APPROACH TO CHOICE A METHOD OF AID DIAGNOSTIC FOR INSTALLATION OF SOLAR AIR CONDITIONING

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Abstract

The building sector is one of the largest sectors of energy consumption. Heating, ventilating, and air conditioning - HVAC- is a critical component of any modern structure, from a ranch house to the tallest skyscraper. Typically, the energy that an HVAC system needs to work is directly drawn from the electric grid, But recently renewable energy offer other alternatives such as cooling with solar air conditioning which use the heat of the sun to reduce the energy needed to drive the cooling process of a conditioning system. This in turn, reduces the energy needed to run the compressor.

The diagnosis is by definition, the identification of the cause of a failure by logical reasoning. In this light, our job is to cite the different methods of diagnosis, and make the best choice for a complex system of solar air conditioning following the characteristics desired and fixed.

Keywords: Diagnostic, Solar Air-Conditioning, Diagnosis Method, Dependability, Renewable energy

Introduction

In the office, a hot day can be stressful. Because productivity can suffer when the temperature exceeds 28°C, more and more buildings are being fitted with air-conditioning systems. This is where solar air conditioning comes in: The summer sun, which heats up offices, also delivers the energy to cool them. The thermal use of solar energy offers itself: Days that have the greatest need for cooling are also the very same days that offer the maximum possible solar energy gain.

The demand for air conditioning in offices, hotels, laboratories or public buildings such as museums is considerable. Under adequate conditions, solar and solar-assisted air conditioning systems can be reasonable alternatives to conventional air conditioning systems. Such systems have advantages over those that use problematic coolants (CFCs), not to mention the incidental CO2 emissions that are taking on increasingly critical values.

Diagnose fault of solar air conditioning may be very difficult given the complexity of such structure, that is why the choice of the method to use is an important step in the further work on the subject. The structure of this article is composed of three parts, the first concerns the definition of solar air conditioning and a brief overview of her functioning, the second is dedicated to the dependability and the position of the diagnosis in the process of maintenance, and the last part is devoted to the comparative study of methods of diagnosis as well as the desirable attributes, to choose the most appropriate for our system.

Solar Air Conditioning

Solar air conditioning means any air conditioning system using the sun as source of energy, the fact is that the times that air conditioning is needed the most are the times when the sun also produces the most power to run the system as we shown in fig 1.

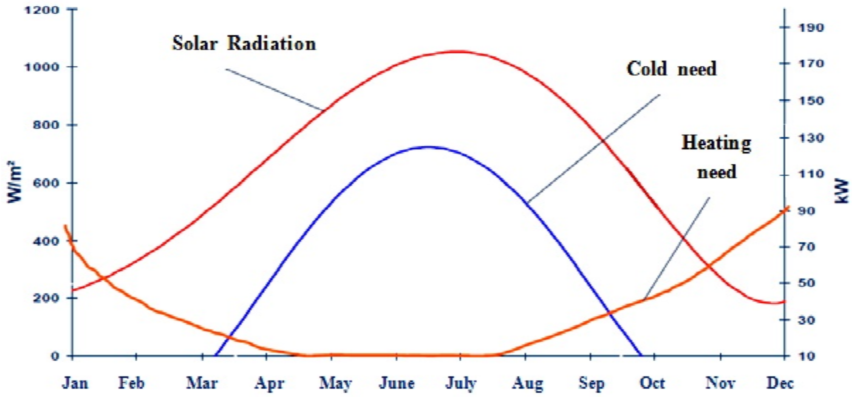

Fig. 1 Annual between solar radiation and cold need

In order to evaluate the potential of solar energy for the different solar cooling systems, a classification has been made by the scientists Best and Orgeta (1998). It is based on the two main concepts: solar thermal technologies for the conversion of solar heat into hot water, and the solar cooling technologies for the cold production. [1], [2].

The solar thermal technologies are:

- Flat plate collectors
- Evacuated tube collectors
- Stationary, non imaging concentrating collectors
- Dish type concentrating collectors
- Linear focusing concentrators
- Solar pond
- Photovoltaic

The solar cooling technologies are mainly classified into two main groups depending on the energy supply: a thermal driven system and electricity (photovoltaic) driven system, see Fig 2.

