AUTOMATIC ELECTRICITY METER READING AND REPORTING SYSTEM

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ABSTRACT

Energy billing is considered to be one of the important tasks for any energy-providing company. It is therefore important to create and develop meters that keep record of energy consumption. As technology advances, newer, more accurate types of meters are designed and manufactured, capable of logging any malfunctions or manipulations on these meters. Due to advances in communication technology, these new meters are developed with the ability to report companies or clients remotely. These meters are called Automatic Meter Reading Systems (AMR). However, replacing old meters with new ones is considered costly. A simple solution for this issue is to design a small module that can be easily attached to meters and can perform the same tasks as an AMR. In this project, such a module is designed and attached to an electricity meter. The module reports several readings to the company's billing server, via SMS. The server acquires the data and stores it in a database. Finally, the server sends an SMS to the client informing them that the electricity bill is ready.

Keywords: automatic meter reading systems, AMR, electricity meter.

1 INTRODUCTION

Energy recording and billing is of great importance not only for the energy provider, but also to clients. In Jordan, these readings are acquired manually by agents from the energy-providing company.

This manual method draws several disadvantages. The energy company has to hire several agents, and provide them with vehicles, just to collect the meter data. Some meters are placed in inaccessible places, such as locked rooms, or are difficult to climb to and reach. This makes it difficult for the agent to collect the required information, especially if the acquisition involves the entry of private properties, which may be inconvenient to the property owner. Moreover, the agent usually takes readings related to energy consumption, and does not keep record of any other vital data - either because of inability to access it, or misconduct. The agent might also record the data incorrectly, resulting in inaccurate billing sheets. However, new technology, especially in the field of communications, is being adapted to meters, giving them the ability to record and send data automatically to the energy company. These new meters are called Automatic Meter Reading Systems (AMR). Some of these AMRs use radio frequency to transmit the recorded data to a nearby agent, who usually carries a handheld device to take these readings. This solution does not cover the issue of hiring agents; however, it covers all other issues. In some countries, there are restrictions on radio frequency usages; such restrictions inhibit the use of such AMRs.

Other types of AMRs use either Wi-Fi technology or GSM/GPRS technology. These can cover all issues discussed in the traditional electricity meter, and require only internet access or communication towers, depending on the technology used. This advantage can also be seen as a disadvantage, as not all populated areas of a country are covered by Wi-Fi or GSM/GPRS.

AMRs are considered a good advancement in client billing, but they come at a cost: they require replacing old meters with new ones, which is costly. Additionally, incorrect disposal of old meters can prove detrimental to the environment. For related work, Tamarkin [1] gave a description and illustration of the main components used in an AMR system. The author gave several examples of communication systems that can be used in an AMR. These systems include telephone, power-line carrier, radio frequency, or cable television. Molina *et. al.* designed an AMR system which utilizes radio frequency as a communication medium [2]. Rodney Tan *et. al.* [3] managed to build a prototype attached to a meter to take its readings each month. The prototype used GSM service in order to send the readings to the server. The proposed design in this paper uses GSM, which uses the current infrastructure provided by mobile telecommunication providers, to send data. This is simpler than establishing a radio frequency network specifically for AMRs.

In this work, we propose a small, low-cost and compact module to convert traditional electric meters to AMR systems. Accounting for the aforementioned cost and environmental issues, in this work we design a module to be attached to existing electricity meters to make them work similarly to AMRs using GSM technology. This solution is expected to cover the cost and waste issues resulting from buying new meters, as well as all disadvantages of traditional meters. A simple server and database system is also designed and implemented. The server side receives stores and organizes the acquired data from the module. The server also informs the client that their electrical bill is ready.

The rest of the paper is organized as follows: Section II shows the design requirements of the proposed system; Section III gives a simple illustration of the system design, including the hardware and software design of the module, and the software design of the server; Section IV discusses some aspects of the project; and Section V concludes the paper.

2 DESIGN REQUIREMENTS

The module design is intended to be as practical as possible. This resulted in several limitations and constraints that were taken into consideration during the design. The constraints are:

- Design constraints: the module should be small and light enough to be easily attached to the electricity meter.
- Economic constraints: the total price of the module and the traditional meter must not exceed the price of an AMR.
- Ethical constraints: the meter should not be hacked or opened under any circumstances. The module must only interface with the accessible ports of the electricity meter.

The design limitations arise from the meter type and the suggested design itself. These limitations are:

- The meter must have an RS-485 communication port so that the module can easily interface with it.
- Meter communication is in compliance with IEC 62056-21, mode C protocol. This will be discussed later in the paper.

