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SMART GRID INFRASTRUCTURE USING HYBID NETWORK ARCHITECTURE

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Abstract:--The Smart Grid represents 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; with smooth integration of renewable and alternative energy through automated control and modern communication technologies. The proposed system aims at well planned distribution networks by effective load management with two ways communication between the user and utility using Hybrid Network Architecture (HNA).The HNA consists of a wired infrastructure, a power line communications (PLC) and the wireless communication comprises of Global System for Mobile communication (GSM).

I. INTRODUCTION

The growing urbanization and industrialization has led to an increased need for more effective power systems to fulfill the needs of various consumers. There is an increasing interest in applying technology to protect and control electric utilities. At present many power utilities are being faced with the reality of conventional centralized control systems limitations, as they can greatly degrade due to the complexity of dealing with network events that would require enormous amount of data to properly manage them. This in turn has led to the development of smart grids. A smart grid is a modern electric power grid infrastructure for improved efficiency, reliability and safety, with smooth integration of renewable and alternate energy sources through automated control and modern communication technologies. The main objective of the project is to design well planned electric distribution networks by effective load management with two way communication between the user and the utility. In the smart grid, reliable and real time information becomes a key factor for delivery of power from the generating units to end users. Also, smart grid enabled new network management strategies provide their effective grid integration in distributed generation (DG) for demand side management (DSM) and energy storage for DG load balancing. According to variety of researches which shows that more active participation in the market by the demand side could have significant benefits for the whole market.

In particular

- Reduction in the energy cost for consumers who shift their demand from periods of high prices to periods of lower prices.
- Reduction in the overall generation cost of the system because this demand shifting will flatten the overall demand profile.
- Even consumers who do not adjust their demand will make a profit if this reduction in cost translates into a reduction in prices.
- Avoiding price spikes (i.e., very large increases in price over short periods of time).
- Reduction in the ability of generating companies to exert market power.

Integrated systems avoid severe economic losses, resulting from unexpected failures, and improve system reliability and maintainability. There are several hardware and software solutions for implementing smart grids for the most varied scenarios. Integrated systems can consist of a number of devices connected to a computer. According to survey, the PLC application in smart grid power consumption field, demonstrate the favourable prospect. The smart grid implementation using HNA uses both wired and wireless infrastructure. The wired communication consists of Power line communication (PLC) and the wireless communication comprises of Global system for mobile communication (GSM).

This system is subdivided into two subsystems:

a) DAS-Data acquisition system
b) SCS-Supervisory controller system

The data interchange, among the subsystems and among the modules, is based on a hybrid communication.

II. DESCRIPTION OF THE PROPOSED MODEL

The proposed system is shown in the figures 1&2. It is subdivided in two subsystems: a) data acquisition DAS b) supervisory controller— SCS. The data interchange, among the subsystems and among the modules, is based on a hybrid communication i.e. wired using PLC Power line communication and wireless using GSM module. In data acquisition system, the electrical data (voltage, current) is collected when consumer switches the load using potential transformer and current sensor. The output of the voltage transformer is proportional to the voltage across the load and output of current transformer is proportional to the current through the load. This data is sent to PIC16F877A microcontroller as an input via port A. Port A converts analog data received into digital data suitable for microcontroller to process. Microcontroller read this data then calculates power and power factor of respective load which is displayed on 16*2 LCD and is sent to the another sub system through PLC modem. In supervisory controller, the data received by PLC modem is sent to another PIC16F877A microcontroller as an input through port C. This microcontroller is programmed to check whether power consumed and power factor are within prescribed limits. If cross checked data is not within the limit, then a message is sent to consumers' mobile through GSM module. At the same time the message is also displayed on computer used at the utility premises with the help of serial communication. This data further helps utility people regarding consumer's energy usage patterns. On receiving message, consumer should compare it with charts provided to him by utility and anticipate his penalty for using over load or low power factor equipments .To overcome this penalty, consumer should shift his load to renewable means like solar or wind power. This system provides instant communication between the utility and the beneficiary which helps to reduce wastage of energy and encourages use of renewable energy sources. The messages sent to the consumer are:

- Overload- When the power consumption crosses the maximum limit
- Low power factor- When the power factor decreases than the minimum specified power factor.

