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Scheduling of Domestic Appliances using Two level Fuzzy Logic Controller

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Abstract: **Electricity is inevitable for our daily life. As the energy demand is increasing with increase in power production, Demand Side Management is mandate. Home Energy Management system is one of the techniques adopted to achieve Demand Side Management. Several works proposed scheduling of appliances for efficient home energy management system. However, the factors influencing operating time of the appliances are not dealt. To circumvent this issue, a two level fuzzy logic based Home Energy Management system is proposed. The proposal considers the environmental factors such as temperature and humidity along with the room and tank capacity in the first level to decide upon the operating time of air conditioner and water heater respectively. Based on these operating times and also for fan and light, the second level fuzzy is invoked to decide the frequency of scheduling. The proposal is implemented in Matlab. The proposal exhibits the influence of parameters on scheduling and also improved scheduling frequency.**

Key words - Home Energy Management System, Two level fuzzy logic, scheduling, smart grid, demand response and scheduling frequency.

I. INTRODUCTION

Modern world has been revolutionized by electricity. It is the most important blessing that science has given to the mankind. Electricity provides comfort to the people and one cannot think of a world without it. Electricity plays a pivotal role in the fields of transportation, communication, machines and consumer usage. Demand of electricity keeps increasing with the growth of population and the technology as well. The demand cannot be met out without participation of consumers. Hence, participation of consumers namely Demand Side Management (DSM) is one of the thrust research areas in smart grids [1- 3]. The DSM is implemented either through implementation of Smart Meters [4]or efficient appliance scheduling thereby achieving efficient Home Energy Management System [5]. Implementing load management programs motivates several utilities. It aims to encourage the consumers to think in different perception in order to reduce the electric bills power consumption and facing the consumer demand [6]. The major energy consumer loads are Lighting, Heating Ventilation and Air conditioning (HVAC) system. Some proposals are meant for the optimized control systems and comfort management for smart sustainable buildings[7].

Many research works focus on Energy Management in smart buildings and homes [7]. In Home energy Management (HEM) has various technologies like sensors, smart thermostats and feedback devices are used to manage residential energy consumption. HEM algorithm managing the high power consumption by considering the priorities. [8] Using Appliance Co-ordination (ACCORD) scheme, a demand response is possible to reduce the cost of energy consumption by reducing the peak demand. This can be achieved by shifting the consumer demands to off-peak hours. [9-10]

The real time electricity pricing models provides huge benefits economically. The problem due to lack of knowledge time-varying prices and building automation system was overcome by optimal and automatic residential energy consumption scheduling by minimizing the electricity payment and the waiting time using simple linear programming computations [11]. These used to reduce peak electric demand as well as user's electricity bills. With these systems, the time of use tariff can be reduced and hence, the HEM is efficient. In demand response, Genetic algorithm is used residents have the opportunity to schedule their power usage in the home by themselves for the purpose of reducing electricity expense and alleviating the power Peak-to-Average Ratio (PAR) [12-13].

Smart homes are nothing without Wireless sensor Network (WSN) as they provide high inhabitant comfort. Smart heating and air conditioning scheduling method for Home Energy Management systems can be achieved by considering consumer convenience and analyzing the

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characteristics of thermal appliances[14]. WSN can be evaluated in terms of delivery ratio, delay and Packet Delay Variance (PDV) for different sizes of network and varying intervals times [15]. However Complex electric power system carriers huge challenges in the reliability of WSN communication in smart grid application [16].

To reduce the peak demand on the power, it is essential to reduce the level of the load curves as early as possible. This problem was handled by many researchers with the help of Fuzzy Logic Controller (FLC). The main purpose of applying the fuzzy logic is to save the energy consumption. Researchers have designed a smart LED lighting based FLC to save energy consumption and a Fuzzy Model Based Multivariable Predictive Control (FMBMPC) and a Cooperative Fuzzy Model Predictive Control (CFMPC) were developed to control HVAC system in a building [17,18,19].Authors in [20] have developed fuzzy control system architecture for maximizing the comfort level of habitants. The Binary Particle Swarm Organization (BPSO) and Time of Use (ToU) pricing scheme were proposed to reduce the cost of electricity. Further the method is proposed in [21], which achieved peak demand reduction focusing on the elasticity of domestic operation duration.

To conclude, various methods to achieve energy efficient Home Energy Management System is discussed. Scheduling is one such technique to achieve energy management .However, the impact of the environmental input factors on the operating time of the appliances is not dealt. To alleviate this issue, a novel two level fuzzy based energy management system is proposed.

II. Proposed System

The Home Energy Management System plays a vital role in the automated demand response when it is not possible to perform the process manually. Demand response event is the period where the consumers need to reduce the stress level in peak hours. An effective and efficient HEM system must contain load shifting and scheduling. In proposed system, four different appliances with different power consuming capacity are considered. The demand limit is assumed to vary for every 60minutes to every hour which is based on the consumer need. Here, the high power consuming appliances such as air conditioner and water heater creates delay and burst in over consumption. This affects the low power consuming appliances like light and fan too. To overcome this tough condition and to mitigate the peak hour demand, a two level fuzzy logic based scheduling technique is proposed to schedule the operating duration of appliances.

