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Energy Forecast Mobile Application for Smart Panel via Bluetooth using Modbus Protocol

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Abstract

Objectives: The main objective of this paper is to develop an android application that communicates with a smart meter through Bluetooth using Modbus RTU as the application layer protocol. **Methods:** The android application will read the data from a smart meter and show it graphically. It will display the timely data such as energy consumption unit and other details (Current in line, Voltage) in a graph. Through this application, the consumers can easily know their electricity usage at any instance and adjust their usage pattern accordingly to reduce their energy consumption and costs. **Findings:** By implementing this mobile application it is possible to provide household electrical monitoring services remotely in a handheld device. This proposed system will improve the existing application in the industry by storing the data in the internal database and provides better results than the existing application. **Applications/Improvements:** The application overcomes the disadvantages of manual metering like mistakes in reading, errors of leakage and the pain of hiring huge manpower.

Keywords: Energy Forecast, Bluetooth, Modbus, Smart Meter

1. Introduction

Currently, the manual meter reading system is mostly prevalent, wherein the energy consumption data of the residential and commercial consumers are recorded manually every month from the electromechanical meters installed in their premises. There are considerable disadvantages to the above convention: There is a need for the hiring of manpower to go to every household and read the energy consumed, note the data read and import it to a receiving module. Also, The Usage of manual meter would lead to mistakes in the reading and prone to error leakage. Also, in the existing meter system, the usage information is presented to the consumers only once in a month when they are required to pay the bill. In order to overcome all these shortcomings of a manual metering system, a smart meter is used[1].

The smart meter used is Schneider Electric's PowerLogic PM5350 which has an inbuilt Bluetooth module (HC-06). Schneider's PowerLogic PM5000 series smart power meters are pretty affordable and have set the standards high in precision metering. They are best suited for high-end cost management applications[2]. They have the measurement capabilities that allocate energy consumption, perform metering and also sub-billing, record the savings done in the energy usage, improve equipment efficiency and optimize utilization, in addition to performing a detailed assessment of the quality of power in an electrical network[3].

The mobile application will establish communication with the smart meter through Bluetooth. The HC-06 Bluetooth component present in the smart meter makes this communication possible. The HC-06 firmware can only act as a slave device, with limited AT commands,

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which is sufficient as the meter acts only as a slave. It is used as a replacement for serial ports. The communication between the smart meter and the mobile application is shown in Figure 1.

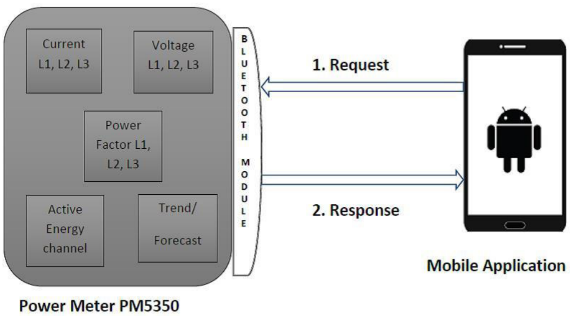

Figure 1. Communication between smart meter and mobile application.

2. Related Works

The application mainly involves communication over Bluetooth and has its own advantages. It is wireless and actually inexpensive compared to other modes of communication. It is also a standardized and upgradeable protocol that consumes very less energy, thus saving a lot of money and energy consumed by the using application. It is one technology that is used worldwide and is standardized to use and will last for several years to come[4].

Modbus RTU is used as the application layer protocol for data exchange. The protocol, Modbus follows the protocol of master and slave communication in which, the master is able to tend to one or more of its slaves. Here, the mobile application acts as the master and the smart meter acts as the slave. Modbus protocol has two transmission modes: The RTU (Remote Terminal Unit) mode or the ASCII mode. RTU mode verifies the authentication the data transferred using CRC (cyclic redundancy check) and can transfer more data than ASCII mode under the same Baud rate. Hence, the application uses Modbus RTU[5].

