# DESIGN AND IMPLEMENTATION OF A 1.5 KVA PORTABLE SOLAR GENERATOR

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**Abstract**

Given the non-steady electric power supply in many third world countries especially Nigeria, there is the need to seek an alternative form of energy for domestic power supply. Among the numerous options, renewable energy alternative such as solar energy system is the most popular choice. Solar energy power supply has many advantages over the traditional power generating alternatives such as using generating set. It is green, noiseless and ubiquitous. This paper highlights the design and implementation of a 1.5 KVA portable solar generator. The solar generator is an all-in-one system housed in a metallic rack measuring 16 inches x 24 inches x 16 inches. The battery bank, the charge controller and the inverting system are all enclosed in the same rack. It is so engineered that its portable feature allows it to be easily moved from one place to another. Two monocrystaline PV-panels of 150 W each serve as the dc voltage generator which charges up a battery bank. The pure sine-wave inverter provides AC outlet for AC appliances; there is also a DC outlet for DC loads. Two additional interfaces provide connection points for the PV-panels and external battery if need be. The system was tested with the intended load and it worked very well.

**Index Terms**: Solar generator, Inverter, Charge controller, and PV panel

## Introduction

Inadequate power supply is one of the major factors impacting negatively on the economy of developing countries. In Nigeria for instance, many urban and rural areas suffer from poor availability of power supply from the national grid. Small scale businesses have high operational cost owing to the high cost of fueling the generating sets. There is the need therefore to engineer a portable solar generator that can replace the traditional gasoline generating sets for small scale business use. Business categories such as POS centres, public phone charging points, small household electric energy need to name a few can comfortably rely on the solar generator for their power need. Students living in self-contained apartments can also purchase and use this system. The cost this prototype is Two Hundred and Fifty Thousand Naira only which is not even up to the price of some traditional generators. It does not require fueling; it is green, almost maintenance free with no noise pollution. By connecting external battery and additional panels, the system can accommodate more loads.

Mass-producing the solar generator will certainly bring down the price. Because solar technology is in its infancy, most of its components are still costly. Research is ongoing in this field so it is expected that in the near future the prices of these components will drop drastically making the solar generator far cheaper than its traditional electromechanical counterpart. Moreover, a typical China-made generator may serve effectively for an average of one year and sooner after that frequent maintenance sets in owing to wear and tear and in less than three years the item has reached its scrap-page value but the solar generator can comfortably serve for an average of four years with little or no maintenance. Solar panel alone can last as long as 25 years (Energy Matters, 2021).

In this paper, the design and implementation of a 1.5 KVA portable solar power generator for both domestic and small business use is highlighted. In this energy model, pv-solar panels convert sunlight energy into a dc power input for battery charging regulated by a charge controller. The inverter system converts the battery stored energy into alternating current (ac) for ac appliances. Also the system can also supply direct current (dc) loads. The system is scalable.

**Review of Related Literature**

Ali *et al.*(2015) presented the design and sizing of stand-alone solar power system which involves designing, selecting and calculating the various component ratings that should be employed during the system implementation. A stand-alone photovoltaic system which would power a medium-energy-consumption residence was designed. The major parameters factored into the design were the orientation of the panels, days of autonomy, the best tilt angle for the solar panels and the likes. The system so designed is both robust and efficient.

Abdelnaser, Kamaruzzaman, Ruslan & Ali (2016) in their paper showed the feasibility of powering remote desert area using PV power generation system. This is against the backdrop that it is not economically viable to supply the energy need of these remote areas from the conventional grid or from fossil fuel as the cost of the later is enormous. The authors designed a design of a stand-alone PV system to power a greenhouse in remote desert area. The energy model is based on Watt-hour demand. Based on the load estimation found to be 61,894kWh/ day, a stand-alone PV generator of 15.6kW capacity was implemented and tested.

Morakinyo, Adu &Atayero (2014)proposed a solar powered street light with automatic switching mechanism. The proposed system would automatically turn on the luminaires at night and turn them off at dawn. At the off time of the system, the battery bank would charge via charge controller; the stored battery energy will deliver power to the luminaries via the inverter and thus the cycle continues. The proposed scheme was implemented and result showed a reliable, energy efficient power source for proper street illumination at night with little human supervision and maintenance.