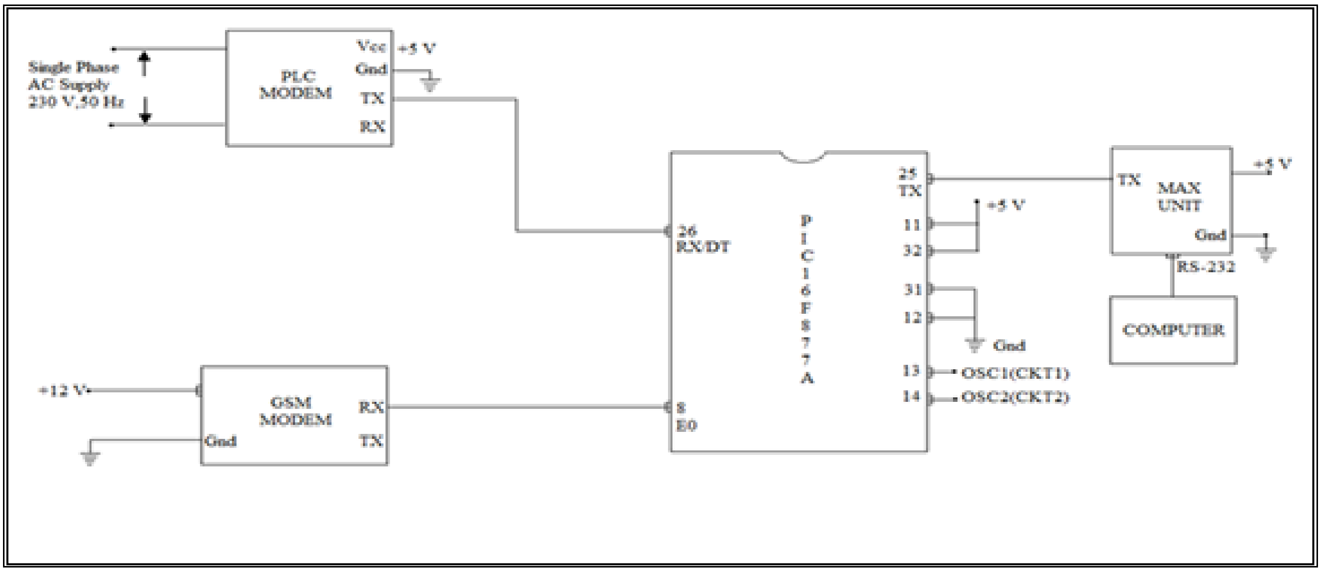

Figure 1. Receiver (utility) circuit diagram

2.1. Hardware components used in the model:

Microcontroller PIC 16F877A, PLC Modem, Power Transformer, Current sensor, LCD, MAX232C, RS232, Load (Inductive, Resistive), power supply, PCB, Misc. (resistors, capacitors, wires, etc).

2.2. Software requirements:

- **MPLAB**: MPLAB® X IDE is a software program that runs on a PC (Windows®, Mac OS®, and Linux®) to develop applications for Microchip microcontrollers and digital signal controllers. It is called an Integrated Development Environment (IDE), because it provides a single integrated "environment" to develop code for embedded microcontrollers.
- **Embedded C (coding language):** Embedded C is a set of language extensions for the C Programming language by the C Standards committee to address commonality issues that exist between C extensions for different embedded systems. Historically, embedded C programming requires nonstandard extensions to the

C language in order to support exotic features such as fixed-point arithmetic, multiple distinct memory banks, and basic I/O operations.

- **Hyper Terminal:** HyperTerminal is a program that you can use to connect to other computers, Telnet sites, and bulletin board systems (BBSs), online services, and host computers, using your modem, a null modem cable or Ethernet connection.

