Design and Construction of Microcontroller Based, Solar- Powered Automated Energy for Office Use

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ABSTRACT

The epileptic nature of power generation, transmission and distribution in Nigeria had necessitated the need for the design and construction of microcontroller based automatic electrical energy as alternative power using solar energy. Research has remained the catalyst in speeding up the rate of technological advancement of every nation, and most of these researches originated from higher institution of learning and thereafter handed to industries for proper implementation, and also to populate the nation with such projects for human satisfaction and consumption. This great and major output of several research works will require uninterrupted energy as a fuel to ensure the custom of research process and activities are kept considerably constant. Since there is no such atmosphere, where uninterrupted energy is being practiced, here in Nigeria, there is therefore the need for any reliable but alternative energy to disregard such existence of power epilepsy in some offices of the federal polytechnic Ilaro, Nigeria. The system has ability to conveniently power three offices with six laptop- computers, ten mobile phones, three energy saving bulbs (ESB) and perhaps, with three DC- fans.

Keywords: epileptic, power, generation, transmission, distribution, Nigeria, uninterrupted, energy, reliable, alternative, offices.

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1. INTRODUCTION

The erratic power supply has become a major concern to all Nigerians. The most predominant source of energy in Nigeria now is no other thing but electrical generator, and besides, the cost of acquiring this set and the need to put the epilepsy supply of energy behind us has therefore called for the quick attention for the construction of the DC – to - AC power inverter(Chukwuka, 2017). The nature of every academic domain has necessitated the need for tremendous and fine but an uninterruptible electrical energy, because every academic community is automatic a potential builder of her nation through living proof of reliable research output. Besides, most higher institutions of learning work hand in hand with industries to mass produce goods that will make life much more better for her citizens. Solar power is therefore the conversion of sunlight into electricity and this is achieved either directly by the use of photovoltaic (PV), or indirectly by the use of concentrated solar power (CSP).

The technology of concentrated solar power systems use lenses or mirrors and also, with tracking systems, so that it will be able to focus wider coverage area of sunlight and fold it into a small beam (Abu, MdTousif, Fazlay &MdRajibur, 2013). Residential-sized solar power systems become more and more popular as the world is growing into an unpredictable but almost the nearest future. It is now very important and also timely to explore such amazing technology even in terms of the performance and size, this wonderful system is very in the frontline. No doubts, inverters leads in this area of application (Sanbo, Lixin & Zongxiang, 2012).

Electricity generation grows from few kilowatts and now to Megawatts. From inception, it was designed to serve the colonial masters back then in Lagos when the first generating plant was installed in 1898. In the late 19th century the Electricity Corporation of Nigeria (ECN) was established by Act of Parliament in 1951, a decade later 1962, Niger Dams Authority (NDA) was set up to develop hydroelectricity which was merged with ECN to form National Electric Power Authority (NEPA) in 1972. There was a decline in the generation of electrical energy in terms of capacity even when the population was on the higher side. No specific techniques of measurement to commensurate such population increase and installed capacity. This unbalanced system therefore caused electric power demand to increasingly overshoot the available supply. Since, electricity play crucial role in the socio-economic and technological development of every nation, Nigeria is therefore no exception if such beautiful amenity is kept uninterrupted (Joseph, Alausa, Olaiya & Olasina, 2016).

Nigeria is large with 356, 667 square miles, 351,649 square miles is purely hardcore of land. Over the land are six Geo-Political Zones. Sprang forth are the 36 states and the Federal Capital Territory. The vegetation cover, physical features and land terrain in the nation vary from flat open savannah in North to thick rain forests in south. Rivers, lakes and mountains scattered all over the country. These national physical and political attributes themselves pose high level of challenges to ensure effective but uninterrupted power to all spheres within the country. The Total Installed Capacity is 24,106 MW, but the available Capacity is about 4,000MW as at December 2009 (Sambo, Garba, Zarma & Gaji, 2010). No way for to commensurate for such huge demand but for almost an individual to rise the feet and do the needful by harnessing the energy of sun.

This project "Design And Construction Of Microcontroller Based, Solar- Powered Automated Energy For Office Use" will be to a great advantage, if it could be adopted by all researchers, and also, the issue of "no energy, no research" will definitely become thing of past.

2. LITERATURE REVIEW

Investment in solar photovoltaic (PV) energy is rapidly increasing worldwide due to its long term economic prospects and more crucially, concerns over the environment. The solar PV system not only consists of PV panels, but also has a few power electronic converters for connecting its output to the grid. The power electronics converters normally used are, the DC-DC converter to boost the PV output DC, and the DC-AC inverter for AC conversion. Generally, the Maximum Power Point Tracking (MPPT) algorithm is incorporated with the DC-DC converter to boost the level of the solar PV array output voltage, and to attain the maximum energy extraction. The use of power electronic converters introduces new problems like power loss, the electromagnetic interference (EMI), thus reducing efficiency, and power quality.

