

Smart Energy Meter

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Abstract— This paper presents a smart energy meter for automatic metering and billing system. The integration of a microcontroller and GSM short message service (SMS) provides the meter reading system with automatic functions that are predefined. The GSM module requires a SIM (Subscriber Identity Module) card just like mobile phones to activate communication with the network. Direct current (DC) components are used to control alternating current (AC) loads. To isolate these components from each other, relays with a network of resistors and diodes are used. Users can recharge and control loads remotely. Utility companies also have remote access to the system such as fault diagnosis and communicating with clients. The proposed energy meter system (EMS) transmits data like consumed energy in kWh and generates a bill over a GSM mobile network. Other advantages include that the system provides domestic power consumption accurately, safely and with a relatively fast update rate.

Keywords—SMART energy meter, microcontroller, GSM short message service (SMS), energy meter system (EMS), remote access, direct current (DC), alternating current (AC)

I. INTRODUCTION

Energy meter billing is an important part of energy distribution [1]. The use of manual systems is undesirable. Due to human errors at utility companies, it is a problem for users to get them corrected; that is, customers have to stopover at the company offices, stand in a queue and get it corrected. There is a need to improve the accuracy of the bills. To avoid human intervention in the billing process, an automatic reading meter system can be used [2–6]. Currently, those imported into the country can only measure and monitor electricity but do not allow remote access. The other problems with the system is that it requires a lot of manpower; it is time-consuming and prone to errors. "Smart energy meter" can solve these issues by providing services to the consumer through SMS along with other inbuilt features such as tamper-proof, fault detection, etc. The energy meter utilizes a GSM module to monitor energy consumed for the authority [2–6].

Similarly, the utility company can use the GSM service so as to send feedback. The GSM technology used enables the consumer to receive messages about the consumption of power (in KW), and when low, it automatically alert the consumer to recharge. This technology holds good for all electricity distribution companies, private communities, IT parks and self-

contained housing projects. The implementation of this project will help in better energy management, conservation of energy and also in doing away with the unnecessary hassles of incorrect billing. The billing system will keep track of consumption and solve any disagreements on consumption and billing [7–11].

Electricity theft is also a common issue. The main disadvantage of the 'ordinary' meter is that it is less reliable, less accurate and non-tamper proof. Even the present day electronic energy meters are not completely tamper-proof. The proposed energy meter has features of detecting faults in the distribution system, which is done by checking the status of supply at a distribution transformer [11–19].

Smart meters are the future because they have vast merits for both the consumers and the producers or suppliers. The main aim is to make the smart meters locally thus improving the number of electronic gadget's manufactured or made locally. The smart meters will, therefore, be able to counteract if not all, most of the demerits of the 'ordinary' meters, for instance; it must allow for remote access and be user-friendly, hence indicating if the amount of electricity used is high or low which leads to regulations and in turn saving energy. A microcontroller and the contactor will be the heart of the design.

II. EXPERIMENT

The smart energy meter circuits will be made by various softwares and components explained within this section. A microcontroller and the contactor will be the heart of the design as shown in figure 1 and 2. The smart meter is designed to give feedback on regular bases. Two main softwares were used: Proteus 8.6 SPO and Arduino software. Proteus was used to design and simulate the circuit. Arduino software was used to program the microcontrollers. Sample code shown in figure 5 was written using the software and then also used to insert the code in the microchip in the circuit on figure 3 [11–19]. ATMEGA 328 is a high performance, low power AVR 8-bit microcontroller. It has advanced RISC Architecture: up to 20 MIPS throughput at 20 MHz, 32 x 8 general purpose working registers. The device also has high endurance. It controls the entire circuit. All actions the circuit does are monitored by the microchip [11–19].

