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Integrated GSM Solution For Power Metering, Billing, And Load Control

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Abstract

Currently, energy meters are installed at domestic or commercial locations to track energy consumption, displaying the data on either a dial or a digital screen. At the end of each billing cycle, a service provider's representative must visit the location to manually record the meter reading for bill generation. This traditional method of energy billing is not only time-consuming but also prone to errors. The goal of this project is to develop an energy meter that not only measures a consumer's power consumption in kWh but also facilitates real-time monitoring, eliminating the need for manual readings. The system continuously tracks energy consumption by measuring voltage and current, sending updates such as low balance, zero balance, and recharge alerts to a registered number via a GSM modem. Additionally, it can detect illegal power usage and instantly notify authorities. Power and energy calculations are performed using Arduino programming, and messages are sent to consumers with details of their energy usage and bill amount

Keywords: GSM, Energy Meter, Load Control, Arduino Project, Smart Billing System .

Introduction

Smart electrical energy meter technologies have been researched and developed for nearly a decade. Over this time, various technologies have been introduced to measure electricity consumption. In the traditional billing process, users receive their energy bills from the energy provider after readings are taken using different methods. In Malaysia, for example, most households still rely on traditional electro-mechanical watt meters, which do not provide automated readings. Consumers must wait for their monthly energy bill and typically, at the end of each month, a representative from the energy board visits each home to manually record the meter reading and deliver the bill.

An electricity meter, or energy meter, is a device that tracks the amount of electrical energy consumed by a residence or business. There are two types of meters for domestic users: single-phase and three-phase. Energy consumption is measured in kilowatt-hours (kWh). Initially, electronic meters were introduced, offering similar functionality to the electro-mechanical meters but using a digital system instead of an analog one. With this system, users can monitor voltage, power readings, current, and the time and date of energy consumption, offering some improvements over the previous models.

Following electronic meters, Bluetooth-based technology emerged as part of the Automatic Meter Reading (AMR) system. This wireless system allows energy consumption data to be recorded on a personal computer, where the meter readings are stored in a database and used for bill generation. The latest advancement is the GSM-based system, which replaces Bluetooth technology. With this system, data is sent via Short Message Service (SMS) to both the customer and the energy provider.

Literature Review

"Islanding Scheme and Auto Load Shedding to Protect Power Systems" by Srinu Naik Ramavathu, Venkata Teja Datla, and Harshitha Pasagadi. This paper presents a method for developing an automatic load shedding and islanding scheme to protect the power system from blackouts and ensure stability during abnormal conditions. The load shedding process is based on calculating the rate of frequency variation during such conditions. The proposed technique, known as the rate of change of frequency (ROCOF), determines the sequence and conditions under which various load shedding and islanding strategies are applied. The scheme is developed in line with international best practices and is designed to quickly restore system stability.

"GSM-Based Automatic Substation Load Shedding and Sharing Using Programmable Switching Control" by S.R. Balan, P. Sivanesan, R. Ramprakash, B. Ananthakannan, K. Mithin Subash. This project focuses on controlling substation load shedding and sharing using a programmable switching control mechanism that operates automatically. It demonstrates the functionality of this process using a microcontroller. The system is configured through a GSM module to manage tasks in the substation, such as switching loads on and off at specific time intervals. The system operates in three modes: Set mode, Auto mode, and Manual mode, with the load status displayed on an LCD. Additionally, the GSM modem sends SMS messages to the control system, allowing remote selection of modes and timings.

"SMS-Based Load Shedding Period Control System" by Dwijen Rudrapal, Smita Das, Swapan Debbarma, and Goutam Pal. This paper discusses the need for modernizing load shedding schemes and introduces an SMS-based approach for controlling the load shedding process. The system allows users to minimize manual intervention by selecting the feeder, substation, and shedding duration through SMS commands, offering a more efficient and automated way to manage load shedding.

[8] With the implementation of Automatic Meter Reading (AMR) technology, electrical utilities (EUs) have been leveraging their own infrastructure to bill customers more efficiently and economically. Since the data required for transmission is relatively small compared to the time available for the task, AMR applications typically require low bit rates. At present, EUs are seeking additional services such as load and alarm management, remote monitoring, and disconnections. In this context, Low Voltage modems need to offer higher throughput while maintaining low hardware costs. The success of this low-complexity AMR technology hinges on two key factors: the cost of customer-premises equipment and the added value services that the system offers, both of which are critical to its business case.

[9] This study explores various methods for allocating distribution transformer loads in power-flow studies. Four different methods are used to calculate individual distribution loads, and the results from these methods are compared with those obtained from actual customer meter readings. The study examines daily kWh, monthly kWh, and transformer kVA.