The photovoltaic (PV) cell directly converts solar energy into electricity. At a unique point on the I-V or P-V curve of a PV cell, called the Maximum Power Point (MPP), the PV system operates with the maximum efficiency and produces the maximum output power. Hence, it is essential to include a MPPT module in the PV system so that the PV arrays are able to deliver the maximum available power.

One of the most successful and simplest methods for MPPT is the Perturb and Observe (P&O) method (Femia, 2014). Here, the controller works by perturbing the PV array output voltage and observing the effect on the output PV power. The major drawbacks of the P&O/HC MPPT method are, oscillations in the vicinity of the MPP, power loss, and degraded solar energy conversion efficiency. In, (Salas, 2015), the P&O method has been improved by using the PV panel current (IPV) as the variable for the calculation of the duty cycle (D). Artificial intelligence (AI) techniques, like artificial neural networks (ANN), (Mellita &Veerachary, 2010) and fuzzy logic (FL), (Kottas &Esram, 2010), have been employed as alternative approaches to the conventional MPPT techniques. Gounden (2010) have presented a Fuzzy logic based MPPT controller for a grid connected PV generation system, and proved that the fuzzy logic control is an effective tool to extract the maximum power from the PV system. The artificial neural network (ANN) based methods can track the MPPs quickly and accurately, in response to quick changes in the environmental conditions.

The cell efficiency of solar cells increases with the increase in the concentration ratio at the low concentration ratio and decreases with the increase in the concentration ratio at the high-concentration ratio. Under the condition of the given output power, the tandem-type cell may increase the voltage output and reduce the ohmic loss. However, the non - uniformity of light intensity distribution and the poor heat dissipation leads to overheat of the cell panel, affecting the current output of the whole cell array. This is called "the current matching problem." (Chow, 2010). Organic solar cells are composed of organic or polymer materials. They are inexpensive, but not very efficient. Organic PV module efficiencies are now in the range 4% to 5% for commercial systems and 6% to 8% in the laboratory. The novel concepts, often incorporating enabling technologies such as nanotechnology, which aim to modify the active layer to better, match the solar spectrum (Gratzel&Andreev, 2013).

3. IMPLEMENTATION, DESIGN AND CONSTRUCTION OF THE SYSTEM

In this design, a photovoltaic (PV) module of 150W; 4.65A converts sunlight radiation into a dc power. The converted energy was fed to the battery storage and also for any further consumption. The energy would be discharged from dry cell battery during usage and a PV load system therefore pushes all the generated DC voltage to the battery, even during energy consumption but although charge controller was put in place to monitor and control the charging rate. AC voltage was then obtained from output of inverter which converted DC to AC for domestic use.

The methods involved are: Installation of three solar panel modules of 50W each on a mounted tower of reasonable height at angle of orientations, Installation of inverter, charge controller and battery. Apart from Charge Controller, Solar Panel Module and Battery, the inverter subsystem is subdivided into: power and charger module, control module, amplification and transformation module and inverting module. Each of these is fully analyzed under a separate sub heading. Below is a typical block diagram of the system.

