

## Load Control Application for Energy Consumption and Demand Management

<sup>1</sup>Mithra P S, <sup>2</sup>Baiju R Naina

<sup>1</sup>Department of Electrical Engineering, TKM College of Engineering, Kollam

<sup>2</sup>Department of Electrical Engineering, TKM College of Engineering, Kollam

E-mail: <sup>1</sup>[mithraps22@gmail.com](mailto:mithraps22@gmail.com), <sup>2</sup>[baijurnaina@gmail.com](mailto:baijurnaina@gmail.com)

### ABSTRACT

Everything is becoming smart today; smart cities, smart things, smart clothes, so the electrical grid networks also. The present day energy scenario has led to implementing cost effective methods for energy conservation and load scheduling. By the advancements in the electrical grid network, implementation of smart meters and demand response management (DRM) have occurred. Differential pricing yields to shifting of flexible loads from peak hours to off-peak hours and thus total energy cost can be reduced. The easiness and usefulness of internet technologies and smart phones have made them important in human life. Thus everything is just one click away. There are several applications used for energy consumption and cost calculations. Developing an application for load scheduling by incorporating the idea of priority based load classification will surely be a promising one. The various electrical loads in a building (Residence, Industrial and Laboratory Loads) is taken and are classified as fixed, delay-sensitive and delay-tolerant in nature according to customer priority. Microsoft Visual Studio is used to develop load schedule by means of several windows forms. It ensures protection to data and at the same time enables efficient computation with the help of .NET framework. The basement of future grid network lies on incorporating these ideas with Internet Of Things (IOT) by developing an efficient user friendly platform for load scheduling.

**Keywords:** RER, Demand Response Management, .NET framework, Delay Sensitive Loads, Delay Tolerant Loads, Queuing, Load Management.

### 1. INTRODUCTION

"The grid," refers to the electric grid, a network of transmission lines, substations, transformers and more that deliver electricity from the power plant to home or business. It's what someone plug into or when he or she flip on the light switch or power up the computer. Current electric grid was built in the 1890s and its technology advanced through decades. Today, it consists of more than 9,200 electric generating units with more than 1 million megawatts of generating capacity connected to more than 300,000 miles of transmission lines.

A smart grid is an electricity network based on digital technology that is used to supply electricity to consumers via two-way digital communication. This system allows for monitoring, analysis, control and communication within the supply chain to help improve efficiency, reduce energy consumption and cost, and maximize the transparency and reliability of the energy supply chain. The smart grid was introduced with the aim of overcoming the weaknesses of conventional electrical grids by using smart automated meters. In short, the digital technology that allows for two-way communication between the utility and its customers, and the sensing along the transmission lines is what makes the grid smart. Like the Internet, the Smart Grid will consist of controls, computers, automation, and new technologies and equipment working together, but in this case, these technologies will work with the electrical grid to respond

digitally to our quickly changing electric demand. The Smart Grid provides an opportunity to move the energy industry into a new era of reliability, availability, and efficiency that will contribute to our economic and environmental health.

Demand Side Management (DSM) has so many advantages and the conventional concept of manual management can be replaced by this digitization. Considering the heterogeneous demands in a residence [1] proposes a queuing based energy consumption management. This paper contains a Queuing-Based Energy Consumption Management for Heterogeneous Residential Demands in Smart Grid. In [2], Optimal Residential Demand Response for Multiple Heterogeneous Homes with Real-Time Price Prediction in a Multi agent Framework. In this paper Heterogeneous home agents(HAs) and retailer agents(RAs) are described. Aspects of Optimal Industrial Load Management Modeling in Smart Grids are described in [4](2017), [5](2016), [13], [14] and [15].

By using Artificial Neural Network(ANN),An Innovative Approach for forecasting of Energy Requirements to improve a Smart Home Management System based on BLE is explained in [3]. Optimal Residential Load Control is explained efficiently by considering various residential loads equipped with RER in [6], [7] [8], [9] and [10]. Customer engagement plans for peak load reduction in residential smart grids is explained in [11]. Peak-to-average ratio constrained demand-side management with consumer's preference in residential smart grid is explained in [12].