The most acceptable and promising technology which enhances the different aspects of electricity is Wireless Sensor Network (WSN). The collaborative and low cost system became significant. Wireless sensor network connects the devices into one another in order to control and monitor the working of appliances based on the customer preferences and power consumption. The next innovative and highest range of intelligence is the invention of smart grid. Smart grid can be framed based on the utility and need of the customers in very efficient manner. On the basis of load priority and the comfort preferences of appliances, the sensing and controlling of grid takes place.

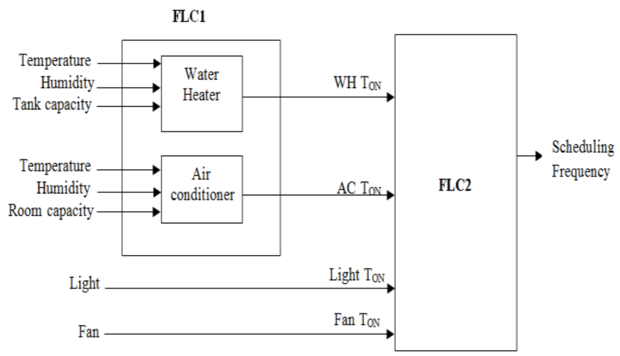

Fig.1 Two level FLC for Two Level Fuzzy based Appliance Scheduling Scheme (TLFASS)

The block diagram of the proposed Two Level Fuzzy logic based Appliance Scheduling Scheme (TFASS) is shown in fig 1. In this, fuzzy logic based appliance scheduling is adopted whenever the supply power is lesser than the total load demand. In such scenario, first level fuzzy is invoked to decide upon the operating duration of water heater and air conditioner based on the environmental factors such as temperature, humidity, size of tank and room etc. Followed by first level fuzzy, the scheduling frequency of the loads is predicted using second level fuzzy. The second level fuzzy considers the operating duration of Air Conditioner (AC), Water Heater (WH), light and fan to predict the frequency of scheduling. The fuzzy rules are formed based on the number of inputs. Mamdani based fuzzy system is simulated using Matlab. The defuzzification adopted in all the FLCs is 'centroid 'method. The flow chart of the proposal is depicted in fig.2 and fig 3.

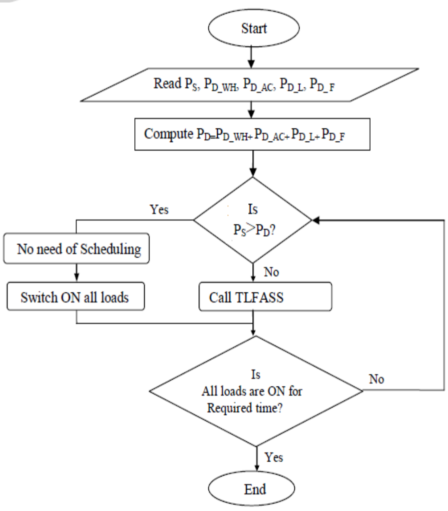

Fig.2 Flowchart of TLFASS

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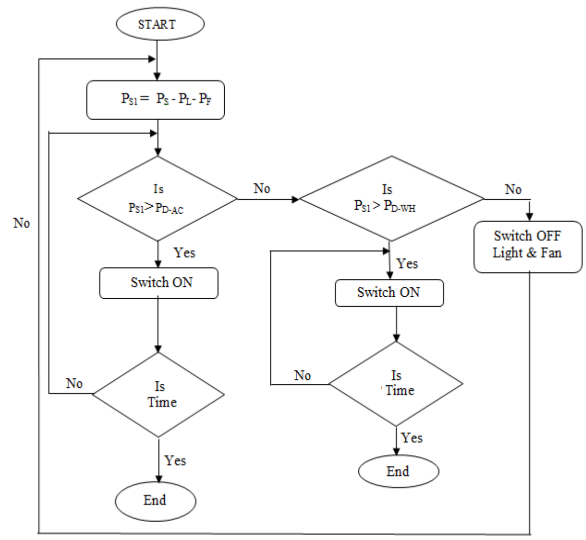

Fig.3 Appliance Scheduling Algorithm (TLFASS)

III. IMPLEMENTATION

Two level fuzzy based appliance scheduling scheme is implemented in MATLAB. The scheduling scheme is implemented in two level fuzzy to reduce the complexity of the system. Also, the accuracy in predicting the scheduling frequency is high in two level system since the environmental and other influencing factors are considered for water heater and air conditioner. The snapshot of the fuzzy system to decide the operating time of water heater is shown in Fig.3.