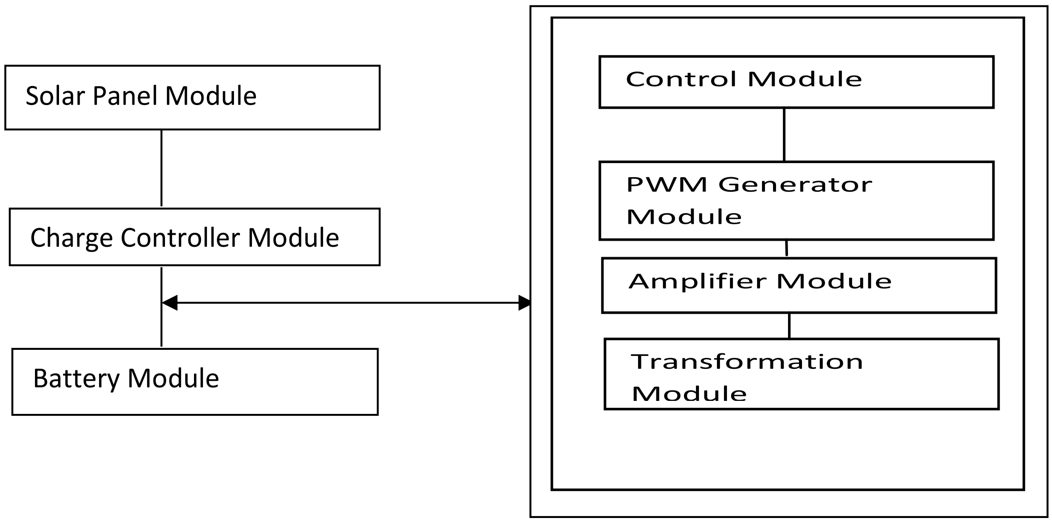

Figure 1: Block diagram of the system

4. DESIGN ANALYSIS OF AN INVERTER SYSTEM

The materials include: Vero board, connecting leads, assorted resistors, assorted capacitors, BJT transistors, SG3524 IC, PIC 16F84A IC, LEDs, power MOSFETs, transformer, switches, LCD, crystal oscillator, voltage regulator, bridge rectifier, inductors, and so on. Some of these components were soldered on the Vero board to generate sub-circuit panels and also, extreme cautions were taken to avoid open-circuits and short- circuits between adjacent terminals and also between sub-circuit connections and terminals.

The construction procedure of 2KVA Inverter was done in modules, and some of these are analyzed below:

4.1 Analysis of Step-Up transformer module

Number of turns were determined using 3000W of power for good number of turns at the primary and secondary coils, and also, flux of density 1.531Tesla was assume and the following calculations were carried out for efficient design:

Using the area of, $A = \sqrt{P}/5.58$

Where A = Area in square meter (m^2), P = power in Watts (W) = 3000W and 5.58 is a constant. It is used to calculate the magnetic flux of the core of the transformer.

$A = \sqrt{(3000/5.58)} = 9.8158cm^2 = 9.8158 \times 10^{-4}m^2$

Also, $E = 4.44f\ \Phi_m\ N$ and $\Phi_m = B_m x A$

Where E = emf of transformer in volt (V), F = Frequency in Hertz (HZ) = 50Hz,
Φ_m= Flux in Weber (Wb), B_m= Magnetic flux density in Tesla = 1.531Tesla,
A = Area in square meter (m^2) = $9.8158 \times 10^{-4} m^2$ and N = Number of turns
$\Phi_m = 1.531 \times 9.8158 \times 10^{-4} = 1.5028 \times 10^{-3}w = 1.5028mWb$

Determination of number of turns on primary and secondary sides, Emf per turn, is E_1, where, $E_1 = 4.44 \times F \times \Phi_m = 4.44 \times 50 \times 1.5028 \times 10^{-3} = 0.3336$ V/turn

For primary turn N_1,
$N_1 = V_1/E_1 = 12/0.3336 = 35.9689$turns ≈ 36turns

For secondary turns N_2, the below formula was used,
$(N_1/N_2) = (V_1/V_2)$
$N_2 = (N_1 \times V_2)/V_1 = (36 \times 220) / 12 = 660$turns

4.2. DC Power Supply for DC Voltages- required Modules and Charger Module
The switching unit, timer, thermal sensor/indicator, and the charging unit, require a well-filtered and regulated DC power to drive their individual components the power supply is made up of step down transformer, which steps the input 220Vacdown to 15Vac.

The bridge rectifier converts the AC signal to DC of the same voltage level. The rectifier consists of bridge diodes D1-D4. The filters help remove any AC ripples from the DC voltage. The IC regulator regulates the DC signal to give a steady, well-regulated dc output voltage.

Transformer Ratings are:
Output voltage (V2) =11V
Input voltage (V1) =220V
Primary turns (N1) =620
Secondary turns (N2) = N2=N1V2/V1 = 620(11)/220 =31 turns.
Transformer output current = 2A

Output power = VI = 11V x 2A = 22W
Peak inverse voltage represents the maximum voltage that the non- conducting diode must withstand. At the instance the secondary voltage reaches its positive peak value, Vm the diodes D1 and D3 are conducting, whereas D2 and D4 are reverse biased and are non-conducting. The conducting diodes D1 and D3 have almost zero resistance. Thus the entire voltage Vm appears across the load resistor RL.

The reverse voltage across the non-conducting diodes D2 (D4) is also Vm. Thus for a Bridge rectifier the peak inverse voltage is given by µ. Since transformer output voltage = 22 V, V_m = 31V. Diode current rating = 2 x transformer current = 2 x 2A = 4A. Rectifier diode to match this rating = IN4007 (Obtained from diode transistor specification book). The output from the rectifier is given as:

Output without capacitor:
$V_{ac} = 1.1 \times (V_{dc} + 2) = 1.1 \times (12+2) = 15.4$v

Output with capacitor:
$V_{ac} = 0.8 (V_{dc} + 2) = 0.8 (14) = 11.2$v
This shows the need for a capacitor. Hence output current
I_{dc} = 1.8 x IDV = 1.8xO.5A =0.9A

Power output after filter stage = 0.9 x 11.2 = 10.0W = 10W

Capacitor value:
C = (I_{dc} x T/Vrip) x106

When I_{dc} = 0.9 , where 106 is a constant value
T = 1/2x50 = 0.008333 (for 50HZ SUPPLY)
Vrip = Vrms x Ripple Vp-p = 0.325V x 2.828 = 0.92V
C (µF) = (I_{dc} x T/Vrip) x 106
C (µF) = (0.9 x 0.00833/0.92) x 106 = 0.00814891 x 106 = 1000 µF (standard value)

Capacitor voltage rating should be at least
= 1.5 x V_{ac} = 1.5 x 11.2 = 16.8V =16V (standard value)

C = 1000µF 16V.

