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Smart Energy Management using Wireless Technology

Rathi.B[1], Prof.S.Raja[2], Asst. Prof. S.Shajila Rani[3]
Student (B.E), Department of ECE, Christ the King Engineering College, Coimbatore, India[1]
HOD, Department of ECE, Christ the King Engineering College, Coimbatore, India[2]
Assistant Professor, Department of ECE, Christ the King Engineering College, Coimbatore, India[3]

Abstract: Smart Energy Management (SEM) is a new emerging technology that will be mandatory for the future electrical network to generate, transmit, distribute, manage and monitor electrical energy and its usage. The major contribution will be from the communication technologies specifically wireless technologies enabling for two way communications. So far, the interface of smart devices is limited to the transmission and distribution side of the power grid, while its interface with the consumer as well as consumer energy consumption is not given major significance [1]. Based on the case study conducted in our university, this paper proposes a Smart Energy Management System (SEMs), that will make use of Internet Of Things (IOT) along with more than one type of wireless communication techniques based on the requirement, to collect energy information from the users and communicate it to the central server. An intelligent sensor node is deployed in the building in order to use the energy, based on the environmental conditions (temperature, humidity, etc). We have proposed decision algorithms which make use of the sensor values for optimization of energy consumption.

Keywords: Smart Grid, Zigbee, Energy Management, Microcontroller.

INTRODUCTION

The demand for electricity has grown drastically and is expected to grow even more. Earlier, the power generation was mainly carbon based and now slowly renewable energy generation is also gaining attention as the entire world is focusing on reducing the carbon footprint, leading to green energy. The existing power grids are centralized and unidirectional in nature. They lack equipments to monitor the usage profile, loss prone areas etc on a real time basis [2]. So Smart Grids are introduced, which integrate the components of generation, transmission, distribution and also the consumers, providing reliable, secure and standard based two way communication technologies in order to solve the above issues. Smart Grids are power-data communications network that enable collection and analysis of near-real time data [3]. Major functionalities that are to be accomplished by the Smart Energy Management System are demand side management, monitoring and control consumer appliances, economical benefits to both supplier and consumers [1], [4].

We are in the world where smart objects follow us everywhere in our lives and those intelligent objects should be completely controllable and independent of user profiles and time and space span instead of only being invented and interconnected. The phrase Internet of Things (IOT) which paves way for the vision of future internet, that connects physical things from currencies to vehicles through a network, where it takes an active part in the internet exchange information about themselves and their surrounding and give immediate access to information about the physical world and objects in it, leading to innovative services and increases the efficiency and productivity.

A survey has been taken in our Institution, on energy consumption of individual buildings and comparison of the energy consumed from TANGEDCO (Tamil Nadu Generation and Distribution Company) and Generator (using diesel) for the implementation of the mentioned proposed idea will be described in detail in the following section. Based on the results which we inferred from our survey, a Smart Energy Management System is proposed in this paper. The system can provide optimized energy usage by means of smart equipments or devices, smart appliances and smart buildings. Demand Response program also allows the user to earn financial incentive during peak sessions by reducing energy consumption. This not only earns lower cost for the users but also avoids the additional infrastructure to cope up with the rising energy demands in the university.

This Smart Energy Management System will provide real time energy monitoring and usage information that helps in real time energy management and electricity price forecasting. Data information is communicated using standard data access techniques combined with web interfaces. This enhances user’s profits and save their time by pre-determined energy consumption details which will be closely related to the actual usage and also enables remote on-off mechanism of the appliances under the complete control of the user. The system can also provide intelligent control, by installing intelligent nodes that will sense human presence, temperature, humidity and luminosity based on which the smart appliances can be controlled.

In this paper, we bring forth an idea of Smart Energy Management System based on the survey conducted in our university through internet of things using Microcontroller. In the rest of the paper, we will describe the details of this application. In Section II, case study that was carried out in our university is briefed; Section III describes the proposed methodology; Section IV describes the algorithm for control of smart appliances; Section V gives the implementation and results of Smart Energy Management System in our University, this concludes paper and proposes some future works.

