An Automatic Electrical Load Monitoring, Control and Alert System

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Abstract: Electricity is one of the most vital blessings that science has given to humanity. It has many uses in the day-to-day life activities of human, which include, the lighting of rooms, powering of fans, televisions, and other domestic and industrial applications. The use of electrical energy provides comfort; on the other hand, the users of electrical energy needs to monitor the actual energy consumption (kWh) and wastage (kVAR) in an electrical appliance. The traditional postpaid energy meter used for measuring the consumption of consumers do not offer such facilities. The coming of the smart energy meter (SEM) was expected to provide an enhanced service to consumers of electric energy; however, the current stage of the SEM does not offer daily consumption alert to consumers, neither does it permit the user to set a threshold value for daily or monthly consumption cutoff. This work sought to design and construct an automatic electrical load monitoring, control and alert system using an Arduino UNO (Atmega328p) microcontroller, which offers real-time alert to users on their energy consumption with no additional wiring work required. An implementation of the proposed system provided efficient monitoring, control and warning of electrical energy consumption as compared with the traditional energy meters.

Keywords: Electrical Energy, Postpaid Meters, Prepaid Meters, Arduino, Electrical-Load-Monitoring, Smart Meters.

1. Introduction

Electrical energy (EE) is one of the most useful energy globally, due to its cleanliness, efficient and cheap. The consumption of electrical energy is typically measured with energy meter (EM). EM is a device that measures the amount of energy consumed. The EM can be categorised as prepaid or postpaid. The postpaid EM (POEM) operates by counting the revolutions of a non-magnetic, but electrically conductive metal disc made to rotate at speed proportional to the power passing through the meter making the number of revolutions proportional to the energy. The POEM supports time-of-day billing that is recording the amount of energy used during on-peak and off-peak hours. Taking readings of the energy meter is time-consuming and an expensive task. Personnel called "meter readers" manually takes the reading of POEM by moving from houses to houses, while consumers stand in long queues to pay the bill after receiving their monthly bill from their supply authority. The POEM system of billing, according to [1] is prone to errors during the computation process, consumer absence during billing time and additional expenditures for the billing procedure. The prepaid EM (PREM) also called smart energy meters, allows power utilities to accumulate energy bills from the consumers before the use of electric power. PREM disconnects the consumer from the supply grid with the help of a built-in internal mechanism. The PREM, approach of energy billing was to eliminate the problems such as unpaid bills and human error in meter readings associated with the POEM system, thereby ensuring justified revenue for the utility [2] Energy conservation is a global issue with substantial environmental, social and political implications, and the introduction of the PREM was aimed at providing timely energy consumption feedback, to enable consumers to be more effective in managing their energy usage. However, the present PREM display the energy consumed but does not display the corresponding cost. Again, the user of the current PREM cannot set their daily consumption cut off. Furthermore, a high percentage of domestic electrical energy consumers are still using the POEM where most of the consumers cannot estimate the amount of electrical energy consumed until they receive their bill at the end of the month [1]. This study seeks to design and construct an automatic load monitoring and alert system using an Arduino UNO (Atmega328p) microcontroller, which offers real-time alert to users on their energy consumption. The rest of the paper is grouped as follows; section 2 presents a review of the literature and related study on smart energy conservation; section 3 presents the methodology adopted for the current study; section 4 presents the outcomes and discussion of the study and section 5 concludes the study with a direction for future study.

2. Literature Review

This section discusses the metring and type of energy meter available, electrical load monitoring and related works.

2.1 Metering

A metering system provides a measuring level of the amount of electrical energy consumes by an electrical installation work. Every meter intermittently measures a parameter, such as electricity consumption, and stores the measured data [3]. According to [4], energy meters are categorised into three, namely, (i) Accumulation meter (ii) Interval meter and (iii) Smart meter.

Accumulation meter (AMs), also known as single-rate or flat-meters, measure the quantum of electricity consumed by an electrical load or installation work. The AMs cannot distinguish when the electrical energy was used. Therefore, consumers are charged a flat-rate for electrical energy irrespective of the time of day that they use the electrical energy [4].

Interval Meters (IMs), this meter record electricity usage every 30 minutes, making power retailers charging different rates dependent on the time of the day one uses electricity. In this case, one may be charged with a time of use tariff. Time of use tariffs can charge customers low rates during off-peak times, such as late at night. However, the trade-off is that the tariffs are higher during peak demand times [4].

Smart Meters (SMs), also known as 'digital meters', are the newest in energy metering technology. SMs can be remotely read in advance countries. Thus a meter reader does not need to visit a property to take the reading [2], [4].

2.2 Electrical Load Motoring (ELM)

ELM is an essential tool to ensure that an electrical installation operates efficiently and safely. ELM helps in determining electrical problems when capacity and quality issues affect the electrical distribution and installation systems. The monitoring process can be achieved through manual inspection of electrical load and automating the monitoring system using computer enable devices. In [5], the authors define appliance load monitoring (ALM) as essential for energy management solutions, allowing energy managers to obtain appliance-specific energy consumption statistics that can further be used to devise load scheduling strategies for optimal energy utilisation.

