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Development of a Home Energy Conservation System Using Power Saving Modes

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Abstract
Energy conservation has become more and more popular in recent years, both on the supply and demand sides. This is sponsored majorly by the rising price of energy production affecting both residential homes and industrial sectors. This project proposes a home energy conservation system using three different energy saving modes such as free, normal and extreme modes of operation. Energy was save based on mode of operation using different parameter as the limiting factors that include time, temperature and current respectively. The system comprises of temperature sensor, motion sensor, current sensor, real time clock, 4x4 keypad, LCD screen and an Arduino microcontroller. The Free mode makes use of time limiting factor to alter the time on and off of output, the Normal mode makes use of temperature sensor and motion sensor to regulate the outputs and the Extreme mode males use of current limiting capability to regulate outputs. The project was designed with the proteus software, while the programming was done on the Arduino IDE software. Result of this project shows the system can help conserve up to 45% energy depending on user's preference.

Nomenclature and units

f_r	Ripple frequency in Hz
γ	Ripple facto
$V_{L(DC)}$	DC voltage of the load
q	Charge in coulomb
C	Capacitance of capacitor

1.0 Introduction

Energy is required to sustain and improve quality of life. Since the industrial revolution, tremendous cultural transformations and six-fold population increase have necessitated massive amounts of energy, which is mostly delivered by coal and petroleum (Hall, Tharakan, Hallock, Cleveland, & Jefferson, 2003). As a result of the world population growth and increased energy requirements, energy consumption has been rising year after year. If proper energy conservation measures are not developed, values with regard to population growth level would rise in a few years.

Electricity, which is a major source of energy in the residential sector contributes for a rising share of the overall consumption which is 50.2% electricity(Najmi & Keramati, 2016) as at 2014, and now with retail electricity purchases accounting for about 43% of total residential sector end-use energy consumption in the UK as of 2021(Huebner et al., 2021), while in Nigeria households account for over 80% of the total energy consumption(Kwag, Adamu, & Krarti, 2019).

The four major energy use as a percentage of primary energy end usage are: space heating (26.4%), space cooling (13%), water heating (12.5%), and lighting (11.6%)(BABATUNDE). This alarming data has led to the increasing research in the areas of energy conservation and management, with the goal to make use of several monitoring and control devices and sensors to obtain instant energy consumption of home appliances and resolving them to low energy consumption mode. This is possible through the exchange of information between the appliance and the energy conservation/management system.

In this paper, an intelligent but basic integrated system for energy conservation in home is presented. With focus on using; current limiting factor, time and sensors to conserve energy by presenting the user with energy conservation modes otherwise known as power saving modes. These modes are: Extreme, Normal and Free mode. The essence of introducing these modes is to give users without a solar powered home the opportunity to save energy with a focus on user's preference.

In recent years, there have been a number of advancements in the technology and design of Home Automation/ Energy Management Systems, although most of the system were mostly geared towards home automation and not necessarily energy saving.

One of the earliest developments for energy management system was proposed by (Tazil, 2011) for a home automation system that uses a standalone Arduino Bluetooth (BT) board to control various home appliances through relays connected to the board's input/output ports. The system allows wireless communication between the user's cell phone and the Arduino BT board and was designed to keep costs low while maintaining flexibility. But there was no provision for time limiting factor for the appliance be controlled, so the user needs to toggle the switches when needed. After which several others followed with similar ideas using several types of communication protocol and control functionalities.

Another research was carried out by (Marimuthu, 2016), proposed a system with more emphasis on using Bluetooth as means of communication simply because of low-cost affordability and popularity. Improved on the nominal systems by introducing additional sensors such as heart beat and overvoltage sensors to further improve its functionalities. However, the system only focused on improving communication protocol not energy saving capabilities.

(Nkamwesiga, 2019) developed a system with aims to improve the reliability of wireless communication of home automation system, using a public university in Uganda as case study. This smart energy saving system integrates a GSM module, Relays, Battery and the Microcontroller. The GSM Module for long range communication with lesser fear of hacks. Although the system helped reduce the electrical energy expenditure of the university it was dependent on network availability and does not provide for user preference in energy saving.

Another work by (Wang, 2017), proposed a system integrating renewable energy sources, such as solar panels This allows for the use of clean, renewable energy, as well as the potential for excess energy to be sold back to the grid. Although effective, the system does not put into consideration the possibility of a home without a source of renewable energy.

