Home Energy Management within Smart Grid via WSN

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***Abstract*—This paper presents a framework for a home automation scenario within a Smart Grid System. The framework is designed to schedule appliances at less expensive hours to decrease the cost of energy usage at home. The important factor of comfort degradation is also addressed using proposed framework. The framework consists of a Wireless Automatic Metering System that helps in solving various issues of electricity expenses and provides the user with information such as different schemes and tariff packages. Through the proposed framework for home automation, the user will be able to control and reduce the energy expenses using an interactive GUI.**

***Index Terms*—Smart Grid, Wireless Sensor Network (WSN), Virtual Smart Meter, Automatic Metering Infrastructure (AMI), Renewable Sources.**

I. INTRODUCTION

The critical infrastructure of electrical grids enhances global warming issues due to the diminishing fossil fuels and resulting in several power disruptions. Moreover, the current system has become inefficient and unreliable due to aging of equipment, power outages and energy thefts. These factors result in monetary and energy losses at both the consumer and utility ends. In recent years, Smart Grids [1] have been proved to provide an innovative, reliable and efficient power grid scenario with two way communication and electricity flow. A smart grid is a system developed with the integration of information and communication technologies. It is a close loop operation, which brings a fault feedback mechanism. It automatically diagnoses and identifies all kinds of faults, brownouts and blackouts and isolates all the defective branches and transmission lines to protect important equipment and delicate devices from further cascading effects. It is more robust and reliable than current power grid because of its auto-healing(Self-renewal automatically restore to original condition), self-diagnosis and outage management nature. It offers reduction of Greenhouse Gases (reduction of gases that fossil fuels may release such as CO2), environmental benefits, improved energy efficiency, new jobs and economic growth.

Wireless Sensor Networks (WSNs) are based on an advance sensing technology where sensors are distributed spatially to monitor physical or environmental parameters [2]. WSNs have been playing a very important role in Smart Grid Communication and 24/7 monitoring of distribution of power energy from power plant to consumers. It provides a real time actionable data with advanced energy management and reduction in Green House Gases (GHG) with the integration of renewable sources at power plant. These sensor nodes gather data at every step and aggregate physical data (temperature, air pressure, distance, time, lightening levels, sound, people nearby, location data etc) further information to Supervisory Control and Data Acquisition (SCADA) systems for monitoring, processing and recording major equipment details like history, due date for maintenance, working life etc for forecast and evaluation purposes.

This paper presents a study of the potential challenges and opportunities that Wireless Sensor Network provides in smart grid applications and presents a model of a load management framework through WSN and a virtual smart meter Communication system.

The rest of the paper is organised as follows, section II gives a description of smart grids and Wireless Sensor Networks. Section III provides a description of our test model. It is followed by results and observations in section IV. The paper is concluded with a discussion over observations and results in section V.

II. SMART GRIDS AND WIRELESS SENSOR NETWORKS

Smart grid with the integration of information and communication technologies provides a high degree of automation and adaptive direction protection i.e. intelligent devices take decisions according to the demand side management and enable power saving profile if the amount of energy and information transfer is little. Through Wireless Automatic Meter Reading (WAMR) consumers can determine their Real-time energy consumption as well as keep track of previous usage. It provides various benefits to both the utility and consumer, considering the consumers preferences. Furthermore, it minimizes the expenses for its maintenance and system operations. It reduces peak demand and offers load forecasting schemes, tariff packages and demand side management in order to utilize energy in an efficient manner with the minimization of comfort degradation.

It renovates the current electrical power grid and replaces mechanical switches with semiconductor switches in order to reduce heating effects, cost and to consume power smartly. Also many devices like Smart Meters, Smart Appliances, Flexible Alternating Current Transmission System (FACTS), Data Management Systems, SCADA System, On-line Transaction Processing (OLTP) devices, two way communication networks, Super Conducting Transmission Cables (STC), Composite Conductors, Advanced Metering Infrastructure (AMI), High Voltage Direct Current Devices (HVDC), Fault Current Limiters (FCL) and Distributed Automation (DA) devices, Phasor Measurement Units (PMU) are implemented in utility grid stations to make it more flexible, fully controllable, robust and up to date[3].

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WSN plays a vital role in Power utilization, Power delivery and Power generation [4].On the consumer end, WSNs can be used to sense parameters like status of appliances, power quality, voltage, current, transformer temperature etc. Utilities can use WSNs to determine circuit breaker position, switches in the substation or distribution station, steam temperature and air, water or fuel flow rates based on hundreds of actuators in generation units.

