Stand-Alone Solar Photovoltaic System for Power Generation

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Abstract— Increasing demand for electrical energy as well as environmental concerns related to fossil fuel usage are the driving forces behind the development of new energy sources, which are renewable and ecologically safe. The energy sources, which include energy from wind, water and biomass, geothermal and solar energy are renewable and environmentally friendly. Among these clean energy sources, solar energy is one of the most promising and fastest growing renewable energy sources worldwide. Solar energy is freely available and it is very clean source of energy. Solar energy can be converted into electrical energy by using different method. Out of them conversion of solar energy into electrical energy by using solar PV panel is possible at many places such as open ground or roof-top of home, office, etc. The main objective of this paper is to study design of solar photovoltaic stand-alone power generating system. In this paper, system of solar power generation is explained. The system consists of solar panels, DC-DC converter, and charge controller, inverter and battery storage. Also, solar PV system can be designed according to the requirement of the load.

Key words: Solar Power Conditioning Unit, Solar Charge Controller, PWM, MPPT, Inverter

I. INTRODUCTION

The motivation for this paper is to design the solar PV power generation system to mitigate the problem of energy crisis and to control pollution. Now-a-days, in India government is also promoting to use renewable energy sources such as solar energy by offering subsidy or depreciation. Hence, there is a huge possibility of fastest growing of solar PV power generation system.

In this paper, design of solar photovoltaic stand-alone power generation system is important aspect. Solar energy is obtained from the sun, it is freely available in environment and its supply is unlimited. Solar power is the conversion of sunlight into electricity, either directly using solar photovoltaic (PV) modules, or indirectly using concentrated solar power.

Solar photovoltaic system may be stand-alone or grid connected system. A stand-alone power generation system is an off grid system. In stand-alone system power which is generated can be directly utilize or store. A grid connected solar photovoltaic power generating system is directly connected to the utility grid.

As stand-alone solar PV system is an off grid system hence can be install at home at individual level or can be install in remote villages where grid supply is not possible. Therefore, more emphasis is given on solar PV stand-alone system.

II. STAND-ALONE SOLAR PHOTOVOLTAIC POWER GENERATION SYSTEM

Stand-alone solar PV power generation system is the system which is not connected to the grid. This system supply power to the load directly. If more power is require by the load then this system can be connected to the other power sources but PV must be the main source. The support from other sources increases the reliability of the system. Stand-alone system divided into several categories, which are described below:

A. Unregulated stand-alone system with dc load

Unregulated stand-alone system with DC load has very simple configuration. Here PV panels are directly connected to the load, as shown in following figure (Fig. 1). This system can work only during sunshine hours. Hence there is need to install the panel in a manner that it is sufficient to run a load during sunshine hours.

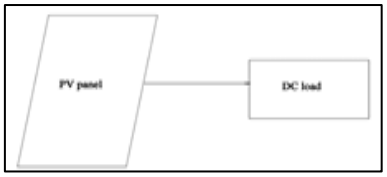

Fig. 1: Unregulated stand-alone system with DC load

B. Regulated stand-alone system with dc load

Regulated stand-alone system has same configuration as that of unregulated stand-alone system. Only difference between both is to regulate supply electronic control is use in regulated stand-alone system, as shown in following figure (Fig. 2).

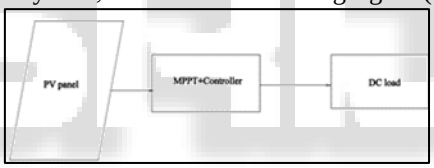

Fig. 2: Regulated stand-alone system with DC load

C. Regulated stand-alone system with battery and dc load

This is the modified version of regulated stand-alone system. In regulated stand-alone system we can use the generated power only during sunshine hour. Therefore, this system was not desirable for non-sunshine hour. To solve this problem, we use battery in the same configuration, as shown in figure (Fig. 3). With the help of battery we can store power generated by solar PV system. Hence, we can use power also in the night time.