CASE STUDY CONDUCTED IN INSTITUTION FOR IMPLEMENTATION OF SEMS

In every University / big corporate sectors, there is a huge demand of electric power, which cannot be completely supplied by the distribution authorities. Universities /corporate sectors have their own local power generation stations to meet their demands. Usually they make use of diesel to generate power. A case study was conducted in our Institution campus, and it reveals that it requires an average of 5 million units of electric power per annum, of which 65% of power is drawn from Tamil Nadu Generation and Distribution Corporation Limited (TANGEDCO), and remaining power is generated using diesel operated power generators (we have 6 generator sets with total capacity of 1860KVA). The graph below shows the comparison of units consumed through TANGEDCO and Genset.

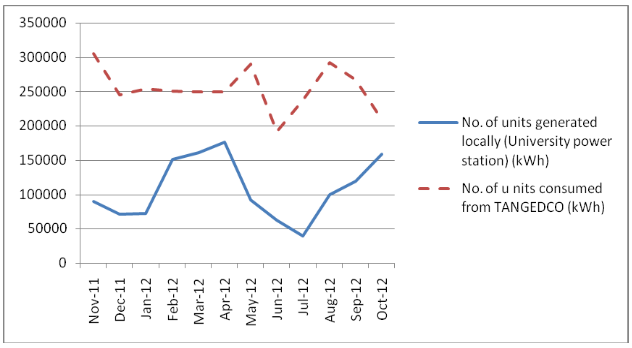

Fig.1. Total number of units consumed during the period Nov-2011 to Oct-2012

According to the recent survey for the period of Nov-2011 to Oct-2012 it is seen that the energy consumed from the TANGEDCO is 3715993 units and the total electricity cost paid is Rs.22,431,069.00/-. Energy consumed through the generator is 1386248 units and the total cost spent for diesel is Rs.20,537,243.76/-. It is evident that the cost incurred in using diesel is approximately 2.5 times the amount paid to TANGEDCO. And the average cost for generating 1 unit of energy using diesel for a period of 12 months was Rs.14.79/-.The graph below shows the comparison between total cost and also cost per unit for consumption from TANGEDCO and also for generation through Genset.

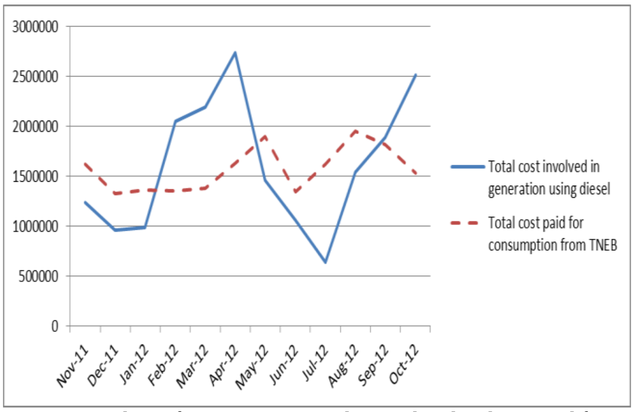

Fig.2. Total cost for energy generated using diesel and cost paid for consumption from TANGEDCO

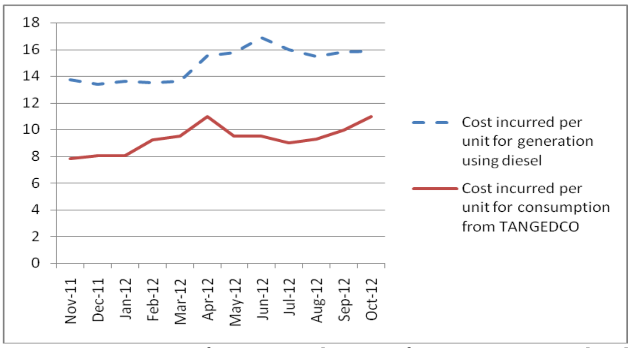

Fig.3. Comparison of cost incurred per unit for generation using diesel and units consumed from TANGEDCO

The maximum demand allowed is 825 KVA. There is an installed maximum demand unit which will give an alarm once this maximum demand is crossed. After this load management is done manually based on the priority levels. These priorities are set based on time. Some loads are either switched to be handled by the generator or shut down based on the requirement. For example during day time hostels, mess halls and gyms do not need electricity and they are given the highest priority to be shed. All these are done manually.

