International Journal of Computing and Digital Systems
ISSN (2210-142X)
Int. J. Com. Dig. Sys. 8, No.2 (Mar-2019)
http://dx.doi.org/10.12785/ijcds/080207

Energy Saving in Distribution System using Internet of Things in Smart Grid Environment

Aadesh Kumar Arya[1], Saurabh Chanana[2] and Ashwani Kumar[2]

[1] Department of Electrical Engineering, College of Engineering Roorkee, Roorkee, India
[2] Department of Electrical Engineering, National Institute of Technology, Kurukshetra, India

Received 6 Dec. 2018, Revised 12 Jan. 2019, Accepted 18 Feb. 2019, Published 1 Mar. 2019

Abstract: An increase in energy consumption of home appliances is a growing problem in distribution system. The Demand Response (DR) strategy for reducing the energy usage is the key for any energy management system (EMS). In order to minimize the electricity consumption in domestic sector, the smart energy controller (SEC) with Internet of Things (IoT) is essential. In this paper, the smart energy controller is proposed for residential air conditioner (RAC) to save the energy and energy cost using new algorithm based on DR. Hardware prototype of SEC and software is designed to demonstrate the proposed the energy management system (EMS) for control the thermostat of RAC. The proposed DR algorithm is applied under three strategies in which the first strategy considers operation during one day of week from 12 pm to 12 am and the second strategy considers controlling of thermostat by sensing inside room temperature during 12 pm to 12 am of the day and third strategy considers operation of RAC by real time price (RTP) with several cases. The Experimental results of the proposed SEC are compared with each other strategy of EMS. The third strategy provides better results in terms of energy consumption and electricity cost.

Keywords: Energy Management System, Energy Consumption, Electricity Cost, Residential Air Conditioner, Internet of Things

1. Introduction

The Electricity is a unique product which plays an important role in the development of any country but it cannot be stored in large quantities economically [1]. With the rapid development in technologies of home appliances and other industrial devices, the usage of electrical energy is increasing day by day. Consequently, the customer has to pay more electricity cost for enhancement of living standard. Nearly about 30% of total electricity is consumed by air conditioners and electric water heaters are the major causes of high cost burden on consumers [2]. In order to minimize the electricity consumption and price, the demand response and dynamic pricing scheme can be implemented under Smart Grid environment. The Smart Grid technology involve various phenomenon viz. demand side management, demand response, smart meter, charging station for electrical vehicle, automation, smart home appliances. The smart grid can be seen as the future electricity grid where information and communication technologies (ICT) are added to the existing network structure. The Smart Grid are application of advanced technologies of electrical engineering, communications engineering and software engineering, to real time monitoring and controls the energy consumption at the level of neighborhood and each home operators to monitor [3, 4]. With the development of smart grid, the consumers can be operate appliances and reduce electricity costs efficiently and wisely [5]. Moreover, the home energy management (HEM) and Home area network (HAN) is an integral part of the smart grid. Therefore, HEM is one of the most important technical innovations to increase energy efficiency and save electricity.

In recent years, many researchers have published survey on impact of RAC on indoor thermal environment and household energy consumption. RAC systems are one of the familiar devices currently used in home appliances [6]. The RACs have become an integral part of nearly all household, offices, commercial buildings and facilities. As a result, RAC consumes the highest percentage of total energy consumption [7]. This problem arising due to higher use of RACs during summer season can be overcome by energy management at the distribution side. In recent years, the energy management is an essential technology of the smart grid which is called Home Energy Management System. In [8], authors proposed a smart home energy management (HEM) system to manage and monitoring of household energy. This system has developed on top of the Hydra framework. The hydra's architecture has more advantages for smooth and flexible operation of home appliances. In [9], authors demonstrated bluetooth low energy based approach to manage the energy in homes and it shows that this approach is socio-economically beneficial for consumers and utilities. The Authors

E-mail: adeshkumararya@coer.ac.in, saurabh@nitkkr.ac.in, ashwa_ks@yahoo.co.in

developed a prototype model of smart home in which two Arduino boards and various sensors viz. lux sensor, a temperature & humidity sensor and a PIR motion sensor [10]. They also simulated the model of smart home with Cooja simulator.

Along with the rapid development of modern information technology, IoT attracts industry attention as a new technology. IoT is a network that provides value-added services by connecting a considerable number of objects, sensors, or peripheral devices via the ICT infrastructure [11]. The IoT sensor plays an important role in the management of smart home energy. On the basis of IoT current development trend, energy management is the application of IoT technology [12]. Researchers [13] designed an energy controller with conservation voltage reduction to manage the energy consumption of home appliances. The Authors [14] designed an IoT based smart controller for air conditioner to save electricity consumption. They also develop a smart meter for controlling of compressor of RAC. In the environment of IoT, the energy data are sent to a cloud server in real time and smart meter control the cooling and heating operations via internet.

Moreover, the DR strategy can be introduced into the smart grid infrastructure using IoT to actively engage consumers in distribution systems. Though, DR has the various concept of electricity tariff viz. real time pricing (RTP), time-of-use (TOU) and day ahead pricing [15]. In [16], authors described that if electricity consumption is increased than demand response is required for consumers to change the energy consumption pattern with varying the dynamic prices. Basically, DR in Smart Grid is very important to encourage consumers to reduce demand during peak hours. So the primary purpose of DR is to reduce electricity bill and maximize the satisfaction of consumers with the information of RTP and managing of the appliances. Consequently, RTP have the impact on DR by various ways, (1) the consumers can be minimize the energy consumption during high RTP (2) load requirement can be reduced during peak hours by scheduling of home appliances (3) load demand can be increased during off peak periods. By these DR measures the electricity bill and power consumption can be managing [17]. In the recent times, the advanced technology is being used to control the smart appliances according to DR. This advanced technology can be implemented as smart energy controller with HAN, IoT, cloud computing and advanced version of microcontrollers.

