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Energy Management in Domestic Household to Reduce Monthly Bill through Feedback

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***Abstract*—**Home energy monitoring and/or management system are tools that could be used by homeowners to increase awareness, which may eventually lead to adoption of energy saving measures. In this technologically advanced era, electricity is essential to support our daily life. People rely upon electricity to help them go through their everyday schedules either at homes, offices and even at all other places. But with the advancement in technology, the demand-supply gap is also increasing. To overcome the issue, we need to increase generation. A lot of Renewable energy generation projects are under process to produce clean and sustainable energy but, to control the problem completely, we need efficient energy utilization to avoid the wastage of energy. Consumers need to adopt low energy consumption lifestyle through awareness and easy access. Customers usually receive no information on how much various energy appliances cost to operate. If consumer attempt to conserve energy, they receive inadequate information about the energy consumption. Because conventional metering system provide electricity bill at the end of every month and most of the consumers are also unable to understand the information provided by the existing metering system because the energy charge is for kWh and details about patterns of consumption are not available. As a result, the consumer does not realize their household's consumption.

In this paper, we propose an interactive system that will allow the user to define the electricity consumption for a particular month according to their own budget. This system will continuously update the user about their consumed electricity and the current bill calculated based on tariff defined by the utility. At the same time the system will also show the expected projected monthly bill based on the previous average electricity consumption pattern. To establish this two-way flow of data we have designed a mobile application that allows a user to define their targeted electricity consumption for a particular month according to the budget. This app will communicate with the controller to collect electrical parameters and timely inform the consumer about their consumption through feedback that will display both instantaneous and processed data.

Keywords: Consumption Awareness, Smart Meter, Energy Management..

I. INTRODUCTION

Energy Management is an approach to deal with the power utilization and adjust to the changing behavior of the community mainly caused by the technological revolution [1-2]. Humanity is facing the biggest energy challenge of inadequacy and the rising energy demands. A lot of measures have been taken to overcome the shortage of electricity in Pakistan; Researcher's in [3] suggest increasing the total generation; this will require a lot of fuel for the production of electricity which makes the price unit of electrical energy to increase. Smart grids [4] are another solution to reduce energy wastage that controls the domestic user appliances in case of system overloading but this system is complex and restrict the user to compromise on their comfort. In an attempt to reduce energy losses, prepayment meters were installed to manage the energy costs that required the user to pay for energy in advance, but the system is costly and inefficient[5]. The solutions presented are not economical for a developing country like Pakistan and require a lot of investment in terms of money. So there is a need to look for better and low cost solution to overcome the issue and that is by raising awareness of the consumption and to reduce energy wastage.

We explore if energy management system can influence homeowners in such a way that they adjust

their energy utilizing practices. We identify a system as home energy monitoring system if it only provides insight, but if the system also allows control, we distinguish it as a home energy monitoring system. A smart meter is not necessary in order to be able to determine the energy utilization, but for better understanding of consumption user need to get adequate feedback [6]. The way feedback is provided is also an important characteristic of the system to allow motivation of homeowners. There are various ways in which the feedback to the households can be given:

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Indirect feedback: Subsequently providing the information after reviewing the past events e.g. using energy bill.

Direct feedback: Immediate Computerized information provided in real time e.g. using smart phones or computers.

Electric Utility Companies used conventional method for providing feedback to house owners in the form of monthly bills which showed consumption for that particular month only and also exhibited the past annual summary of their total energy use.

Over the last decades this situation has changed considerably, and the preference is given to direct feedback through smart meters or devices that give visual displays.

Researchers from the European environment agency (2013) indicates that combining both form of feedbacks (direct and indirect) has, so far been the most effective in achieving energy savings and changing the consumer behavior [7]. Another research finds that communicating with the feedback devices and setting a target for energy saving by consumers themselves has the potential to yield the best results [8]. Research by Murray et al. (2015) also indicates that households and the individual appliances they use have distinct energy consumption pattern, and thus a personalized feedback approach is needed [9]. Kobus (2016) concluded that feedback should be provided frequently in real time because it enables the user to link their behavior to the consequences. The study also shows that expressing energy consumption in costs has a great impact on energy saving measures [10].

We explore how this system can provide them knowledge about the possibilities to change their behavior and get insight in the possible profit that that can be achieved. Jesper Kjeldskov et.al (2012) designed a mobile application named "Power advisor" that provided conservation of electricity through tailored information on a tablet or mobile phone [11]. Findings provided insight into people's awareness of electricity consumption in their home and how this may be influenced through design.

