

Design, Construction, Test and Evaluation of a Stand alone 75 Watts Solar Electric Generator

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Abstract: In this study, a stand alone 75 watt solar electric generator is designed and constructed to convert the solar radiation of appropriate wavelength from the sun into direct electric current based on photovoltaic principle. The system has proven to meet the necessary requirement under laboratory testing with only few shortcomings. The system can be employed to supply power to laboratory equipment such as signal generator, oscilloscope, network analyzer and spectrum analyzer (all in the power range of 75 watts) useful in field research of electronic communication research. The 75 watt solar electric generator designed and constructed is also useful in remote areas to produce electric power where there is no easy accessibility to utility electric power or other useful sources of electric power.

Key words: Design, construction, stand alone, 75 watts solar electric generator, measurement, Nigeria

INTRODUCTION

The need for a dependable and efficient power supply cannot be overemphasized in laboratory researches and field works. Utility power which had been a very useful source of power has become very erratic and of low quality, besides its usage is not often facilitated in remote areas where useful research, particularly in the field of electronic communication are carried out. An alternative source which include the battery used with an inverter has limited storage capacity which is undependable thus inefficient. One will be far from accurate measurement since all other available sources such as electrical generators still introduce noises (in form of unwanted frequencies) to the parameters under measurements.

Therefore, a dependable alternative source of electric power is absolutely required. In this study, a 75 watts solar electric generator is designed to convert the solar radiation of appropriate wavelength from the sun into direct electric current based on photovoltaic principle which is then converted to useful alternating current by an appropriate inverter for the purpose of using it to run electronic communication laboratory measuring equipment, namely: signal generator, oscilloscope, network analyzer and spectrum analyzer. The Photo Voltaic (PV) cell or solar cell is a semiconductor device consisting of a large area p-n junction diode which in the

presence of sunlight is capable of generating usable electrical energy (Frohlich, 1973). The conversion is called the photovoltaic effect. Over the years, the principle has been employed in conversion of solar radiation into electricity (Quinlan, 1979; Stupca *et al.*, 2007). Perhaps, the biggest advantage of photovoltaic devices is that they can be constructed as stand-alone system to give outputs from microwatts to megawatts. The electrical output generated from the photovoltaic cell has been used to power a variety of electrical and electronic appliances, whole buildings and industries inclusive (Dunlop, 1997; Perlin, 2002). The size and type of solar electric generator depends on the load requirements, load profile and amount of available solar radiation. Accurate estimation of load and their timings are important for photovoltaic system design since the system is sized on the minimum requirement to satisfy the demand over a day (Page, 2002; Miles *et al.*, 2005). Moreover, the selection of other components like inverter depends on the nature of the power needed. All these are factored into considerations in this design. The objectives of this study are to design and construct a mobile solar electric generating system useful in field work (electronic communication research) and remote areas where there is no easy accessibility to utility electric power or other useful sources of electric power and to provide a cost effective, stable and dependable solution to power supply problems in the laboratory research works.

MATERIALS AND METHODS

The study discusses step to step description of the techniques employed in the design of a stand alone 75 watts solar electric generator.

Step 1. System sizing: This is the process of estimating the load in terms of its power rating and its subsequent power requirement. It also involves the determination of the sizes of the solar panel array, battery bank and various ratings of the other components that make up the balance of the system (Dunlop, 1997; Perlin, 2002).

Simple system sizing algorithm:

Variables:

- P_L = Power rating of load (watt)
- q = Quantity of load (Units)
- h = Required number of hours of supply per day
- S_h = Number of sunshine hours per day
- D_f = Degree of freedom (%)
- QWH_{rs} = Quantity-Watt-hour
- P_s = Power rating of solar panel (watt)
- P_R = Required module power (watt)
- N_s = Number of solar panels or module

Module sizing:

- Step 1: Start
- Step 2: Obtain $P_L, q, h, d, f, S_h, P_s$
- Step 3: $QWH_{rs} = q * P_L * h$
- Step 4: $P_R = D_f * QWH_{rs} / S_h$
- Step 5: $N_s = P_R / P_s$
- Step 6: Write N_s, P_R
- Step 7: Stop

Variables:

- V_s = Voltage requirement of inverter
- D_o = Depth of discharge of battery
- B_s = Required battery size
- B_R = Battery rating (AH)
- N_B = Required number of battery

Battery sizing:

- Step 1: Start
- Step 2: Obtain QWH_{rs}, D_o, V_s, B_R
- Step 3: $B_s(AH) = QWH_{rs} * D_o / V_s$
- Step 4: $N_B \sim N_s \sim P_L$
- Step 5: Write B_s, N_B
- Step 6: Stop

Design of a system with 5 h of operation per day with a load requirement of 75 watts (power requirement for the Spectrum analyser GPS810) and 15% in degree

of freedom, the 15% degree of freedom corresponds to an increase of 15% in the quantity-watt-hour required and with an average of 7 h sunshine hours per day. Therefore:

- $P_L = 75\%$ watt
- $S_h = 7$ h
- $h = 5$ h
- $d_f = 1.15$
- $q = 1$
- $P_R = 1.6$ watt were obtained

A 65 watts polycrystalline silicon solar panel which is available in the market fitted the estimated design value of 61.6 watts with the extra 3.4 watt power to improve the efficiency of the system.