Each feeder unit has a display unit that indicates how much energy is being consumed. There is also a ring main unit in which there are provisions for displaying the past and present MD and also the future MD. These values are read manually at regular intervals of time so as to take measures in advance to manage the load or stay within the demand limit.

We have energy meters for each block, hostel and quarters. But some labs like CSE, CAD/CAM, and Xerox office all have separate energy meters as their consumption levels are high compared to the departments and class rooms. For these labs the capacity that they can consume is fixed and if they exceed it is understood from manually reading the energy meters.

Based on the case study given above, this proposed Smart Energy Management system provides solution to minimize this cost as well as achieve Green Energy. This Smart Energy Management System (The central server) should monitor the usage of power in all major points like Computer lab / CAD/CAM Lab, Workshop / Lathe Units / Hostels/ Staff Quarters around the university campus and based on the detailed profiling, they take decision to control the remote devices / units for efficient management of Energy. The Energy Usage Profile is also prepared by having a detailed study about the usage pattern of various units at our University under various time domains and periods. Based on the energy usage profile and priority based algorithm, this Smart Energy Management System will cut down the cost involved as well contribute for the GREEN ENERGY.

PROPOSED METHODOLOGY

The objective is to optimize the usage of energy in our campus. In order to optimize, we should know the usage profile of the entire campus. This will be helpful in implementing an efficient energy management schedule. Figure 4 gives a model of the proposed implementation scenario.

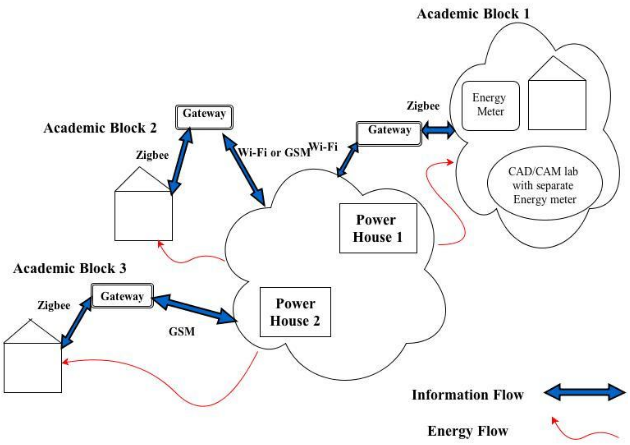

Fig.4. Proposed model of the implementation scenario

The maximum demand is monitored continuously. Once it exceeds the permitted value, then the necessity for load management arises. Hence to manage load, priority levels should be fixed. For example during daytime the feeder lines that supply the hostel buildings can be cut off. And in other buildings energy usage can be optimized by placing intelligent sensor nodes.
Till now there are techniques to interface the smart meters to the equipments in the transmission side. But there are no solid ways in which a smart meter can be interfaced directly or indirectly with the smart appliances at client side. To provide a solution to this problem, a gateway or smart server is designed, which can interact with the utility meter, smart appliances and the intelligent node which will be introduced later in this section. Figure 5 shows the system architecture.

