A Novel Air Conditioner for Smart Grid Applications

Arun Kumar Gangwar
Assistant Professor
Electrical Engineering Department
Invertis University
Bareilly, India

Farheen Chishti
Assistant Professor
Electrical Engineering Department
Shri Ram Murti Smarak Women's College of Engineering & Technology
Bareilly, India

Abstract— **This paper represents concept of fuzzy logic controller to adjust the temperature setting of the air conditioner by taking input voltage as the reference during peak demand hours. The control is directed to reduce the peak demand without sacrificing the customer's comfort level. The proposed concept is directed to increase the grid efficiency and to reduce the supply demand gap. The proposed fuzzy based controller is directed to increase the temperature settings of the AC by taking voltage drop as the reference value, thereby resulting into the reduced motor compressor operating time and reduced demand from the grid. When no. of ACs are assumed to be controlled by such controller, the peak demand on the grid can be reduced. This will help in reducing the greenhouse gases emission resulting due to polluting and expensive plants like coal, diesel and gas based power plants.**

Keywords—Fuzzy Controller, Demand Side Management, In-house controller

I. INTRODUCTION

Electricity is fundamental to modern society and the world economy. However most of the world relies on the power system that is 50 year old. These are inefficient and cannot offer appropriate response to current global challenges. Smart grid will be the necessary enabler of these challenges. Smart grid is an intelligent, digitized energy network delivering electricity in an optimal way from source to consumption. This is achieved by integrating information, tele-communication and power technology with the existing power system [7]. The benefits of smart grid include improved efficiency and reliability of the electricity supplies. Although Smart Grid includes a number of different characteristics, this paper focuses on characteristics pertaining to Demand Side Management (DSM).For the grid to be an efficient source of energy it should constantly balance the power demand supply. The demand fluctuates second by second. The grid balances this gap by using carbon emitting power stations. Smart grid gives the opportunity to the customer to understand his/her energy usage and to make decision about how much it can use and when it can use. Smart grid makes the existing power system more intelligent by sharing of information between consumer and producer so that they can regulate their activities and hence can balance the demand–supply gap. This paper focuses on the finding solution of the grid balancing through demand side management [4].

Modernization of existing grid requires several key parts should be added to today's grid which includes the advanced metering and control devices such as information technology, sensors, high speed and real-time two way communication, energy storages, distributed generation and in-home energy controllers By having an in-house controller connected to all the appliances, every customer would be able to control

his/her energy consumption automatically with respect to load variations [6]. The in-house controller will convert every air conditioner into a smart and user friendly device. The most comfortable temperature for human body lies around 180c to 240c. According to INDIAN ELECTRICITY ACT, 1958 the maximum permissible voltage variation is +-5%.The voltage drop occurs whenever the demand increases supply. The in-house controller will read the voltage level of the grid and adjust the cooling of room accordingly and results into reduced demand from the grid. Here the software solution using fuzzy logic never overrides the primary function of the air conditioner and will makes the energy balancing easy.

II. OPERATION OF AIR CONDITIONER

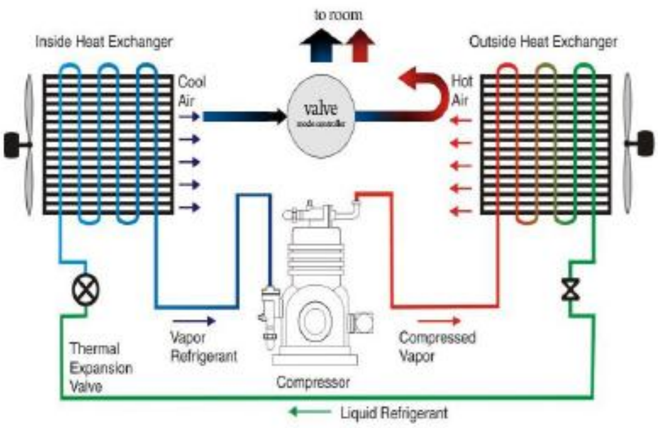


Fig. 1. Schematic of Air conditioner

Air conditioner makes the surrounding environment highly comfortable for human beings. The schematic of air conditioner is shown in Fig. 1. Air conditioners are heat exchangers. They take warm air from the room, blow it over cooling coils to remove the heat and then return it to the room. The heat absorbed by the cooling coils is then blown outdoors.

