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"Modelling analysis and design of Heat Pump System Using Predictive Fuzzy Logic Controller"

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Abstract— *Appropriate working of heating, ventilation, and air conditioning (HVAC) systems is significant for well-organized thermal management, as well as operational costs. Furthermost of these structures use nonlinear time variances to handle instabilities, along with controllers that try to balance rise times and stability*
Heat pump is used to provide or absorb heat. The air-conditioning systems now are usually used in the buildings. Temperature control is important for both human comfort and for smooth functioning in industries. So there are two categories for the different applications, one is for comfort living and the other one is for industrial application. The control items in the air-conditioning include temperature, air quality and humidity in one room. The indoor environment is very important for the health and it can affect the efficiency of production. People usually spend a lot of time in the buildings, so the air conditioning system is designed to keep a comfortable environment for human beings. Many researchers have donated much time on the comfortable environment indoors and they find temperature and humidity are the major factors to human comfort. MATLAB software is used as the tool to make model and process calculations due to is simplicity to use and also because it has a dedicated toll box to run the testing and training of system. In the paper, intelligent control methods are proposed to achieve the optimum controlling of this heat pump. Such method are expected to reduce the cost of machine along with exponential rise in efficiency of system.

Keywords: *Fuzzy Logic Controller, Heat Pump,FLC, MATLAB/Simulink, HVAC.*

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I. Introduction

In comparison with other conventional heating cooling system, heat pump is far more economical and energy saving system. From all HVAC system it is expected to be as environment friendly as possible. The main reason to focus on making energy saving system is that,the importance of energy saving in present day and the side effect of global warming is very well understood to all. Most of the energy in India (70 %) is still generated using fossil fuel based power plants which make situation more vairable. Hence using an optimized heat pump, one can save a significant amount of energy thus making system more efficient. In buildings, cooling/heating is done using various different methods ranging from centralized cooling to separate section wise cooling [7]. Each technique has its own advantages and disadvantages. Controlling section wise is more adopted this days due to its high energy saving. The reason behind this energy saving is that instead of cooling each section, one can simply transfer heat form one section to another based on requirement. Hence, a lower use of refrigerant and heat exchange from outside environment will be required. The exchange can be further optimized using controllable heat pump operation which allow the flow of refrigerant according to demand. Hence by the knowledge of demand one should decide the appropriate quantity and speed of refrigerant flow in system. In this work use of Artificial intelligence (fuzzy logic is also a part of AI) is proposed for estimating the position of heat pump according demand and present condition.

The advantage of fuzzy has been observed in several area in last couple of years and is still going strong. The reason for its exceptional output in all cases is due to its ability to adjust itself based upon historical data (nonlinear) and to derive meaning from nonlinear data. It has proved to be of great help in areas in which parameters are of uncertainty in nature.

II. Literature Review

In the following section a brief discussion of work done in the field of optimizing heat pump performance using various techniques is discussed.

SahithullahMahaboob et. al. [1] in 2018 has proposed that most of the domestic, as well as industrial devices are power electronic based and are the main source of heat pump optimization system. In this work author has used a technique in which he utilized the concept of shunt active power filters along with PPFO based algorithm for the sake of removing harmonic content

Satyavarta Kumar Prince et. al. [2] in 2018 has discussed that in recent times more dynamic load patterns are observed which eventually require optimized heat pump. The model has outperformed the conventional p-q theory-based PI controlled power quality improvement technique and the previous one was found superior in terms of performance.

Snehaprava Swain et. al. [3] in 2017 has proposed an controller for HVAC system which will make the generator be in continuous contact with grid so as to feed power continuously even at the time of fault situation. The results of this technique have been verified by designing and simulation the proposed model over MATLAB/Simulink software and the results are very much up to the mark.

Rini Ann Jerin et. al. [4] in 2016 has discussed that due to progressive integration of heat pump to the power system, loads have become more sensitive towards the change in input voltage supply. The authors has proposed a technique called DVR for providing assistant in such conditions. This DVR has the responsibility to provide firing angle to PWM based inverter supply.

Om Prakash Mahela et. al. [5] in 2016 has proposed that in order to regulate the operation of heat pump, DSTATCOM could be very useful. The objective is to control this reactive with the help of STATCOM device. The work has been tested over 13-bus system and has found to be affective.

