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Control System GSM/GPRS Unit Module
Configuration for Smart Home Efficient Energy
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Development of a Wireless Intelligent Electronic Control System GSM/GPRS Unit Module Configuration for Smart Home Efficient Energy Management System

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Abstract—The paper proposes a design and prototyping of an intelligent electronic control unit system intended for the implementation of smart home in urban and rural areas, with the intention to control and monitor energy usage by household electrical appliances. Measurement, verification of power usage, and automated efficient use of Solar power as substitute of primary power supply (Eskom power supply) in South Africa in order to reduce the high energy demand on the national grid and create low cost affordable energy to the consumers. The proposed wireless energy management system will incorporate and interface with the distribution Box (D-Box) with intelligent electronic and digital system unit with the purpose to detect presence or absence of primary power (Eskom) integrated together with solar power as alternative power supply to manage available power efficiently for free or at low cost.

Keywords— *Smart Grid, Distribution Box, Measurement and Verification (M&V), SMS, PIC, Uninterruptable Power Supply (UPS), Internet of Things (IoT)*

I. INTRODUCTION

The main electric power supply utilities in South Africa, Eskom produce about 34 000 megawatts of electricity from coal to meet current demand of electricity [1], this figure is growing every year resulting to energy tariff increase. Electricity is a basic need; how will poor people survive without Eskom?

Big businesses and wealthier households may leave the Eskom grid and invest in their own electricity generation such as solar or gas [2]. Investing in alternative power generation is a good idea but people have to be at their homes to manually switch on or off their appliances while they can do the same no matter where they are.

Electricity network that can intelligently integrate the actions of all users connected to it is called a smart grid [3]. Management of energy consumption in smart grid enabled by Internet of Things (IoT) play a significant role in developing smart grid which eventually lead to low cost energy management and energy savings.

To save energy using this proposed approach, we need interconnection of embedded device to control measure and verify usage of energy wirelessly. Smart internet connectivity is becoming more interesting to internet users when intelligent electronics embedded devices are connected together to simplify energy usage systems. The

household appliances control come at a cost proportional to the smart home comfort.

In this paper, we will also seek to develop a robust techniques/algorithm that will ensure software integration to the smart grid system using Internet of Things technologies. Furthermore, the advent of the development of Information Communication Technology (ICT) make life easier to most people in the cities, this paper shall present an innovative technique and low-cost energy management systems that will help bridge a gap in energy supply between people in urban and rural area alike.

II. RELATED WORK

The work of Muhammad Tanveer Riaz, Eman Manzoor Ahmed, Fariha Durrani and Muhammad Asim Mond [9] developed a system which consist of a phone, a wi-fi hot spot device, a server PC and a microcontroller circuitry. They designed their own circuitry board, however the introduction of a PC-server to their system increases implementation cost dramatically. Most people in the rural areas cannot afford to implement such a system.

The work of Rajesh and Bindyashree [10] present a system which consist of a cell phone, an embedded gate (Arduino Ethernet board and Arduino Mega board) and an R transceiver (nRF2401). No server is required and therefore the costs can be kept low and affordable. They have done a good design physically with an Arduino board embedded with their software.

Basically, the transmitter transmits anything it gets on the data pins and receiver output with anything it receives irrespective of the board rate, as long as the communication is slow enough [10]. This kind of communication is very susceptible to noise and it is recommended to use a board rate of 9600b/s or less [11].

The work of Rajeev [12] presented a system which consist of three platforms environment, remote access device (user with android smart phone), internet network and the home environment (router, Arduino Ethernet server, home appliances and sensors). In this kind of system, user sends information over the internet using cell phone application through TCP/IP, at home environment Arduino Ethernet sever support TCP/IP and creates output messages in JavaScript Object Notation (JSON) format. Here, Router acts as a hotspot which means the user can also switch ON and OFF appliance at home as well remotely with its device. If the router is down the whole system can continue running

using 3G or 4G as indicated in the conclusion [3]. Why using Arduino Ethernet board and Arduino development board while own boards can be designed to meet requirements? These systems meet current technology development and implementation is expensive. Our proposed system is standalone device using 3G and very cheap to implement. Arduino boards will be used for modelling purpose and our final product will have our own circuitry designed boards and packaging enclosure.