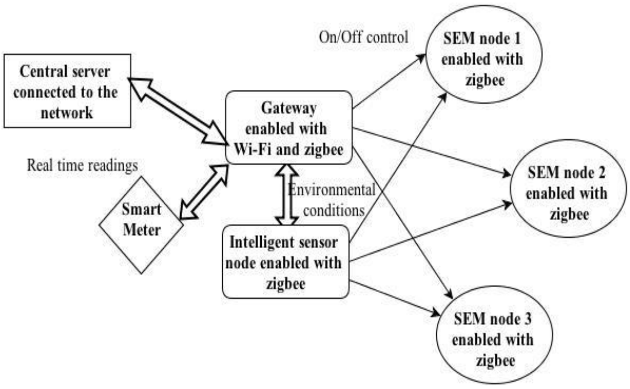

Fig.5. Overall System Architecture

We have a central server that will be connected to the internet or intranet of the university. For connectivity a Wi-Fi or Ethernet connection can be used. This collects energy usage information from all the buildings and also monitors the maximum demand. When the demand exceeds the threshold level, it will display the priority list of feeders that can be cut off and also sends a warning signal to other buildings which will still be functioning in the usual way. Here the maximum demand threshold for our university is 825kVA. Between the server and the building there is a gateway node. This will be a way to communicate between the building and the central server. The gateway is a microcontroller interfaced with Wi-Fi that has the capability to run a web server. This can also be connected with an RF transceiver to send commands to the smart appliances, read values from the smart meter, etc.

A. Smart Server or Gateway

The smart server consists of a microcontroller board using at mega 328 family microcontrollers, a Wi-Fi module – MRF24WB0MA, a RF transceiver- CC2500, power supply for each module, a laptop or system with Wi-Fi capability and that can be configured in either Adhoc mode or Infrastructure mode. The Wi-Fi module and Microcontroller communicates using the Serial Peripheral Interface or 4-wire interface. Figure 6 shows the block diagram of the Microcontroller interfacing with the MRF24WB0MA module.

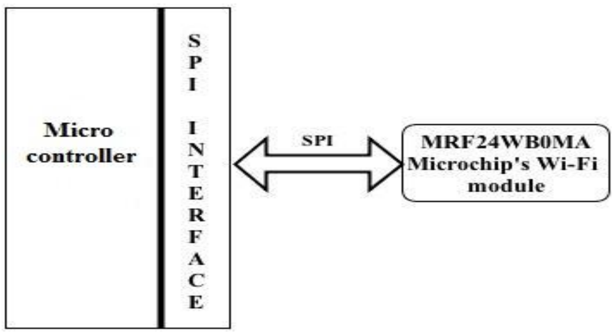

Fig.6. Microcontroller interfacing with MRF24WB0MA

In the initial stage Smart Server was designed and a webserver was initiated. To do this the following parameters should be configured manually.

- A unique IP address for the wishield
- Gateway IP

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- Subnet mask
- Mode of configuration

Once these parameters are configured the microcontroller with Wi-Fi becomes an addressable server. A user intractable webpage was also designed from which we can provide digital control to the I/O pins. This provides a provision for digital (on/off) control of appliances connected to it. This idea was further extended to control a smart appliance. Figure 7 shows the microcontroller Wi-Fi setup and the experimental setup that is controlling the smart appliances.

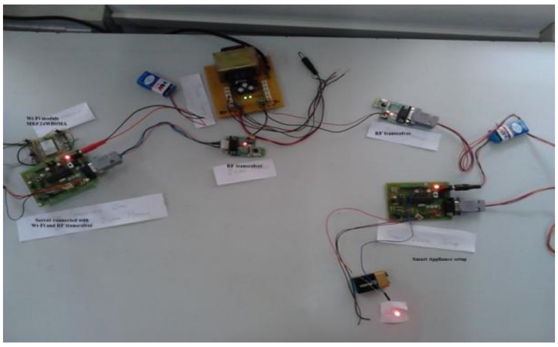
Fig.7. Prototype displaying the Smart Server and Smart Appliance

In order to do this the microcontroller interfaced with Wi-Fi, was connected with an RF transceiver-CC2500. A smart appliance is one which has microcontroller board interfaced with the RF transceiver. The Smart Server will receive the commands from the user through Wi-Fi and will send to smart appliance via RF transceiver. The smart appliance which is also enabled with RF transceiver receives the control and exercises digital control. The experimental setup is shown in Fig.8. Initial experiment was carried out in adhoc mode. Later the server was configured in infrastructure mode and we were able to provide digital control through the internet.

