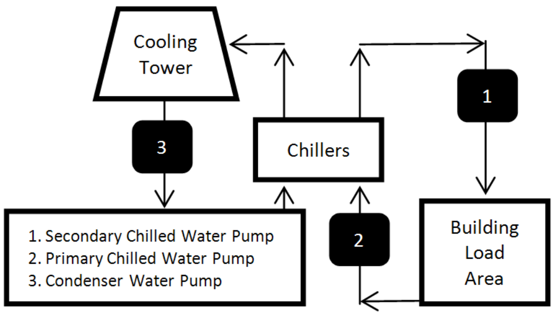

Fig. 1. Operation Diagram of a classic Chiller Plant [7]

Among all building services such as escalators, elevators or fire-fighting system, the importance of ACMV systems energy usage is significant. In the USA, 50% of building consumption and 20% of the total electric consumption is dominated by ACMV system. According to Fig. 2, it is clearly stated that ACMV is dominating around 50% and above of the electric intake of a building [1], [8]. Those electrical appliances such as chillers, air handling unit or even cooling towers had to be highlighted in terms of regular service and maintenance in order to prevent any undesirable electric waste which leads to excessive costs.

Table I shows some common factors and reasons why chillers do not function well.

The knowledge and experience of an expert will no longer remain in the company or institution when he/she is away from the duty. Others can get those needed chillers service information from handbooks or other reliable resources, but somehow this knowledge can only be accumulated through the years of experience. To keep the knowledge and experience of an expert, an expert system or a computer program can be created to virtually represent the expert knowledge. When the new coming workers need to gain some information from the senior, he/she can get it through the expert system in a short period of time. The expert system is one of the artificial intelligence (AI) technologies that were developed and is able to simulate human cognitive skills for problem solving. As clearly seen in Fig. 3, an expert system shell consists of an inference engine and a knowledge base. The knowledge base is used to store the knowledge accumulated by the expert. 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 [9], [10].

II.1. Expert Chillers Faults Diagnosis System

The fault diagnosis expert system for building chillers involves a multi-stages development. These consists of an user interface, chillers data gathering, choosing the right chiller specification, developing a program tree structure, coming out with program coding, developing the program, program testing and verification. Kappa-PC is suitable to develop this kind of expert systems. There are four main selectors of Kappa-PC which are (i) knowledge based, (ii) knowledge acquisition module, (iii) inference engine, and (iv) user interface.

Knowledge acquisition is defined as the knowledge extracted from experts in the form of interviews conducted, notes and even through observation [12]-[14].

The user of an expert system will enter into a session or a dialogue to allow the user to describe the problem including the causes or factors to the error. The expert system will then give the solution or recommendation, telling the user what to do next.

Dialogs will be prompted by the expert system, so that the end user can answer a series of questions and enter the required necessary information to assist in decision making.

The expert system applies on backward chaining or goal reasoning, with only match to the “if...then” rule to give the best recommendation [15], [16]. Most ACMV companies do provide this type of expertise and knowledge to their engineers and mechanics in dealing with all the daily maintenance procedures.

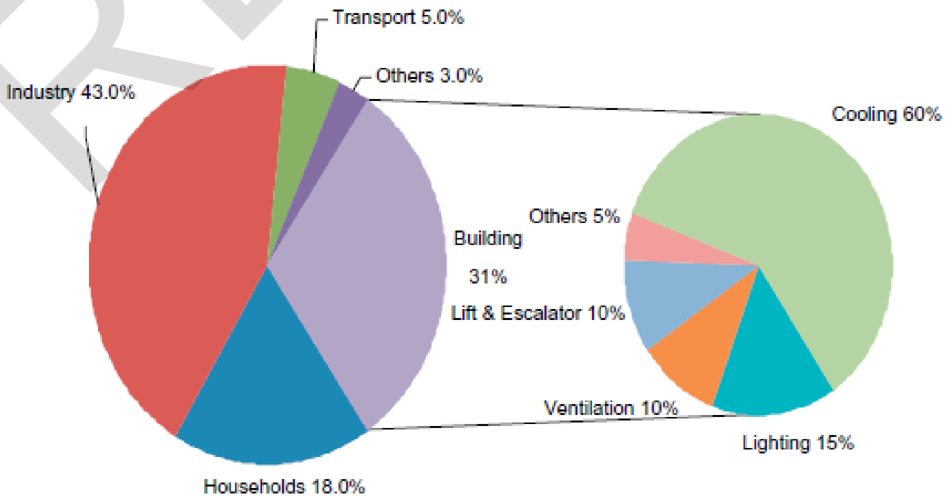

Fig. 2. Typical electricity consumption by end use in Singapore and in the building sector (Photo reprinted from K.J.Chua, 2012)