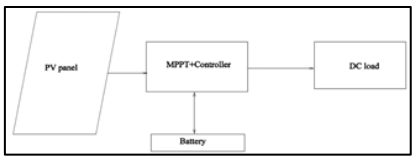

Fig. 3: Regulated stand-alone system with battery and DC load

D. Regulated stand-alone system with battery and ac/dc load

All the above systems were suitable for the DC load. But all those systems are useless if we think for AC load. Therefore, in this configuration we use inverter also, as shown in figure below (Fig. 4). Inverter is a device which converts DC to AC. Hence in this system we can connect DC as well AC system to the system.

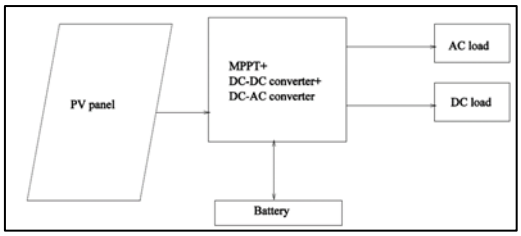

Fig. 4: Regulated stand-alone system with battery and AC/DC load

Advantages for stand-alone solar PV system are, this system has very simple configuration. We can connect auxiliary supply along with the system if solar PV system unable to generate desired power required by load. We can use power during non-sunshine hour by storing it into the batteries.

Disadvantages for the system are due to very less efficiency of the system many times we have to take a help of auxiliary supply to fulfill the demand. Initial cost is very high.

III. Design of Stand-Alone Solar Photovoltaic Power Generation System

The design of stand-alone solar PV power generation system is as shown in following block diagram. From this diagram (Fig. 5), we can see that electricity is generated from solar radiation by using solar panel. Solar panels are connected in series to obtain desired voltage level and connected in parallel to obtain desired current value. Solar panels can also be connected in series-parallel fashion to obtain desired current and voltage level. For series-parallel connection, after connecting panel in series, rows of series connected panel are then connected in parallel fashion by using array junction box. Power from solar panel is then send through DC Miniature Circuit Breaker, then through DC energy meter towards solar power conditioning unit then power is provided to load. Solar power conditioning unit consist of charge controller and inverter. Input from mains is also connected to load via Solar PCU.

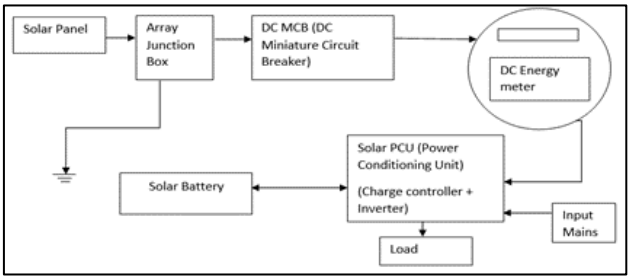

Fig. 5: Block diagram of stand-alone solar PV power generation system

IV. Major Components for Designing Solar Photovoltaic Standalone System

The main objective of this paper is to study design of solar photovoltaic stand-alone power generation system. In this paper, system of solar power generation is explained. Major components for this system are-

- Load
- Solar Panel
- Array Junction Box
- Solar Power Conditioning Unit
- Solar Charge Controller
- Inverter
- Solar Battery

A. Load

To determine the total load demand, individual ac and dc loads and usage hours of particular equipment's or appliances are considered. Here we are considering the load for one house. The total load present at home can be calculated using following equation,

Total load = (ac load × hours of operation per day) + (dc load × hours of operation per day)

B. Solar Panel

Solar panel is most important part for solar PV power generation system. It traps solar radiation and converts it into electrical energy. Parallel connecting solar panels gives higher current. And voltage will remain the same. By connecting Solar Panels in series connection. It will increase Voltage and current will remain the same. Solar panels can also be connected in series-parallel fashion to obtain desired current and voltage level.

C. Array Junction Box

Array Junction Box is meant for combining all the incoming lines from the solar panel strings/arrays and deriving one common array output for the multiple array inputs. Array Box is a junction box which allows several photovoltaic strings (from 8 to 32) to be connected in parallel. The total DC power is then distributed to the photovoltaic inverter. It includes photovoltaic string protection, overvoltage protection and a DC output switch disconnector. They are well adapted for Power plants as well as for photovoltaic large buildings.

