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Web-Based Application for the Sizing of a Photovolatic (PV) Solar Power System

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ABSTRACT: *The harnessing of solar energy, especially for provision of energy for residential consumption, has been on the rise in developing countries, especially Nigeria, in recent times. Due to this reason, there is the need for a tool which makes the design of the system needed to harness this abundant energy more accurate and efficient by considering several factors including specific climate conditions of the country. This paper presents the design and development of a web-based application that helps to estimate the ratings and quantities of the components of the Solar Photovoltaic (PV) System (which converts the solar energy to electrical energy) required based on several factors including the specific climatic conditions of major cities in Nigeria.*
Index Terms*-- climate conditions,Harnessing, Photovoltaic (PV) system.*

I. INTRODUCTION

The world's need for clean and efficient energy is on the rise due to increasing concerns of global warming and depletion of some of the conventional sources of energy (Coal, Oil and Natural Gas). This has led to an increase in the harnessing of renewable energy sources. Among the renewable energy resources, the energy from the sun can be considered the most essential and prerequisite sustainable resource because of the ubiquity, abundance, and sustainability of solar radiant energy. Regardless of the intermittency of sunlight, solar energy is widely available and completely free of cost. [1]

In most developing countries, a major problem being faced is that of energy. Most developing countries are not generating enough electricity to meet the needs of the populace [2] and most of the existing electricity generating infrastructures are purely conventional (i.e. hydro and thermal). This has led to some of the populace opting for alternative sources of electricity to meet their domestic needs and the use of renewable sources especially solar energy has been receiving more attention due to the abundance of solar radiant energy in most of these countries and the long run cost efficiency of solar installations. Also, the continuation of this trend will build a solid foundation for the implementation of distributed generation in these countries as a level of awareness of the merits of distributed generation would have been created.

However, the design of solar PV systems in most of these countries is mostly done by what can be described as 'trial and error' methods resulting in the early failure of some of these installations. This paper therefore presents a more effective and efficient tool to aid in the design of these systems in developing countries that have challenges generating enough electricity for her populace, using Nigeria as a case study. It discusses the design and development of a simple and easy-to- use web-based PV solar sizing application that facilitates the efficient use of solar power for domestic consumption through optimal estimations of the ratings and quantities of the components of the system utilized in the transformation of the available solar energy to the needed electrical energy. The application is programmed to determine the amount of energy required to sustain the estimated load of the user for some specific number of hours, which is also determined by the user. The calculations made by the application are based on a number of factors including the weather conditions of the user's location.

II. METHODOLOGY

This work is divided into two parts. The first part deals with the design of a template for sizing the components of the solar PV system while the second part involves the development of the application itself using some high level programming languages including HTML, CSS, PHP, JavaScript and MySQL.

2.1 Design

The major components of a solar PV system are: solar panels, charge controllers, batteries and inverters; and the ratings and quantities of each of these devices required for a particular installation must be determined. The procedures for determining these ratings and quantities for each of these components are highlighted under this section.

***1). Solar Panel*:** This can be regarded as the first part of the system. It is the part of the system that converts the sun's solar energy to electrical energy. For standardization purposes, solar panels are rated under what is referred to as Standard Test Conditions (STC) i.e. 1 atm of atmospheric pressure, cell temperature of 25^0C and a solar irradiation of 1000 W/m^2 [3]. However, in the real world, these conditions are not likely to be obtained majorly due to variations in the ambient temperature conditions and solar irradiation values with respect to the location of installation of the panels. These variations are therefore taken into consideration in the sizing of the solar panels as follows.

Assuming a system efficiency of 75%,

$$P_{solar} = 1.25E_{req} / (n \times H_{sun}) \quad (1)$$

Where P_{solar} is the total size of the panels required (at STC), E_{req} is the energy required (obtained by multiplying the kW needed with the number of hours of intended usage), n is the efficiency of conversions due to temperature and H_{sun} is the hours of sunlight which will be obtained from the daily solar irradiation (G will be expressed in terms of $1kW/m^2$ multiplied by number of hours).

n is obtained using the equation:

$$\mathbf{n} = 1 - [\gamma_{vmp} (T_{cell} - T_{stc})] \quad (2)$$

Where, γ_{vmp} is the temperature coefficient of the cells which has a typical value of $0.5\%/^0$C for crystalline silicon panels which are generally more efficient due to their higher fill factor [4] and $\mathbf{T_{stc}}$ is 25^0C.