Ueno ET. Al. Constructed a system known as "Energy consumption information system (ECOIS)" [12] for creating awareness at residential level and to motivate energy-saving activities. The system comprised of two parts; monitoring and distribution. Monitoring of the power consumption was done through meters and Distribution side included a lab-based computer which was used to distribute data to the information terminal for each user via email.

End-use load monitoring at the individual customer level, gives a fuller understanding of how much electricity is used for what purpose, and when, is vital information for efficient energy management.

Knowledge of load shapes is also important for calculating the cost of supplying a specific end-use [13]. The central POEM (Power-efficient occupancy-based energy management) Unit collects the data which can be displayed or transferred to other systems for analysis.

P.Ilatchiya et.al (2016) [14] designed and developed a smart monitoring and controlling for household electrical appliance in real time. The control mechanism was implemented via android application where the message was sent to mobile through GSM giving information on power consumption of each load and control was done in remote by creating popup window.

All the solutions presented were to reduce the electricity consumption but the limitation of the researches is that these are more focused on energy feedback and did not allow user interaction to enter their targeted monthly bill according to their budget.

II. System Modeling

The proposed system mainly consists of a Controller, Real Time Clock (RTC), Wi-Fi module, Relay module and LCD display.

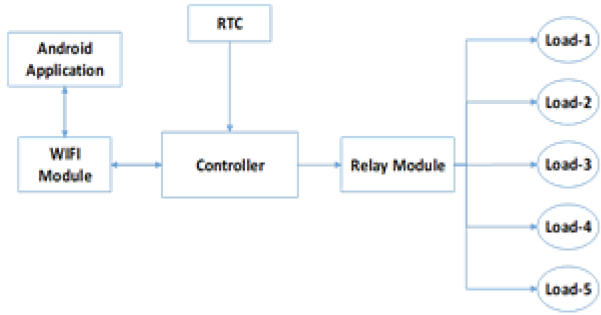

Figure 1: System Block diagram

As illustrated in Figure 1 proposed system is divided into two parts; data collection and control unit.

A. Data collection

In order to help the customers to reduce their electricity consumption and become more aware, the main aim is to know the electrical parameters of the household such as voltage and current. This data is essential for an accurate quantification of energy which will provide detailed electricity consumption and thereby calculating the power consumed.

Sensing units are used to measure the values of current and voltage, thus calculating the total power. The sensors used are ACS712 (20A) and ZMPT101B, for measuring current and voltage respectively.

Current sensor is a device which senses AC or DC current in a conducting wire and produces a voltage proportional to it. A current sensor ACS-712 (20A) is used in this project which operates on 5V and consists of linear Hall sensor circuit with a copper conduction path located near the surface of the die. The Hall IC sense the magnetic field produced by current flowing through copper conducting path and produce voltage proportional to the current. ACS 712 measure positive and negative 30Amps, corresponding to the analog output. This voltage value is then fed to controller for controlling the devices.

For voltage measurement the sensor used is ZMPT101B. It is used to measure AC voltage and has high accuracy for measuring power and can measure voltage up to 250V. The output voltage is stepped down to 5V suitable for interfacing with the controller.

B. Control Unit

Control Unit is the main brain of this project. It will receive data from mobile application as well as the loads and manipulate the data to make decisions accordingly.

Arduino MEGA 2560 is used as the central controller. The programming language is simple and can easily run on windows, LINUX and Mac. The controller stores the data assigned by the user through mobile application and compares it with the real time power. On the basis of these values, the controller is able to provide the information about the consumed units and the remaining units limit. When the consumed units exceeds the targeted units for a day, it will either inform the user in the form of a pop-up message on mobile device or will automatically switch off the optional loads and let the basic loads running.

Wi-Fi Module

Communication of the controller with other devices is done through a Wi-Fi module i.e. ESP 8266 which is serially interfaced with controller. It is a low-cost Wi-Fi microchip that can give access to Wi-Fi network (or the device can act as an access point).

C. Real Time Clock (RTC)

RTC is real time clock in the form of an Integrated Circuit. RTCs are present in almost every electronic device which needs to keep accurate time to stay updated.

In order to provide real time feedback to consumers about energy consumption, our system must keep an updated track of the current time. We have used RTC because it has low power consumption and is more accurate than other time calculating methods.

III. Simulation of Proposed System

A. Proteus model

ISIS8 PROFESSIONAL (Proteus) is used for simulation. The real time simulation of system is shown in Figure 2. The built-in library of simulator consists of thousands of devices. To meet the design requirements of the system, several components have been used which are available and can be implemented at a practical level. The connections are established, and hex file is burnt into the Arduino in simulation.