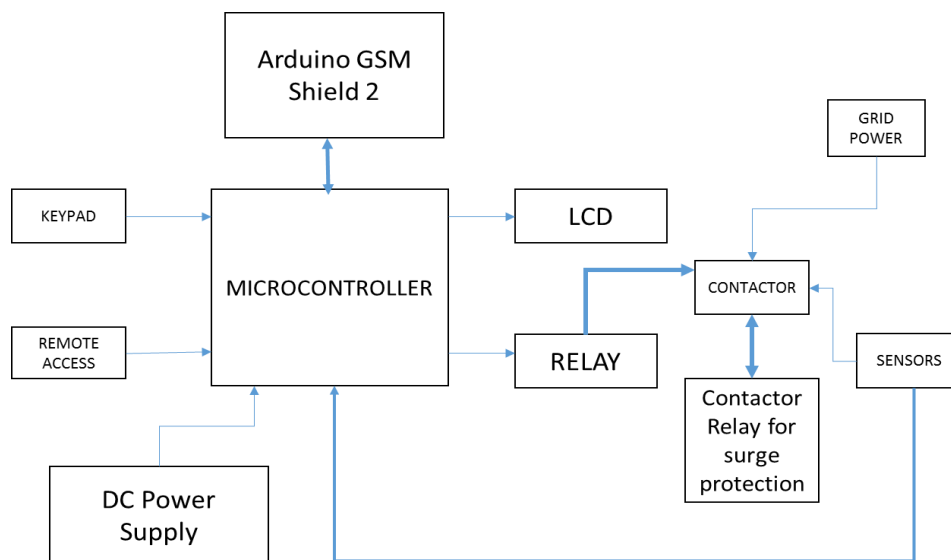


Fig. 1: block diagram

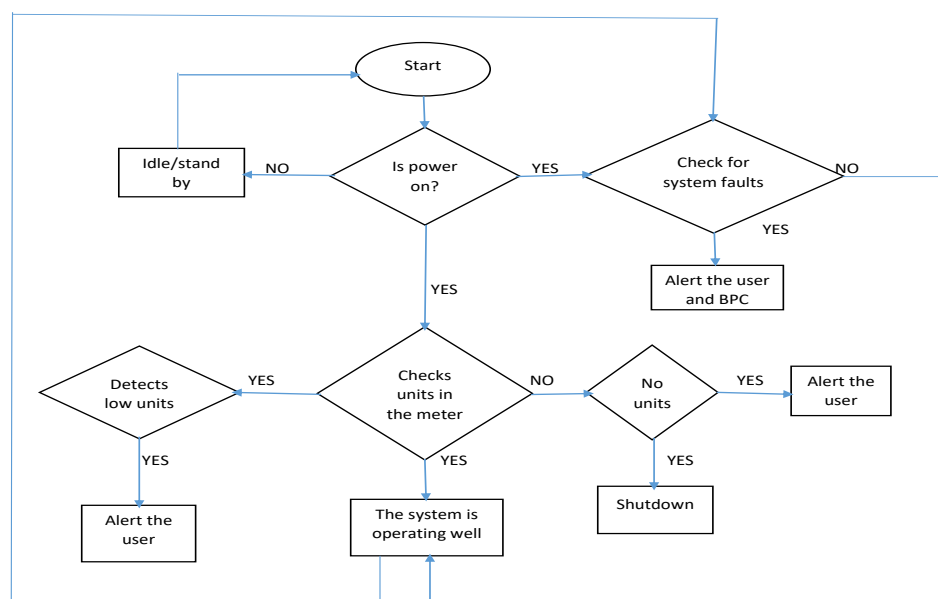


Fig. 2: flow chart

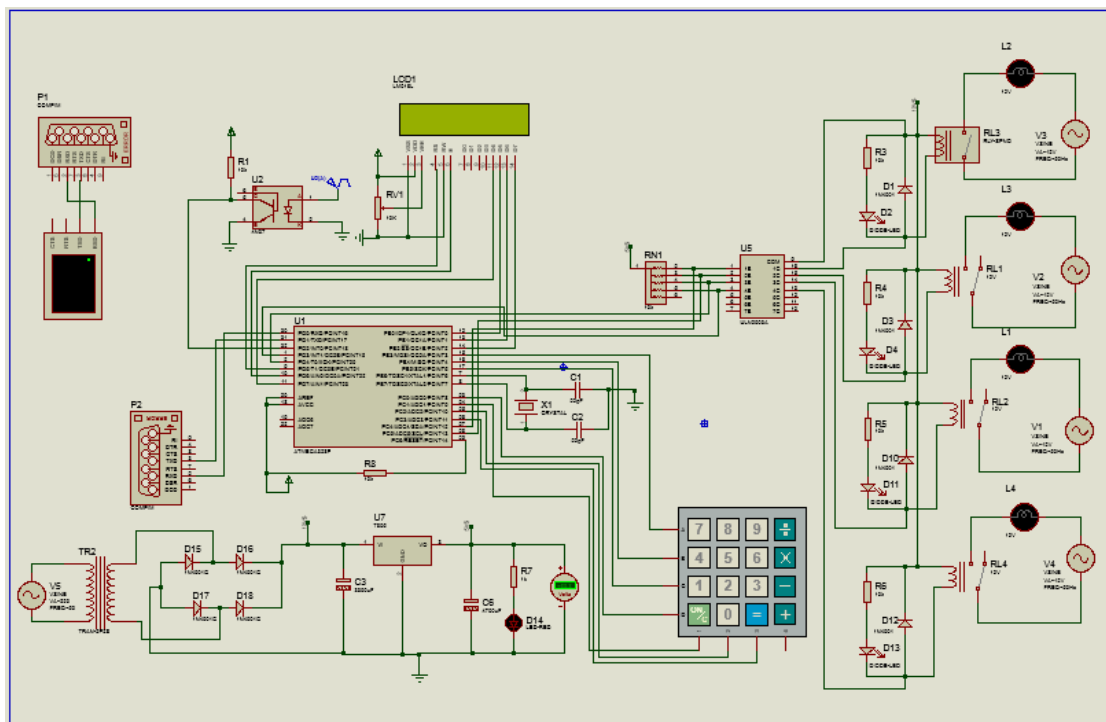


Fig. 3: Circuit diagram

```
#include <LiquidCrystal.h>
#include <TimerOne.h>
// defining library for making working keypad
#include <Password.h>
#include <Keypad.h>

//lcd(RS, E, D4,D5,D6,D7);
LiquidCrystal lcd(5, 6, 7, 8, 9, 10);

float x = 9.9;

#define Pin "pin"
#define ok "OK"
#define ERROR_str "ERROR"
#define Connected "Connected"
#define Connecting "connecting"
#define CLCC "+CLCC:"
#define atCLCC "AT+CLCC"
#define CMGF "AT+CMGF=1"
#define CMGL "+CMGL:"
#define CMGS "AT+CMGS=\""
#define CMGD "AT+CMGD="
#define UNREAD "AT+CMGL=\"REC UNREAD\""
#define CMGDA "AT+CMGDA=\"DEL ALL\""
#define CNMI "AT+CNMI=0,0,0,0"
```

Figure 5: Sample code

The COMPIMs and the virtual terminals allow wireless communication between the user and the meter. Virtual terminal COM1 represent a cell phone used by the user and COM2 is the GSM connected to the circuit. The Arduino GSM Shield 2 allows an Arduino board to connect to the internet, make/receive voice calls and send/receive SMS messages. One of the aims of the project is to allow for remote access as such the shield will help accomplish that as the system will be able to send/or receive text [1]. The function of the power source together with the AC to DC convertor circuit is to provide electrical energy to components which are connected to it [11—19].

The USB cable was used to connect computers to peripheral devices. USB cables are 'Hot Pluggable', in other words, you can connect and disconnect the cables while the computer is running without fear of freezing the computer. USB cables carry power as well as signals. This allows for "USB powered" gadgets as well as recharging batteries in USB peripherals. Figure 3 also shows a 16-button keypad that provides a useful human interface component for microcontroller projects. Convenient adhesive backing provides a simple way to mount the keypad in a variety of applications [11—19].

