International Journal of Engineering Research in Electrical and Electronic Engineering (IJEREEE) Vol 1, Issue 8, October 2015

Smart Home Energy Management System Using DSM Incorporating Load Forecasting

[1]Chithra. A. S, [2]Aju. S. Nair
[1]Student, [2]Professor
Department of Electrical and Electronic Engineering,
Amal Jyothi College of Engineering, Kanjirapally
[1]chithuampattu@gmail.com,[2]ajusnair@amaljyothi.ac.in

Abstract **– This paper aims at developing a Smart Home Energy Management System using Demand Side Management (DSM) incorporating load forecasting. Here energy management is achieved by the DSM techniques such as peak clipping and load shifting. Peak clipping is achieved by a microcontroller based circuit that uses zigbee for data transfer and load shifting is attained manually through a control panel with a keyboard and a display. The choice of which DSM technique is to be used could be selected by the consumer. Moreover, the load cutting is made either on priority basis or on consumption basis. Thus the system is made simple and user friendly and it is capable of providing proper energy management without cutting down the occupant comfort. The reliability of the system is improved by incorporating the short term load forecasting system. Efforts are also made in this paper to develop a cost effective system.**

Keywords **- Energy management system, Zigbee, Matlab, Proteus, Demand side management, load forecasting, fuzzy logic, Smart Home Energy Management System.**

I. INTRODUCTION

Buildings are one of the major energy consumers in the world. About 41% of the total energy consumption in the world is by buildings of which 22% is by residential buildings and the rest by the commercial buildings. Since the world is facing a problem of energy crisis, it necessary to adopt different technologies for getting considerable energy savings. As a result of this energy management in buildings has become a topic of increasing concern. The latest studies have revealed that the world energy consumption is increasing day by day. According to the latest accounts, the energy consumption is expected to increase by 56% between 2010 and 2040. i.e. from 524 quadrillion British Thermal Units(Btu) to 820 quadrillion Btu. The energy pricing is also increasing at an alarming rate due to the tremendous increase in energy demand. It is estimated that the energy price is increasing by 36% in every three years. These are the two main observations that lead to the development of different energy management systems in buildings.

The energy management systems (EMS) in buildings are mainly meant for realizing the aim of converting all the buildings into zero energy buildings (ZEBs). A zero energy building is the one with a very low use of energy with proper share of renewable energy. ZEBs are developed with the concept of minimizing energy wastage without cutting down the occupant comfort. With this background, this thesis aims at developing a microcontroller based smart home energy management system using the concept of demand side management and incorporating a fuzzy based load forecasting system. Efforts are being made to make the system cost effective as well as user friendly. Emphasis is obtaining considerable energy savings at a reduced cost without cutting down the occupant comfort. Awareness is also provided to the consumer about his daily usage of energy through a small load forecasting system. Thorough study about different types of building energy management systems are also made to state the advantages and the disadvantages of the proposed system. The work also aims at making a remark on the future scope for the further developments that could be brought to the proposed system.

II. LITERATURE REVIEW

John. C and Van Gorp in 2004 proposed an enterprise energy management system. These systems are one of the earliest methods of energy management with the prime aim to maximize the energy savings. These systems have shown that energy savings can be dramatically increased and maintained over time by adopting and implementing consistent energy management practices and recognized measurement and verification procedures. Organizations can apply EEM systems to gain a comprehensive understanding of current energy performance, plan and select cost-effective energy conservation measures, track performance of measures that have been implemented and verify the savings realized. It uses the concept of strategic energy management[1].

X. Ma, R. Cui, Yu Sun, C. Peng, Z. Wu developed another model. The realization that the buildings are important contributors to energy consumption accounting for around one-third of energy consumed in cities, where large public buildings are the dominant energy consumers and energy consumption might be significantly decreased through. It consists of a PC or an embedded computer system running a BEMS software designed to connected to distributed energy metering system, wireless sensor networks, even conventional building automation (BA) systems. The supervisory and management software consists of information inquiry, energy consumption metering, and energy efficiency analysis and decision support subsystems. The system was developed for energy consumption monitoring and management, with main installation target of air conditioning and lighting. Through the integrated monitoring of the environment variables and power consumption, the building energy-consuming characteristics and efficiency were analyzed by the proposed system. [2]

In October 2010 ***S. Narasimhan, D. McIntyre, F. Wolf, Yu Zhou and D. Weyer S. Bhunia*** proposed a supply - demand based energy management system. The idea that the energy harvesting from the environment can play an important role in reducing the dependency of an electronic system to primary energy sources led to the proposal of a supply-demand based scalable energy management system for improved energy utilization efficiency. It states that for reliable and efficient energy harvesting, it is important to manage, route and match the harvested energy with the demand of various energy sources. This assures best user experience.[3]

