

Cortex-M3 based Prepaid System with Electricity Theft Control

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Abstract: In many developing countries, especially in India, governments are failing to satisfying ever increasing demand of electricity because of revenue loss. It is happening due to lack of proper maintenance of Power by the electricity department. So many reasons are there. i.e. sometimes consumer cant paid unexpected bills in time, sometimes service man can't take proper reading at meter while billing and one more major problem is electricity theft occurred at meter like by passing meter, cutting meter and un authorized utilization of power , all these should not known to electricity department. To get rid of all these problems installation of a prepaid system in every consumer house is a solution. In this system a server is maintained at the service provider side. Both the meter and the server are equipped with GSM module which facilitates bidirectional communication between the two ends using the existing GSM infrastructure. In this project we are designing a prepaid system with electricity theft control. It calculates power consumption and detects automatic electricity theft at which house its occurred and informs the electricity department about theft, it automatically disconnects the load on detection of theft using relay and also informs the consumer about low balance to avoid sudden power cut. This meter will work on prepaid recharging only. Consumers can easily recharge their energy meter by sending a PIN number hidden in a scratch card to the server using SMS. The bidirectional GSM communication using SMS ensures the effectiveness of these measures. Legal actions against dishonest consumers can also be taken in this system.

Keywords: Cortex-M3 Processor, Server, LCD display, Buzzer, prepaid system, GSM infrastructure, electricity theft, SMS.

I. Introduction

According to the survey, Indian power system faces loss of about 30% of its total production of electricity. This loss is very high which takes place because of electricity theft, transmission losses, etc. Major portion of its losses is due to power theft. Power theft is done by taking tapping or hooking from the meters. Generally this type of power theft is seen in residential area which can't be easily detected as this type of theft is done during night hours. Moreover, this kind of power theft causes unbalance/overloading of distribution transformer. Due to unbalance/overloading condition, the transformer is damaged due to heating of the overloaded phase, hence huge revenue loss for the electricity department.

II. Overview Of Proposed Prepaid System

In this project we design a prepaid system with electricity theft control. In the proposed system the power utility maintains a server (System) and each consumer is provided an energy meter. Below figure shows an overview of the proposed prepaid system. The energy meter produces pulses proportional to the energy consumed. The microcontroller calculates the energy consumption by counting the output pulses of the energy metering chip on an interrupt basis. The microcontroller uses AT command set to communicate with the GSM module (mobile phone).

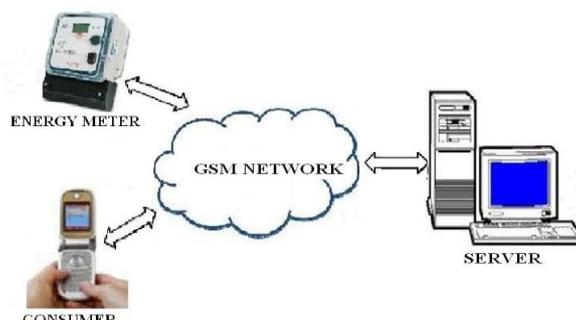


Figure 1. Over view of the proposed prepaid system.

This system automatically detects theft at household meter and informs the server. The C programming language (Depends on processor) has been used to program the microcontroller and to implement the server, respectively.

The recharging process in the prepaid system is similar to that of recharging balance in a mobile phone. The user has to buy a scratch card and scratch it to uncover the secret pin number of the corresponding energy unit he has bought and sends it to server. Then server checks the validity of pin number, if its valid then extracts information and sends back to corresponding balance to meter. The household meter then receives the corresponding unit and is activated. As the user consumes the energy, the corresponding units are deducted from the total balance and the remaining units are displayed using LCD. Buzzer also indicate about Low Balance when it reaches reference units (about low balance) to avoid sudden power cut in home. After the consumption of the allocated energy, the meter automatically disconnects the load from the main power line using the relay until the user recharges again.