Several technologies have been proposed for use in WSNs such as Home Area Networks (HANs), Building Area Networks (BANs), and Local Area Network (LANs) and Zigbee Protocol is a preferable choice whereas from generation to delivery Wireless HART(Highway Addressable Remote Transducer) protocol or International Society of Automation (ISA 100.11) standard[5] have been used to deploy a sensor network. WiMAX technology is used considerably for Wireless Automatic Meter Reading (WAMR), fault detection and restoration, and Real-time pricing.

A. *Hardware for Test Model*

This project includes the following hardware:

- Programming board/gateway: MIB520
- Two sensor boards MDA100 sensing temperature and light intensity
- A window PC with Mote works [6] software installed
- Three motes: standard addition of MICA2 (MPR4x0)

We observed the values of various parameters of the nodes, like their health, power, quality path cost, current time, battery life etc. A frame work has been designed to schedule appliances at less expensive hours to decrease the cost of energy usage at home and reduce the comfort degradation for the user. Figure 1 shows the flowchart of proposed design.

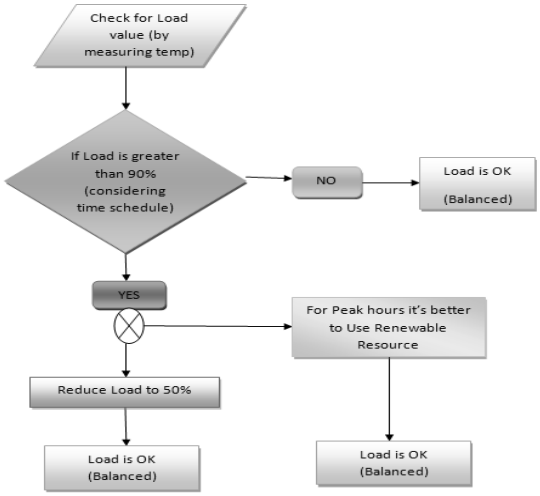


Figure 1: Framework of load management through temperature

Power has been approximated through the temperature sensor, as more current flows through the transmission line, more power would be consumed and more heat would be produced. Temperature sensors measure the increase in heat and approximate it with wattage ratings as if there is any resistor or thermostat in the transmission line where the heat is consumed or measured. We approximate the power as centigrade heat unit. The temperature calculation is performed using Eq. 1, 2 and 3.

$$T_A + T_D = T_T \quad (1)$$

$$TT - TA = TD \quad (2)$$

$$PD = 0.52752793 * TD \quad (3)$$

One centigrade heat unit (International Table) = 0.52752793 watt-hour

Where T_A is the ambient temperature and T_D is the temperature of the device that is its heating effect. T_T is the total temperature and P_D is the power associated with the device. Heating effect can be defined as the heat released by the device due to continuous operation.

B. *Home Automation through Wireless Sensor Networks*

Figure.2 shows the home automation scenario, consisting of three loads which are further sub-divided into number of appliances. These loads communicate wirelessly with the smart meter but they are physically connected through a transmission line which comes from the main supply connected to a smart meter and loads individually. The central block is the thermostat which measures the heat release in the form of temperature and gives a sense of current flowing through transmission line.

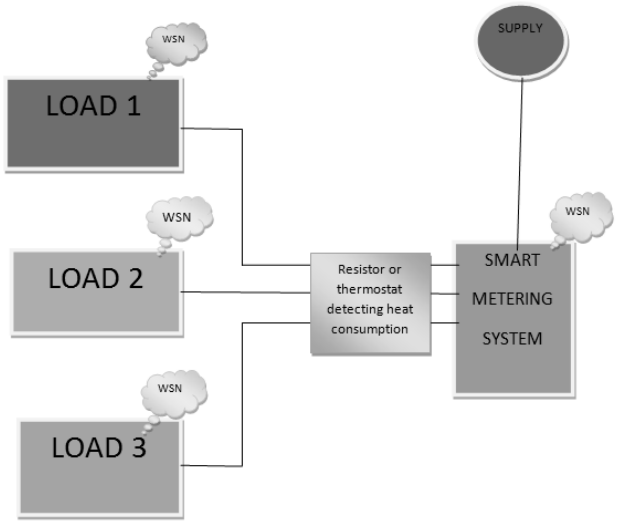


Figure 2: Block diagram shows the home automation scenario

Table 1: Appliances being used as 3 loads

LOAD 1	LOAD2	LOAD3
Fan 100W	Microwave 1500W	Air conditioning 1100W
Incandescent bulb 100W	Washing Machine 500W	Iron 1000W
TV 200W		DVD player 500W

