

Priority Based Load Management System Using Bluetooth Device

Noor Ullah, M.Idrees, Taimoor Mohsin, M.Usama, Imtiaz Ali Shah

Abstract— Energy crises nowadays is a big issue in the entire world and countries like Pakistan are affected more and severe short fall occurs in energy sector which affects economic growth and industrial development. In Pakistan fossil fuels like (furnace oil, natural gas, coal), hydel are the main sources of energy generation along with very limited renewable energy resources. Government have been planning various strategies to resolve the issue of energy crises and most of them are long term planning. In this research, a cost effective method of smart metering has been applied to narrow down the gap between supply and demand where electricity units can be calculated in peak and off peak hours separately and switch off unnecessary loads in peak hours, so by managing the different loads in peak and off peak hours we can overcome the energy crises and also a great impact will be seen in utility bills.

Index Terms— Smart meter, energy management system, Demand side management, Load Control, energy management controller, Smart pricing, consumer participation.

I. INTRODUCTION

Electrical energy is very important for every organization Industries, educational institutions, information technology, agriculture, and commercial markets. Any country that wants to improve living standards and grow its economy must secure a bulk energy supply. The uses of energy increases every month and year due to increase of new industries, homes, markets and new projects. As more countries rise out of poverty and develop their economies, energy demand rises correspondingly. Pakistan depends upon hydro, oil and gas resources to meet and fulfill energy requirements. The resources of gas and oil are not enough to quench energy thirst of a growing economy. As a result Pakistan has to import large quantity of oil from Middle East countries especially from Saudi Arabia. Total installed

capacity is around 24,000 MW with 54% and 48% share of public and private sector respectively. Country would need additional 10,000 MW by the year 2020, requiring an investment of approximately \$15 billion. The government has been issued various policies/ guidelines from time to time in the past at both federal and provincial levels. The government has issued licenses and NOCs to power generation companies of public and private sectors to generate additional electric power by using coal, hydro and renewable energy resources on emergency basis in order to eliminate electricity short fall. The total generation of Pakistan is 15,465 MW against demand of 21,500 MW, currently country is facing short fall of around 6,000 MW power in peak summer months whereas the power demand has been growing by 7-8% per annum resulting into load shedding of 6-12 hours. Hospitals, security and defense, water supply system, communication system, industries and educational institutions are worst affecting due to load shedding. [1] At the present government is trying his best to overcome the recent power short fall which has adversely impacted many departments and organizations as mention above it has also impacted on national economy. A number of initiatives are in progress to enhance generation capacity of the system, including power plants based on coal, hydel, gas and renewable resources, both in public as well as private sector. The government of Pakistan has recently approved power generation policy 2015 which provides attractive incentives for private investors. Extensive networks of high voltage transmission lines and grid stations are being developed to evacuate power from upcoming mega projects of coal and hydro to be located southern and northern part of country. Electricity situation could be improved by managing load of electricity. Scattering daily peak among the off-peak, load shedding and shortage can be reduced. Some office and household appliance can be kept switch off during peak. Use of this switch can reduce electricity consumptions of some households and official appliances. This is useful in saving a handful of energy and is thus useful for the overcoming of energy demands of the country. Due to power shortage in Pakistan the utilities departments (WAPDA, KESC etc) managed the load demand by load shedding. The load shedding of power is actually switching off the load feeder for some time, the feeder can be switched on again after some time. In 132 kV to 11 kV substations, three phase supply is incoming in 132 kV lines which can be step down through power transformers into medium voltage 11 kV, this 11 kV supply is provided to outgoing feeders through a control panel or medium voltage (MV) panel.

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In the control panel, circuit breaker, protection relay, ampere meter, energy meter and a control circuit for on off are installed. There are two push buttons in the control panel; these are on push button and off push button, which are used for switching on/off the 11 kV panel or feeder. Oil or vacuum circuit breakers are used in 11 kV feeders. Over current, short circuit and phase sequence failure relays are commonly used in these control panels. These control panels are operated manually by a substation operator. The energy meters in the control panels are connected to potential transformer (PT) for voltage measuring and current transformer (CT) for current measuring. From these signals of voltage and current the energy meter measures kilo watt hours (kWh), kilo watt (kW) and kilo volt ampere reactive hours (KVARh).