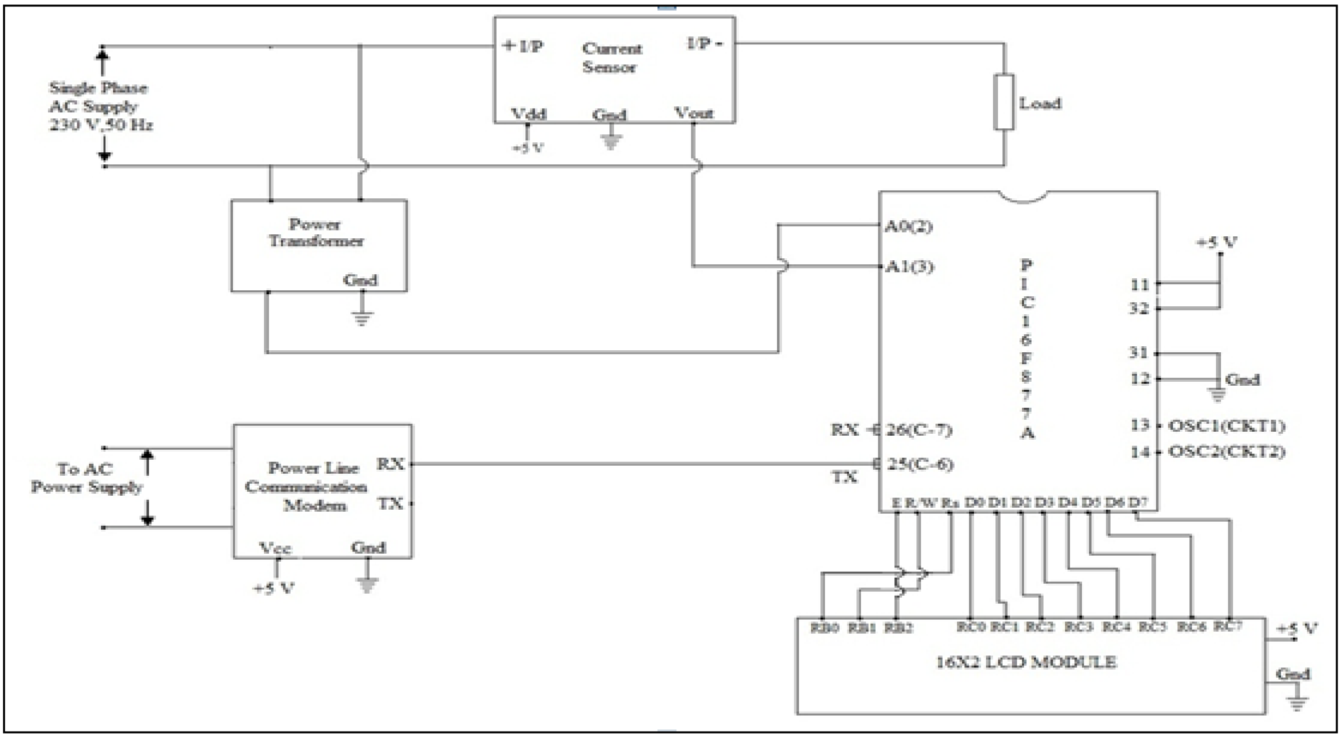

Figure 2. Transmitter (consumer side) circuit diagram

2.3. Data Acquisition System:

2.3.1 Current sensor:

A current sensor is a device that detects electrical current (AC or DC) in a wire, and generates a signal proportional to it. The generated signal could be analog voltage or current or even digital output. It can be then utilized to display the measured current in an ammeter or can be stored for further analysis in a data acquisition system or can be utilized for control purpose. Hall Effect current sensor is a type of current sensor which is based on phenomenon of Hall Effect discovered by Edwin Hall in 1879. Hall Effect current sensors can measure all types of current signals i.e. AC, DC or pulsating current. The Hall Effect is the production of a voltage difference (the Hall voltage) across an electrical conductor, transverse to an electric current in the conductor and a magnetic field perpendicular to the current.

2.3.2 Power transformer:

The 230 V, 50 Hz is step downed using voltage transformer and current sensor is used to extract the waveforms of current. The output of the voltage transformer is proportional to the voltage across the load and output of current transformer is proportional to the current through the load. These waveforms are fed to Voltage Comparators constructed using LM317A op-amp. Since it is a zero crossing detector, its output changes during zero crossing of the current and voltage waveforms. A zero crossing detector is used as analog circuit to achieve the converting process of the current and voltage it consists of diode Rectifier Bridge which converts ac to dc and a voltage comparator. These outputs are fed to the PIC16F877A which does the further power factor calculations.

2.4. Supervisory Control System:

2.4.1 PIC16F877A Microcontroller:

PIC16F877A is powerful (200 nanosecond instruction execution) yet easy-to-program (only 35 single word instructions) CMOS FLASH-based 8-bit microcontroller packs with Microchip's powerful PIC® architecture into a 40 pin package. The PIC microcontroller architecture is based on a modified Harvard RISC (Reduced Instruction Set Computer). It is designed with 8K bytes of flash programmable and Electrically Erasable Programmable Read-Only Memory (EEPROM). The on-chip Flash allows the program memory to be reprogrammed in-system or by a conventional non-volatile memory programmer. By combining a versatile 8-bit CPU with Flash on a monolithic chip, the PIC16F877A is a powerful microcomputer which provides a highly-flexible and cost-effective solution to many embedded control applications. The PIC16F877A features 256 bytes of EEPROM data memory, self-programming, an ICD, 2 Comparators, 8 channels of 10-bit Analog-to-Digital (A/D) converter, 2 capture/compare/PWM functions, the synchronous serial port can be configured as either 3-wire Serial Peripheral Interface (SPI™) or the 2-wire Inter-Integrated Circuit (I²C™) bus and a Universal Asynchronous Receiver Transmitter (USART). All of these features make the PIC16F877A ideal for more advanced level A/D applications in automotive, industrial, appliances and consumer applications.

2.4.2 LCD

LCD (Liquid Crystal Display) screen is an electronic display module and find a wide range of applications. A 16x2 LCD display is very basic module and is very commonly used in various devices and circuits. These modules are preferred over seven segments and other multi segment LEDs. The reasons being: LCDs are economical; easily programmable; have no limitation of displaying special & even custom characters (unlike in seven segments), animations and so on. A 16x2 LCD means it can display 16 characters per line and there are 2 such lines. In this LCD each character is displayed in 5x7 pixel matrix. This LCD has two registers, namely, Command and Data. The command register stores the command instructions given to the LCD. A command is an instruction given to LCD to do a predefined task like initializing it, clearing its screen, setting the cursor position, controlling display etc. The data register stores the data to be displayed on the LCD. The data is the ASCII value of the character to be displayed on the LCD.

