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Automatic management of energy flows of a stand-alone renewable energy with support of hydrogen

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1. Introduction

This work deals with the design and built of an automation system for controlling the electric energy flows that take place at the continuous current bus (DC Bus) of a wind-solar system with support of hydrogen. The automation system is based on a Siemens PLC s7_313C_2DP. This PLC has been equipped with a Micro Memory Card (MMC) of 2 MB in order to allow the massive storage of data related to the control and monitoring of the benchmark. This system has to perform the required switching between the components of the hybrid electric energy generator. These elements are: photovoltaic generator, wind turbine generator, fuel cell system, electrolyzer.

The scheme of the system is shown in Figure 1. It is composed of a photovoltaic generator, a wind turbine generator, a battery set, an electrolyser, a metal-hydride system for hydrogen storage, a fuel cell and a system in charge of supervisory control and data acquisition. In summer, solar energy is enough to power the application, maintain a high state of charge of the batteries and run the electrolyser to produce hydrogen. Hydrogen is stored in the metal hydrides. In winter when the state of charge of the batteries is low, the fuel cell recharges the batteries avoiding a cut in electric power to the application.

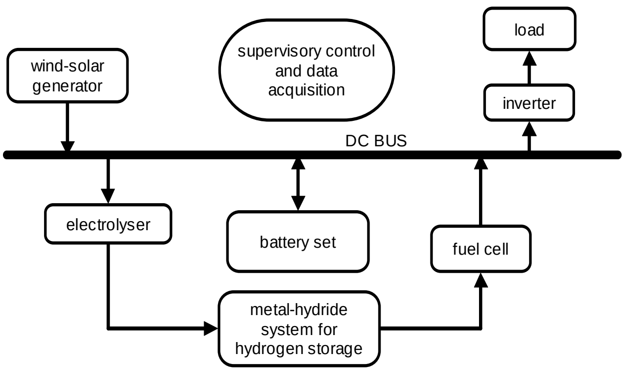

Figure 1. Scheme of the wind-solar hydrogen system

A stand-alone RE system based on energy storage as hydrogen has been developed and installed at the Technical Thermodynamic Lab of the Industrial Engineering School of the University of Extremadura, in Badajoz (Spain), and successfully tested for autonomous operation with developed control system and power conditioning devices.

Key words

Wind-solar hydrogen system, fuel cell, electrolyzer, control strategies, stand-alone RE system

2. System Description

The working principle of the joint system is based on the block diagram that appears in the Figure 2.

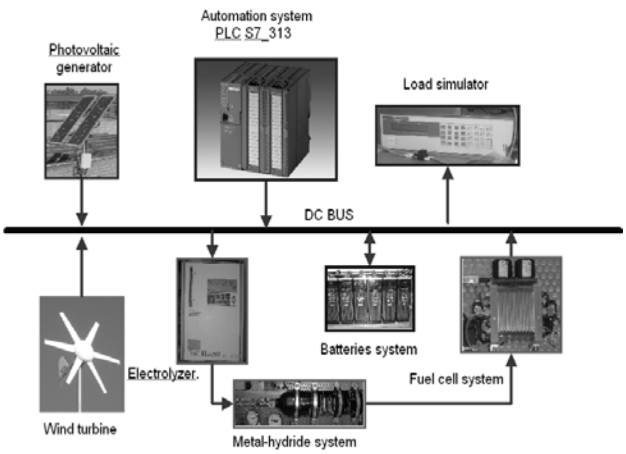

Figure 2. Flow chart of the wind-solar installation supported with hydrogen

3. Description of the Control System

The goal of the control system of the wind-solar installation with support of hydrogen is the optimization of the performance of the combined system electric energy generator/hydrogen generator.

The working principle of the desired system is shown in Figure 3. As can be observed, before the system goes to the stationary regime, a delay must be introduced in order to initialize all the subsystems of the test bed and the involved variables. After that, the system goes to the "*Main step of working*", where the demanded energy is supported by the wind-solar generator. In this step the working regime of the global system is checked.