S.Praveen, K.Gopal and N.S. Vanitha in the later months of 2011 proposed a Microcontroller based power demand control and energy management system using zigbee. This energy management system is a microcontroller based energy management system that could be used for energy management in residential buildings. It consists of microcontrollers of which one is the central processor and the rest connected to the various devices in the home. This system uses the concept of load cutting when the total load in the building exceeds the predetermined threshold value with the help of relays. The data transmission between the microcontrollers takes place with the help of the Zigbee wireless module. The microprocessors connected to the devices continuously monitor the power and sends the information to the central processor through the zigbee module. The central processor sums these powers and if this becomes greater than the threshold value which is previously set, the system operates the relay and cut the device which is highly consuming.[4]

Patel Parth Manoj., Ashish Pravinchandra Shah proposed a Fuzzy logic methodology for short term load forecasting. For proper and profitable management in electrical utilities, short-term load forecasting has lot of importance. High forecasting accuracy as well as speed is the two most vital requirements of short-term load forecasting and it is of utmost importance to analyze the load characteristics and identify the main factors affecting the load. In this, the inputs to the fuzzy set based classifier i.e. hourly data of forecasted temperature and time are given to the fuzzy inference system through fuzzification block. The fuzzy inference block is the heart of the system as it processes the input data and gives output as the forecasted load. The inference system accomplishes the task of forecasting by the used of the fuzzy rule based prepared by the forecaster. The accuracy of the forecast depends on the experience of the forecaster, the rules prepared by the forecaster and the number of rules prepared. After, the inference system gives output; the defuzzification block converts the fuzzified output to the crisp output. In the proposed system time temperature and the previous day similar load was taken as the inputs and the forecasted load was the output. A rule base of 341 rules was created based on the studied load pattern of the building. The best part of this system was that that fuzzy logic approach is very easy for the forecaster to understand as it works on simple IF-THEN statements.[5]

III. PROPOSED MODEL

The paper aims at developing a microcontroller based smart home energy management system. The main advantage of using the microcontroller is its reduced cost and that it is easily programmable as per the requirement. In order to make it user friendly, a user interface is provided. Through this, the consumer could schedule the appliance operation as per the priority or load consumption and also can get information regarding the energy consumption through load forecasting. The simple schematic representation of the proposed system is as shown in figure given below.