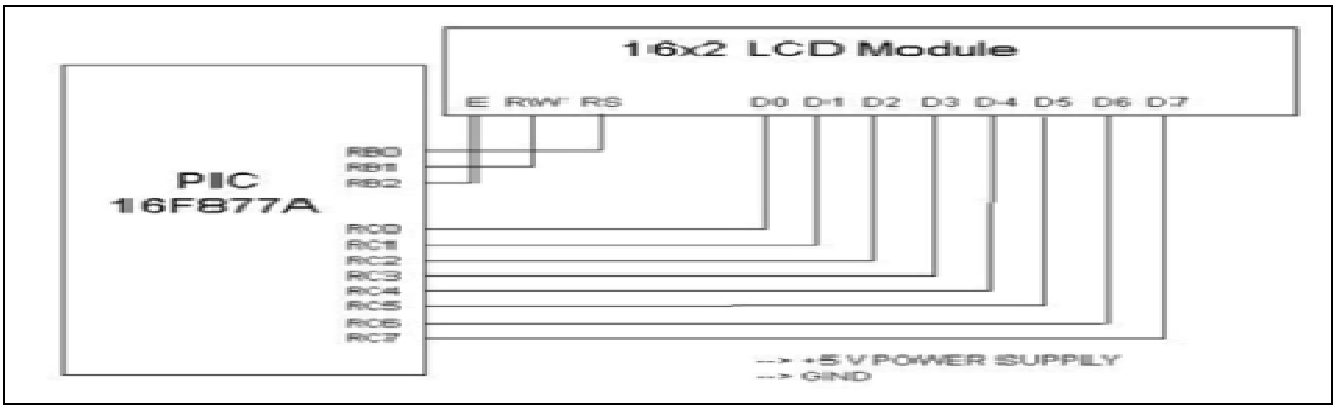

Figure 3. Interfacing of LCD with PIC16F877A

2.5. Communication System:

2.5.1 PLC modem:

Power line modem is useful to send and receive serial data over existing AC mains power lines of the building. It has high immunity to electrical noise persistence in the power line and built in error checking so it never gives out corrupt data. The modem is in form of a ready to use circuit module, which is capable of providing 9600 baud rate low rate bi-directional data communication. Due to its small size it can be integrated into and become part of the user's power line data communication system. The module provides bi-directional half-duplex communication over the mains of any voltage up to 250V AC and for frequency 50 Hz or 60 Hz. Half Duplex communication means it can either transmit or receive data at a time but not both at same time. Normally module is in receiving mode all the time listening to incoming communication on the power line. Once your application gives serial data to transmit on its RX-IN pin, it switches over to transmit and transmits the data through power line. Once transmit process is complete it switches back to receive mode. The transmission of data is indicated by Red LED. The reception of data by modem is indicated by Green LED which is on TX out pin itself. Data communication of the modules is transparent to user's data terminals and protocol independent; as a result, multiple units can be connected to the mains without affecting the operation of the others. There is no hassle of building interface circuits. Interface to user's data devices is a simple data-in and data-out serial link.

Table .1 Interfacing Pin Details

Pin	Pin Name	Details
RX-IN	Receive Input	Input serial data of 5V logic level Usually connected to TXD pin of microcontrollers.
TX-OUT	Transmit Output	Output serial data of 5V logic level Usually connected to RXD pin of microcontrollers.
+5V	Power Supply	Regulated 5V supply input.
GND	Ground	Ground level of power supply. Must be common ground with microcontroller.

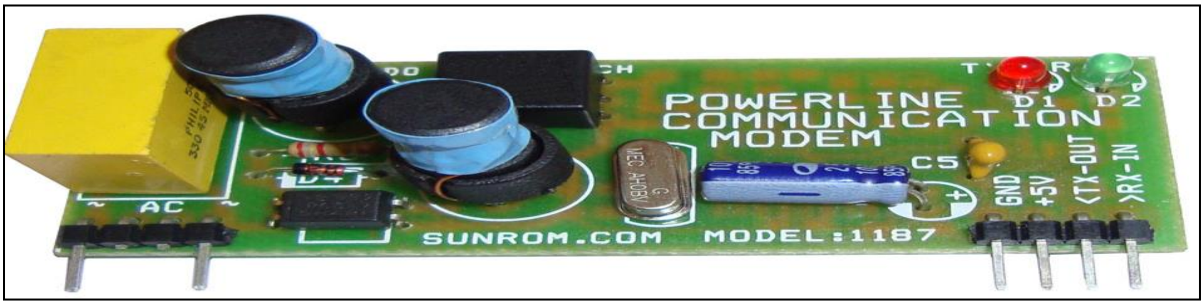

Fig 4. PLC modem

2.5.2 RS232 & MAX232:

Computer uses serial communication to communicate with PIC16F17A. To allow compatibility among data communication equipment made by various manufacturers, an interfacing standard called RS 232 was set by electronics industries association (EIA) in 1960. Since the standard was set long before the advent of TTL logic family, its input and output voltage levels are not TTL compatible. In RS232,a 1 is represented by -3 to -25 V, while a 0 bit is +3 to +25 V, making -3 to +3 undefined. For this reason, to connect any RS232 to a microcontroller system we must use voltage converters such as MAX232 to convert the TTL logic levels to the RS232 voltage levels, and vice versa. MAX232 IC chips are commonly referred to as line drivers.