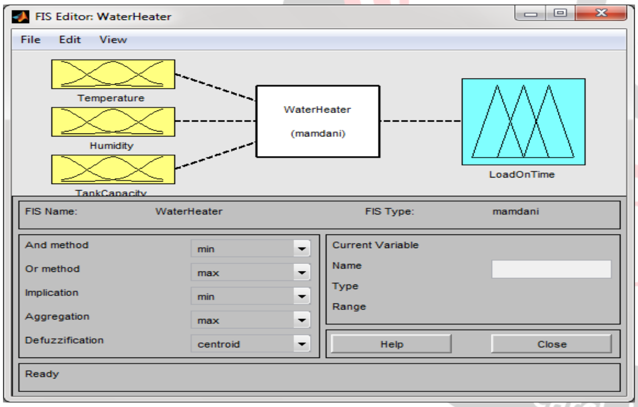

Fig.4 Fuzzy System for Water Heater

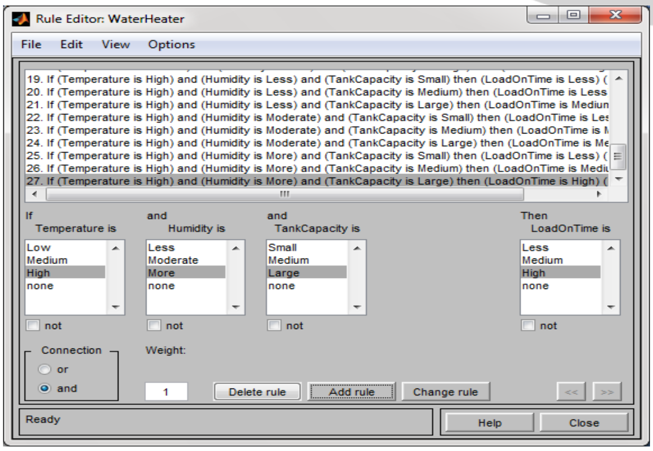

Fig.5 Snapshot of Fuzzy Rule Base

The membership functions along with their limits for both input and output parameters used in simulation are presented in Table1. The limits are based on real time scenarios. Based on the number of term sets for input parameters, 27 (3x3x3) rules are formed and the Fuzzy Rule Base (FRB) is illustrated in Table. The snapshot of implemented FRB is portrayed in Fig. 5.

Table1. Input Parameters along with their term sets and membership functions-Water Heater

Rule No.	Temperature	Relative Humidity	Tank capacity	ON Time (Load)
1	Low	Less	Small	Medium
2	Low	Less	Medium	High
3	Low	Less	Large	High
4	Low	Moderate	Small	Medium
5	Low	Moderate	Medium	High
6	Low	Moderate	Large	High
7	Low	More	Small	Medium
8	Low	More	Medium	High
9	Low	More	Large	High
10	Medium	Less	Small	Less
11	Medium	Less	Medium	Less
12	Medium	Less	Large	Medium
13	Medium	Moderate	Small	Less
14	Medium	Moderate	Medium	Medium
15	Medium	Moderate	Large	Medium
16	Medium	More	Small	Less
17	Medium	More	Medium	Medium
18	Medium	More	Large	High
19	High	Less	Small	Less
20	High	Less	Medium	Less
21	High	Less	Large	Medium
22	High	Moderate	Small	Less
23	High	Moderate	Medium	Medium
24	High	Moderate	Large	Medium
25	High	More	Small	Less
26	High	More	Medium	Medium
27	High	More	Large	High

Table2. FRB for Water Heater

Input Parameters	Term Sets	Membership functions	Limits
Temperature in °C (20°C -40°C)	Low	Trapezoidal	{-10;0;10;20}
	Medium	Triangular	{10;25;30}
	High	Trapezoidal	{25;30;35:40}
Relative Humidity in % (55%-80%)	Less	Trapezoidal	{-20;0;40;55}
	Moderate	Triangular	{50;60;65}
	More	Trapezoidal	{60;65;75;80}
Tank Capacity (40- 100 gallons)	Small	Trapezoidal	{-20;0;20;40}
	Medium	Triangular	{40;55;70}
	Large	Trapezoidal	{60;70;90;100}

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Output Parameters	Term Sets	Membership functions	Limits
Water Heater Operating Time (1-2 Hrs)	Less	Trapezoidal	{-0.5;0;0.5;1}
	Medium	Triangular	{0.75;1.25;1.5}
	High	Trapezoidal	{1.25;1.5;1.75:2}

To realize the impact of temperature on the operating time for water heater, the temperature is varied and the corresponding change in the operating time or Load ON time of water heater is observed and plotted in Fig.6.