D. Solar Power Conditioning Unit

Solar Power Conditioning Unit (PCU) is an integrated system consisting of a solar charge controller, inverter and a Grid charger. It provides the facility to charge the battery bank either through Solar or Grid/DG Set. The PCU continuously monitors the state of Battery Voltage, Solar Power output and the loads. Due to sustained usage of power, when the Battery Voltage falls below a preset level, the PCU will automatically transfer the load to the Grid/DG power and also charge the Batteries through the in-built Grid Charger. Once the Batteries are charged to the pre-set level, the PCU cuts off the Grid / DG power from the system and will restore to feeding the loads from the battery bank & continue to charge the battery bank from the available Solar power.

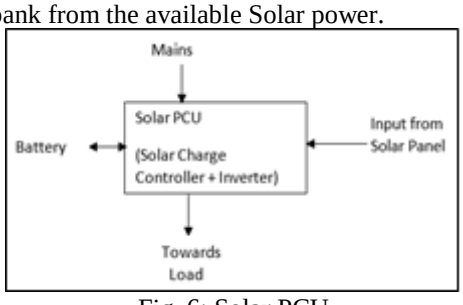

Fig. 6: Solar PCU

The PCU always gives preference to the Solar Power and will use Grid/DG power only when the Solar power/Battery charge is insufficient to meet the load requirement. It's a Power Conditioning Unit (PCU) with special feature like pure sine wave output and more for using in remote areas, where utility line is weak and renewable

Energy (RE) sources are available. The PCU is designed to convert energy from RE source as the first priority and to stream energy from grid line when energy from the RE source is lower than the set level.

E. Solar Charge Controller

Solar charge controller is very important part of the solar photovoltaic power generation system. It saves battery from damaging. The electricity produced by the solar panel is in the form of DC and is used to charge batteries via a solar charge controller. Any DC appliances that are connected to the battery will need to be fused. A charge controller, or charge regulator is basically a voltage and/or current regulator to keep batteries from overcharging. It regulates the voltage and current coming from the solar panels going to the battery. The two types of charge controllers most commonly used in today's solar power generating systems are pulse width modulation (PWM) and maximum power point tracking (MPPT). Both adjust charging rates depending on the battery's charge level to allow charging closer to the battery's maximum capacity as well as monitor battery temperature to prevent overheating.

1) Pulse Width Modulation

Pulse Width Modulation (PWM) is the most effective means to achieve constant voltage battery charging by switching the solar system controller's power devices. When in PWM regulation, the current from the solar array matches according to the battery's condition and recharging needs. It adjust charging rate depending on the battery's charge level to allow charging closer to the battery's maximum capacity as well as monitor battery temperature to prevent overheating.

2) Maximum Power Point Tracking

The efficiency of a solar cell is very low and also when solar cells are connected together to form a panel then its efficiency is still not increased. In order to increase the efficiency (η) of solar cell or solar panel we have to use maximum power transfer theorem. The maximum power transfer theorem says that the maximum power is transfer when the output resistance of source matches with the load resistance i.e. solar cell or solar panel impedance. So all MPPT technique's principles are based on maximum power transfer theorem that always trying to matching the impedance of load to source.

The maximum power point tracking (MPPT) is now habitual in grid connected PV power generation system and it is becoming more popular in isolated or stand-alone power generation systems as well because of the V-I characteristics in PV power generation systems is nonlinear, So it is difficult to supply a constant power to a certain load.

F. Inverter

Inverter plays crucial role in this system because most of the loads are of AC type. An inverter's basic function is to invert the direct current (DC) output into alternating current (AC).

G. Solar Battery

In stand-alone photovoltaic power systems, the electrical energy produced by the solar PV panels cannot always be used directly. Because, demand from the load does and solar panel capacity may not always equal. Also, electrical power usually needs to be available when the sun is not shining, it usually necessary to store electricity, hence battery banks are used.

V. CONCLUSION

From this paper, design of photovoltaic stand-alone power generation system is studied. Also, if any interruption occurred in the system of solar power generation or if main supply gets interrupted in that situation how solar power conditioning unit will operate smartly. Hence, power will supply to home continuously. Therefore, for today it is very good solution for reducing the problem of energy crisis in today's era.

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