However, HAN is an integral part of Smart Grid and helps provide a better solution to reduce electrical energy consumption. The HAN is developed through communication and information technology which is used to provide the collected information of energy consumption by all devices. HAN technology is also used for real time monitoring and remote control of smart home appliances by personal computer/ android phone [18].

In this paper a novel energy management scheme for RAC having a smart energy controller using IoT and real time pricing strategy has been proposed. This controller is implemented in hardware using Arduino Node MCU ESP8266. The proposed energy management strategy with SEC is compare with conventional methods and energy saving consumers is demonstrated.

Section 2 describes the complete system architecture for energy management system. Section 3 gives the details of problem statement. Section 4 and 5 give the IoT base system design and proposed algorithm. This hardware experimental setup is described in section 6. In section 7 the outcome of present research is discussed. In section 8 the conclusion of the study is presented.

2. System Architecture for Energy Management System

The architecture of the proposed system is shown in block diagram which illustrate in Fig.1. Wi-Fi module is embedded with the Arduino 'Node MCU'. Arduino is an open source platform to build electrical and electronic projects. It consists of a programmable circuit board and software or IDE part running on the computer used to write the dynamic programming and upload to the computer. The proposed system consists of smart energy controller (SEC), a local area network (LAN), Web server, MySQL software and IoT. The home appliance, RAC is connected to SEC and current transformer and potential transformer are used to measure the current and voltage across load. The RAC controlled by SEC is working by DR algorithm. The Wi-Fi device is used to send and receive the signal through a local area network (LAN).

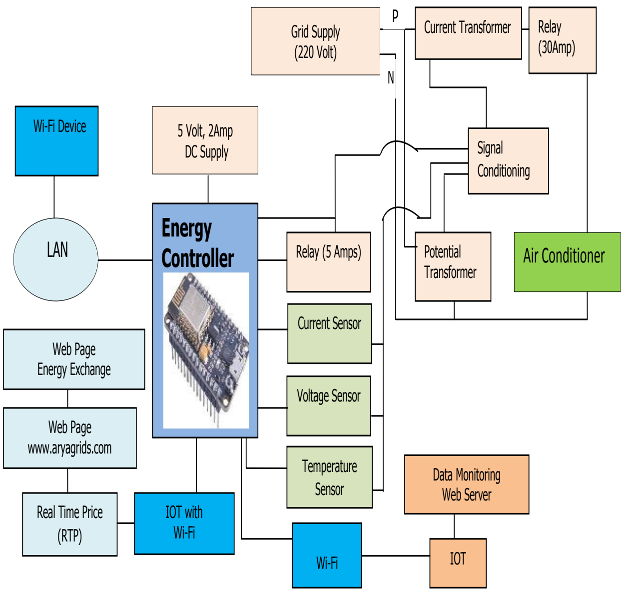

Figure. 1 Depicts the System Architecture for Prototype Model

The LAN is used for communicating the data to server with link or wireless. The appliances communicate to cloud server through IoT which establishes the connection with the internet and measure the energy consumption by RAC and it is displayed on cloud server.

In this system, the cloud server, Thingspeak platform is used for real time monitoring of performance of SEC. The measurable quantities current, voltage, power and energy published and displayed on the Thingspeak platform. Thingspeak is an open source web application of IoT. This server receives and sends the data through API with HTTP and LAN over Internet. This application is used to transmit the sensor reading to cloud server. Thingspeak is integrated with MATLAB software. Through this server the data can be analyzed and visualized by MATLAB This server uses channels to store the received data from controllers. However, Thingspeak server is not capable of saving more than 100 entries of data because new data overwrite to the old data.

3. PROBLEM STATEMENT

In terms of controlling the smart home appliances, several algorithms and techniques have been developed. Several conventional controllers were utilized in air conditioners to meet the thermal demands for energy saving. In fact, the on/off controllers for thermostat of air conditioner used in practice cannot cope with direct changes in thermal requirements directly related to human comfort and energy efficiency. These conventional controllers are not appropriate to sensitive and immediate control corresponding to advanced technologies of communication and IoT.

Consequently, the smart energy controller is designed for residential air conditioner to save the electrical energy and minimize the cost of electricity. The objective of proposed research is to save the electrical energy and minimize cost of electricity to consumers using DR algorithm. The two strategies for DR algorithm are based on real time price (RTP) and room temperature sensing mode. The RTP is varied at 15 minute interval during 24 Hours in wholesale electricity market. In this paper two DR algorithm are proposed, the compressor of RAC should be operate by sensing of inside room temperature and sensing of RTP (i) Room temperature $\geq 24^{o}$ C, the RAC is ON otherwise OFF (ii) Thermostat of RAC is varies with respect to RTP. Here we consider five range of RTP. However, in these three algorithms, the current, voltage, power and consumption of energy is measured through energy controller and IoT. In this paper, the sampling time for energy and power is taken as 1 min, which is relatively very short.

Strategy 1: Normal Mode

In this algorithm, the set point of RAC thermostat $T_{st}(t)$ is fixed by user throughout the day

Objective Function

$$F_1 = Obtain \begin{cases} Energy\ Consumption \\ Cost\ of\ Electricity \end{cases}$$

Constraint

$$T_{st}(t) = User\ Defined \quad (1)$$

Strategy 2: Sensing Inside Room Temperature

In this strategy, the RAC is on/off by sensing the inside room temperature. If inside room temperature $T_{in}(t) \leq 24^{o}\mathrm{C}$, the thermostat will be on otherwise $T_{in}(t) > 24^{o}\mathrm{C}$ RAC is off.