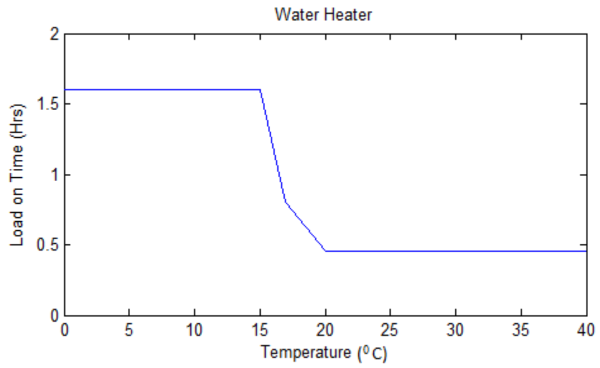

Fig.6 Temperature Vs. Operating Time (Water Heater)

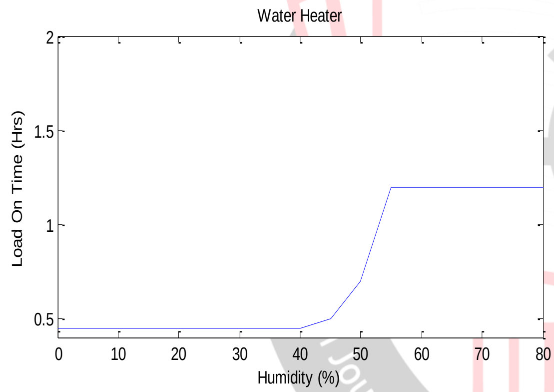

Fig.7 Humidity Vs Operating Time(Water Heater)

From Figure 6, it is observed that the operating time is high for temperature range less than room temperature and it is found to decrease when the temperature exceeds room temperature. Similarly, the operating time for relative humidity is observed and plotted in figure 7. The Fig. 7clearly illustrates that the operating time increases with increase in humidity. Other influencing factor namely the tank capacity is varied and the corresponding operating time is observed and portrayed in Figure 8. From fig.8. It is evident that the operating time increases with increase in tank capacity.

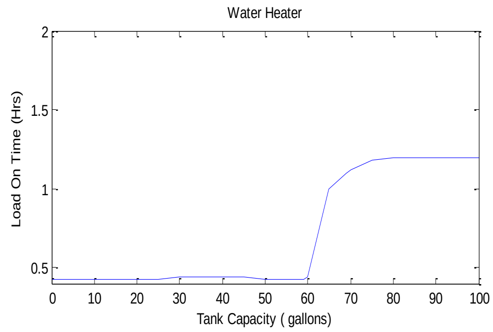

Fig. 8 Tank Capacity Vs Operating Time (Water Heater)

Further, to realize the impact of environmental and influencing factors on operating time of air conditioner, fuzzy logic is invoked and simulations are carried out with three input parameters namely temperature, relative humidity and room capacity. The snapshot of the fuzzy system for air conditioner is depicted in figure.9. The term sets along with their membership functions for both input and output parameters are shown in Table3. 27 rules (3x3x3) is framed for air conditioner is shown in table3.and the implemented FRB is portrayed in Fig.10.

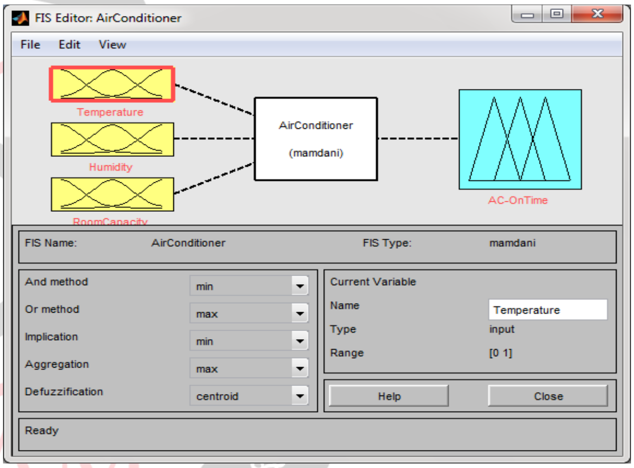

Fig. 9 Fuzzy system for Air Conditioner

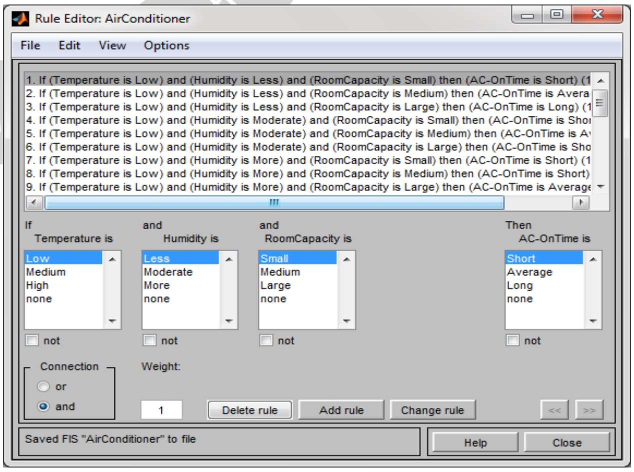

Fig.10 Fuzzy Rule Base (AC)

Input Parameters	Term Sets	Membership functions	Limits
Temperature in ◦C	Low	Trapezoidal	{-10;0;10;20}
	Medium	Triangular	{10;25;30}

