# Smart home energy management system

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# Smart Home Energy Management System

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***Abstract:*** - As global energy problem is becoming more significant, energy companies worldwide are resorting Time of Use (ToU) tariff. The project aims at developing a smart Home Energy Management System (HEMS) that helps consumers to manage their loads according to the time of use tariff system and in turn help in bringing down the cost incurred. RFID (Radio Frequency Identification) is the method chosen to identify the devices plugged in at home and this information is displayed on a mobile application. When the rates of energy consumption are high during particular periods during the day, the smart HEMS notifies the user through the mobile application about the energy being consumed during higher tariff periods and the corresponding cost incurred.

***Keywords:-*** HEMS; smart home; RFID; time of use tariff

## I. Introduction

Numerous countries are adopting the time of use (ToU) tariff in order to ease the peak demand and it won't be long for India to introduce ToU tariff for its consumers. The ToU tariff system is such that usage of devices during peak period taxes the consumer with heavier tariff and usage during non-peak hours subjects the consumers to certain incentives. The fundamental idea of HEMS is to use energy information to help save in-house energy usage. Also consumer should be very keen on smart HEMS investment in such way the system should be economical or returns in the form of energy savings.

This paper proposes to design a smart Home Energy Management System (HEMS) model with following concepts:

- A smart HEMS is designed in order to help consumers manage their loads according to the ToU tariff system.
- When a device is powered on, the consumer becomes aware of it through an application. This application notifies him of how long the particular device has been operating and also the units consumed accompanied with the corresponding cost incurred. Also consumer has complete control of the turning on/off of these connected devices.

Some loads can be rescheduled to a later period when the cost incurred according to the time of use rates is considerably lesser.

## II. Necessity of smart HEMS

### A. Measures to smoothen load curves

Although there has been drastic increase in consumption of electric power as a result of growing urbanization and industrialization, but production of electricity has not been able to match up to this change. To complicate this further, there is the ever increasing scarcity of fuel. In an electricity grid, electricity consumption and production must balance at all times; any significant imbalance could cause grid instability or severe voltage fluctuations, and cause failures within the grid [1]. Demand response programs are being used by electric system planners and operators as resource options for balancing supply and demand. Such programs can lower the cost of electricity in wholesale markets and in turn lead to lower retail rates [2]. One of the issues faced by electric power service provider companies is the problem of peak power demand which happens as a result of excessive usage of appliances by majority of the consumers simultaneously during a particular period of the day. One way to decrease this peak power demand is to reduce the power demand at the usual peak period. Thus this paper brings forth a smart HEMS that results in a smoother load curve of the household.

### B. Time of Use (ToU) Tariff

ToU is a method that promises to reduce the power demand during peak periods. According to this tariff system, consuming electricity during designated peak periods would be expensive to the consumer, while consuming maximum power during off-peak periods subjects the consumer to incentives such as much lower electricity rates. [3]

In India, ToU tariff system that was used mostly for industrial sector is now slowly being introduced for commercial sector as well. Soon in the near future, it will be introduced for residential sectors as well as an effort to achieve energy efficiency.

The loads available for residential purposes can be classified into two categories - schedulable and non-schedulable loads. Non-schedulable loads are loads that cannot be rescheduled to operate at a later period in order to save money. For example, the refrigerator cannot be turned off at peak hours for the sake of saving up on the electricity bill because food stored inside may get spoilt.

Assuming a typical time of use tariff system, the off-peak is usually fixed during the night when majority of the population is asleep and therefore not using heavy loads. Since there is

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sufficient generation, the charge inflicted on the user during the off-peak period is considerably low. The first peak period can be fixed in the morning hours when a majority of appliances are utilized for the purpose of convenience, for example water heaters, water pumps, induction stoves etc. The second peak period is in the evening when the lighting system is turned on in every street and household. Due to this power generation during peak period is strained and utilities are struggling to supply to all consumers. There can be a shoulder period in-between the peak and off-peak and the user is charged accordingly.

Thus, the smart HEMS brought about in the project schedules the schedulable loads based on available peak/off-peak data of the day such that they operate during off-peak periods, thereby reducing the cost of energy.