The appliances which have been used as the loads are presented in Table 1 along with their energy consumption ratings. WSN nodes have been programmed to continuously monitor the state of appliances and heat release and provide the ratings of load in temperature from which power values are calculated. In order to control the load and save energy, we have presented three main scenarios [6]:

ON Peak The time where there is a maximum load on grid, which tends to increase electricity rates. The smart meter will inform the user about its rating so that user will be able to minimize the load.
Mid Peak: The time when the electricity is little expensive.
OFF Peak: The time where the electricity has cheapest ratings.

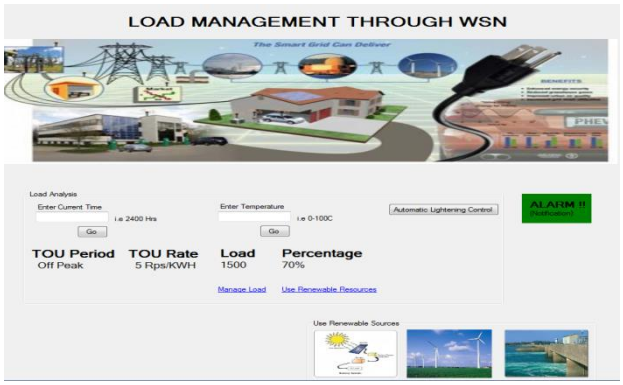
Table 2: Time slots showing tariff packages (PEPCO)

TOU Period	Time	TOU rate	Max Load	Temperature
ON Peak	6:00am to 12:00PM	11.77 rupees/KWH	5000W, 90% or greater	>60C & <70C
Mid Peak	12:00pm to 6:00PM	9.77 rupees/KWH	4000W, 80% or greater	50C & <= 60C
ON Peak	6:00pm to 12:00AM	11.77 rupees/KWH	5000W, 90% or greater	>60C & <70C
OFF Peak	12:00am to 6:00AM	7.18 rupees/KWH	3000W, 50% or greater	30C & <=50C

Table 2 shows the different prices of electricity at different time slots which can be used for scheduling of appliance usage. As can be observed, the cost of electricity consumed increases dramatically if no time scheduling is being used. The Wireless Automatic Metering System will help in solving this problem and provide the user with different schemes and tariff packages. It will interact with the utility grid, and also with the integration of renewable and alternate energy sources users can sale energy back to the grid through smart metering system.

C. *Software*

An interactive virtual smart meter GUI enabling control of the load has been developed that informs the user about energy management and its right usage at the right time. It also provides information on automatic lightening control system,



load controlling and impact of renewable sources. The GUI is shown in Figure. 3.

FIGURE 3: A SMART INTERACTIVE GUI

III. RESULTS AND OBSERVATIONS

We used two sensor nodes and one base station connected to the PC, one was placed in the room and other was placed outside. During day time we observed the high values of light intensity and temperature in comparison with night time. Three types of control are provided by our framework which can be accessed through our GUI.

- In first part it acknowledges user about Time Of Usage (TOU) period and time of usage cost.
- Figure 4 shows different TOU periods and its corresponding rates.

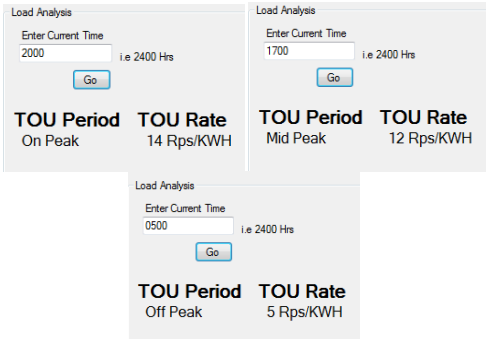


Figure 4: Different TOU periods and TOU rates

- In second part on the basis of released heat and temperature, it calculates the overall load running inside the home with the wattage ratings of particular appliances being used. Through this smart interactive GUI, a virtual smart meter user is able to control the load, or can utilize the renewable sources. If the load is maximum (90% or above) and at the ON or MID peak hours where the electricity is already expensive it would alert the user by generating a Red Alarm, so that right action should be taken to minimize the extra expenses the user has to pay for no reason. It mainly involves two areas, one either to use **renewable resources** or other, to **manage your load** by shutting off some appliances. And when the load is balanced it will alert a green Alarm signal. Figure. 5 and Figure. 6 show the maximum load and balanced load conditions respectively.