2.5.3 GSM module:

GSM (Global System for Mobile Communications, originally Groupe Spécial Mobile), is a standard developed by the European Telecommunications Standards Institute (ETSI) to describe protocols for second generation (2G) digital cellular networks used by mobile phones. A GSM modem is a specialized type of modem which accepts a SIM card, and operates over a subscription to a mobile operator, just like a mobile phone. From the mobile operator perspective, a GSM modem looks just like a mobile phone.

M660 GSM module: With the ultra-compact design, M660 is intended to be used in a wide range of applications, including industrial and consumer devices. M660 is a GSM/GPRS module with EDGE of downlink. It features with voice, SMS, and data services.

Figure .5 M660 GSM Module

2.6. Power Supply & Load

2.6.1 Power Supply:

Regulated power supplies are commonly used in engineering projects. Power supply is food of any circuit. The circuit consists of a 9V step down transformer, voltage regulator IC (7805) and some capacitors, used for filtering purpose. The step down transformer, down-converts the high voltage AC input (230V, 50 Hz) to a 9V, 2A; because the transformer we used here having a specification of 9V/A. The alternating voltage from secondary terminal of the transformer is given to a bridge rectifier. The bridge rectifier converts alternating voltage to unidirectional voltage with the switching action of diodes. This voltage is finally fed to a 5V regulator IC through a 470uF, 50V electrolytic capacitor, which eliminates the ripples and make the output stable. After regulation we get a 5V DC voltage at the output of 7805 IC.

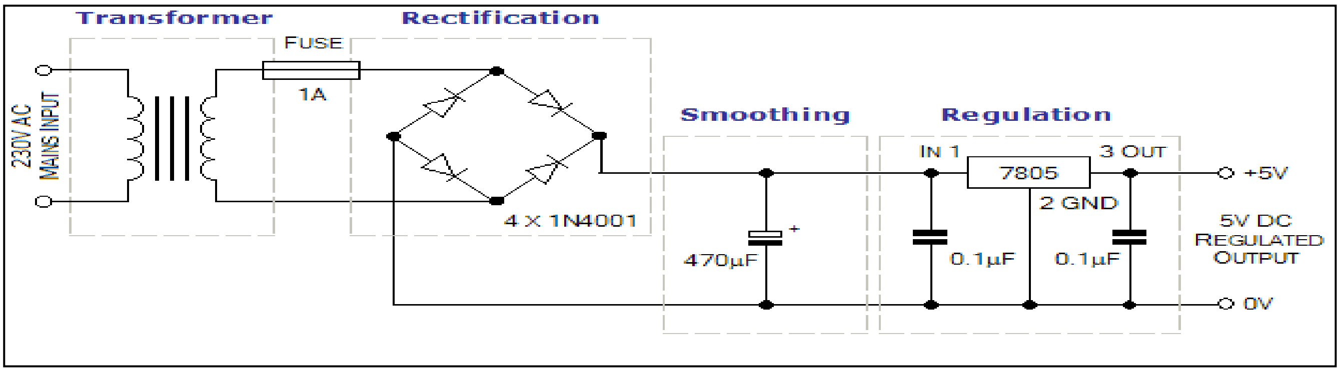

Figure 6. Circuit Diagram of 5V DC power supply

2.6.2 Load:

In the proposed model, two types of loads are considered:

1. Three incandescent lamp of 15W, 40W, 200W as a resistive load having following ratings
    - Voltage: Single phase 230V, 50 Hz.
    - Power factor: Unity.
    - Manufacturer: PHILIPS.

2. Exhaust Fan of 45W as an inductive load having following ratings
    - Motor: 230V 50Hz, single phase induction motor with lagging power factor.
    - Speed: 1400 rpm

