# Design and Implementation of Smart Inverter

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Abstract— In this paper, a smart inverter with the ability to automatically regulate incoming voltage was developed using microcontroller with the oscillating circuit that generates a sinusoidal pulse width modulation (SPWM) signal which is safe for home appliances. Combination of electromechanical relays with voltage sensing circuit produces automatic voltage regulation that enables the system switch to appropriate output voltage. AVR circuit is integrated into the inverter circuit to regulate supply and conserve energy in the power bank for efficient usage. The system also incorporates Arduino based switching system comprising of the circuit and control applications. The smart switching module utilizes the Arduino Uno microcontroller for remote switching of over the internet with capability to select a power source for an outlet (whether battery or mains), and also keep an outlet switched on for a userset length of time per day.

*Index Terms*— lawn cutting machine, semi-autonomous mode, Ackermann steering, operator's fatigue.

## I. INTRODUCTION

**N**IGERIA has its peculiarities regarding electricity sufficiency [1]. The primary source of electricity is hydroelectric power whereby turbines are driven at 50Hz producing standard minimum voltage of 11kV [2]. The voltage thus generated is stepped up to 330kV or 132kV at the primary or secondary grid voltage to accommodate energy loss during transmission [3]. At the distribution centres, electric power is stepped down to a final voltage of 415V (phase to phase) and 230V (phase to neutral) for direct consumption by electric load [4].

According to [5], problems associated with uninterrupted electricity supply in Nigeria include insufficient generated power, lengthy transmission lines, overloading of distribution transformers, vandalization of transmission lines, low power factor of distribution network, inadequacy of infrastructural maintenance culture, lack of system planning and corruption in the energy sector. These factors and more result in epileptic power supply as well as

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Godswill Nnamdi Samuel is with the University of Lagos, Akoka, Yaba, Lagos 101017, Nigeria (phone: +2347020457302; e-mail: godswillnnamdisamuel@gmail.com). poorly regulated voltage supply. There also exists the problem of inefficient usage of energy resources by consumers such as the use of high energy consuming incandescent bulbs for long durations and the act of leaving electrical appliances plugged to mains when not in use. These may lead to excess billing without an appreciable return on investment, scarcity in energy supply and reduction in the expected lifespan of appliances to mention but a few [6].

A study carried out by [7], consumer electricity demand dynamics was studied and it was found that in Nigeria, a 1% increase in electricity tariff would lead to an average of 32.45% decline in the quantity of electricity demanded. Also, a 1% increase in the income would lead to a 39.57% average rise in the quantity of electricity demanded. To curb the challenges relating to epileptic power supplies, consumers have sought alternative power supply sources ranging from electric power generating sets to large capacity batteries for storing electric energy (gotten primarily either from solar panels or the national electric power grid). These alternate sources of power also come with challenges which consumers have tried to eliminate, the most basic challenges being the cost of maintaining these devices and sufficient electric power to run electrical appliances, etc. as most generating sets cannot carry even some of the necessary appliances like refrigerating sets and heating/ cooling appliances. These and more have seen the growing demand of automatic voltage regulators and also power inverters by domestic users.

# II. LITERATURE REVIEW

Designed and implemented a 3 kVA pure sine wave inverter using a microcontroller (PIC18f2550) programmed to carry out all the control functions including producing a multilevel pulse width modulation. In their work, a MOSFET driver (IR2112) which steps up current and voltage of the pulse width so as to drive the MOSFET, a Hbridge MOSFET network for sine wave production, a transformer with three taps on the secondary winding, a relay network, filter to remove noise components from the generated waveform [8,9,10]. Another relevant work was carried out by [7] where switch mode square wave (SMSW) switching was employed in the design of an inverter system with automatic voltage regulation. The SMSW design scheme consisted of the inverter and AVR sections and in all consisted of eight modules [11,12]. For the generation of DC voltage, a lead-acid battery was used and to compensate for the current drawn from the battery by a load of 1kVA, MOSFETs of 110A rating were also implemented in switching and rectification. These MOSFETs were also coupled to the transformer to enable the 12 V battery to be charged from the AC mains. This charging was achieved by turning the secondary coil of the transformer into primary by stepping down the 220 V supplied from the mains to 12.5 V AC. The latter is then fed into the MOSFETs arranged in a bridge as shown in Figure for rectification to DC. The DC voltage is then used to charge the 12V battery.