The module will only work if the aforementioned points are accounted for in the meter. The electricity meter used in this project is ME172-D3A42-M3K03 (henceforth referred to as “The Meter” or "ME172”), which is manufactured by Iskraemeco. This type of meter can be found in different buildings and properties in Jordan. Meter designs follow specific rules and standards, set by the International Electrotechnical Commission (IEC). One of these standards is related to port communications. Meters are usually equipped with optical ports and, sometimes, with serial ports, in order to program the meter and/or transfer data to or from it.

The current standard used in The Meter is IEC 62056-21, mode C. This standard shows the required baud rate for communication, the data format and what instructions are used to interface with the meter. This specific standard stands-out among other communication standards because the data does not require encryption throughout communication. Furthermore, establishing communication is straightforward; the module only needs to send a very simple command, which is “ /?!”, and The Meter will then transmit a total of 2KB of data to the module. Other standards require encryption of data before transmission, and not all companies that design meters which communicate using such standards are willing to give away the encryption type and key. This requires hacking the meter, conflicting with the ethical constraints. Although an optical port is available on almost all meters, communication happens through the RS-485 serial communication port. The RS-485 communication port sends the data in a differential line without changing its format before transmitting. This means that the module connects to The Meter using a pair of differential wires. Use of the optical port requires designing a probe, which is difficult, but increases design complexity. In other words, the RS-485 differential port ensures a simpler design for the module, compared to a probe.

3 SYSTEM DESIGN

3.1 Module Hardware Design

In order to interface with The Meter and be able to send data via SMS, a microcontroller, programmed specifically for these tasks, is used. The microcontroller used in the module is a Microchip PIC16F88 MCU. It was chosen due to its small size and because featured all modules needed to perform the required tasks. Table 1 shows some of the key specifications of the PIC16F88 MCU, which are used in the hardware and software designs.

Other parts of the hardware include a MAX-485 chipset, which is used to convert from TTL serial communication - used in the microcontroller - to RS-485 serial communication - used in The Meter - and vice versa. A GSM/GPRS Arduino shield module was used in order to send the acquired data from the meter to the server via SMS. As the GSM/GPRS Shield design is slightly elevated - due to the use of male connectors - the shield will be placed on top of the whole circuit, using female connectors to cover it. As connectors are used, the GSM/GPRS Shield can be easily removed from the circuit if there is any need to do so. The supply for the entire circuit will be a 9V battery. Three LEDs are also connected to the microcontroller, making it easy to identify if the microcontroller is powered, working, receiving data from The Meter, transmitting data to the GSM/GPRS Shield module, or if the microcontroller is sleeping until the next reading time, in order to save power. For the microcontroller to know the exact time, a 32.768 KHz crystal is added to act as a real time clock and is connected to Timer1 of the microcontroller. Timer1 of the PIC16F88 microcontroller can work and count even if the microcontroller is in sleep mode, as long as an external oscillator is connected to it. Fig. 1 shows the circuit of the designed module.

Table 1: Key specification of a PIC16F88 microcontroller

Microcontroller specifications	
Number of pins	18
RAM size	368 B
EEPROM size	256 B
Program memory size	4096 B
Number of timers	3
USART module	Available

3.2 Module Software Design

The previous section illustrates no actual way for the client to interact with the module. The LEDs indicate the module's current status. This means that the client will not be able to modify the program once the module is out on a PCB board. This, in turn, means that the module must be programmed to work as a plug-and-play device. Once it is connected to The Meter via RS-485 communication port and powered up, it will automatically take the readings. Based on the time and date of current data acquired, the next reading time is calculated. Figure 2 shows a flow chart of the program execution.

When the module is activated for the first time, it will try to acquire the data from the meter by sending " /?!". In order to do so, the USART terminal of the microcontroller will be initialized to 9600 bits per second. The data format must be 1 start bit, 7 data bit, 1 stop bit and 1 parity bit. The previous settings are in compliance with IEC 62056-21, mode C standard. The meter will never reply if the previous settings were not met. It should be noted that the microcontroller cannot set the USART terminal with 9600 bps exactly; the USART terminal is set to 9615 bps, which means that The Meter would not always take the command from the first time. If the microcontroller does not receive any data from The Meter, the microcontroller will automatically send the command again for another attempt. It will keep doing this until it receives the data from the meter. As the total size of data coming from the meter is 2 KB and the size of the RAM of the microcontroller is 368 Bytes, the microcontroller is programmed to receive only the most important pieces of data. The data acquired from the meter includes the time of the reading, date of the reading, how many times the terminal cover of The Meter was opened, how many times the main cover of The Meter was opened, how many times a magnetic field was detected, and the total absolute active energy consumed at the time of the reading. Other data is ignored.