The transfer agent in a heat exchanger is called refrigerant which moves in a gas state to a liquid state as it flows through the air conditioner. When liquid becomes a gas, it absorbs heat and when gas is compressed to a liquid it releases heat. Warm room air is drawn through the filter by a fan and then blown over the cooling coil which circulates the refrigerant in its liquid state. As the room air flows through the coil, it causes liquid in the coils to evaporate and in this process heat is absorbed by refrigerant as it turns to gas. The cooled air is blown back to the room. The refrigerant gas is then compressed, increasing its temperature. To return to the liquid state the refrigerant must give up its heat. The heat transfer is accomplished by having outdoor air blown through the condenser coils containing the compressed gas. Thus cooling the gas and transforming it back to a liquid which is then returned to the cooling coil.

III. FUZZY CONTROLLER FOR AIR CONDITIONER

The fuzzy logic controller involves four main stages: fuzzification, rule base, inference mechanism and defuzzification as shown in Fig. 2.

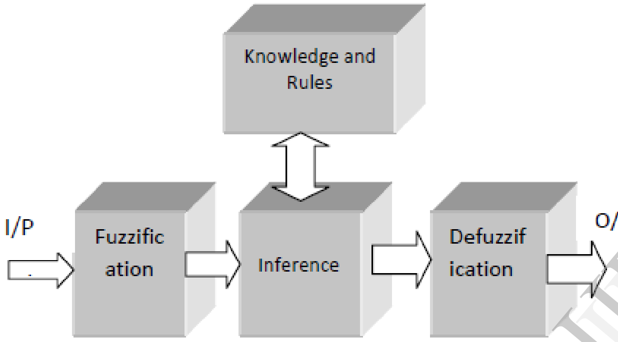


Fig.2. Fuzzy system diagram

The fuzzification and the defuzzification stages are needed to convert and reconvert real world crisp signals into fuzzy values and vice versa. The inference mechanism determines the matching degree of the current fuzzy input with respect to each rule and decides which rules are to be fired according to the input field. Next, the fired rules are combined to form the control actions. The fuzzy controller uses voltage error and rate of change of error as the input variable [2].

The in-house controller takes two inputs as the references. The two inputs are:
1. Voltage error
2. Rate of change of voltage error

The fuzzy controller takes two inputs, processes the information and outputs a temperature setting. This can be represented as in Fig. 3. The range of inputs and output variables is shown in Table 1. These two inputs are obtained through the sensors. It is assumed that we have these inputs at our hand. Anyway the two stated points need a bit of introduction which follows. The voltage error represents the difference of present system voltage and the reference voltage. The rate of change of voltage is the rate by which the voltage is advancing in positive or negative direction.

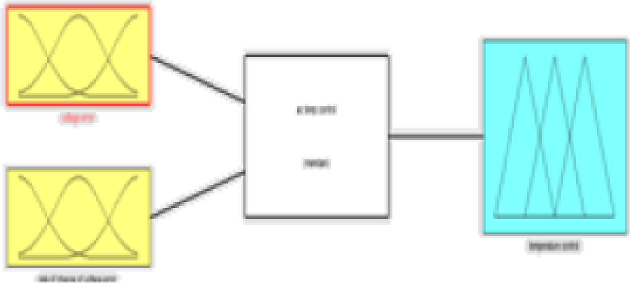
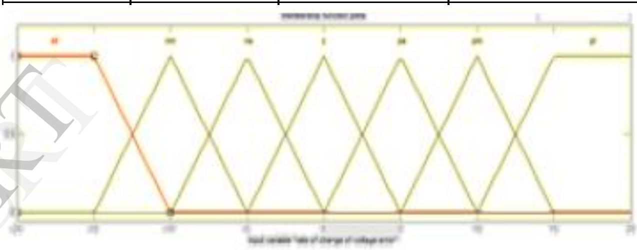


Fig.3. Input and output membership functions

Table.1. Range of input and output

Member ship function	Voltage error	Rate of change of V error	Air conditioner cooling (temp)
NL	-60 to -20	-20 to -10	16 to 18
NM	-30 to -10	-15 to -5	17 to 19
NS	-20 to 0	-10 to 0	18 to 20
Z	-10 to 10	-5 to 5	19 to 21
PS	0 to 20	0 to 10	20 to 22
PM	10 to 30	5 to 15	21 to 23
PL	20 to 40	10 to 20	22 to 24