T_{cell} is obtained using the equation

$$T_{cell} = T_{ambient} + G \times (NOCT - 20)/0.8 \quad (3)$$

Where, $T_{ambient}$ is the ambient temperature of the location of installation of the panel, **G** is the solar irradiance, NOCT is the Nominal Operating Cell Temperature which has a typical value of 45^0C.

The total number of the panels needed is then obtained by dividing P_{solar} by the rating per panel which will be selected by the user from a list of ratings that will be provided. Also, the array voltage will be selected by the user. It is assumed that due to cabling losses and some other losses, the output from the solar panels would have dropped by 5%.

***2). Charge Controller*:** Charge controllers are needed to charge batteries which will be used to store the energy gotten from the sun to cater for conditions of very little or no irradiation including dark periods, cloud overcast periods, rainy periods etc. The charge controllers ensure that the battery is not overcharged or deeply discharged and also in some cases find the maximum power point (MPP) of the solar panels.

The voltage rating of the charge controller will be more than the open circuit voltage rating of the panel to be used which will be determined by the user while the current rating will be obtained from the short circuit current values of the solar panels and some other safety factors.

$$\text{Current rating} = I_{sc} \times \text{no. of panels in parallel} \times 1.25 \times 1.25 \quad (4)$$

The first 1.25 is the safety factor while the second is an additional safety factor to cater for continuous operation of the system (which is at least 3 hours of continuous usage according to the National Electric Code (NEC)) and also to cater for heat and equipment stress. A further drop of 5% is assumed due to the charge controller and associated cablings.

***3). Battery*:** As earlier stated, there is a need to store the energy from the sun and this is where the battery comes in. In most solar applications, lead acid batteries are commonly used due to their low cost and high charging efficiency of about 90% [5]. To obtain the size of the batteries required, the following equations are employed.

$$\text{Initial Battery Ah} = 1.15E_{req} / \text{Battery Array Voltage} \quad (5)$$

The selected battery array voltage considered in this project is either 12V or 24V. Using a Depth of Discharge (DOD) of 50% and user defined autonomy (which is the number of days of intended use without recharge to cater for conditions such as rainy days, cloud overcast etc.), we obtain a final expression for the battery Ah.

$$\text{Final Battery Ah} = \text{Initial Battery Ah} \times 2 \times \text{Autonomy} \quad (6)$$

The number of batteries required will then be obtained by dividing the Final Battery Ah by the individual battery Ah that will be chosen by the user.

4). Inverter: The solar panel and the battery deals with DC voltage. However, most household equipment are fed by AC voltage. There is therefore the need to convert this DC voltage to AC voltage and this is where the inverter comes in.

The rating of the inverter will be 1.05 multiplied by the total power required plus 30% of the total power required as safety factor. A power factor of 0.8 will be used to convert the rating to kVA values.

2.2 Development

The project is developed based on the input and output system i.e. the system takes in some form of input from the user and outputs some data back to the user after some computations have been carried out. The major inputs required from the user are:

- The loads to be powered, their quantities and the number of hours of intended usage.
- The location where the PV solar power system is to be installed.
- Preferred size of each solar panel, preferred size of each battery and preferred array voltages for the solar panels and the battery bank.

while the outputs that the application displays are:

- The ratings of the solar panels and the number of panels required.
- The ratings of the inverter required.
- The ratings of the charge controller required.
- The ratings and the number of batteries required.
- The total kilowatts (kW) of the user.

A simplified flowchart of the application is as shown in Fig. 1. High level languages including HTML, PHP, CSS, JavaScript and MySQL are then used to implement the algorithm. A screenshot of part of the application is as shown in Fig. 2.

III. SIMULATION AND RESULTS

Discussed below is the order of program flow of the application. The application initializes by waiting for input from the user. The inputs expected are: (1) the location of the user and; (2) the estimated load of the user in kWh. Next, the application computes the rating of the solar panel, the ratings of the charge controller, the ratings of the inverter, and the ratings of the batteries needed.