2.7. Source Code for PIC16F877A Microcontroller:

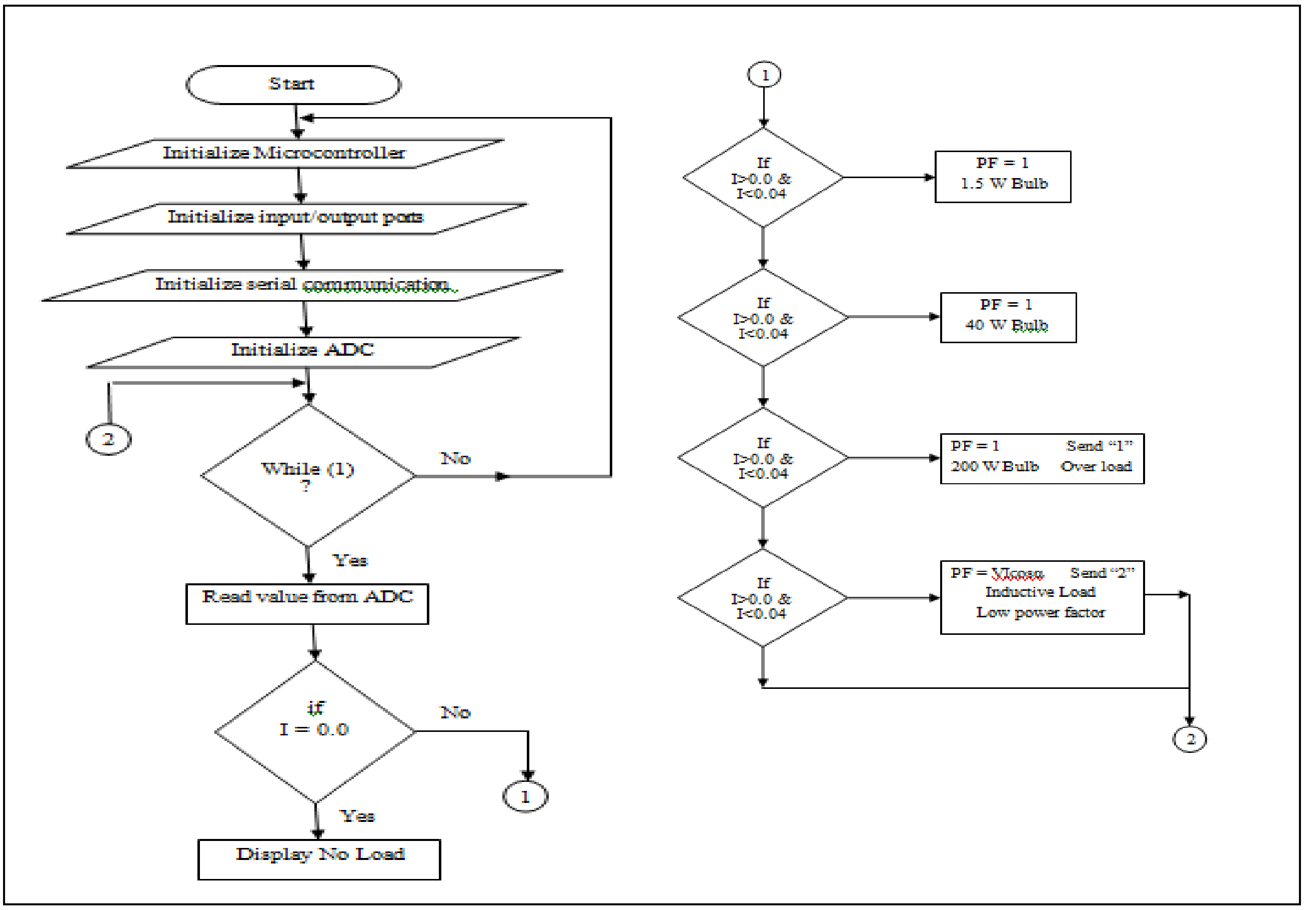

Figure 7. Source Code in the form Flow Chart

III.RESULTS AND ANALYSIS

3.1. For Inductive load:

Exhaust Fan of 45W as an inductive load having following ratings

- Motor: 230V 50Hz, single phase induction motor with lagging power factor.
- Speed: 1400 rpm
- Manufacturer: BHERO ELECTRICALS.

For an inductive load of 45 W, Power factor is calculated and a message “PF<1 low PF“displayed on computer using HyperTerminal software and same message is sent to consumer mobile. The power factor is lagging i.e. less than unity.