Objective Function

$$F_2 = Min \begin{cases} Energy\ Consumption \\ Cost\ of\ Electricity \end{cases}$$

Constraint

$$T_{in}(t) = 24^{o}\mathrm{C} \quad (2)$$

Strategy 3: Payload Mode

This strategy is based on DR algorithm, RTP. In this algorithm, the set point of RAC thermostat $T_{st}(t)$ is varies according to real time price (RTP). The node MCU (ESP8266) is the center processing unit of the proposed IoT based SEC system which is used for communication between the RAC and gateway web server to display and monitor the parameters at the web cloud server (Thingspeak). There are two main parts of proposed model, the first one is the DR algorithm with embedded ESP8266 module and the second one is the IoT for energy management system. The architecture of our proposed digital meter with Wi-Fi module is shown in Fig. 6. The Fig. 7 shows the real time prototype model for smart energy controller with RAC.

The thermostat will be set at lower temperature for low RTP and RTP is high than the thermostat will be set at higher temperature. In this algorithm five cases are considered for RTP and setting temperature of RAC.

Objective Function

$$F_3 = Min \begin{cases} Energy\ Consumption \\ Cost\ of\ Electricity \end{cases}$$

Constraint

$$n_{min} \leq n(t) < n_{max} = T_{st}(t) \quad (3)$$

According to RTP range, $T_{st}(t)$as given in table I

Table I

$n_{min} \leq n(t) \leq n_{max}$	$T_{st}(t)$
$2.0 \leq n(t) < 2.7$	17° C
$2.7 \leq n(t) < 3.5$	20° C
$3.5 \leq n(t) < 4.2$	22° C
$5.0 \leq n(t) < 5.7$	24° C
$5.7 \leq n(t) < 6.7$	27° C

Where

t = Time slot, t = (1, 2, 3……………. T)
T = Total no of time slots
$n(t)$ = Real Time Price in slot t (Rs. /kWh)*
n_{min} = Minimum Real Time Price
n_{max} = Maximum Real Time Price
$T_{in}(t)$ = Inside Room Temperature
$T_{st}(t)$ = Set point of RAC Thermostat
*Current conversion rate 1 US$ = 70.24 INR.

4. IOT BASED SYSTEM DESIGN

In fact, demand side management and DR are responsible for the reliable and smooth operation of the network in the smart grid. The various strategies of DSM and DR manage and controls the energy consumption by scheduler embedded in the smart energy controller [19]. In proposed model, the microcontroller Node MCU ESP8266 is used to control the RAC according to communication provided by home owner. Besides, the digital temperature sensor, current transformer and voltage transformer are embedded with smart energy controller to measure the temperature of atmosphere, current, voltage across load 'RAC' respectively.

All these data is monitored through IoT on web server. The output of the voltage transformer and current transformer is clamped by the level change circuit to make the signal as high as 3.3 volts because this is the input voltage range of the analog-to-digital converter (ADC) in Node MCU ESP8266 controller. The CT and PT are programmed to measure current and voltage respectively. The current signal is responsible for the voltage drop across the resistor, so the voltage signal can be supplied to the controller. After calibration, these data display on the cloud server through Thingspeak. The relay is working as switching circuit which connected in series with the RAC as shown in Fig. 1. The controller signal is supplied to the relay control circuit. The signal from the controller is provide to the driver circuit of the relay and RAC is controlled. The digital temperature sensor (DS18B20) is connected to board of Node MCU ESP8266 at GPIO 2 corresponding to Pin D4, Vcc and ground. Through IP 184.106.153.149 or api.thingspeak.com temperature data at interval of 5 second can be send to an online web server. The applied controller, Node MCU (ESP8266), receives the data and measures the consumed energy by RAC. The controller sends all data periodically at interval of 5 Sec through IoT. The Indian Energy Exchange (IEX) is a power trading exchange regulated by the Central Electricity Regulatory Commission (CERC) which provides the day ahead market (DAM) price or daily electricity price or real time price (RTP) is implemented through the web portal at 15 min interval for 24 hrs. For the proposed research the DAM price is taken and provided to controller through web portal (www.aryagrids.com) for the operation of RAC in energy saving mode.

The different types of controllers are used by engineers and researchers viz. PIC controller, Raspberry pi, Arduino. The Arduino is available with and without Wi-Fi module. The Node MCU ESP8266 is a type of Arduino with Wi-Fi module. The IOT devices, Arduino, Raspberry Pi and Node MCU ESP8266 are suitable controllers for power management in home automation applications. However we have preferred to use Node MCU ESP8266 because all arduino except MCU microcontroller don't have integrated Wi-Fi chip. An extra Wi-Fi device is required to connect these microcontrollers with internet. A low cost Wi-Fi chip is incorporating with ESP8266 board. The ADC channel is used to read the analog values The Raspberry Pi3 is not having any ADC channel. Therefore it is not suitable for this application. The arduino contains 8 (A0-A7) ADC channels .This major limitation of Node MCU ESP8266 is that having only single (A0) ADC channel.

Another limitation of proposed system is that the storage capacity of data is limited because of the cloud server is to be operated such that existing data is overwritten by new data. To overcome this problem, MySQL software is used for the database management. The MySQL software provides the data in tabular form. This software is used to collect the data from cloud and transfer to web portal after that this data can be saved. We can easily search data with the help of query language.

5. IOT BASED SEC ALGORITHM

The SEC algorithm provides load shifting considering customer comfort and lifestyle with load shedding during demand response events. The SEC algorithms provide the information to the home appliance and RAC algorithm. The objectives of SEC algorithm are to minimize energy drawn from grid and minimize the electricity bill. The SEC measures the power consumption and calculates the energy consumed by RAC during real time. The Fig. 2 illustrates the algorithm for displaying the data on Web Server. This flow chart shows that Node MCU ESP8266 fetch the sensors data and send to cloud server (Thing speak) through IoT.

