Development of a Standalone Photovoltaic Design and Sizing Software

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Abstract—*This paper presents the development of a MATLAB based standalone photovoltaic design and sizing software. In the proposed software, a photovoltaic system designer can size efficiently the photovoltaic module, Battery, Inverter and Charge controller. The developed software also has the capability of determining the payback period of the photovoltaic system and a graph is displayed to enable better understanding. Using this software, the standalone system is modeled by providing the daily energy demand, peak load and also other necessary data required. The developed software determines the feasibility of the stand-alone system in terms of photovoltaic size, daily and annually energy produced with the economic payback period. This software can be used to perform any photovoltaic system analysis and design using any available data.*

Keywords—*software; standalone system; photovoltaic; solar radiation; payback period*

I. Introduction

Photovoltaic (PV), also called solar cells, are electronic devices that convert sunlight directly into electricity, [1]. The modern form of the solar cell was invented in 1954 at Bell Telephone Laboratories. Today, PV is one of the fastest growing renewable energy technologies and it is expected that it will play a major role in the future global electricity generation mix, [2]. Solar cells are excellent replacement for the supply of electricity at locations distant from the electricity grid [3].

Independent solar systems (off-grid) have been developed as well as network connected systems (on-grid). In the meantime, a considerable increase in wide use of solar cells has been recorded in rural areas where electricity network and infrastructure have not been developed. Electricity produced in these areas is used for pumping water, cooling energy, telecommunications and other household appliances and everyday life needs, [4]. The idea of developing environmentally friendly PV plants was discussed in [5] and suggested that huge green energy source generated from the sun, PV industry will gain the best opportunity to grow up. This paper cover all the preferences addressed by the [6] in their paper; Costs, Payback period as an economical parameter, location, and capacity utilization factor (CUF) as a technical parameter and type of cell and performance ratio as PV parameters.

A PV system consists of PV cells that are grouped together to form a PV module, and the auxiliary components (balance of system - BOS), including the inverter, controls, etc.

The rest of the paper is organized as follows: Section two briefly discusses some of the related works. Section three presents the methodology. Section four displays the result of the developed software. Conclusion and future work makes up section five. Conflict declaration makes up Section six.

II. RELATED WORKS

Several related works have been done on PV sizing software. the work of [7] presented a solar PV design expert system which determines a composite parameter as a function of latitude and longitude. The parameter combines both site and array characteristics to avoid the problem due to variability of several climatological parameters.

[8] designed a tool that has the capability to allow the user to employ meteorological data such as ambient temperature, irradiation data, and peak sun hour (PSH) in designing the PV system.

Recently a MATLAB based software tool called PV.MY was developed by [9] to find the optimal size of PV systems. The software features the capabilities of predicting meteorological variables using artificial neural network (ANN) function.

- Our contributions: in this paper, we employed the economic payback period of the PV system which is compared with life span of the PV panel which is 25 years and the graph is displayed to show the result of the calculations.
- User-friendly MATLAB based software was developed to serve standalone software for PV system designers.

III. METHODOLOGY

PV system designers can use the software to easily size the components of the PV systems. The method of sizing the system employed in developing the software are highlighted as follows;

A. Develop the PV Module Sizer for the Software

Information about the dc voltage of the system, V_{dc}, average sun hours of the installation site per day, T_{sh}, and daily average energy demand in watt-hours, E_d, should first be determined before the actual sizing of the PV array.

Sizing the array begins by first determining the required daily average energy demand, E_d, then the average peak power or solar panel rating is then obtained by dividing the required daily average energy demand by the average sun hours of the area per day, T_{sh}, battery efficiency and PV derating factor, shown in (1), (Kaushika & Rai, 2006).

$$P_p = \frac{E_{rd}}{T_{sh} \times PV_{df} \times B_{eff}} \tag{1}$$

PV_{df} and B_{eff} are the PV derating factor and battery efficiency, respectively.