Once the required data is received, the microcontroller will calculate the next date or time, determined by the electricity company, in which the module is required to take the readings again for billing or/and recording. The calculated date and time will be saved in the microcontroller's EEPROM and the counter for Timer1 will be set. This step is taken to make sure that the microcontroller does not lose track of the next time it has to take readings, in case of power cutoff. Then, the microcontroller will turn on the GSM/GPRS Shield in order to send the

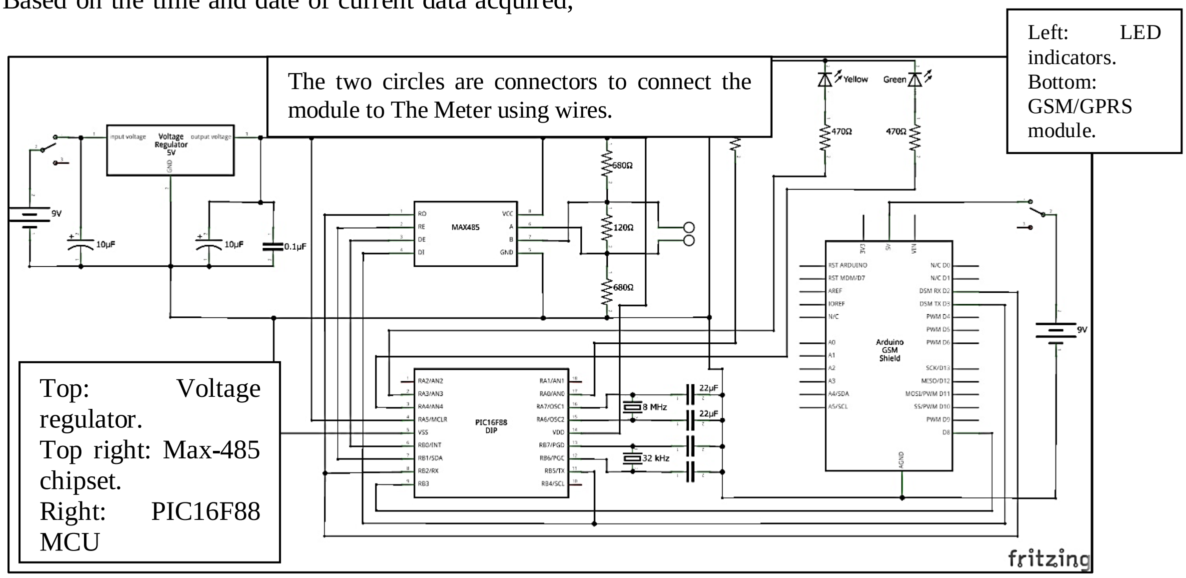


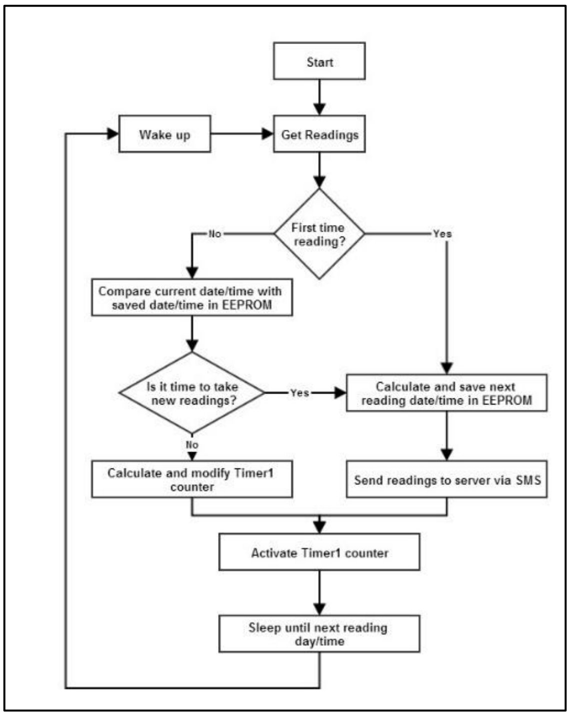
Figure 1: Circuit diagram of the module.

SMS containing the acquired data to the server. After sending the SMS, the shield will be turned off to save power, after which Timer1 is activated to count when the next reading will be taken, and the microcontroller is put to sleep to save power.

Figure 2: Flow chart of program execution in the microcontroller.

