Power Management System applied to Solar/Fuel Cell Hybrid Energy Systems

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INTRODUCTION

Green Engineering is one of the emerging research topics around the globe. We are currently observing a very fast development of new electrical power sources denominated by the renewable energy sources. These sources are often environment friendly and use primary energy carriers including solar, wind. In addition, by increasing the use of renewable energy resources, it is possible to support sustainable development of global economy. The particular renewable energies that have shown progress and great potential for market penetration includes photovoltaic, wind turbines and fuel cell. A Hybrid Photovoltaic/Fuel Cell Energy System (HPFES) is a system that takes energy from sunlight and converted to hydrogen as an energy feeder for a specific electric network (AC or DC). Energy storage is needed due to the intermittent nature of solar energy and one of the most critical issues is to maintain the continuous feeding to electrical load. To meet all those requirements is necessary to implement a Power Management Model (PMM) [1].

In this abstract we present a Power Management Model designing process, applied to a Solar/Fuel Cell Hybrid System with DC load. PMM implementation allows the coordination between different energy sources such as solar cells, electrolyzes and fuel cells.

POWER MANAGEMENT MODEL

There are several design phases through Power Management Model (PMM) design process. A continuous DC load operation needs to be placed as the number one priority because special requirements for critical load. PMM also needs to take into account various components of the hybrid energy system. A shown in figure (1), A Power Management Model is a combination of mathematical models, block diagrams and technical requirements or constraints that are defined in order to create a logic operation of the Hybrid Energy system.

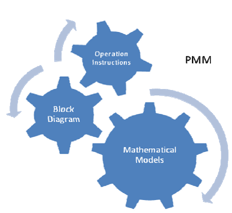

Figure 1. PMM components.

Solar/Fuel Cell Hybrid Energy System (fig. 2) is compound by Photovoltaic cells that work as a primary source, converting the energy from the sun into electricity that is given to a DC bus. The second component is denominated as the electrolyzer, a device that produces hydrogen and oxygen from water as a result of an electrochemical process. When there is an excess of solar generation available, the electrolzyer is turned on to begin producing Hydrogen which is sent to a storage tank. The produced Hydrogen is used by the third component of the system, the fuel cell stack, that produces electrical energy to feed a DC bus, by using Hydrogen mentioned above.

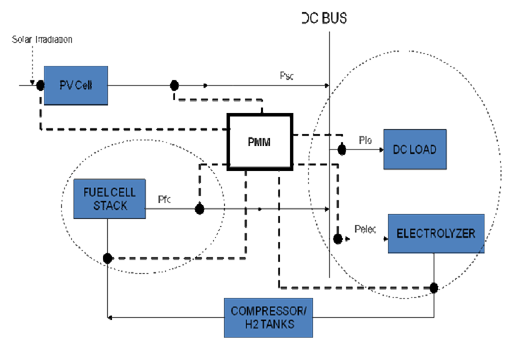

Figure 2. Hybrid Energy System.

The power balance equation for this hybrid system is:

$$P_{net} = P_{sc} - P_{lo}$$

Main part of mathematical models is a result of the governing control strategy (fig 3.) defintion. Control strategy is that, at any given time, any excess PV generated power (Pnet>0) is supplied to the electrolyzer to generate hydrogen that is delivered to the hydrogen storage tanks through a compressor. Therefore the power balance equation can be written as:

$$P_{sc} = P_{lo} + P_{elec}$$
$$P_{net} > 0$$

When there is a deficit in power generation (Pnet<0) the fuel cell stack begins to produce energy from the load using hydrogen from the tanks. Therefore power balance equation for this scenario can be written as:

$$P_{sc} + P_{fc} = P_{lo}$$
$$P_{net} < 0$$

Block diagram is shown in figure 3.