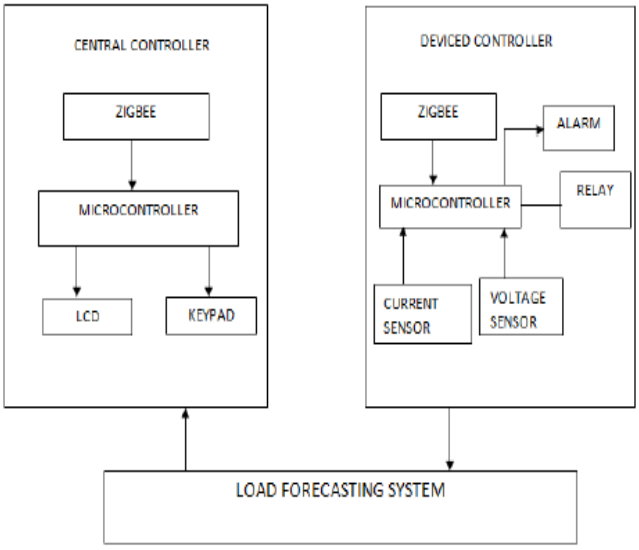

Fig.1 : Proposed model of the Smart Home Energy Management System

The device controller module is directly connected to the device. It consists of a Zigbee, a microcontroller, voltage and current sensors, alarm and a relay. The central controller consists of a Zigbee module, a microcontroller unit, an LCD and a keypad. The two sensors i.e. the current and the voltage sensors measure the current and voltage from the respective device and transfer this information to the microcontroller. From this information, the microcontroller calculates the power consumed by the device and transfers this data to the central controller via Zigbee. The central microcontroller receives this data through the Zigbee module. Similarly the central module receives information from the other devices as well. The microcontroller unit in the central controller then sums these powers and check whether it exceeds the threshold value which is already set as per the load pattern of the consumer. If it does not exceed the threshold value then no action will occur and the central module will display the current power consumption and its corresponding cost. If the value exceeds the threshold value then there can be three modes of operation which could be selected by the customer himself. The keypad serves this function. In the first mode, the microcontroller compares the power consumption of each device and then cuts down the load which consumes more power. Then it again checks the total power. If it again exceeds the threshold value, then it cuts down the next highly consuming load and so on. This process will continue till the load falls within the limit. At that condition the system resets and restores to its normal operation. The second mode of operation arises when the highly consuming load becomes an essential load. In such a case cutting down such a load creates discomfort to the occupants. In this case, the operation could be set on priority basis. Then the system cuts down the load with the least priority and checks whether the total load falls within the desired limit. If not, then the next least priority load will be cut down and so on. When the desired limit could not be attained in any case, that means when all the loads are essential, then the entire operation could be cancelled. For this purpose a reset button is provided so that the system resets and reverts back to its normal operation. For the ease of the consumers to identify the highly consuming load or the load which is to be cut down, an alarm and a signal LED is provided which rings and blinks at the time of energy management operation. An additional feature called a load forecasting system is introduced in the system in order to increase its reliability. The hardware model of the system is as shown in figure 2

IV. LOAD FORECASTING

The main aim behind the inclusion of load forecasting in this system is to increase its reliability and flexibility. This makes the user aware of the current energy

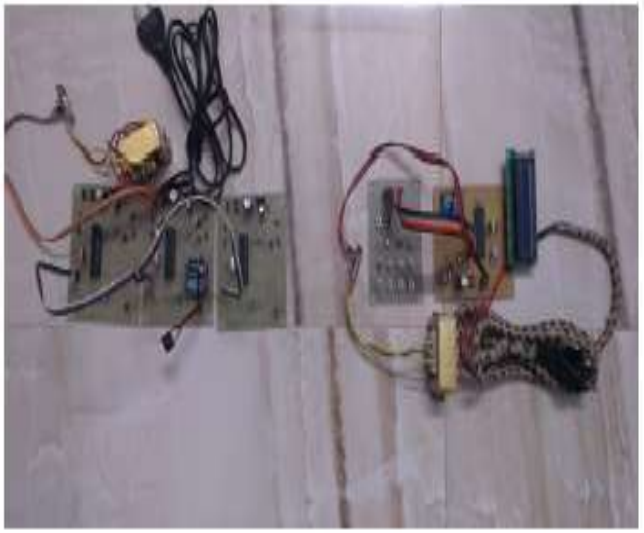

Fig.2 : Hardware realization of the proposed system

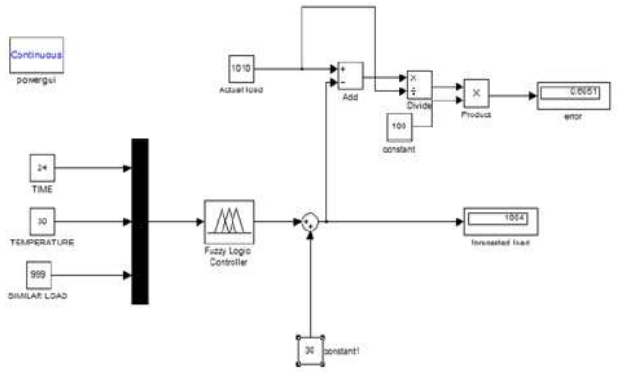

Fig.3: Simulation of the load forecasting system

consumption and allows him to plan his daily energy usage in such a manner as to attain considerable energy savings. Here short term load forecasting is done. The fuzzy logic methodology was adopted for simulating the load forecasting model using the Matlab simulink. For this purpose, the load pattern of the selected consumer is studied and recorded for a period of one month. This helps to find the factors that affect the load pattern of the house which in turn helps in creating the fuzzy set of rules. It has been found that the important factors that affect the load use pattern of the building are the time, temperature and the previous day similar load. These three factors were taken as the inputs and the forecasted load was taken as the output. The three inputs are divided into different number of member functions and then the fuzzy rule base is created based on the load pattern of the consumer. The simulation is done in simulink.

TABLE 1: Simulation results of load forecasting

Sl.No	Time	Temperature	Similar Load(W)	Forecasted Load(W)	Actual Load(W)	% Error
1	1	32	1226	1234	1272	2.98
2	4	27	960	968.4	976	-1.268
3	8	30	870	1416	1396	-1.458
4	12	32	300	1663	1660	-0.1529
5	16	32	484	674	680	0.8888
6	20	28	324	674	680	0.8862
7	23	30	999	1020	1010	-0.9638

The error is also calculated. The output is then taken out through the serial port and is displayed in an LCD display periodically. The results obtained from the simulation are as given in the following table 1. Then these two systems – the load forecasting system and the energy management system are integrated to obtain the proposed system. This system is also cost effective since the total cost of the system for a normal household falls within INR 10000. The system has a very small payback period. Hence the savings achieved will be more.