3.3 Server Software Design

As previously mentioned, insufficient RAM



capacity means only the most important parts needed for record keeping are selected by the microcontroller. The readings are then passed to the GSM module, to be sent via SMS to the server at the electricity company. At the receiving end, another GSM module is connected to the end device, acting as the server by a USB-to-TTL converter. The USB-to-TTL converter makes it possible to retrieve the meter data from the GSM module using AT-Commands. The C# programming language was chosen in programing because it is platform neutral, supported with the necessary modules, and widely-supported in programming communities. The program, upon retrieving the SMS message with the meter data, then breaks it down to eight items:

- Meter number
- Meter phone number
- Date
- Time
- Number of times the terminal cover was opened
- Number of times the main cover was opened
- Number of times a magnetic field was detected
- The total absolute active energy consumed

The next step is to pass these items to a database for record keeping. Figure 3 shows a flowchart of the program execution. To make it easier to access newly-received messages, the recently-analyzed message is deleted. This will move a new message to the top of the message list, to be analyzed next.

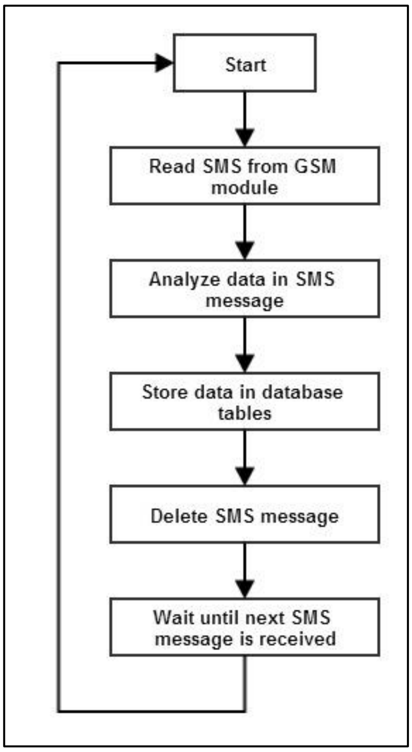


Figure 3: Flowchart of program execution in the server.

The program creates a database with three tables. The first table – Client Details – is for storing client information. The client's phone number, name and address are not obtained from the meter data and have to be filled in manually. The second table – Readings Table – is for storing the client's meter data details and the final billing value. Finally, the Events Table stores the number of times the terminal or main cover have been opened and the number of times a magnetic field was detected nearby the meter.

The database is designed so that each client gets a record in all tables, and is represented by their meter numbers. For each client, the database will save twelve entries of meter data: one for each month, for a whole year. The date and time fields are filled from meter data on the first entry only; the remaining eleven entries are calculated by the database itself, and stored in their respective fields.

The total bill is the final amount of money the client has to pay. It also has twelve entries in the table, one for each month, and is calculated by multiplying the total absolute active energy by the charge per kWh assigned by the company. The client's details table is not changed unless a client obtains a new personal phone number or address.

The Events Table is for security measures. If the terminal or main covers are opened, The Meter records the number of times this has occurred and it is saved in the database. The same applies for the magnetic field detection count. These counts are important because they indicate whether The Meter was tampered with. The company can then take action towards such violations.

At the beginning of each month, after the new readings have been saved and the final bill calculated, the program uses the data stored in the database to create a new SMS message containing the total bill value and sends it via the GSM module to its respective client using their provided phone number.

4 DISCUSSION

The main purpose of this project is to design a low cost system that would be used to upgrade current meters to work as an AMR. The module design is considered a prototype, so there is much room for improvement.

The first thing to consider is the total system cost. The total cost of the module and the traditional meter may be more expensive than an AMR unit. The overall cost of the system can be reduced by using other types of GSM modules.

The GSM was chosen and preferred over other wireless technologies because to account for the possibility that not all parts of Jordan are provided with GPRS or 3G+ technology. It should also be noted that country regulations might prevent attaching a separate module to a meter.

The server's program can be better improved by adding a function that checks if all the readings of meters from the previous day were successfully received. In other words, if a meter did not send its readings within the expected time, the server must flag it to notify the company.

As SMS service is being used to send and receive The Meter data and billing information, this might result in a congestion problem at the server's end. A server with higher specifications may solve this issue.

Finally, as the billing information is sent to the client using their provided personal mobile phone numbers, it is important that the electricity company stays up-to-date with client information.

5 CONCLUSION

Energy recording and billing is an important task for any energy-providing company. Wireless technologies have made it possible to take meter readings without the need to send any agents to the field. However, this requires replacing traditional meters with new ones. This project managed to address this issue by designing a module that attaches to current meters in order to take their readings automatically. The readings are sent to a server for record-keeping and bill calculation. The server also informs the client of their final bill after it is recorded. The design provided a low cost solution to convert old traditional electricity meters to become AMRs.

6 REFERENCES

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