(Amoran, 2021), proposed a system which interfaces a microcontroller, Bluetooth communicating technology with an android application with specific aims of making the system user-friendly. The system implemented the use of google assistant as a mean of controlling appliance via voice prompt, time limiting factor to enable user pre-time appliance and also, Relays and Triacs are as switching mechanism. Although very effective, the system does not have current limiting feature to assist user conserve energy when at maximum consumption level.

An enhanced home automation system focused on energy saving was proposed by (Abubakar, 2022). GSM, IoT and Bluetooth technologies were used as communication protocol. Along other sensors, the system was specifically integrated with solar capabilities, scheduling lighter loads to be used on solar while keeping heavier loads on the mains. Energy used on the solar is then considered saved energy. The downside of this system is that it also does not necessarily provide a means of saving energy for homes without solar provision.

This paper presents a system that can efficiently regulate power consumption based on individual user's preference; by providing the user with the Extreme, Normal and Free energy saving modes,

which majorly uses; current limiting function, time regulation and sensors to conserve energy. The system is void of cyber-attacks as it operates offline, can be used by users of solar and non-solar homes increasing its userbase.

2.0 Materials and Methods

In this section, the materials and methods for this research are presented. Starting from the system description, which involves the power supply unit, sensor and control units design were described. In addition, the programing of Arduino using proteus software was introduced.

2.1 System Description

The block diagram shows the unitary composition of the system and their interconnections. Figure 1 shows the block diagram of the system comprising of the control unit, actuating unit, power supply unit and sensory unit

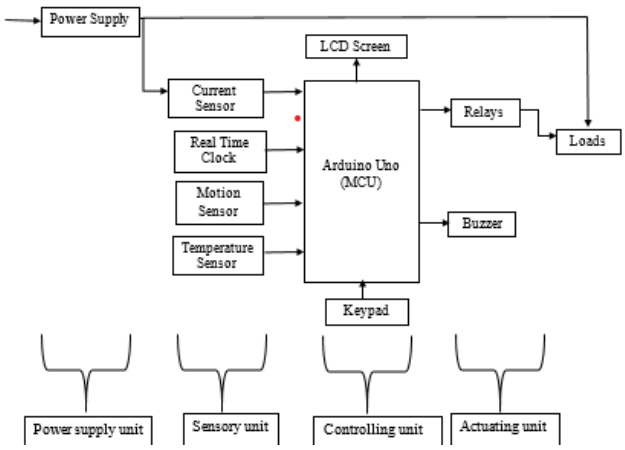

Figure 1 Block diagram of the HECS

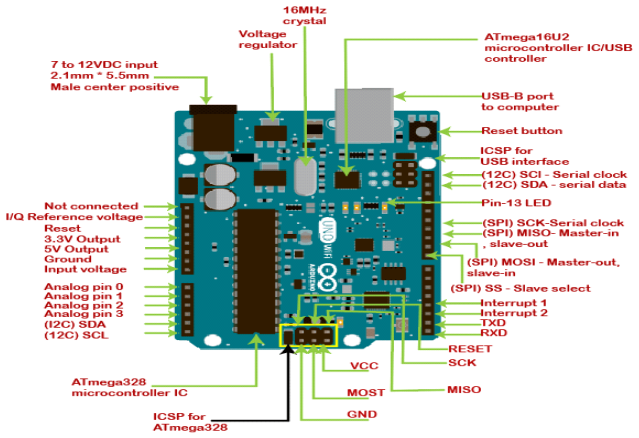

Figure 2 Arduino Uno pin configuration

- Power supply Unit:

The power supply unit comprise of a 220V/12V transformer, bridge Rectifier, filtering capacitor and a 7805-voltage regulator.

The output voltage of a typical transformer can be obtained as follows:

$$V_{out} = \sqrt{2}\, x\, V_{rms}\, x\ \ k(4 - V_D) \tag{1}$$

Similarly, the current for the filtering capacitor can be obtained via the following formula:

$$I_C = \frac{dq}{dt} \tag{2}$$

Where, q is the charge in coulomb, the current can then be expressed as;

$$I_C = C\frac{dv}{dt} \tag{3}$$

But $f_r = \frac{1}{dt}$

Where f_r is the Ripple frequency

$$I_C = Cf_r dv \tag{4}$$

The capacitance of the filtering capacitor can be obtained as follow;

$$C = \frac{Ic}{f_r dv} \tag{5}$$

R.M.S value of ripple voltage is given as

$$V_{rms} = \gamma V_{L(DC)} \tag{6}$$

Where:

$\gamma = ripple\ factor$

$V_{L(DC)}$ is the $D.C\ voltage$ of the $load.$

So, the capacitor value can also be determined by the given equation below

$$C = \frac{Idc}{4\sqrt{3}\, f_r V_{out)}} \tag{7}$$

- Sensory Unit:

The sensor unit comprise several components whose output serve as the input of the microcontroller. It includes; the current sensor which enables the current limiting function, a motion sensor which helps to detect motion, a real time clock which enables the time limiting function and temperature sensor which monitors the rise or fall of temperature.

