A New Approach to Estimating the Size of Components in a Photovoltaic (PV) Hybrid Power System

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Abstract

One of the applications of PV generators today is PV-hybrid power system for remote residences. In these systems, one or more PV array(s) are combined with another source of power (diesel and/or wind) for making a more reliable electricity supply. Batteries are used in these systems for supplying electricity during the nights as well as cloudy days. One (or more) diesel generator(s) is (are) used to ensure that the batteries are not undercharged.

The objective of this paper is to present an accurate design process for a complete self-contained PV-hybrid power system. This paper focuses on a 2.5 kWp PV-hybrid power system to supply a remote located house with no access to national grid.

This paper offers a method for optimum sizing of the components in PV-hybrid systems. For the purpose of optimum sizing we need to possess following data from the site.

- Location, load and optimum configuration
- Design insolation, kWh/m², receivable sun energy
- Peak Sun Hour (PSH) in different sessions of the year
- Number of no-sun days possibly might happen

The design procedure has been simulated in computer for:

- generalizing the system design to any size
- predicting the system’s performance

A further objective of this paper is to present a numerical approach for evaluating the performance of PV-Hybrid power systems. A simple method is developed to predict the performance of all components integrated into a PV-hybrid system. The system under investigation is a hybrid power system, in which the integrated components are PV array, a battery bank for backing up the system and a diesel generator set for supporting the battery bank. State of charge (SOC) of batteries is used as a measure for the performance of the system. The running time of diesel generator is determined by this SOC. In this method it is shown that the usage of PV electricity is maximized, the size of the components is optimized and the amount of fuel used for the diesel generator is minimized.

1. INTRODUCTION

The usage of renewable sources of energy which produce less (and in some cases no) pollution are considered more seriously. Rapid advances in solar photovoltaic technologies as well as wind energy technology have brought good opportunities for the utilization of solar PV and wind power. Moreover, the economic aspects of these technologies are now sufficiently promising to also justify their use in small-scale stand-alone applications for users who are not connected to national electricity grid. It must be mentioned that PV and wind are the most economical option compared with line extension if the user is located more than two km away from the grid. Literature survey shows that several design scenarios have been proposed for the solar PV and/or wind power systems in which some other type of generating units are integrated for making a more reliable generating system.
2. SYSTEM CONFIGURATION

The block diagram for the system under investigation is shown in Figure 1. The system is designed to supply a reliable power for a remote located house. The system consists of PV array, storage batteries, and a backup generator. The size of PV array is so that is able to supply the load completely during three months of summer period. During the day when the generated power by PV generation exceeds the demand the PV array start charging the batteries. As the size of PV array is so that this excess power will not cause overcharging of the batteries there is no need for a dump load to be integrated in the system. Batteries will supply power during the nights and cloudy days. Every day the backup diesel generator operates to charge the batteries. In order to minimize the fuel cost and avoiding wasting the electricity, the diesel generator keep charging the batteries until a specified upper limit for the battery voltage is reached. At this point the backup generator will stop charging the batteries. In our calculations we have chosen the SOLAREX™ MSX-83 modules. Their output characteristics are:

![Figure 1. Configuration of the system](image1)

![Figure 2. Load pattern](image2)


3. LOAD

3.1 Estimating the Total Daily Energy Load for the Purpose of System Design

The first step of system design is to make an Energy Budget Chart of all loads. We need to list all the devices in the house that consume electricity. We have to make sure to include everything. We have assumed for our calculation that the house uses 12kWh of electricity every day.

4. SIZE OF PV ARRAY

We have adopted a relatively simple size procedure in which the PV array is the main supply. Our system design is based on the seasonal energy balance between the radiation and the load. In order to avoid wasting PV electricity the size of PV array is determined based on the summer radiation data (3 month out of the 12 months of the year). Obviously the PV energy is not able to supply enough power during nine months of the year other than summer months. Battery bank is there to support the PV array and the diesel generator to backup the battery bank.

The energy deficit is covered effectively by a diesel generator set. The radiation data for the site, together with the panel orientation are used to determine the incident solar radiation on the panel for a typical day in summer months of the year.
• The number of series connected modules is determined by the DC operating voltage. As the modules are used for battery charging we are more interested in the current at a good battery charging voltage under normal operating conditions.
• The number of parallel strings is directly related to the:
• The current requirement for the load \( I_L \)
• The nominal current \( I_P \) which is required from the PV array when working at its maximum power point and irradiated by the standard AM 1.5 radiation at 1 kW/m\(^2\)
• The nominal current supplied by an individual PV modules.

We can also introduce a sizing factor SF which can be introduced to oversize the amount of current available from the array.

5. SIZE OF BATTERY BANK

The daily and seasonal charge deficits have to be calculated. It must be ensured that the night periods and cloudy periods are covered satisfactorily. At the same time, excess energy generated and not used during the sunshine periods must be stored. This analysis determines the daily charge and discharge percentage of the battery that usually can not exceed a given value for the safe operation. The size of PV array is so that during summer periods the PV generator generates an amount of energy which is equal to the energy required by the load. The energy balance for the summer periods is set in such a way that the day energy excess is stored effectively to cover the energy deficit during the night and cloudy times.

In our calculations, we determine the size of battery bank based on the number of no-sun days. This depends on the location of the site and differs from place to place. For the sizing of battery bank for the system under investigation we are assuming 5 days of autonomy, no-sun-days. Therefore the AH of battery bank should be determined by following equation:

6. SIZE OF DIESEL GENERATOR

Diesel generator is used in the system for following tasks:
To bring the SOC of batteries to an acceptable level. This can be done by running the diesel generator for 1 – 5 hours every day depending on the size of diesel generator and the climate conditions; To charge the batteries when 5 no-sun-days happen. When this case occurs the diesel generator must be large enough to charge the batteries to avoid batteries undercharging.

7. DISCUSSION

This paper presented an approach for evaluating the performance of a PV hybrid system which supplies a reliable power for a remote located house. Figure 3 shows the generation pattern ie. Solar PV array and diesel generator set. Figure 4 shows the energy balance. Figure 5 the state of charge of batteries and Figure 6 shows the effect of variation of operating time of diesel generator on the state of charge of batteries. Hourly solar radiation and power demand, and a time step of one hour were used in the study. By selecting one hour as a time interval, we were assuming a constant solar radiation and constant power demand during each hour. This assumption does not have considerable effect on the general hourly response of the generating system since hourly average data were used. Since solar radiation and power demand can vary seasonally, more accurate results can be obtained if the study is performed using seasonal data. The study results presented in this paper are for one set of system components selected based on the actual solar radiation data available at one specific location (in southeast Melbourne) to supply the power demand of a house in an Australian remote located away from national grid. However, the approach can be applied to other locations and applications if and when data is available. Using actual solar radiation data at several locations, to bring forth the versatility of the proposed approach. This is the subject of a future study by the authors.
8. CONCLUSIONS

This paper presented an approach for predicting the performance of stand-alone PV power systems. It is a useful tool for predicting the performance of the such power systems before they are built.

This paper presented a performance prediction method based on the SOC of the batteries. This paper also has shown that the solar array is the main source of generating system and backup diesel generator is only used when SOC of batteries needs to be controlled.

The results obtained from this research work presented in this paper are to predict the performance of a stand-alone PV-hybrid power system to supply a reliable power for a remote located house. The method developed by our research team and presented in this paper can be used for any locations by any applications provided solar radiation data are available and daily electricity consumption are known.

REFERENCES