2.3 Related Works

The benefits and safety associated with electrical load monitoring have resulted in numerous studies aimed at improving the quality and efficacy of monitoring systems.

The section discusses, in brief, a few of these studies.
A monitoring, control and measurement system of an electric load for the domestic application was proposed by [6]. The proposed system enables consumer of electricity not exceeding a specific limit of consumption; the device handled circuit switching, display and storage of information. However, it could not work wirelessly or wire using the Zigbee standard. Smart energy monitoring and control system based on wireless communication was also proposed by [7]. The proposed smart energy meter was integrated with a monitoring and control system to monitor the quality of electrical power supplied to consumers and to protect them upon unusual situations with the ability to keep all the events in real date and time as history [7]. Real-Time energy management (controlling and monitoring) system based on wireless sensor networks in order to operate electrical appliances automatically when the weather condition is unstable and fluctuating was proposed by [8], [9]. However, these modules could not set the daily electrical energy threshold to control the consumption of users. In another study, a low-cost IoT-based system with a real-time application to monitor and control load and water demand, in order to have a smarter and more efficient use of these two essential resources was proposed in [10]. Despite, the remote capabilities of the proposed system through IoT, it was incapable of offering electrical energy threshold limit to consumers. A demand-side energy management system was proposed in [11], which could help reduce electrical energy consumption at Wits University in South Africa [11]. An AC power monitoring system was proposed in [12]; the proposed system makes available specific circuit energy consumption data at any given time. Despite the existing of many energy monitoring systems, the current study offer, an alert mechanism as an addition to existing technology to prompt users of electrical energy of their daily amount of units consumed in a simplified manner and also allows for automatic cut off of supply when a preset consumption threshold by a user is reached.

3. Materials and Methods

This section discussed in brief the materials and methods used in this study.

3.1 Arduino UNO (Atmega328P)

The Arduino (Atmega328) is a microcontroller board based on the ATMEGA328P (components 101, 2018). It has 14 digital input/output pins (of which six can be used as PWM outputs), six analogue input pins, a 16MHz ceramic resonator, a micro USB connection port, an ICSP header, and a reset button. Figure 1 shows the Atmega328 used for this study.

Figure 1. *Arduino UNO Microcontroller*

3.2 Storage Device (SD)

The load cannot be monitored and stored for future analysis successful without the means of a storage device to store the amount of power consumed to determine the off-pick point and on-pack period. A 16GB micro storage device was used to store the interment consumption reading of the system so that it can further be analysis. Figure 2 shows the SD card used for the study.

Figure 2. *Storage Device*

3.3 Current Sensor (CS)

This module is based on a resistance point's pressure principle, and it can make the input current of the red terminal (live wire) reduce five times of initial voltage. The max analogue input voltage for our Arduino was 5 V, so the input voltage of the CS was not more than 5 V x 5 = 25 V. The virtual reality resolution was 0.00489 V (5 V / 1023), and the input voltage was 0.00489 V x 5 = 0.02445 V to meet the Arduino AVR chip which had 10 bit AD. Figure 3 shows the current sensor used for this study.

Figure 3. Current sensor

3.4 Human-machine Interface (HMI)

The HMI is a combination of electronic circuits to interact with the user in a high-level language. It is made up of buttons for inputting data into the system and a display unit (LCD) through which system information is communicated back to the user. The display unit consists mainly of a 4×24 LCD. The processed information and data in the proposed system are communicated to users using the HMI shown in figure 4.

Figure 4. *The Display Unit*

3.5 Buzzer Unit

A buzzer also called beeper is an audio signalling device, which may be electromechanical, mechanical or piezoelectric. Figure 5 shows the schematic diagram and a picture of the buzzer used in the current study. In this study, the buzzer was used to give a beeping sound as soon as the set consumption threshold by a user elapses.

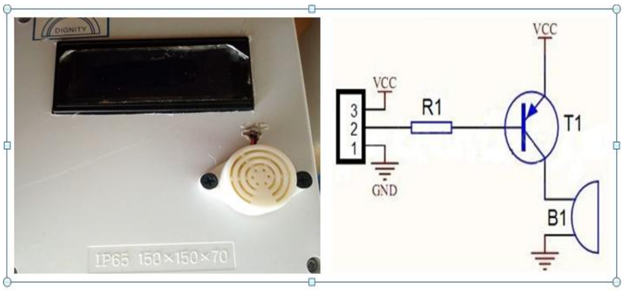

Figure 5. Show a schematic and picture of buzzer used

3.6 System Design

A block diagram of the proposed system is shown in Figure 6. The designed was partitioned into seven basic blocks: voltage sensor, control unit, storage, real-time clock, power supply unit and finally the display, as shown in figure 6. Each block is a combination of several components concerning the functional theory to form a module. The power supply unit supplies electrical energy to the whole design. The unit takes in 240V AC and then convert it to 5V DC through a bridge rectification circuit. The 5V output is then supplied to the current sensor unit. The voltage from the Arduino is fed to the real-time clock (RCD), display unit and the storage device which stores consumption information for future analysis. The sensor measures the voltage information in the form of electrical signals and supplied to the control unit for further processing. The information fed into the control unit was then used to make the corresponding decisions based on the system microcontroller. The electrical commands issued at the control unit as decisions are used to perform the load monitoring and alert system through the relay modulo circuit. The relay modulo unit interfaces the control block with the high voltage line of the national grid. The 20×4 liquid crystal display (screen) displays the information recorded by the control unit. The schematic diagram of the proposed system is, as shown in Figure 7.