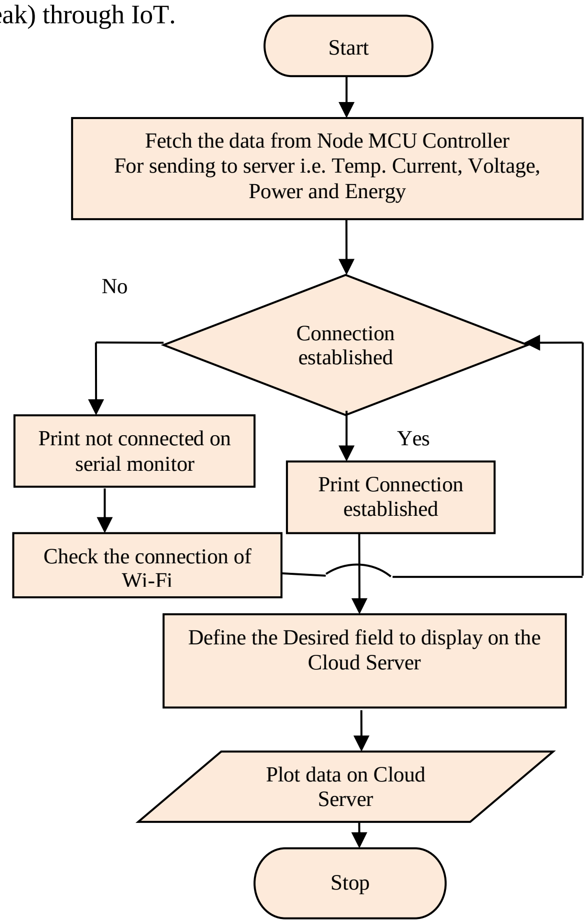

Figure. 2 Flow chart for displaying the data on Web Server

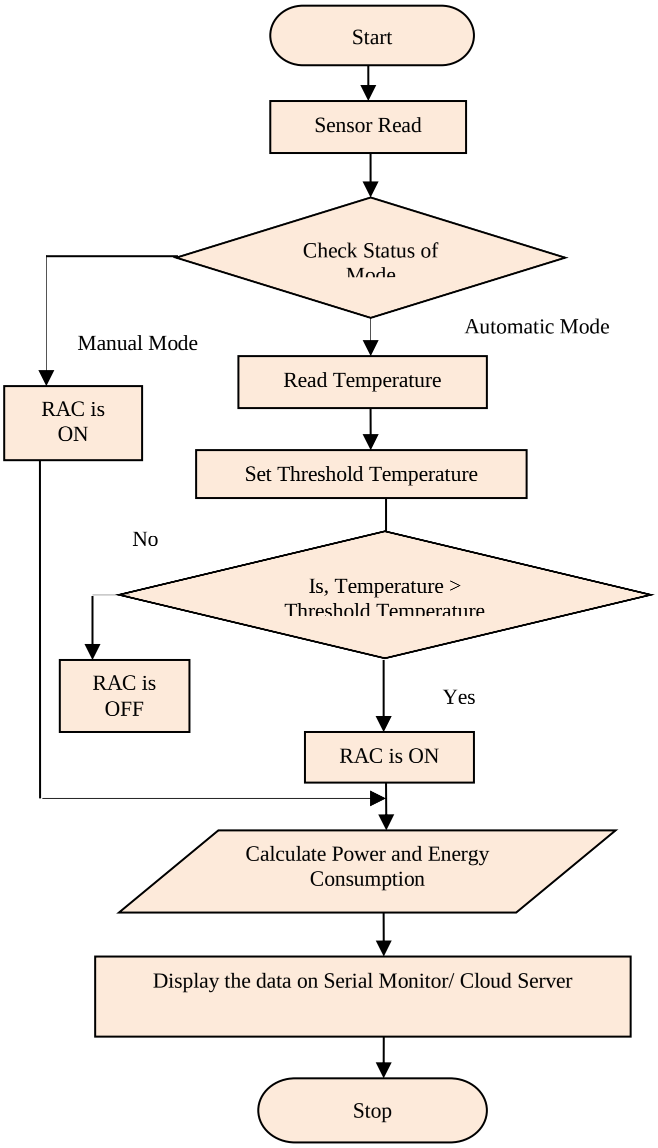

Figure.3 Flow chart for Automatic RAC control

The Fig. 3 illustrates the algorithms for controlling the RAC by inside sensing room temperature and this flow chart represent two mode (i) Normal mode (ii) Automatic mode based on sensing inside room temperature. In normal mode the sensors read the data and controller calculates the energy and power consumption by RAC and displays all data on serial monitor/ cloud server. In automatic mode the threshold temperature ($24^0\ C$) is set and ON the RAC than sensors read the data and controller compared the inside room temperature with threshold temperature. If room temperature is lower than the threshold temperature the RAC is OFF otherwise ON and as previously displays all data on serial monitor/ cloud server. Fig.4 illustrates the flow chart for controlling the RAC by thermostat temperature with RTP. The smart energy controller operates to the RAC with desired temperature according the RTP and displays all data on serial monitor/ cloud server.