Introduction is described in section 1; system description in section 2; Application developed is explained in section 3; Results and discussions are explained in 4; and conclusion in section 5.

## 2. SYSTEM DESCRIPTION

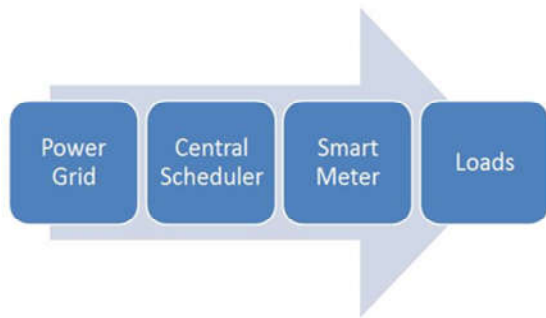


Figure 1- System Model

The energy is supplied through the power line from power grid to several users. Each user has a smart meter, which is used to distribute the electricity from the power line to all appliances in any firm/residence. It also collects each user's demands and preference information. Through the communication line, the smart meters are capable of sending the collected information to the central scheduler and based on this information, the central scheduler will calculate the consumption over the day and allocate all appliances accordingly.

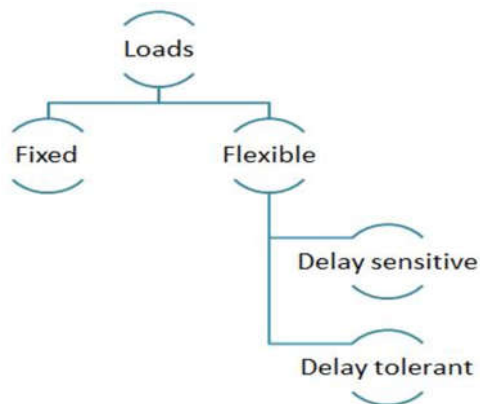


Figure 2- Classification of Loads

The demands in the power grid network are categorized into two types, essential and flexible loads. The essential loads are the base or fixed loads and these are the one with higher priority. The time of use of fixed loads cannot be changed. The flexible loads plays the key role in load scheduling since its time of use can be shifted accordingly from peak period to off-peak period. The flexible loads can be

further classified into delay-sensitive and delay tolerant loads among which delay sensitive loads are more prior than delay-tolerant loads. Delay sensitive loads cannot be waited too long but delay- tolerant loads tolerates delay just as the name indicates.

Energy bills are increasingly taking a bigger part out of small business budgets. No matter what state the business happens to be in, it can be a costly expenditure for a small business. The customer can also lower how much you pay by being proactive, using energy-efficient devices and monitoring your energy usage. There are several energy apps, tools, platforms and websites (all available with a related app or in-app format) will help to monitor how small business uses energy so that the customer can make the necessary changes to lower monthly bill. By using Microsoft Visual Studio2010 a priority based load scheduling application 'SCHEDULE' is developed using C# language.

### Algorithm Representation

Step 1 : Start

Step2: Inputting Fixed loads  $FL_i$  :  $i=1$  to  $m$  (Here  $m=10$ ) Sensitive loads  $SL_j$  :  $j=1$  to  $n$  (Here  $n=15$ ) and Tolerant loads  $TL_k$  :  $k=1$  to  $p$  (Here  $p=15$ ).

Step 3: Inputting various time slots of various loads. Time slot is  $s$  :  $1$  to  $t$  (here  $t=24$ ).

Step4 :Inputting price and maximum demand of each slots and checking whether the price and demand for each loads are within the maximum values.

Price  $P_s$  :  $s = 1$  to  $t$ (Here  $t=24$ )

Maximum Demand  $MD_s$  :  $s = 1$  to  $t$ (Here  $t=24$ )

FLs-Total fixed load in each slot

SLs-Total sensitive load in each slot

TLs-Total tolerant load in each slot

FLPs-Total price of fixed loads in each slots

SLPs-Total price of sensitive loads in each slot

TLPs-Total price of tolerant loads in each slot

First priority is given to fixed loads, second priority to delay sensitive loads and third priority is given to delay tolerant loads for each slots.

