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Electric Power Telemetering System Design Using Microcontroller Device Via GSM

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Abstract
Traditionally, energy meter readings are performed by human operators moving from house to house collecting readings. This exercise requires a large number of labor operators and a lot of time to achieve complete meter readings in a given area. This paper seeks to eliminate this problem by using telemetering systems. With this system, power can be measured from remote locations. To achieve this, readings from the on-site energy meter are processed by a microcontroller device which then sends energy consumption information to the Global System Mobile (GSM) module. The GSM module then sends this information using microwaves to specific mobile phone subscribers who receive it in the form of Short Message Service (SMS). The readings are also transmitted to a web-based telemetering system through a server. At remote sites, remote computers that can access the internet can obtain data from servers over the internet. The microcontroller is developed in such a way that it achieves communication between the energy meter and a specific server using the Transmission Control Protocol (TCP) protocol. Software programs were also developed to facilitate the transfer of data to users on remote sites. With web-based telemetering systems connected to the internet, electrical energy measurement can be accessed globally. Transmission line efficiency is important for the success of SMS and web-based telemetering systems.
Keywords: Telemetering system, remote sites, GSM

1. INTRODUCTION

There is an upcoming increase in operating costs due to the expansion of the customer base. Therefore, the need to implement a system that can reduce the annual expenses incurred as a result of the process of taking readings manually is very important for companies. In addition, this traditional manual reading process is influenced by the outside world where weather, road and transport conditions and other human factors play a large role in the accessibility of the area where measurements must be made.

All these factors, affect the efficiency of the meter reading process. Telemetering systems based on internet and mobile phone communication systems should thus be designed. This system overcomes the above-mentioned difficulties along with the problem of human error that is prone to occur when the operator takes meter readings. Telemetering systems combine computer network technology and wireless communication technology to improve the efficiency and reliability of the electricity meter reading process, reduce the operating costs of power companies, avoid human error and enable optimized modern management of enterprises.

With the introduction of digital technology, analog electromechanical meters have been replaced by digital electronic meters. This digital technology provides a good platform for the implementation of Automatic Meter Reading (AMR) systems as it involves the use of electronic systems [1,2].

It must be noted that the concept of telemetering systems can be applied in many fields today, from meteorology to space science, water management, medicine, and even military intelligence. However, this paper describes a telemetering system whose purpose is to measure the electrical energy consumed by a particular consumer. Efficiency and reliability in taking meter readings in AMR systems have proven to be a major challenge in the past. Many methods and technologies using Power Line Carrier (PLC), Supervisory and Data Acquisition (SCADA) communication, Ethernet, Wi-Fi internet, Bluetooth, RF modules, ZigBee have initially been developed to demonstrate the reliability, efficiency, and effectiveness of AMR [3,4].

The methods mentioned above have proven too expensive to implement and operate, they require complex infrastructure setup as is the case with SCADA or are prone to fault and reliability issues due to noise in transmission lines or weather conditions. The rapid development of GSM infrastructure in recent decades has made wireless AMR systems more reliable and possible. Therefore, the focus will be on the design of a system that will be able to take meter readings from remote sites and transmit these readings to a central station so that billing can be done by utilizing GSM technology.

2. METHODOLOGY

In this section, the methods used to implement the design are discussed using the following steps;

1. Measurement of energy consumed.
2. Transmission of signal reading.
3. Reception of signal readings.

To measure the energy consumed, current and voltage values are considered. The rated voltage is taken as 240V, 50Hz which is the standard value of single phase voltage. This is the voltage value used throughout this paper.

The current drawn on the other hand is constantly changing depending on the load connected to the meter. Therefore, the change in current determines the amount of energy consumed per hour. The power factor for low power consumers is not easily low because the current drawn is low.

It should be noted that the load used in this paper is a purely resistive load, therefore the voltage is in phase with current. This means that the power factor will always be 1 because the cosine of 0 is 1. Therefore, the waveform for power will always be positive and never negative for this resistive load. This means that power will always be dissipated by resistive loads, never returning to the source as is the case with reactive loads. For high-power consumers, reactive loads are mostly connected. This affects the value of the power factor.

After the readings are made, they are processed by the microcontroller in a meter and then transmitted to the central station using GSM technology. The GSM module has a Subscriber Identification Module (SIM) card that facilitates this transmission process.