### C. *Previous HEMS modules*

Using Zigbee communication to transfer information about consumption within the household in order to monitor consumption rate and Power Line communication to monitor renewable energy generation energy can be conserved [4]. But it is more expensive and depends on renewable energy. A hierarchical wireless master-slave RFID reader architecture of multi standard NFC (Near Field Communication) and UHF (Ultra High Frequency) technologies can be used to build a smart home service system [5]. This system is more complex and aiming to achieve a smoother and more convenient user routine rather than focusing on conserving energy. Loads can be classified into schedulable and non- schedulable loads and the non-schedulable ones are subjected to Wavelet transforms, Artificial Neural Networks and transformed back to serve as a forecasting model for a given system [6].Utilizing RFID as it is cost-effective, there have been similar smart home architectures proposed for improving daily routines based on a home server, embedded network appliances, and RFID modules thus giving rise to a safe and context based light and temperature management system using sensor and RFID tags[7].

## III. Operating Concepts

The work constitutes two segments, a hardware part and a software part. The hardware segment comprises of design of the RFID based system that is responsible for detection of type of load and its ratings and thus communicates with the microcontroller as shown in Fig. 1. The device's plug will have a RFID tag while the plug point has the reader, and when the device is plugged in, the RFID reader reads the unique 12 byte tag ID. This information is sent to an Arduino via serial communication; the Arduino then processes this data and communicates this information to the user mobile application via the Bluetooth facility. Apart from this, the application also has peak/off-peak data so that when heavy loads such as water heaters, washing machines, pumps, air conditioners etc., are turned on during peak load periods the application warns the user about the higher charges that will be incurred.

The software segment includes design and development of the application that allows the user to monitor and control the operation of these devices. The application will also allow the user to remotely turn off a device or program an automatic tripping mechanism. He receives information about amount of total units being consumed and the total cost incurred at the moment.

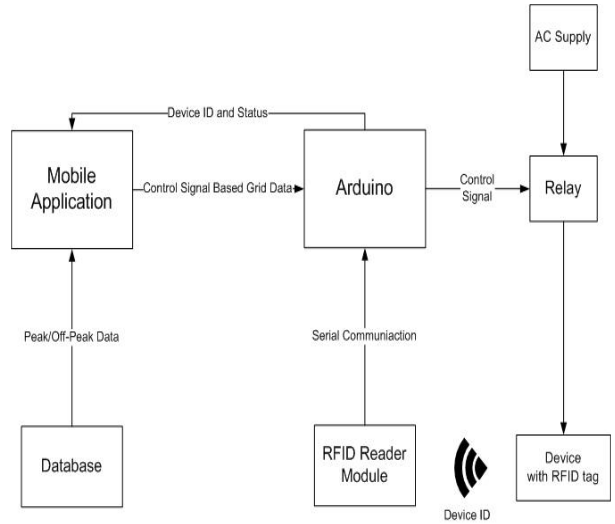


Fig. 1 Block Diagram of HEMS

## IV. Smart Phone Application

### D. *User Interface*

The smart phone application developed for the purpose of enabling the user to control the devices under the smart HEMS has a user interface as shown in the Fig. 2 and Fig. 3.

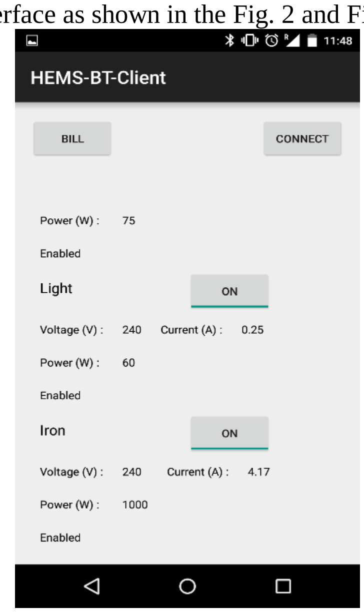


Fig 2. Smartphone UI screen 1

The user gets notified on this application of every device that is plugged in at his house. The list of devices is listed on the user interface with options to turn on or off. Along with this information, the application also displays the voltage and power ratings of that particular device by referencing the device ID received by RFID and Bluetooth technology with a database of devices and their ratings. It also displays how long the particular device has been turned on.

If the user decides to turn off loads, the application immediately displays the total power consumed in kWh or units. The user can also able know about the net electricity bill to be paid according to the ToU rates at that moment.

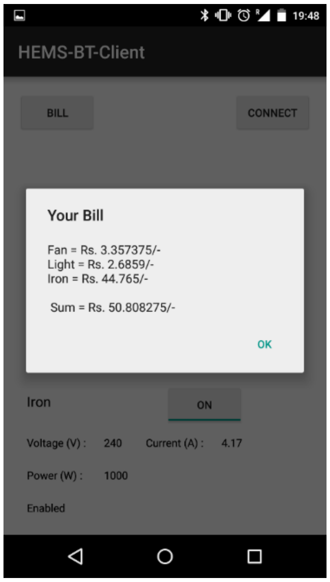


Fig 3. Smartphone UI screen 2

## E. *Android Application Back-end*

Once the Bluetooth is turned on in the mobile, the developed android application (APP) connects to the HC-05 Bluetooth Module which is connected already with Arduino. Initially APP lists out all connected appliances and other plugged devices. The RFID tags which are connected along with plug sends the comment to mobile APP through Arduino in case of any new appliance plugged in. When App receives the ID, it displays details of the respective appliance and makes the user to switch ON/OFF.