[10] A microprocessor-based automatic meter reading system is implemented to provide a cost-effective, reliable, and interference-free data transfer between remote meter reading units and the utility control center. This system eliminates the need for human involvement in meter reading and management processes. Built on existing telephone networks, it offers flexibility for utility companies to access, service, and maintain the meter reading system. A user-friendly, window-based interface has been designed, fully utilizing the personal computer's terminate-and-stay-resident (TSR) programming technique to enable communication between remote meter reading units and personal computers at the utility control center. This paper details the hardware design of the remote reading unit, the software implementation of the communication module, and the user interface.

[11] We propose an innovative Automatic Meter Reading (AMR) system based on IEEE 802.15.4-compliant wireless networks. The mesh network-based automatic utility data collection system (AUDCS) offers a cost-effective solution by harnessing the self-organization and self-healing capabilities of mesh networks, as well as utilizing advanced semiconductor chips and radio transceivers compliant with IEEE standards."

Methodology:

The ESP8266 uses a 32bit processor with 16 bit instructions. It is Harvard architecture which mostly means that instruction memory and data memory are completely separate. The ESP8266 has on die program Read-Only Memory (ROM) which includes some library code and a first stage boot loader. All the rest of the code must be stored in external Serial flash memory (provides only serial access to the data - rather than addressing individual bytes, the user reads or writes large contiguous groups of bytes in the address space serially).

Depending on your ESP8266, the amount of available flash memory can vary. As any other microcontroller, ESP8266 has a set of GPIO pins (General Purpose Input(Output pins) that we can use to “control” external sensors.ESP8266 has 17 GPIO pins but only 11 can be used (among 17 pins, 6 are used for communication with the on-board flash memory chip). It also has an analog input (to convert a voltage level into a digital value that can be stored and processed in the ESP8266). It also has a WIFI communication to connect your ESP8266 to your WIFI network, connect to the internet, host a web server, let your smartphone connect to it, etc. Another advantage of an ESP8266 is that is can be programmed as any other microcontroller and especially any Arduino.

Fig 1: ESP8266 Node Micro Controller

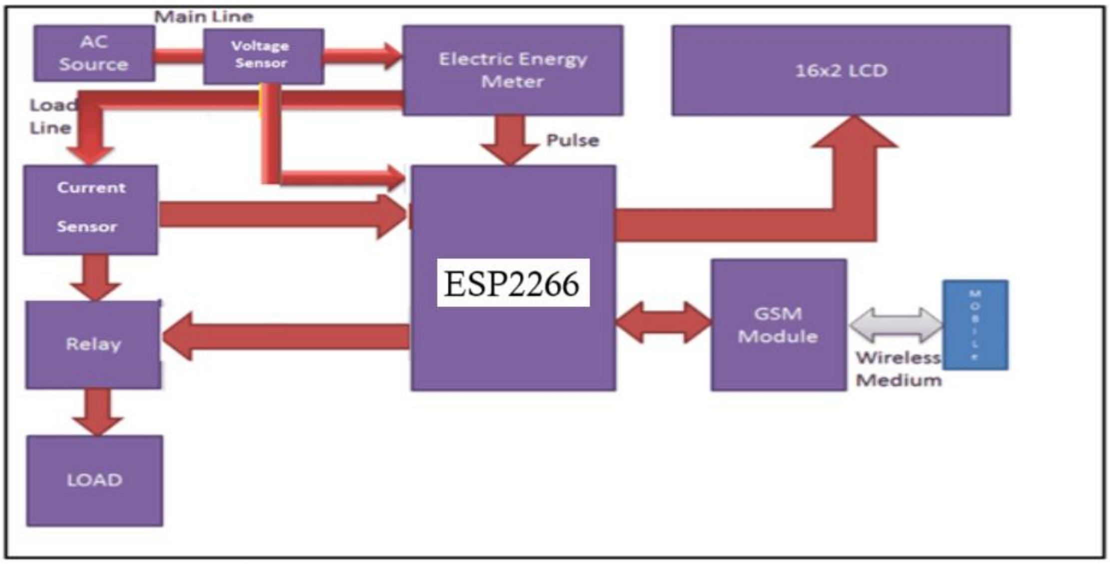

Figure 2: System Architecture

1. Modelling of Device.(all Units)

- Input controlling unit
- GSM Operating unit
- Energy meter and Processing Unit

2. Design of Controller using microcontroller ESP8266.

3. Design of GSM based configuration model.

4. Design of combinational cycle of energy meter, Loads etc.

5. Design of relays for each load and project model.

6. Connection all units in sequential order.

7. Observing the billing of each operating load and which is controlled.

The voltage value, in volts, is stored in a float variable called 'voltage,' and it is continuously displayed on the LCD for monitoring purposes. The microcontroller also uses the voltage value stored in this variable to calculate power and energy consumption. The ACS712 current sensor is connected to the analog A4 pin of the microcontroller and provides an output in millivolts corresponding to the current flowing through the load. A conversion factor of 66 is used to calculate the actual current flowing in the circuit. The Atmega328p microcontroller features a 10-bit built-in ADC that converts the 0-5V analog signal to a digital range from 0 to 1024. The current value, in amperes, is stored in a float variable called 'current,' and it is continuously displayed on the LCD for monitoring. The microcontroller uses this current value for power and energy consumption calculations as well.