The meter-pulse regulates the rate at which the electrical units in the meter are consumed depending on usage. i.e. high pulse is for high consumption and vice versa. Connecting wires allows an electrical current to travel from one point to another because electricity needs a medium through which to move. In case of computers, wires are embedded onto circuit boards, carrying pulses of electricity that are interpreted as binary signals of zeroes and ones [11—19]. Various capacitors were used which are marked in a variety of ways. The actual format of the capacitor code or marking depends upon the type of capacitor. There are different codes used depending upon whether it is a traditional leaded component, or surface mount and/or type of capacitor dielectric or technology. Size also plays a major part as it determines the space available for the marking. The function of the electrolytic capacitor is to offer high capacitance value on to the circuit board [11—19].

Resistors play an important role to limit the current and provide only the required biasing to the vital active parts like the transistors and the ICs. The crystal oscillator provides a very stable signal. The device can be used in radio for tuning to a specific wavelength or providing that wavelength signal. They can also be used to determine an unknown signals frequency. Any time a very precise signal is required, a crystal oscillator is used. The circuit also has a potentiometer of 10K. In electrical engineering parlance, the term "potentiometer" is used in either one of two ways. It may refer to an instrument that measures an unknown emf or voltage by comparing it to a standard emf. In this instance, it is functioning as a null instrument; it permits precise measurement by adjusting the value of a circuit element until a meter reads zero. Alternatively, "potentiometer" may refer to an electronic component that is used to vary the resistance in a circuit [11—19].

The relays used are electromagnetic devices used to isolate two circuits electrically and connect them magnetically. They are very useful devices and allow one circuit to switch another one while they are completely separate. They are often used to interface an electronic circuit (working at a low voltage) to an electrical circuit which works at very high voltage. The LCD (Liquid Crystal Display) screen used is an electronic display module and finds a wide range of applications. A 16x2 LCD is a 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 characters [11—19].