The readings are then received either via SMS or to the web application. In this paper, readings are received via SMS and also through a web application. With this, real-time access to meter readings can be obtained. However, to minimize too much traffic on the server for practical real-world implementation, the meter can be programmed to send meter readings after every 15 minutes.

2.1 Measurement of energy consumed

At the measurement point, the current needs to be lowered to a low value before it is allowed to flow to the microcontroller without damaging the device. For high current values, a current transformer say 1000/5A can be used. With this, the microcontroller can be programmed to recognize that when reading the value of 5A, then it knows that this is 1000A, therefore the value of the current to be transmitted to the central station is 1000A. This is for the case of heavy electricity consumers. The data flow in units of measurement is as follows;

1. Analog input signal: In this case the input signal to the unit of measurement is current.
2. Analog to Digital (AD) converter, is a part of the meter measurement system that produces calibrated instantaneous current digital values from analog input signals. For this paper, this ADC is in the Arduino microcontroller device.

2.1.1 Data preparation

The processor determines the average digital value of the instantaneous value and the current generated from the ADC. This average value is averaged over one second in each case. The average value in one second is; active power, and current.

2.1.2 Signal processing

The microcontroller calculates the following measured amount of the average value provided by the signal processor:

- Power on in 1 second
- Current in one second

2.2 Simulation using Proteus software

The simulation of our work is done using Proteus software. This is done using the following set of components;

1. Resistor.
2. Liquid crystal display (LCD).
3. Power supply.
4. Load 240 Ohms.
5. An Arduino Uno.
6. Capacitor.
7. ACS712T Hall Effect current sensor.

2.2.1 Current Measurement

Current measurements are achieved using ACS712T (20A). This current sensor is connected in series with the load for easy current measurement. ACS712T is a sensing device that provides an economical and precise way to sense AC current passing through it using the hall-effect principle.

ACS712T is based on the hall-effect. According to this principle, when a current-carrying conductor is placed in a magnetic field, a voltage is generated at its edges perpendicular to the direction of the current and the magnetic field.

Due to the presence of the Lorentz force (force due to the combination of magnetic and electrical forces), the distribution of current no longer crosses the hall element and thus a potential difference is made at the edge perpendicular to the direction of the current and the field. This voltage is called the hall voltage.

The ACS712 device consists of a precise, low-offset, linear hall sensor circuit with a copper conduction path located near the die surface. When current is applied through a copper conductor, a magnetic field is generated and this is sensed by the hall element. The strength of the magnetic field is proportional to the magnitude of the current through the conductor. The signal conditioning and filter circuit present on the chip stabilizes the induced hall voltage to the appropriate level so that it can be measured through the microcontroller's ADC channel.

The conduction line terminals are completely electrically isolated from the sensor cable. Therefore, ACS712T eliminates the risk of damaging the current monitoring circuit as a result of high voltage on the conduction side.

Since our study involved the use of low-frequency, 50Hz AC, an RC filter circuit was added to the output of the ACS712 device. This is useful for increasing the signal-to-noise ratio. It should be noted that there are no connected resistors in the RC filter, this is because ACS712 contains internal resistors connected to the output of the on-chip signal amplifier. Therefore, a simple addition of an external capacitor between the filter pin and ground is sufficient. Since bandwidth decreases with increasing capacitance, the ACS712 datasheet recommends using 1nF for capacitors to reduce noise under normal conditions.

2.2.2 ACS712 output

ACS712-05B can measure currents up to ±20A and provide an output sensitivity of 100mV/A (at +5V power supply). This means that for every increase in current 1A through the conductor in the positive direction, the output voltage also rises by 100mV. At zero current, the output voltage is half of the supply voltage (Vcc/2). The voltage at zero current was found to be 2.4V when Proteus software was used in the simulation. This value is close to the halfway value of 2.5V. This is the offset of the current sensor ACS 712.

The ACS712 provides an output ratio because the output current is zero and the sensitivity of the device are both proportional to the supply voltage, VCC. This feature is useful because ACS712 is used with ADCs and A/D conversion depends on stability if a reference voltage is used in ADC operation. The ACS712 has a voltage stabilizer that keeps the output constant at 2.5V.