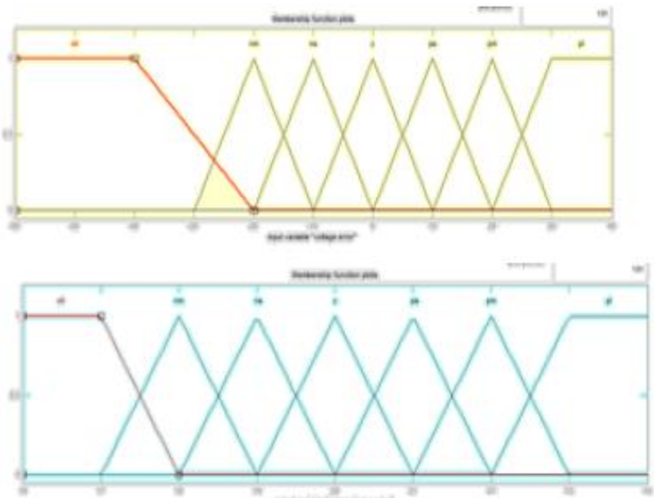


Fig.4. Membership function for various inputs and output

IV. IMPLEMENTATION AND RESULTS

Seven membership functions are used for inputs and output of the fuzzy controller as shown in Fig. 4. Therefore the fuzzy controller has (7*7=49) rules. Rule base for fuzzy controller is shown in FAM Table-2.The Fig. 5 shows the surface view of fuzzy controller for which rule bases are given in Table-2.Values of the input variables voltage error and the rate of change of error are specified in the table 1. The decision which the fuzzy controller makes is derived from the rules which are stored in the database. These are stored in a set of rules. Basically the rules are if-then statements that are intuitive and easy to understand, since they are nothing but common English statements. Rules used in this paper are derived from common sense [1].

We have a rule base with a set of the rule form as follows.

IF Ai AND Bi THEN Ci.

The sets of rules used here to derive the output are:

Here PL=positive large, PM=positive medium, PS=positive small, Z=zero, NS=negative small, NM=negative medium, NL=negative large.

1. If voltage error is PL and rate of change of error is PL then temperature setting is NL;
2. If voltage error is PL and rate of change of error is PM then temperature setting is NL;
3. If voltage error is PL and rate of change of error is PS then temperature setting is NL;
4. If voltage error is PL and rate of change of error is Z then temperature setting is NL;

The various rules are given in FAM Table-2 given below.

Table 2: FAM rule base for the proposed air conditioner

v / RCE	NL	NM	NS	Z	PS	PM	PL
NL	PL	PL	PL	PL	PM	PS	Z
NM	PL	PL	PL	PM	PS	Z	NS
NS	PL	PL	PM	PS	Z	NS	NM
Z	PL	PM	PS	Z	NS	NM	NL
PS	PM	PS	Z	NS	NM	NL	NL
PM	PS	Z	NS	NM	NL	NL	NL
PL	Z	NS	NM	NL	NL	NL	NL

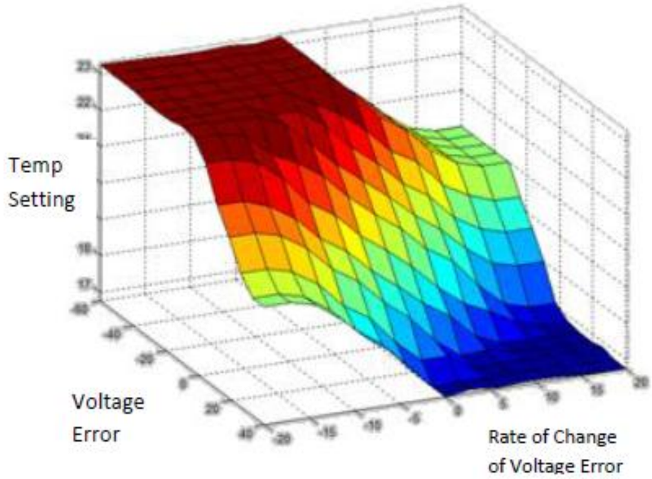


Fig.5. Surface view of the fuzzy controller shows the variation of refrigerator temperature setting wrt voltage and rate of change of voltage

V. CONCLUSION

The paper proposes demand side management scheme (in house controller) for smart grid applications using fuzzy controller based air-conditioner. The performance of the proposed fuzzy controller is found commendable and a smooth variation of the temperature setting of the air conditioner is obtained by taking voltage as the reference. Although the analysis in this paper neglected many finer details, but it clearly maps out advantage of fuzzy logic in dealing with the controlling of the air conditioner cooling by using voltage as the reference and hence can results into reducing the supply-demand gap and can makes the existing power system more efficient and reliable.

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