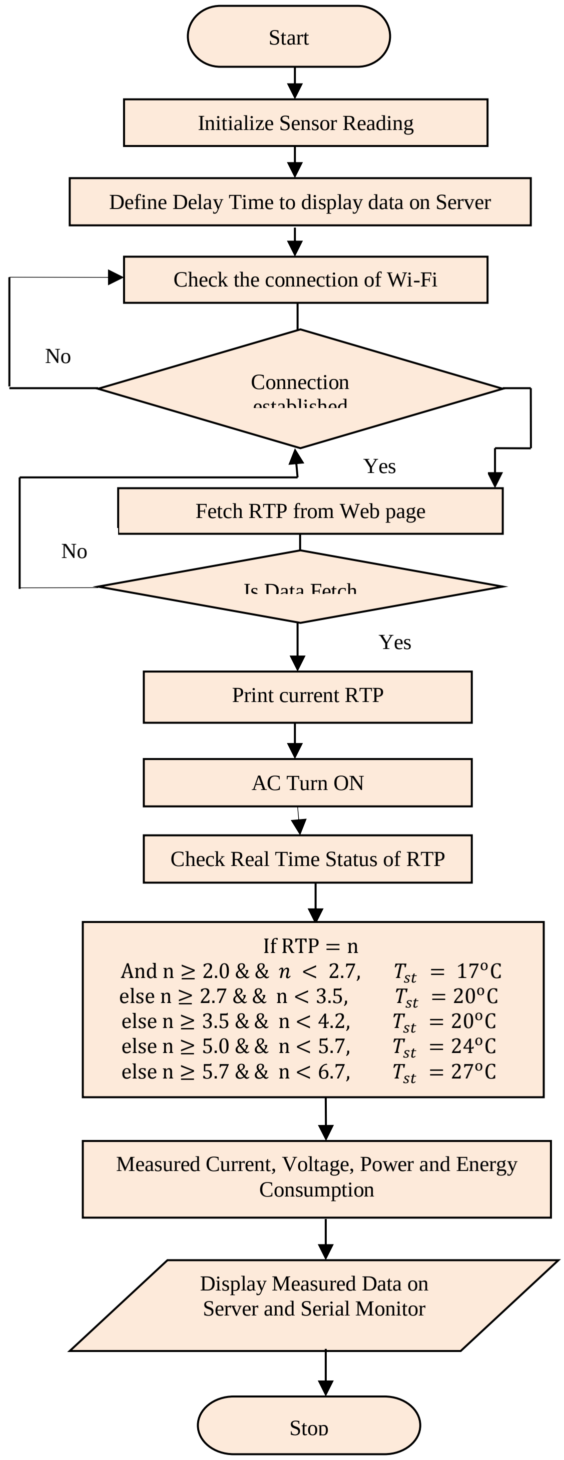

Figure .4 Flow chart for RAC Control through RTP

6. HARDWARE SETUP

The node MCU ESP8266 is the control processing unit of the proposed IoT based SEC system which is used for communication between the RAC and gateway web server to display and monitor the parameters at the web cloud server (Thing speak). This microcontroller is work as brain of the system. The proposed prototype model has two main parts (i) Hardware model (ii) software. To design the hardware model the main component required are the node MCU ESP8266, current transformer (0-60A), potential transformer (0-12Volt), one relay (5A) one relay (30A), regulator, transistors, diodes and various resistors etc. The software is developed with dynamic programming using demand response in arduino IDE. The Fig. 5 shows the real time prototype model for smart energy controller with RAC. The IoT model with proposed system is shown in Fig. 6.

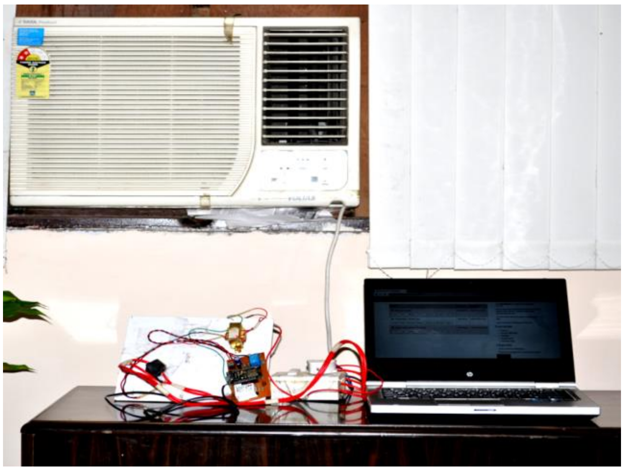

Figure.5 Prototype model of smart energy controller with RAC

is integrated itself. Therefore, the ESP8266 MCU controller is used in the proposed research. The ESP8266 is a low cost Wi-Fi module consisting of a TCP / IP stack and an integrated node MCU by Shanghai manufacturer Espressif. The ESP8266 consists of a built-in 1MB flash memory, which allows devices to connect to the Wi-Fi module. It consists several of features viz. HTTP module, programmable Wi-Fi module, reading of analog signal, Event-driven API for network applications.

There are five types of IoT communication protocols. (1) Wi-Fi (2) Thread, (3) Z-wave (4) Zig-Bee and (5) Bluetooth Low Energy. But Wi-Fi protocols are interface communication technology used to communicate with various electronic devices. The Wi-Fi is a wireless local area network (WLAN) to share data using 2.4 GHz UHF radio waves and 5 GHz SHF. Wi-Fi is enabled in the Node MCU ESP8266 to connect to the Internet within the range of WLAN specified. The MCU node ESP8266 is connected to the Internet through a public access point (hotspots). Android phones and laptops can use the Wi-Fi module to access the node MCU.