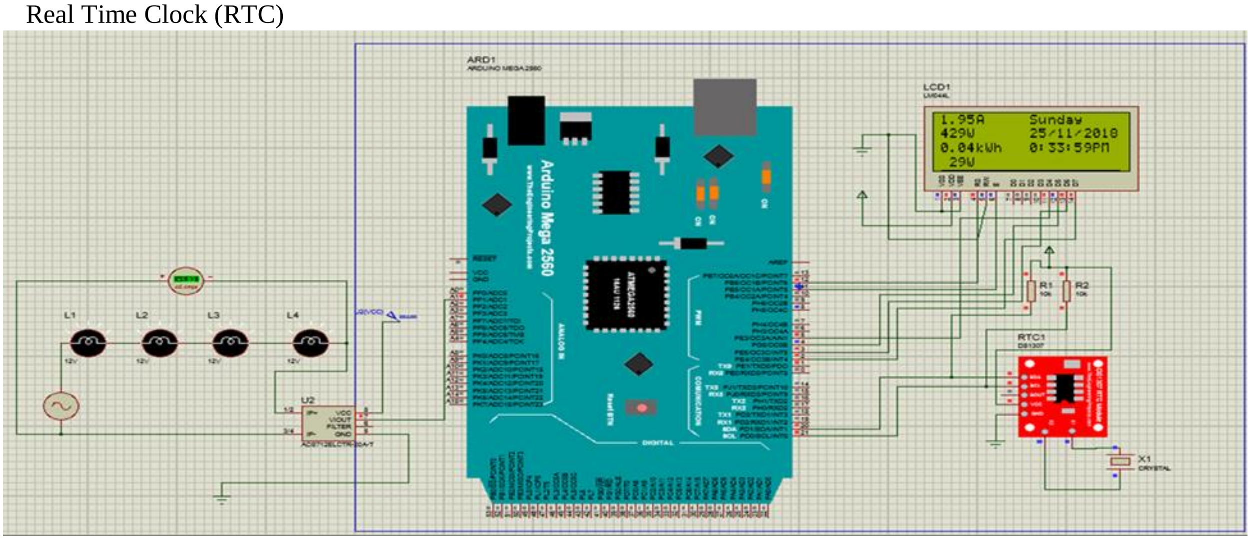

Figure 2: Proteus Model

B. Flow Chart and Algorithm

The controller has been programmed according to the effective, well defined and efficient algorithm to get required goals. We have taken five loads (L1, L2, L3, L4 and L5), two of which are categorized as optional loads i.e. L1= Air Condition, L2=washing machine and the other three loads are categorized as basic loads that always needs to be running i.e. L3=Bulb, L4= fan and L5=Refrigerator.

We have also defined two modes (strict and relax modes). In the strict mode, if the consumed energy (Ec) is less than the energy limit (EL), all the loads will remain on but if the consumed energy (Ec) exceeds energy limit (EL), controller will automatically switch off the loads categorized as optional (L1 & L2) and the basic loads (L3, L4 & L5) will keep running. In the Relax mode, user comfort is not compromised and controller will notify the consumer in the form of a pop-up message on their mobile device, if the consumed energy (Ec) exceeds the energy limit (EL). The whole operation of the controller is presented by a flow chart in Figure 3.