The 11 kV feeders are then transmitting power to the consumers through distribution transformers 11 kV/ 440V. The power utility company/suppliers have installed energy meters before the consumer loads, which record the consumed energy units (kWh). The energy consumers pay bills according to energy consumed on monthly basis. In Pakistan the energy demand is increases in morning and evening in summer season. The government has introduced peak and off peak hours to meet the energy demand and to aware the consumers to minimize the load in peak hours. The energy tariffs are higher for peak hour load than off peak hour load. But this function is not available in the traditional electromagnetic and rotating disc type energy meters. The modern digital microprocessor based energy meter records the energy consumed in peak hour and off peak hour separately. PESCO has introduced energy charges only thirteen Rupees per kilowatt-hour with no demand charge between 10:00 p.m. and 6:00 p.m., but increase to nineteen Rupees per kilowatt-hour with a demand charge between 6:00 p.m. and 10:00 p.m. [1]. Thus the consumers will avoid using maximum load during peak hours, but still some consumers don't avoid using maximum load in peak hours. The designed project "priority based energy monitoring and auto load shedding" will switch off low priority load in peak hours to minimize the load. Example of high and low priority equipment's mentioned in table 2.1. [5][6]

CURRENT SCENARIO OF SMART ENERGY METERS

There are different types of smart energy meters recently presented for residential energy consumers. Some of them are wired and some are wireless based (GSM, Wi-Fi etc.) energy meters, which calculate the consumed energy and prices. The consumed energy units can be sent daily and monthly through GSM to mobile phone of the consumer or data monitoring system/ database system of the utility. The smart meter also sent an alert message to the consumer to avoid extra load, or take other action to minimize load and energy units from over billing. In Wi-Fi based smart meters, power system parameters energy units are calculated in microcontroller and sends these data over Wi-Fi through the home's Wi-Fi wireless router to the database or monitoring station. A Base station is based on an application which extracts the data from TCP/IP protocol, sent by the smart meters. The entire TCP/IP communication system protocol is a standard implemented by almost all the communication

systems. It provides a communication link between smart meter and base station based on IP addresses. Some systems were designed to combine capabilities for web-based control and monitoring control. The purpose of the internet based control and monitoring system is to allow users to check and control the energy data via a home URL with a GUI (graphical user interface) [3] [4]. ON/OFF: depends on load limit, HP load will remain in ON condition if the loads under limit, HP load will switch OFF if the load exceeds the limit.

Table I. Different Types of Loads

Type of Electric Load	Priority level	Status in peak hours
Lighting-a	Important	ON
Electric Fans-a	Important	ON
Computers-a	Important	ON
Lighting-b	High Priority	ON/OFF
Electric Fans-b	High Priority	ON/OFF
Computers-b	High Priority	ON/OFF
Microwave Oven	High Priority	ON/OFF
Water Pump	Low Priority	OFF
Motors (grinder, cutter etc.)	Low Priority	OFF
Computers	Low Priority	OFF
Air Conditioners	Low Priority	OFF
Others	Low Priority	OFF

II. PROPOSED METHODOLOGY

The aim of our proposed project is to reduce or eliminate planned and unplanned load shedding in Pakistan via switching off the unnecessary equipment's in peak hours. There are many smart meters developed recently, many smart meters have function of energy calculation, billing and sending data to monitory station through wired and wireless communication. But these smart energy meters are not helpful to reduced load shedding and meet the energy demand.