V. CONCLUSION

From the results obtained it could be concluded that the system with the concept of Demand Side Management exhibits improved performance when compared to the conventional Energy Management Systems. It proves to be more user friendly as the consumer comfort is not disturbed with its operation. Thus it is a reliable and simple system. Even common people will be able to operate it for proper energy management. The main advantage of this system is that it need not be set for all the appliances. We can connect the system to the highly consuming devices so that considerable energy savings could be attained with the net effect of reducing the electricity bills. Moreover, the system is not that much expensive. Thus it is a cost effective system. Complex algorithms are also not involved in the system. This system is also flexible as its operation is scheduled based on the load usage pattern of the customers.
In case of the load forecasting system, it makes the people aware of their energy consumption and will help them to plan their daily load usage. Short term load forecasting system shows improved performance with the inclusion of outage factor. Moreover its precision also improved with the increase in the member functions that inturn resulted in increase in the number of rules in the rule-base of the system. When the outage was not considered, there has been a great variation in the error percentage so that a tolerance range cannot be stated for the given system. But now, when the outages were considered, the error percentage falls within the tolerance range of 3%. That means the error is decreased considerably. This means an increase in the reliability of the system.

The main disadvantage of the system is the requirement of the study of load use pattern of the consumer. It is a tedious task as it involves monitoring of the hourly load usage pattern of the consumer for a period of atleast one month. Consumer awareness is also necessary for proper operation of the system to achieve the desired benefits. For practical implementation of this system, continuous online monitoring of load, time and temperature is to be used. This requires additional components like sensors, timers etc which adds to the cost of the system. Another main drawback is that it will be difficult to present accurate load forecast when there is a wide variation in the load usage by the consumer. There is a greater chance for the damage of the components since they are minute

electronic components. However, within the limits of the thesis schedule, the developed system could be a new SHEMS in the path of future development in the said field.

FUTURE SCOPE

The proposed system could be a more efficient and popular domestic home energy management system in future. More add on features could be incorporated into this system as it is flexible. Indoor environment of the home could be improved by including the light control, temperature control and humidity control system. Thus the design could be improved to increase the thermal comfort inside the building along with energy management which leads to the concept of Zero Energy Building (ZEB). Harmonic analysis could also be incorporated into the system for better performance. SHEMS along with green concepts will prove to be the most promising building energy management technology of future.

REFERENCES

[1] J.C. Van Gorp, *Maximizing Energy Savings with Enterprise Energy Management Systems*, Industrial and Institutional Power Measurement Technical Paper Number 320,2004

[2] X. Ma, Ran Cui, Yu Sun, C. Peng, Zhishen Wu. *Supervisory and Energy Management System for Large Public Buildings*, Proceedings of International Conference on Mechatronics and Automation, pp. 928-933,August 4-7, 2010

[3] S. N. D. McIntyre, F. Wolf, Yu Zhou, D. Weyer, S. Bhunia, *A Supply-Demand Model Based Scalable Energy Management System for Improved Energy Utilization Efficiency*, Proceedings of International Conference on Renewable Energy, pp. 978-986, October 2010

[4] S.Praveen, K.Gopal and N.Suthanthira Vanitha, *Microcontroller Based Power Demand Control and Energy Management System Using Zigbee*, Elixir International Journal, 38(3), 4038-4040, 2011

[5] P. P. Manoj, A. P. Shah, Fuzzy logic methodology for short term load forecasting, *International Journal of Research in Engineering and Technology*, 3(4). Pp.322 328, April 2014

[6] B. Becker, A. Kellerer, H. Schmek., *User Interaction interface of Energy Management in Smart Homes*, 2nd International Conference on Innovative Smart Grid Technologies Europe (ISGT Europe), Berlin, , no.978,pp.1-8, 2011

[7] S.Praveen, K.Gopal and N.Suthanthira Vanitha, *Microcontroller Based Power Demand Control and Energy Management System Using Zigbee*, Elixir International Journal, 38(3), 4038-4040, 2011

[8] J. A. O. Lima, A. F. Martins, C. Lima, V. D. Gomes, J. M. Pina., *Towards an Energy Model For Supporting the Real-time Energy Management* , IEEE 16th International Conference on Intelligent Engineering Systems, no.12, pp.203-208, June 13-15, 2012