Further, the mobile application constitutes an internal database which stores the timely data from the meter. The flow of the communication will be such that, the app will read the energy values stored in the meter's registers using Modbus RTU protocol by establishing a connection with the meter through Bluetooth[6]. The read data will be stored in the database on a timely basis and a graph is plotted out of this data. Not only the energy usage data but also the forecast data predicted by the meter is displayed. This forecasted value is compared with the previous usage data to draw a clear picture of energy usage which would be of great help to the consumer. Also, with the details of how much a unit of energy is priced at, the bills are calculated and displayed on a timely basis[7].

3. The Smart Meter

The meter has got a large display with the help of which the three phases along with the neutral can be monitored at the same time. The PM5350 Power Logic smart meter is shown in Figure 2.

3.1 Main Characteristics

Monitoring and control of circuit breaking is easy – The meter has two high performance relay outputs that have the ability to directly control much of the circuit breaker coils. In addition to that, without taking the help of external power supply, the switches that are monitored can be directly wired to the smart meter.

Analysis of Power Quality – The meter presents the THD and also the TDD measurements as its standards. The Total Demand Distortion depends directly on the point of common coupling (PCC) that is a common point which makes the power source provides energy directly to any user. TDD is used for comparing the how much is contributed by harmonics with the maximum demand load.

Management of load – The peak demands and the timestamp in which they were recorded are provided. The predicted demand values are fruitful for elementary application with high load

Provision of alarming by means of time stamping – There is the presence of 30 alarm conditions, for example: conditions of under/over, changes in digital input, and imbalance in phase that tell about any event's occurrence. A log that is time stamped maintains a record of the past 35 alarm events.

Load timer – a maintenance requirement, which helps in monitoring the load and can be adjusted to particular set points.

3.2 Other Features

The PM5350 meter is not only used for measuring the currents and voltage but also power factor, reactive power etc. The PM5350 Power Logic smart meter cannot be used on Direct Current (DC) circuits. The non-volatile memory stores the highest or lowest value (max/min values) of real-time reading at any given second. The non-volatile memory mainly stores data and metering configuration values. The smart meter displays all the min/max values from the last reset and also the reset date and time. The min/max values can be reset. The non-volatile memory has a life of 40 - 45 years, if operated in the operating temperature specified.

Figure 2. Power meter PM5350.

4. Modbus Protocol

The Modbus is a serial communication protocol created and also published by Modicon in the year 1979 in order to establish interaction with their respective Programmable Logic Controllers (PLCs). It is used for transmitting information between electronic devices over serial lines. The Modbus Master is the device that is requesting the information and the Modbus Slave is the device that is supplying information. In the Modbus network, there is the presence of one Master and 247 Slaves and every slave has a unique Slave Address starting from 1 to 247. The Master is also capable of writing information to the Slaves.

The Modbus protocol is an open protocol that is available for free for manufacturers to build into their equipment without them having to pay any royalties. It has now become a standard communication protocol for industrial usage. It is the most commonly available and used method of connecting electronic devices present in industries. The Modbus is generally used to transmit the signals from the control and instrumentation devices back to the data gathering device or the main controller. As an example, a system that measures the temperature and the humidity, communicates the results that it recorded to a computer.

The voltage data is sent as bits. Bits are a series of ones and zeroes. The positive voltages are zeroes and the negative voltages are ones. They are sent quickly with the transmission speed of 9600 baud (bits per second).

The advantages of the Modbus protocol are:

1. *The protocol is Open Standard*: There is no need for the users to pay license fees and no fear of infringing intellectual property rights.
2. *Communication is message oriented*: Many of the electrical interfaces like RS232, RS422, RS485, Ethernet, etc. are supported by Modbus. There is no need for a dedicated chip and hardware, it only uses the standard parts that are available commercially[10].
3. *Simple and efficient*: Modbus is the most compact protocol, given the simplest frame format. Sample codes, controls and software tools can be downloaded from the Modbus-IDA website and various other third party website.

The Modbus is predominantly used to connect a supervisory computer having a Remote Terminal Unit (RTU) in supervisory control along with data acquisition (SCADA) systems. There are various versions of the Modbus protocol for all the serial lines (Modbus RTU and Modbus ASCII) and also for the Ethernet (Modbus TCP).