Sayed Salem Basyoni, Sayed Salem Basyoni & Al-Dhlan(2017) designed and implemented a small scale photo voltaic system (PV system) which would provide electric power for a living room, kitchen and bathroom. The load requirement was based on power saving mode rather than the conventional lighting. This option ensured that the overall energy demand on the PV system was minimal as well as the cost. The PV system was tested and it worked efficiently.

**Units of the Solar Generator**

This solar generator is made up of two units of 150 W PV panels, two units of 12 V, 40 AH storage battery bank, a charge controller and 1.5 KVA inverter unit. The PV panels draw sunlight energy and convert it to direct current electricity;the dc current charges the storage battery bankvia a charge controller (Nwankwo & Azubogu, 2016). The stored energy in the batteries can either converted into ac sine wave for feeding ac appliances. All the units of the solar generator are housed in a metallic casing equipped with rollers for easy movement from one place to another.

To power dc loads, all dc loads are directly connected to the dc rail of the charge controller for 12V dc system. According to (SMA Solar Technology, 2009), apure DC coupled system hasall loads and generators coupled exclusively at the battery voltage level, but the system under consideration is a hybrid system. The battery bank feeds the inverter with dc current which the later converts into 240 V, 50 Hz ac signal using pulse width modulation technique. The ac output of the inverter supplies current to ac appliances as depicted in figure 1.

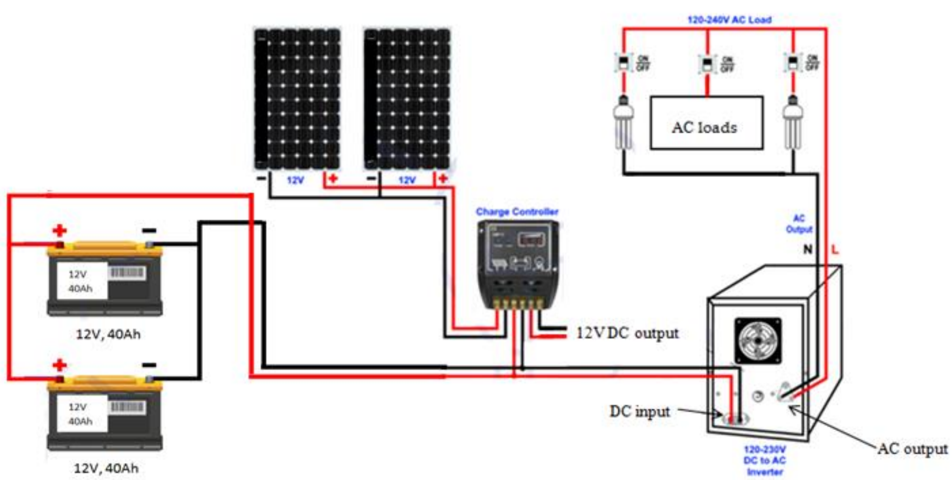


Fig. 1: Solar system block diagram

**System Design and Implementation**

This portable solar generator basically consists of four components: Two units of 150 W monocrystalline PV panel, two deep cycle storage batteries cascaded in series each with a voltage rating of 12 V 40 AH, a charge controller and a1.5 KVA inverter. Since this solar energy model is designed to take care of small business energy need such as POS outlets, picnic events and homes with very small energy needs, the simple power consumers so considered in this paper are lamps, POS terminal, laptop, and so on. Mobile phones, dc lamps, dc fans, etc can be coupled on the DC side of the system while radios, ac lamps, laptops, and so on are connected to the inverter AC outlet. It should be noted that AC appliances are readily available worldwide and cheaper than their dc counterparts.A user of this system will have to make basic energy calculations in order not to overload the system.

Connecting solar panels together to build up larger arrays is an important aspect of a well-designed solar power system (Alternative-energy-tutorials.com, 2020). Solar panels can be connected together in series, parallel or a combination of both to achieve a specific design objective.

As solar panels are connected together in parallel, the resultant output current of the array is the sum of the output of each panel while the total output voltage is that of a single panel in the array. All the positive terminals are tied together and all of the negative terminals are tied together (Hes PV, 2014).In this design, thetwo solar panels are combined in parallel to produce the desired PV array with load voltage of 12 V.

Based on average 7 hours of sunlight in Nigeria and estimated load of 1.0 KWH energy requirements, the calculations below are done to determine the PV array size needed.