Soumya Mishra et. al. [6] in 2016 has proposed a novel method called JAYA which has the responsibility to control the PI controlling units output which is used along with DSTATCOM. This work incorporate a controlled heat pump system. According to authors, the main advantage of JAYA, which make it far better, then algorithm-based techniques, is that it has no dependence over linear controlled parameters.

III. Introduction To Heat Pump

A heat pump is an electrical gadget that concentrates heat starting with one spot and moves it then onto the next. The heat pump is certainly not another innovation; it has been utilized the world over for quite a long time. Refrigerators and air conditioners are both normal instances of this innovation.

Heat pumps move heat by circling a substance called a refrigerant through a pattern of evaporation and condensation. A compressor pumps the refrigerant between two heat exchanger coils. In one curl, the refrigerant is dissipated at low pressing factor and ingests heat from its environmental factors. The refrigerant is then packed on the way to the next loop, where it gathers at high pressing factor. Now, it delivers the heat it consumed before in the cycle.

Refrigerators and air conditioners are the two instances of heat pumps working just in the cooling mode. A fridge is basically a protected box with a heat pump framework associated with it. The evaporator loop is situated inside the case, normally in the cooler compartment. Heat is assimilated from this area and moved outside, normally behind or under the unit where the condenser loop is found. Essentially, an air conditioner moves heat from inside a house to the outside.

The heat pump cycle is completely reversible, and heat pumps can give all year atmosphere control to your home – heating in winter and cooling and dehumidifying in summer. Since the ground and air outside consistently contain some heat, a heat pump can supply heat to a house even on virus winter days. Indeed, air at – 18°C contains around 85 percent of the heat it contained at 21°C.

An air-source heat pump retains heat from the open air in winter and rejects heat into outside air in summer. It is the most well-known sort of heat pump found in Canadian homes as of now. Nonetheless, ground-source (likewise called earth-energy, geothermal, geoexchange) heat pumps, which draw heat starting from the earliest stage groundwater, are getting all the more broadly utilized, especially in British Columbia, the Prairies and Central Canada.

IV. METHODOLOGY:

Following techniques are utilized in present work for the purpose of optimizing VRF:

Artificial Neural Networks (ANN):The evolution of ANN has been dated back in 1980's with the evolutions of computers. From the very same process of evolution, the term artificial neural network is been derived. The word artificial is used to denote the capability of this model to replicate the working of human brain. Usually, machines possess a property work according to pre-defined instruction saved in it. However, this is not how human works. The brain of any human has the capacity to take decision based on its experience which we call training in computers language. Hence, it gives capability to brain to take decision that too right in cases which are new to it. Therefore, machine learning is a method by which we inherit this specialty of human biological thinking system and try to replicate same in computer/machine.

Now let's understand how human brain works to form exact algorithm which can give similar outputs. Brain consist of billions of neurons, which are interconnected with each other. These interconnections have a certain strength, which makes our memory storage. Based on these memories we take decision over everything in real time. The strength of these connections depends mainly on signal from various cells/neurons situated in

each part of our body. These neurons continuously send signal according to sense organs response to brain in the form of electromagnetic pulses.

Fuzzy Logic: Introduction

The word 'fuzzy' usually used for cases in which there is no clear answer or boundary like there is a vague situation. Fuzzy unlike Boolean logic where things can be either 0 or 1 i.e. true or false represent value with the degree of truth. This fuzzy logic is applicable to all real-world problems because in none of them the boundary is clear. The value in fuzzy logic comprises of value between 0 & 1 Including two.

Fuzzy logic was proposed in the USA by Prof L. A. Zadeh, in the early 1960s. Lofti A. Zadeh. This method mimics the way operation of expert's opinion over any decision making. Let us understand the concept of fuzzy logic by taking a real-life event and comparing it with crisp set. Let there be a person named Rahul. Now we use crisp set which is also known as Boolean set then it can be represented by following figure

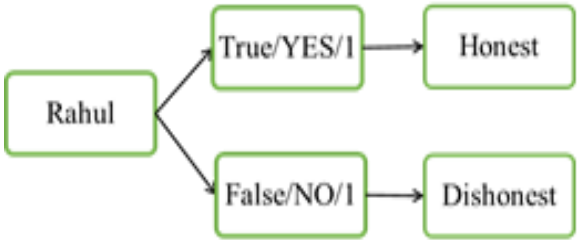

Figure 1 *Boolean set logic*

Now in this set Rahul can either be honest or dishonest. Now let's represent same situation using fuzzy logic. Now let's represent same situation using fuzzy logic.