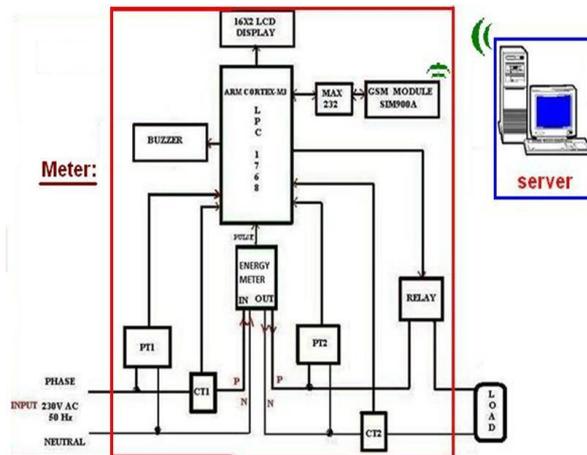


Figure 2. Block diagram of prepaid system.

III. System Hardware

The basic hardware components used in the Project are shown below in Fig.3



Figure 3. Prototype of the proposed prepaid system

A. Microcontroller (Arm Cortex M3-Lpc1768)

In this project we are using Cortex M3 Processor. This LPC1768 is an ARM Cortex-M3 based microcontroller for embedded applications featuring a high level of integration and low power consumption. The ARM Cortex-M3 is a next generation core that offers system enhancements such as enhanced debug features and a higher level of support block integration. The LPC1768 operates at CPU frequencies of up to 100 MHz. The ARM Cortex-M3 CPU incorporates a 3-stage pipeline and uses Harvard architecture with separate local instruction and data buses as well as a third bus for peripherals. The peripheral complement of the

LPC1768 includes Ethernet MAC, USB Device/Host/OTG interface, 8-channel general purpose DMA controller, 4 UARTs, 2 CAN channels, 2 SSP controllers, SPI interface, 3 I2C-bus interfaces, 2-input plus 2-output I2S-bus interface, 8-channel 12-bit ADC, 10-bit DAC, motor control PWM, Quadrature Encoder interface, 4 general purpose timers, 6-output general purpose PWM, ultra-low power Real-Time Clock (RTC) with separate battery supply, and up to 70 general purpose I/O pins. The LPC1768/66/65/64 are pin-compatible to the 100-pin LPC236x ARM7-based microcontroller series.

B. GSM module (SIM900A)

GSM module is used for communication. In this project we have chosen SIM900A GSM module for communication with consumer, server and energy. This GSM module required standard 12V supply. This will be supplied from power supply section. If we want to communicate with energy meter we can use below commands. It's connected to P0.2, P0.3 pin of LPC1768 microcontroller through MAX232. It's connected to microcontroller which would transmits data from a meter to cell phone and also receive command from cell phone to energy meter. AT commands set which stands for attention terminal are used by energy meter to communicate with the GSM Modem.

Command	Description
RCG	For recharging of the meter
PWRCUT	For making Power OFF(only server can use)
PWRON	For making power ON(only server can use)

Communication commands

Commands explanation:

1. If we want to recharge meter with Rs.50/- we can send SMS as <RCG050> to <server Number>
2. If server wants to cut the power at particular house, Server can send SMS as <PWRCUT> to <Registered Meter Mobile number>
3. If server wants to ON the power at particular house he can send SMS as <PWRON> to <Registered Meter Mobile number>



Figure 4.SIM900A

1. Dual band GSM/GPRS 900/1800MHz
2. Dimensions: 24* 24 * 3 mm
3. Weight: 3.4g
4. Supply voltage range 3.4 ... 4.5 V
5. Low power Consumption
6. Operation temperature: -30 °C to +80 °C

C. Instrument Transformers

Potential Transformer and Current Transformer combinedly known as **Instrument Transformers**. Instrument transformers are high accuracy class electrical devices used to isolate or transform voltage or current levels. The most common usage of instrument transformers is to operate instruments or metering from high voltage or high current circuits, safely isolating secondary control circuitry from the high voltages or currents.



Figure 5. Instrument transformer.

Specifications:

Voltage: 2 x 12V, Current: 1 x 500mA, Rated power: 12VA.

D. Energy meter

In this project we have chosen AC 1ph, 2 wire static wathour meter of Powertech Measurement systems. This meter will take inputs from phase, neutral line and generate pulses based on consumption of power and those pulses output given to microcontroller pin Po.6 for calculation purpose of remaining balance of the prepaid energy meter. Connection of meter can be shown in schematic diagram.

Technical requirements:

- a) Rated voltage (Vref): 240 V phase to neutral (Single phase, two wire system)
- b) Rated current: Min. Current 5A (IB)
Max.Current 30A (Imax)



Figure 6. AC 1ph, 2 wire static wathour meter.