However, care must be taken when working with the ACS712 sensor as it is susceptible to wild magnetic fields. The following conditions may affect the perceived current value;

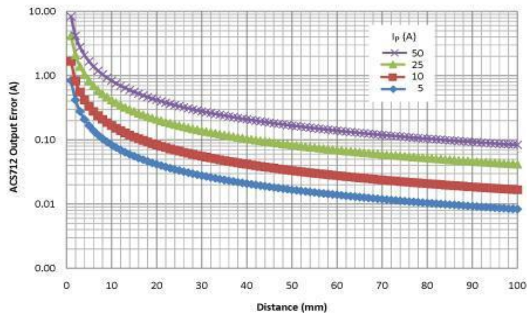

Figure 1 Absolute Output signal error versus distance between element hall and external PCB conductor at various current levels

1. A stray field resulting from current flowing across a printed circuit board or external current-carrying conductor close to ACS712.
2. The external current-carrying conductor is in the same plane as the current sensor.

Figure 1 below shows the absolute current error (in A) versus the distance of the hall element from the primary conductor (in mm) for different current values, in A.

Therefore, shielding must be done on the hall element to prevent the deviated magnetic field from interfering with the measurements made.

2.3 Time Measurement

Time is important because the energy consumed is directly proportional to the time period the load is connected to the supply and draws current.

To measure time, no external hardware is needed as the Arduino has a built-in timer. The millis() function is used in code. What this function does is return the number of milliseconds since the board started running the program. Therefore from the moment the program is run, the start time is taken into consideration.

With this function, the meter will provide real-time energy consumption readings that can then be transmitted.

2.4 Data Processing

By scanning the average values per second (active power, voltage, frequency, power factor), the microprocessor forms a corresponding measured amount. This was done by AT mega 328 on board Arduino Uno. This measured quantity is then displayed on the LCD screen. Remote reading is also ready at this time.

2.4.1 Arduino Uno R3 Microcontroller Unit

Arduino Uno is used to process data readings and send them to the GSM module for transmission. Arduino is an ATmega328P-based microcontroller board. It has 14 digital input/output pins; 6 of them can be used as Pulse Width Modulation (PWM) outputs. It also has 6 analog inputs, a 16MHz quartz crystal, a Universal Serial Bus (USB) connection, power plugs, an In-Circuit Serial Programming (ICSP) header, and a reset button.

2.5 Transmission Measurement

The GSM module is connected with a microcontroller as shown in Fig.2 to ensure the exchange of information about the measured quantity. In this case, the GSM module obtains information about the measured amount from the microcontroller. Serial communication at a predetermined baud rate ensures communication between these two devices.

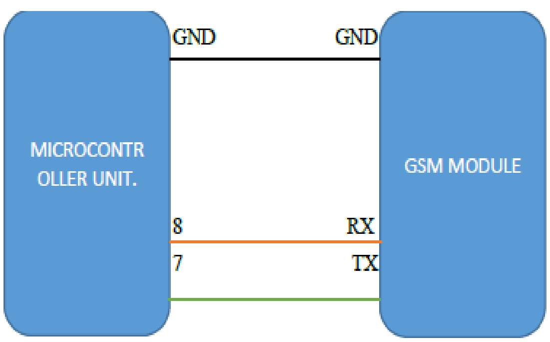

Figure 2. GSM module and microcontroller interface

The unit of measurement has a unique serial number that makes it possible to interrogate it specifically and obtain all the information about the measured amount. Therefore, it provides real-time access to the measured amount.

The GSM module used is SIM 900A. It is an ultra-compact and reliable wireless module made by SIMcom that works well with Arduino microcontroller units. It is a complete dual-band GSM/GPRS module in Surface Mount Technology (SMT) type and allows us to benefit from small dimensions and cost-effective solution. It has SMT pads and uses a single-chip processor that integrates ARM926EJ-S. The module delivers GSM/GPRS 900/1800MHz performance for voice, SMS, data and fax with low power consumption. With a small configuration of 24mm x 24mm x 3mm, this module can meet many space requirements for our applications.

2.5.1 Data transmission using SMS

Once the calculation of power and energy consumed is done by the microcontroller, the data is now ready to be sent to the central station.

Here, code is also written to make the SIM900A start operating in SMS text mode thus allowing the GSM module to send SMS to the subscriber of the specified mobile phone. It should be noted that the GSM module has two modes of operation, SMS text mode and SMS Protocol Data Unit (PDU) mode. In SMS text mode, SMS is represented as readable text while in PDU mode, all SMS messages are represented as binary strings encoded in hexadecimal characters.