The GSM module connected to the Arduino microcontroller receives AT commands from the microcontroller to initiate the connection. These commands enable the GSM modem to send and receive SMS messages. The microcontroller calculates power and energy consumption using inputs from both the current and voltage sensors, and it tracks the unit balance in the energy meter, which has a default value of 4 units. When the unit balance drops below 4 units, the microcontroller sends a command to the GSM modem to alert the user via SMS about the low balance and prompt a recharge.

If the consumer does not recharge after receiving the low balance alert SMS and the unit balance falls below 2 units, the microcontroller sends a HIGH signal to the relay to disconnect the power supply to the household loads and sends an SMS notifying the consumer that the power supply has been cut off due to low balance. Once the consumer makes a recharge by sending a text SMS like 'Recharge_100' to the GSM modem, the modem sends the SMS to the microcontroller. The microcontroller reads the message and takes appropriate action based on the code, sending a LOW signal to the relay to restore the power supply. The microcontroller also sends a recharge confirmation SMS to the consumer's mobile phone through the GSM module.

Additionally, the consumer can check the current unit balance and the connected load on the energy meter. To do so, they must send a 'Get_Status' SMS to the GSM modem of the energy meter. The microcontroller reads the SMS serially through the serial port and sends a response SMS, providing the current unit balance and the load in MW. This smart energy meter also allows the consumer to remotely control the household power supply using the GSM modem. To turn off the main power supply, the consumer must send an SMS 'Supply_OFF' to the GSM modem, and they will receive a confirmation SMS indicating the power supply has been turned off. To turn the power supply back on, the consumer sends an SMS 'Supply_ON' to the GSM modem, and they will receive a confirmation SMS that the power supply has been restored.

The current is transformed, and the load is connected in series. To convert current into voltage, a power transformer is connected in series with a current transformer. In this setup, the voltage of the power transformer is fixed at 5V. The current transformer converts the voltage into a ratio-based voltage. The power and current transformers are linked in such a way that a specific string can be matched with the format, allowing the appropriate actions to be taken.

The energy measuring unit consists of a voltage divider circuit, an opto-coupler, and a crystal oscillator to generate clock pulses. The voltage divider circuit receives the incoming signal from the transformer, and the clock signals generated by the voltage divider are input to the opto-coupler. The opto-coupler acts as an isolating device between the energy measuring unit and the microcontroller, ensuring safety. The output from the energy measuring unit is then sent to the microcontroller, which serves as the central unit, interfacing with all connected devices such as the display system, GSM module, and energy measuring unit.

The microcontroller counts each pulse from the energy measuring unit and converts it into the units of energy consumed, based on the program it is running. Each energy meter is assigned a unique ID by the system, which is linked to the unique service number of the SIM card. Alerts are sent to the three phone numbers specified in the system's channel.

The system facilitates communication between the power provider and consumer without the need for human intervention. If the power supply is cut off due to non-payment, the system waits for an incoming signal to restore the supply after the dues are cleared. The input message must follow a specified format and be kept confidential so that the system can match the string and take the appropriate actions accordingly.

Conclusion and Future work

After implementing the GSM-based energy meter billing system with load control, all the objectives outlined in the proposal have been successfully met, and the desired results have been achieved. This system plays a significant role in raising awareness among users about their energy consumption, contributing to the conservation of finite traditional resources. The proposed system offers an effective solution for real-time load control. The ESP32-based load sharing and control system was specifically designed to monitor and prevent overloads. The design incorporates a dual load system and utilizes solid-state components, such as relays. The methodology employed in the project ensures proper stages for overload detection, switching, and cutting off the supply when necessary. Future improvements may include adding a dashboard to the system, complete with auditing and consumption tracking features

The GSM-based energy meter is easy to install and offers benefits to both the energy provider and the customer. It reduces manual labor costs and minimizes human errors. Additionally, it addresses common customer issues, such as meter malfunctions, overloads, and helps prevent theft. In the event of a fault, the system alerts the customer, who can then notify the energy provider. The provider can easily disconnect the power by sending an SMS to the specific ID number associated with the customer's SIM number. The statistical data on load usage and consumption profiles enable customers to better manage their energy usage, helping them reduce outstanding payments. This system can also be adapted for use in remote areas by modifying the modem type and adjusting its communication frequency range. Overall, this device helps eliminate revenue-related issues and improves energy usage efficiency across the country.

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