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(20◦C -40◦C)	High	Trapezoidal	{25;30;35:40}
Relative Humidity in % (55%-80%)	Less	Trapezoidal	{-20;0;40;55}
	Moderate	Triangular	{50;60;65}
	More	Trapezoidal	{60;65;75;80}
Room Capacity (100sf- 350 sf)	Small	Trapezoidal	{-100;0;50;100}
	Medium	Triangular	{70;150;175}
	Large	Trapezoidal	{160;250;300;350}
Output Parameters	**Term Sets**	**Membership functions**	**Limits**
Air Conditioner (4-10 Hrs)	Short	Trapezoidal	{-2;0;3;4}
	Average	Triangular	{3;5;6.5}
	Long	Trapezoidal	{5.5;7;8;10}

Table 3. Input Parameters along with their term sets and membership functions-Air Conditioner

Rule No.	Temperature	Relative Humidity	Room Capacity	ON Time (Load)
1	Low	Less	Small	Short time
2	Low	Less	Medium	Average time
3	Low	Less	Large	Long time
4	Low	Moderate	Small	Short time
5	Low	Moderate	Medium	Average time
6	Low	Moderate	Large	Short time
7	Low	More	Small	Short time
8	Low	More	Medium	Short time
9	Low	More	Large	Average time
10	Medium	Less	Small	Long time
11	Medium	Less	Medium	Average time
12	Medium	Less	Large	Long time
13	Medium	Moderate	Small	Short time
14	Medium	Moderate	Medium	Average time
15	Medium	Moderate	Large	Long time
16	Medium	More	Small	Short time
17	Medium	More	Medium	Short time
18	Medium	More	Large	Average time
19	High	Less	Small	Average time
20	High	Less	Medium	Long time
21	High	Less	Large	Long time
22	High	Moderate	Small	Average time
23	High	Moderate	Medium	Average time
24	High	Moderate	Large	Long time
25	High	More	Small	Short time
26	High	More	Medium	Average time
27	High	More	Large	Long time

Table4. FRB for Air Conditioner

The fuzzy scheme is implemented and the results are portrayed in figs. 11,12 and 13 respectively.

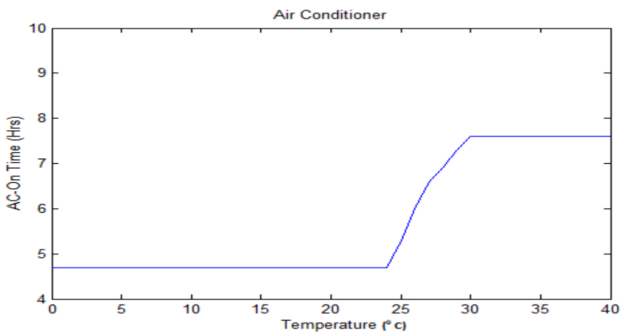

Fig. 11 Temperature Vs Operating Time (AC)

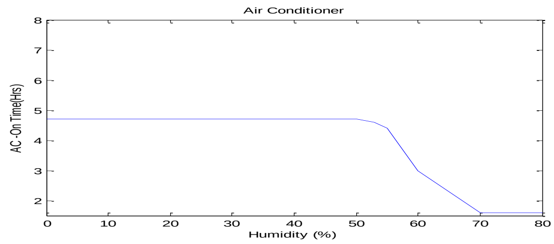

Fig.12 Humidity Vs Operating Time (AC)

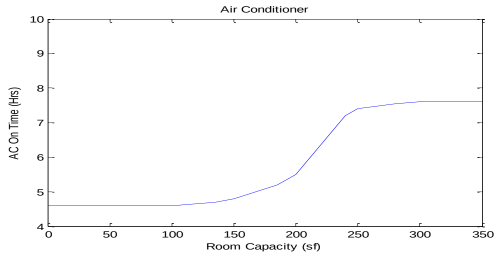

Fig.13 Room Capacity Vs Operating Time (AC)

The temperature is varied and its impact on the operating time of air conditioner is plotted in Fig.11. From Fig.11, it is revealed that the operating time increases with increase in temperature. Similarly, the impact of relative humidity on operating time is studied and depicted in fig.12. From fig.12, it is clear that operating time is found to decrease with increase in humidity. Further, the impact of room size on the operating time is read and portrayed in Fig.13. From Fig.13, it is evident that the operating time increase with increase in room capacity or size.

After obtaining the operating time of water heater and air conditioner, second level fuzzy is invoked. Along with the output of first level fuzzy i.e the operating time of water heater and air conditioner, the operating time of light and fan are considered as input to decide upon the frequency of scheduling. Here, the two level fuzzy is implemented to reduce complexity of the system. When the system is implemented in one level fuzzy then FRB should consist of 6561 (3x3x3x3x3x3x3x3) rules. Whereas here, the number of rules is 81 which is 81 times lesser.