**PV array design**

$$1000 Watt - Hour \div 7 Hours = 143 Wattsarray$$

Accounting for 15% real world losses (Wholesalesolar.com, 2018),

$$143\ arraywatts \div 0.85 = 168\ Wminimumsizeforthe PV array.$$

For a more reliable system in the face of other losses, the array of watts is increased to 300 Watts array.

### Charge Controller Sizing

The charge controller is rated at 125% of the solar panel short circuit current. Using the relation:

$$Charge\ controller\ capacity\ (in\ A) = PV\ short - circuit\ current \times 1.25 \quad \text{(Douglas G.,2019)}$$

That is $I_{ccc} = I_{pv-sc} \times 1.25$

Where $I_{ccc}$= charge controller capacity in amperes; $I_{pv-sc}$= PV panel short circuit current; scaling factor = 1.25. For this design, the PV panel of choice has short circuit current of the PV module is $I_{SC}$ = 10 A.

Thus, the required rating of solar charge controller is

$$= 2\ panels \times 10\ A \times 1.25 = 25A$$

The next nearest rated charge controller is 30A

Inverter Sizing

Making the Inverter capacity 125% of the total load value will compensate for losses and efficiency problem inherent in the inverter itself. In this design, a total load of 1KW is proposed and therefore the inverter capacity will be given by:

$$\text{Inverter capacity} = 1000\text{W} \times 1.25 = 1250\text{W}$$

To make provision for further scalability, the inverter capacity is chosen to be 1.5KVA

Common charge controller output voltages are in the orders of 12V, 24V or 48V (Solarpanelsvenue.com, 2020) with an input voltage and current ratings up to 60V and 60 A respectively. A solar charge controller is a regulator that delivers power from the PV array to system loads and the battery bank (Douglas, 2019). A solar charge controller performs the work of protecting the battery bank against overcharging and undercharging. A charge controller equipped with low voltage-disconnect (LVD) switching protects the battery bank against over-discharging.In this part of the world sunlight is in abundance so the choice of charge controller is PWM charge controller which is cheaper than the MPPT type.

**Connection of solar battery bank**

The batteries are connected in parallel in order to add up the amp-hour capacities of the individual batteries while the voltage will remain unchanged. Connecting the two solar panels in parallel charges the batteries faster (Electrical Technology, 2020). The battery connection is shown in figure 2. The inverter is connected to the battery bank.

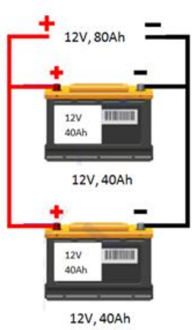


Fig.2: Battery bank connected in parallel

The design calculations are as follows:

$$System\ voltage = 12V; System\ load = 1000Watt - hour, days\ of\ autonomy = 1\ days, depth\ of\ discharge, DoD = 50\%, Battery\ bank\ ambient\ average\ temperature = 86°\text{F}.$$

Back up duration =

$$total\ daily\ load\ \times Days\ of\ autonomy = 1000Wh\ per\ day \times 1days = 1000Wh$$

To take DoD factor into account, the result is divided by 50%.

$$1000Wh/0.5 = 2000Wh$$

Because of average ambient temperature of 86°F, it is multiplied by a factor of 1.00

$$2{,}000Wh \times 1.00 = 2{,}000Wh$$

Dividing by the system voltage gives:

$$2{,}000Wh/12V = 167Ah$$

So we can use a battery bank of say, 200Ah capacity. However, for portability sake, 80Ah battery is deployed and an external interface provided for additional 120Ah when absolutely necessary. The effect of battery under-sizing is that the system will not run for the stipulated amount of time.

**Test and Results**

Various tests were carried out on the main components of the system. First, the inverter was tested and was in good working condition. The battery voltage was 12 V and charged up to 13 V. Depth of discharge was not allowed to exceed 50%. The test showed that the system is robust and performed optimally.

**Conclusion**

In this paper, the design and implementation of a 1.5 KVA portable solar generating set was covered. Basic calculations of the PV array wattage and battery bank capacity, charge controller amperage and the inverter capacity were all carried out using relevant formulae and unavoidable assumptions. The system was tested and found to have performed well. It is both cost effective and robust. In order to replicate the design however, factors such as environmental conditions of a place and differences in parameters as well as tolerances of solar components must be considered.

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