Step 2. Voltage regulation and charge controller rating:

The charge controller is a DC-DC controller that converts the relatively high DC voltage from the solar panel to the normal DC voltage sufficient to drive current into the battery (Dunlop, 1997). It regulates the charging of the battery and is connected across the output of the panel and the battery. A 12 V-10 A rated charge controller is capable of withstanding the current from the panel and at the same time supply the 12 V required for the charging of the battery. Table 1 shows the characteristics of some available charge controller in the market.

Step 3. Battery rating:

The inverter required for converting the DC output of the solar panel to the useful AC required to power the load has an input of 12 V which would be supplied by the battery. With a depth of discharge (D_o) of 80%, the battery amperage needed for the generator is estimated accordingly (Dunlop, 1997; Miles *et al.*, 2005). D_o of 80% corresponding to 20% increment in $QWH_{rs} = 120\% = 1.2$; $V_s = 12$ V. Therefore, the required battery size $B_s(AH)$ obtained is 37.5 AH and a 45 AH, 12 V battery which is available in the market is adequate for this design.

Step 4. Inverter stage:

The inverter is the 4th subsystem in the design and construction of the solar electric generator. The inverter stage serves to convert the direct current from the battery sources to alternating current needed to power any of the laboratory equipment previously mentioned. The method of design employed in this stage involves the conversion of the low voltage (12 V) DC power to AC by oscillator (astable multivibrator mode) and then the use of a transformer to boost the voltage to 220 V required by the load as shown in Fig. 1.

Table 1: Characteristics of the charging controller (Miles *et al.*, 2005)

Type	SDRC5 (I)	SDRC-10 (I)	SDRC-15(I)
Rated charge current	5 A	10 A	15 A
Rated load current	5 A	10 A	15 A
Work voltage	12 V; 12/24 V		
Overload, short circuit protection	1.25 rated load current 60 sec, 1.5 rated loads current 5 sec, over load protection action. ≥ 3 rated load current short circuit protection action		
No load current	≤ 6 Ma		
Charging circuit voltage drop	≤ 0.26 V		
Load circuit voltage drop	≤ 0.15		
Over voltage protection	$17 \leq; \times 2/24$ V		
Over discharge voltage	11.1 V (no load) – real-time modified voltage by the discharge rate; $\times 2/24$ V		
Over discharge return voltage	12.6 V $\times 2/24$		
Control mode	PWM charge mode; modified discharge voltage by the discharge rate		

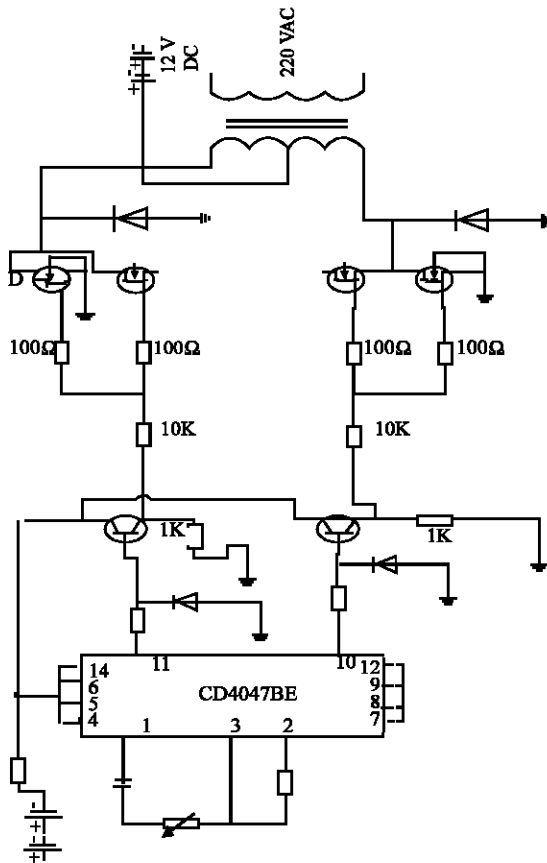


Fig. 1: Invrter circuit diagram

Oscillator circuit: The circuit comprises of an oscillator circuit which is used to produce a filtered wave of the desired sine wave with a steady frequency of 50 Hz that has little distortion. This is made possible by the use of specific capacitors and resistors. The IC used in the oscillator circuit is CMOS low power CD 4047 connected in a free-running mode (Fig. 1). To achieve the free running mode, an external capacitor is connected between the C-timing and RC-connected terminal. The period of the square wave at Q and Q outputs in this

mode are a function of these external components-resistor and capacitor. The value of the resistors and capacitors were chosen to give a 50 Hz frequency wave with 50% duty cycle.