4.3. Efficiency of the system
Efficiency is the ratio of the dc output power to ac input power. The maximum efficiency of a Full Wave Rectifier is 80%. For a 2KVA inverter, the maximum load that should be applied is 1600W.Assuming the load applied is 1600W:
Efficiency = output/input x 100%
Efficiency = 1600/2000 x 100% = 80%

Other components values were carefully chosen and some were chosen based on specifications from datasheet of used components. Below shows the components mounted to bridge-boards and simulation of inverter system.

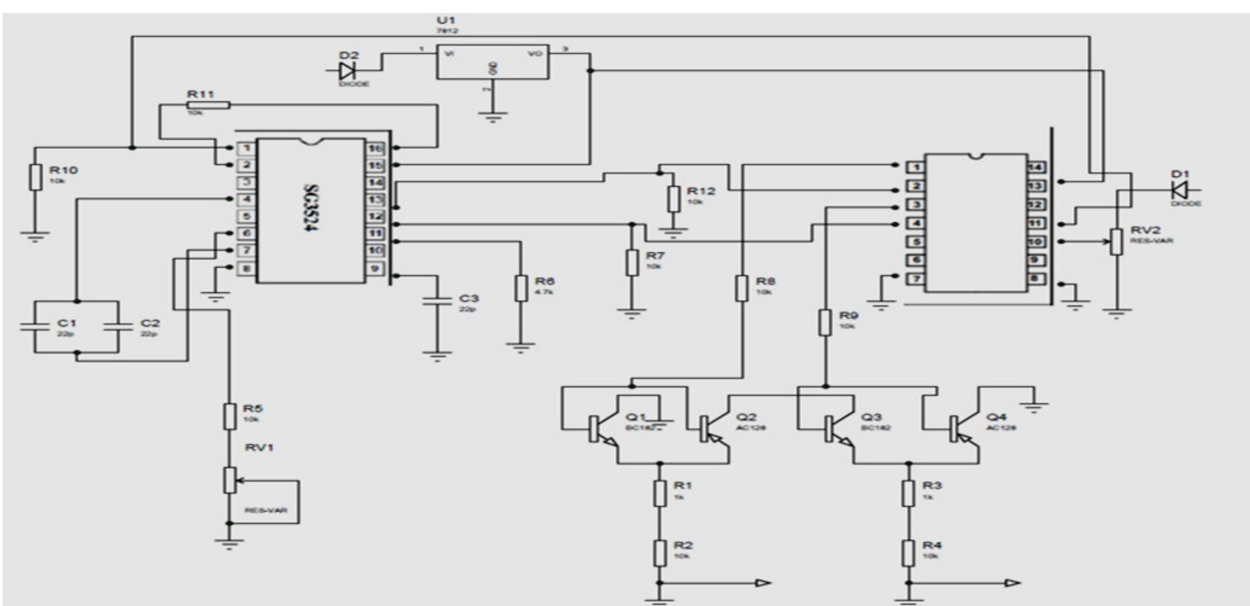

Figure 2 : Circuit diagram of the inverter

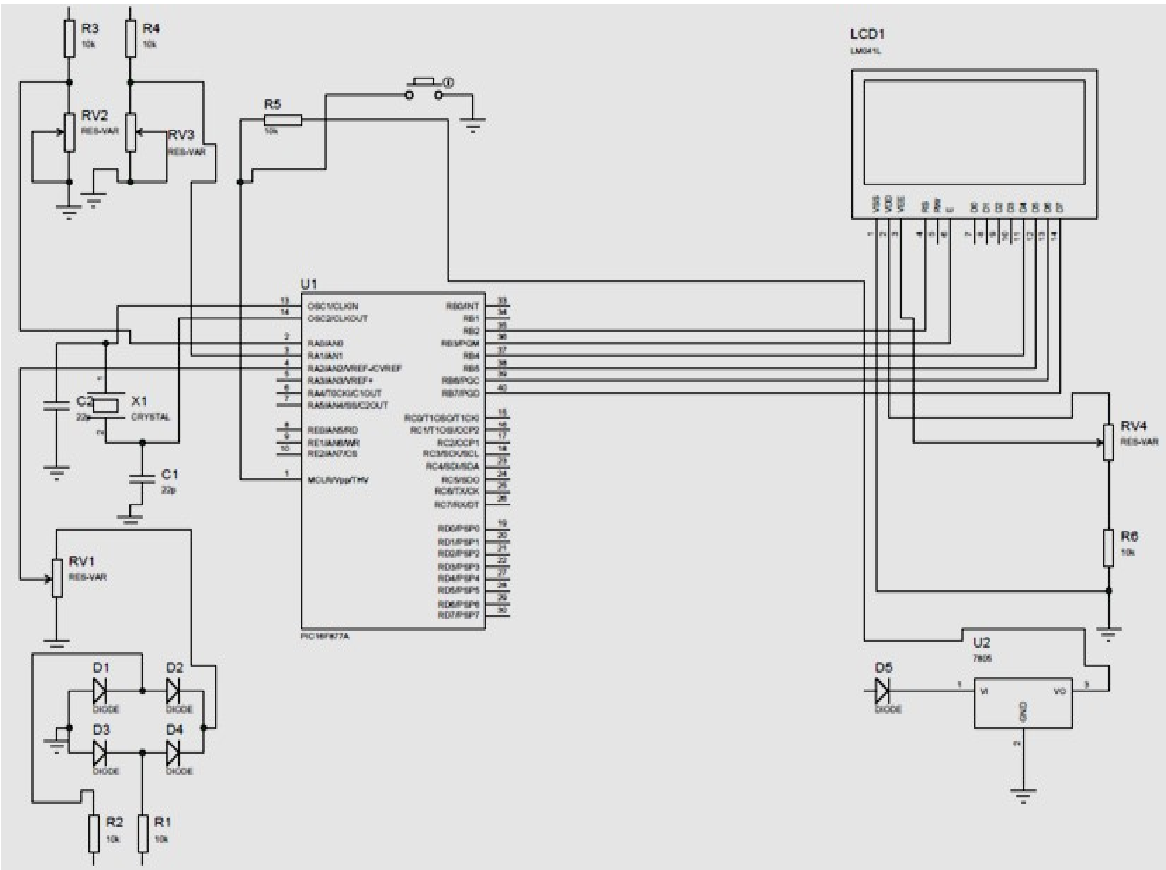

Figure 3: Circuit diagram of the LCD

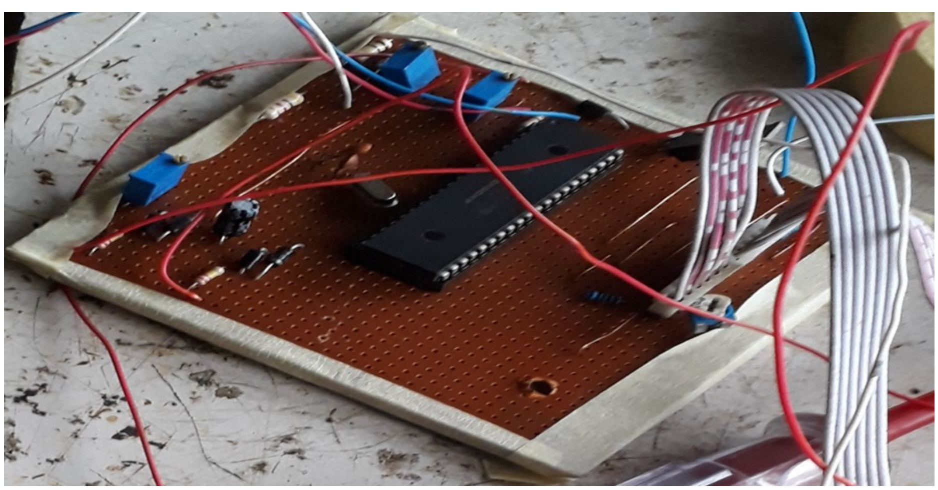

Figure 4: Vero board illustration control and LCD display modules