The format for the master's query is established by the Modbus RTU by placing the data into it. The query is sent by the master devices to the slave devices which in turn send responses back to the master according to the specified code. The device (broadcast) address, the function code defining the requested action, the error checking, and the data to be sent is all contained in the message frame. The protocol used is a point to point open serial communication protocol that can be used to develop Multi-Master Slave/Server Client communication. The slave address, the stop bit, the start bit in the data, the CRC code, the time out and the framing error detection is taken care of by the physical layer. The recognition or rejection of the function code, the busy or re-pool data is taken care by the data link layer. Figure 3 shows the Modbus RTU frame format.

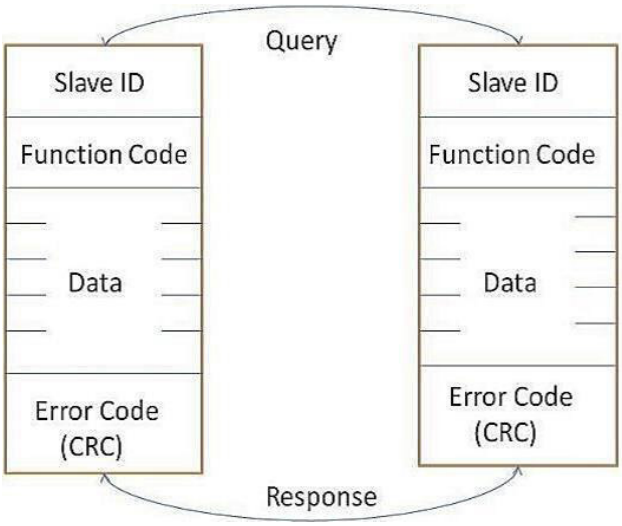

Figure 3. Modbus RTU message cycle and its fields.

Slave ID— The Slave ID is a one byte address field. Up to 256 devices can be connected to Modbus network. The Slave ID 0 is used as a master or for broadcasting. The other Slave IDs from 1 to 247 are used for the Slave devices and the IDs 248 to 255 are used for the gateways.

Function Code— the function code is a 1 byte address field. The function that is present tells the slave device, the type of action that it needs to carry out.

Data— the data field is also a single byte address field. It consists of a start bit, an 8 bit data along with one or two stop bits. The data of field devices which are united into a network is contained in the data field.

Error Code— there are two types of error codes that are present in the Modbus protocol. Predominantly Cyclic redundancy check (CRC) is used in the Modbus RTU[9].

5. Bluetooth Module (HC-05/ HC-06)

The serial port is converted to a Bluetooth port using a Bluetooth serial module. The module has two modes: master and slave. The Bluetooth modules named after even numbers (ex: HC-06) are defined to be master/slave when they are manufactured. But odd numbers named Bluetooth modules (ex: HC-05), provides the user a chance of configuring to be the master device or the slave device using AT commands. They are shown in Figure 4.

The main functions of this module are:

1. There are two Multipoint Control Units (MCUs) that communicate with each other. One of them is connected with Bluetooth Slave device and other to Bluetooth Master Device. The pairing of Bluetooth master and slave is done and connection is established. A serial port line which is linked to this Bluetooth connection includes two signals: Receive Data (RXD) and Transmit Date (TXD). Hence this linked module acts as the main communication medium between them.
2. The MCU has an ability to communicate with smart phones and computers using the Bluetooth module embedded in them, if the slave module is present in it. Once the communication is established there exists a serial line between both the modules.
3. Some of the Bluetooth module present in the market are mostly slave devices. For example: Bluetooth printer, Bluetooth GPS etc. By pairing the master module, communication medium is established with these devices.

Communication always takes place between master and slave and requires an authentication.

The two working modes of HC-05 module are: Automatic connection work mode and Order-response work mode. In addition to it, the module has 3 roles for automatic connection work mode: Master role, Slave role and Loopback role. Automatic data transition takes place by following the default way set lastly, if the module works in automatic connection work mode. In case of order-response work mode, a set of AT commands is used to set the configuration parameters and order of control. The module pin (PIO11) at the input level, is controlled in order to switch between the work modes of a module.