In code, a delay of several seconds is used after each command to give the GSM module enough time to interpret and respond to the command.

In determining the content of the sent SMS, the program is arranged in such a way that it is called the voltage, current and energy output of the code used to measure the energy parameters. This output is then sent to the specified customer as shown in the code. The received SMS has data on the energy consumed, voltage and current value.

2.5.2 Data delivery to web applications

Thing Speak is also used to show the results of energy consumption. Thing Speak is an open-source Internet of Things (IoT) web application that can store and retrieve data using Hypertext Transfer Protocol (HTTP) and TCP protocols over the internet or over a local area network. This enables sensor logging applications for different types of sensors. With the web application, the value of energy consumed in KWh is recorded online in real time. This data can be displayed in many different ways. Used in this case is a graph that displays the energy consumed on the y-axis and the time of day when data is collected on the x-axis. This web application is advantageous because once the data is uploaded, it is stored in a database and can be queried at a specific date range for analysis purposes or whatever the user wants.

To upload energy consumption readings, a program was written to create a GSM module to transmit measurements of energy consumed in KWh to the ThingSpeak web application in real time.

In the code, a command that searches for information about the registration status and the presentation cell access technology is written. This is important because it checks whether the SIM card can actually perform the required tasks. These tasks include GPRS capabilities. The code that also attaches this packet service is written, then the GSM module is set for a single IP connection and the Access Point Name (APN) is set according to the Internet Service Provider (ISP) used. For our case, we use Airtel APN. GPRS is then activated and the IP address is obtained through the appropriate AT command as shown in the code. A TCP connection is then initiated to the remote address that for this case is api.thingspeak.com, a web application that will display the results remotely.

With the above settings, electrical energy consumption data is sent to the web application using the specified ATtention (AT) command. The data is then ready for analysis from the web application.

2.6 Final schematic diagram design

The final design diagram is shown in figure 3.

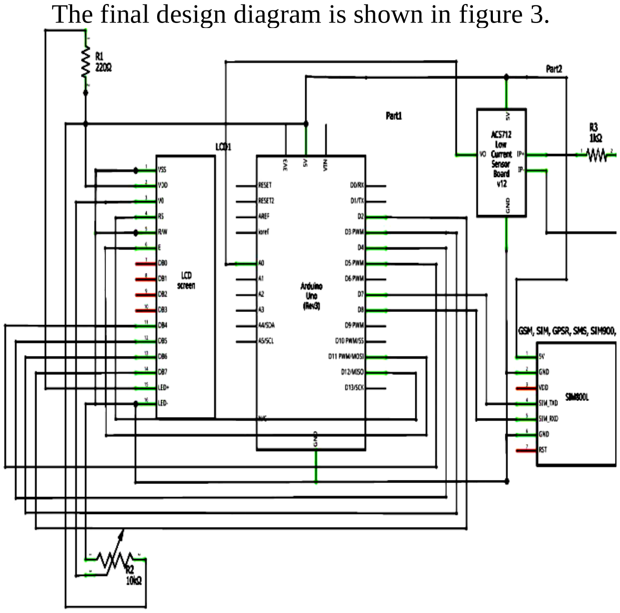

Figure 3. Final Design

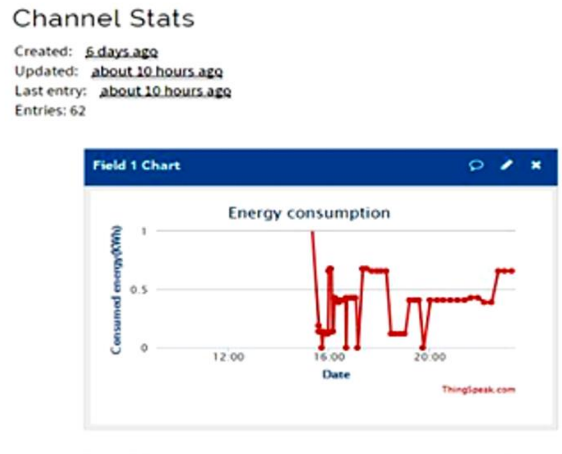

Figure 4. Chart showing energy consumption

3. Results

The result in this paper is the amount of current and energy consumed when different loads are connected. It is seen that a larger load attracts more current and consequently consumes more energy. This phenomenon can be seen from the graph on Fig.4 which shows energy consumption when different loads are connected.

