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Design Considerations of Stand-AloneSolar Photovoltaic System

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ABSTRACT—The stand-alone solar photovoltaic (PV) systems are a convenient way to provide the electricity for people far from the electric grid or for people who want the electric power without any dependence on utility grid, to run their usual activities either at homes or at businesses. The size of these systems vary according to the available solar radiations and different load conditions. Therefore, this paper takes an organized approach regarding the designing of these systems. For this purpose, the detailed guidelines and technical considerations needed in the design process of a solar PV system is presented for stand-alone application. The guidelines for the selection of appropriate site/location along with the method for the assessment of solar energy resource at the chosen site is provided in this paper. The technical considerations for assessing the load energy demand on daily basis and sizing of the different components of solar system including PV panels, charge controller, storage batteries, inverter and other appurtenances such as cables etc. required for the design configuration and installation of a solar PV system are given in this work. So, this photovoltaic (PV) technology as it is the best and reliable way of converting solar radiation into electric power [2]. Due to the modular nature in comparison to other renewable technologies, **and urban areas.**

Keywords—stand-alone, solar, considerations, PV, panel, module, array, charge controller, battery bank,inverter.

I. INTRODUCTION

The renewable energy has attracted a lot of attention all over the world in the recent times due to the growing energy demand, increased environmental sustainability concerns, and scarcity and increased prices of fossil fuels.

The solar energy is the most prominent among all the enewable sources, as it is an inexhaustible and cleanest resource of energy and its utilization is also ecologically friendly. The current worldwide energy the solar PV technology emerges as an ideal solution for offgrid power [3]. This technology has gained a great attention for his successful attempts to supply electrical power to autonomous off-grid rural areas and since many implementations has been successfully done worldwide. Moreover; owing to zero sound pollution and green house gas emission, it highly contributes towards the sustainability of the environment [4]. In addition, its production capability can be conveniently expanded as per need and low maintenance is required due to the absence of any moving parts [5]. Depending upon the consumer demands, a variety of configurations, ranges from few watts to hundreds and from hundreds to kilo-watts power systems and micro-grids can be designed using this technology for small housing and business communities either in urban or in remote localities [3]. But, the demands are fairly less than the available potential of solar energy [1]. The exploitation of solar energy for electricity production in the last few years has been increasing substantially as compared to other renewable resources, majorly because of the due to thegrowth in their demands and competitiveness of the markets[3, 6].

The stand-alone electricity generation systems using PV technology has come up as a major and favored way to harness the solar energy due to its multi-dimensional advantages such as energy independence, safety, security, lack of electric bills, easier and timely installation, long- term back-up in case of storage system and power whenever and wherever you needed

[7]. Therefore, the stand-alone solar PV system is an ultimate, convenient and self-sufficient alternative to provide electricity for people living far from the electric grid in remote locations where grid extension is practically unviable or for people living

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II. CONFIGURATION OF STAND-ALONESOLAR

metropolitan areas who want electric power without having a connection to utility grid [8]. So, the aim of this work is topresent the detailed guidelines and considerations for the designof such systems using an organized approach. Thus, this paper selection of site [11]. PV SYSTEM The general configuration of stand-alone solar PV power system is given in Fig. 1. A stand-alone system based upon solarpower comprises of a PV panels array to collect solar energy, acharge controller as a control unit, a battery as a storage deviceand an inverter for DC/AC conversion for AC loads [9]. Due tothe simple, easier, uncomplicated and troublefree nature of the
stand-alone PV systems, they are rapidly

- Selection of site/location either at roof or at groundwhich has minimum shade.
- Orientation and direction of the selected site/location.
- Total available land/surface area of the selectedlocation/site.
- In case of roof,the type and structure of the roof.

Sun-Light/Solar

Possible routes for cables, battery and inverter from the selected site/location.prevalent throughout the world[10]. The working of standalone solar system starts with the capturing ofsunlight by tilted B. Solar Energy Resource AssessmentPV panels that is converted into electricity. Theproduced The solar energy resource assessment on the selected electricity is thennight time or at output power. Therefore, when assessing the resource of solar any other time when the sun-shine is notavailable due to energy, the mean daily insolation in peak-sun hours per day or cloudy weather. The inverter converts the DCelectricity to AC kilo- watt hours per square meter per day (kWh/m2/day) is to runthe AC loads (i.e. household appliances, lampsetc.). neededfor all the months in a whole year [9]. This can be obtain from the records of nearby meteorological station or can III.PLANNING GUIDELINES FOR STAND-ALONE be
found using internet resources for solar radiation data.SOLAR PV SYSTEM Moreover, the following points should be considered standalone solar system, so that whenthe sun is least

Radiation
Stand-AloneSolarPVSystem

AC Load

PV Modules

Charge Controller Battery Bank Inverter Distribution Board
Fig. 1. Configuration of stand-alone solar PV energy system.

resource point of view is very important for the designing and installation of a stand-alone solar PV system. Therefore, it is available due to weather conditions, the solar systemcan work [8].