Step 5 : Calculating total energy;

FLEs-Total energy of fixed loads in each slot,

SLEs-Total energy of sensitive loads in each slot,

TLEs-Total energy of tolerant loads in each slot.

Step 6 : Stop

### 3. APPLICATION DEVELOPED FOR LOAD SCHEDULING

An application named SCHEDULE is developed by means of several Windows Forms.

#### Form1-Setup

Figure 3- Form 1

Form1 is the one which enables load configuration and time configuration. Load configuration includes buttons to enter into forms for Fixed, Sensitive and Tolerant loads as FL, SL and TL. It also includes a Go button which is used to enter into another form in which total energy calculation is carried out. Time configuration include a button configure to enter into another form in which time slots for various loads can be selected. Also an exit button to end the process is also given.

#### Form2-Fixed Load Data

Figure 4- Form 2

Form2 gives provision to enter the details of various fixed loads. Here 10 checkboxes and textboxes are provided to input the details of 10 fixed loads. Checkboxes are for selection of the loads and corresponding textboxes will enter the load in Watts. Set button is used to input this data. Set button ensures that all the textbox data are inputted if corresponding checkboxes are selected. A Back button is provided to go back to Setup Form and a Clear button is provided to clear all data from checkboxes and textboxes so that new data can be loaded.

#### Form3- Sensitive Load Data

Figure 5- Form 3

Form which enables provision to enter the details of various sensitive loads. Here 15 checkboxes and textboxes are provided to input the details of 15 sensitive loads. Checkboxes are for selection of the loads and corresponding textboxes will enter the load in Watts. Similar to FL form Set button is used to input this data. Set button ensures that all the textbox data are inputted if corresponding checkboxes are selected. A Back button is provided to go back to Setup Form and a Clear button is provided to clear all data from checkboxes and textboxes so that new data can be loaded.

#### Form4-Tolerant Load Data

Figure 6- Form4

Form which enables provision to enter the details of various tolerant loads. Here 15 checkboxes and textboxes are provided to input the details of 15 tolerant loads. Checkboxes are for selection of the loads and corresponding textboxes will enter the load in Watts. Similar to FL and SL forms Set button is used to input this data. Set button ensures that all the textbox data are inputted if corresponding checkboxes are selected. A Back button is provided to go back to Setup Form and a Clear button is provided to clear all data from checkboxes and textboxes so that new data can be loaded.

**Form5- Time Configuration**

Figure 7- Form 5

A select button associated with three comboboxes are provided for entering time-slot details of various loads. By clicking the select button, the three comboboxes named FL\_select, SL\_select and TL\_select are enabled and now it is possible to enter the various timeslots of various loads accordingly. 24 labels and corresponding checkboxes are given to select the time slots. Refresh button is provided to clear the details of previous data entry for each listed load. Price button is provided to go to another form from where prices of 24 timeslots are inputted. MD button is provided to go to another form from where maximum demand of 24 timeslots are inputted. Schedule button is used to generate the load schedule according to the priority based load inputs and other data.

Set button is provided for setting the time flag according to which at least one time slot must be selected. Back button is provided to go back to setup form so that it is possible to calculate the total consumption by clicking Go button of setup form. Back button is enabled only if Set button is enabled. Details of price, maximum demand of each slot should also be inputted.

**Form 6-Price**

It has 24 labels with corresponding textboxes to input the price of 24 time slots. Set button is used to take the price data. Back button is provided to go back to time configuration form for entering other data. Back button is enabled only if prices of all slots are given. Clear button is provided to clear the price data of 24 slots so that the user can give another set of prices.

Figure 8- Form 6

**Form7-Price and Energy Calculator**

Figure 9- Form 7

Here two group boxes are given for calculating price and energy. The price calculator calculates the price for each slot, total price needed for all fixed loads(PFL), total price needed for all sensitive loads(PSL), total price needed for all tolerant loads(PTL). Finally it calculates the price of all loads and assign it as PL. For displaying the values of PFL, PSL, PTL and PL four textboxes are also given. The energy calculator calculates the energy for each slot, total energy needed for all fixed loads(EFL), total energy needed for all sensitive loads(ESL), total energy needed for all tolerant loads(ETL). Finally it calculates the energy of all loads and assign it as EL. For displaying the values of EFL, ESL, ETL and EL four textboxes are also given.