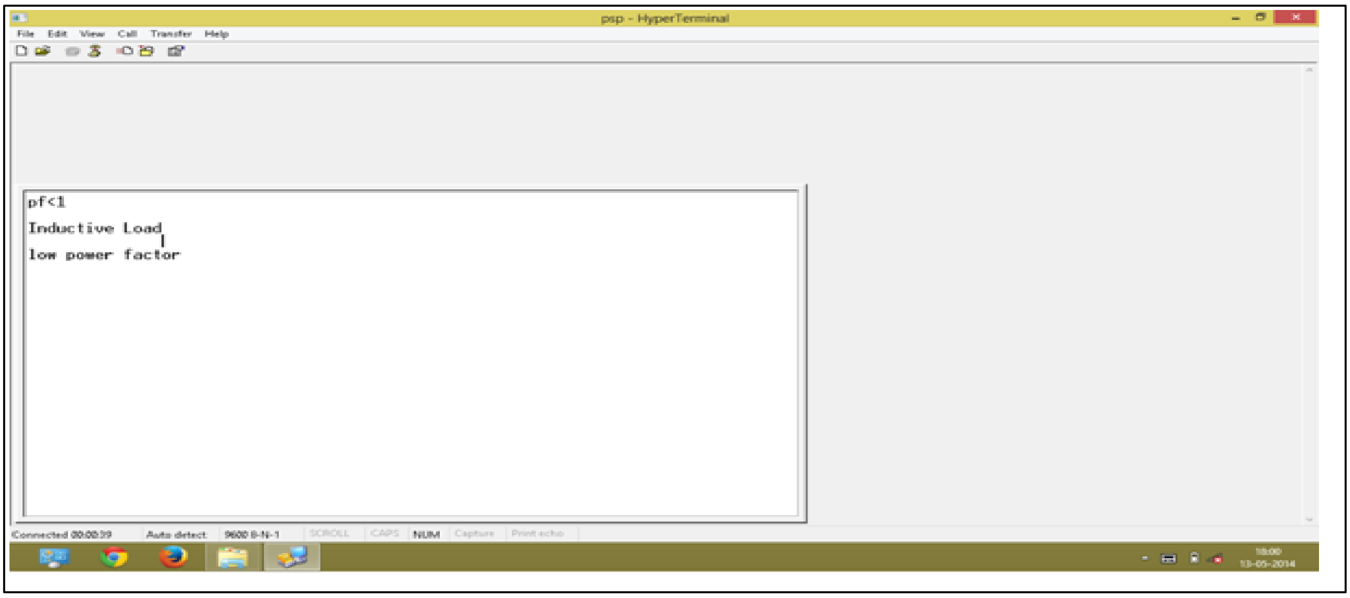

Figure 8. Screenshot of Hyper terminal displaying information of inductive load

3.2. For Resistive load:

Three incandescent lamp of 15W, 40W, 200W as a resistive load having following ratings

- Voltage: Single phase 230V, 50 Hz.
- Power factor: Unity.
- Manufacturer: PHILIPS.

For a resistive load of 200W, result obtained is “PF=1, Overload” .This message is displayed on computer and sent to consumer mobile. For normal load i.e. less than 200 watts no message is displayed.

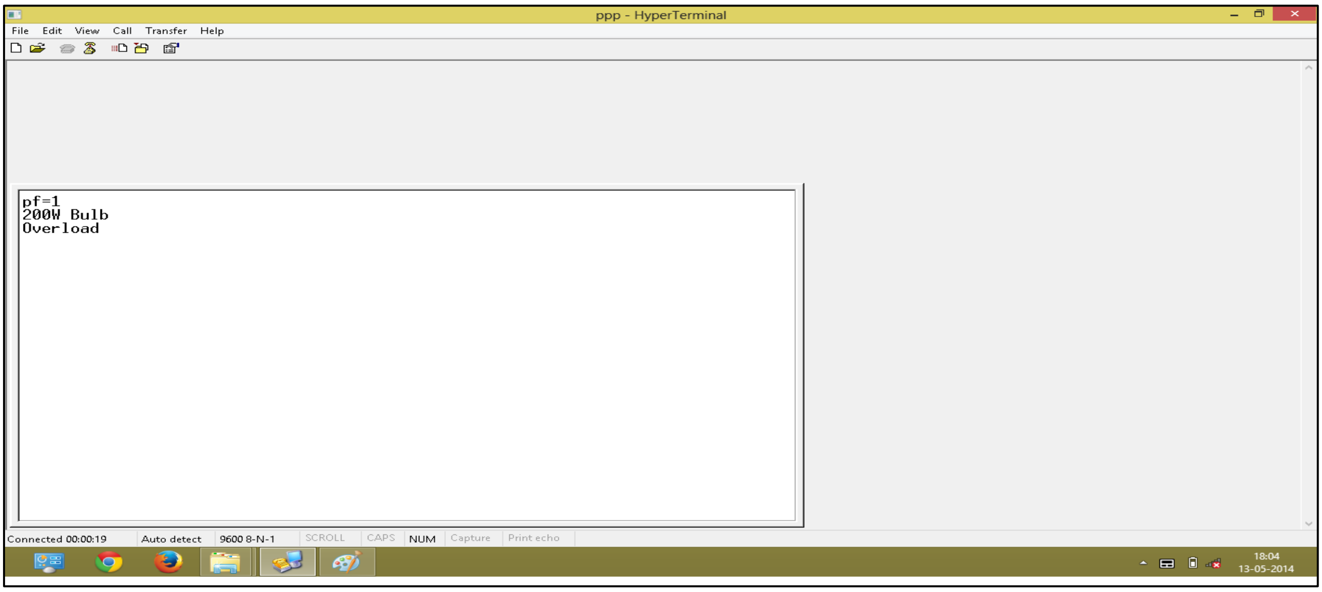

Figure 9. Screenshot of Hyper terminal displaying information of resistive load

3.3. Utility Reference Chart:

These are the charts provided by the utility to consumers for reference regarding their load power factor and consumed load. By referring these charts, consumer may improve his load power factor and utilize the power under his sanctioned limit.

3.3.1. For lagging power factor

* Power Consumption = 250 units
* Tariff =Rs.2.40/unit
* Specified Normal Factor = 0.85
* Penalty/Lag = Rs.0.02 (For LT consumers)
  Rs.0.03 (For HT consumers)
* Total Penalty Charges = Lag x No. of units Consumed x Penalty/Lag

Table 2. Variation of Total energy cost for different power factors.