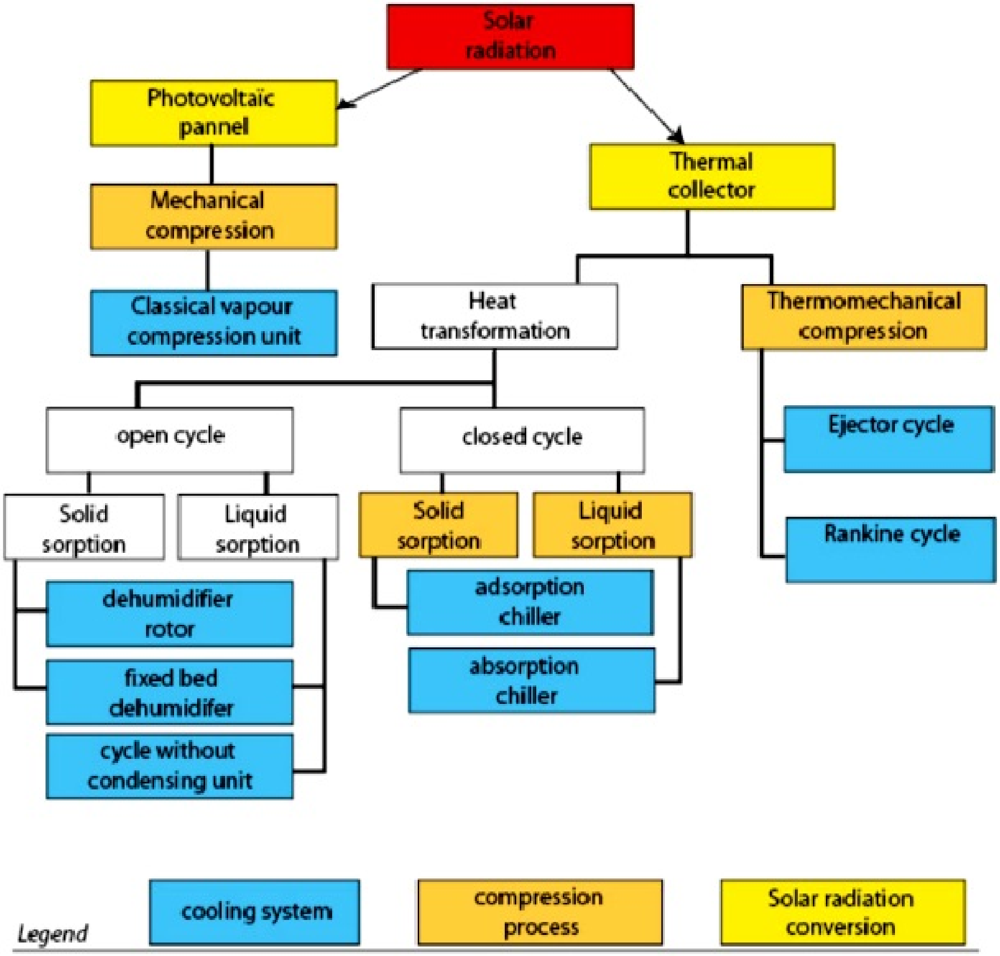

Fig. 2 Solar cooling process

Among the methods of solar air conditioning, we can distinguish these four ways to produce cold by solar energy:

- Use photovoltaic system to ensure the air conditioner compressor (traditional air conditioner)
- Use solar thermal energy and convert it into mechanical energy coupled to an air conditioner compressor.
- Use solar thermal energy to run a sorption machine (absorption or adsorption)
- Use solar thermal energy to run a air conditioning system based on evaporative air.

The solar powered cooling system generally comprises three main part: the solar energy conversion equipment, the refrigeration system, and the cooled object.

The solar system considered in this work is a absorption chiller (see Fig 3), in the most simplistic sense, allows a building to use thermal collectors to power its air conditioning. The water heated by solar energy in these collectors is used to initiate a thermal dynamic process. The chiller water is then brought to a series of copper pipes that efficiently cool air blown through the pipes and the indoor. Except for a few pumps, the system is entirely passive, has no moving parts and requires no electrical input. [3]

