Hybrid Power Generation Using PV and Fuel Cell

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Abstract

A stand-alone Hybrid power system is an autonomous system that supplies power to the user load without being connected to the electric grid. This kind of Hybrid system decentralized system is frequently located in rural areas. The purpose of this paper of a stand-alone hybrid power system, referred to as Hybrid Power generation by using PV and Fuel cell . It couples a photovoltaic cell , fuel cell, and solar inverter to give different system topologies. The PV cell, thus, converts light directly into electricity. The system is intended to be an environmentally friendly solution since it tries to maximize the use of a renewable energy source.

During the rainy period no solar radiation auxiliary power is required, fuel cell is used to keep the system's reliability at the same level as for the conventional system while decreasing the environmental impact of the whole system.

The fuel cell consumes gases which are produced by an electrolyser to meet the user load demand when the photovoltaic energy is deficient, so that it works as an auxiliary generator. Solar inverter appropriate for the conversion and dispatch the energy between the components of the system.

This paper deals with the generation of electricity by using renewable energy sources, PV and fuel cell combine together leads to generate electricity day and night with affordable cost and without disturbing the nature balance.

Key words: Fuel cells, PV Cell , Renewable energies.

Introduction

In India the gap between demand and supply of electrical power is widening every day. This has resulted in the last option of controlling the stability of power system by resorting to load shedding. Load shedding has adversely affected economic growth of our country due to its direct effect on the industries in particular and commercial and agricultural sector in general.

Rural areas are deprived of electric supply for several hours. Installation of new generating stations seems to be one of the solutions to bridge the gap between demand and supply. But it requires huge capital, time and space. The fossil fuel reserve is dwindling throughout the world; hence installation of new generating station will put tremendous pressure on these reserves. More over this type of generating stations are potential hazards to the environment including global warming. In view of these facts non-conventional means of energy sources are the promising technologies of present and future. In renewable energy the solar power happens to be at the top of this pyramid. In India solar energy is available in abundance almost throughout the year.

The bottleneck in the acceptance of solar power technology is its initial investment which is quit high at present. Reduction in the cost of this technique is the need of the hour which depends on the number of such products produced. An increase in the number of products can bring down the cost to an appreciable level. A lot of research is needed in this direction which will focus on the maximum utilization of the naturally available energy resource. So far as Indian Scenario is concerned, focused research is highly needed to Hybrid Power System Using PV Cell & Fuel Cell.

It couples a photovoltaic cell(PV), a proton exchange membrane fuel cell (PEMFC) and power conditioning units (PCU) to give different system topologies. The system is intended to be an environmentally friendly solution since it tries maximising the use of a renewable energy source. Electricity is produced by a PV cell to meet the requirements of a user load. Whenever there is enough solar radiation, the user load can be powered totally by the PV electricity. During periods of low solar radiation, auxiliary electricity is required. A proton exchange membrane (PEM) fuel cell is used to keep the system's reliability at the same level as for the conventional system while decreasing the environmental impact of the whole system. The PEM fuel cell consumes gases which are produced by an electrolyser to meet the user load demand when the PV energy is deficient, so that it works as an auxiliary generator.

PCU are important for a PVFC hybrid system because they are used with a PV module to track the Maximum power point tracker (MPPT).

Solar Irradiation

Due to scattering interaction, the direction of sun rays changes. This results in redistribution of scattered radiation randomly in all directions. The scattered radiation is called diffuse radiation The radiation which does not go through either absorption interaction or scattering interaction, but reaches the earth surface directly is known as direct radiation or beam radiation. Once the radiation reaches the Earth's surface some of it (diffuse and direct as well) get reflected by the ground and other objects on the ground. This reflected component is called as albedo radiation. Thus, the total radiation reaching a given point on the earth surface is sum of diffuse radiation, direct radiation and albedo radiation. This sum is know as global radiation.

Photovoltaics Cell

The photovoltaic PV effect is the electrical potential developed between two dissimilar materials when their common junction is illuminated with radiation of photons. The PV cell, thus, converts light directly into electricity. A French physicist, Becquerel, discovered the PV effect in 1839. It was limited to the laboratory until 1954. when

Bell Laboratories produced the first silicon cell.