From figure 4, it can be seen that there are variations in the energy consumed over time. The 100W load which is the largest load used for this paper, consumes an average of 0.66KWh. It can be seen on the chart around 1800hrs while the load consumption of 60W is about 0.41KWh which can be seen on the chart at 2000hrs. It can also be observed that the energy consumed is quite constant for a given load. This means that the current drawn does not vary too much for one expected connected load. In the calculation of energy consumed, the time period of the bulb ON is 5 hours. This is to ensure that the value of energy consumed is significantly greater for the purpose of recording consumption.

From calculations; $P=V\times I$

For a load of 100W, with a supply voltage at 240V, 50Hz, the calculated current values to be drawn ignoring the loss are as follows;

$I= P/V=100W/240V=0.4167A$

The measured current was found to be 0.55A. The difference between these two values is found to be 0.133A. A 60W load on the other hand has a rated current calculated as follows; $I=60W/240V=0.25A$

This value is slightly different from the measured value of 0.35A. It should however be noted that the readings recorded when no current is flowing are actually 0.12A, meaning that the ACS712T shows a zero error of 0.12A. Taking into account this error, the rated current drawn by a 100W load is

0.55-0.12=0.43A

The percentage of error becomes;

[(Calculated value × Measured value)/Calculated value] ×100
= [(0.4167×0.43)/ 0.4167] ×100 = 3.2%

As for the 60W load, the actual current measured is 0.35-0.12 = 0.23A and the error percentage for this value is 8%.

Small differences in these values are as a result of errors caused by differences in supply voltage. This voltage is assumed to be constant at 240V. This may not happen all the time as this value can drop slightly thus contributing to the difference in the two current values.

As mentioned earlier, the value of energy consumed recorded on this particular chart is for loads that have been connected to the power supply for 5 hours.

For cumulative energy meter recording, the chart shown in Fig.5 shows the measured energy consumption for a 60W connected load over a 9-hour period.

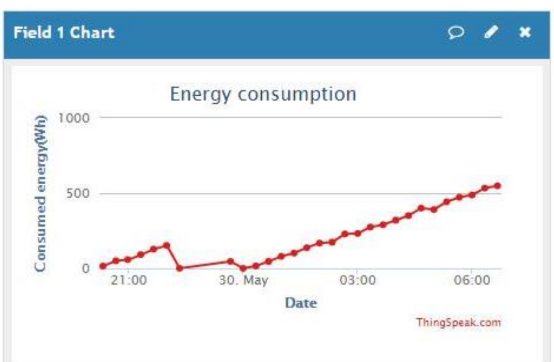

Figure 5. Chart showing meter readings as seen from the web application

From the graph on Fig.5, it is observed that between midnight and 6 am, the energy consumed continues to increase. This is because between these time periods, a 60W load is connected to the supply and hence consumes a total of 524Wh or 0.524KWh. The readings recorded on the web application can be viewed from Table 1. It is also seen that the load is turned off around 1927 hours and 2052 hours. The attendant of the utility company in the central location, must consider this effect so that when calculating the energy consumed for this particular consumer, only the peak value is summed.

Therefore, the total consumption according to the graph is 1217.11Wh or 1.217KWh as seen in Table 1.

For all these energy values consumed, the measured current was found to be 0.35A. When you consider a zero-error value of 0.12A, then the current actual value is 0.23A. Comparing this with the calculated current value of 0.25A, we get that the two are very close.

Readings are also obtained remotely via SMS. The photo on Fig.6 shows meter readings as received via SMS.