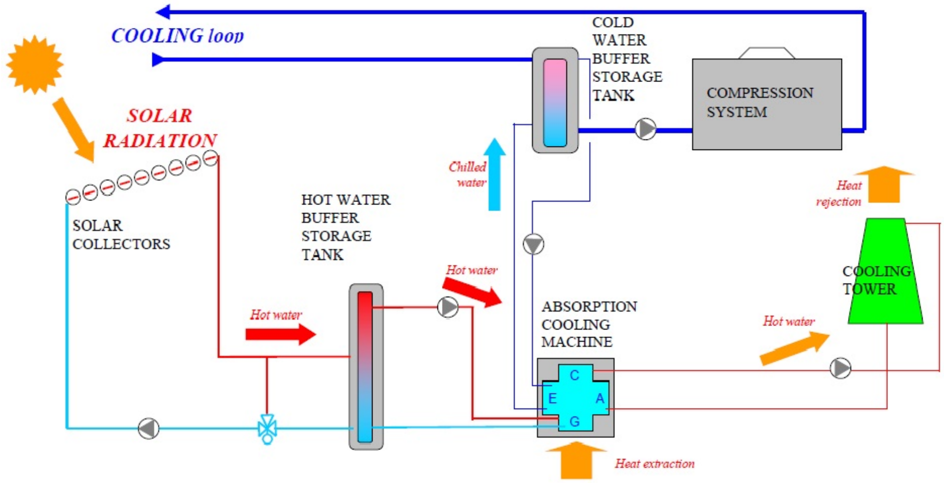

Fig. 3 Operation of solar air conditioning (absorption)

A solar air-conditioning system must not comport any failure in energy consumption level, it must ensure comfort for all the people living in the building, and protect the environment. This operating system requires efficient equipments but also needs to be managed by a maintenance system that must be capable of detecting and correcting all the failures very fast.

The analysis of behavior of our system as measured with various sensors is necessary for control and maintenance purposes. The basic problem is to detect, localize and diagnose any deviation with respect to a reference behavior.

The diagnosis is by definition, the identification of the cause of failure by logical reasoning. In this light, the objective of this paper is the development of methods to automatically optimize the operation of building equipments, detecting fault of these facilities, and diagnosing their causes. These methods should be implemented in the building management system (BMS).