Then, the total number of modules, N_{tm}, that form the array is determined by diving the peak power by the power rating or watt-peak, w_p, of selected solar panel as shown in (2).

$$N_{tm} = \frac{P_p}{w_p} \tag{2}$$

Then, evaluate the number of Series connected modules in the system using (3).

$$N_s = \frac{V_S}{V_{NM}} \tag{3}$$

V_S and V_{NM} are the system voltage and nominal module voltage, respectively.

Finally, the number of modules connected in parallel string is obtained using (4).

$$N_p = \frac{N_{tm}}{N_s} \tag{4}$$

B. Develop the Inverter Sizer for the Software

First, determine the power in volts-ampere (VA) rating for solar inverter based on (5) shown below.

$$P_{gen} = \frac{Peak\ Load}{Power\ factor} \tag{5}$$

P_{gen} is the power rating of the solar inverter in KVA.

The inverter must be large enough to handle the total amount of watts that will be used at one time, [8]. The work of [10] suggested the inverter size should be 25-30% bigger than total watts of appliances as shown in (6).

$$P_{inverter} = Safety\ factor \times P_{gen} \tag{6}$$

The value of 1.25 (or 1.30) is chosen as safety factor.

Finally, determine the number of inverters, $N_{inverter}$, to be deployed using (7).

$$N_{inverter} = \frac{P_{inverter}}{Chosen\ inverter\ rating} \tag{7}$$

C. Develop the Battery Sizer for the Software

The battery type recommended for use in solar PV power system is deep cycle battery, [10]. This battery is specifically designed such that even when it is discharged to low energy level it can still be rapidly recharged over and over again for years, [10]. The battery should be large enough to store sufficient energy to operate all loads at night, cloudy, rainy and dusty days. Sizing the battery begins by first determining the estimated power, in KVAhr, as shown in equation (8).

$$KVAhr = \frac{E_d}{Power\ factor} \quad (8)$$

Then, get the capacity of the system, C_{bt}, by applying (9).

$$C_{bt} = \frac{KVAhr}{V_{bk}} \quad (9)$$

The voltage rating of battery bank is denoted by V_{bk}.

Next, the total number of batteries N_{bt}, can then be obtained by dividing the total capacity of the battery bank in ampere-hours by the capacity of one of the selected batteries in ampere-hours, C_b, as given in (10).

$$N_{bt} = \frac{C_{bt}}{C_b} \quad (10)$$

The number of batteries in series N_{sb}, can now be determined by dividing the system dc voltage, V_{dc}, by the rated dc voltage of one battery as in (11).

$$N_{sb} = \frac{V_{dc}}{V_b} \quad (11)$$

Finally, determine the number of parallel battery strings, N_{pb}, by dividing the total number of batteries by the number of batteries in series as in (12).

$$N_{pb} = \frac{N_{bt}}{N_{sb}} \quad (12)$$

D. Develop the Charge Controller Sizer for the Software

The standard practice of sizing the charge controller is to ensure that it is able to withstand the product of the total short circuit current of the array, I_{SC}, and a certain safe factor, F_{safe}. The safe factor is necessary in order to allow for a reasonable system expansion. Thus, the charge controller current rating, I_{rcc}, is as given by (13), [10].

$$I_{rcc} = I_{SC} \times N_{pm} \times F_{safe} \quad (13)$$

I_{cc} is the current of the charge controller.

Equation (10) is then utilized to calculate the number of charge controllers, N_{cc}, required for the PV system.

$$N_{cc} = \frac{I_{rcc}}{I_{cc}} \quad (14)$$

E. Plot the Payback Period

The period of time taken to generate the amount of funds invested in PV system is called payback period. It also refers to how long something takes to pay for it or being equal to. Shorter payback periods are preferable to longer payback periods, [11]. Payback period is usually expressed in years. The payback time is strongly influenced by the annual solar radiation on the PV system. Factors that influence payback time are [12]:

a. Sunnier the location: the greater the PV yield and the shorter the payback time.
b. Grid electricity costs: the higher these costs, the shorter the payback time.
c. Initial costs of the PV system.

In practice, often more factors must be taken into account than in the simple example above.