III. PROPOSED SYSTEM LAYOUT



Fig 1. Smart Home [8]

Figure 1 above shows the proposed smart home layout with its electrical appliances. Smart Home USA website [4] defines a smart home as one that provide comfort, security, energy efficiency (low operating cost), and convenient at all time regardless whether anyone is home. This paper proposes a low-cost device which is uses Global System for Mobile (GSM) communication to switch ON and OFF, maximum of four electrical appliances remotely. In case of power failure or power restore the system intelligently detect the device shall allow user to choose which appliance/s supposed to be ON or OFF during power failure or load shedding by using Short Messaging Services (SMS) and Android cell phone application.

Some of the challenges we will seek to address through this paper work, is how we can use some of the existing electrical engineering technologies to solve the problem of scarce electricity [16].

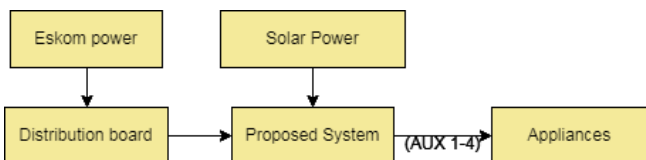


Fig 2. Block diagram for Smart home power supply

However, figure 2 above shows that proposed system having two inputs (Eskom power and Solar power), the system will work even if there is one input preferably Eskom power. It is imperative that propose system is operated at the highest level of efficiency. In case of Eskom power failure or load shading the device shall call the user as a notification of power failure and the user shall then manage the power/energy usage from the installed solar panel or UPS. The user shall reply to choose which

appliance to switch on or off from their cell phone, thereby reducing the heavy power demand on ESKOM and the customer saving substantially on the electricity bill. The approach might drastically reduce load shading if not eliminate the challenge. The user can cook supper while still at work since Eskom experience high demand between 17H00 and 22H00 during week days. The proposed shall reduce Eskom power demand during their peak hours.

The proposed system shall intelligently cut off if the load draws too much current when connected to Solar power. When there is no load shedding and power failure the system shall also notify the user if there is sufficient alternative energy and the user shall start saving by switching to available alternative energy and determining which device/appliance should be ON. The system shall also predict the point where it will automatically switch to Eskom and also notify the user.

A. Abbreviations and Acronyms

AUX – Auxiliary

ADC – Analogue to Digital Conversion

APK – Android Package

DB - Distribution Box

GSM - Global System for Mobile

MC – Microcontroller

UJ – University of Johannesburg.

PIC – Programmable Interface Controller

SMS – Short Messaging Service

B. Equations

$(Resolution\ of\ ADC) / (System\ Voltage) = x / (analogue\ voltage\ read\ PIC\ ADC\ pin)$

For 10 bits resolution and 5V system voltage:

$1023/5V = x / (analogue\ voltage\ read)$

x is decimal number to be transmitted via Bluetooth to the proposed system MC.

IV. SYSTEM IMPLEMENTATION

This will increase the availability of skills needed by engineers, technologists, technicians as well as researchers in the following areas [16]:

- Solution oriented electrical/electronic intelligent control circuit.
- Energy measurement and verification (M&V) and efficient management.
- Alternative renewable energy (e.g.: Solar energy) as supplement to ESKOM.
- Implementation of the (IoT) technologies, in smart grid systems.

The development of network technology and communication technology make life easier to most modern people in the cities and this device shall bridge gab between

metropolitan/cities and rural area technologies. It shall also create jobs in rural areas, improve life and introduce skills and training in soldering and prototyping. Only PCBs production would be outsourced, the aim is not making dramatic money but to encourage people to follow engineering fields and give back to community.

In cities water and electricity are payable, in rural only electricity is payable. Renting is very expensive in the cities, in rural area is tenth of what is payable in city. *Table 1* below compares rural cost and city cost.