Fig.8. Experimental setup

In the next stage, the smart electricity meter which is interfaced at home or other buildings, labs in case of university are made to interact with the server via zigbee or RF transceiver. When the server receives a command to collect the parameters, it will transmit it to the smart meter through the RF transceiver. When the energy meter receives the command, it will transmit the values through the zigbee interfaced with it. The user can know the present usage and based on that, he can take decision to control the devices. Thus the consumer can monitor his energy usage and control his appliances through the gateway from anywhere in the world. The central server can use this gateway to send the maximum demand information and a warning notification to the end users.

B. SEM Intelligent sensor node

The main function of the sensor node is to monitor the environmental conditions based on which energy usage will be optimized. So the basic parameters to be monitored are temperature, humidity, light and human presence. Human presence has the highest priority [5]. Only if human beings are present then there will be a necessity for energy usage. For example if a staff is available in his cabin, then there will be a need to turn on fan or light. But still there are situations where there is enough light and the temperature but still the fan and lights are turned on. So the intelligent node will monitor the temperature, humidity and light and only if they are not up to the required levels then the fan and lights will be turned on.

Sensors used are: Temperature sensor – LM35, Humidity sensor – syhs220, Light sensor – LDR, PIR sensor. Figure 9 shows the interfacing diagram of sensors with the microcontroller.

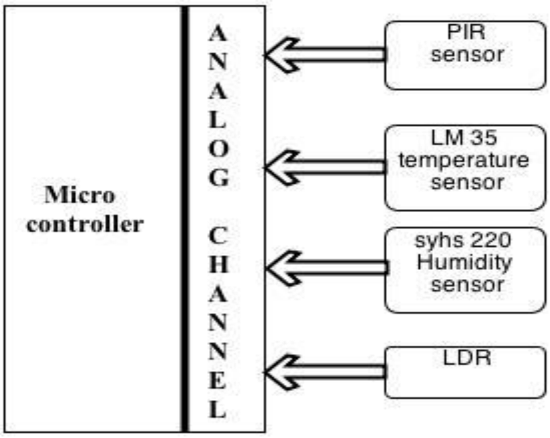

Fig.9. Sensors interfacing with microcontroller microcontroller

ALGORITHM FOR SMART APPLIANCE CONTROL

Let P represent the presence or absence of human, L represent the amount of ambient light, T represent ambient temperature and H humidity. We will also define thresholds for each parameter such as T_P, T_L, T_T, T_H. As we are providing digital on/off control we have these thresholds as reference. Let us also make the following assumptions. P will be either 0 or greater than 0. If temperature is greater than T_T then the digital output will be 1 and 0 if it is lesser. Same way we will assume for other parameters too.

So,

P = 0; absence of human;
P > 0; presence of human
$L > T_L$; output = 0; $T > T_T$; output =1; $H > T_H$; output = 0;
$L < T_L$; output = 1; $T < T_T$; output =0; $H < T_H$; output = 1;

When the daylight is sufficient, there is no need additional illuminence. So the output must be 0 and hence no lights

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will be turned on. When temperature is high, then the fan should be switched on to lower the temperature. Table I will give the threshold for each parameter and these are conditions for summer [7], [8].

THRESHOLD VALUE FOR EACH PARAMETER

Parameter	Threshold
Light	T_L = 30 lux
Humidity	T_H = 60%
Temperature	T_T = 28°C; if $T_H < 60\%$ T_T = 25.5°C; if $T_H > 60\%$

Algorithm
Step 1: Start
Step 2: Check whether automatic control is activated. If yes then continue, else go to start.
Step 3: Check if human being is present (P > 0?). If yes continue, else go to step 12
Step 4: When luminosity is less than 30 Lux? If yes continue, else go to step 6.
Step 5: Turn on light and go to step 2
Step 6: Turn off light and go to step 2
Step 7: If relative humidity is less than 60%? If yes continue, else go to step 11.
Step 8: Check if temperature is greater than 28°C. If yes then continue, else go to step 10.
Step 9: Turn on fan and go to step 2
Step 10: Turn off fan and go to step 2
Step 11: Check if temperature is less than 25.5°C. If yes go to step 10, else go to step 9.
Step 12: Stop

All the sensors will sense continuously, so that once the threshold values are reached, the appliances can be turned off which will also help in energy conservation.