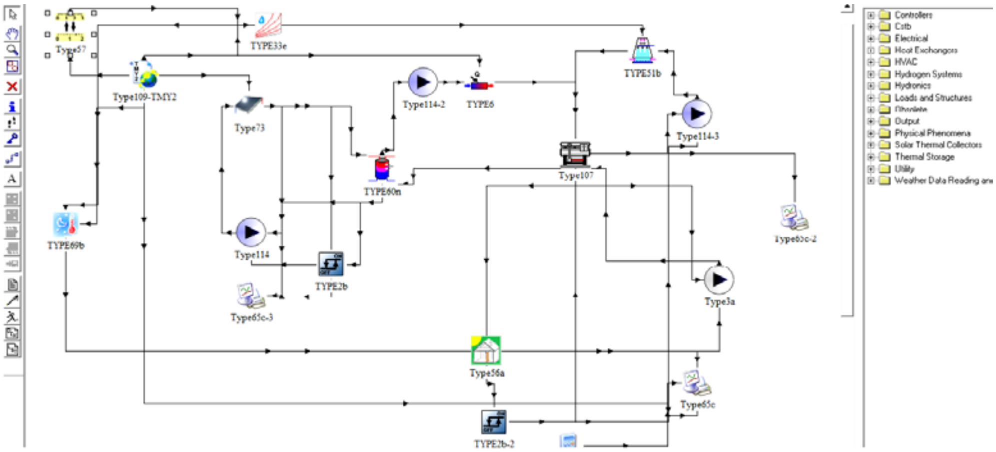

Fig. 4 Scheme for the installation of solar cooling in TRNSYS

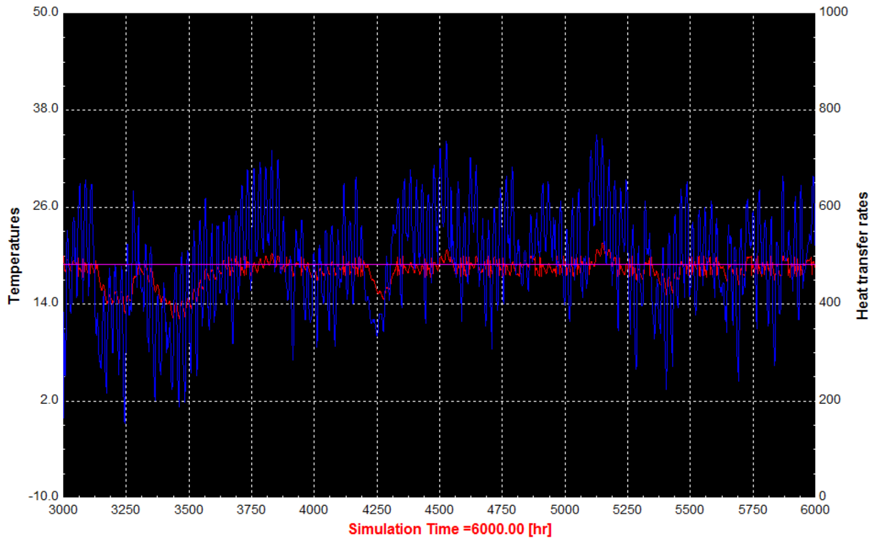

Fig. 5 Simulation results

Transient System Simulation Program (TRNSYS) software was used to simulate the solar cooling installation by representing the different component of the system and also by adding sensors and actuators at different levels of the installation as we shown in Figure 4.

We simulated our system by introducing the meteorological data of temperature variations of one year in Tlemcen city (Algeria) to see how our system work and responds to the change of temperature by operating the air conditioning system function. And we see that the system can ensure suitable temperature during the high heat periods of the years. And we can see the simulation result in figure 5.

Fault detection and diagnosis

Dependability

The dependability of a system is its ability to deliver specified services to the end users so that they can justifiably rely on and trust the services provided by the system. Dependability has several attributes, including reliability, maintainability, avaibility, and safety [4].

A systematic exposition of the concepts of dependability consists of three parts: the **threats** to, the **attributes** of, and the **means** by which dependability is attained, as shown in Figure 6.

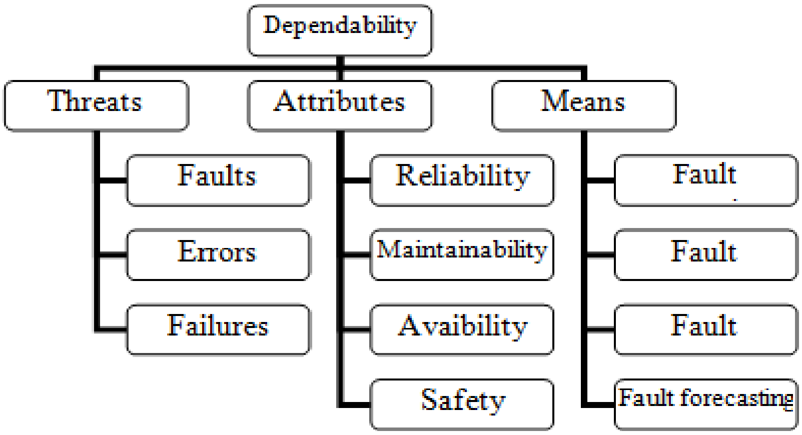

Fig. 6 The dependability tree

Diagnosis

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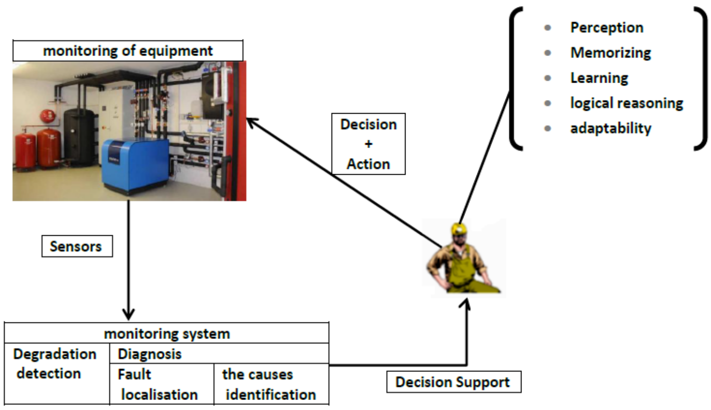

Fig. 7 System decision support for the diagnosis of equipment

Diagnosis methods

A short exposition on the various diagnostic methodologies is now presented. Diagnostic methods differ not only in the way the process knowledge is utilized but also in the form of knowledge required. A classification based on the form of process knowledge is shown in figure 8. [10], [11]