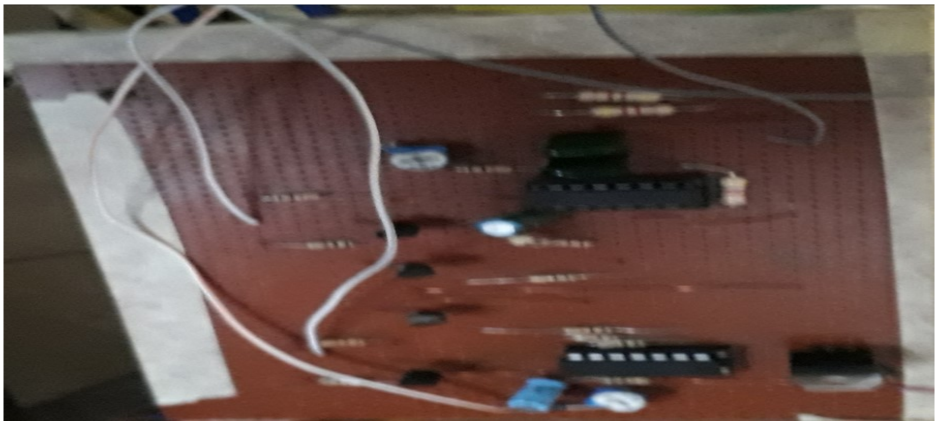

Figure 5: Vero board illustration of the inverting and Power Modules

Figure 6: The Inverter

4.4. Assembling

Having constructed the circuit board and the enclosure and being satisfied with the functionality of the constructed circuit, the project was then assembled. Assembling was simply fixing the circuit board firmly in the enclosure and screwing that there was no conducting object like lead ball; nail soon inside the enclosure and also that enclosure was not too small for the circuit board since this might cause compression which might result to breakage or the Vero board track. Proper connections were made between the units. This was a beat complicated and demand great care and attention since the use of a lot of connecting wires were involved.