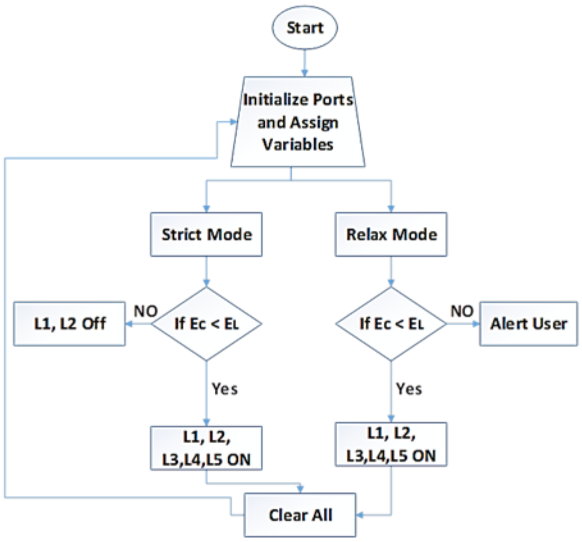

Figure 2: Flow chart

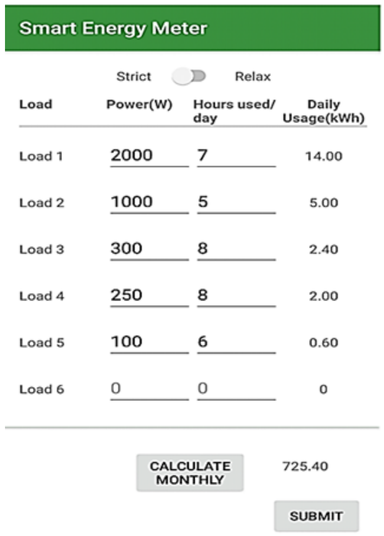

Figure 4: Slots for each load

IV. Performance Evalution

A. Android Application

A mobile application has been designed called Smart energy meter to explore different kinds of information and feedback on power consumption. This application can be used to calculate daily/monthly load's energy consumption and provide detailed and tailored information on the pattern of consumption. Figure 4 shows the main window of the application that integrates two menu items; load planning and load management. Load planning allows the user to define their targeted electricity consumption in the form of hourly usage of each appliance. Load management tab allow us to switch on and off the loads remotely from android application.

Figure 3: Application Home page

In the load planning windows, the user first assigns the rated power and daily usage hours of each load as shown in Figure 5. By using these parameters, the app will calculate total monthly KWH.

Figure 6 shows some additional options where user will enter the different slabs and their per unit price defined by utility. To get more accurate estimated bill, surcharge tax, general sale tax and fuel adjustment tax option is also included in the app. By clicking the estimated tab, it will display the total calculated monthly bill based on total KWh.

Figure 5: Additional Options

The user can make the monthly bill according to their budget by modifying the appliances daily usage hours. To activate the system, the user will press the submit button and then controller will start controlling the loads according to schedule.

During a month, any time the user can check the current bill (based on energy consumed) and expected bill (based on average consumption). Which encourage consumer to reduce the energy consumption to keep the bill within their defined budget.

B. Results

The designed system was tested several times in laboratory where we used bulbs as four different loads. After successfully evaluating the system it was properly installed at household level to further validate the results. Figure 7 shows the hardware prototype examination in laboratory and figure 8 shows complete hardware system installed at main junction box of one of the household selected to perform case study. Successful verification of strict and relax modes was also done where if the energy limit for a day exceeded, all optional loads were switched off or the user was informed by a pop-up message appearing on the android device screen. The proposed system is flexible and scalable which makes it better than the systems currently available in the market.

Figure 7: Prototype testing at lab

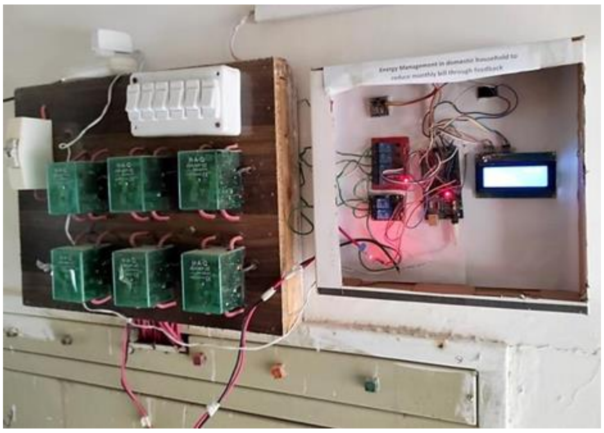

Figure 8: Hardware Installed

C. Case study

In order to accomplish the electrical energy conservation at residential level, a case study was conducted. The study was performed in 2018 for three households. House 'A' consisted of four family members, the House 'B' with seven members, and the third house 'C' with a total family member of nine persons. Each house comprises five bedrooms and the commonly used appliances by the families were refrigerators, air conditioning systems, electric heating systems, microwave ovens, electric kettles, fans and lights. Monthly energy meter readings were noted down for each household with and without this system.

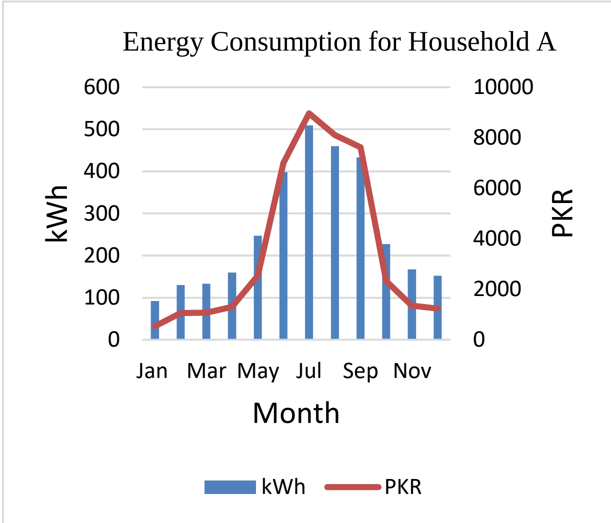

Figure 9 (a): Energy utilization of household A in 2017 before system installation