EXPERIMENTAL SETUP AND RESULTS

With all these ideas a test bed was setup. It consists of the Smart Appliance or the Smart Energy Management node, Gateway or Smart Server, SEM intelligent node and Smart meter. Internal view of the Smart Appliance is shown in Fig.10. The intelligent node was designed and the decision algorithm was proposed and implemented.

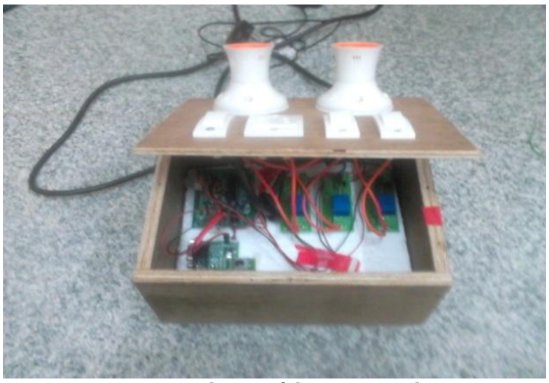

Fig.10. Internal view of the Smart Appliance

The Smart Appliance consists of an intelligent circuit that can control the appliances according to the command it receives. To make the appliance intelligent a microcontroller is added to each node and is connected with an RF transceiver. The loads are connected to the I/O pins of microcontroller. They cannot be connected directly as the output current of the microcontroller pin is only 20 mA and it will not be sufficient to drive AC load. So a relay circuit is also designed. The test bed consists of Smart Appliance, Smart Server and the SEM intelligent sensor node, was deployed at our university and it is shown in Fig. 11and Fig. 12 shows the setup of SEM intelligent sensor node.

Fig.11. Smart Appliance deployment

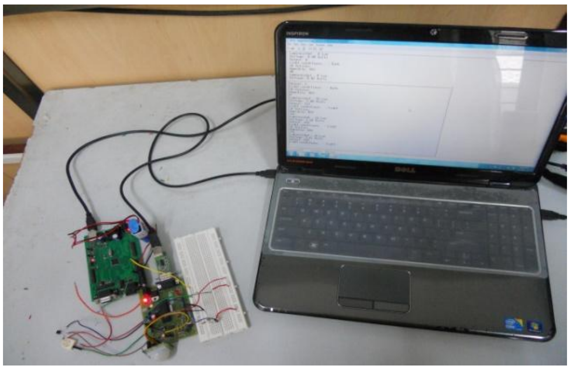

Fig.12. SEM intelligent sensor node

The test bed was tested with various communication techniques like Bluetooth, WI-Fi, wired LAN networks. Each Smart Appliance is enabled with zigbee as the backend network. It was controlled via internet and also locally. The output of the intelligent node was used to control the Smart Appliances based on the environmental conditions.

CONCLUSION AND FUTURE WORK

We have proposed the idea of implementing a Smart Energy Management System through Internet of Things using a microcontroller which is efficient in terms of cost compared with existing technologies used in Smart Grid. This test bed is established in Institution and tested with various communication technologies such as Wi-Fi, Bluetooth and Ethernet and it was able to perform well. The decision algorithm with intelligent server provides better load management and in overall the system provides optimized energy utilization.

In future, energy consumption tests can be carried out in order to measure the efficiency level of the system. This test bed idea can be further extended to control real time loads. The same test bed can be subjected to interference so as to study the acceptable interference levels and security vulnerabilities. Based on the study, a suitable algorithm can be proposed to protect the smart grid against security and interference issues. The entire process history such as real-time energy consumption, managing the load, time-of-use, etc., can be ported to cloud database to manage the load which will further contribute to the energy balance.

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