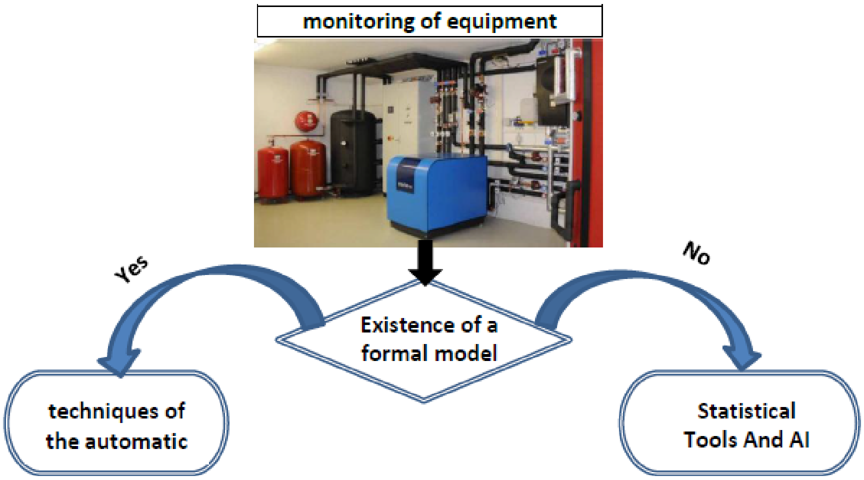

Fig. 8 Different approaches to diagnosis

During the process, the dynamic detection tool scans continuously the system. When a failure or degradation occurs, an alarm is raised and the diagnosis tool starts. According to the information provided by the detection tool, the diagnosis tool proposes to the operator the possible causes of the symptom as well as the fuzzy interpretation of these causes. This point of view enables us to predict a possible failure.

Specificity of the System

The selected method of diagnostic must be able to manage very complex structure, given the size of our solar air conditioning system and the multitude of equipment that may exist in this type of installation; comparing an electromechanical system; solar air conditioning comes as an extended system with many components more complex, diverse and interconnected; but also regulation circuits such as valves and pumps… All these components are installed in several locations and over a large area. This is why the installation of sensors and actuators is necessary to have data that can be subsequently used by the diagnostic system. This is why we are interested to the maintenance of such system.

Within the automatic control of technical systems, supervisory functions serve to indicate undesired or not permitted process states, and to take appropriate actions in order to maintain the operation and to avoid damage or accidents. The following functions can be distinguished: [12]

- Monitoring: measurable variables are checked with regard to tolerances, and alarms are generated for the operator;
- Automatic protection: in the case of dangerous process state, the monitoring function automatically initiates an appropriate counteraction;
- Supervision with fault diagnosis: based on measured variables, features are calculated, symptoms are generated via change detection, a fault diagnosis is performed and decisions for counteractions are made.

The diagnostic procedure is based on the observed analytical and heuristic symptoms and the heuristic knowledge of the process. The extracted knowledge from a solar air conditioner system are various types: numerical, analytical and symbolic. Include (figure 9):

- FMEA (Failure Mode and Effects Analysis);
- BMS (Building Management System);
- CMMS (Computerized Maintenance System);
- SPC (Statistical Process Control).

Fig.9 Input data

Tab.1 Artificial intelligence methods

Methods based on operational models		
Automats of finished states	▪ Simulation of normal functioning ▪ Rather for detection	Detection of the abnormal modes by comparison with the system. Not real application (interest for modeling).
Petri Nets	▪ Model with states of breakdowns. ▪ Back Pulling to find the states at the origin of the states of breakdown.	
Methods of form recognitions		
Neural Network (NN)/Logic Fuzzy (LF)/Neuro Fuzzy (NF)	▪ Recognition of modes. ▪ No identification of the causes.	Intelligent detection: alarm with information. Not the search for causes (solution in the cases)
Reasoning starting from case	▪ Recognition of the cases similar to the problem. ▪ Diagnosis explained a priori	

	in the definition of the case.	
Methods based on explicative models		
Causal graphs	▪ Model: relations binding the causes for their effects (facilitated by the tree from failures and FMEA (failure modes and effects analysis)). ▪ Algorithm of search for causes (Abduction).	They allow the localization and the identification starting from observation of symptoms
Contextual graphs	▪ Model: reasoning held in context. ▪ Rend account of duality procedure/practice.	
Petri nets	▪ Model: probabilistic model of breakdown ▪ Algorithm of search for causes (calculation of probabilities)	
Logic Fuzzy (LF)	▪ Model: causality relation with consideration of the imprecision's ▪ Abductif diagnosis: one seeks explanations to the observations	
Neuro-Fuzzy (NF)	▪ Model: Recognition of modes. ▪ Diagnosis is extract starting from the cases base.	