The output at Q and Q are fed into the two transistors at the buffer stage via the two diodes meant to prevent the backward flow of power into the IC. The transistors are connected in the common-emitter mode to produce unit gain thereby presenting the exact signal from to the N-MOSFETs power drivers. The circuit outputs two square waves that have a phase difference of 180° and whose combination mimics a sine wave (a modified sine wave) (Rodriguez *et al.*, 2002; Jim *et al.*, 2007; Akande *et al.*, 2007).

Power driver stage: The power driver stage supplies the transformer with the needed current and circuit voltage. It is driven by the core oscillator circuit and alternatively switches the direction of the current through the transformer at a rate determined by oscillator circuit. In order to create AC power, current must be constantly switched from one direction through the transformer winding to the other. This is achieved by a center-tapped transformer. By supplying 12 V to the center-tapped and alternatively ground out each leg of the secondary using the N-MOSFET, the current first travelled one way through the transformer and then the other producing an AC power. The N-channel MOSFETs has extremely low on resistance resulting in low power dissipation through the N-MOSFETs when they are on and conducting high current and also because turning on an N-MOSFET with its source connected to ground requires supplying its gate with a positive voltage above its threshold voltage (Williams, 1991; Owen, 1996; Rodriguez *et al.*, 2002).

Transformer: The transformer employed in this design is a step-up, center-tapped type used to step up the 12-220 VAC required by the load. From the transformer ratio equation (Akande *et al.*, 2007):

$$\frac{E_s}{E_p} = \frac{N_s}{N_p} \quad (1)$$

$$\therefore \frac{12}{220} = \frac{N_s}{N_p} \quad (2)$$

Hence, the ratio of turns at the secondary turns to the primary turns is 6:110. The core is laminated to reduce heat losses. The transformer is capable of supplying the power to a load ranges from 50-150 watt without saturation.

Step 5. Panel positioning: The general rule of panel positioning is that the solar panel should face due south in sites in the northern hemisphere and due north in sites in the southern hemisphere. Since, the sun travels from east to west, the panel should either face south or north to prevent the sun from casting the shadow of the module and its stand. Because of the cosine effect, the tilte of the solar panel should correspond to the latitude of the site. This ensured that the module received the greatest possible quantity of insolation hence produced maximum power during testing and evaluation (Page, 2002; Miles *et al.*, 2005).

RESULTS AND DISCUSSION

A stand alone 75 watts solar electric generator (Fig. 2) designed and constructed was tested under laboratory conditions at each sublevel and the final stage. The inverter stage was designed with high degree of freedom at the most important stages: the oscillator, the power driver and the transformer (Fig. 1). The power driver N-MOSFETs is capable of sinking 30 A while actually a load of 100 watts will only draw current of 8.3 A. The transformer is configured to produce 220 VAC at the 12 VDC input and a maximum load of 100 WAH will



Fig. 2: Showing a stand alone 75 watts solar electric generator: the solar panel and the housed

produce no saturation in the transformer core. The output of the solar panel was tested during various times of the day. The panel average voltage is around 10 VDC at the evening hours and 15 VDC at noon.

The panel designed is able to supply the minimum voltage required to charge the battery and hence, produce the power required to derive the inverter even when there is no sunlight. And during times of intense sunlight, the panel can produce the power required to drive the inverter without the need for charges storage in the battery. The system has proven to meet the necessary requirement with only few shortcomings.

CONCLUSION

The study presents design, construction, test and evaluation of a stand alone 75 watts solar electric generator. The scalability advantages inherent in solar energy conversion for electrical energy production were employed in this research. That is to say, the generator can be constructed to give output that match the power requirement of any load ranging from microwatts to megawatts.

The system is useful in field work (electronic communication research) and remote areas where there is no easy accesibility to utility power or other useful sources of power. It also provides a cost effective, stable and dependable solution to power supply problems in the laboratory research. The system can be used to power laboratory equipment that has maximum power of 75 watts: signal generator, oscilloscope, network analyzer and spectrum analyzer.

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