TABLE I
COMMON FACTORS OF CHILLERS BREAK DOWN [18]

Factors	Explanation
Poor Operating Practices	Bad operating practices not only decrease the chiller efficiency, but affect chiller lifespan. Most of such practices are the result of one or two common situations: making the chiller do something that exceeds its design efficiency and load or to do or not understanding the effects of a selected action. For instance, one common practice is to boom the rate of chilled water flow through the chiller when the customer insists in getting cooler air in shorter period. The concept is that with a higher flow rate, greater cooling water will be available. In truth, increasing the flow rate through a chiller beyond its stated limit will decrease the operating efficiency of the chiller. Similarly, increasing the flow rate beyond the recommended will increase the rate of erosion in the chiller's tubes, leading to early tube failure.
Ignored Maintenance	Although implementing accurate upkeep practices is important for the efficient operation building equipment, there are few regions where this is more evident than in the maintenance of building chillers. As an instance, consider the effect that good maintenance can have on chiller efficiency. Most new, high efficiency centrifugal chillers bring a complete-load efficiency rating of about 0.50 kW per ton. If that chiller is well maintained, in five years it can be predicted to have a full-load efficiency of 0.55-0.60 kW per ton. A poorly maintained chiller will use 20-25 percent more energy annually to supply the same cooling. Regular agenda inspections and recording maintenance logs is an essential operation to keep checking, and allows to save money in the long run.
Corrosion and Solutions	Most chiller tubes are made of copper, and experience galvanic corrosion due to two metals being dissimilar. The corrosion and loss of carbon steel can affect the performance of the chiller due to poor water flow issues and sediment buildup; this will eventually lead to the perforation of the tube and refrigerant losses. To combat this, PES Solutions can coat the components of your chiller with an epoxy solution. First, abrasive blasting is performed on the parts affected to remove any bad metal or blemish, and apply our epoxy to said parts using the product: PES 101 Power Metal Paste. This paste is a two component solvent free epoxy metal repair compound, and can be machined and cured in as little as 1.5 hours. For a full load on this epoxy it is best to wait 2 days. At PES Solutions we carry a large array of products to prevent downtime and dissatisfaction. The best warranties in the market and trained professionals are offered to help reach the goals.
Oversizing/Under-sizing	When a facility is new or undergoing renovation, a chiller might not be sized correctly. Under-sizing can result in insufficient airflow, which means that the chiller will not be able to achieve its full cooling capacity. Over sizing might restrict the low-load operations, which will result in higher operating costs due to excessive cycling.

II.2 Kappa-PC

KAPPA-PC is a rule-based expert system shell that helps in developing an expert system [2], [19]-[21]. The main menu of the developed KAPPA-PC system is shown in Fig. 4 and Fig. 5.

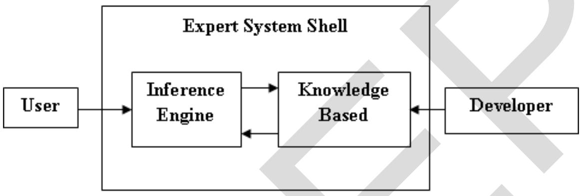

Fig. 3. The structure of an expert system shell
(Photo reprinted from P.Jackson, 1998)