The increased rules will eventually increase the time and space complexity thereby reducing the efficiency of the system. The snapshot of the second level fuzzy invoked is portrayed in Fig. 14. The input and output parameters along with their term sets, membership functions and their limits are presented in Table 5.

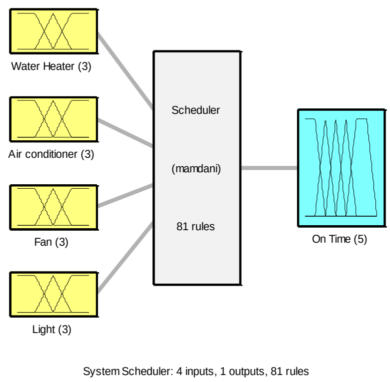

Fig. 14 Second level Fuzzy scheme to determine frequency of scheduling

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Table 5. Input and output Parameters along with term sets, membership functions and their limits-Second level Fuzzy scheme

Input Parameters	Term Sets	Membership functions	Limits (Time periods)
Water Heater (1-2 Hrs)	Less	Trapezoidal	{-0.5;0;0.5;1}
	Medium	Triangular	{0.75;1.25;1.5}
	High	Trapezoidal	{1.25;1.5;1.75:2}
Air Conditioner (4-10 Hrs)	Short	Trapezoidal	{-2;0;3;4}
	Average	Triangular	{3;5;6.5}
	Long	Trapezoidal	{5.5;7;8;10}
Fan (4-12 Hrs)	Less	Trapezoidal	{-4;0;3;4}
	Medium	Triangular	{3;5;8}
	High	Trapezoidal	{7;8;10;12}
Light (4-8 Hrs)	Minimum	Trapezoidal	{-4;0;3;4}
	Average	Triangular	{3;5;6}
	Maximum	Trapezoidal	{5.5;6;7;8}
Output Parameters	**Term Sets**	**Membership functions**	**Limits (Scheduling)**
On Time (Loads)	Very Less Frequent (VLF)	Trapezoidal	1.75 - 3
	Less Frequent (LF)	Triangular	1.25 - 2
	Little Less Frequent (LLF)	Triangular	0.75– 1
	More Frequent (MF)	Triangular	0.25- 1
	Little More Frequent (LMF)	Trapezoidal	0- 0.5

Table 6.FRB for second level fuzzy

Rule No.	Water Heater	Air conditioner	Fan	Light	Scheduling
1	Less	Short time	Less	Minimum	VLF
2	Less	Short time	Less	Average	VLF
3	Less	Short time	Less	Maximum	LF
4	Less	Short time	Medium	Minimum	VLF
5	Less	Short time	Medium	Average	LF
6	Less	Short time	Medium	Maximum	LF
7	Less	Short time	High	Minimum	LF
8	Less	Short time	High	Average	LF
9	Less	Short time	High	Maximum	F
10	Less	Averagetime	Less	Minimum	LF
11	Less	Average time	Less	Average	LF
12	Less	Average time	Less	Maximum	F
13	Less	Average time	Medium	Minimum	F
14	Less	Average time	Medium	Average	F
15	Less	Average time	Medium	Maximum	LF
16	Less	Average time	High	Minimum	LF
17	Less	Average time	High	Average	LF
18	Less	Average time	High	Maximum	MF
19	Less	Long time	Less	Minimum	LF
20	Less	Long time	Less	Average	LF
21	Less	Long time	Less	Maximum	F
22	Less	Long time	Medium	Minimum	F
23	Less	Long time	Medium	Average	F
24	Less	Long time	Medium	Maximum	MF
25	Less	Long time	High	Minimum	MF
26	Less	Long time	High	Average	MF
27	Less	Long time	High	Maximum	LMF
28	Medium	Short time	Less	Minimum	LF
29	Medium	Short time	Less	Average	LF
30	Medium	Short time	Less	Maximum	F
31	Medium	Short time	Medium	Minimum	LF
32	Medium	Short time	Medium	Average	LF
33	Medium	Short time	Medium	Maximum	F
34	Medium	Short time	High	Minimum	F
35	Medium	Short time	High	Average	F
36	Medium	Short time	High	Maximum	MF
37	Medium	Average time	Less	Minimum	MF
38	Medium	Average time	Less	Average	LF
39	Medium	Average time	Less	Maximum	LF
40	Medium	Average time	Medium	Minimum	LF
41	Medium	Average time	Medium	Average	F
42	Medium	Average time	Medium	Maximum	F
43	Medium	Average time	High	Minimum	LF
44	Medium	Average time	High	Average	F
45	Medium	Average time	High	Maximum	MF
46	Medium	Long time	Less	Minimum	LF
47	Medium	Long time	Less	Average	F
48	Medium	Long time	Less	Maximum	MF
49	Medium	Long time	Medium	Minimum	LF
50	Medium	Long time	Medium	Average	F
51	Medium	Long time	Medium	Maximum	MF
52	Medium	Long time	High	Minimum	MF
53	Medium	Long time	High	Average	MF
54	Medium	Long time	High	Maximum	LMF
55	High	Short time	Less	Minimum	LF
56	High	Short time	Less	Average	LF
57	High	Short time	Less	Maximum	F
58	High	Short time	Medium	Minimum	LF
59	High	Short time	Medium	Average	LF
60	High	Short time	Medium	Maximum	MF
61	High	Short time	High	Minimum	MF
62	High	Short time	High	Average	MF
63	High	Short time	High	Maximum	LMF
64	High	Average time	Less	Minimum	LF
65	High	Average time	Less	Average	LF
66	High	Average time	Less	Maximum	MF
67	High	Average time	Medium	Minimum	LF
68	High	Average time	Medium	Average	F
69	High	Average time	Medium	Maximum	MF
70	High	Average time	High	Minimum	MF
71	High	Average	High	Average	MF