4.5 Installation Procedure

The 18.9V, 150W solar panel module was connected to the charge controller module through a cable, from the source of the charge controller module another cable was connected to 12V, 100AH Battery. The Battery was connected to 2KVA inverter which converts DC to AC. The inverter supply electrical power to the three offices through the cables and junction box connected to it. This figure is shown below:

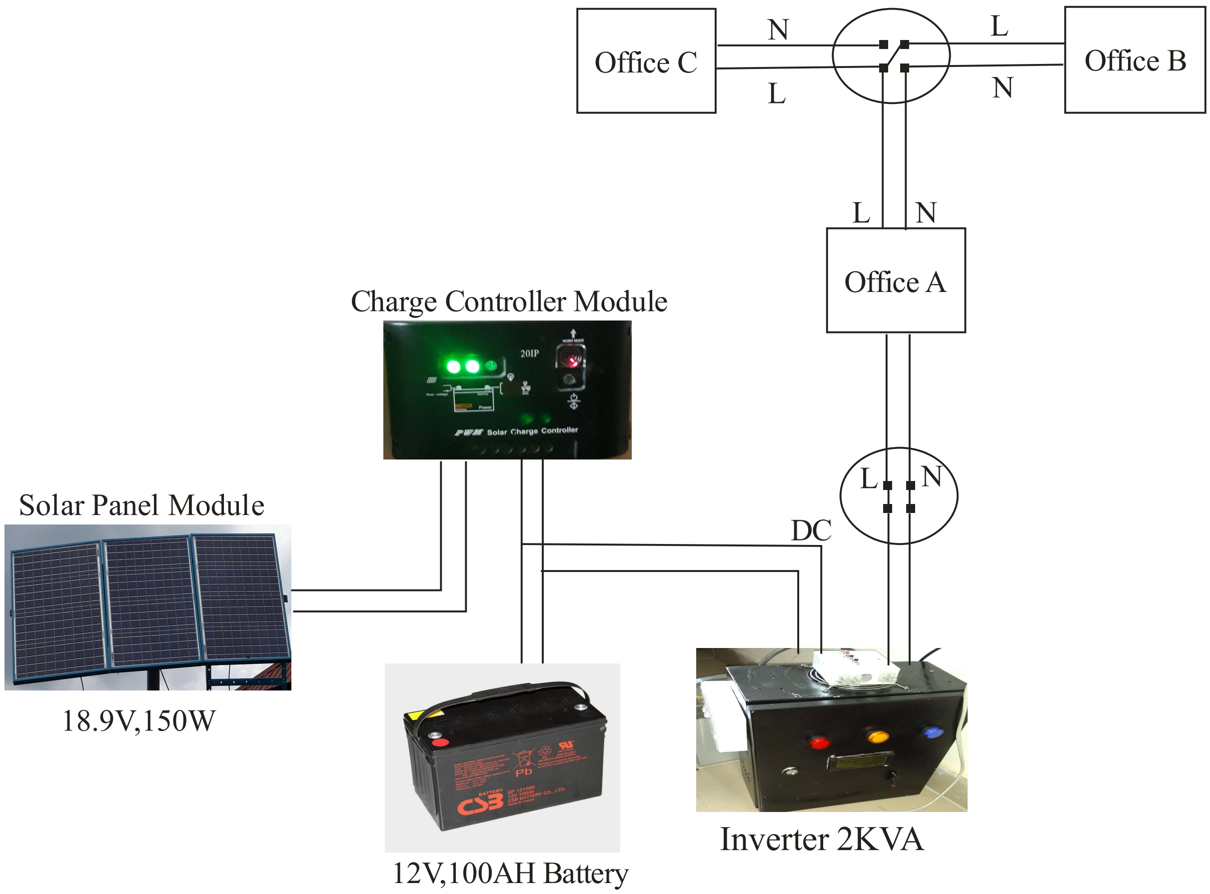

Figure 7: Schematic Illustration of the system

5. RESULTS AND DISCUSSION

The result of the project work was computed based on the performance of the system when the loads for which it was designed for were applied to it, under specific conditions of the system and a given duration of time.

