PRINT ISSN 1119-8362
ELECTRONIC ISSN 1119-8362
Full-text Available Online at
https://www.ajol.info/index.php/jasem
http://ww.bioline.org.br/ja
J. Appl. Sci. Environ. Manage.
Vol. 23 (1) 145–149 January 2019

Development of Smart Switch for Household Appliances Using Web-Based Technology

*[1]AJIBOLA, OOE; [2]BALOGUN, AO

[1]Department of Biomedical Engineering, First Technical University, Ibadan, Nigeria
[2]Department of Systems Engineering, University of Lagos, Lagos, Nigeria
*Correspondence Author Email: olawale.ajibola@tech-u.edu.ng; +2348034488877

ABSTRACT: The paper depicts design and prototypic implementation of household automation switching system for electrical appliances using web based interface technology. The proposed system consists of two parts, the first part is the hardware module, which provides appropriate interface to switches of home appliances. Second part is the software component that comprises the user control interface which monitors and controls energy consuming units in the household. Users and system administrator can locally (LAN) or remotely (WAN) control system code to activate or deactivate a desired appliance. The outcome of the study revealed that the smart household switch engendered substantial reduction in energy consumption on all kinds of appliance and it poses no threat to security of lives and properties. The device is desirable for conservation and efficient use of energy.

DOI: https://dx.doi.org/10.4314/jasem.v23i1.21

Dates: Received: 30 December 2018; Revised: 19 January 2019; Accepted 25 January 2019

Keyword: smart switch, remote control, energy efficiency, household appliances

Smart home technology generally refers to any suite of devices, appliances, or systems that connect into a common network that can be independently and remotely controlled. When home electrical network, namely: the thermostat, lights, audio speakers, TVs, security cameras, locks, appliances, and more are all connected into a common system, which can be controlled from a smart phone. Residential and business buildings account for approximately 20% of the overall world-wide energy consumption, with an increasing trend over time. The major energy consumers in buildings are space heating and conditioning, water heating, lighting, and the use of computers and other electronic devices. According to the research report from the Energy Information Administration (EIA) in the US, the lighting tops the electricity consumes in the commercial building, and it is almost tripled the second one, ventilation. Figure 1 presents the pattern of energy consumption in commercial buildings. It reveals that lighting is significant among energy consumers in buildings for it consumes massive quantity of the energy. The lighting source could be wasted or overuse in some cases (Zhou, 2014; Koch, 2011). Smart switching unit niftily enables home-owners optimize usage of energy with amazing results, viz: easy of control, flexibility for new devices and appliances, maximizing home security, remote control of functional units, increased energy efficiency, improved appliance functionality and home management insights (Ziqi, 2014). However, with the growth of networks in homes, electronic products can automatically send periodic signals about its status. With enhanced awareness there may be a need for increased cybersecurity and privacy to prevent the activities of hackers.

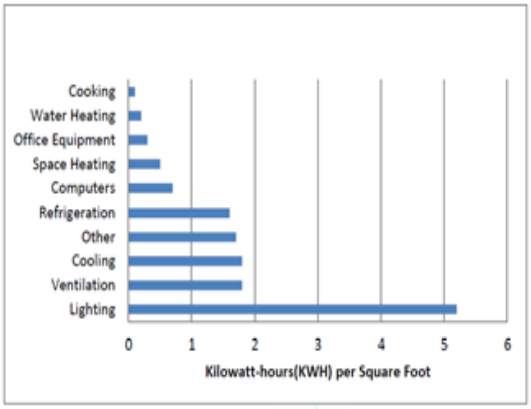

Fig 1: Energy consumption pattern in Commercial Building
Source: Wang and Zhou, 2014

The term automation had existed for many years. It began with a student connecting two electric wires to the hands of an alarm clock in order to close a circuit of a battery and light bulb. Other companies later developed automated systems of their own to control

alarms, sensors and cameras thereby creating the first automated buildings (Delgado *et al*, 2009). Earlier smart devices are smart home automation system (SHAS) of Thakur and Sharma which proposed voice control and Zigbee based home automation system where user has to give voice command to control in-home appliances. Zigbee is used to communicate between base station and remote station. A global system for mobile (GSM) based home automation system (HAS) can control in-home appliances by sending SMS to an HAS placed in home environment via GSM modem which interfaced with switching module through a microcontroller. A GSM and ZigBee based communication and control for home appliances has been presented by many researchers. However, the drawback of these systems is that, in ZigBee, range plays important role while a GSM requires adequate coverage of GSM mobile signal (Malik, 2009).

Recent home switches have tendencies to incorporate embedded devices and consumer appliances into software systems. The possibility of having access to many devices within a building from anywhere at any time solves a lot of problems of the user often saving significant amount of resources. It also boosts security in a building. Access could be achieved from many different digital devices given that network hierarchy has been lowering rapidly in the chain towards smaller and more personal devices using internet of things (Greaves and Holmstead, 2006). With exponential growth of the internet and telecommunication technology, home automation is experiencing an accelerated growth based on different kinds of residential network. The role of GSM wireless transmission in setting up home automation system cannot be overemphasized. And its cost implication is relatively low when compared to other modes of communication. GSM-related monitoring and control systems have been implemented in the past for automation of irrigation water controller system, management of digital energy meter, highway vehicle traffic monitoring system and others, incorporating several wonderful features. Of concern in this study are the conservation of energy at homes and offices by developing an automated switching system with the capability to monitor and regulate energy usage within a remote building with the ultimate aim of optimizing usage of available energy resources and also to design a platform where electrical consumers can control their household appliances from any location with mobile phones.