III. RESULTS AND DISCUSSION

When the circuit is simulated, the LCD displays as in figure 6. After GSM connection, the LCD then displays as in FIGURE 7. Either the keypad or the cellphone can be used to access the meter. When using the keypad, 0 is used to move down the menu interface while 2 is used to move up. The equal sign (=) is used to select the option the user wants, either recharge or start and (*) is used as back. To input units in the meter, the recharge option should be selected and the meter units' number inputted using the keypad. The LCD should then display the new balance. These can also be done using the phone. After recharging, the user can escape the recharge interface and enter start to show electric consumption. The LCD shows the remaining units in the meter, i.e. the meter counting down. The phone can also be used to switch on/off loads. There are unique alphabets the user needs to input to switch on/ off a certain load. Here are the results of the outputs when they are controlled by the virtual/real cellphone.

Table 1: output results

INPUT	Output controlled	Effects
Pressing a	L1	Turns the bulb ON
Pressing b	L1	Turns the bulb OFF
Pressing c	L2	Turns the bulb ON
Pressing d	L2	Turns the bulb OFF
Pressing e	L3	Turns the bulb ON
Pressing f	L3	Turns the bulb OFF
Pressing g	L4	Turns the bulb ON
Pressing h	L4	Turns the bulb OFF

Results of when controlling the system using a keypad as an input device are shown below.

Table 2: Keypad results

INPUT	Output controlled	Effects
Pressing 0	L1	Turns the bulb ON
Pressing 1	L1	Turns the bulb OFF
Pressing 2	L2	Turns the bulb ON
Pressing 3	L2	Turns the bulb OFF
Pressing 4	L3	Turns the bulb ON
Pressing 5	L3	Turns the bulb OFF
Pressing 6	L4	Turns the bulb ON
Pressing 7	L4	Turns the bulb OFF

For the GSM to be connected to the circuit it must be switch-on which is indicated by a light and this should be pressed immediately after it is powered up. It is indicated by figure 5 below. The lights are a confirmation that the GSM is switched on and/or that the GSM is connecting.

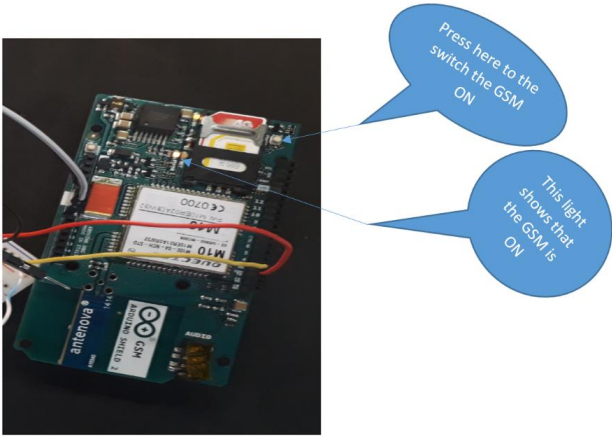


Fig. 5: Setup of the GSM



Fig. 6: GSM connecting to the system

After the GSM is connected, it will then wait for a call (communication with a mobile-phone) for configuration. It should be noted that only one number, for now, can be configured. This is relevant because it is crucial in allowing for user interaction with the system. The mobile-phone is the one which will be used to communicate with the system. Figure 8 shows the system waiting for a call to configure the number.



Fig. 8: System waiting for call



Fig. 7: GSM connected

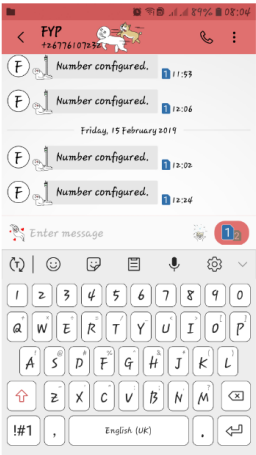


Fig. 9: configuration of the cellphone number

After the GSM received a call, it then sends a configuration message to the number that was used to call the system. Figure 9 shows the number configuration confirmation. Once the

configuration is done, the user will now be able to use the system.

The display shown in figure 10 below is for recharging, which allows users to enter recharge numbers. A particular number entered will recharge the system with particular monetary value and power units depending on the amount used to buy the recharge number.



Fig. 10: recharge of 50 units below.

Since the system is user friendly, it allows for checking of available units after or before recharge. Therefore, the figure below is relevant because it shows the available units after recharge.