5.1 Performance Test

Performance test was carried out on the system by subjecting it to a specific workflow. The system was tested during the following stages and observations were fully noted:

1. At full battery capacity, the charge controller was able to limit the rate at which electric current was flowing into the battery to prevent over charging.
2. When the battery is fully charged and supplying the inverter with the required energy, it was observed that at maximum load capacity, the system was able to supply the loads with required output power for about six hours.
3. At low battery, with the indication from the charge controller, the system was still able to support few loads for a period of time before going off.

Therefore, the testing of the project proved satisfactorily awesome.

5.2 Performance Evaluation

A PV system performance can be calculated based on hours by hour records for the period when the sun was raised. Power of solar panel can generate up to 80W, for 4 hours. The energy is the product of solar panel watt by the hours (E = Pt). The appliances and light bulbs are rated in watts. To work out how much energy an appliance or light will use, you multiply it's wattage by the number of hours in use. A battery capacity of 12V, 100AH is measured in amp hours that is used for the storage power source capacity, and loads were used for testing the energy source. The battery used was draining quickly, when the load reach some certain values. That shows the system will perform much better and longer when the number of battery increases to two, and if that of PV panel could be increased also.

6. PRESENTATION OF RESULTS

Table 1: Power against time characteristics curve

Time of Day		Input characteristics			Output characteristics		
12hours	24hours	V_i(V)	I_i(A)	P_i(W)	V_O(V)	I_O(A)	P_O(W)
11:45am	11:45	13.09	0.22	2.55	246	0.48	118.1
12:35pm	12:35	12.15	0.36	4.37	268	0.57	152.8
12:50pm	12:50	11.30	0.42	4.75	279	0.65	181.4
01:05pm	13:05	11.08	0.55	6.09	284	0.78	221.5
01:20pm	13:20	10.12	0.62	6.27	295	0.84	247.8
01:35pm	13:35	9.07	0.71	6.44	304	0.91	276.6
01:50pm	13:50	8.98	0.78	7.00	310	0.99	306.9
02:05pm	14:05	8.40	0.89	7.48	315	1.05	330.8
02:20pm	14:20	7.65	0.99	7.58	324	1.11	359.6
02:35pm	14:35	7.21	1.10	7.93	330	1.20	396.0