MATERIALS AND METHOD

The main thrust of this study is control of electrical and electronic components of household appliances. The control of the circuit is accomplished with the use of an Arduino Uno (AU), programmed in C-language. The microcontroller delivers commands to the smart switch. AU is a microcontroller board based on the ATmega328 (datasheet) with 14 digital input/output pins of which pin 6 is used as pulse width modulation (PWM) outputs; 6 analog inputs; a 16 MHz crystal oscillator; a USB connection; a power jack; an in-circuit serial programming (ICSP) header; and a reset button. It contains everything needed to support the microcontroller simply connected to computer with USB cable or powered with AC-to-DC adapter to get started. The Arduino development board consists of microcontroller, Ethernet shield, Transistor, Diode, 7805 Voltage Regulator, Relay, Teleduino, Teleduino controller, Arduino integrated Development Environment (IDE) and external power supply. Figure 2 is the operational flow diagram for the smart switch system while the circuit diagram is contained in Figure 3:

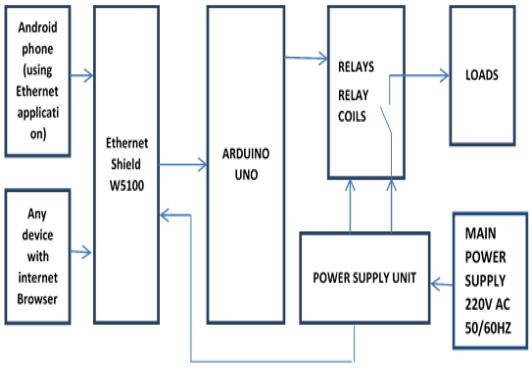

Fig 2: Schematics of smart switch system

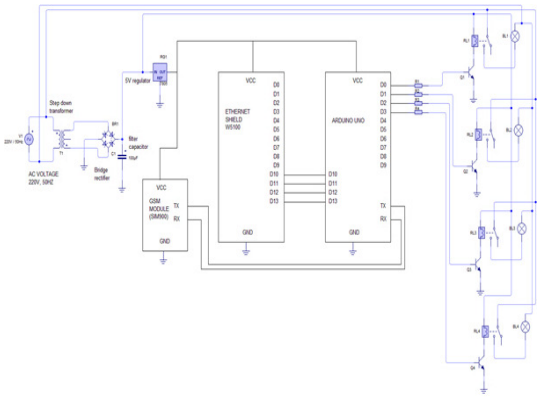

Fig 3: Circuit diagram of the smart switch

This system provides a modern era automation system where the status of an appliance is monitored and controlled from anywhere in the world. The devices to be controlled are interfaced with Arduino microcontroller unit through switches relay and con-

troller which receives from android application through internet modem (Ethernet shield) interface.

Arduino integrated Development Environment (IDE): For this project Arduino integrated Development Environment (IDE). Built up with the 8-bit Atmel AVR microcontroller's that are manufactured by Atmel or a 32-bit Atmel ARM, these microcontrollers can be programmed easily using the C or C++ language in the Arduino IDE. (Louis, 2016).

Teleduino: Teleduino platform converts Ethernet enabled Arduino into a powerful and versatile tool for interacting with devices over the internet. Teleduino server is the interface that translates instructions received from the internet into actions on the Teleduino device. Teleduino platform enables users to perform the following tasks with Arduino Uno via simple web service:

- Reset, ping, get uptime, and get free memory.
- Define pin modes, set digital outputs, set analog outputs, read digital inputs, read analog inputs, or read all inputs with a single API call.
- Define, and read and write from serial port (4 for the Mega).
- Read and write from EEPROM.
- Define and position up to 6 servos (48 for the Mega).
- Set preset values for the above functions, which get set during boot. Preset values are stored in the first 178 bytes of the EEPROM.

Fig 4: Teleduino controller home page

Teleduino controller: user friendly application works on android device. Figure 4 shows detailed user interface window that enables human interaction with the system.

RESULTS AND DISCUSSION

Figure 7 is the prototype of the smart switch with the components arranged inside the white box. All home appliances are connected to the device for ubiquitous control via android phone that have the application software installed with the right API key.