Omotosho, et al., 2017 designed in two stages, a low cost, high efficiency inverter to run AC appliances [13]. The first stage of this inverter consisted of a DC-DC converter based on push-pull design and aimed at stepping up 24VDC to 300 VDC. Using pulse width modulation (PWM). The second stage which involved the inversion of DC voltage to AC voltage used a 40 kHz square wave modulated by a 50 Hz sine wave to drive four power MOSFETs arranges in Hbridge configuration [14]. Using an IC SG3524 and a pair of twelve MOSFETs to drive the load, a 5Kva inverter which works on the principle of pulse width modulation designed and implemented. Using a full wave bridge rectifier, he was able to convert the input AC signal to DC. The output waveform of this inverter howbeit modified sine wave in nature, successfully gave an output voltage of 220 VAC at a frequency of 50Hz.

## III. METHODOLOGY AND MATERIALS

### A. Materials

The materials deployed in this work include: inverter, containing metal oxide semiconducting field effect transistor (MOSFET), a pair of 12V 200A, the operational Amplifier (LM358), programmable Integrated Circuit (PIC) Microcontroller (PIC16F72), a linear voltage regulator LM7805, H-Bridge, Arduino Uno, ESP8266 Wi-Fi Module, Relays, Electromechanical relays

The study considered technical build-up of the smart inverter in phases, namely: H-Bridge MOSFET configuration (Fig. 1), Arduino functions (Fig. 2), Control software development (Fig. 3) and the coupling of various modules into smart inverter unit as shown in block diagram (Fig. 4).



Fig 1: Block diagram for sensor

In Fig. 1, operating adjacent switches determine the kind of voltage produced. Table 1 outlines the switching configurations.

TABLE I Switching configuration of H-Bridge									
А	В	С	D	Voltage Across Load					
On	Off	Off	On	Positive					
Off	On	On	Off	Negative					
On	On	Off	Off	Zero potential					
Off	Off	On	On	Zero potential					

According to Faraday's laws, an ideal transformer has zero losses therefore,

$$V_1 N_2 = V_2 N_1$$
 (1)  
 $\rightarrow \frac{V_1}{V_2} = \frac{N_1}{N_2}$  (2)

where we have taken  $V_1$ ,  $V_2$ ,  $N_1$  and  $N_2$  to be the voltage in the primary coil, voltage in the secondary coil, number of turns in the primary coil and number of turns in the secondary coil respectively. We take  $V_1 = 220V$  V,  $V_2 =$ 12V,  $N_1=300$  turns. Therefore,  $V_1\approx 18$  turns using the above formula. A shell type transformer which performs duals functions as step-up cum step-down transformer was used in this work.

Table 2 contains ESP to Arduino connection configuration at programming mode. After the programming is complete, the normal operation of the ESP module is established by the configuration specified in Table 3.

TABLE 2							
ESP TO ARDUINO CONNECTION CONFIGURATION							
ESP Module Arduino Board							
VCC	3.3V						
TX	TX						
RX	RX						
EN	3.3V						
IO 0	GND						
RST	-						
GND	GND						

TABLE 2 ESP TO ARDUINO CONNECTION CONFIGURATION							
ESP Module Arduino Board							
VCC	3.3V						
TX	RX						
RX	TX						
EN	3.3V						
IO 0	-						
RST	-						
GND	GND						

In table 3 TX and RX pins are interchanged since, for normal operation, signals transmitted by the Arduino has to be received by the Wi-Fi module and vice versa unlike the programming mode of Table 2, where the communication was not closed but only meant as a corridor from the PC through the Arduino to the ESP module. On successful programming, if ESP module is not to be restarted, the reset (RST) pin should be momentarily connected to GND to reset the module. In the physical implementation, this is achieved through the use of a push button (tact switch). The IO has been disconnected from GND, because the IO 0 pin is only grounded for programming operations but left disconnected on normal operation. In the physical implementation, this is achieved through the use of a slider switch. Proceedings of the International MultiConference of Engineers and Computer Scientists 2021 IMECS 2021, October 20-22, 2021, Hong Kong

The architecture of the smart inverter is presented in modules in Figures 2 and 3. The Arduino functional circuitry system is described in Figure 2 while that of control software is as summarized in Figure 3:











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	Relay Number	Alias	Schedule Type	Switch On Time	Switch Off Time	Daily Hours	Hours Spent	Allowed	
Dashboard	1		None	00:00:00	00:00:00	0	0	Any	
Configuration	2	Security Lights	Schedule	18:00:00	06:00:00	0	0	Any	
comgutation	3		Schedule	00:00:00	15:22:00	0	0	Any	
Restart	4	Refrigerators and Freezers	None	14:51:00	14:50:00	0	0	Direct	
	5		Schedule	00:00:00	15:22:00	0	0	Any	
	6	Air Conditioner Ground Floor	None	05:01:00	20:00:00	0	0	Any	
	7		None	00:00:00	00:00:00	0	0	Any	
	8		None	00:00:00	00:00:00	0	0	Any	

Fig 4: Block diagram for User software configuration interface

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## Server Software Development

The server software serves as a driver for the configuration profile set by the user software. This software handles the scheduling of the smart switch by changing the control values stored in the server, these values are in turn, polled by the smart switch microcontroller module thereby changing the output states. The server application console is as shown in Figure 5 below:



Fig 5: Server application console

# Network Interconnectivity Setup

The smart switch module comprises of a number of sections that interoperate for the purpose of full functionality. The microcontroller exchanges information with a Windows server through the help of the ESP8266 Wi-Fi module, the software communicates with the microcontroller by consuming the data from the Windows server and this creates a network structure illustrated by the Figure 6:



Fig 6: Block diagram for User software configuration interface

The server software serves as a driver for the configuration profile set by the user software. This software handles the scheduling of the smart switch by changing the control values stored in the server, these values are in turn, polled by the smart switch microcontroller module thereby changing the output states.

### IV. RESULTS AND DISCUSSION

In this paper, inverting circuit with a rating of 5kVA operating on 24V DC battery to deliver 220 V with alternating current at 50 Hz has been produced. Its output waveform is purely sine as shown by the simulated results. The automatic voltage regulator was designed to handle

ISBN: 978-988-14049-1-6 ISSN: 2078-0958 (Print); ISSN: 2078-0966 (Online) voltage ranges between 160V and 300V. Simulations were carried out with the circuit.

The smart switch parts were assembled initially according to the schematic presented in Figure 7 using a bread board.



Fig 7: Schematic for smart switch module connection

Tests were carried out to ascertain the working condition of the system after programming the ESP wifi module and the Arduino board and found to be working. On confirmation of the connections made through the breadboard, physical connections were further made permanent by transferring the system on to the perf board.

The results obtained by using the user control application to switch the circuit relays were as shown in Figure 8:

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	SERVER ONLINE	_							
Dashboard		Refresh	•	ONTROL		STATES			
Configuration		RELAY 1	OFF	-	ON				
Restart									
		RELAY 2	OFF	•	ON				
		-	0.00	_	0	-			
		RELAT 3	011	-	UN				
		RELAY 4	OFF	-	ON				
		RELAY S	OFF	•	ON				
		PELAY 6	OFF	-	ON	-			
			0.11	-					
		RELAY 7	OFF	•	ON				
		RELAY 8	OFF	•	ON				

Fig 8: User dashboard showing relays 1, 3 and 4 turned ON

And the physical implementation is as featured in Figure



Fig 9: Module with Relays 1, 3 and 4 turned ON

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In Nigeria, power outage is not only a common occurrence, when power supply is restored it is not uncommon that it comes with fluctuations. And most home and office appliances cannot withstand such fluctuations as they were not designed with energy stabilizers which might arrest such irregularities when they occur. It is therefore imperative that users of electronic appliances power regulators for each of the appliances. The advantage of the smart inverter is its ability to control fluctuations that often accompany irregular power supply in most African countries centrally. To this end, the device is effective and cheap to maintain.

# V. CONCLUSION

This work has developed a smart inverter with the ability to regulate voltage automatically. It uses sinusoidal pulse width modulation technique to obtain quality output waveform. System was simulation was done using Proteus and MultiSim software and the results were compared. The inverter which operates on 24V DC facilitated by two 12V, 100A batteries to produce 220V AC at 50Hz frequency. Its AVR circuit stabilizes voltage within the range of 160V to 300V. The system was successfully remotely controlled, and the switches worked as programmed to the scheduler. This device is useful to all electricity consumers in Africa irrespective of location whether in the urban or rural area of the continent.

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