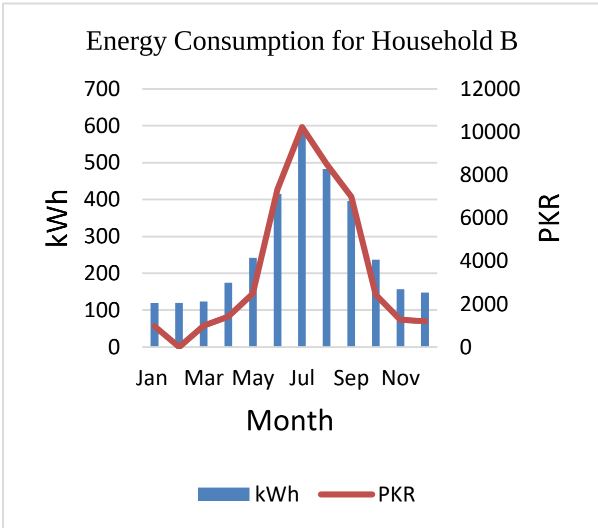

Figure 9(b): Energy utilization of household B in 2017 before system installation

Here the electrical energy conservation was achieved by using the system and defining their targeted electricity consumption. They were also advised to change their common behavior in order to avoid wastage of electrical energy and motivated them not to leave the appliances in standby modes. To carry out an effective statistical analysis, the achieved results in 2018 were also compared with the previous year 2017 meter readings for the same months.

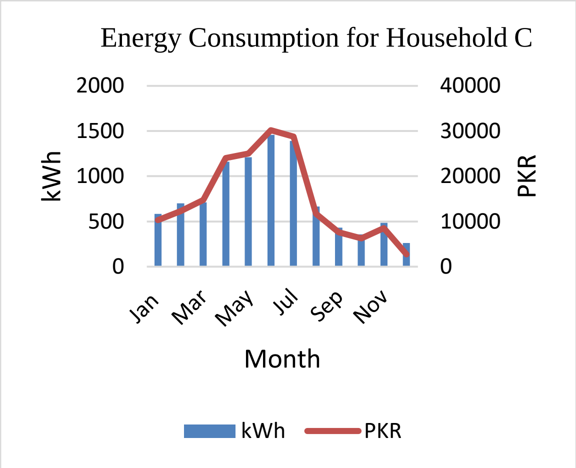

Figure 9(c): Energy utilization of household C in 2017 before system installation

The data for unit's consumption and monthly bill of three households for the year 2017, before the system was installed, is shown graphically in figure 9 (a,b,c). Household A was considered to be the most efficient consumer with least waste of resources, household B was average consumer, and household C was the least efficient consumer of electricity. For the household 'A', average consumption before the installation of system was 259kWh. For household B the average consumption was 266.5833kWh, and for household C, the average consumption was calculated to be 727.75kWh.

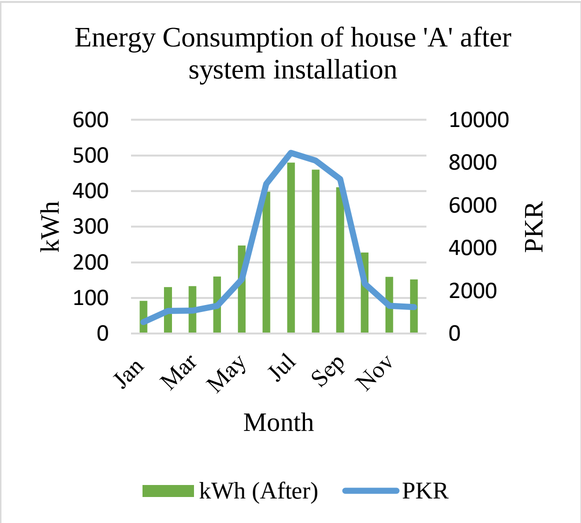

Figure 10(a): Energy utilization of household A in 2018 after system installation