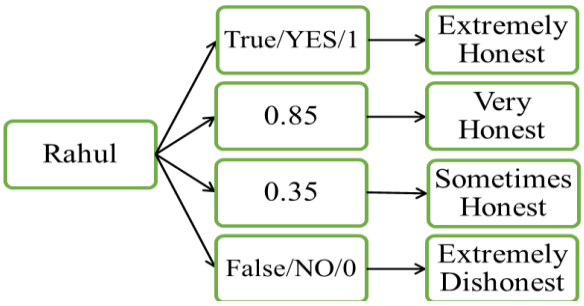

Figure 2 *Fuzzy set logic*

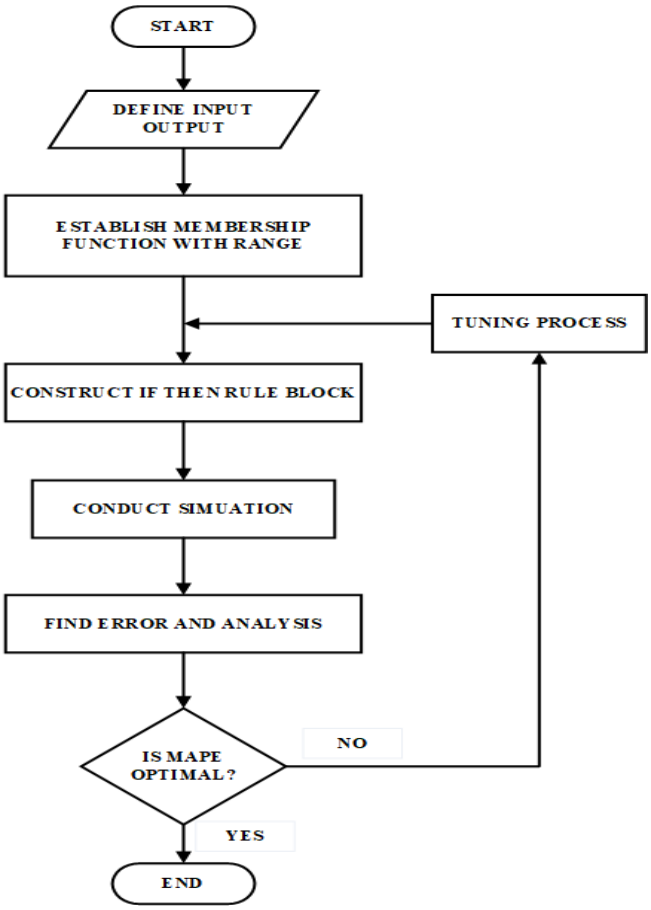

Figure 3 *Flow chart for fuzzy logic*

After defining membership function the next step is to develop rule base using knowledge base by expert opinion. These rules are defined based on if then conditional statement. Once these rules are formed a simulation is done based on input and output data. Based on this data error is calculated on forecasted and actual value of output parameter. After evaluation of error a comparison is done with the required optimum error value. If target is reached then no further training is required and process will end, otherwise a further tuning of the process is done to improve result and same steps are followed again.

V. Results

In this section the results obtain from the proposed model are shown and discussed. The work comprises of technique with fuzzy logic controller. The outputs obtained from model are compared and conclusion is made.