III. DESIGN CONSIDERATIONS OF STAND-ALONE SOLAR PV SYSTEM

The technical design considerations for a stand-alone or off-grid solar photovoltaic system differs from those adopted for a grid connected system. A stand-alone PV system is supposed to meet the daily demand of a household rather than meeting the respective demand per annum. The photovoltaic system must have capacity to charge the battery bank enough so that the appliances and/or lights keep operating. Therefore, it should incorporate an adequate amount of battery storage to provide the power at nights, other low sun-shine times and for a certain number of days and nights in a row when the sun is not available. So, without the utility back-up as a supplemental electricity source, the sizing of a solar system's component and its integration witheach other are technically a critical part of the designing stage which should be done very cautiously for reliable operation of the designed system [12]. A mismatch among operational features of the various parts of the system may result in the reduction of the output energy.

Therefore, the following technical considerations for the sizing of photovoltaic array, charge controller, battery bank inverter and cable for the connection of these components are very important for designing an optimal solar PV system for stand-alone application.

A. Calculation of the Energy Demand

This is the fundamental step in designing a stand-alone solar PV system for a home or office or any other building is to calculate the total energy demand on daily basis [13].

For this purpose, the load of each lamp or appliance is measured in watts and the time of use or operation of that appliance is considered in hours. Load and the running time vary from appliance to appliance. Therefore, be careful in measuring and considering the load of appliances or any other devices along with their time of use as the size of stand-alone PV system totally dependent on this step [14]. The energy consumption demand of individual load in Wh (watt-hours) is calculated bymultiplying the appliance's load power with its time of use as:

$E_i = P\ T_i \times _u$ (1)

Whereas:

- Ei represents the energy demand per day of individual loadin watt-hours.

Whereas:

- Et represents the total energy demand in per day of all theload in watt-hours.

B. Sizing of the PV Array

The different size of PV panels or modules produce different

Whereas:

- Pt-pv represents the complete size of PV array in watts. ▪

PGF represents the power generation factor. ▪ The value

1.3 represents the scaling factor.

The power generation factor in (3) is taken to account for the impact of climate conditions at different site locations [16]. However, the most common mathematical relationship use to calculate the total size of PV array by utilizing the mean daily insolation in peak-sun hours to run the required load is given asfollow [13, 17].

$P_t{}^{-}\ pv = E^t \times 1.2$ (4)

Tpeak hours−

Whereas:

- Tpeak-hours represents the lowest daily average peak-sunhours of a month in an year.
- The value 1.2 represents the scaling factor same as in(3).

Hence, the number of PV modules or panels required against the total size of PV array in (3) or (4) is computed usingthe peak-watts of the chosen panel size on market availability as [15]:

Pt− pv

Nmodules = (5)

Wpi

Whereas:

or a battery. Thus, the ampere size or current rating of solar charge controller is calculated mathematically as [14, 15]:

$I_{scc} = I_{sc} \times 1.3$ (6)

Whereas:

- Iscc represents the size of solar charge controller in amperes.
- Isc represents the short circuit current rating of selected PVunit.
- The value 1.3 represents the safety factor.

D. Sizing of the Battery Bank

To ensure the availability of energy at night and under cloudy amount of power according to their market availability. Generally, conditions, the photovoltaic modules must store energy in some they are rated in peak-watts which depends on their module size type of storage during the peak sunlight hours. The different types and the weather conditions of the selected location of site [15]. of rechargeable batteries are available in market but the most Therefore, to calculate the size and number of PV modules needed commonly used type is lead-acid because they are readily for specific loads, the rated peak-watts produced by the chosen available, cost-effective, longevity and more suitable for stand

panel is required.
Thus, the total size of solar panels or PV array against specific load demand is calculated as [15, 16]:

$P_{t-pv} = E^{t} \times 1.3$ (3)
PGF
alone solar electric power systems [8, 22].
The capacity of batteries are expressed in ampere-hour (Ah). The various factors are considered during the selection and sizing of batteries or battery bank. These factors include the appliances total load, inverter size and efficiency, days of autonomy, discharge depth and the battery nominal voltage [13]. However, among all factors, the factor of autonomy days is very important should be increased to 1.5-3 times more to make it oversize rather one. These days represents the number of cloudy days in a row than undersize [21]. The simplest relationship used to determine that might occur and for which the batteries will need to supply the size of batteries or battery bank for a certain load demand is energy to the load. Usually, 3 days is considered as a standard for as follow [14]:
number of autonomy days [23]. Thus, the battery size or capacity

- Nmodules represents the total number of modules. regulator that controls the current and voltage from PV panels to batteries and rejects the back current toward the solar modules [13, 21].