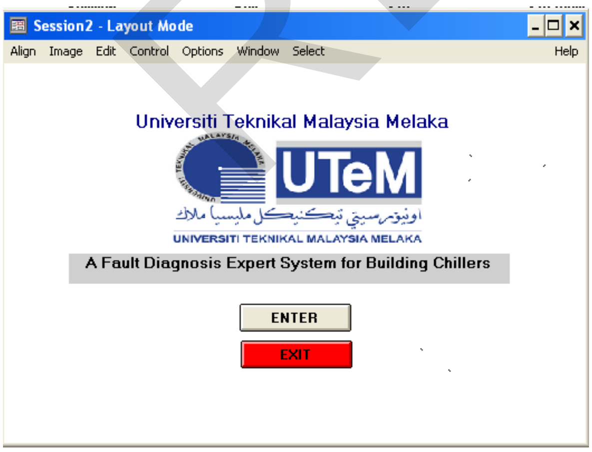

Fig. 4. User Interface for Building Chillers

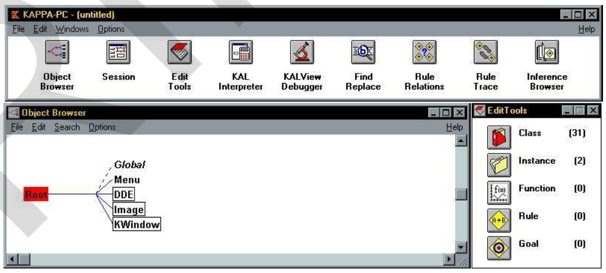

Fig. 5. Main menu of KAPPA-PC software

The object browser of the developed fault diagnosis system is shown in Fig. 6. The tools and elaboration of the function is in the main menu of KAPPA-PC software, as shown in Table II.

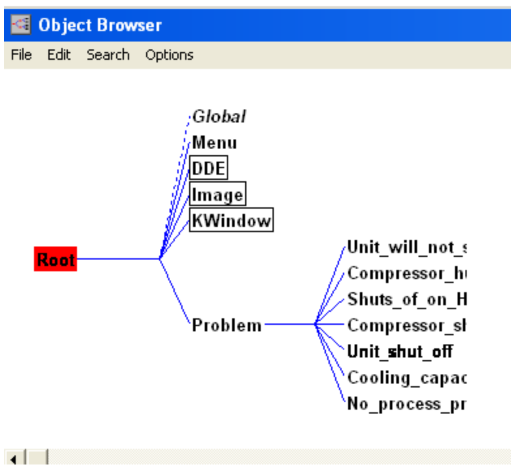

Fig. 6. The object browser of Kappa-PC Software

TABLE II
TOOLS AND FUNCTIONS IN KAPPA-PC SOFTWARE [19]-[21]

Tools	Function
Object Browser	An object can be created and edited in this function.
Session	In this function, a session window can create or edit a graphical resource editor which will form a user-interface in the expert system
Edit Tools	This function includes invoking the editors of classes, instances, function, rules and goals.
KALView Debugger	This is a tool to use for debugging KAL code.
Find/Replace	This is used 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	It displays the graphical traces of the rules and allows to step in the inference process.

Fig. 7 and Fig. 8 show the main session layout mode of Kappa-PC software when creating text and the button option to create the user interface. Fig. 9 shows the structure or framework of the system.

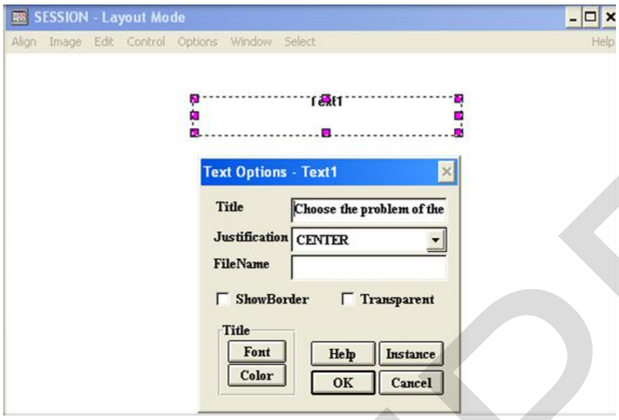

Fig. 7. The main session layout mode of Kappa-PC Software on creating text

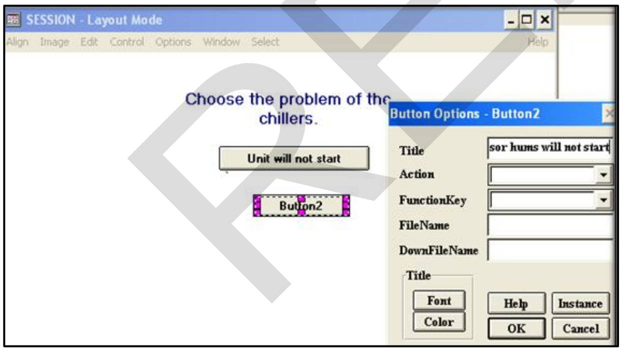

Fig. 8. The main session layout mode of Kappa-PC Software on creating button option