- Control Unit:

The control unit comprises of the keypad which helps to send in commands to the system, the LCD which serves as a human-machine interface and the microcontroller itself which controls the entire system. Figure 2 shows the pin configuration of an Arduino Uno.

- Actuating Unit:

The actuating unit comprise of the Relay and the Buzzer. The Relay is an electromechanical switch which assists in switching on and off loads on its terminal, with Normally open and normally closed contacts as seen in Figure 3. While the buzzer is an electromechanical and electro-acoustic audio signaling

device. A beep sound from the buzzer indicates the pushing of a switch or that certain operations have taken place in the system.

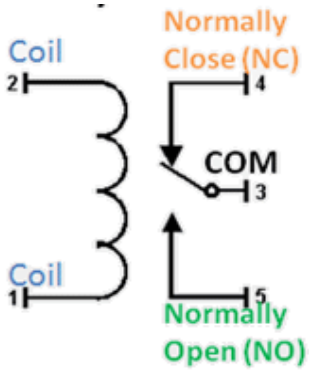

Fig. 3 Relay Circuit Diagram

2.2 System Design

The Circuit was designed using the proteus software in accordance with the block diagram. The components were selected according their best fitted properties and the resulting circuit diagram is shown in Fig. 4. The program was written using the Arduino IDE software and coded using c-programming language

The flowchart as shown in Fig 5, depicts the algorithm which the system uses to in its energy conservation. The strategy used mostly depends on the ability of the sensors and real time module to convey accurate data which is used to regulate the outputs. On powering on the system is programmed to use the Sensor/Normal mode which is governed by the motion sensor and temperature sensor. Once motion is not detected all outputs are turned off, with assumption that user is not present. Other modes can then be activated via the keypad.

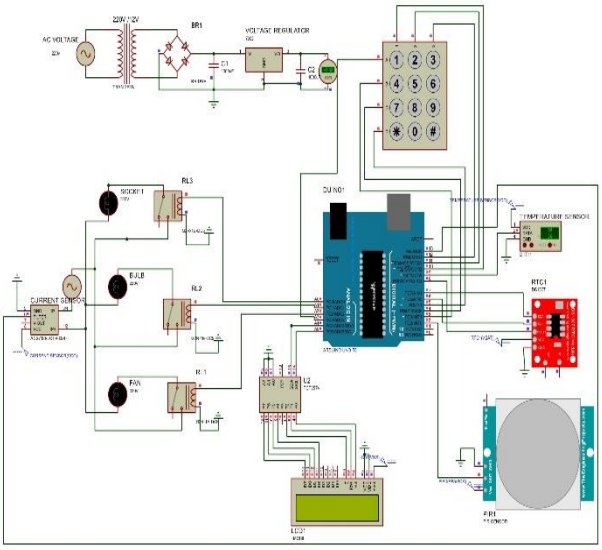

Figure 4 Program Circuit diagram

3.0 Results and Discussions

The data used include random scenarios of human negligence in which energy wastage most commonly occurred. Similarly, data was taken for scenarios where the HECS was actively used on any mode of preference.

Firstly, the average energy consumption of loads on output was measured taken, Table 1 shows average energy consumption of each output in kwh and Table 2 was obtained to show average hours in a day for which the loads on the three outputs are used.