TABLE 1 : COST EFFECTIVE MEASURES

Cost	Effective Measures	
Transport	R1500	R400
Equipment	R2000	R2000
Administrative	R400	R400
Renting	Free	>R4000
Water & Electricity	R500	R900
Total	R4400	>R7700

V. METHODOLOGY & DESIGN

Devices with microcontroller are widely used in industrial field, we will design interface for connecting more than one device for parallel control. Microcontroller shall interface with GSM, Bluetooth module and 4 relays as shown in *figure 3*. The purpose of GSM is to enable the user to communicate with the device irrespective of his/her geographical area provided there is sufficient signal strength surrounding GSM (Global System for Mobile), Bluetooth module receives digital level of battery and 4 relays control appliances. In *figure 3*, GSM and SIM card send and receive SMSs through microcontroller, Bluetooth module receive ADC value from the battery read and sent by separate PIC connected to another Bluetooth module in *figure 4* below.

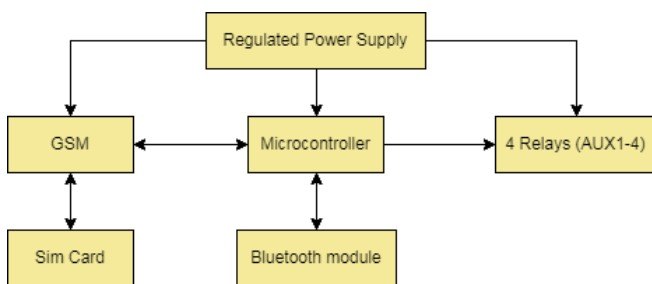


Fig 3. Block diagram of proposed system

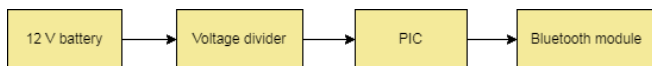


Fig 4. Battery monitoring block diagram

Bluetooth communication should only be used in occasion where there is a need for quick short-lived network communication with little concern of security [8]. Bluetooth in *figure 3* & *4* would not negatively affect the proposed system if attacked.



Fig 5. SIM900 module [13]

For the GSM module, the common SIM900 module from Sim Com shall be selected. This all-in-one module provides a standard "AT" command set for call and message management with multi-band operation for use on global GSM network carriers. As it is a commonly used GSM module, it has limited availability and is suitable for integration into custom designs.

The SIM900 is designed to be powered directly from a 3.4V-4.5V Lithium Ion battery, reducing the system cost by not requiring an additional regulator with high current. However, an unfortunate electrical characteristic of the SIM900 is a 3.1V absolute maximum voltage on its digital interface pins. As the rest of the system runs from a common 3.3V rail regulated from the battery [14]

A. Micro controllers

40-Pin PDIP

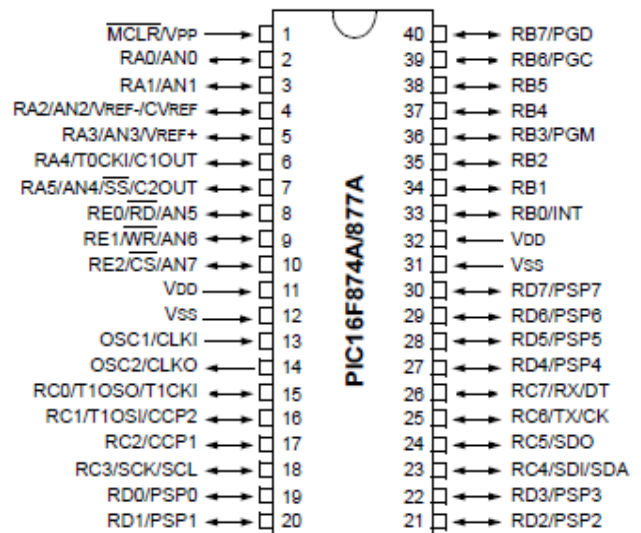


Fig 6. PIC16f877 [6]

A low-cost PIC micro MCUs have many sources of interrupt. These sources generally include one interrupt source for each peripheral module. The interrupts going to be used are [6]: Interrupt pin, USART Interrupts, Receive Interrupt, Transmit Interrupt, Data EEPROM Write Complete Interrupt and Timer1 Overflow Interrupt.