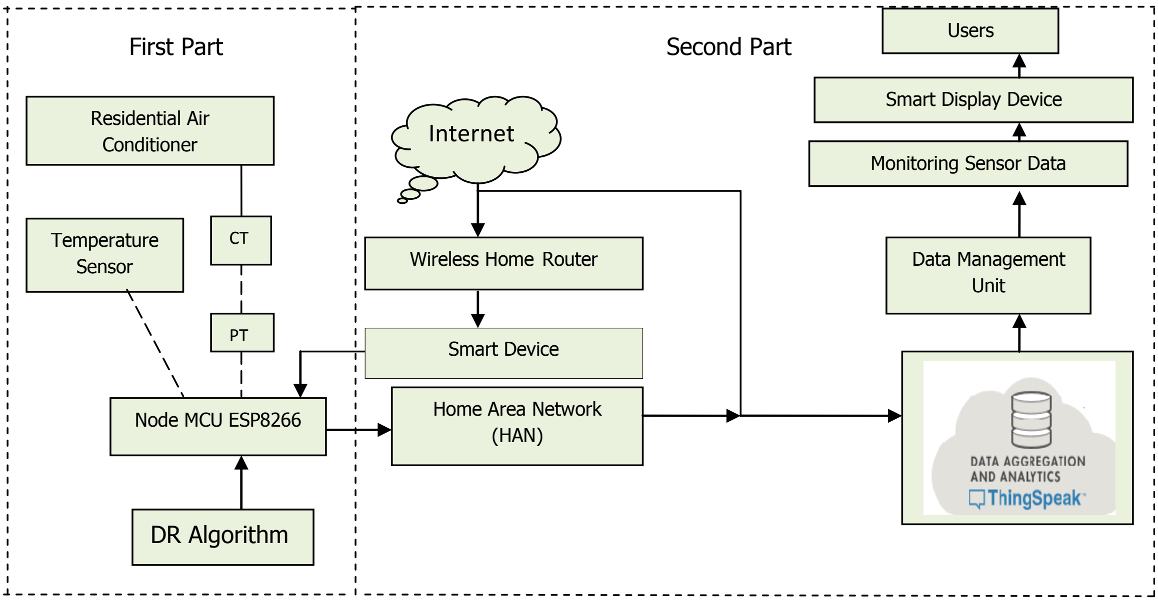

Figure. 6 The IoT model of Proposed System

In the Proposed research, Arduino and Raspberry Pi are not used due to certain limitations as described in section 4. For the home automation or energy management Wi-Fi module is needed. Arduino controller can be used for home automation or energy management with extra device viz. Zig-Bee or Wi-Fi device. The Raspberry Pi controller is not able to receive an analog signal (current and voltage). The ESP8266 MCU node controller can receive an analog signal and Wi-Fi module

7. EXPERIMENTAL RESULT AND DISCUSSION

In this section the performance of smart energy controller is discussed. To investigate the performance of SEC the two RAC of 1.9kW rating are installed in two rooms of (3.6576×3.5052×3.6576) size in meter. In order to check the performance of the DR algorithm and SEC, three different strategies have been studied. Consequently, for the investigation of proposed smart energy controller, the RAC were operated during 12:00 PM on 12th September, 2018. As mentioned earlier, the proposed algorithm used by RTP signal which is based on data available from IEX. The Real Time Price data which is used in the proposed study, it is shown in Fig. 7. The real data is monitored through cloud server (thingspeak.com) and stored on personal web portal through MySQL data base management.

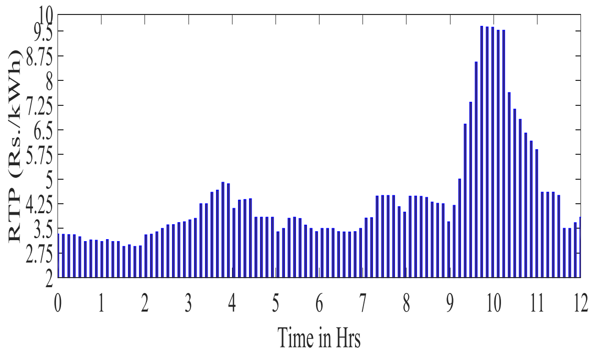

Figure. 7 Real Time Prices of 12 Hrs

In the first strategy normal mode operation the setting of thermostat of RAC is considered as 20 ℃ throughout the study period. It is observed that energy consumption is 23.17 kWh in 12 Hrs. In the second strategy sensing inside room temperature mode the energy consumption is 19.96 kWh and in third strategy payload mode the energy consumption is 18.73 kWh. The energy consumption and electricity cost has been reduced by third strategy. The energy comparison and its cost for different strategies are shown in Table II. In various strategies the power consumption by RAC are shown from Fig.8 to Fig. 10 and energy consumption are illustrated from Fig. 11 to and Fig.13. The Fig. 14 illustrates the temperature variation in various modes.