Parameters Of Solar PV Cells

Short Circuit Current

Short Circuit Current is the maximum current produced by a solar cell when its terminals are shorted. When a photon is absorbed in a solar cell, it generates an electron-hole pair, which is separated by the junction and then transported to the external circuit.

Open Circuit Voltage

Open circuit voltage *Voc* is the maximum voltage that can be obtained from a solar cell when its terminals are left open. The *Voc* is corresponding to the amount of forward bias of a *P-N* junction due to light-generated current (at this voltage *IL* becomes equal and opposite to forward bias diffusion current of a *P-N* junction diode).

The recombination current is represented by *Io* in the expression for *Voc* , which is written as:

$$Voc = \frac{kT}{q} 1n\left(\frac{I_L}{I_o} + 1\right)$$

Maximum Power Point (Pmax)

This is defined as the maximum power (P_{max}) output of a PV module under standard test condition (STC), which corresponds to 1000 W/m2 and 250^{C} cell temperature in PV module. Under the STC the power output of a PV module is maximum; therefore it is also referred as peak power or Watt (peak) or W_p. This is given as product of V_m and I_m

$$P_m = I_m \times V_m$$

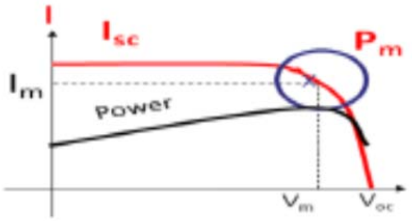


Fig. 1: Maximum power

Fill Factor (FF)

Fill Factor (FF) is defined as the squareness of the *I-V* curve and mainly related to the resistive losses in a solar module. It can be defined as the ratio of actual maximum power output to the ideal maximum power output. In ideal case, its value can be 100% corresponding to square *I-V* curve. But it is not feasible to have square *I-V*. There are always some losses which reduces the value of FF. The best value of FF that can be obtained for a solar cell can empirically be written as a function of Voc

$$FF = \frac{Voc - In\,(Voc + 0.72)}{Voc + 1}$$

Efficiency (η)

Efficiency is the most commonly used parameter to compare performance of one solar cell to another. Efficiency of a cell also depends on solar spectrum, intensity of sunlight and temperature of the solar cell. Efficiency is defined as the ratio of energy output from solar cell to input energy from the sun.

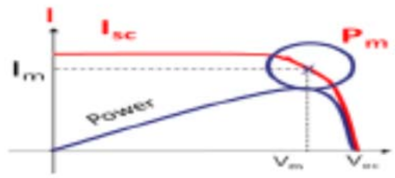


Fig. 2: Efficiency of PV cell

$$\eta = \frac{Max.\,Cell\ Power}{Incident\ light\ Intensity} = \frac{V_m I_m}{P_{in}}$$

$$\eta = \frac{V_{oc} I_{sc} FF}{P_{in}}$$

Sun Intensity

The magnitude of photocurrent is maximum under a full bright sun (1.0 sun). On a partially sunny day, the photocurrent diminishes in direct proportion to the sun intensity. At a lower sun intensity, the I-V characteristic shifts downward as shown in Figure 3. On a cloudy day, therefore, the short-circuit current decreases significantly. The reduction in the open-circuit voltage, however, is small.

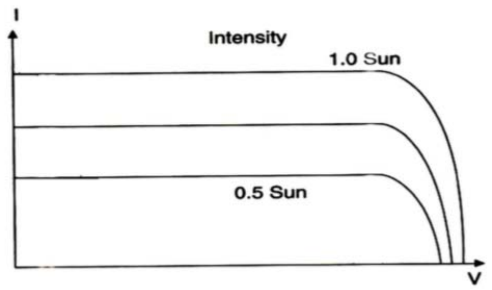


Fig. 3: I-V Characteristic of PV module shifts down at lower sun intensity.