**Form8- Maximum Demand**

It has 24 labels with corresponding textboxes to input the maximum demand of 24 time slots. Set button is used to take the maximum demand data. Back button is provided to go back to time configuration form for entering other data. Back button is enabled only if MD of all slots are given. Clear button is provided to clear the MD data of 24 slots so that the user can give another set of MD.

Figure 10- Form 8

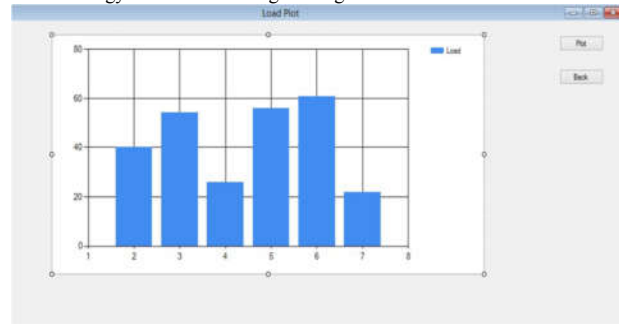


Figure 12- Form 10

### Form9- Scheduler

Figure 11- Form 9

In this window a Run button is provided and when this button is clicked the scheduling is carried out and after completing the scheduling process the Run button name is changed to Finish. When the Finish button is clicked the time configuration window will appear and by clicking the Back button in time configuration window the user can go back to Setup window. Then by clicking the Go button of setup window the energy and price calculation can be done.

### Form10- Load Plot

This form is used to plot loads in each slot (X axis- kW, Y axis -time). Plot button is used for this purpose. Back button is provided to go back to previous form.

## 4. RESULTS AND DISCUSSIONS

### Case 1 Domestic Area

A domestic building has been identified for the study in which the basic (fixed) loads includes 6 Lamps, 2 Fans, 1 Plug Socket and Water Pump. The lamps are named as FL1, FL2, FL3, FL4, FL5 and FL6. The fans are named as FL7 and FL8. Water pump is taken as FL9 and Plug Socket 1 is named as FL10.

Sensitive loads includes 3 Plug Sockets, 2 Garden lamps, Gate Lamp, Kitchen Exhaust fan, Washing Machine, TV, Fridge, Mixer Grinder, AC, Induction Cooker, Microwave Oven and Iron Box. Plug Sockets are named as SL1, SL2 and SL3. Garden Lamps are named as SL4 and SL5. Gate Lamp is taken as SL6. Kitchen Exhaust Fan is SL7, Washing Machine is SL8, Fridge is SL9, Mixer Grinder is SL10, AC is SL11, Induction Cooker is SL12, Microwave Oven is SL13, Iron Box is SL14 and TV is taken as SL15.

Tolerant loads includes 3 Plug Sockets, Laptop Charging, Desktop PC Charging, Inverter Battery Charging, EV Charging, Water Heater, AC, Washing Machine, Agriculture Pump Set, Dishwasher, Hair Dryer, Shaver Socket and Toilet Exhaust Fan. The three plug sockets are named as TL1, TL2 and TL3. The laptop Charging plug is taken as TL4, the desktop PC charging is taken as TL5 and inverter battery charging is taken as TL6. EV charging plug is named as TL7. Water heater is named as TL8, Washing Machine is taken as TL9. Agriculture Pump set is named as TL10. Dishwasher, Hair Dryer, Shaver Socket and Toilet Exhaust Fan are named as TL11, TL12, TL13 and TL14. AC is taken as TL15. Here we can the same washing machine is taken as both SL8 and TL9 according to customer priority. Similarly AC can be both sensitive or tolerant loads according to customer preference.

The 24 hour of a day is divided into 24 blocks and for each block the price of energy and maximum demand is taken. The energy and price plots for the domestic loads are given below.