E. LCD display

A liquid-crystal display (LCD) is a thin, flat panel used for electronic visual display. In this project I have used 16x2(5x7 matrix) LCD display. A 16x2 LCD display is very basic module and is very commonly used in various devices and circuits.

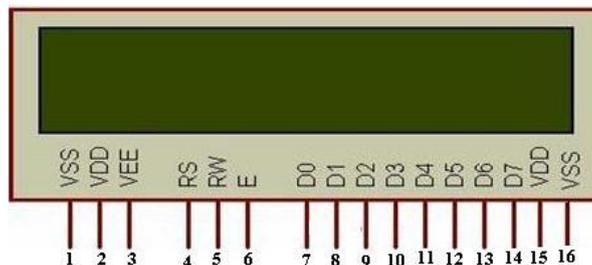


Figure 7. 16x2 LCD display. Supply voltage (VDD): 5V (4.7-5.3V), Ground (VSS):0V

F. Buzzer

A **buzzer** or **beeper** is an audio signaling device, which may be mechanical, electromechanical, or piezoelectric. Typical uses of buzzers and beepers include alarm devices, timers and confirmation of user input such as a mouse click or keystroke. Supply Voltage: 5V, Ground: 0V.

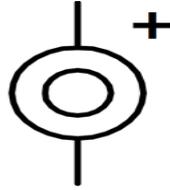


Figure 8. Electronic symbol

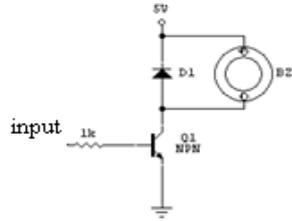


Figure 9. Buzzer circuit

G. Relay

A **relay** is an electrically operated switch. Many relays use an electromagnet to mechanically operate a switch, but other operating principles are also used, such as solid-state relays. Relays are used where it is necessary to control a circuit by a low-power signal. Relays were used extensively in telephone exchanges and early computers to perform logical operations.

Power supply ratings: 12VDC, &A/250VAC, 10A/28VDC, SPDT.

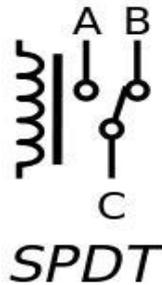


Figure 10. SPDT Relay Symbol. Figure 11. Relay NRP07.

H. Load

Load is anything which consumes power. In our project I have chosen 60 watt Bulb as load.

IV. System Software

The system software is implemented by Embedded C language in the Keil micro Vision IDE software along with flash magic. All software development tasks including editing, compiling and debugging can be accomplished using the above mentioned software's.

V. Detecting And Controlling Electricity Theft

In this prepaid system, along with prepaid recharging we are measuring few electricity theft (i.e., Complete meter bypassing, phase line shorting) occurring at meter and immediately informing the server about which type of theft is being occurring and at which meter it is being occurring and disconnecting load using relay. To avoid these types of thefts we are using instrument transformers to measure phase, neutral line currents and voltages between phase and neutral of input line and out line. Power consumption can be calculated by Microcontroller, and also microcontroller detects electricity theft.

i). Protection against complete meter disconnecting.

In this case, microcontroller continuously checks the voltages from input side and load side with the help of PT1 and PT2 respectively. Here PT1 & PT2 are Potential Transformers. These PT1 and PT2 inputs are connected to the General purpose digital I/O pins of microcontroller. In this case (whole meter disconnecting) if micro controller does not detect voltages at both side from PT1 and PT2, it will assume that there is a power cut to the meter and immediately informs the server by sending SMS. Then the server confirms that the power cutting done from their side or not. If the power cut not done from sever side and even this type of message came means, server assumes that there is a power theft occurring. During this case server sends authority for manual check up of meter where theft has been occurred. This theft can be shown in figure.12.

