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Modeling and simulation of a hybrid energy source based on solar energy and battery

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ABSTRACT

With the increasingly prominent energy crisis and environmental pollution caused by automobiles, the solar energy, as a new and clean energy, has attracted much attention. In this paper, a novel topology of hybrid generator with a PV energy conversion system with a battery in a DC-coupled structure is adopted to solve the problem and replace Fuel Cells, which have important diesel fuel consumption and high energy costs.

In the proposed system, the PV Source represents the main source, the DC link and battery the transient power source. This latter can absorb or supply power peaks.

Finally, the proposed system is verified by the results of simulation.

Introduction

More likely than not, getting a vehicle from point “A” to point “B” involves combustion of a fossil fuel, a process that emits gasses and affects the environment. According to the U.S. Environmental Protection Agency, more than half of the air pollution in the world is caused by mobile sources, primarily automobiles. Further contributing to the pollution potential of cars is the fact that they are filled with numerous fluids, which can harm the environment in the cases of leakage or improper disposal.

One solution to the current emissions problems that we face is the Hybrid vehicles, as they offer lower emissions than gasoline automobiles.

Fuel cell (FC) technologies are expected to become a suitable substitution for conventional power generators and grid utility for residential applications, as they are more efficient and environmentally friendly in comparison with other conventional power generators. However, in order to provide power demand of a residential load, it may be required to over design fuel cell power module which is not economically advisable. Furthermore, due to the sluggish dynamic response of fuel cell in transient events, there will be load following problem [1]. Not to mention diesel fuel consumption and energy costs that makes FC less effective (Fig. 1).

In such cases, a renewable energy, such as PV Panel, has been incorporated in order to overcome these problems [2].

In an electric vehicle using a single energy source, the necessary power is transferred from the permanent source, the PV Panel for example, to the load.

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The permanent source must frequently supply or absorb the picks of power resulting from the accelerations and the braking. This double uses of the permanent source, as energy source and as power source, is strongly penalizing: the losses and the weight are increased and the lifetime of the energy source is reduced [3].

One solution to this problem is the hybridizing of the source with a battery which manages the power picks. Hence the permanent source can only supply the average power which insures the vehicle's energetic autonomy.

The battery system provides power to the vehicle during periods of peak power demand such as vehicle acceleration or traveling at a high constant speed.

Hybrid sources allow dissociating mean power sizing from peak transient power sizing, the aim being to reduce in volume and weight [4,5].

In this paper a hybrid power source using PV Panel and battery supplying a load is proposed to make the system highly efficient and reliable.

In a first step, a dynamic modeling of the overall system is given. Secondly, a description of the components of the proposed system is provided. Finally, simulation results in presence of DC Bus voltage changes and load resistor disturbances, using Matlab-Simulink, are presented.

Dynamic modeling

The converter topology for the renewable hybrid system is depicted in Fig. 2.

Modeling of PV panel

A photovoltaic PV generator consists of an assembly of solar cells, connections, protective parts, supports etc. Solar cells are made of semiconductor materials (usually silicon), which are specially treated to form an electric field, positive on one side (backside) and negative on the other (towards the sun). When solar energy (photons) hits the solar cell, electrons are knocked loose from the atoms in the semiconductor material, creating electron–hole pairs. If electrical conductors are then attached to the positive and negative sides, forming an electrical circuit, the electrons are captured in the form of electric current (photocurrent) [6].

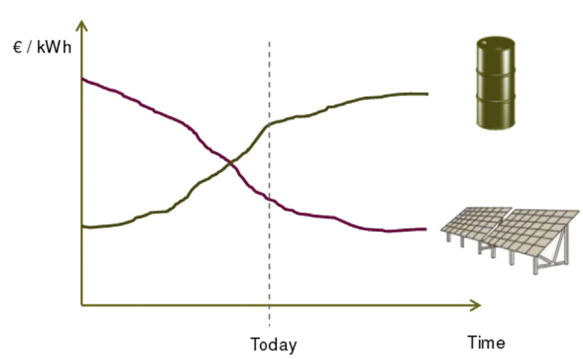

Fig. 1 – The price for PV systems has decreased by more than 60% in the last 3 years. Fuel costs for diesel generators are constantly rising. Source: Juwi Group ASIA Pacific: Quantifying Commercial Benefits of Fuel Saver Systems.

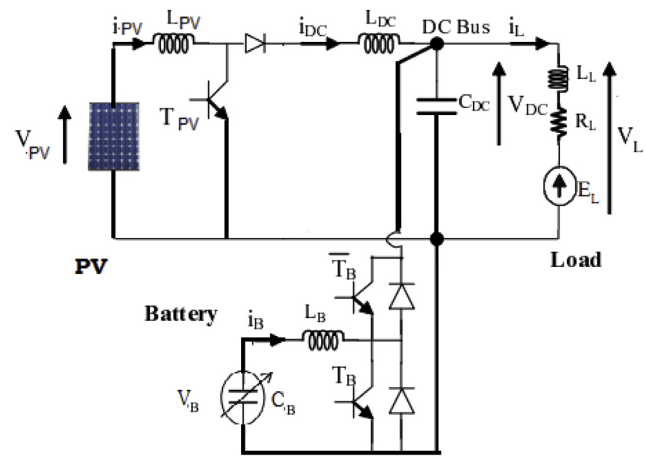

Fig. 2 – PV/Battery hybrid system configuration.

The simplified equivalent circuit of a solar cell consists of a diode and a current source connected in parallel (Fig. 3). The current source produces the photocurrent, which is directly proportional to solar irradiance. The two key parameters often used to characterize a PV cell are its short-circuit current and its open-circuit voltage which are provided by the manufacturer's data sheet [16].

In Fig. 3, R_S, R_P and C components can be neglected for the ideal model [6].

The p-n junction has a certain depletion layer capacitance, which is typically neglected for modeling solar cells.

At increased inverse voltage the depletion layer becomes wider so that the capacitance is reduced similar to stretching the electrodes of a plate capacitor.

Thus solar cells represent variable capacitance whose magnitude depends on the present voltage. This effect is considered by the capacitor C located in parallel to the diode.

Series resistance RS consists of the contact resistance of the cables as well as of the resistance of the semiconductor material itself.

Parallel or shunt resistance RP includes the “leakage currents” at the photovoltaic cell edges at which the ideal shunt reaction of the p-n junction may be reduced. This is usually within the kΩ region and consequently has almost no effect on the current–voltage characteristic [7].

The diode is the one which determines the current–voltage characteristic of the cell. The output of the current source is

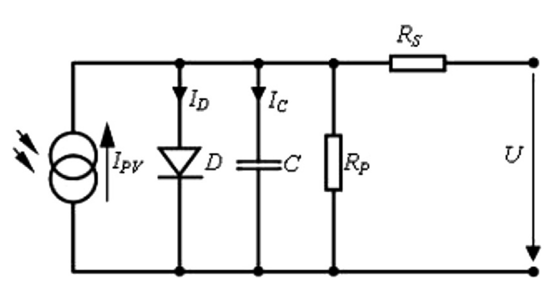

Fig. 3 – Equivalent circuit diagram of a solar cell.