If the user decides to turn ON the device, the App checks tariff system at the moment. In case, the application notifies the higher tariff rates, App informs about the peak period to user and then sends the ON command to the Arduino. If it is not peak period at the moment, the application directly sends the ON command to the Arduino to actuate the relay of respective device.

Also at the back end APP calculates the total energy consumed and cost of electricity. The algorithm of Smart HEMS is shown in Fig. 4.

# IV. SMART HOME ENERGY MANAGEMENT SYSTEM

Fig. 5 shows the proto type module of smart HEMS with two switch boxes on considering as two rooms in a house. The setup is tested and verified with the developed APP under peak and off period tariffs.

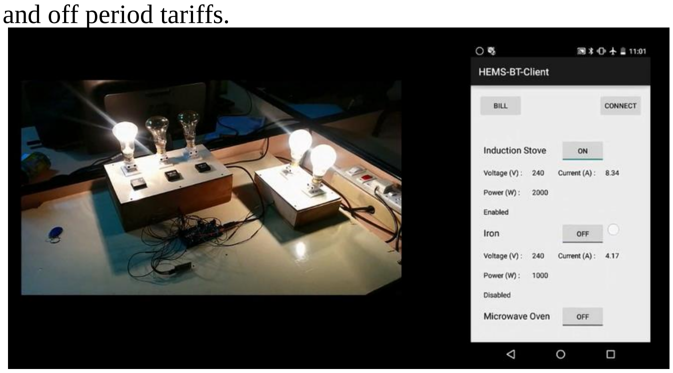


Fig. 5 Proto type module of smart HEMS

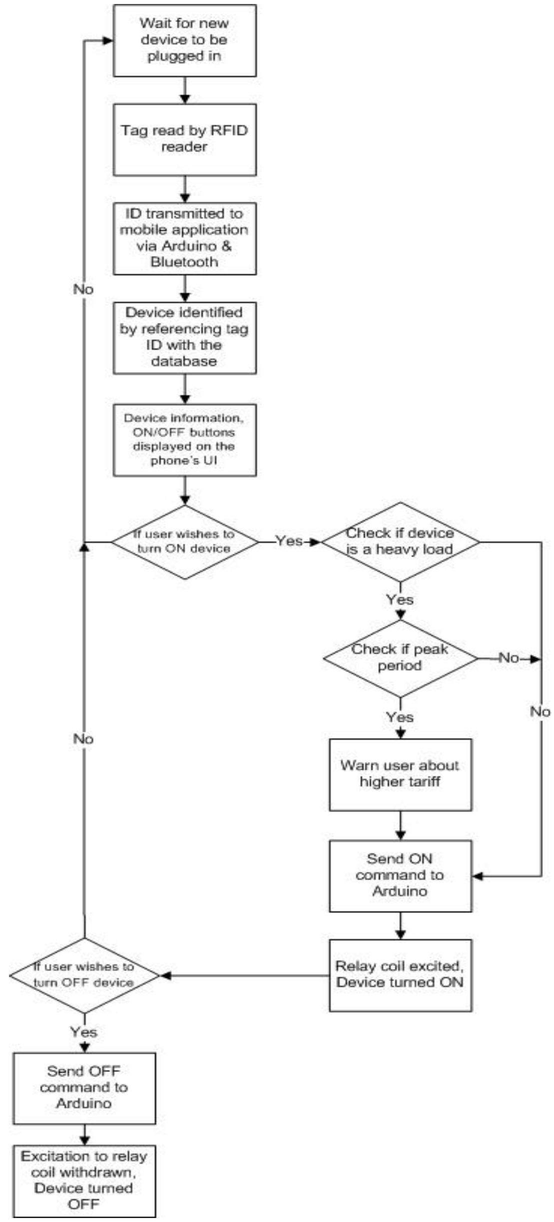


Fig. 4 Smart HEMS Algorithm

## A. *Effect on Monthly Electricity Bill*

In order to understand the effect of using a smart HEMS, three cases analyzed – a single, double and triple bedroom houses in the summer for the following assumed ToU tariff rates:

TABLE 1
TIME OF USE TARIFF SCHEDULE

| Period | Time | Tariff |
|---|---|---|
| **Peak** | 7:00 – 11:00<br>18:30 – 22:30 | Rs. 7.00/unit |
| **Shoulder** | 11:00 – 18:30 | Rs. 6.30/unit |
| **Off-peak** | 22:30 – 7:00 | Rs. 4.50/unit |

i) Single bedroom house:

For a single bedroom, consider a typical routine followed by two occupants – one person working throughout the day and the other person stays at home. Assuming usage of basic amenities such as rice cooker, induction stove, heater, iron box, TV, ACs liberally daily load curve without shifting the load is shown in Fig. 6a. Using the ToU tariff schedule, loads are assumed to be shifted according to peak and off peak periods load curves are plotted as shown in Fig. 6 b. By shifting loads as much as possible without affecting the user convenience the monthly saving comes up to Rs. 333/- as described in Table 2.

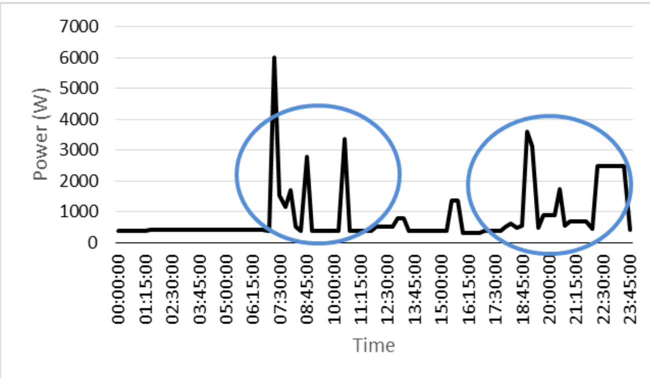


Fig. 6a Load Curve of a single bedroom house (without scheduling)

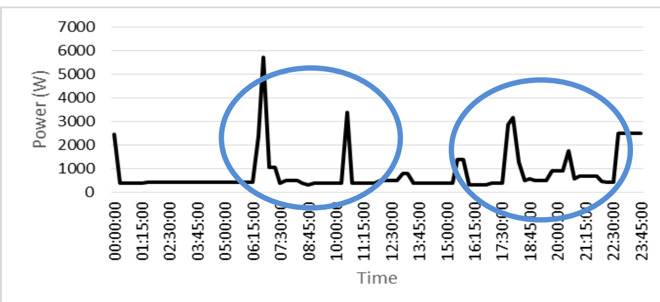


Fig 6b. Load Curve of a 1 bedroom house (with scheduling)

TABLE 2
SAVINGS PER MONTH FOR SINGLE BEDROOM HOUSE

| | Consumption in watts per day (Units) | Cost incurred per day (Rs.) | Cost incurred per month (Rs.) |
|---|---|---|---|
| **Unscheduled** | 19.459 | Rs. 118.29 | Rs. 3,548.79 |
| **Scheduled** | 18.834 | Rs. 107.17 | Rs. 3,215.23 |

ii)Double Bedroom House

For a double bedroom, we consider two to four occupants – two persons are working throughout the day and also considering presence of school going children. Assuming usage of basic amenities such as rice cooker, induction stove, heater, iron box, TV, ACs. Load curves for both non-scheduled and scheduled are shown in Fig. 7a and &b. There is a notable increase in the units consumed per day. By shifting loads as much as possible the monthly savings come up to Rs.500/-

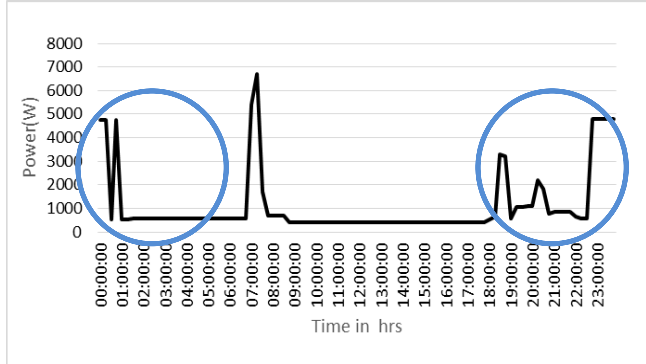


Fig7a. Load Curve of a 2 bedroom house (without scheduling)