Choice of the method

The industrial diagnosis methods can be separated in two main classes according to have or not a supervised process model. The first case uses the redundancy informations and knowledge supplied by the model to characterize the operating mode or the system state to decide of its normal or abnormal situation. This is the case of the automated techniques. The inconvenient of these techniques is the uncertainties existence produced by the physical modeling which not considers all parameters and risks capable to affect information on a diagnosis factor.

In the second case, it is analysis of the data provided by the system which permits to decide on its state. Two solutions exist in this case, the diagnosis with statistical tests and the diagnosis with symbolic model. The first solution is less performed than the second because the part of detection failures is not considered.

In diagnosis without model, the supervision function is often considered as only a recognition form application. The forms represent the input vector composed by different equipment data (measurable and qualify data) and the classes represent the different operating mode. This paper deals with the supervision problem with a complementary aspect which appear fundamental notably in relation to diagnosis which – compared to faults detection- not resolves only forms recognition. The faults origins research become a primordial step which require different techniques.

The extracted knowledges from an industrial system are with various types: numerical, analytical and symbolic. For example: **FMEA** (failure modes and effects analysis), **BMS** (Building management system) [5], **CMMS** (Computerized maintenance management system), **SPC** (Statistical process control),… All these data can be used by the diagnostic support system. and It is very difficult to condense all these knowledges in a unique formalism. For these applications, ***the Artificial Intelligence (AI)*** techniques (Table 1) characterized by their capacity to treat:

- A great information quantity
- Non homogenous data (numerical/symbolic)
- Data which depend on context
- Not complete data

Give interesting solutions to the diagnosis problem (figure 10).

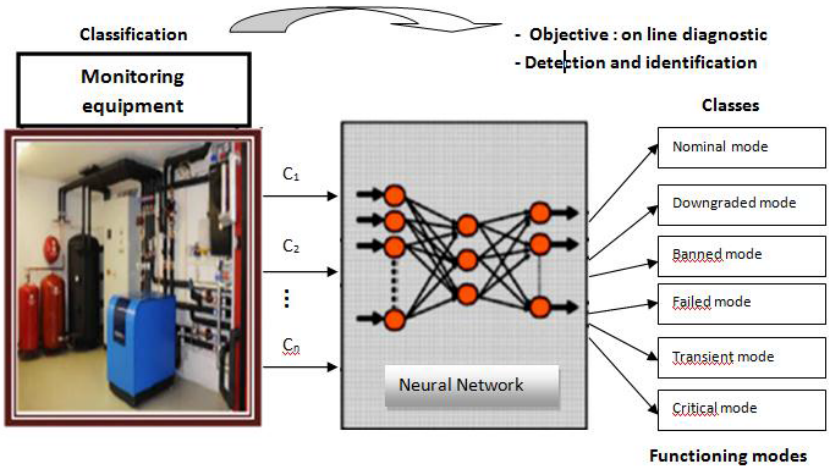

Fig.10 Diagnostic support system process

From the synthesized specialized literature on AI applied to diagnosis of industrial systems, four essentials criteria can be retained to evaluate and to compare the different proposed solutions. These criteria can be announced as:

- The difficulties toward acquisition of the necessary information and particularly the model,
- The capacity to consider the unsure and the imprecision,

- The tools design and their capacity to evolve with the system,
- The validation (or evaluation) of the obtained results.

And it is for this reason that the methods of artificial intelligence prove to be a good solution for the development of a diagnostic support system for solar air conditioning. [6], [13]

In the field of artificial intelligence, neuro-fuzzy refers to combinations of artificial neural networks and fuzzy logic. The synergizes of these two techniques is in order to combine the human-like reasoning style of fuzzy systems with the learning and connectionist structure of neural networks. [7]

Conclusion

The basic aim of this paper is to organize, classify, review and compare various approaches to fault diagnosis from different perspectives. And describe the state-of-art efforts in terms of solar air conditioning.

Towards that goal, we classify the different methods into three categories: (1) process model based, (2) statistical technique, (3) artificial intelligence. We also present a framework that shows how these different approaches relate to and differ from each other regarding the transformation of information from the measurement space to the decision space.

As a result from the demanding of process safety, reliability and environmental constraints, a called of fault detection and diagnosis system become more and more important. A variety of methods already proposed whether applied single or combined method. The combination of Artificial Neural Network (ANN) and Fuzzy Logic (FL) is considerably practical because it combined both the advantages and makes the entire system more robust.

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