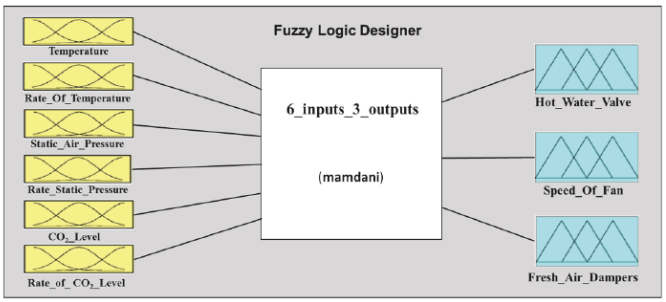

Figure 4: Fuzzy logic designer application in Matlab

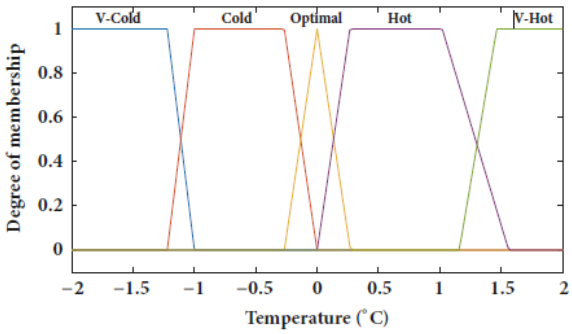

Figure 5: Membership Function of zone temperature difference

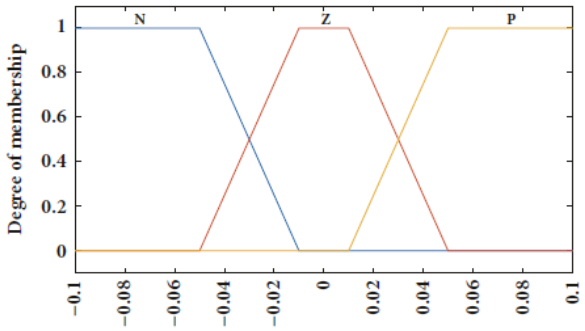

Figure 6*:* Membership Function of change in temperature

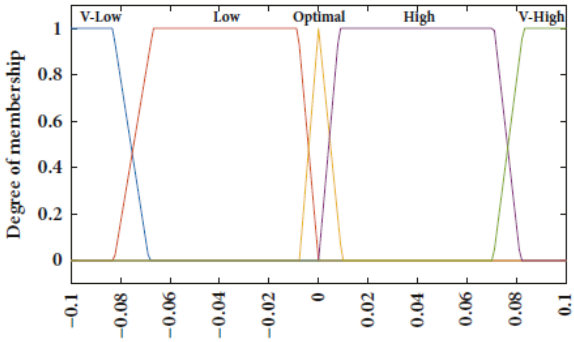

Figure 7: Membership Function of static pressure difference

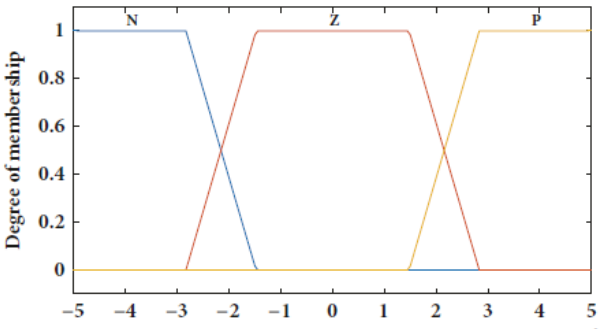

Figure 8*:* Membership Function of change in static pressure

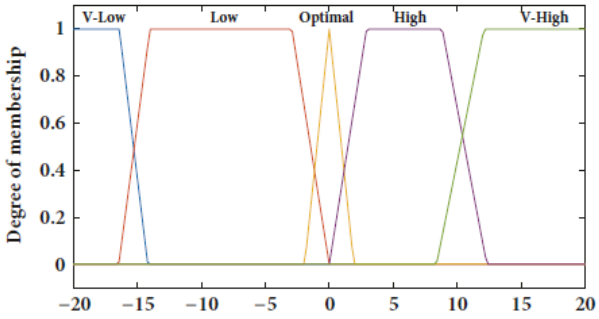

Figure 9: Membership Function of CO2 level difference

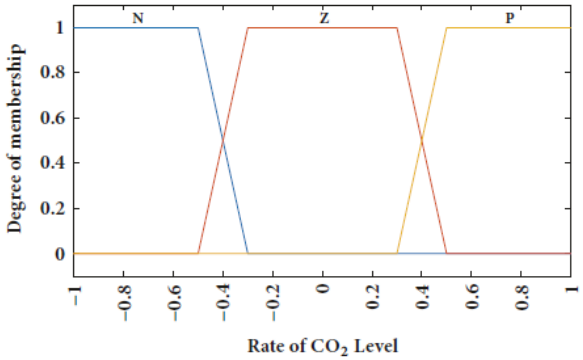

Figure 10: Membership Function of change in CO2 level

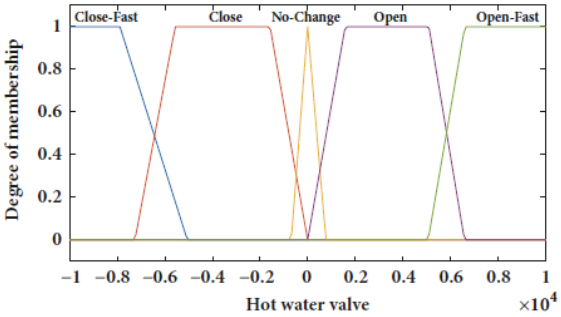

Figure 11: Membership Function of Hot water valve.