Table 1 Average Power Consumption of Loads on Output

S/N	Loads Type	Quantity	Rating (w)	Average Load (kwh)
1	Light	1	20	0.02
2	Fan	1	39	0.039
3	Television	1	100	0.1

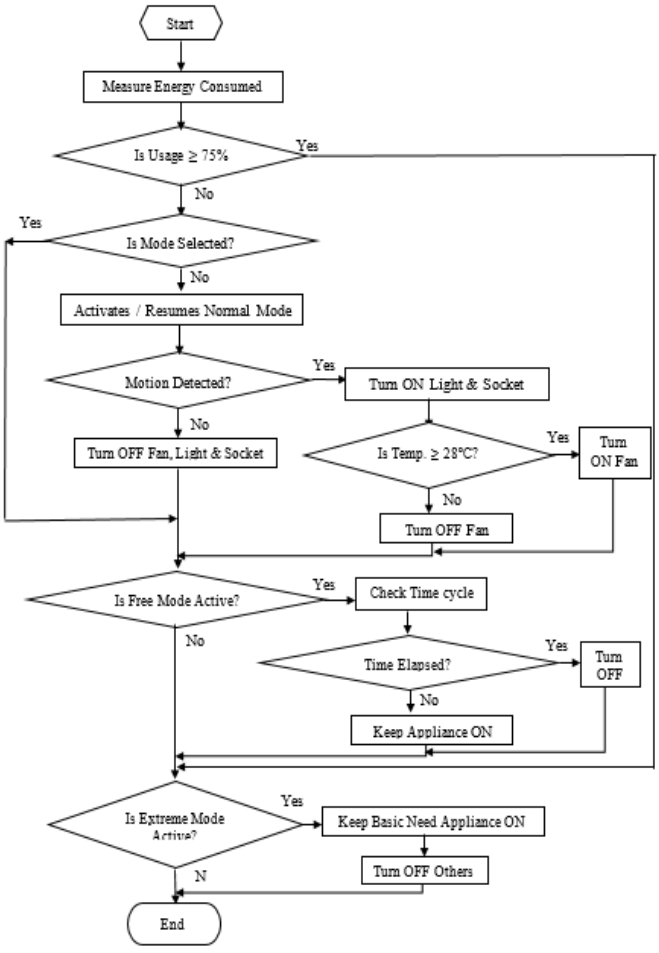

Figure 5 Flow Chart for System Operation

Table 2 Three Hours Usage Distribution of Output Load

Daily Hours	Without HECS			With HECS		
	Fan	Light	Socket	Fan	Light	Socket
6am -9am	On	On	On	Off	On	On
10am-12noon	On	On	On	Off	Off	Off
1pm- 3pm	On	On	On	Off	Off	Off
4pm- 6pm	On	On	On	On	On	On
7pm- 9pm	On	On	On	On	On	On
10pm-12am	On	On	Off	Off	Off	Off
1am- 3am	On	Off	Off	Off	Off	Off
4am- 6am	On	Off	Off	Off	Off	Off
Total Usage (Hrs)	24	18	15	6	9	9

From Table 2, the assumptions made here are as follows:

- User generally keeps the fan on throughout the day
- Lights and sockets are mostly not put to use during day, as most users are not home.
- Temperature always drops below minimum threshold of 28^{o}C from about midnight to 6am.
- Also, motion is not detected from about 10pm as user is asleep.

The energy consumed in kwh against each load in instances where the HECS was used and when energy was used without the HECS was depicted in Figure. 6

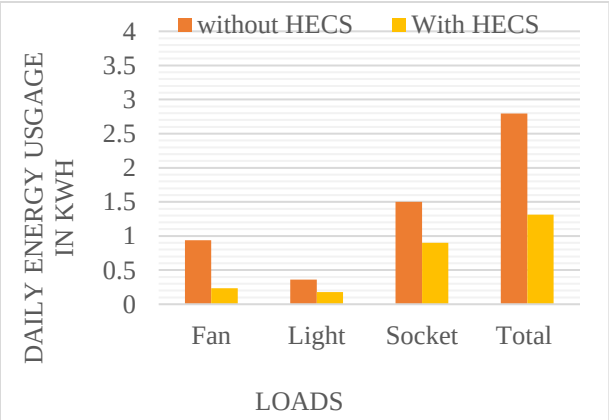

Figure 6 Comparison Between the Energy Used with HECS and Without HECS

4.0 Conclusions

This research proposed a basic but useful strategy for conservation of energy in homes. In order to improve the functionality of the HECS, it can be integrated with wireless communication protocol as it enables more output to be controlled from remote location.

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Declaration of conflict of interest

The authors have collectively contributed to the conceptualization, design, and execution of this journal. They have worked on drafting and critically revising the article to include significant intellectual content. This manuscript has not been previously submitted or reviewed by any other journal or publishing platform. Additionally, the authors do not have any affiliation with any organization that has a direct or indirect financial stake in the subject matter discussed in this manuscript.

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