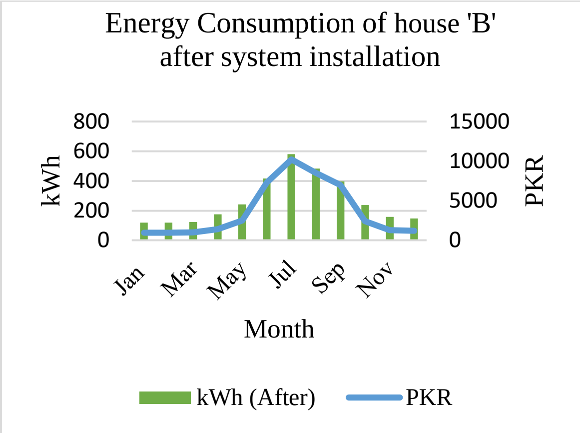

Figure 10(b): Energy utilization of household B in 2018 after system installation

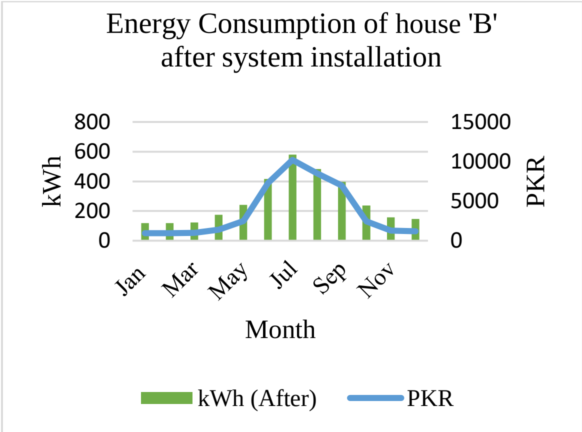

Figure 10(c): Energy utilization of household C in 2018 after system installation

But after the installation of the system in 2018 for conservation of energy, the system showed clear reduction in the consumed units, thereby reducing the monthly electricity bill. Following graphical Figure 10 (a,b,c) shows clear reduction in consumption of electricity for three household

It was concluded that the household A was much more aware of their consumptions and was using the electricity very efficiently even before the system was installed. Their average consumption in 2018 came out to be 254kWh thereby, saving 21.25kWh and on average saved 6.25% of electricity for the year 2018. Similarly the average consumption of house B came to be 267kWh and saved a total of 63kWh with a percent saving for year 2018 to be 16.41%.

On the other hand, household C was consuming electricity very generously and was worried about their increased electricity bill before system installation. But after the system was installed they became more aware and informed about the consumption and reduced their average consumption to 780.5kWh saving 291.4 kWh units of electricity with 22.75% energy saved for complete year.

D. Savings through Strict and relax mode

The mobile application named SMART ENERGY METER also has an additional feature that allows the user to plan the usage of electricity according to their own budget and is able to calculate the expected monthly bill. It further has two modes (i) Strict and (ii) Relax mode; in which if the system is in strict mode, all the unwanted loads will automatically turn off once the targeted consumption is achieved, leaving the basic loads running. While in relax mode the user gets notified in the form of a pop up message about their increased consumption.

This feature was specifically tested for summer season in the month of May and June. In order to do a comparison between the energy saved through strict and relax modes, consumer C was selected because of their already increased electricity consumption.

Relax mode (May 2018)

For the month of May, system was considered to run under relax mode. In relax mode user comfort is not compromised and controller will notify the consumer in the form of a pop-up message on their mobile device, if the consumed energy exceeds the energy limit. Consumer C set the targeted units to be 1000kWh and daily consumption units were calculated, but at the end of month the consumed units were 1285kWh. Table 1 summarizes the details about the targeted units, consumed units and average daily consumption.

Table 1 Targeted and Consumed units under relax mode
May 2018 (Relax Mode)

May 2018 (Relax Mode)	
Target Units	**1000 kWh**
Weekly Allowed	250 kWh
daily allowed	33.33 kWh
Consumed Units	**1285 kWh**
Weekly Consumed	321.25 kWh
Daily consumed	42.833 kWh
Exceeded units	285 kWh

The user tried to reduce consumption in order to meet the targeted unit's and consumed a total of 1285kW units with a total monthly utility bill of 26000 PKR. Compared to the last year bill for the same month, they were able to reduce their consumption and saved 35% of the energy for May 2018.

Strict Mode (June 2018)

To study the effect on energy conservation through strict mode Household C was again selected for June 2018. In the strict mode, if the consumed energy exceeds energy limit, controller will automatically switch off the loads categorized as optional and the basic loads will keep running. E.g. if the user has consumed their targeted units for a day at 9:00pm, their optional loads (AC, Washing Machine, dishwasher etc.) will be switched off automatically and they have to wait till 12:00am until the next day starts in order to make the optional appliances operational again. But in case of emergency, if there is a dire need, user can manually restart the devices. This will count on as the extra units consumed.