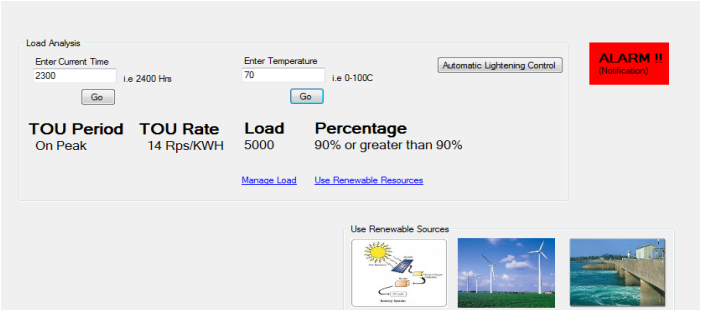


Figure 5: Shows the maximum load value 5000W, 90%

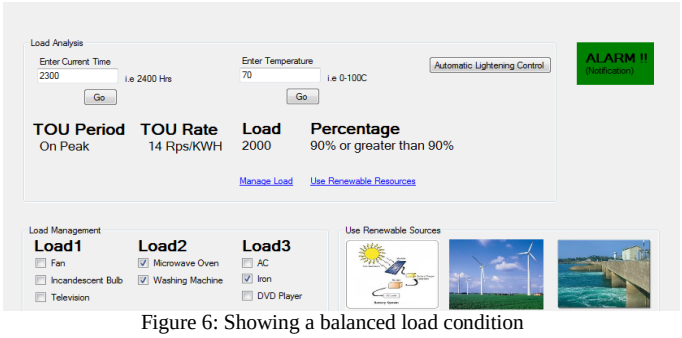


Figure 6: Showing a balanced load condition

- In the third part an Automatic lightening control system has been designed with the help of light intensity sensor. Threshold values of every room, kitchen, and hallway have been already set. Table 3 shows the threshold values, below that threshold value automatic light would be ON (White light), if the infrared sensor inside a room detects any kind of movement. And above that threshold value there is no any need of lights to be ON, it will automatically shut OFF (Grey light) the lights. For testing purpose, the value has been input manually. Through WSN we observe the light intensity values and then set the threshold accordingly, these have been presented in Table 3.

Table 3: Threshold values

Smart Home	Threshold Value
Kitchen	400
Bed Room	600
Hallway	800
Study Room	1000

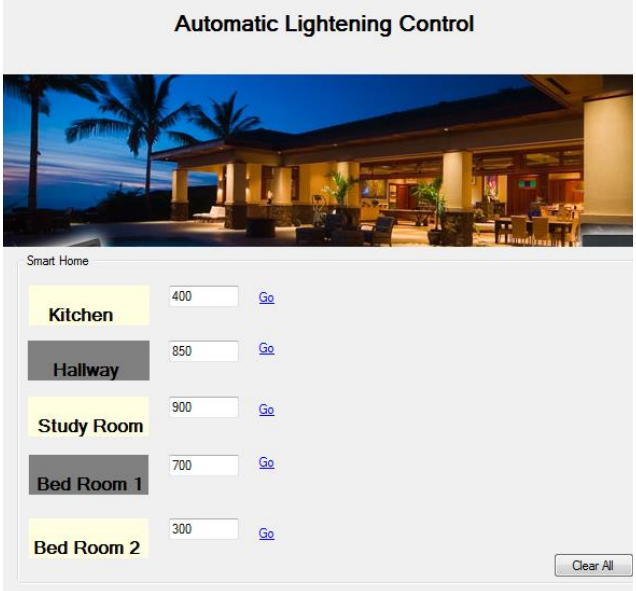


Figure7: Automatic lightening control system

IV. Conclusion

In this paper a framework has been designed to schedule appliances at less expensive hours to decrease the cost of energy usage at home and reduce the comfort degradation for the user. The Wireless Automatic Metering System will help in solving problems related to unmanaged consumption of electricity and provides flexibility to the user with different schemes and tariff packages. It will interact with the utility grid, and also with the integration of renewable and alternate energy sources, the user can sale energy back to the grid through smart metering system.

Acknowledgment

We are thankful to the support and assistance of Professor Rasheed Sheikh, R&D Consultant, MUET for his helpful suggestions, supervision and guidance in completing our paper.We are also grateful to Engr. Abbas Shah, whose detailed technical reviews and ideas helped us to furnish our work in a better way.

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