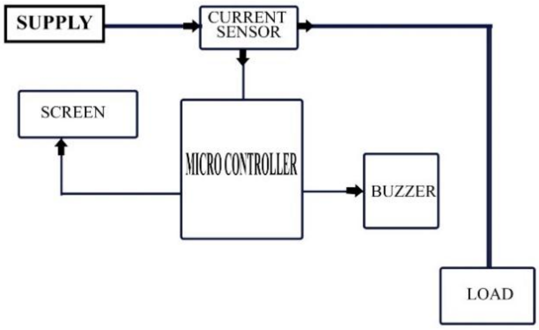

Figure 6. *Block diagram of the proposed system*

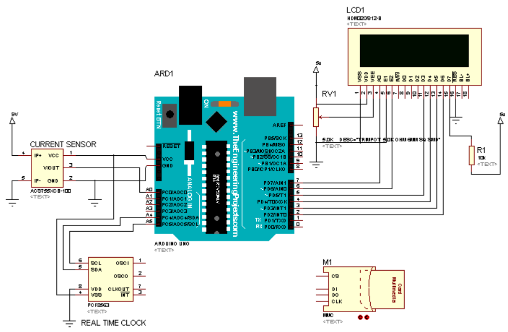

Figure 7. *Schematic diagram of the proposed system*

4. Results and Discussion

This section presents the results and discussion of the proposed system based on the study schematic diagram.

4.1 Final Circuit

Figure 8 shows the final circuit of proposed automatic load monitoring, control and alert system, based on Arduino (Atmega328) and other electrical and electronic components.

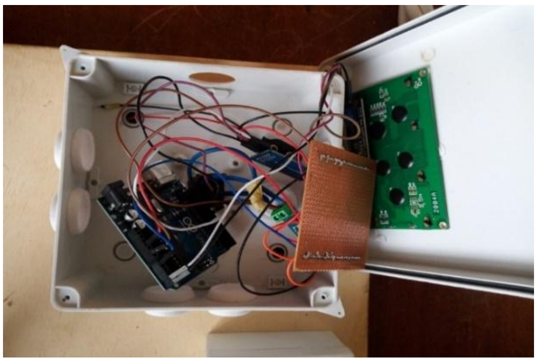

Figure 8. Final Design

4.2 Experimental setup

Figure 9 shows an experimental set up of the proposed system with a 36W and 45W compact fluorescent lamp (CFL), to test how efficiently the proposed system can respond to overloading and energy wastage in a system.

Figure 9. System Testing 36W and 45W CFL

4.3 Empirical Results

Table 1 shows the test results of the proposed system with variable load at a preset threshold value of 0.016 kW. From Table 1, the buzzer state is OFF (0) for load values between 0.01kW to 0.15kW and ON (1) for load values between 0.18-0.45kW. The results revealed that any consumption above the set value causes the buzzer to beep an alarm, to alert the user that the power consumption in the installation has exceeded the set values (over-consumption). Thus any value below the threshold can not cause the buzzer to beep an alarm, but it will be displayed on an LCD screen regular consumption. As indicated in Table 1, ON (1) means over-consumption and OFF (0) means usual consumption. The results revealed that the proposed system could effectively and efficiently alert consumers if their consumption exceeds their preset values. The obtained results imply that the implementation of the proposed system can help consumers of electrical energy to reduce their consumption and also alert them safely if there be any overload and wastage in their installation.

Table 1. *A test of the proposed system with variable load at a threshold of 0.16kW*

Threshold	Load (kW)	Buzzer status
0.16	0.01	0
0.16	0.02	0
0.16	0.11	0
0.16	0.15	0
0.16	0.18	1
0.16	0.19	1
0.16	0.26	1
0.16	0.33	1
0.16	0.37	1
0.04	0.45	1

5. Conclusion

The current study aimed at design and constructing an automatic electrical load monitoring and control with an alert system to prompt the user if their loads are drawing more energy then the preset threshold values; using Arduino UNO (Atmega328p) microcontroller. The results from the experimental setup revealed that the proposed system is capable of alerting consumers with a beeping signal as soon as consumption exceeds the threshold value. The inbuilt mechanism added in the proposed system to protect consumers from sustained overload operated successfully to switch off the supply when consumption exceeded users preset values within 2 minutes. However, users can turn this mechanism off. Despite the success achieved in the current study, the alert system needs an enhancement. Therefore, it is recommended that future work advanced the current study with wireless technologies such as Wi-Fi, Web, Bluetooth, ZigBee, GSM, Xbee to improve the alert system through mobile. Thus, we believe, this will enable users to have complete monitoring of their system from a different location.

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Conflicting interests

The authors of the current study declare that there are no potential conflicts of interest concerning the research, authorship, and publication of this article.

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