The cumulative cost of the generated electricity is obtained by adding the previous year's costs to the next year's which is then compared with the total installation and maintenance cost of the system graphically to see when we have paid back on the investment that is, the payback period. 25years is used which is the total life span of the PV module, [13].

IV. RESULTS AND DISCUSSION

A real data was collected from a case study area which is the second flight hangar at the Nigerian college of aviation Zaria was simulated on the developed software. The Figure.1 shows the image of the workspace of the software before simulation while Figure.2 show the image of the workspace showing the result obtained after simulation. From Figure 2, the payback period considering the sample data is calculated and shown in the graphical part of the figure.

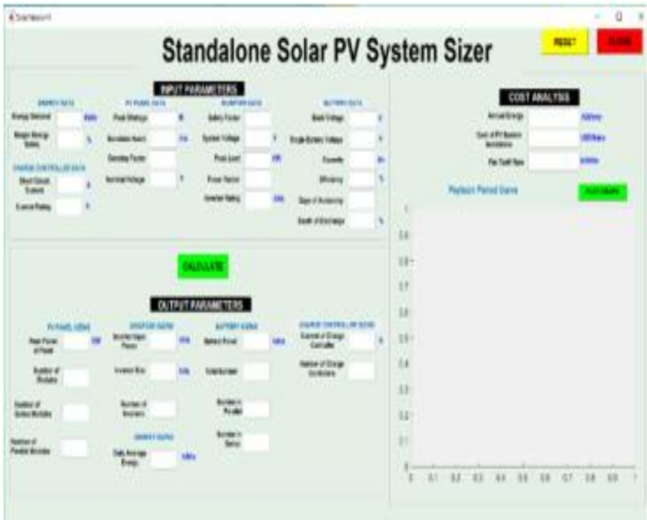

Fig. 1. Workspace of the developed software

The image above shows an empty workspace of the software; it is portioned into three segments; input, output and cost analysis. Results of calculations are displayed after input information are given through the GUI of the software and the calculate button is clicked. Fig. 2 shows the results of calculations done when some set of inputs needed to design and size a PV system.

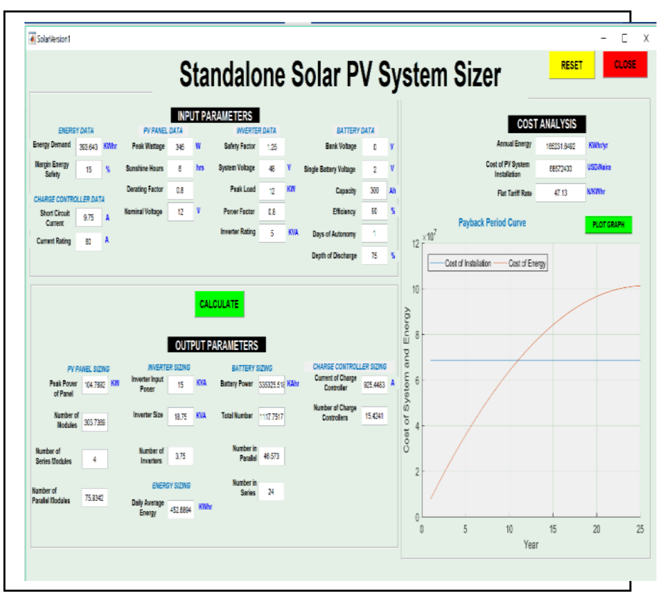

Fig. 2. Results of calculation

From the figure above, the results of the calculations can be shown and the graph of the economic payback period of the system which can be seen as 11years. Thus, the developed software can accurately and quickly design and size a standalone PV system.

V. CONCLUSION

In this paper, software capable of sizing and calculating the economic payback period of a PV system has successfully been developed using MATLAB. The design equations were utilized in developing the software GUI. In our future research work, we will be presenting an improved standalone PV system sizing software and economic payback period analyzer.

VI. CONFLICT OF INTEREST

All the parties involved in this research paper declares ‘’NO CONFLICT OF INTEREST’’.

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