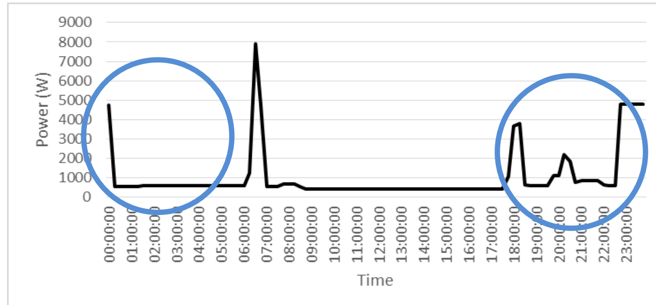


Fig 7b. Load Curve of a 2 bedroom house (with scheduling)

TABLE 3
SAVINGS PER MONTH FOR DOUBLE BEDROOM HOUSE

| | Consumption in watts per day (Units) | Cost incurred per day (Rs.) | Cost incurred per month (Rs.) |
|---|---|---|---|
| **Unscheduled** | 26.571 | Rs. 150.30 | Rs. 4,509.04 |
| **Scheduled** | 24.603 | Rs. 133.15 | Rs. 3,994.38 |

iii)Three Bedroom House

For a triple bedroom and six occupants – two persons working throughout the day two more in house and considering presence of school going children. Assuming usage of basic amenities such as rice cooker, induction stove, oven, instant heater, iron box, washing machine, Fridge, TV, ACs etc.. There is noted increase in the energy consumption per day. By shifting loads as much as possible without affecting convenience the monthly savings come up to Rs.400/-. Load curves are shown in Fig. 8a and 8b and Table 4 shows the cost incurred per month in triple bed room house.

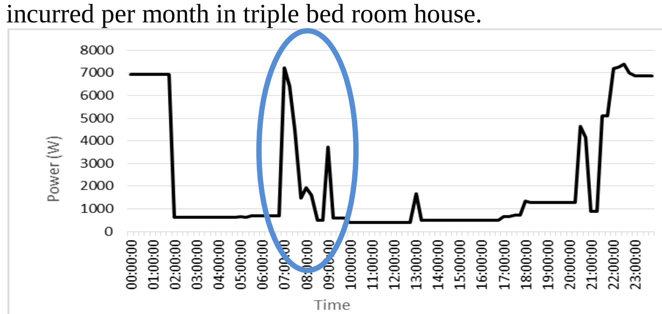


Fig 8a. Load Curve of a 3 bedroom house (without scheduling)

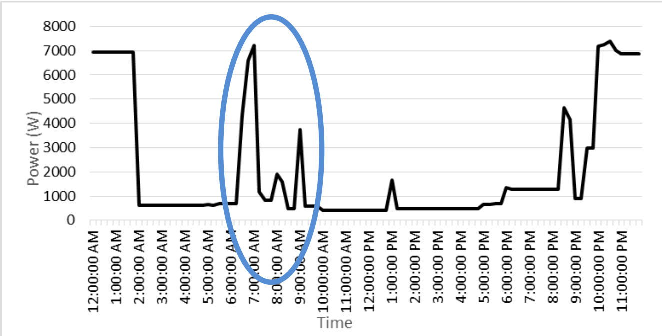

Fig 8b. Load Curve of a 3 bedroom house (with scheduling)

TABLE 4
SAVINGS PER MONTH FOR TRIPLE BEDROOM HOUSE

| | **Consumption in watts per day (Units)** | **Cost incurred per day (Rs.)** | **Cost incurred per month (Rs.)** |
|---|---|---|---|
| **Unscheduled** | 50.99 | 281.54 | 8446.4 |
| **Scheduled** | 50.99 | 268.37 | 8051.19 |

TABLE 5
OVER ALL RESULT

| | Cost for SHEMS | Cost incurred per month (Rs.) (unscheduled) | Cost incurred per month (Rs.) (scheduled) | Savings per month (Rs) | Return back |
|---|---|---|---|---|---|
| Single bedroom house | Rs. 6835 | Rs. 3,548.79 | Rs. 3,215.23 | Rs 333.56 | 20 months |
| Double bedroom house | Rs. 7390 | Rs. 4,509.04 | Rs. 3,994.38 | Rs. 514.66 | 14 months |
| Triple bedroom house | Rs. 7945 | Rs. 8446.40 | Rs. 8051.19 | Rs. 395.21 | 20 months |

## V. CONCLUSION

The smart HEMS proposed in this paper thus effectively adjust usage to the time of use tariff rates, thereby decreasing the cost incurred per month. With the help of RFID load identification technique, each household schedulable load can easily be controlled by consumers without affecting convenience or disrupting their daily routines but at the same time effectively reducing costs.

Approximately a consumer would save around Rs.400/- per month on his monthly bill. By implementing smart HEMS in homes, consumers will get benefit from second year onwards.

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