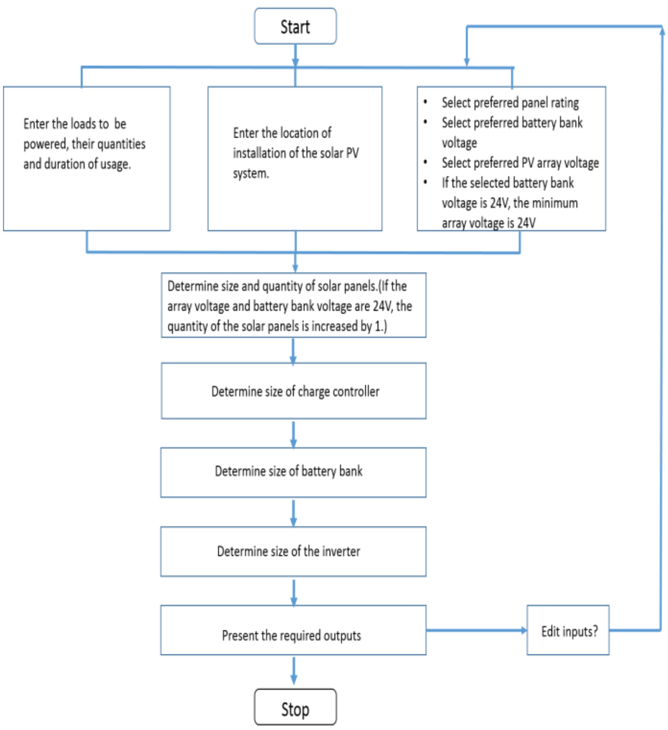

Fig. 1. A simple flowchart of the application

IV. CONCLUSION

Finally, the application presents various configurations that can be employed for the installation of the panels. Some of the economic factors influencing the cost feasibility of a PV installation are the cost of basic materials [4,5] and the flexibility of the installation to meet various domestic needs of the user [6]. Some of the economic factors influencing the cost feasibility of a PV installation are the u9cost of basic materials [6,7] and the flexibility of the installation to meet various domestic needs of the user [8].

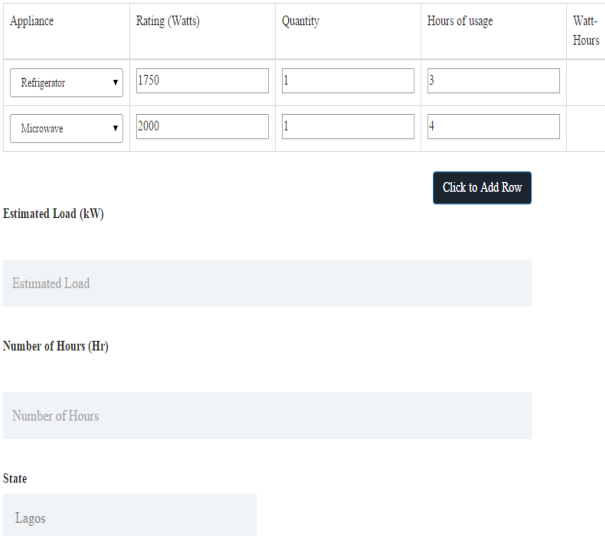

Fig. 2. A screenshot of the data-input section of the application

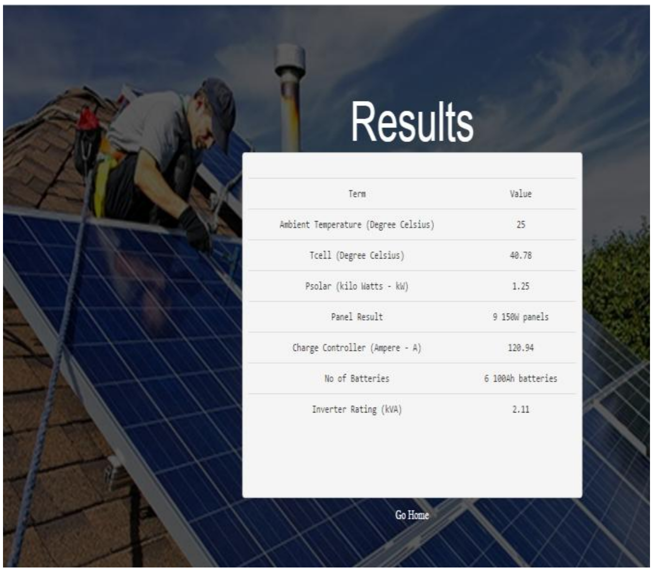

Fig. 3. A screenshot of the result of the application

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