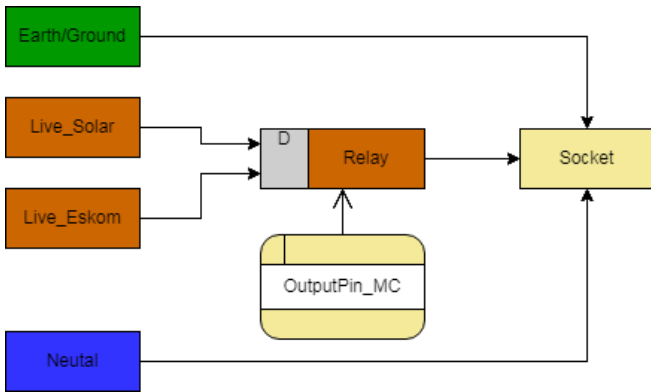


Fig 7. Relay connection

Solar power and Eskom power shall have same 'Earth' and 'Neutral', since we only switch between 'Solar live' and 'Eskom live'. Figure 7 should be repeated 4 times to accommodate 'AUX1-4'. Appliances would connect directly on the proposed system.

B. PROTEUS SOFTWARE (Student Vision)

This software is used to design circuit diagram, simulate the application and modelling. In addition, animate components have also been used to design the PCB layout of the project. Proteus as the ability to simulate the interaction between software running on a microcontroller and analogue or digital inputs connected to microcontroller. Virtual terminal is one of the features of Proteus Software for transmitting and receiving data outside microcontroller.

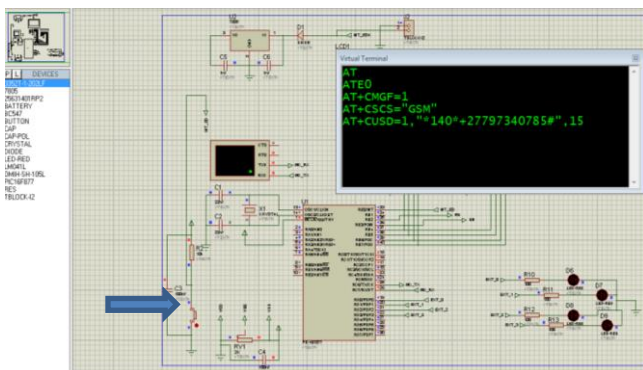


Fig 8. Eskom interrupt

Blue arrow on bottom left of figure 8 above shows the button switch which is normally high representing the presence of Eskom. The external interrupt defined in PIC is going to raise a flag at the decreasing edge of the clock, meaning the time it goes from high to low. Regulated power supply from Eskom should be detected but external interrupt of microcontroller.

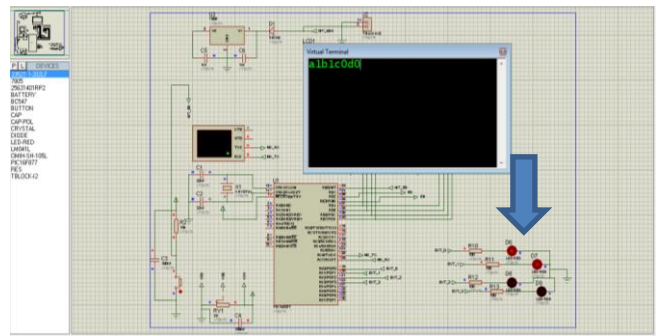


Fig 9. Switching ON/OFF devices

The blue arrow in figure 9 shows the results obtained when manually input command of "a1b1c0d0" on virtual terminal and transmitted to the microcontroller. The string "a1b1c0d0", means (a, b, c and d) are the devices to be switch on or off and (0/1) after letter 0 means off and 1 mean on. So a1b1c0d0 device 'a' and 'b' will be ON and device 'c' and 'd' will be OFF. The results show on the LEDs the output shall also be connected to the relays to indicate which power source is in use. The code test response "Gjkja1b1C0d0kjhkj" tested the presence of 'a1b1C0d0' in the string and produce required results.