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		time			
72	High	Average time	High	Maximum	LMF
73	High	Long time	Less	Minimum	F
74	High	Long time	Less	Average	MF
75	High	Long time	Less	Maximum	LMF
76	High	Long time	Medium	Minimum	MF
77	High	Long time	Medium	Average	MF
78	High	Long time	Medium	Maximum	LMF
79	High	Long time	High	Minimum	LMF
80	High	Long time	High	Average	LMF
81	High	Long time	High	Maximum	LMF

Second level fuzzy is also implemented in fuzzy. When second level fuzzy is invoked, it automatically invokes first level fuzzy and the output of first level fuzzy is loaded as input to second level fuzzy.The variation of scheduling frequency for different operating time of four appliances is shown in Figs. 15 and 16.

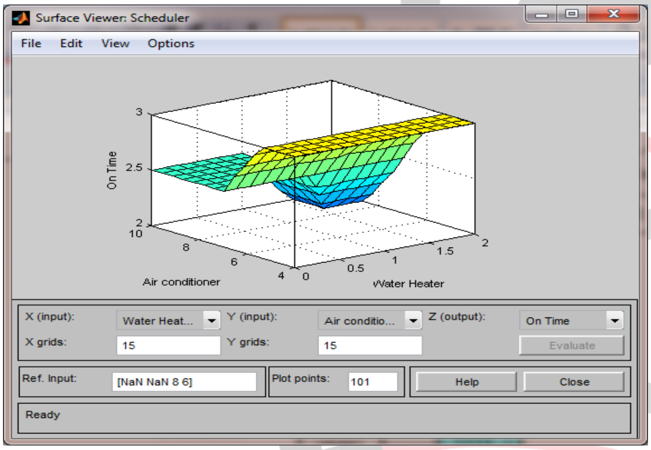

Fig.15 Operating Time Vs WH & AC

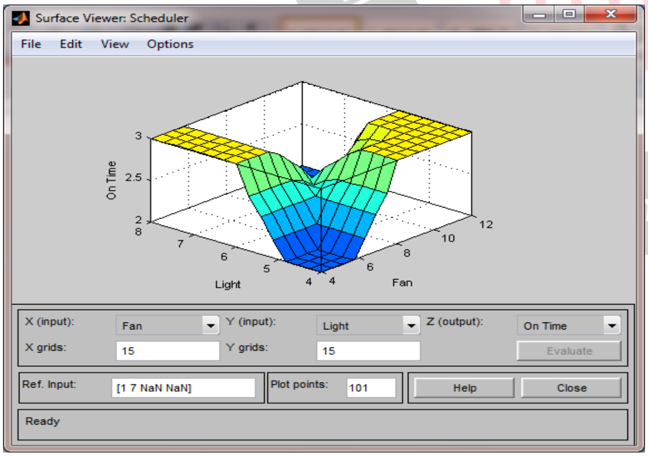

Fig.16 Operating Time Vs Fan &Light

From figs.15 and 16, it is evident that as operating time of water heater and Air Conditioner increases, the scheduling is very frequent and vice versa. Hence, it is concluded that two level fuzzy based appliance scheduling is found to exhibit more accuracy in scheduling.

IV. Conclusion

Scheduling of appliances is one of the demand response scheme to achieve peak shaving. In this home energy management system, two level fuzzy based appliance scheduling scheme is proposed. The environmental conditions and capacity are considered as input to first level fuzzy to predict the operating time of heavy loads namely water heater and Air conditioner. Then , based on these operating time and switching on duration of light and fan, the frequency at which scheduling should be carried out is predicted. The proposal is implemented in matlab. The proposed scheme exhibits efficient prediction of scheduling frequency.

References

[1] S. Maharjan, Q. Zhu, Y. Zhang, S. Gjessing, T. Basar, "Dependable demand response management in the smart grid: A Stackelberg game approach", IEEE Trans. Smart Grid, vol. 4, no. 1, pp. 120-132, Mar. 2013.