An inference engine running via the knowledge base storage, with all the list of chillers problems and factors, is placed by KAPPA-PC tool kit with the aid of "if-then-rules", to seek for the right fault diagnosis action. Once the fault has been identified, the system will prompt the user to diagnose the malfunction chillers and parts. Ultimately, the system offers suggestions on the remedy to the given troubles.

The knowledge acquisition process can subsequently be continuously updated with the knowledge of experienced engineers and area professionals.

The main layout session of the software where users can choose the chiller problem is shown in Fig. 10. The user interface can always be customized with graphics and designs, to allow creating an interface that simplifies the interaction with the end user.

The graphical representation of the object browser hierarchy tree is shown in Fig. 11. There are the two main branches which are the water based and air based chillers of this project.

The function editor, as shown in Fig. 12, allows the developer of the expert system to code the possible scenario and suggestion.

The expert system can propose suggestions, based on important guidelines and rules which have been built using the knowledge base. For example, to start the chiller fault diagnosis process, the condition of the chillers must be identified and known. Examples of rules for chillers fault diagnosis process are shown in Fig. 13.

The goal for the inference engine of the expert system can be defined, examined and edited using the goal editor (Fig. 14). The body of goal editor, expressed in KAL programming language, contains a set of tests that the inference engine can apply when attempting to test whether the goal is achieved. The class editor in Fig. 15 contains two scrollable boxes which are the menu bar (Slots and Methods) and the text edit box (Comment). Slots contains a list of the sub-classes of the chiller and their values which the developer can add, delete, edit, or even rename with the slot editor. The methods contains a list of methods within the class where developer can add, delete, edit, rename and localize methods. Fig. 16 shows the rule system for the case study.

