RESEARCH ARTICLE OPEN ACCESS

Solar PV Energy Conversion System and its Configurations

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ABSTRACT
Solar PV based energy conversion system is now used in commercial and residential buildings. Advancements in Power electronics leads the researchers to enhance the use of solar application in various configurations. These configurations may be used to utilize the energy optimally. The main objective of this paper is to present an overview of the various configurations of solar PV energy conversion system.
Keywords – Power Electronics, Solar PV, Standalone, Grid Connected, Hybrid

I. INTRODUCTION

The demand of electrical energy is increasing exponentially worldwide [1]. This demand is met by the generation of electric power in which coal is used as a major component. The burning of coal in thermal power plant leads to emission of carbon gases, which possess serious climatic threats. The other concern is of energy crisis as coal reservoirs are very limited. A Critical environmental issue has emerged to minimize the causes which increases global warming and climate change threats [2-5]. The world has agreed that renewable energy sources (RES) like production of energy from solar Photovoltaic (PV) should be able to reduce the carbon di oxide emission considerably and be able to meet the growing energy demand [6-8]. Solar Energy is reliable source of energy and an efficient tool for the mitigation of global warming [9-10]. The safety concerns related to solar energy is almost negligible.

Solar Photovoltaic (PV) is used to convert solar energy into unregulated electrical energy [11]. Due to advancement in Power Electronics, it becomes possible to regulate the electrical energy from solar PV [12]. It is also identified that the combination of solar PV along with power electronics converters can be used in different applications [13]. Solar PV has been commercialized around the globe for its long term economic prospects [14-15].

These solar PV's have very low conversion efficiency. Also, the characteristic of PV is non linear i.e. it varies with solar irradiation and ambient temperature. Due to these constraints it becomes essential to harness maximum power from solar PV.

A method known as Maximum Power Point Tracking (MPPT) is developed by researchers to extract the maximum power from solar PV under normal and varying ambient conditions [16]. Various types of MPPT schemes are proposed, mainly are open circuit voltage, short circuit current, Incremental conductance, perturb & observe etc. The working of solar PV energy conversion system and characteristic are described by researchers [17 -25]. The various configurations are also described in various literatures [26- 38]. The main objective of this paper is to give an overview the various configurations of solar PV system.

II. MODELLING & CHARACTERISTICS OF SOLAR PV

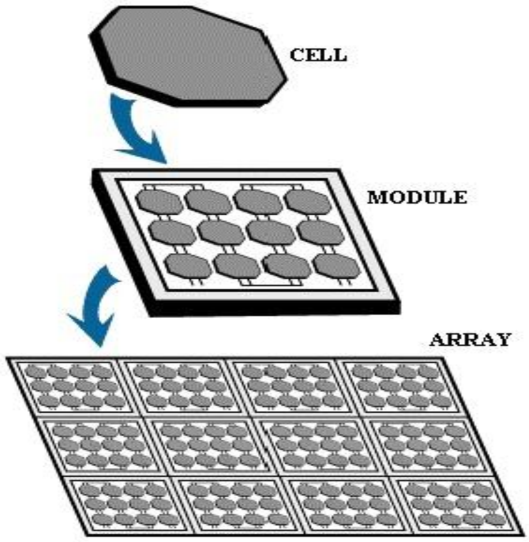

Fig. 1: Solar PV Configuration

The basic element of solar PV system is PV cells. These cells are connected to form modules. It is further expanded in the form of arrays as per the power requirements as shown in Fig. 1. These PV cells exhibit nonlinear characteristics. The output of the PV cell varies with solar irradiation and with ambient temperature. The equivalent circuit model of PV cell and module are shown in Fig 2. The characteristic equation of PV cell based on this model is given by equation 1, 2 and 3 [17-18].

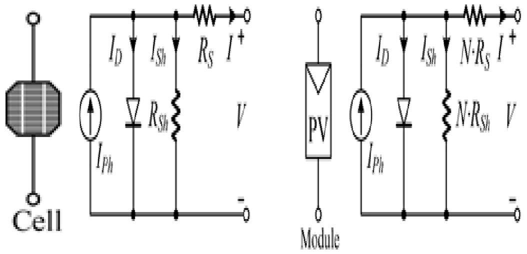

Fig. 2: Equivalent Circuit Model of Solar PV Cell,Solar PV Module

$I = I_{ph} – I_{os} \{\exp [(q/AKT) (V + I R_s)] – 1\}- ((V +I*R_s)/R_p)$ (1)

$I_{os} = I_{or} \exp [q E_{GO}/ Bk ((1/T_r) – (1/T))] [T/T_r]^3$ (2)

$I_{ph} = S[I_{sc} + K_I (T- 25)]/100$ (3)

The current equation of PV module where N identical cells are connected in series (Fig. 2), is given by equation 4.

$I = I_{ph} – I_{os} \{\exp [(q/AKT) (V + I*N*R_s)] – 1\}- ((V+I*N*R_s)/(N*R_p))$ (4)

Where I is the PV module output current, V is the PV cell output voltage, R_p is the parallel resistor, R_s is the series resistor. I_{os} is the PV module reversal saturation current, A, B are ideality factors, T is temperature (^oC), k is boltzmann's constant, I_{ph} is the light-generated current, q is electronic charge, K_I is short-circuit current temperature coefficient at I_{SC}. S is solar irradiation (W/m^2), I_{SC} is short-circuit current at 25^{o}C and 1000 W/m^2, E_{GO} is bandgap energy for silicon, T_r is reference temperature and I_{or} is saturation current at temperature T_r.