Since June is warmer than the month May, energy consumption was proportionally higher than the previous month. User set the targeted electricity units to be 1250 kWh and average daily allowed consumption was calculated to be 42 kWh, but consumed 1341 kWh by the end of June 2018 under strict mode. Table 2 summarizes the details about the targeted units, consumed units and average daily consumption.

Table 2 Targeted and consumed units under strict mode
June 2018 (Strict Mode)

June 2018 (Strict Mode)	
Target Units	**1250 kWh**
Weekly Allowed	310 kWh
daily allowed	42 kWh
Consumed Units	**1341 kWh**
Weekly Consumed	335 kWh
Daily consumed	44.7 kWh
Exceeded units	91 kWh

Their total consumed units by the end of June 2018 were 1341 kWh with a monthly bill of 27759 PKR. Compared to the last year bill for the same month, this user saved 38% of the energy for June 2018 under strict mode.

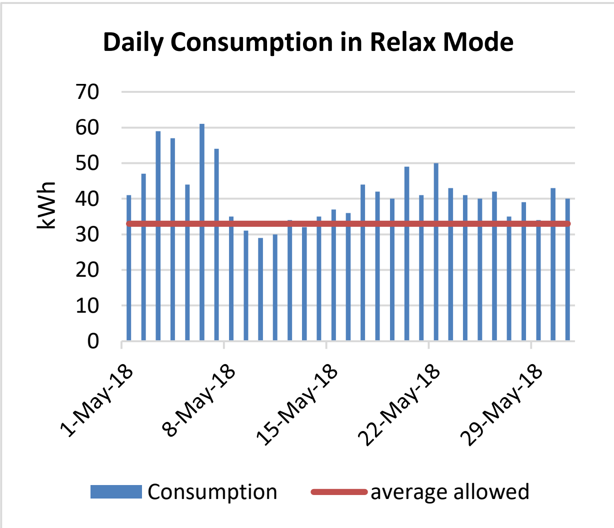

Figure 11(a): Daily consumption under Relax Mode

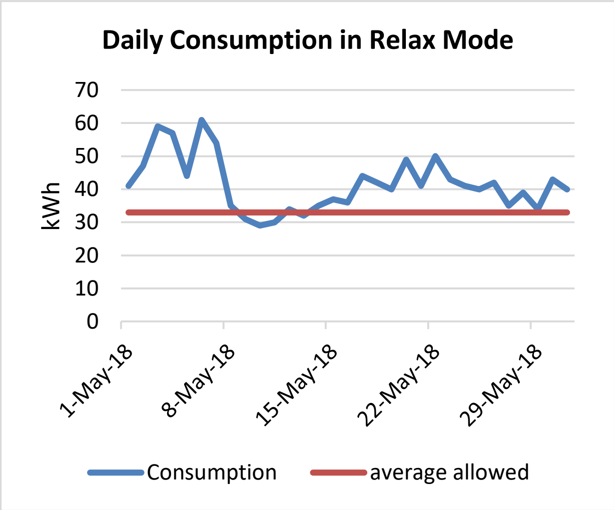

Figure 11(b): Daily consumption under Relax Mode

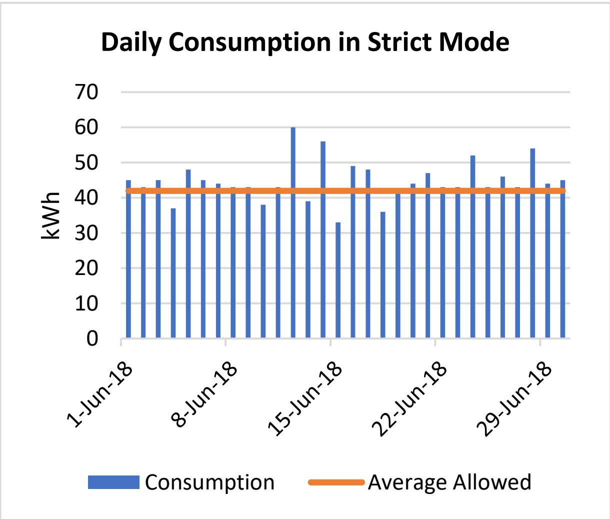

Figure 12(a): Daily consumption under Strict Mode

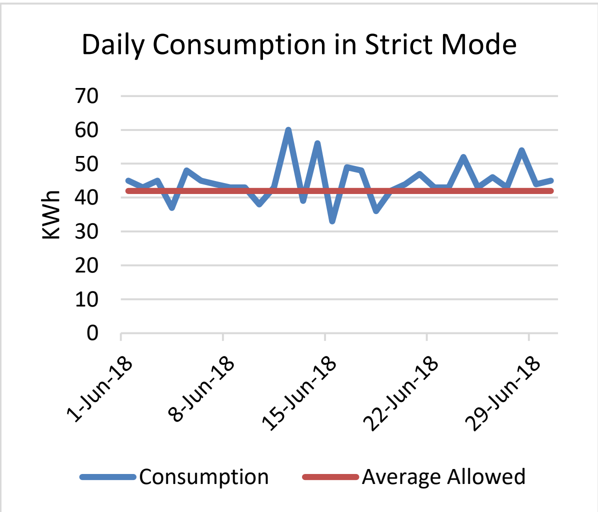

Figure 12(b): Daily consumption under Strict mode

Therefore, it can be concluded that more energy can be saved when the system is running under strict mode. Summary of the study is shown by a line graph and bar chart in figure 11 (a,b) and 12 (a,b), respectively.

Conclusion

In this era of technology, it is the most economical and efficient operation developed to facilitate the mankind. This project identifies that how consumers can manage their energy consumption by just using an application installed on their android devices. It is the most practical and accessible way to provide control of the loads by assigning their desired usage according to customer's budget.

Android Application has made it possible to select as many loads as you can and assign them as many units as per liking. This energy meter with addition to the app will keep user updated with the number of units consumed and calculating the expected bills. Thus letting the users know about their usage and help them reduce their monthly bills and energy consumption by better management of loads.

In order, not to compromise on the user privacy and comfort, two options for the controlling of the devices is included; (i) Strict mode and (ii) relax mode. In strict mode when the usage limit exceeds, the optional loads are automatically switched off, while in relax mode user gets notified about the usage in the form of a pop-up message.