The load connected to supply load are divided into three sections, i.e. high priority (H.P), low priority (L.P) and important/necessary load through triacs (switch). The triacs are used to switch on and off high priority (H.P) and low priority (L.P) load sections during peak hour. The peak hour can be adjusted via Bluetooth device connected to the smart meter. The switching on/off L.P and H.P load function can be enabled and disabled commands, these commands can be sent to energy meter through mobile phone with Android software. Current Transformer (CT) in series of line of load and Potential Transformer (PT) are connected in parallel of the load and supply source. The current signal needs to be converted to a voltage signal with a burden resistor. Some current transformers (CT) have built in burden resistor, theses current transformers (CT) will provide a voltage signal, and there is no need to connect an external resistor. From PT and CT signals microcontroller measures voltage, current and power. Alternating current and voltage signals are shifted into DC offset signal.



These signals are now analogue not alternating current signal, the magnitude of voltage current signals varies but do not change the direction.

In Arduino UNO ATMEGA 328 controller there are built in analogue to digital converter which converts these analogue voltage and current signals into digital and then provided to micro controller.

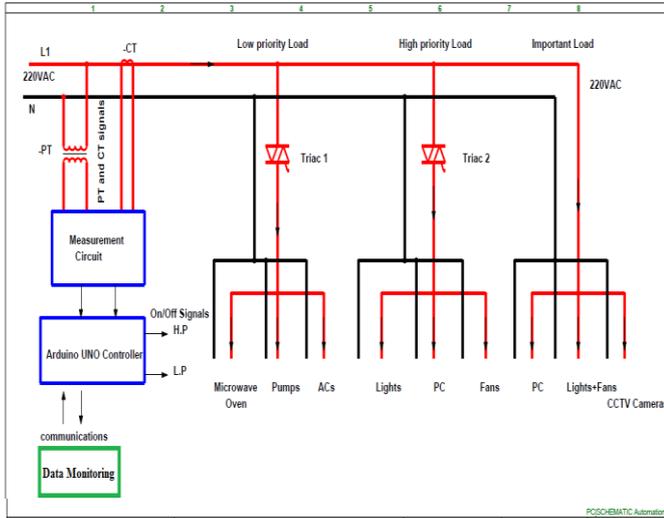


Figure 1: Circuit diagram of the proposed system

Using C++ programming in Arduino IDE software, the voltage current, power and energy have been calculated. These values are also shown on LCD 4 x 20 character display. According to programming in microcontroller, the H.P and L.P load will switch on and off through power triacs. A 5VDC source is provided to controller for operation. To connect a CT sensor to an Arduino, the output signal from the CT sensor needs to be conditioned so it meets the input requirements of the Arduino analog inputs, i.e. a positive voltage between 0V and the ADC reference voltage (05 VDC). This can be achieved with the following circuit which consists of two main parts: The current transformers (CT) and burden resistor, the biasing voltage divider (R1 & R2). CT wires are connected to ground and other is given to voltage divider, the voltage would vary from positive to negative with respect to ground. However, the Arduino analog inputs require a *positive* voltage. By connecting the CT lead we connected to ground, to a source at half the supply voltage instead, the CT output voltage will now swing above and below 2.5 V thus remaining positive. Resistors R1 & R2 in the circuit diagram above are a voltage divider that provides the 2.5 V source. Capacitor C1 has a low *reactance* provides a path for the alternating current to bypass the resistor, a value of 10 μF is suitable [11]. An AC voltage measurement is needed to calculate real power, apparent power and power factor. This measurement can be made safely (requiring no high voltage work) by using an AC to AC power adaptor. The transformer in the adapter provides isolation from the high voltage mains.

As in the case of current measurement with a CT sensor, the main objective for the signal conditioning electronics detailed below, is to condition the output of the AC power adaptor so it meets the requirements of the Arduino analog inputs: a positive voltage between 0V and the ADC reference voltage. The first thing important to know is the

voltage rating of potential transformer (PT). A 220vac to 6vac potential transformer (PT) is for voltage measurement. The output voltage from the potential transformer is sinusoidal waveform. We have a 6V (RMS) power adapter the positive voltage peak be 8.4 V, the negative peak 8.4 V.