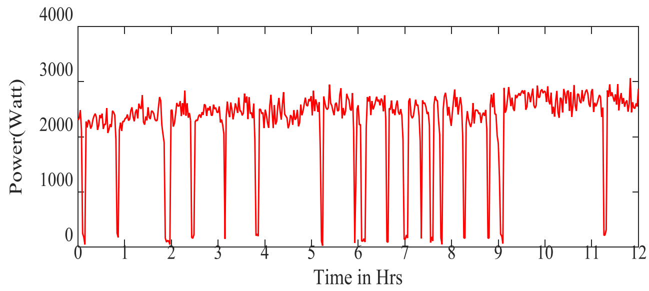

Figure.8 Power Consumption in First Strategy

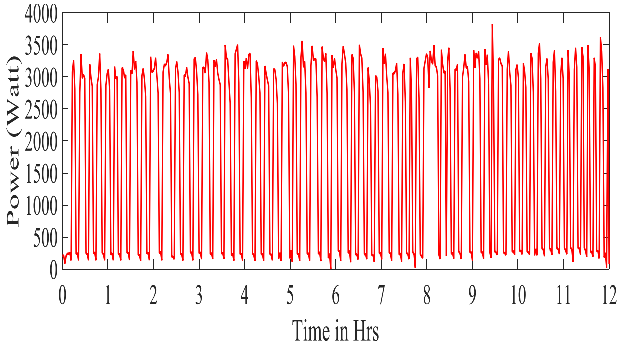

Figure.9 Power Consumption in Second Strategy

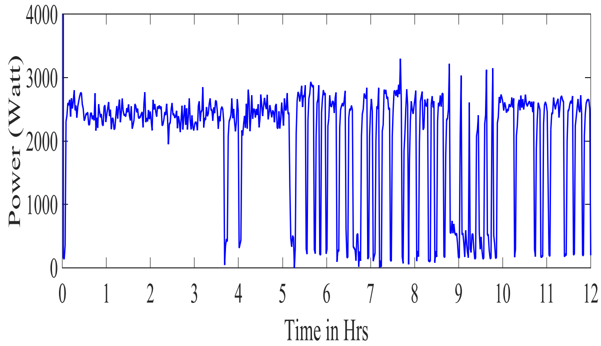

Figure.10 Power Consumption in Third Strategy

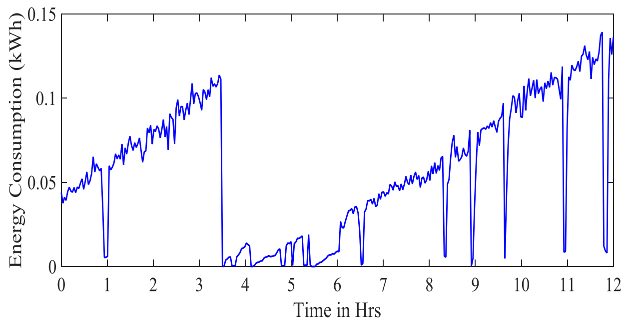

Figure.11 Energy Consumption in First Strategy

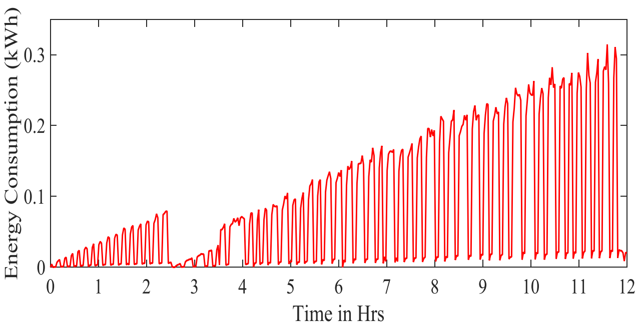

Figure.12 Energy Consumption in Second Strategy

Table I

S.No	Energy Consumption in different strategies			Energy cost in different strategies		
	Strategy-1	Strategy-2	Strategy-3	Strategy-1	Strategy-2	Strategy-3
1.	23.17 kWh	19.96 kWh	18.73 kWh	Rs. 100.65	Rs. 99.8	Rs. 89.283

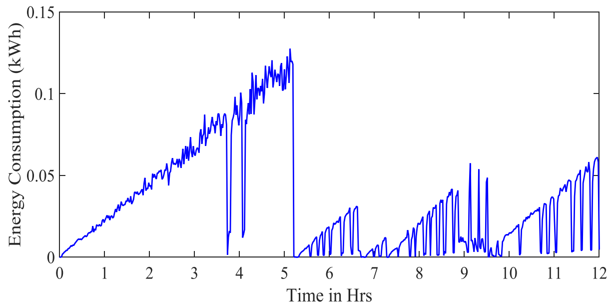

Figure. 13 Energy Consumption in Third Strategy

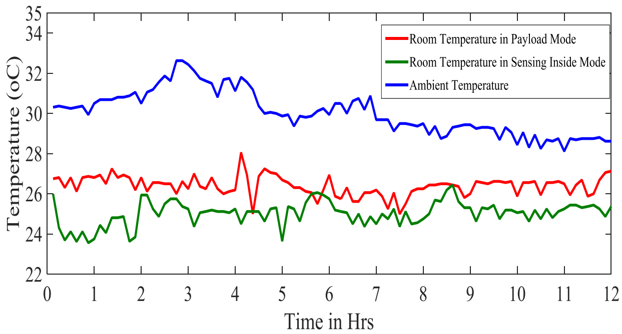

Figure. 14 Temperatures in various modes

8. Conclusion

Currently, the consumers are interested in managing their household energy consumption. In the present research the authors have developed a new demand response algorithm to save energy and reduce electricity bill. This concept is implemented to reduce energy consumption of residential air conditioners. The performance of new algorithm has been investigated by the hardware prototype of smart energy controller. The experimental results show that the proposed smart energy controller is capable to control the operation of RAC economically. Consequently, the smart energy controller is beneficial for consumers to save electricity and electricity bill maintaining comfort zone. In future Smart Grid the all home appliances will be operated by RTP of electricity to save cost and increase reliability, efficiency and transparency. Consequently, the proposed smart energy controller will beneficial for home in smart grid environment.

References

[1] Xing Yan, Yusuf Ozturk, Zechun Hu and Yonghua Song, "A review on price-driven residential demand response," Renewable and Sustainable Energy Reviews, vol. 96, pp. 411–419, 2018

[2] Jianghong Wu , Chaopeng Liu, Hongqi Li, Dong Ouyang , Jianhong Cheng , Yuanxia Wang , Shaofang You, "Residential air-conditioner usage in China and efficiency standardization," Energy, vol. 119, pp. 1036-1046, 2017.