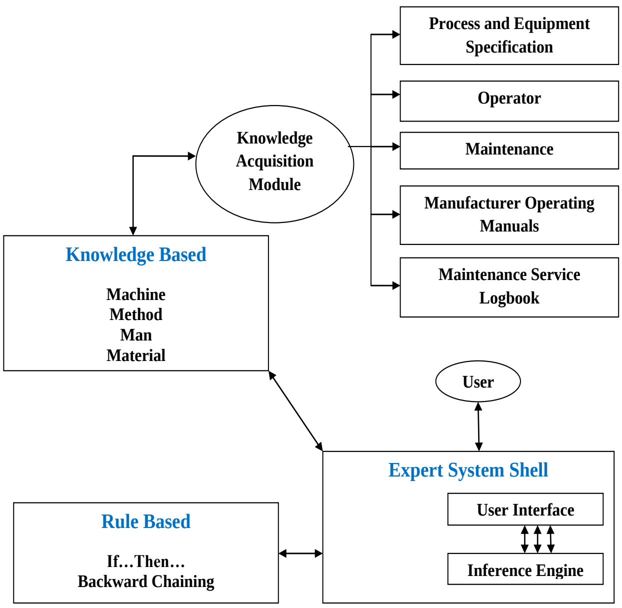

Fig. 9. The framework of the expert system

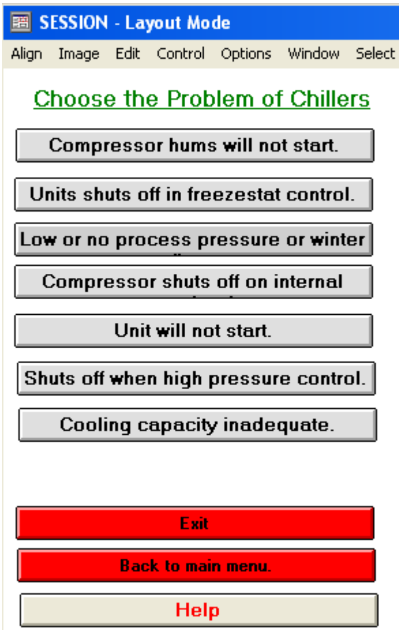

Fig. 10. The main finalize session layout mode of Kappa-PC Software

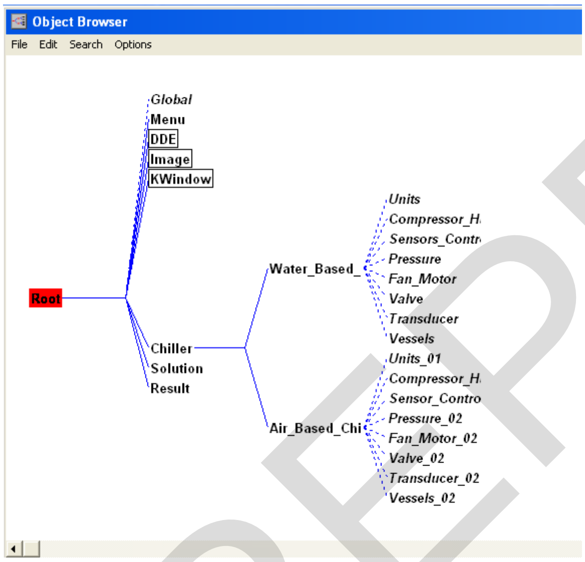

Fig. 11. The hierarchy tree

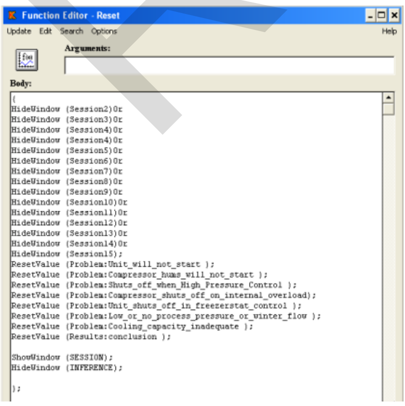

Fig. 12. The function editor of Kappa-PC Software. Reset Value (Result: conclusion) means that remove the current value. HideWindow (INFERENCE) means that the Inference browser will not be displayed

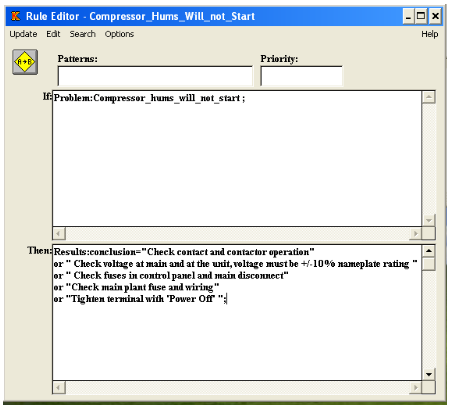

Fig. 13. The rule editor of Kappa-PC Software

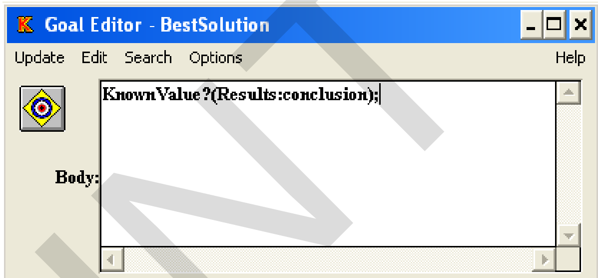

Fig. 14. The goal editor of Kappa-PC Software

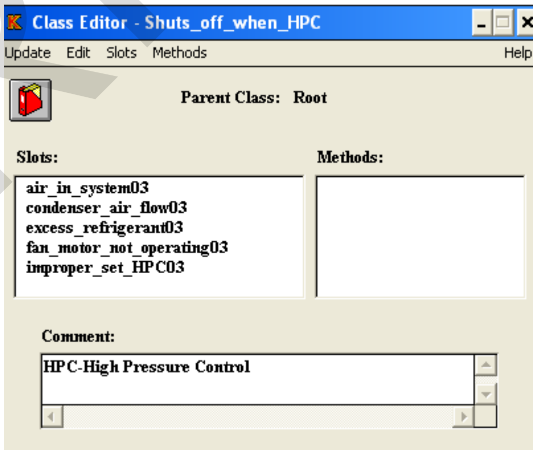

Fig. 15. The class editor of Kappa-PC Software

III. Case Study

Using the developed fault diagnosis expert system, a case study has been conducted on the main library of Technical University of Melaka Malaysia (UTeM) where the specifications and information regarding the water-cooled chillers is given by the appointed officer. All chillers parameters and specifications are standardized as stated in the Operational Maintenance and Service Manual. Since the library is operating seven days in a week, the ACMV system will be operating for a long period. Hence, the probability for chillers to break down is high. Whenever chillers breakdown, the UTeM building service officer has to call upon outsourcing experts, and charging fees per visit are expensive.