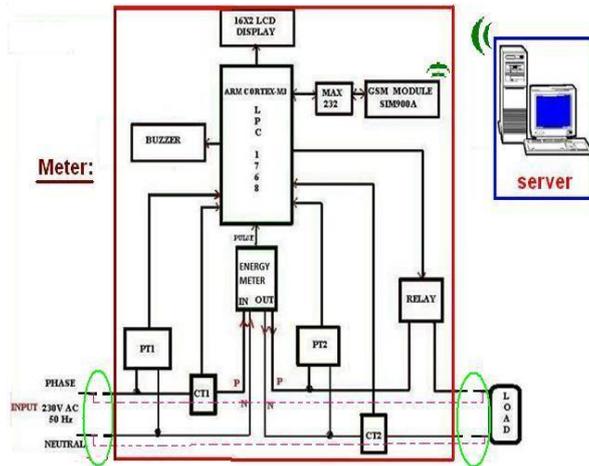


Figure 12. Disconnecting the whole meter.

ii). Protection against shorting of the phase line

In this case microcontroller continuously checks the currents in phase and neutral line with the help of current transformers CT1 and CT2. The output voltages of CT1 and CT2 are provided to the ADC inputs of the microcontroller. If the phase line is shorted then there will be difference between the output voltages of T1 and CT2. The microcontroller compares the voltages of CT1 and CT2 and if any significant difference ($>1.5v$) is found, it disconnects the load immediately using the relay. In such events the energy meter informs the server of the corresponding theft through SMS. Upon receiving SMS from meter, the server blocks the energy meter by sending 'PWRCUT', message to the meter and sends the authority. The authority can take legal action against the un authorized consumer.

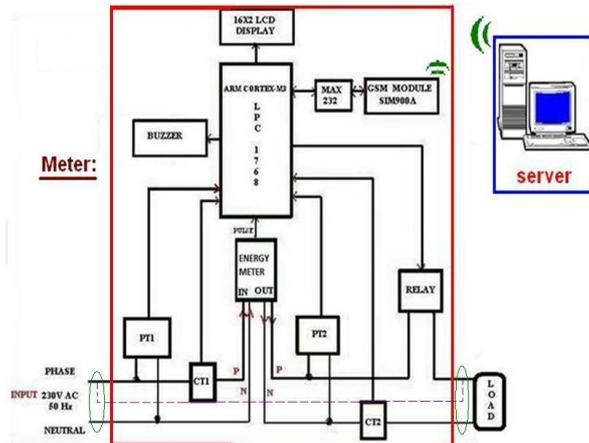


Figure 13. Shorting the phase line.

VI. Flow Chart And Algorithm

The algorithm is as follows:

- Step1: Give proper power supply to the required components.
- Step2: Initialize GSM module, microcontroller, LCD etc.,
- Step3: First register the consumer number by giving missed call to the GSM module of the energy meter.
- Step4: Second register the server number by giving missed call to the GSM module of the energy meter.
- Step5: Recharge the meter by sending SMS to the server by "RCG" command to start work.
- Step6: On receiving balance from server, energy meter start working.
- Step7: On reaching low balance (10 units) buzzer will indicate about low balance at meter and message will be sent to the registered number of the customer.
- Step8: Potential transformer and current transformer output will be given to microcontroller; microcontroller will continuously monitors the power in phase and neutral line of the meter.

Step9: If any theft occurred at meter microcontroller automatically disconnects load using Relay, and send information by SMS to the server about which type of theft at which house.

Step10: If balance reaching zero meter automatically disconnects load by using Relay until we recharges again energy meter to utilize power.