Fig. 11: the total amount of units available

IV. CONCLUSION

Some of the research aims were met, for instance, to allow the meter to be able to send messages to a mobile-phone and to allow for remote access, this was enabled by the Arduino GSM shield 2. Also, the smart meter can be recharged. Problems were experienced with the microcontroller having fewer ports than anticipated. The number of outputs were reduced to address the problem together with some modifications to the circuit. The system also depended for 3G sim cards which are no longer in use. These sim-cards have been faced out in Botswana. The only resort was to change the SIM800A GSM module to GSM shield 2 which allowed for the use of 4G sim card.

V. REFERENCES

- [1] O. A. O. N. C. A. "Design and Testing of a Smart Energy Metering System Based on GSM modem," *European Journal of Engineering and Technology*, Vols. 3, no.4, no. 2056-5860, pp. 35-56, 2015.
- [2] Arduino, "Arduino GSM Shield 2 (Integrated Antenna)", [Online]. Available: <https://store.arduino.cc/arduino-gsm-shield-2-integrated-antenna>. [Accessed 24 January 2019].
- [3] Arduino, "Arduino Mega 2560 Rev3", [Online]. Available: <https://store.arduino.cc/arduino-mega-2560-rev3>. [Accessed 24 January 2019].
- [4] "Electronic Components", Engineers Garage, [Online]. Available: www.engineersgarage.com. [Accessed 30 November 2018].
- [5] C. Fritz, "Hunker," [Online]. Available: <https://www.hunker.com>. [Accessed 2 December 2018].
- [6] Kushagra, "Electronic Components," Engineers Garage, [Online]. Available: <https://www.engineersgarage.com>. [Accessed 2 December 2018].
- [7] S. M. S. Praveen Vadda, "Smart Metering for Smart Electricity," Master Thesis Electrical Engineering, pp. 3-7, 2013.
- [8] Giri Prasad .S, "IoT BASED ENERGY METER," *International Journal of Recent Trends in Engineering & Research (IJRTER)*, no. 2455-1457, pp. 61-62, 2017.
- [9] M. J. Jubi.K, "Prepaid Energy Meter with GSM Technology," *American International Journal of Research in Science, Technology, Engineering and Mathematics*, no. 2328-3580, p. 195, 2013.
- [10] Saddam, "Prepaid Energy Meter Using GSM and Arduino," *Circuit Digest*, 6 February 2016. [Online]. Available: <https://circuitdigest.com/microcontroller-projects/prepaid-energy-meter-using-gsm-and-arduino>. [Accessed 10 February 2019].
- [11] Svsembedded, "GSM based Energy Meter Billing with Load Control using Arduino," Youtube, 29 November 2017. [Online]. Available: <https://www.youtube.com/watch?v=Su97JLExmHE>. [Accessed 5 February 2019].
- [12] F. B. M. N. B. M. Y. S. A. C. A. Win Adiyansyah Indra, "GSM-Based Smart Energy Meter with Arduino Uno," *International Journal of Applied Engineering Research*, vol. 13, no. 0973-4562, p. 3950, 2018.
- [13] C. McNally, "ARDUINO BASED WIRELESS POWER METER," Master of Electrical Engineering Program Cornell University Design Project Report, pp. 18-27, 2010.
- [14] E. E. Queen, "Smart Meters and Smart Meter Systems: A Metering Industry Perspective," Edison Electric Institute, Washington, D.C, 2011.
- [15] R. R. P. N. K. K. R. A. V. J. A. Geetha B, "Smart Energy Meter Load Control," *International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering*, vol. 2, no. 8, p. 7, 2013.
- [16] Y. Y. B. S. P. Z. Sandhya Shinde, "IoT Based Smart Energy Meter," *International Journal of Trend in Scientific Research and Development (IJTSRD)*, vol. 1, no. 6, p. 3, 2017.
- [17] Muhammad Ansar, "Prepaid Energy Meter Billing VIA SMS | Arduino and GSM Based Smart Energy Meter", Youtube, 22 January 2019. [Online]. Available: <https://www.youtube.com/watch?v=Sxg0jkP6AtY>. [Accessed 7 May 2019].

[18] Nevon Projects, "Power Meter Reader Plus Load Control Using GSM", Youtube, 2 July 2015. [Online]. Available: <https://www.youtube.com/watch?v=EeUO3SZtRd8>. [Accessed 7 May 2019].

[19] Vipul Deshbhratar, "Smart Energy Metering with Real-time Power Analysis and Auto Monthly Billing", Youtube, 7 March 2017. [Online]. Available: <https://www.youtube.com/watch?v=-0frwbl4G40>. [Accessed 7 May 2019].