Losses In Solar Cells

A loss in a solar cells refers to loss of photon energy (partial or full) which, due to some reason, is not able do deliver an electron out of a solar cell. This loss could be due to the fundamental reason (limited by material properties) or it could be due to the technological reason (limited by cell processing capabilities). There are several ways in which photon energy loss could occur.

Fuel Cell

The conversion of hydrogen into electricity can be achieved by different methods such as fuel cell and combustion reactions. The advantage of the fuel cell reaction is its higher overall conversion efficiencies. Therefore, the fuel cell will be the topic of interest in this dissertation.focus was set on transportation applications of fuel cells. Their aims are lower amounts of resources for longer distances with fewer emissions.

Proton Exchange Membrane (PEM): PEM fuel cells use thin, solid, organic polymer as the electrolyte and operate at relatively low temperatures (175°) . They have an efficiency of 25-30 per cent. PEMs have high power density, can vary their output quickly to meet shifts in power demand, and are suited for applications such as in automobiles, where quick startup is required. This type of fuel cell is sensitive to fuel impurities. Cell outputs generally range from 50 watts to 75 kW.

Hydrogen is oxidized on the anode and oxygen is reduced on the cathode. Protons are transported from the anode to the cathode through a PEM and electrons are carried to the cathode over an external circuit. On the cathode, oxygen reacts with protons and electrons forming water and producing heat. Both the anode and the cathode contain a catalyst to speed up the electrochemical processes. Basic description of a PEM fuel cell operation is shown in Fig. 4.

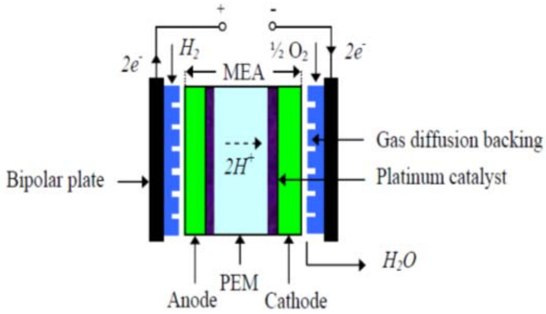


Fig. 4: Basic description of a PEM fuel cell operation .

The theoretical cell voltage for a PEM fuel cell is about 1.23V at standard conditions. The cell voltage decreases because of over-voltages, which can be divided into the activation, ohmic and concentration (diffusion) over-voltages. The activation over-voltage is due to the slow charge transfer of the oxygen reduction and it is the major source of losses. The ohmic overvoltage is due to the resistance of the membrane, other materials, and their junctions. The concentration over-voltage arises when the mass transportation is limiting the reaction. A single fuel cell produces a limited voltage, usually less than 1V. In order to produce a useful voltage for practical applications, several cells are connected in series to form a fuel cell stack.

The output voltage depends on the number of the cells in the stack. A view of a PEM fuel cell structure and a PEMFC stack are presented in Fig. 5. The main part of a single cell is the Membrane Electrode Assembly (MEA) which consists of an anode, electrolyte membrane (PEM), and cathode. These components are pressed between two gas diffusion backings and two bipolar current collector plates. The **Anode** (fuel electrode) must provide a common interface for the fuel and electrolyte, catalyse the fuel oxidation reaction, and conduct electrons from the reaction site to the external circuit. The **Cathode** (oxygen electrode) must provide a common interface for the oxygen and the electrolyte, catalyse the oxygen reduction reaction, and conduct electrons from the external circuit to the oxygen electrode reaction site. The **Electrolyte Membrane** (PEM) must transport one of the ionic species involved in the fuel and oxygen electrode reactions, while preventing the conduction of electrons (electron conduction in the electrolyte causes a short circuit).