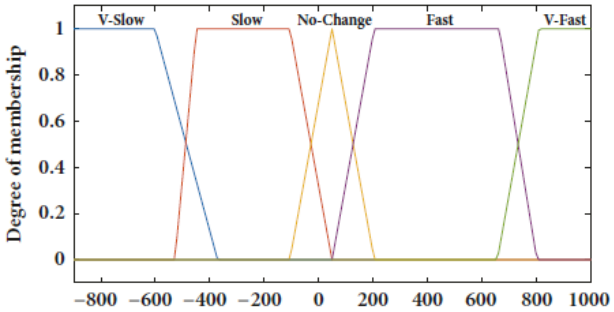

Figure 12: Membership Function of speed of fan

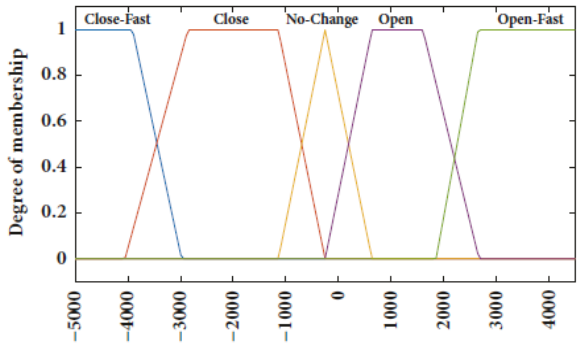

Figure 13: Membership Function of fresh air dampers

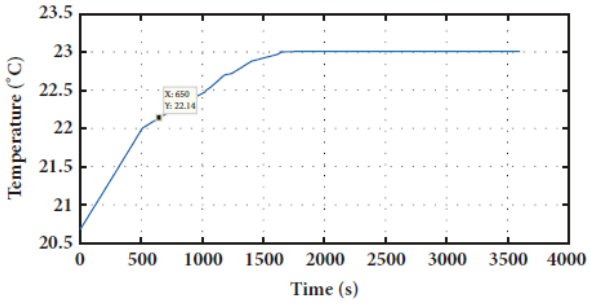

Figure 14*:* Zone temperatureresponse

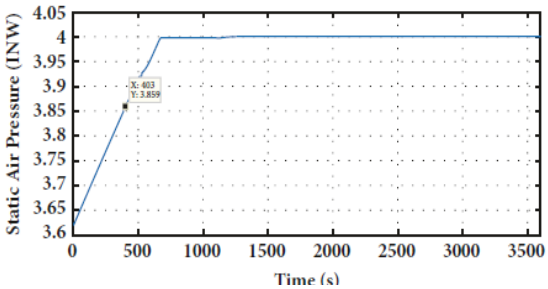

Figure 15: Static pressureresponse

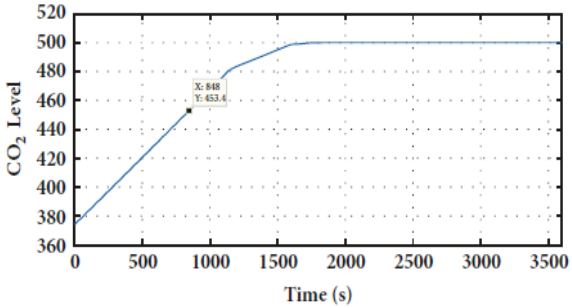

Figure 16: CO2 level response

Fig 14displays the 1st output responsethat determine the system's stability. Zone temperature attains the setpoint of 23°C at a rise time of only 10min. and with no overshoot.Fig 15describes the second response of static pressure,with a rise time around 6 minutes and having no overshoot.Figure 16displays the CO_2 level response, attaining thesetpoint, with no overshoot, at a rise time of around 14minutes.

VI. Conclusion

This paper depicted a simulation of air handling unit's using MATLAB/Simulink software. A fuzzy logic controller is used to prepare model with the three air handling units' parameters.The results show that the FLC performed better than that of conventional algorithms, such that adequate control was attained from FLVCfor HVAC system. Further the system is proved to be robust in nature.

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