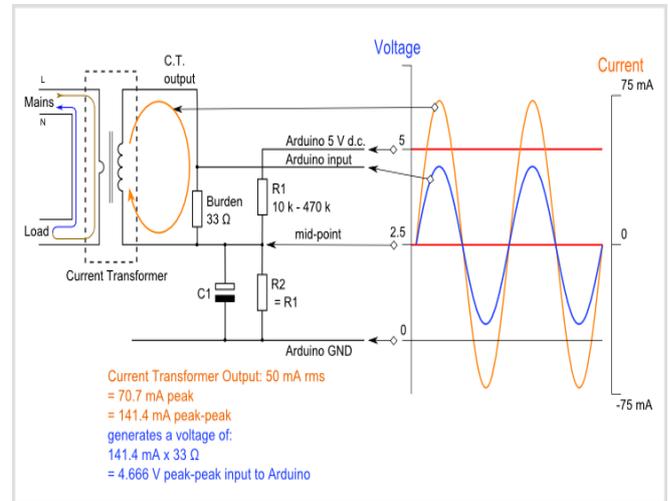


Figure 2: Current measurement circuit

The signal conditioning electronics needs to convert the output of the adapter to a waveform that has a positive peak that's less than 5V and a negative peak that is more than 0V. So we need to shift the waveform and add an offset so there is no negative component.

The AC voltage waveform can be shifted into DC offset voltage using a voltage divider connected across the potential transformer terminals, and the offset can be added using a voltage source created by another voltage divider connected across the Arduino's power supply (+5 VDC). Resistors R1 and R2 form a voltage divider that scales down the power adapter AC voltage. Resistors R3 and R4 provide the voltage bias. Capacitor C1 provides a low impedance path to ground for the AC signal. The value is not critical; the value between 1 μF and 10 μF will be satisfactory. R1 and R2 need to be chosen to give a peak-voltage-output of ~1V. For an AC-AC adapter with a 9V RMS output, a resistor combination of 10k for R1 and 100k for R2 would be suitable:

$$V_{out} = \frac{R_1}{R_1 + R_2} \cdot V_{in} \quad (1)$$

Peak voltage output = $10k / (10k + 100k) \times 8.4V = 0.76 V$,
The voltage bias provided by R3 and R4 should be half of the Arduino supply voltage. As such, R3 and R4 need to be of equal resistance. If the Arduino is running at 5V the resultant waveform has a positive peak of $2.5V + 0.76V = 3.26V$ and negative peak of 1.35V satisfying the Arduino analog input voltage requirements. This also leaves some "headroom" to minimize the risk of over or under voltage. [11]

III. HARDWARE DESCRIPTION

Arduino Uno is a microcontroller board based on the ATmega 328 P. It has fourteen digital input/output pins, six analog inputs, a 16 MHz quartz crystal for clock speed, a USB connection for communication and program uploading, a 5 VDC power supply pin and a reset button. It contains everything needed to support the microcontroller; simply connect it to a computer with a USB cable or connect it to +5 VDC to get started. [13]

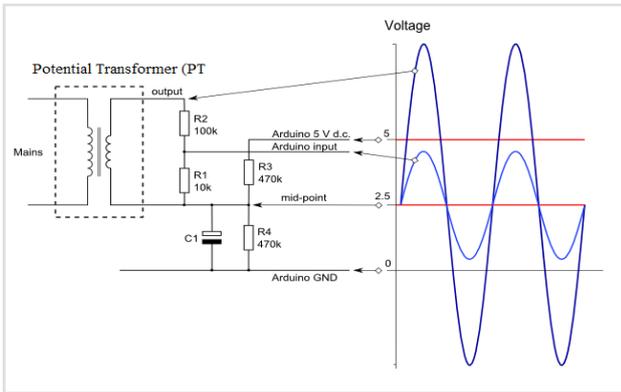


Figure 3: Voltage measurement circuit

A liquid-crystal display (LCD) is a flat panel display, or video display, electronic visual display that uses the light modulating properties of liquid crystals. 20 x 4 means that 20 characters can be displayed in each of the 4 rows of the 20 x 4 LCD, thus a total of 80 characters can be displayed at any instance of time. [12][13]

Display is used to show the power system parameters voltage, current, power, energy and time.