[3] S.A Massoud, and B.F. Wallenberg, "Toward a smart grid: power delivery for the 21st century," IEEE Power and Energy Magazine, vol.3, Issue 5, pp. 34-41, September 2005

[4] Y. Guo, M. Pan, Y. Fang, and P.P. Khargonekar, "Coordinated energy scheduling for residential households in the smart grid," In Proc. of IEEE 3rd International Conference on Smart Grid Communications, Tainan, Taiwan, pp. 121-126, November 2012

[5] N. Chakraborty, A. Mondal, and S. Mondal, "Intelligent Scheduling of Thermostatic Devices for Efficient Energy Management in Smart Grid," IEEE Transactions on Industrial Informatics, vol. 13, Issue, 6, pp. 2899 – 2910, December 2017

[6] JinWoo Yoo, Sung Bin Hong, Min Soo Kim, "Refrigerant leakage detection in an EEV installed residential air conditioner with limited sensor installations," International Journal of Refrigeration, vol. 78, pp. 157–165, 2017

[7] Shumit Saha, Sudip Kumar Saha, Ibnul Sanjid Iqbal, Anindya Kumar Kundu, MD. Tofael Hossain Khan, Sumit Kumar Pramanik "Designing of a Air-Conditioning System using Fuzzy Logic with Advantage of Energy Saving," In Proc. of 3rd International Conference on Informatics, Electronics & Vision, Dhaka, Bangladesh, 23-24 May 2014

[8] Jahn M, Jentsch M, Prause CR, Pramudianto F, Al-Akkad A, Reiners R (2010) The energy aware smart home. In: Proceedings of the international conference on future information technology, Busan, South Korea, pp 1–8, 21-23 May 2010

[9] Mario Collotta, and Giovanni Pau, "A Novel Energy Management Approach for Smart Homes Using Bluetooth Low Energy" IEEE Journal on selected areas in communications, vol. 33, no. 12, December 2015

[10] Nicholas Liew Long Guang, Thillainathan Logenthiran, and Khalid Abidi, "Application of Internet of Things (IoT) for Home Energy Management," In Proc. of IEEE PES Asia-Pacific Power and Energy Engineering Conference, Bangalore, India, 8-10 Nov. 2017

[11] L. Atzori, A. Iera, and G. Morabito, "The Internet of Things: A Survey," Computer Networks, vol.54, Issue 15, pp. 2787-2805, October 2010

[12] Xue Li, Lanshun Nie, Shuo Chen, Dechen Zhan, Xiaofei Xu, "An IoT Service Framework For Smart Home: Case Study On HEM," In Proc. of IEEE International Conference on Mobile Services, New York, NY, USA, 27 June-2 July 2015

[13] Ali Parsa¸ Tooraj Abbasian Najafabadi, Farzad Rajaei Salmasi, "Implementation of Smart Optimal and Automatic Control of Electrical Home Appliances (IoT)," In Proc. of Smart Grid Conference (SGC), Tehran, Iran, 20-21 Dec. 2017

[14] Wei Song, Ning Feng, Yifei Tian, Simon Fong, "An IoT-Based Smart Controlling System of Air Conditioner for High Energy Efficiency," In Proc. of IEEE International Conference on Internet of Things and IEEE Green Computing and Communications and IEEE Cyber, Physical and Social Computing and IEEE Smart Data , Exeter, UK, 21-23 June 2017

[15] N. Venkatesan, J. Solanki, and S. K. Solanki, "Residential demand response model and impact on voltage profile and losses of an electric distribution network," *Appl. Energy*, vol. 96, no. pp. 84-91, Aug. 2012

[16] K. M. Tsui and S. C. Chan,, *"*Demand Response Optimization for Smart Home Scheduling Under Real-Time Pricing,*"* IEEE Transactions on Smart Grid, vol. 3, no. 4, December 2012

[17] Sergio Salinas, Ming Li, and Pan Li, "Multi-Objective Optimal Energy Consumption Scheduling in Smart Grids," IEEE Transactions on Smart Grid, vol. 4, No. 1, March 2013

[18] G. M. Toschi, L. B. Campos, and C. E. Cugnasca, "Home automation networks: A survey," Computer Standards & Interfaces, vol. 50, pp. 42–54, 2017

[19] Logenthiran, T., Srinivasan, D., Shun, T. Z., "Demand side management in smart grid optimization," IEEE transactions on smart grid, vol. 3, No.3, pp. 1244-1252, 2012

Aadesh Kumar Arya received his B. E degree in Electrical and Electronics Engineering from Dr. B. R. Ambedkar University, Agra and M.Tech degree in Communication Engineering from Shobhit University, Meerut in 2003 and 2009 receptively. Presently he is pursuing Ph. D in Electrical Engineering in Department of Electrical Engineering at National Institute of Technology, Kurukshetra. His main interests focus on Smart Grid technology Distributed Generation, FACTS applications, DR and DSM and smart appliances.

Saurabh Chanana received B. Tech degree in Electrical Engineering, M. Tech in Power System and Ph.D in Electrical Engineering in 1996, 2002 and 2011 receptively in the Department of Electrical Engineering at National Institute of Technology, Kurukshetra, India. Dr. Saurabh Chanana is a member of IEEE and ISTE. Presently, he is Associate Professor in the Department of Electrical Engineering at National Institute of Technology, Kurukshetra, India. He has his interests in power system restructuring, FACTS applications, power systems dynamics, Demand Side Management; price forecasting, Smart Grid and Distributed Generation. He is principal Investigator of Industrial project for DRDO. He is the member of IEEE.

Ashwani Kumar received B.Tech degree in Electrical Engineering from G. B. Pant University of Agriculture and Technology, Pant Nagar and M.Tech degree in Power System from Punjab University, Chandigarh and Ph. D from IIT Kanpur, India in 1988, 1994 and 2003 respectively. He is also having the Post Doctoral Fellow, USA during Jan. 2008-May 2008. He has joined the National Institute of Technology, Kurukshetra, India in the 1994. Presently, Dr. Ashwani Kumar is Professor in the Department of Electrical Engineering at National Institute of Technology, Kurukshetra. He has his interests in power system restructuring, FACTS applications, power systems dynamics, distributed generation, demand side management, price forecasting and Smart Grid. He has published more than 80 research papers in Refereed international journals/national journals. Also he has published 84 research papers in proceedings of international and national conferences. In past, he has been investigated many Industrial project. Currently, he is handling DST project. He is the member of various societies' viz. ISTE, Institution of Engineers India (IEI) and IEEE, IEEE-PES society.