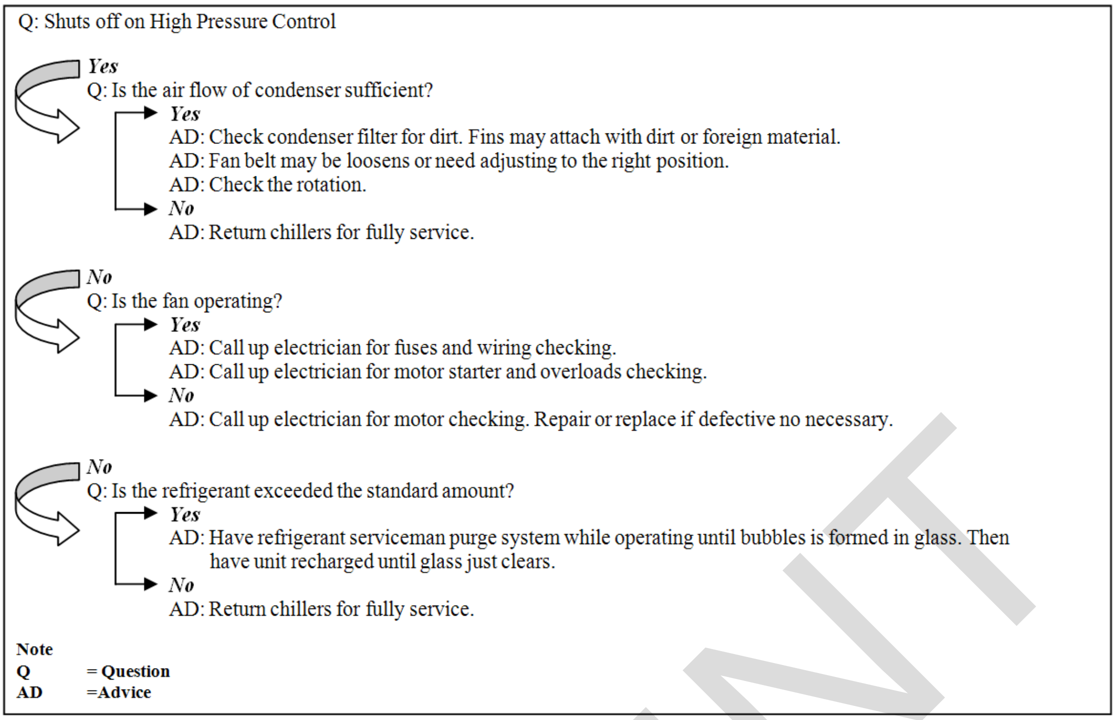

Fig. 16. The rule for case study

This does not include service and others charges. With this system, the UTeM building service officer can directly diagnose the problem and figure out the solution which can cut down costs the most. Through this case study, it shows that the developed system can help a big academic institute to reduce cost of hiring outsource experts when problem arise.

III.1. Field Testing

The developed system is deployed and validated with real world problem. Table III is the detailed specification of centrifugal water cooled chillers for purpose of case study.

TABLE III
CENTRIFUGAL WATER –COOLED CHILLERS SPECIFICATION

Model	York
Type	Water-cooled (Twin Screw Type)
Series No	YEWS 1000A500
Capacity Range Tons	2000-6000
kW/Range.	0.50-0.60
Coefficient of Performance	5.85-7.02
Refrigerant	134a
Turndown % Capacity	10

As shown in Fig. 17, multiple variable questions with "YES/NO" options are provided to assist in the fault diagnosis process. Ten technicians were asked to use the expert system to trouble shoot the building chillers. The best recommendation action is shown in Fig. 18. The objective of this case study is to determine whether the expert system meets the actual requirements. Besides, it also determines the validation of the system and user acceptance to this system. Table IV shows eight field testing chillers fault diagnosis results and their respective validation.