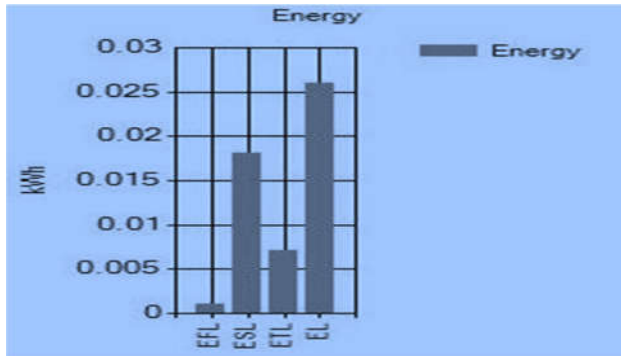


Figure 13- Energy Plot: Domestic Area



Figure 14- Price Plot: Domestic Area

### Case 2 –Industrial Area

A newsprint industry is taken for the study. The power sources includes 15MW turbo generator, 7MW turbo generator, 2.5MW diesel generator and 2\* 110 kV grid (KSEB).This particular industry belongs to Extra High Tension tariff (EHT) customer of KSEB with a contract demand of 22MVA. Time Of Day (TOD) metering is used for pricing. Different periods in a day is divided as;

- Normal : 6.00pm-6.00am (Rs.5.10 per unit)
- Peak : 6.00pm -10.00pm (Rs.7.20 per unit)
- Off Peak : 10.00pm-6.00am (Rs.3.60 per unit)

No	Fixed Loads	Sensitive Loads	Tolerant Loads
1	FL1-PMC Drive	SL1-DIP	TL1-Chipper Wood
2	FL2-PMC Auxillary	SL2-CP – Washing	TL2-Recovery Loads
3	FL3-PMC Stock	SL3-CP – Bleaching	TL3- Limekiln Plant
4	FL4-PMC Finishing House	SL4-CP – Cooking	TL4- Evaporator
5	FL5-PMC Pump House	SL5-Chipper Reed	
6	FL6-Utility	SL6-Colony	
7	FL7-Effluent	SL7-CMP Raffinator	
8	FL8-Other	SL8-CMP Auxillary	

Table 1- Industrial Loads

### Raffinator is used during peak hours

During peak hours (6 PM to 10 PM) highest load (Raffinator-9000kW) is allowed to run. Here Raffinator is taken as sensitive load SL7. Thus total power of loads in kW become higher than maximum demand (11300kW). In this case scheduling is not possible and thus energy and price calculation is not done.

### Raffinator is shutdown during peak hours

Rescheduling is carried out and during peak hours (6 PM to 10 PM) and highest load (Raffinator-9000kW) is not allowed to run. Raffinator is taken as SL7. Thus total power of loads in kW become within maximum demand (11300kW). In this case scheduling is carried out and energy and price calculation is done.

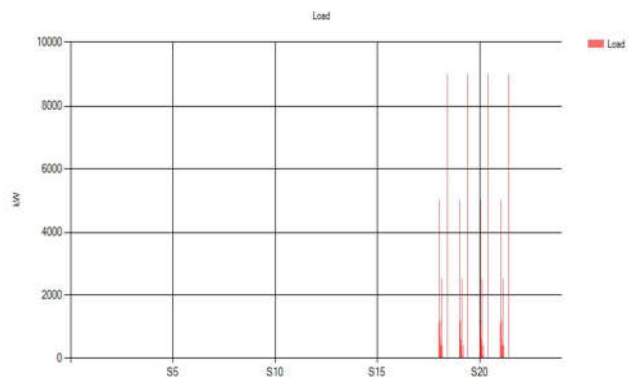


Figure 15- Load Plot :Un scheduled Case

In this case the highest demanding load SL7 (Raffinator) is allowed to run during peak hours. SL7 of 9000 kW and the maximum demand for peak hour is 11300kW. But when SL7 is allowed to run the total power of loads exceed this maximum demand and scheduling is not possible.