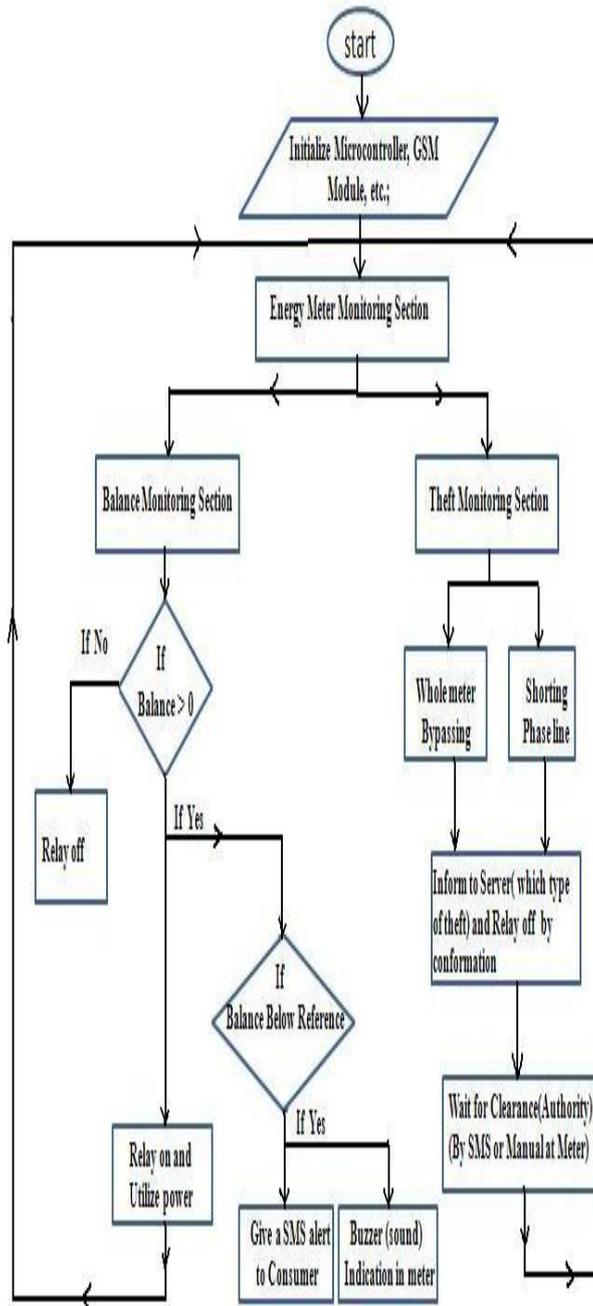


Figure 14. Flow chart illustrates working of system.

VII. Results

1. On successful registration of consumer number we will get as below message

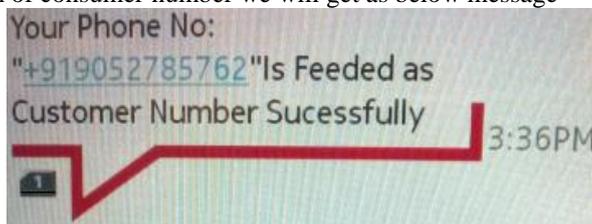


Figure 15. Successful consumer number feeded

2. On successful registration of server number we will get as below message.

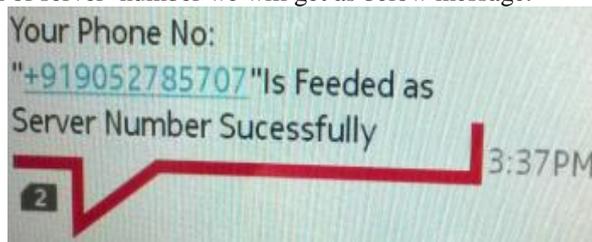


Figure 16.Successful server number feeded

3. On detection of meter cut and utilization of un authorized power.

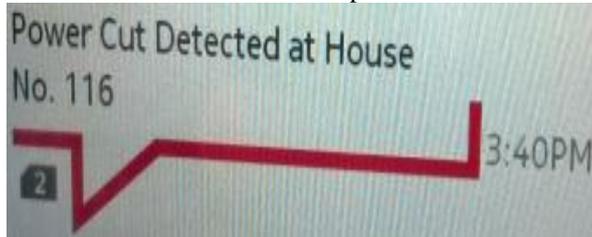


Figure 17. Meter cutting message

4. On detection of main phase line shorting and bypassing meter we will get below message

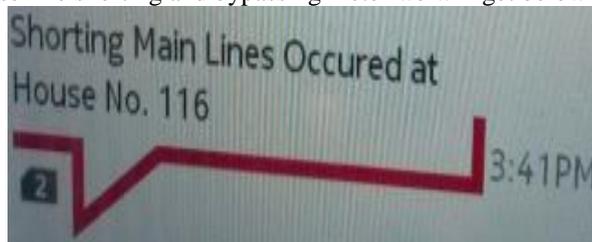


Figure 18.Shorting Main lines or bypassing meter message

5. On low balance, message sent to the registered customer mobile number



VIII. Conclusion And Future Scope

This Prepaid energy meter acts like antitheft control system, also informs to the server about the theft and informs the consumer about low balance to avoid sudden power cut at houses. All these communication done among meter, server and consumer by sending SMS. Hence this prepaid energy meter makes to avoid the unpaid bills and generate the revenue to the electricity department. In the future this prepaid system can be modified to a 3-phase supply. Remote recharging can be implemented through internet. The overall size of this system can be reduced.

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