The developed expert system has the ability to diagnose the causing root to different scenario and thus recommends precise and systematic troubleshooting procedures which match the actual chillers fault.

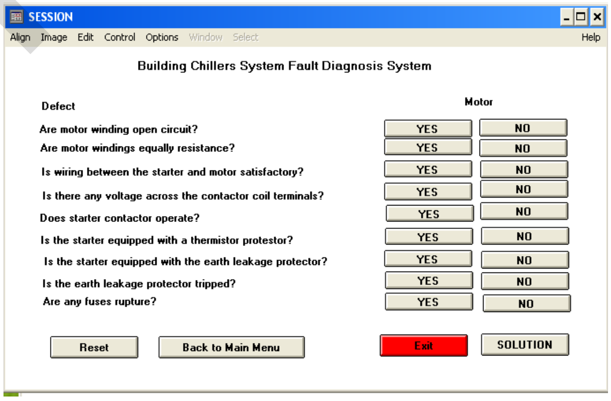

Fig. 17. A typical data input module

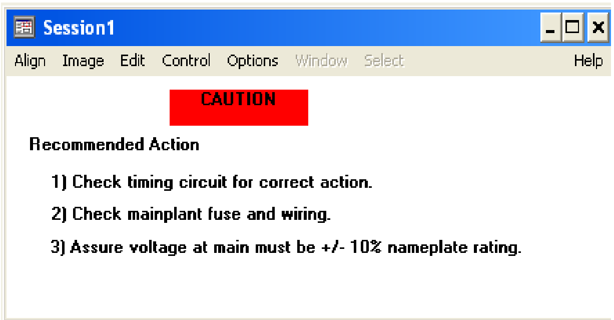

Fig. 18. A result screen module

TABLE IV
CASE STUDY RESULT

No	Problems	Actual Root Cause	Expert System Results	Match
1	Are motor winding open circuits?	Resistance of motor winding is not equivalent.	Check for the resistivity of motor.	YES
2	Are motor winding equally resistant?	Unbalanced load.	Adjust load.	YES
3	Is wiring between the starter and motor satisfactory?	Broken wiring of high resistance would result in an unbalanced load.	Check for the wiring.	YES
4	Is there any voltage across the contactor coil terminals?	Check timing currents for correct actions. Remembering that, initially, the main contactor should be energized and at the end of each time period a subsidiary contactor will also be energized, until all contactors are energized.	Check current across the contactor.	YES
5	Does the starter contactor operate?	Control circuit of the wiring of the starter may be faulty.	Check for the wiring.	YES
6	Is the starter equipped with a thermistor protestor?	Inform authorities.	Inform Engineer.	YES
7	Is the starter equipped with the earth leakage protector?	Inform authorities.	Inform Engineer.	YES
8	Is there any fuses rupture?	Short circuits between phases, phase to neutral and phase to earth.	Replace ruptured fuses.	YES

IV. Conclusion

An ACMV expert system has been developed by using Kappa-PC expert system shell. The developed system comprises an inference engine, a user interface and knowledge acquisition module. The system generates user friendly prompts related to the user input data pertaining to the situation at hand. The developed system can help service personnel with insufficient experience in ACMV industry to provide right service procedure for chillers fault diagnosis. The system needs to be updated once in a while, to expand the database of the system. Besides, the constraint values for this developed expert system are based on the building chiller design data and expert's experience. A major achievement of this system is that it provides the user with useful suggestions and recommendations based on the knowledge and experience of building chiller experts. With the existence of this expert system, the detection of causes and factors can be determined in shorter time when the expert is not around. The system is scalable as it can be upgraded to enhance the system use with multiple types of chillers. With the increasing coverage of long-term evolution (LTE) enabled high speed internet access [22], [23], an expert system that could directly connect to the Internet-of-Things enabled smart ACMV system could definitely help to streamline the sensor data and knowledge collection of the expert system.

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References

[1] Vakiloroaya. V, Samali. B, Fakhar. A, Pishghadam. K, A review of different strategies for HVAC energy saving, *Energy Conversion and Management, Vol. 77*, pp. 738-754, 2014.