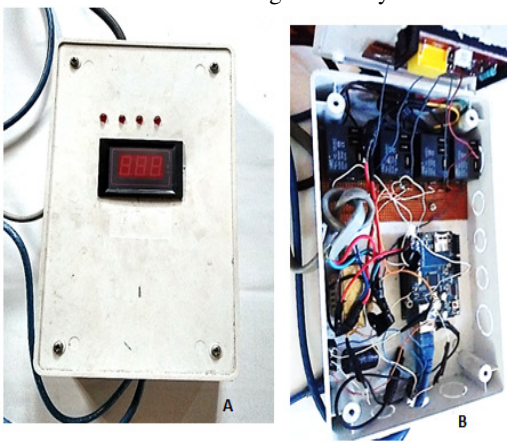

Fig 5: Smart switch prototypes: (A) Enclosed, (B) Opened to reveal components

A study of Figure 6, the result obtained from computational analysis of energy consumption in a typical home setting with and without the smart switch. The results revealed how the energy consumption of appliances in the home reduces drastically when connected to the smart switch.

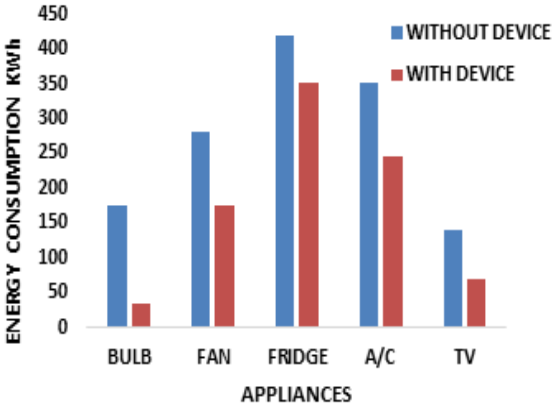

Fig 6: Daily Energy consumption in KWh

Figure 6 reveals a clear departure in energy consumption with the installation of smart switch as compared to the situation without the device. The categorization of equipment was done in the order of

electric bulb, fan, refrigerator, air conditioners and television sets and the energy gained from installation of smart switch were 80%, 40%, 20%, 35% and 50% in that order. Depending on length of usage, the highest disparity has been recorded on lighting with energy consumption reducing to about 20%of the original consumption when smart switch has not been installed. Other sets of appliances namely fans, refrigerators, air-conditioning systems and television sets witnessed considerably reduced energy consumption to about 60%, 80%, 70% and 50% respectively. A run-down of the cost analysis of the components of the smart home switch is as contained in Table 1.

Table 1: Cost Analysis for Design and Fabrication of EDW

Material	**Cost (₦)**
Arduino UNO	38,000.00
Ethernet Shield	25,000.00
Transistor	2,000.00
LED display meter	7,000.00
Diode	1,500.00
7805 Voltage regulator	3,000.00
Relays	15,000.00
Transformer	2,000.00
Case	1,500.00
TOTAL	**95,000.00**

The concept of smart homes has been developed since the 1990s. According to one of the most recent definitions, a home which is smart enough to assist the inhabitants to live independently and comfortably with the help of technology is termed as smart home (IEA, 2003). According to Cavone, *et al.* (2011) and Christian, (2007), smart switch home is an interactive space where all electrical and electronic devices are interconnected forming a network that can communicate with one another and with the user. Smart home has the ability to automate and assist the users in different forms. It has ambient intelligence, remote control mechanisms or home automation systems (Alam et al, 2012; Albany, 2015). These descriptions confirm that, the primary objective of a smart home is to increase occupants' comfort and make daily life easier (Somayya and Ramaswamy, 2014). And these qualities are present in the device.

According to Le *et al*. (2012), smart homes have five fundamental characteristics, namely: automation, Multi-functionality, adaptability, interactivity and efficiency. New information and communications technology (ICT) infrastructures supporting a more efficient smart home will also include frequent price updates to follow the evolution of the balance between supply and demand in near real-time (Siano *et al*. 2013; Kraning *et al.* 2013). The system may be programmed to adopt particular load-shifting regime that offer customers a more effective way to manage the cost of their electricity bill. It work by storing relatively inexpensive electricity during off-peak demand periods and using this stored energy during peak periods, when electricity energy demands are high. Smart unit enables actions allow users to reduce electricity bill and save energy (Graditi *et al*. 2015; Matthias, 2008). Cybersecurity in the home may not be the most dramatic application of intelligence and connectivity, but the system is indisputably useful. Home appliances designs should be smarter, equipped with embedded microprocessors and wireless transceivers to provide increased comforts especially when employed in a private home (Parra *et al.* 2008; Mohsenian-Rad and Leon-Garcia, 2010). On the other hand, automation system installed in a commercial building do not only increase comfort but also allow centralized control of heating, ventilation and lighting, contributing to overall cost reduction as a result of energy conservation (Ramchurn *et al.* 2010; Turner *et al.* 2014; Mohsenian-Rad *et al.* 2010). Although, Nigeria does not generate enough electricity to satisfy energy requirement of the citizenry, leakages and leakages are chief cause of blackout experienced by the masses but smart switch may eliminate the problem especially when adapted to a renewable sources of energy such as the solar systems.

*Conclusion***:** The study proposes an efficient means of conserving energy for homes and commercial buildings. The cost-effective web-based technology provides safe energy management mechanism for homes. The system design and architecture involves only basic levels of control. This work is targeted at eliminating wastage thus creating adequate atmosphere for optimized usage of Nigeria's meagre energy resources. And the smart switch can be used both in rural and urban settings.

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