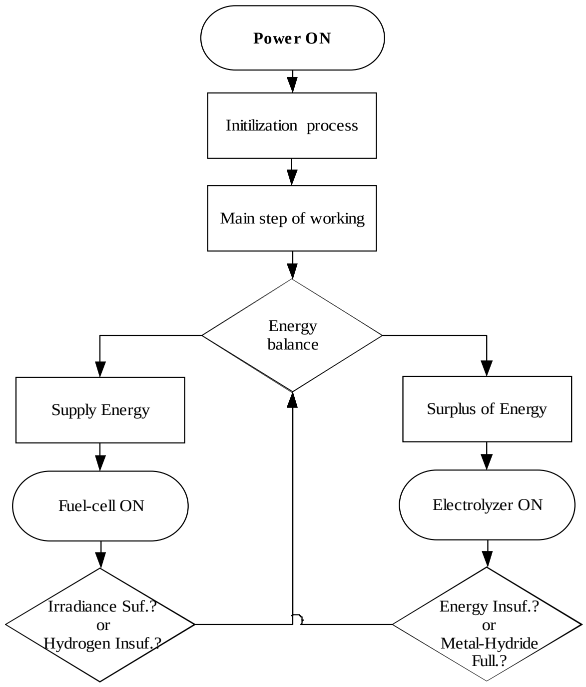

Figure 3. Flux diagram

To achieve this goal, the energy balance between the supplied energy by the wind-solar generator, the demanded energy by the user and the battery charge state is done. By means of this analysis, the working conditions for the fuel-cell and the electrolyzer are obtained.

The energy balance between the electric energy supplied by the wind solar system, the required energy by the user and the state of charge of batteries is done by the comparison of the currents at the DC Bus. Moreover, irradiance conditions and wind speed are taken into account too. In this way, the switching conditions of the fuel cell and the electrolyzer are obtained. Next, the determination of both set of conditions is carried out.

The electrolyzer will switch "ON" when the following conditions are simultaneously fulfilled:

- The fuel-cell must be *switched off.*

- Minimum conditions of *irradiance* are necessary: The irradiance *(G) (measured by the piranometers)* should be sufficient for providing an electric current capable of generating hydrogen $G>G_{min}$. This value had been obtained of experimentally form.

- The wind-solar generator must be able to generate an electric current (i_P) such that:

$$i_P > i_E + i_B + i_{DC} + i_{AC}$$

where:

i_P : is the supplied current by the generator.

i_E : is the demanded current by the electrolyzer.

i_B : is the demanded current by the battery.

i_{DC} : is the demanded current by the DC loads.

i_{AC} : is the demanded current by the AC loads.

Moreover, the pressure of the metal-hydride system for storing the generated hydrogen is inside its limits. These limits depend on the selected hydrogen storage system. In these conditions, the hybrid system is generating hydrogen from the surplus energy of the wind-solar generator.

The fuel-cell will *switch "ON"*, in order to supply the necessary energy, if it is required for the energetic demand conditions, when the following conditions are simultaneously fulfilled :

- The DC Bus can supply the necessary energy level for switching on the input electro-valve of hydrogen.
- The pressure of the metal-hydride system for storing the generated hydrogen is higher than 1 bar.
- The temperature of the fuel-cell is higher than 5º C and lower than 50º C.

The fuel-cell will *switch "OFF"* when:
- The irradiance *(G)* is enough for providing the demanded energy.
- The pressure of the hydrogen circuit falls down at values lower than 1 bar.

4. Conclusions

Automatic management of energy flows of a stand-alone renewable energy with support of hydrogen has been carried out by a PLC. The developed control system has been successfully tested for autonomous operation and energy management of the installation. The designed system behaves as an effective test bed for testing control strategies and optimization algorithms based on acquired data by the monitoring and supervisory system.

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