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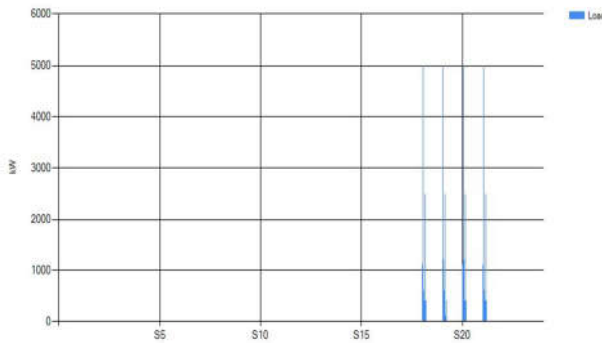


Figure 16- Load Plot : Scheduled Case

maximum demand for peak hour is 11300kW. Here the total power of loads lies within this maximum demand and scheduling is possible. Also from the above figures it is clear that the highest load is reduced to 5000kW (scheduled case) from 9000kW (un scheduled case).

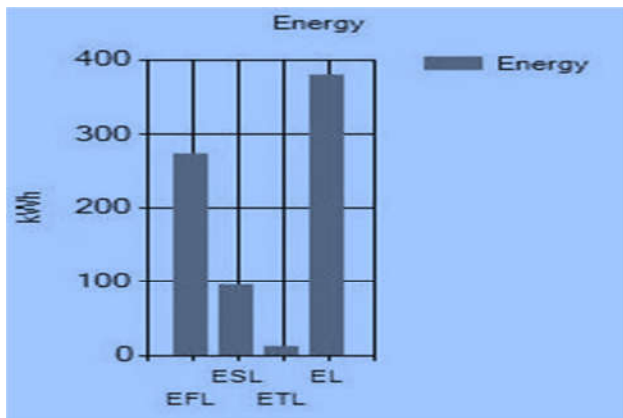


Figure 17- Energy Plot: Industrial Area



Figure 18- Price Plot : Industrial Area

### Case 3 – Laboratory

A laboratory has taken for study. It is a building with three floors. Common area, office, VIP room and two labs are situated in the ground floor. One washroom is also provided in the ground floor. Two labs, coffee shop, washing area, staff

changing room, MRI room with Console and CT Room with Console etc are situated in first floor. X-Ray, TMT/EEG/EMG, Mammogram, Ultra Sound etc are situated in second floor. A store room and accounts room are also provided in second floor. Along with the loads in various sections motors for fire pump and water pump are also provided. Lift is also provided there.

#### Total demand is not within maximum demand

Highest demanding timeslots are from 11AM to 5PM. Total power of loads in kW are higher than maximum demand (110kW) for the following time slots;

- 11 AM - 12 PM
- 2 PM - 3 PM
- 3 PM - 4 PM
- 4 PM - 5 PM

In this case scheduling is not possible and thus energy and price calculation is not done.

#### Total demand is within maximum demand

Highest demanding timeslots are from 11AM to 5PM. Loads are rescheduled such that total power of loads in kW are within the maximum demand (110kW) for the following time slots;

- 11 AM - 12 PM
- 2 PM - 3 PM
- 3 PM - 4 PM
- 4 PM - 5 PM

Scheduling is carried out in this case and thus energy and price calculation is done.

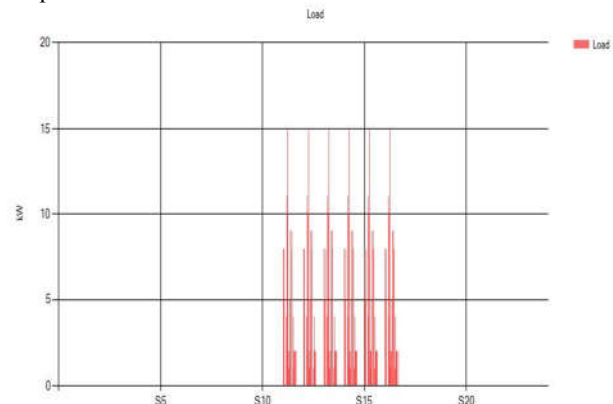


Figure 19- Un scheduled case : Laboratory

Here power of loads in kW in the highest demanding timeslots are shown.(11 AM to 5 PM).The maximum demand is 110kW. But for the timeslots 11AM to 12 PM and 2 PM to 5 PM, the power of loads exceed this limit and thus scheduling become not possible.