[2] L. Song, Y. Xiao, M. van der Schaar, "Demand side management in smart grids using a repeated game framework", IEEE J. Sel. Areas Commun., vol. 32, no. 7, pp. 1412-1424, Jul. 2014.

[3] T. Logenthiran, D. Srinivasan, T. Z. Shun, "Demand side management in smart grid using heuristic optimization", IEEE Trans. Smart Grid, vol. 3, no. 3, pp. 1244-1252, Sep. 2012.

[4] G. Stribac, Chin kimGan et alii, "Benefits of Advanced Smart Metering for Demand Response based Control of Distribution Networks", Centre for Sustainable Electricity and Distributed Generation Imperial College, London, April 2010.

[5] R. Deng, Z. Yang, J. Chen, N. R. Asr, M.-Y. Chow, "Residential energy consumption scheduling: A coupled-constraint game approach", IEEE Trans. Smart Grid, vol. 5, no. 3, pp. 1340-1350, May 2014.

[6] HainiQu, Ping Ling,Libo Wu, "Electricity Consumption Analysis and Applications Based on Smart Grid Big Data," 2015 IEEE 12th International Conference on Ubiquitous Intelligence and Computing.

[7] P. H. Shaikh, N. B. Mohd Nor, P. Nallagownden, I. Elamvazuthi, and T. Ibrahim, "A review on optimized control systems for buildings energy and comfort management of smart sustainable buildings", Renewable and Sustainable Energy Reviews, vol. 34, pp. 409-429, March 2014.

[8] Manias Pipattanasomporn, Murat kuzluandSaifurRahman, "An Algorithm for intelligent Home Energy Management and Demand Response

 DOI : 10.18231/2454-9150.2018.0748 © 2018, IJREAM All Rights Reserved.

Analysis, "IEEE transaction on Smart Grid, vol.3, no.4, pp2166-2173, Dec2012.

[9] MelikeErol- Kantarci and Hussein T. Mouftah, "Wireless Sensor Networks for Domestic Energy Management in Smart Grids" 25th Biennial symposium on communications, IEEE.

[10]M. A. A. Pedrasa, T. D. Spooner, I. F. MacGill, "Coordinated scheduling of residential distributed energy resources to optimize smart home energy services", IEEE Trans. Smart Grid, vol. 1, no. 2, pp. 134-143, Sep. 2010.

[11] Amir-HamedMohsenian-Rad & Alberto Leon –Garcia, "Optimal Residential Load Control with Price Prediction in Real –Time Electricity Pricing Environments," IEEE transactions on Smart Grid ,vol.1,no.2, Sep2010.

[12] Zhuangzhao, Woncheol lee, Yoanshin and kyung- Bin Song, "An Optimal Power Scheduling Method for Demand Response in Home Energy Management System," IEEE transactions on Smart Grid ,vol.4,no.3, Sep2013.

[13]Y. Liu et al., "Peak-to-average ratio constrained demand-side management with consumer's preference in residential smart grid", IEEE J. Sel. Topics Signal Process., vol. 8, no. 6, pp. 1084-1097, Dec. 2014.

[14] Hyung-Chul Jo, Sangwon Kim, Sung- Kwan Joo, " Smart Heating and Air Conditioning Scheduling method incorporating customer convenience for Home Energy Management System," " IEEE transaction on consumer electronics, vol.59,no.2,May2013.

[15] MelikeErol- Kantarci and Hussein T. Mouftah," Wireless Sensor Networks for smart Grid Applications,"

[16] M.ElBrak and M.Essaaidi ,"Wireless Sensor Network in Home Automation Network and Smart Grid," IEEE.

[17] J. Liu, W. Zhang, X. Chu, and Y. Liu, "Fuzzy Logic Controller for Energy Savings in a Smart LED Lighting System Considering Lighting Comfort and Daylight", Energy and Buildings, vol. 127, pp.95-104, September 2016.

[18] A. Preglej, J. Rehrl, D. Schwingshackl. I. Steiner, and M. Horn, "Energy-efficient fuzzy model-based multivariable predictive controlof a HVAC system", Energy and Buildings, vol. 82, pp. 520-533, August 2014.

[19]M. Killian, B. Mayer, and M. Kozek, "Cooperative fuzzy model predictive control for heating and coolings of buildings", Energy and Buildings, vol. 112, pp. 130-140, August 2014.

[20] P. H. Shaikh, N. B. MohdNor, P. Nallagownden, and I. Ellamvazuthi, "Building Energy Management through a Distributed Fuzzy Inference System", International Journal of Engineering and Technology (IJET), vol. 5, pp. 3236-3242, September 2013.

[21] P. Srikantha, C. Rosenberg, and S. Keshav, "An analysis of peak demand reductions due to elasticity of domestic appliances", In Proceedings of the Third International IEEE/ACM Conference on Future Energy Systems (e-Energy), Madrid, Spain, May 2012.

 DOI : 10.18231/2454-9150.2018.0748 © 2018, IJREAM All Rights Reserved.