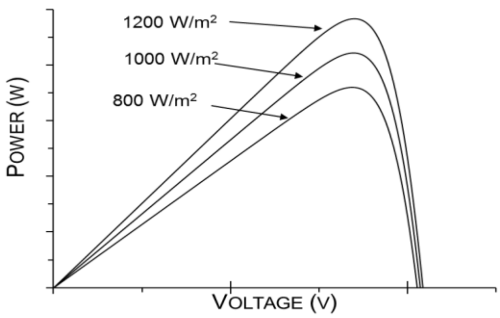

Fig. 3: PV Characteristic Curve of a Module: Power vs Voltage

Fig. 3 shows the variation of PV power with PV module voltage at different solar irradiation. The power increases with the increase in solar irradiation.

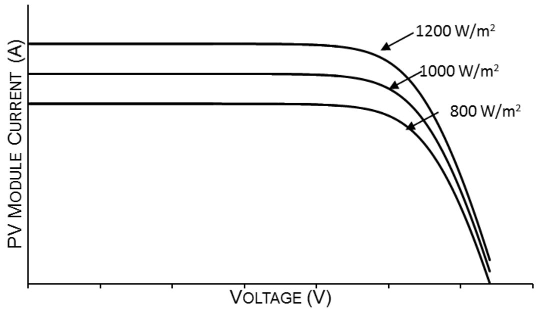

Fig.4 : PV Characteristic Curve of a Module: Current vs Voltage

Fig. 4 shows the variation of PV module current with PV module voltage.
In all these characteristic curves the power varies non-linearly.

III. CONFIGURATION OF SOLAR PV ENERGY CONVERSION SYSTEM

The solar PV energy conversion system is broadly used in three configurations:
(i)- Stand Alone PV System
(ii)- Grid Connected Solar PV System
(iii)- Hybrid Solar PV System

(i)- STAND ALONE PV SYSTEM

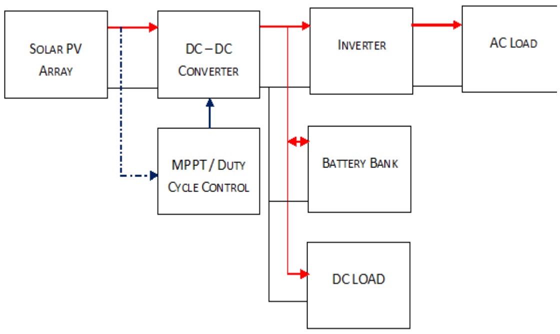

Fig.5: Standalone Solar PV Energy Conversion System

Fig. 5 shows the typical complete block diagram of standalone solar PV system [21-23]. The power harnessed from solar PV is regulated by using DC-DC converter and MPPT algorithm is implemented to in the control of DC-DC converter [24]. The battery is connected to increase the reliability for power supply to the load. The DC loads may be connected after DC-DC converter. A single phase or three phase inverter is connected to convert DC- AC following which AC loads are connected [25-27]. In actual installations inverter and AC load may or may not be present.

(ii)- GRID CONNECTED PV SYSTEM

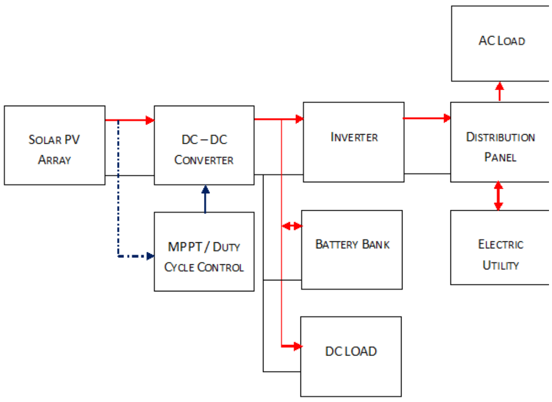

Fig.6: Grid Connected Solar PV Energy Conversion System

Fig. 6 is the block diagram of grid connected solar PV energy conversion system. The inverter is connected to the grid and allows bidirectional power flow depending on the requirement.

The above configuration are also known as two stage PV system [28-30]. The inverter could be a one way or two way type [31-32]. The flow of power is controlled optimally to meet the demand response [33-34].

(iii)- HYBRID SOLAR PV SYSTEM

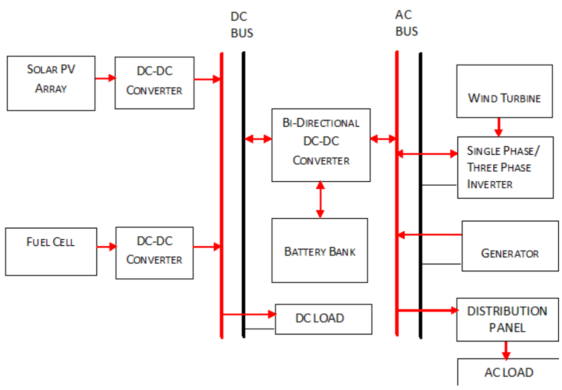

Fig.7: Hybrid Solar PV Energy Conversion System

Fig. 7 is the configuration of Solar PV used with other energy sources like fuel cell, wind turbine and conventional generators [35]. The power flow to DC load and to the AC load is optimized from the available energy [36]. It is the most preferable configuration as the reliability to meet load demand is very high.

IV. CONCLUSION

The main objective of the work of this paper is to give an overview of various types of solar PV configuration. The three main types i.e. standalone, grid connected and hybrid solar PV system is described.

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