The Triac is a solid state three terminals semiconductor device belongs to thyristor family. The Triac can be used for switching and controlling current. The Triac is an ideal device to use for AC switching applications because it can control the current flow over both positive and negative half cycles of an alternating cycle [14][15]. BTA 41 triacs are used in this circuit, having current 41 ampere and voltage rating of 600 V peak. MOC 3023 is an opto-triac used for switching on/off of the Triac.

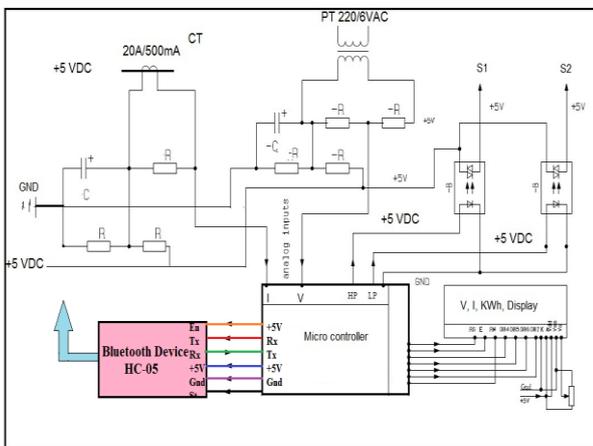


Figure 4: Wiring diagram of energy monitoring and priority based load shedding project

In this project, HC-05 Bluetooth device is used for communication between consumer and energy meter. The consumer can send the commands to the controller for adjusting energy meter parameter i.e. load limit, peak hour timing and enable/disable function. The consumers receive data from energy meter via this Bluetooth device. This module can be set as a transmitter or receiver, transmitter can pair with receiver, receiver can pair with computers and cell phone's Bluetooth, receiver and receiver or transmitter and transmitter can't communication between each other.

