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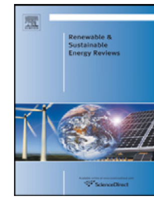

Power management strategy in the alternative energy photovoltaic/PEM Fuel Cell hybrid system

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ABSTRACT

This paper deals with the control and management of a hybrid power system composed of two clean generators connected to the load via a DC-Bus. The system configuration can solve certain problems inherent to reliability and power supply quality emanating from generators renewable energy resources based connected to the load. Since the primary natural energy resource cannot be easy to handle due to fluctuations appearing at the output. This can be solved by using an adequate control strategy including intermediate energy storage. The paper describes some research works achieved till now in hybrid energy system area, including the assessment of the modeling and control methods used and a survey of control problems which must be carried out. The main contribution in this paper focuses with modeling the hybrid PV/PEMFC energy system, using Matlab/Simulink, optimizing a hybrid system devices using artificial intelligence and carrying out simulation studies using a real climate data and practical load profile. A comprehensive results of simulation showed that the model is effective, operational and that backup system composed of PEM Fuel Cells and electrolyser can be integrated with photovoltaic power systems to provide uninterrupted high-quality power.

Contents

1. Introduction

Energy is vital for the preservation of the life in the world; it expresses the economic stability of populations. It is fundamental to improve quality of life by the exploitation of natural resources. The unconcerned exploitation of these resources affects the environment on which these systems develop. The energy problem is thus synonymous to environmental and economic problems. The efforts must, consequently, have the obligation to find an optimal solution for the sustainable energy supply. The world's demand of energy increased in an exponential way, and on the other hand, the conventional energy resources are exhaustible and limited in the offer. Consequently, there is an urgent need to preserve what

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we have in hand and to explore the broader use of the alternative energy resources. Currently, more than half of the world's population of the developing countries live in the rural areas. The largest share of these populations makes use of fuels such as wood and agricultural wastes [1]. In addition, the lack of water could become one of the major concerns of humanity during this century. In certain parts of the world, climate warming will result in shortages of water and the dryness and deserts become increasingly large. Following a severe water shortage in two decades and meet to the increase in request [2,3]. Algeria has begun looking for a dynamic solution by promoting non-conventional water resources, such as desalination of brackish water.

Several works were carried out for the hybrid energy system production within the framework of sustainable development. Ghosh et al. propose a probabilistic model of simulation of autonomous systems Wind-Diesel (without batteries) based on the use of statistical data of loads and the swiftness of the wind [4]. Other authors describe the progress made in the hybrid systems Photovoltaic-Wind-Diesel in terms of electronic control systems (voltage regulators and frequency of the diesel generators and the wind mills), various experiments of hybrid systems in various places of the world, as well as the tools for simulation of these systems [5].

Several authors studied the behavior of the systems Photovoltaic-Wind-Diesel in [6]. In [7] the effect of the management of the energy demand in the systems PV-Wind-Diesel is studied in details. In this paper real and practical data are used for modeling and managing the PV–PEM Fuel Cell hybrid system, as well as the simulation of a management strategy of the flow energy with Matlab/Simulink is proposed. An overall power management strategy is designed for the system to coordinate the power flows among the different energy sources.

2. Hybrid systems

In the PV–PEM Fuel Cell hybrid system, the renewable PV power is taken as the primary source, one of the generators is a photovoltaic module and the other is a PEM Fuel Cell (Proton Exchange Membrane Fuel Cell) fed out of hydrogen where energy can be stored in the hydrogen form playing the role of backup and storage system. It should be noted that the two generators can function in parallel, thus, contributing to the global energetic efficiency. The sizing of PEM Fuel Cells system can be made up on the basis of a very simple calculation of the number of PEM Fuel Cells type necessarily laid out in series and/or parallel to answer the nominal output of the load. The boost converter is used here to adapt the whole PEM Fuel Cells output voltage to the DC-Bus voltage. In this study, the output voltage of DC-Bus is maintained to 220 V. According to the characteristics of the PEM Fuel Cell, it is found in the area of concentration with a current load of 15 A to avoid this zone and to leave a safety margin of operation. Operation point is selected around 10 A that gives a tension V_{pemfc} of 24 V. Thus, to approach a tension of 220 V at converter DC/DC input, the required number of PEM Fuel Cells is:

$$N_s = \frac{\text{PEM Fuel Cell system voltage}}{\text{PEM Fuel Cell stack voltage}} = \frac{220\,\text{V}}{24} = 9 \quad (1)$$

The number of PEM Fuel Cells stacks in series to compile 20 kW PEM Fuel Cells is:

$$N_p = \frac{\text{PEM Fuel Cell system power}}{\text{PEM Fuel Cell stack power}} = \frac{20\,\text{kW}}{9 \times 500\,\text{W}} = 5 \quad (2)$$

Thus, PEM Fuel Cell in the hybrid system is arranged as 9×5 stacks ((1) and (2)).

Electrical energy generated from various preliminary resources is controlled by auxiliaries controller artificial neural network What confers on the system is a hybrid behavior; since the configuration changes with each time, when one or the other of the resources is used for supplying the load; for example, the structural configuration is different if the electrolyser is working or not. The whole PV–PEM Fuel Cell system is composed of elementary devices which are automatically reconfigured when the conditions change. In addition to an auxiliary controller for each conversion system, there must be a high level controller which deals with the total strategy operation of all the system, according to the external variables such as the environmental and climatic conditions (solar radiation, temperature, etc.). This makes it possible for the modules to start up and to stop when necessary, thus changing the dynamics of the system.

The system dynamics are determined by the dynamics of both generators (the photovoltaic module and PEM Fuel Cell system) and of the control strategy. The disturbances are the solar radiation (and other variables of environment such as the temperature) and state of the load, while the output is the electric output (required by the load).

Very few efforts are presented for hybrid energy management to the level production facilities and are not found on in optimization approach [8–11]. The diagram of a PV–PEM Fuel Cell hybrid energy system for stand-alone application is indicated in Fig. 1. The system is constituted of photovoltaic generator, optimization device, power interfaces, and energy storage backup including an electrolyser, PEM Fuel Cell system and load unit. The relative tendencies with the availability of DC-Bus tension are carried out by means of electronic converters. In addition, the storage power devices have immense possibilities in near future.

3. Management of energy power systems

In multi-source alternative energy systems, an overall control strategy for power management among different energy sources is fundamental. Each combination of physical components of the hybrid system has an optimal control strategy, i.e., a way to manage the energetic (power) flow between different components with optimal approach and with the more low costs of possible operation by taking into account the useful components lifespan. Each control strategy is carried out for discrete numerical values of the various control variables. The control strategy determines how to manage flow energy. For each hour of time, according to the values of the weather variables, a load energy consumption (DC/DC converter and/or hydrogen production) and the energy storage device states (batteries, hydrogen tank), the control strategy determines which components must function and which not, where must one store energy "excess" surplus or which device must provide overdrawn energy to supply the load [12,13].

All these strategies have a basic principle the use of renewable sources to supply the request for potential consumption, using the excess energy to charge the batteries, to produce hydrogen or to feed the auxiliary components [14]. If the instantaneous request (power requested less power produced by the renewable sources) is negative, i.e., excess power produced by the renewable energy sources, then the surplus power is used to charge the batteries (or other accumulators). If the batteries are loaded to the maximum and the continuous excess of power, it is said whereas there is an excess of energy. In the case where the net request is positive, i.e., it is not sufficient with the renewable energy sources to answer the entire load requested, then the backup devices are used to supply the load if this one has an insubstantial load.