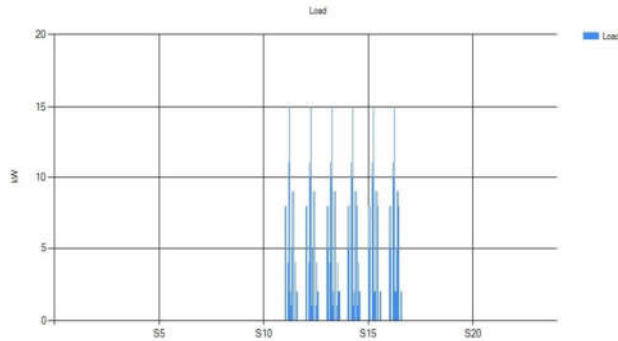


Figure 20- Un scheduled case : Laboratory

Here also power of loads in kW in the highest demanding timeslots are shown.(11 AM to 5 PM).The maximum demand is 110kW. Here for the timeslots 11AM to 12 PM and 2 PM to 5 PM, the loads are arranged such that the power of loads are within this limit and thus scheduling can be done. From the above figures the loads are lesser in number for the scheduled case.

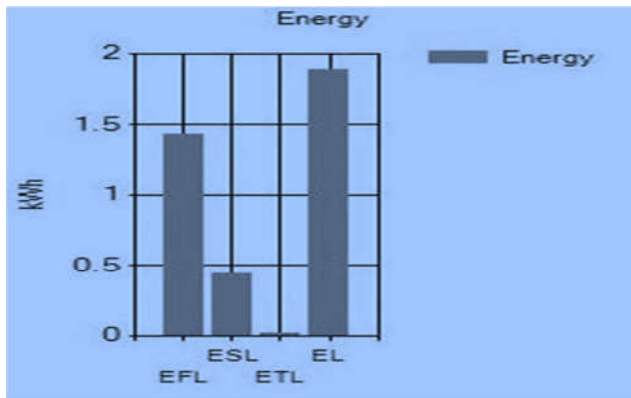


Figure 21- Energy Plot : Laboratory



Figure 22- Price Plot : Laboratory

## 5. CONCLUSIONS AND FUTURE SCOPE

Smart grid facilitates a large number of new concepts for power system operation or customer services. Different techniques can be used to perform demand modeling in electricity systems. In traditional method the demand and supply is balanced by means of adjusting the supply level. But demand response management seeks to adjust demand instead of supply. For this purpose differential pricing scheme is adopted which promotes shifting of loads from peak hours to off-peak hours thus customers have to either shift the loads to a low price off-peak hour or decide to pay a higher price for their electricity thereby increasing demand during periods of high supply and/or low demand.

Microsoft Visual Studio is used to develop a load schedule for residential demands on basis of a priority is carried out according to consumer preferences. For study purpose one residence, one laboratory and one newsprint industry are selected based on which different electrical loads are classified as fixed and flexible loads. The number of time slots per day is taken as 24 each of 1 hour duration and according to the priority given to the loads a schedule for different loads (fixed, sensitive and tolerant) is developed. The price and energy is calculated for each slot in a day according to maximum demand given. A chart is also plotted according to the energy and price values for one day.

Calculating the delay/waiting time is still there for which the arrival rates of different loads in the queue for different time slots must be determined. This must be studied further and may adopt as a research area for future. Developing a load scheduling app for mobile phones (Android, IOS etc). With the help of Internet Of Things (IOT) it is possible to develop an efficient user friendly platform for load scheduling.

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## AUTHOR PROFILES

1. **Mithra P S** received the BTech degree in Electrical and Electronics Engineering from Pankajakasthuri College of Engineering and Technology, in 2014 and MTech Degree in Power Systems from TKM College of Engineering in 2019. Her area of research interest includes demand side energy management and load scheduling.

2. **Baiju R Naina** received the BTech degree in Electrical and Electronics Engineering from College of Engineering, Trivandrum and MTech Degree in Power Systems from NIT, Thiruchirappally. She is currently working as an Associate Professor at TKM College of Engineering, Kollam, Kerala.