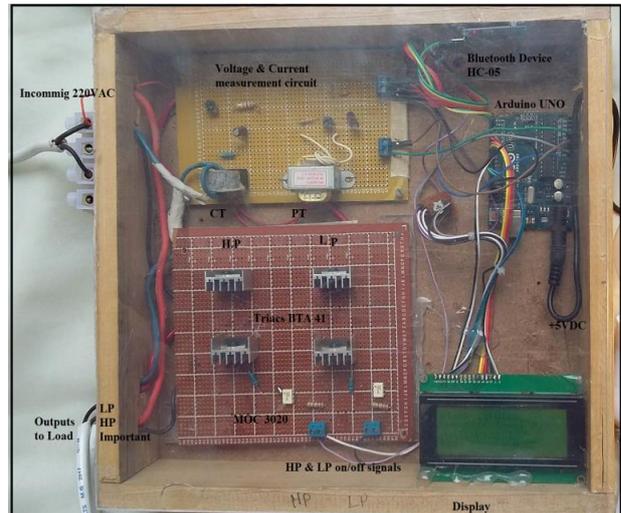


Figure 5: Project hardware of smart energy meter

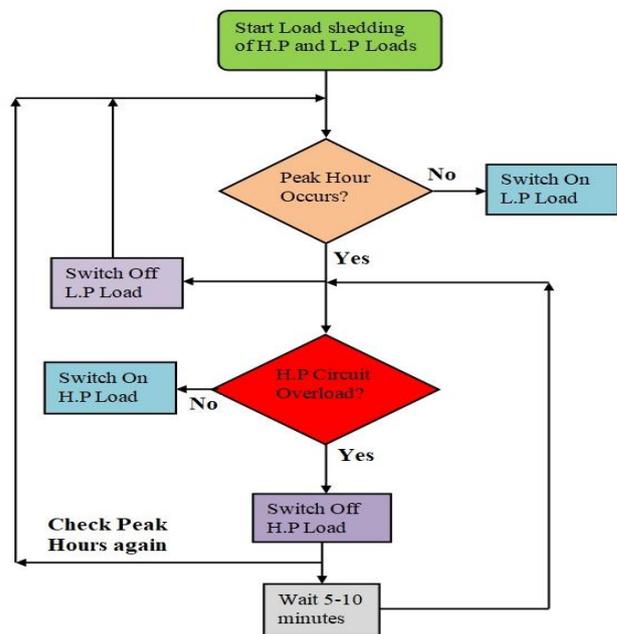


Figure 6: Flow chart of current system approach

The data is showing on LCD of the smart meter and also is showing on computer or consumer mobile phone via Bluetooth. Power system parameters voltage, current, power, energy and time are shown on LCD 4 X 20 character display. The consumer can check the consumed energy unit any time.

The consumer can send the commands to the controller for adjusting energy meter parameter i.e. load limit, peak hour timing and enable/disable function via HC-05 Bluetooth device used for communication. Displayed data can be shown in fig

When the peak hour starts (18:00 -22:00 here in this project), the low priority load disconnect to reduce load in peak hours. But the high priority load will disconnect only when it exceeds load limit peak hours. The consumer can adjust this limit via Bluetooth.

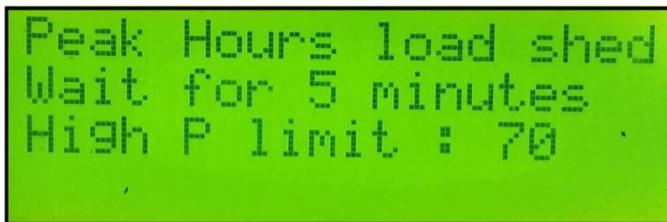
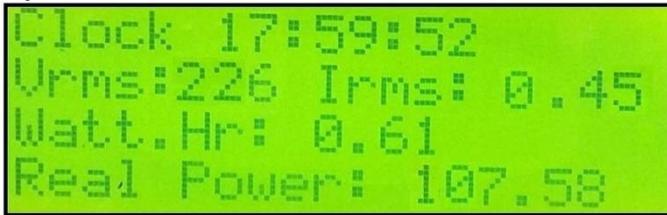


Figure 7: LCD Display shows the value of V, I, P, and load peaks

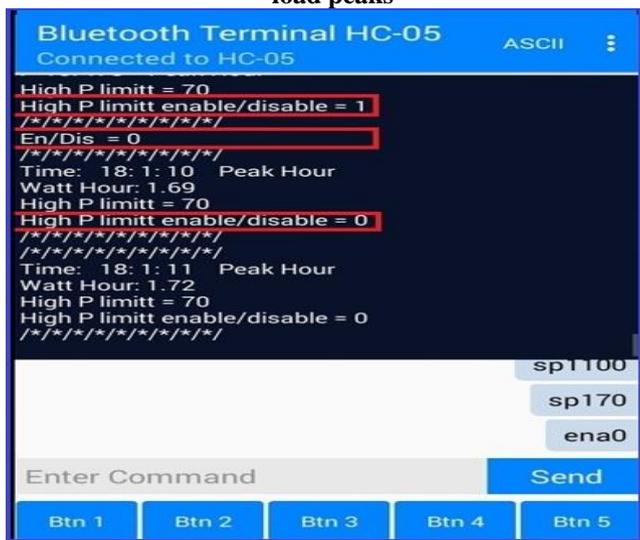


Figure 8: Energy meter data and status

When high priority load disconnected then will connect again after some time about 5 minutes. After 5 minutes duration, the high priority load will connect again if the load limit not exceed then will remain on otherwise will trip. The consumer can check the status of energy meter and load parameters via wireless communication system i.e. Mobile phone or computer etc.