Figure 4. HC-05 and HC-06 Bluetooth modules

6. Implementation

The GUI design of the mobile application will have four major tabs. The first tab will have the toggle button for Bluetooth. This button is used to switch the Bluetooth feature of the mobile phone on/off. When the Bluetooth is switched on, it will display a list of available and paired devices. The HC-06 Bluetooth module in the meter will make it act as a Bluetooth device. Thus, the meter is paired with the phone and the connection is established. The second tab instantaneously shows the read values from each line in the smart meter (Voltage and Current) graphically[8].

The Modbus RTU protocol will start reading the values from the holding registers of the smart meter using the function code 03. After reading this data, it is displayed in the graph, which plots the energy consumed (in kWh or unit) across a given time period, which can be altered according to the user's preference (day-wise, week-wise or month-wise). However the writes to the database are always replacement writes, meaning, the newly recorded value will be written into the database as a replacement for the previously recorded value. Hence, the database holds only the most recently recorded energy value.

There is another feature in the smart meter which forecasts the energy consumption of the user in the upcoming time period, by observing the consumption so far. An in-built prediction algorithm computes this value and stores it in a separate register. This register is again read using the Modbus RTU function code and the value is plotted in comparison with the previous values in the similar graph of time versus energy consumed. Using this, the tariffs are calculated and displayed accordingly.

The application will also be alerting the user with alarms if the energy consumption exceeds beyond a particular threshold set by the user. The user can set individually in each line, a particular benchmark value. When the read value of energy consumption from the meter exceeds this value, the alarm will be raised indicating the user that the usage is beyond the limit.

With the help of this mobile application, consumers will be able to see how much they paid for electricity in the near past, monitor the energy consumed on a particular day and also see the rate at which their consumption will progress. An annual report will draw a comparison between the electricity consumed during various months of the year, and a daily report will identify the peak hours of energy consumption. Figure 5 shows a flowchart explaining the communication system between the app and the meter.

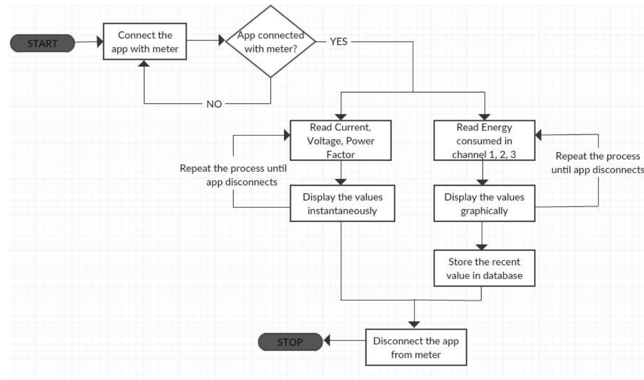

Figure 5. Flow chart explaining the event flow and communication between the mobile application and the meter.

7. Conclusion

This paper will make energy monitoring an easy task and reduce the errors in manual reading of energy meters and reporting. Consumers can monitor their actual electricity consumption by themselves with just simple touches in their smart phone. By bringing forth a precise and timely measurement system and a mobile application that will graphically show the measured energy data, the user is strongly motivated to save energy. Furthermore, there will be huge improvements in metering, billing efficiency and accuracy and also the manual meter reading system could be replaced. Through this mobile application, electricity usage can be easily understood by the users and since the data transmitted wirelessly, there are no issues of electromagnetic interfacing. Graphical information on all instantaneous consumptions, the change in the load shape as an effect of a single burden, the usage pattern and the forecast as per the prediction of the meter, etc. are all given by the UI. The application helps the consumer to change his consumption accordingly thus enabling him to avail the advantage of getting the lowest prices that are in offer during the day and also to improve energy efficiency. It not only measures the amount of electricity that is used, but it also allows the customer by means of Bluetooth communication to control the maximum consumption. In this way, the usage of such a powerful smart meter along with an appropriate communication model like the Modbus protocol over Bluetooth connection could facilitate remote access as well as planning of energy consumption, which is the need of the hour.

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