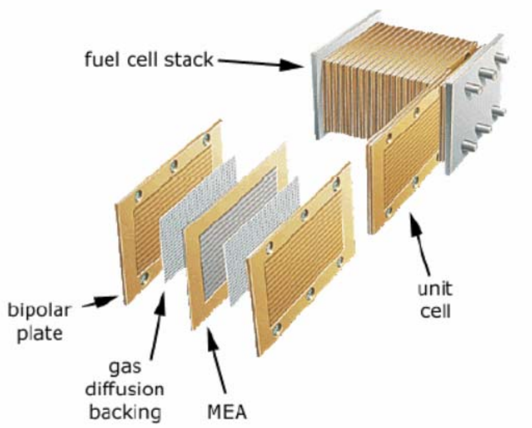
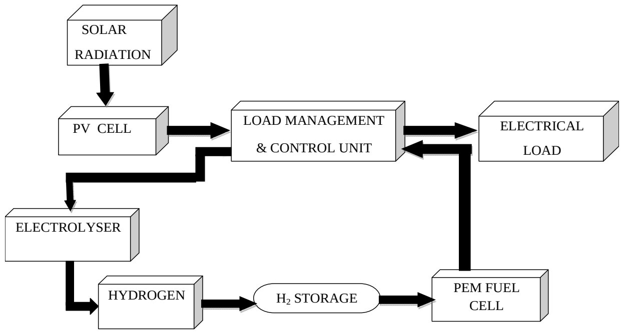


Fig. 5: PEM unit cell structure and a PEMFC stack .

In a PEM fuel cell, the gas diffusion backings provide electrical contact between the electrodes and the bipolar plates, and distribute reactants to the electrodes. Also, they allow the reaction product water to exit the electrode's surface and permit passage of water between the electrodes and the flow channels. These layers are made of a porous, electrically conductive material, usually carbon paper. In a fuel cell stack, bipolar plates or separator plates separate the reactant gases of adjacent cells, connect the cells electrically, and act as a support structure. Bipolar plate materials must have high conductivity and be impermeable to gases.

PVFC hybrid power systems

In PVFC hybrid power systems, the input power of the system varies continuously with time. The output characteristics of a PV generator have peak power points that depend on solar radiation and cell temperature. Therefore, it may be advantageous to use an MPPT to optimally utilize the input power source. PVFC hybrid power system couples a photovoltaic cell(PV), a proton exchange membrane fuel cell (PEMFC) and power conditioning units (PCU) to give different system topologies. The system is intended to be an environmentally friendly solution since it tries maximizing the use of a renewable energy source.



Block Diagram of PVFC

Electricity is produced by a PV cell to meet the requirements of a user load. Whenever there is enough solar radiation, the user load can be powered totally by the PV electricity. During periods of low solar radiation, auxiliary electricity is required. A proton exchange membrane (PEM) fuel cell is used to keep the system's reliability at the same level as for the conventional system while decreasing the environmental impact of the whole system. The PEM fuel cell consumes gases which are produced by an electrolyser to meet the user load demand when the PV energy is deficient, so that it works as an auxiliary generator. Power conditioning units are appropriate for the conversion and dispatch the energy between the components of the system.

PVFC hybrid power systems can use the power conditioning units. Photovoltaic or fuel cell power systems, which generate power as a direct current (DC), require power conversion units to convert the power from DC to alternating current (AC). This power could be connected to the transmission and distribution network of a utility grid. There are other applications, where it is necessary to be able to control power flow in both directions between the AC and DC sides. For all these cases power conditioning units are used. PCU is a bidirectional power converter which converts AC power to DC power and hence acts as rectifier and DC power to AC power and hence acts inverters. PCU is heart of PVFC hybrid system as alongwith a PV module it tracks the MPPT and provides highest possible output. The combination of PCU with electrochemical units fuel cell avoids the damaging of fuel cell and boost up the voltage of these units , especially the large scale system.

PCU alongwith other components of the system performs the function of inverter, regulator and also wave shapes.

Conclusions

Hybrid power generation system is good and efficient solution for power generation than conventional energy resources. Hybrid power generation system is highly safe in environment as it does not emit harmful gases. It has long life span and hence it is a reliable and affordable solution for electricity generation.

During rainy period no solar radiation auxiliary power is required fuel cell is used to keep the system reliability at the same level as far the conventional system while decreasing the environmental impact of whole system.

In this system the generation of electricity by using renewable energy sources , pv and fuel cell combined together leads to generate electricity day and night with affordable cost and without disturbing the nature balance.

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