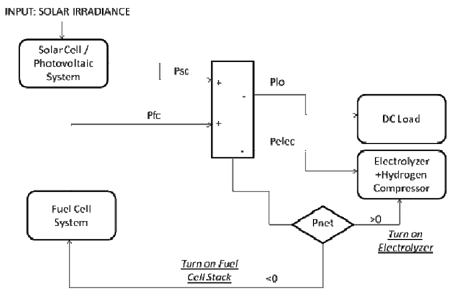

Figure 3. PMM Block Diagram.

For PMM designing process is neccesary to stablish initial conditions such as the load system varies in time (hourly), the study is going to be developed for one day at week and photovoltaic array, fuel cell and electrolyzer subsystems must be size[3]. By following DC load profile, the photovoltaic array, fuel cell and electrolyzer were dimmensioned: 314kW (PV array), 150kW (electrolyzer) and 56kW (fuel cell stack).

Finally, it is neccesary to describe set of operation conditions for this hybrid system. To achieve this a general simulation of HPFES operation under PMM control will be running by using Labview sofwtware tools. Solar irradiation data and a specific value for DC load will be used as the main input variables.

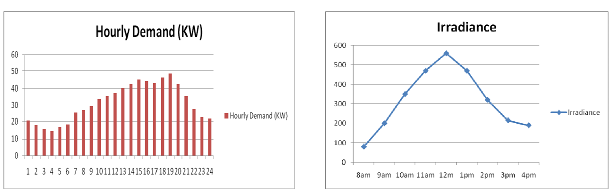

Figure 4. Input data.

Simulations operate under schedule constraints, that means that we can obtain an approach for solar cells, electrolyzer and fuel cells operation schedule by using hourly solar Irradiation and mathematical model for solar cells, fuel cell and electrolyzer subsystems. Some of the results show that PMM implementation will contribute to the optimun hybrid system performance, by using PV array from 8 am to 4 pm, to feed the DC load and the electrolyzer. During the other hours the fuel cell is activated to provide the power to the load.

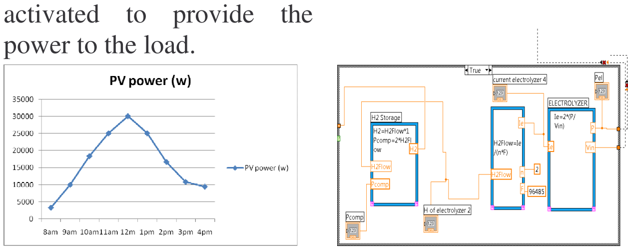

Figure 5. Some results.

COST ANALYSIS

The PMM design process requires that electrical demand be meet while minimizing an objective function which will be the hourly operation cost of the hybrid system. This function will be identified as C_T. C_T is the sum of the hourly cost of the capital and the maintenance hourly cost.

$$C_T = C_C + C_M$$

$$C_C = C_{csc} + C_{celec} + C_{cfc}$$
$$C_M = C_{msc} + C_{melec} + C_{mfc}$$

$$(C_{csc} + C_{msc}) = \alpha$$
$$(C_{celec} + C_{melec}) = \beta$$
$$(C_{cfc} + C_{mfc}) = \lambda$$

$$J = \alpha P_{sc} + \beta P_{elec} + \lambda P_{fc}$$

Linear programming application can be found in labview functions. α, λ and β are the subsystem cost-related parameters, that can be expressed in US$/Watts or how much is the cost to produce 1 Watt by PV array, Electroyzer and Fuel Cell stack. Information about α, λ and β is found in technical and statitical documentation. Thus, cost modeling can be developed in research works conducted in the future.

Conclusions

Hybrid Energy Systems must be operated under a Power Management Model in order to achieve an efficient system performance. PMM designing process involves several design steps including load requirements, mathematical models, block diagrams and cost analysis. One of the most important results is the proposed PV array, fuel cell stack and electrolyzer operation schedule. In general, fuel cells provide needed energy to the load during low solar radiation time frame by using hydrogen produced during high solar radiation times. Labview programming was utilized to simulate hybrid system operation under PMM control.

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