The size of a solar charge controller is rated in current and voltage. The value of current rating is calculated using the short circuit current rating of selected PV modules. While, the value of voltage rating is the same as the nominal voltage of batteries

Et
(Ah)bank = ×Daut ×1.25 (7)
Vdc sys−

Whereas:

- (Ah)bank represents the size or capacity of battery bank inampere-hour.
- Vdc-sys represents the solar system voltage in DC. ▪

Daut represents the days of autonomy.

- The value of 1.25 represents the factor to account forthe efficiency.

However, another way to calculate the capacity of batterybank is as follow:
on AC power. While, the solar modules generates DC power that is stored in batteries. Therefore, an inverter of optimum size is used in between the batteries and AC loads to convert the stored DC power in batteries to AC power to run the AC home appliances.

Usually, an inverter is chosen considering different parameters including cost, maintenance requirements, reliability, frequency and voltage regulation and efficiency [20]. The size of the inverter is optimized based upon PV array output which considers the total load. There must not be a mismatch among the battery bank and inverter voltage. The output capacity of the inverter, for a stand-alone system, must be high enough to support the peak load power demand. Therefore, its size should be 20-30 % higher than the total power of all the running load for ensuring safety [11, 21].
Moreover, in the case of an appliance has a motor or a compressor for its working, then the size of inverter shouldbe considered 3-5 times greater than the power demand of that appliance [13]. Thus, the size of inverter is mathematically calculated as [14]:

Vdc sys−
(Ah)bank = Et ×Tbackup ×0.05 (8)

Whereas:
(VA)inv = (VA)t load− ×CF. (10)

Whereas:

- Tbackup represents the total time required for backup inhours.
- The value of 0.05 represents derating factor.

Thus, the number of batteries required to construct the size of battery bank in (7) or (8), is calculated as follow using the size of single battery as per market availability.

- (VA)inv represents the rating of inverter in volt-ampere. ▪ CF represents the correction

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factor for safety whose value is 3 for motor loads and 1.25 for simple loads without motor.

- (VA)t-load represents the total electrical load in l the individualloads as:

(VA)t load− = (VA)i = pPfi (11)

- pf is the power factor of each individual load.

Whereas:

(Ah)battery

Nbatteries = (Ah)bank (9)

F. Sizing of the Cables

The size of cables is very important for stand-alone solar system as they are used to connect the different components of the PV system with each other and to the electrical load. In general, their size depends on the maximum current carrying capacity and should be sufficient in order to minimize the voltage drops and

- Nbatteries represents the total number of batteries required against the size of (Ah)bank.
- (Ah)battery represents the capacity of single battery inampere-hour.

E. Sizing of the of Inverter

The inverter is a device that is used to convert the DC power to an AC power. Normally, the household appliances operate resistive losses. Moreover, they need to be UV and water resistant, and suitable for outdoor applications [24]. The low voltage systems usually encounter the issue of high voltage drop owing to inappropriate cable selection. Therefore, they must be sized correctly to give minimum voltage drops, typically less than 2% [25]. The undersize cables will not only produce energy losses but can also be highly hazardous by producing excessive heat and even fire. While, the oversize cables is simply the wastage of money. The size of the cable includes the length and cross-sectional [3] K.R. Sharma, D. Palit and P.R. Krithika, “Economics and management of

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system. While, the cross-sectional area (A) of the cable is [4] A.S. Joshi, I. Dincer and B.V. Reddy, “Performance analysis of calculated mathematically as [11]:

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Whereas:

ρ max

Vd

A = ×2 (12)

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- ρ represents the resistivity of the conducting wire materialin ohm-meters.
- l represents the length of cable.
- Vd represents the maximum permissible voltage drop incable.
- Imax represents the maximum current carried by the cable.

For PV solar systems, the cable sizes are especially imperative for sections between: solar panels and batteries; batteries and inverter; inverter and load distribution board. The value of Imax in (12) will vary from section to section and depends upon the voltage and power rating of their section components.

IV. CONCLUSIONS

The stand-alone solar PV energy system is an excellent way topower, heat, cool, and light our homes and businesses far from the electric grid in remote areas or without the dependence on the utility grid in the urban areas. The solar PV electric power system is fueled by the sun, provides an emission free electricity which is reliable, secure, noise free, friendly to use and does not necessitate to refuel. It also helps to reduce the consumption of fossil fuels in power plants, pollution and greenhouse gas emissions causing climate damage. This paper presents the guidelines and technical considerations in a systematic means for the designing of decentralized stand alone solar PV system in order to supply the energy for small housing and business communities. Whether the requirement is a cabin in the woods, a rural or urban house, a business center, a cruising sailboat or a garden shed. Based on the daily utilization and load demand, the capacity sizing of PV array, solar charge controller, backup battery storage, DC/AC inverter and connecting cables is provided in this work. This paper will be useful for designing and installing the solar PV system for stand-alone task either for replacing the conventional source or for providing the sustainable source.

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