Some screen shot of consumer’s mobile phone are taken and given below. Two incandescent lamp of 100 watt are connect to the load, one lamp is connected to the low priority (L.P) load and second one is connected to the high priority (H.P) load. Both lamps were switch ON in off peak hours, as peak hour reached one lamp of LP circuit switched off. A 100 watt load limit was set already, which was

change to 70 watt. Sp1100 means set point 1 is 100 watt, sp170 means set point 1 is 70 watt for H.P load limit. Ena0 means disable the above functions, ena1 means enable the above functions. The smart meter sends data after every second.

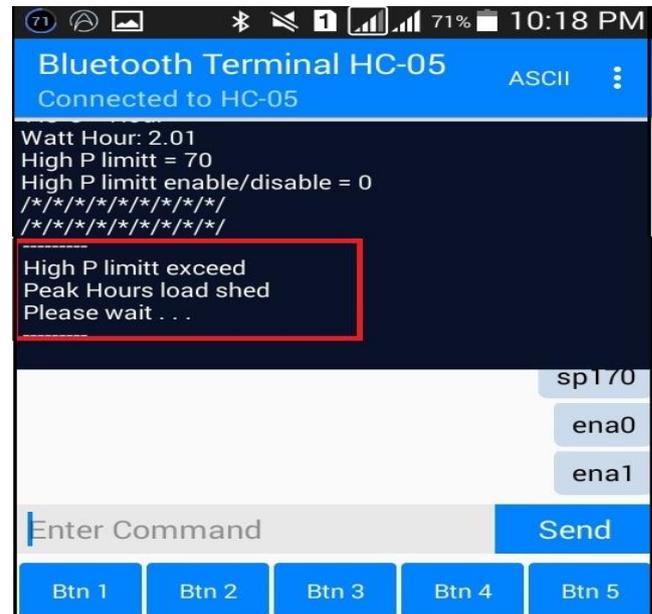


Figure 9: HP load shed in peak hour as limit exceeded

IV. TRADITIONAL ENERGY METERS AND BILLING SYSTEM

The present electricity billing system present in Pakistan have many problems i.e. energy thefts, payment collection, waste of time paper for bills printing, electricity bill distribution. These meters can calculate only the numbers of consumed energy units (kWh) and cannot calculate consumed energy units of peak and off peak hour separately. Due to these problems traditional electricity billing system is unreliable, costly and slow. These meters cannot calculate the other parameters of power system, voltage, current and record of load profile and have no wired or wireless communication system with utility monitoring system and consumer GUI system. Thus the electricity billing system in smart meters have overcome these problems. [6] [9].The traditional energy meters do not meet the requirement of the peak hour’s demand. Example of energy billing system of the traditional energy meter Suppose the total consumed energy unit of a monthly bill of a consumer is 350 kWh, the pricing system is as:

Table II. Energy consumption vs Cost rate

Energy consumption	Unit Charges
0 – 100 kWh	6 Rs/kWh
100 – 300 kWh	8 Rs/kWh
Above 300 kWh	11 Rs/kWh

The total energy cost will be:
 $(100 \times 6) + (200 \times 8) + (50 \times 11) = 600 + 1600 + 550 = 2750$

Tax (17 %) 2750 x 0.17 = 467
 Total Bill = 2750 + 467 = 3, 217 Rupees/month

V. DIGITAL ENERGY METER

The digital energy meters have functions of calculating energy units consumed in peak hours and off peak hours separately and they have different energy cost for off-peak and peak hours. If the same amount of electricity (350 units) is consumed by newly introduced digital energy meter then the monthly billing is calculated as

Off peak hours unit= 300 kWh, and peak hour unit = 50 kWh

The total amount is:

Off peak hours:
 (100 x 6)+(200 x 8) + (0 x 11) = 600 + 1600 = 2200
 Peak hour: 50 x 20 = 1000
 Tax (17 %) 3200 x 0.17 = 544
 Total Bill = 3200 + 544 = 3, 744 Rupees/month
 Unit prices increases 16.5 %
 Tax increase 17%
 Total Bill prices increased 17.5 %

VI. PROPOSED SYSTEM APPROACH

Now after applying our Priority Based Auto Load Shedding approach, we have successfully reduced the energy cost that can be seen below.