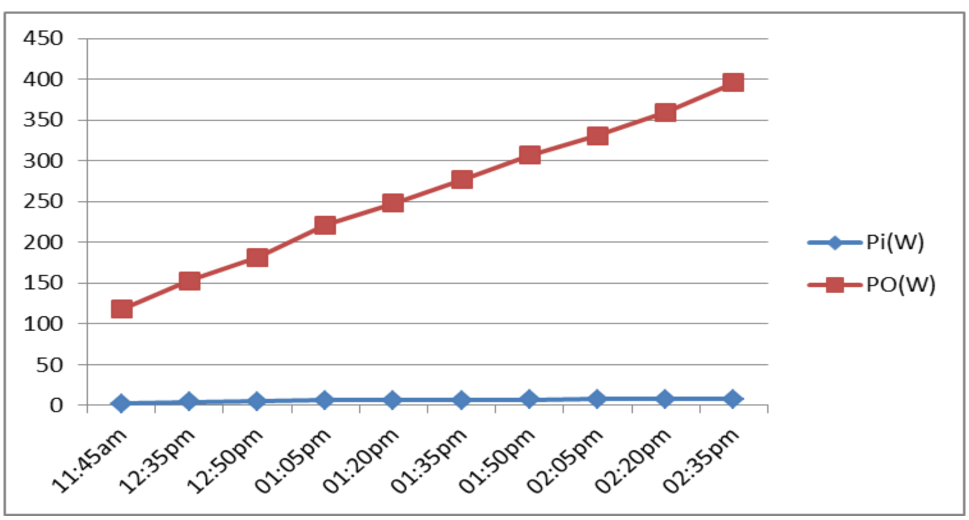

Figure 8: Graph of power against time for input and output characteristics

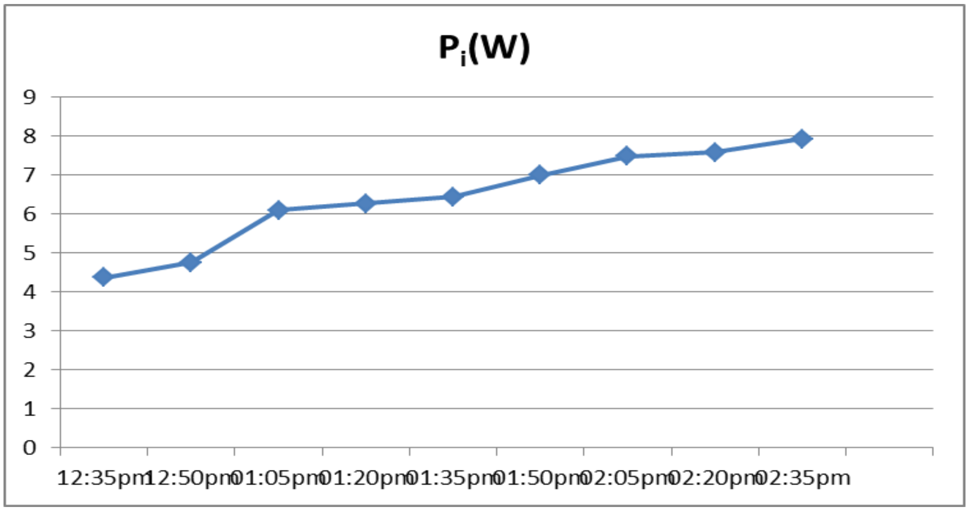

Figure 9: Graph of power against time for input characteristics

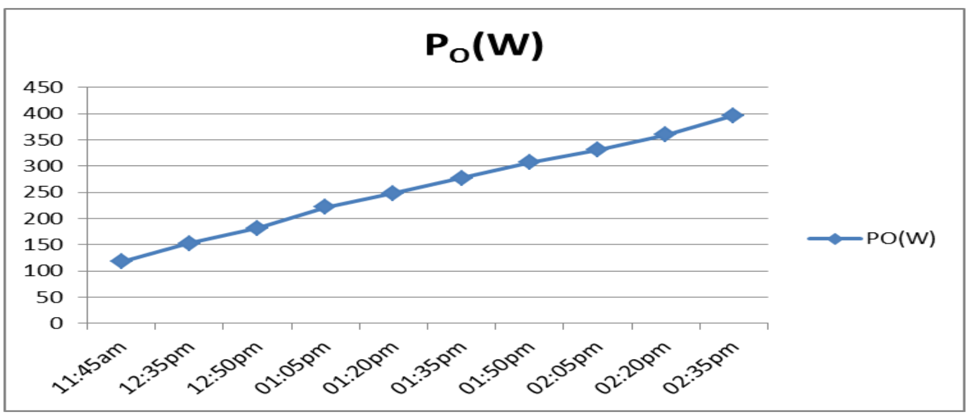

Figure 10: Graph of power against time for output characteristics

6.1 Discussion of Results

According to table1, it was discovered that the input power increases down the line from 2.55W to 7.93W as the time increased from 11.45am to 2.35pm. Also, this increases in the value of input power caused corresponding increase in output power. That is, at input power of 2.5W, there was a corresponding output power of 118.1W; and also, at input power of 4.37W, there was a a corresponding output power of 152.8W; and the value increase in correspondent order and also related linearly with each other and infact, it could be concluded that the two parameters are no doubt, linearly related (i.e, input power is directly proportional to the output power, P_i α P_o). Each of the figures graphically and fully explained the tabular concept in a better pictorial format. Figure8 shows the combination of output power and input power against time, and of course, it is obvious from the table that small increment in the value of input power led to corresponding but large increase in the value of output power. Figure9 and Figure10 respectively depicted input power against time, and output power against time. The results were subjected to further observation, and it was discovered that at when the battery was fully charged, the final total output power was fluctuating between 1.89KVA to 1.98KVA.

7. CONCLUSION AND RECOMMENDATIONS

The solar panel was able to trap energy of the sun and then push the inrush of electrons (current) to the battery , and the battery was able to store the charges and of course, the charge controller worked perfectly in monitoring the charging voltage to ensure moderate charging. As soon as the battery became fully charged, the controller automatically stopped the process until when the charged voltage level drops. Also, the inverter converted the DC power into AC power that was collected as the final output power, which was 2000VA (or 2KVA). Most importantly, the system was able to conveniently carry the intended total loads of about 1200VA(or 1.2KVA) for more than six hours when the battery was at its peak value. Besides, tolerance of about 0.8KVA was put into consideration to commensurate for any subsequent overloading.

The system was flexible in design and operation, therefore it is recommended that more battery and more solar panel will further increase the length of full load time to almost times two of its intended time.

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