[2] Mansyur. R, Rahmat. R.A.O.K. & Ismail. A, A Prototype Rule-Based Expert System for Travel Demand Management, *UNIMAS E-Journal of Civil Engineering, Vol. 4*, n. 4, pp. 34–39, 2013.

[3] Liebowitz, J. Expert System: A Short Introduction, *Engineering Fracture Mechanics* , Vol. 50, n. 5/6, pp. 601-607, 1995.

[4] Gemignani. M. C., Lakshmivarahan, S. & Wasserman, A.I, *Advances in Computers, Vol. 22*, 1983.

[5] Dym C.L. Expert systems: New approaches to computer aided engineering. *J Eng Computer*, Vol. 1, n. 3, pp. 9 – 25, 1985.

[6] Terry Anthony Byrd, Expert systems implementation: interviews with knowledge engineers, *Industrial Management & data systems*, Vol. 95, n. 10, pp. 3-7, 1995.

[7] Chen., Lee. C, & Chen. C, To Enhance the Energy Efficiency of Chiller Plants with System Optimization Theory, *Energy & Environment*, Vol. 21,n. 5, pp. 409-424, 2010.

[8] Han. H, Gu. B, Wang. T, & Li. Z, Important sensors for chiller fault detection and diagnosis (FDD) from the perspective of feature selection and machine learning, *International Journal of Refrigeration*, Vol. *34*, n. 2, pp. 586-599, 2011.

[9] Waterman. D.A, A guide to expert systems, *Addison Wesley Publishing Company, USA*, 1986.

[10] Turban. E, Expert systems and applied artificial intelligence, *Macmillan Publishing Company, New York*, 1992.

[11] P. Jackson, *Introduction to Expert System*, Addison Wesley, 1998.

[12] Anon, *Turboprop Gas Turbine Engine Maintenance Manual for Model Pt6a-114* (Serial No: 3021242), (Pratt and Whitney of Canada, 1995).

[13] Goodall. A, *The Guide to Expert System, Learned Information* (Europe) Ltd, 1985.

[14] Waterman. K, *Expert System Techniques, Tools and Applications*, (Addison-Wesley, Reading, MA, 1986).

[15] Adalew. K.O, Abdalla. H.S, and Nash. R.J, A computer-based intelligent system for automatic tool selection , *Materials and Design*, Vol. 22, n. 2, pp. 337-351, 2001.

[16] Mustapha. F, Sapuan. S, Ismail. N, & Mokhtar, A, A computer-based intelligent system for fault diagnosis of an aircraft engine, *Engineering Computations*, Vol. 21,n. 1, pp.78-90, 2004.

[17] Chua. K, Chou. S, Yang. W, & Yan. J, Achieving better energy-efficient air conditioning ,A review of technologies and strategies, *Applied Energy*, Vol. *104*, pp. 87-104,2013.

[18] Wang. S.K, *Handbook of air conditioning and refrigeration*, (New York: McGraw-Hill, 2000).

[19] C. K, & Ercelebi. S. G, The Journal of the Southern Africian Institute of Mining and Metallurgy, *An Expert System for Hydraulic Excavator and Truck Selection in Surface Mining*, Vol. *109*, pp. 727-738, 2009.

[20] IntelliCorp, *Kappa-PC User's Guide*, (Version 2.0, IntelliCorp, Inc., USA, 2006).

[21] IntelliCorp, *System Description and Data Sheet*, (Kappa-PC Version 2.0, 2006).

[22] Ghaleb AM, Cheng D, Ting A, Kwong Kae Hsiang, Lim Kim Chuan, Lim Heng-Siong, Throughput Analysis of IEEE802. 11n using OPNET, *IET International Conference on Wireless Communications and Applications* (ICWCA), pp. 1-7, 2012.

[23] Ghaleb AM, Cheng David, Ting Alvin, Ng She Chun, Lim Kim Chuan, Lim Heng-Siong, Preservation of QoS Across Hybrid LTE-WLAN Router, *IET International Conference on Information and Communications Technologies (IETICT), Beijing*, 2013.

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International Review of Mechanical Engineering (IREME)

Aims and scope

The ***International Review of Mechanical Engineering (IREME)*** is a peer-reviewed journal that publishes original theoretical and applied papers on all fields of mechanics. The topics to be covered include, but are not limited to:

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