Off peak hours unit= 230 kWh, and peak hour unit = 20 kWh

The total amount is

Off peak 100 x 6 + 130 x 8 + 0 x 11 = 600 + 1040 = 1640
 Peak hour 20 x 20 = 400
 Total energy price = 1640 + 400 = 2040
 Tax (17 %) 2040 x 0.17 = 347
 Total Bill = 1640 + 347 = 2, 387 Rupees/month
 Unit prices reduced up to 28.3 %, Tax reduced up to 37.2 %
 Total Bill prices decreased 35 %
 If the use of electricity in the country is reduced up to 28.3 % by using this project then the shortfall will be eliminated.

Currently the total demand of Energy in Pakistan is

Demand = 21,500 MW Generation = 15,500 MW

Short fall = 21,500 – 15, 500 = 6,000 MW

If the usage of Electricity reduced 28.3 % = 21,500 x 0.283 = 6,084

6,084 – 6,000 = 84 MW

This 84 MW generation will become extra, however it is not possible because some areas and organizations are very sensitive, where electricity is required 24 hours and load shedding free feeders. These load shedding free feeders are supply electricity to airports, hospitals, IT and telecom system, parliament and defense areas. If the power utilization of these areas are considered to be 30 -40 %, then shortfall will remain up to 2,000 - 2,500 MW which can be

control in peak season by supply alternative energy resources i.e. solar, wind and biomass.

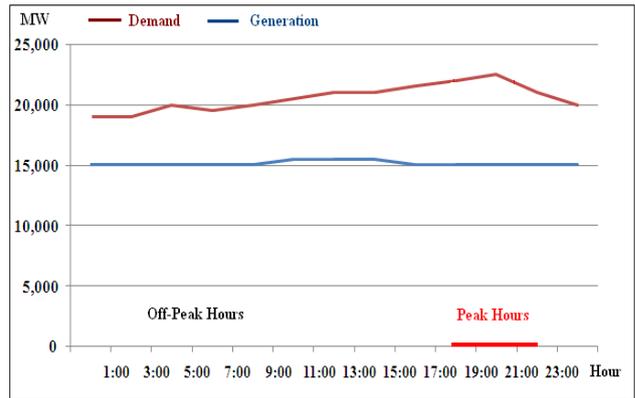


Figure 10: Current scenario of Pakistan

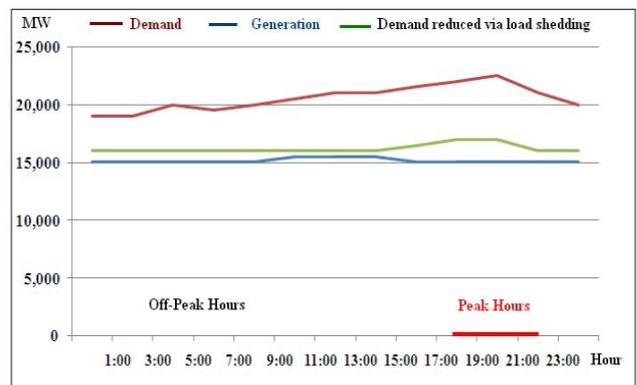


Figure 11: Load reduction by applying proposed approach

VII. CONCLUSION

The aim of the designed project is to minimize load on customer side during peak hours and off peak hours. Due to these energy meter the energy demand will be reduced in peak summer season when power shortfall reaches up to 6,000 MW. The planned and unplanned load shedding will also reduce.

The usage of uninterruptable power supply (UPS) will also reduce which is also a cause of power losses because the efficiency of UPS is not greater than 70 %. It means 5 KVA UPS will use power of about 5 kW when connected into power supply but will provide only 3- 3.5 kW during load shedding period. The efficiency of UPS will degrade as battery charging degrade, a faulty battery will consumed more power than it capacity and provide minimum or small amount of energy. The design energy meter has functions of calculating energy units consumed in peak hours and off peak hours separately. It can control the usage of energy in peak hours.

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