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References

[1] Introduction to energy management in smart grids VDI-Guideline VDI 4602, page 3, Beuth Verlag, Berlin (2007)

[2] [2] "Brief History of Energy Management ..." Elahee, Mohammad Khalil (2019). Energy Management Research Journal. 2 (No. 1): 39–49.

[3] Overcoming electricity crisis in Pakistan: Renewable and Sustainable Energy Reviews (2017) 72:734-745 Gordhan Valasai, Mohammad Aslam Uqaili Hafeez Ur Rahman Memon; Saleem Raza Samoo

[4] A Survey on Demand Response Programs in Smart Grids: Pricing Methods and Optimization Algorithms John S. Vardakas; Nizar Zorba; Christos V. Verikoukis (2014)

[5] Attitude of Consumer towards Prepaid Meters (2009) Susheem Pandey

[6] Behavioral Change and Building Performance: Strategies for Significant, Persistent, and Measurable Institutional Change AK Wolfe EL Malone J Heerwagen J Dion April (2014)

[7] EEA Technical report No 5/2013 ''Achieving energy efficiency through behavior change''

[8] "A review of intervention studies aimed at household energy conservation" by Wokje Abrahamse, Linda Steg, Charles Vlek, Talib Rothengatter.

[9] "Understanding usage patterns of electric kettle and energy saving potential" (2015) D.M.Murray J.Liao L.Stankovic V.Stankovic

[10] One SizeDoes not fit all: Establishing the need for targeted eco-feedback Khosrowpour, Ardalan, Xie, Yimeng, Taylor, John, Hong, Yili. (2016)

[11] Kjeldskov, Jesper, Mikael B. Skov, Jeni Paay, and Rahuvaran Pathmanathan. "Using mobile phones to support sustainability: a field study of residential electricity consumption." (2012)

[12] Ueno, Tsuyoshi, Fuminori Sano, Osamu Saeki, and Kiichiro Tsuji. "Effectiveness of an energy-consumption information system on energy savings in residential houses based on monitored data." Applied Energy 83, no. 2 (2006): 166-183.

[13] Allera, S. V., and R. A. Sturges. "End-use monitoring with the ‘POEM ‘system." (1996): 208-212. (UK), and the National Grid Company plc. - Datum Solutions (UK)

[14] Ilatchiya, P., M. Sudhakaran, and R. Seyezhai. "Power Management and Control for Domestic Appliances using GSM and Android Application." International Journal of Emerging Technology in Computer Science & Electronics (IJETCSE) 21, no. 3 (2016): 44-49.

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