The SMS received is not case sensitive because each character received is converted to upper case. This keeps the project simple and understandable. Only the table 2 logic and table 3 characters should be learnt by the user.

TABLE 2 : LOGIC TABLE

State	Logic
ON	1
OFF	0

Each character is individually scanned, if the character is 'a' or 'A' is converted to upper case then the array of characters is created. The following character after 'A' should be number '0' or '1' if not the array is discarded and look for 'a' or 'A' again. The third character should be 'b' or 'B' if not discard the array and starts from 'a' or 'A'. The loop will continue until the array of eight characters is valid according to below table. Where 'a' or 'A' means lower case or upper case of letter 'A' and '0' or '1' means digit 0 or digit 1.

TABLE 3 : CHARACTER TABLE

Char no:	Valid characters							
	0	1	2	3	4	5	6	7
Char	a/A	0/1	b/B	0/1	c/C	0/1	d/D	0/1

C. Android Studio developer[15]

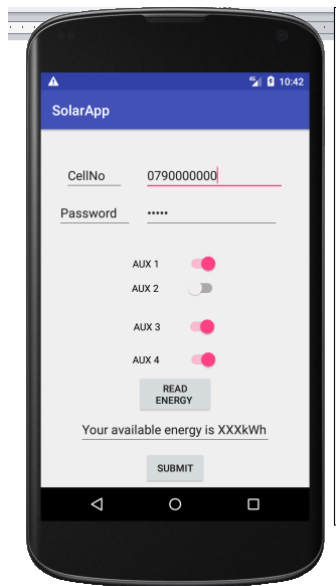


Fig 10. Android Solar App

The user shall enter cell number and password, if password is correct the Solar App will send an SMS to the GSM connected to the SIM card with cell number entered. 'Read Energy button' in figure 10 above will read available power on the batteries display the value above 'Submit button'. AUX (1 - 4) represent appliance connected on the system similar to device "a, b, c, and d" in Table 3 and shall only be active after 'submit button' is pressed.

An ordinary phone can also send an SMS to the device and achieve the same results without reading available energy. Android Studio [15] offers even more features that enhance your productivity when building Android apps, such as: a fast and feature-rich emulator, a unified environment where you can develop for all Android devices, instant run to push changes to your running app without building a new APK, code templates and GitHub integration to help you build common app features and import sample code, testing tools and frameworks, Lint tools to catch performance, usability, version compatibility, and other problems, support C++ and a built-in support for Google Cloud Platform, making it easy to integrate Google Cloud Messaging and App Engine.

VI. CONCLUSION

The proposed intelligent electronic control system uses both internal and external interrupts of microcontroller (MC). External interrupt handles the presence and absence of Eskom power which is binary 0 or 1, internal interrupts handles the presence of 8 bits transmitted or received character in the buffer memory of MC. Internal timer interrupt of MC connected to battery which charge through Solar power, use 16 bit timer to count 500 μ S hundred times to make 50mS and read analogue value external battery voltage and covert it digital using 'B. Equation' under 'III

Propose System' and transmit it to the proposed system connected to Solar panel and inverter. The receiver interrupt has higher priority than other interrupts in this proposed system.

The availability of free services which most of our service providers provide will make the proposed device to be cheaper. For an example Vodacom give one chance to personalize 'Please Call Me' with maximum name of 10 characters per day and also allow the subscriber to send about ten 'Please Call Me' every day. This means the user will have one free chance to control electrical appliance per day. In conclusion, this paper proposes a cost-effective device and mass production will make it affordable to everyone. In the future, we intend to develop a PHP web server with MySQL database to monitor and verify power usage of electrical appliance and calculate the amount saved when using solar power source.

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