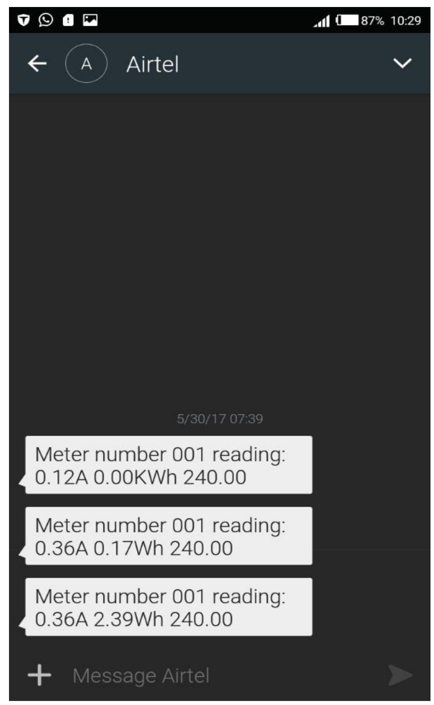

Figure 6. Screenshot of meter readings as received via SMS

This image best illustrates the zero error talked about earlier. It can be seen from the first reading that no load has been connected yet, the recorded current value is 0.12A. In the code, the if statement is written so that if the current value is less than 0.12A, then the meter will take this current value as zero. Therefore the above KWh reading is 0.00. Therefore, it will solve the problem where the meter records energy consumption in cases where no load consumes any energy. The resistance of the connecting copper conductor may have contributed to this current flow when the load was off.

Table 1 Meter Readings on Web applications with 10-Minute intervals

Created_at	Entry_id	Consumption (Wh)
2017-05-29 18:45:59 UTC	113	127.95
2017-05-29 19:08:01 UTC	114	152.31
2017-05-29 19:27:56 UTC	115	0.16
2017-05-29 19:38:57 UTC	116	15.37
2017-05-29 20:44:44 UTC	117	46.05
2017-05-29 20:52:47 UTC	118	0.05
2017-05-29 20:56:31 UTC	119	0.05
2017-05-29 21:00:26 UTC	120	0.05
2017-05-29 21:03:44 UTC	121	0.05
2017-05-29 21:09:09 UTC	122	0.15
2017-05-29 21:20:11 UTC	123	16.17
2017-05-29 21:31:13 UTC	124	32.16
2017-05-29 21:42:14 UTC	125	45.87
2017-05-29 21:53:16 UTC	126	58.05
2017-05-29 22:04:18 UTC	127	80.16
2017-05-29 22:15:20 UTC	128	91.57
2017-05-29 22:26:22 UTC	129	101.47
2017-05-29 22:37:23 UTC	130	122.04
2017-05-29 22:48:26 UTC	131	137.3
2017-05-29 22:59:27 UTC	132	152.54
2017-05-29 23:10:29 UTC	133	167.77
2017-05-29 23:21:30 UTC	134	173.86
2017-05-29 23:32:32 UTC	135	198.25
2017-05-29 23:54:36 UTC	136	228.72
2017-05-30 00:05:38 UTC	137	231.75
2017-05-30 00:16:39 UTC	138	259.19
2017-05-30 00:27:41 UTC	139	274.42
2017-05-30 00:38:43 UTC	140	304.17
2017-05-30 00:49:45 UTC	141	289.67
2017-05-30 01:00:47 UTC	142	320.15
2017-05-30 01:11:48 UTC	143	335.39
2017-05-30 01:22:50 UTC	144	350.62
2017-05-30 01:33:52 UTC	145	365.86
2017-05-30 01:44:54 UTC	146	400.15
2017-05-30 01:55:55 UTC	147	396.33
2017-05-30 02:06:57 UTC	148	390.99
2017-05-30 02:17:59 UTC	149	426.82
2017-05-30 02:29:15 UTC	150	442.06
2017-05-30 02:51:09 UTC	151	472.53
2017-05-30 03:02:06 UTC	152	487.77
2017-05-30 03:13:08 UTC	153	528.15
2017-05-30 03:35:12 UTC	154	533.47
2017-05-30 03:46:14 UTC	155	548.71
2017-05-30 03:57:15 UTC	156	958.74
TOTAL ENERGY CONSUMED		**1217.11**

4. CONCLUSION

The telemetering system is designed using Arduino Uno which has an Atmega 328P microcontroller as its processing unit. The ACS712T current sensor (20A) is used as the current measurement unit while the GSM SIM 900A is the transmitting unit. The loads used are 100W and 60W lamps. Simulations were performed on Proteus to test the work of the measurement unit with Arduino Uno. As shown, real time measurements of current and energy consumption are transmitted using GSM modules to mobile subscriber numbers and consumed energy data is uploaded to a web application named ThingSpeak.com. With this the purpose of the paper is fulfilled. The indicated zero error of the unit of measurement is considered when taking the calculation of the current drawn by the load. Through this, it is seen that the percentage of measurement error is quite small.

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