Sl. N0	Power Factor	Lag	Penalty Charges(Rs)	Total Energy costs(Rs)	Remarks
1	0.85	0	0	600	Normal
2	0.80	5	25	625	LPF
3	0.75	10	50	650	LPF
4	0.70	15	75	675	LPF
5	0.65	20	100	700	LPF
6	0.6	25	125	725	LPF

Total Energy Costs = [No. of Units consumed x Cost/unit] + Total Penalty Charges
Note: Consumer need to increase the power factor of load by installing capacitor banks to avoid penalty charge.

3.3.2. For over loads

* Total energy consumption = 250 units
* Sanction Load = 1KW
*Tariff =Rs.2.40/unit
* Excess Energy Consumption / 250 watt of load (for LT consumers) = 10 units
* Excess Energy Consumption / 250 watt of load (In irrigation sector) = 60 units

Table.3 Variation of Total energy cost for excess load consumption.

Sl. N0	Utilized Load in KW	Excess Load in KW	Penalty Charges/250 W (Rs)	Total Energy cost (Rs)	Remarks
1	1	0	0	600	Normal
2	2	1	24	624	Over Load
3	3	2	192	792	Over Load
4	4	3	288	888	Over Load

Penalty Charge /250 W (in Rs.) = Energy Consumption in units / 250 W of Load x tariff

Total Energy Charge = [Normal Energy Consumed (in units) x Tariff] + Penalty Charges (in Rs)

Note: Consumer need shift excess load to Renewable Sources (wind/Solar) to avoid penalty charge.

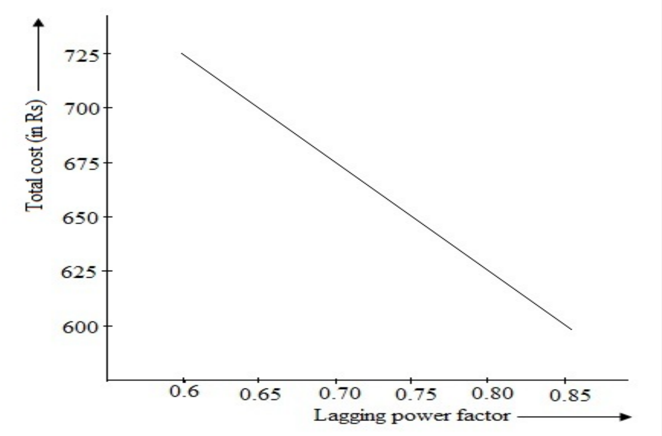

Figure 10. Graph of Power factor v/s Total Energy costs

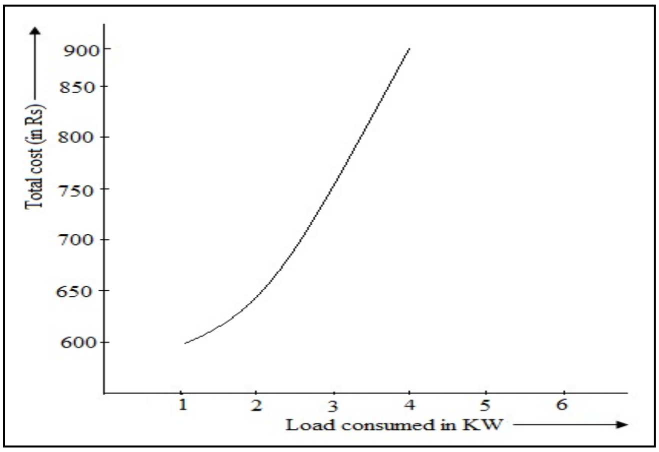

Figure11. Graph of Load v/s Total Energy costs

IV. CONCLUSION

The system provides flexibility, fault tolerance, high sensing fidelity, low cost, rapid response, and interoperability, making the system an ideal platform for power usage evaluation and condition monitoring altogether, and allowing the construction of high level intelligent power management system in smart grids. The use of PLC technology has proved to be an interesting alternative considering that the electrical grid is available for use not requiring new wired structure. But showed problems in moments of greater power flow. Smart grid is a new idea for electricity networks across the World. Smart grids are customer- driven marketplaces and this technology provides cost-efficient grid and market connection for consumers and Distributed Generation (DG). Smart grids enable efficient operation of centralised and DG, offer services to promote consumer level energy efficiency and guarantee uninterrupted and high-quality supply of energy. Traditional grid includes centralised power generation and at distribution level one-directional power flow and weak market integration. Smart grids include centralised and distributed power generation produced substantially by RES. They integrate distributed resources (i.e. generation, loads, storages and electricity vehicles) into energy markets and power systems. Smart grids can be characterised by controllable multi-directional power flow. Smart grid is an evolution towards an optimised and sustainable energy system which is more intelligent, efficient and reliable and it has positive influence on the climate change.

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