U.P.B. Sci. Bull., Series C, Vol. 74, Iss. 1, 2012 ISSN 1454-234x

A HYDROGEN-BASED PEAK POWER MANAGEMENT UNIT

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The paper deals with an electrical power management solution for combining renewable energy sources (RES) with hydrogen technologies in order to overcome the problems generated by the natural fluctuations and intermittencies that characterize RES. A "Hydrogen-based Peak Power Management Unit" has been designed and built to allow the use of solar and wind energy. The power is delivered to the load via a rechargeable battery stack, whose state of charge (SoC), along with the level of power provided by RES, represents the decision factors for the power management. The energy balance for a 4 month operation period is presented.

Keywords: renewable energy, Hydrogen, power management, energy balance

1. Introduction

Nowadays within the EU and worldwide there is a general consensus for a long term need for a transition towards sustainable energy systems due to limited fossil resources and the need for greenhouse gas emissions induced climate changing mitigation. In order to face the threat of the irremediable environmental damage and of the lack of energy, we had to look for solutions. A way to meet the challenges aforementioned is represented by the growing use of Renewable Energy Sources (RES).

The most readily and widespread forms of RES are solar and wind. Unfortunately, RES are relying heavily on largely unpredictable natural phenomena, being generally characterized by fluctuations and intermittencies. Wind and solar are no exceptions: the availability of solar energy is limited to daylight periods and depends on the geographical location and the weather conditions, and those of wind energy is characterized by quite large and irregular fluctuations. In order to encompass these disadvantages and harmonize the load power demand with the RES coming energy offer, an integrating element must be chosen and a managing system must be designed, having the function of storing the excess energy and release it under environmental condition variations.

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Hydrogen is a clean energy carrier that can be produced from any primary energy source and fuel cells provide the most efficient conversion device for converting hydrogen into electricity. It is now widely recognized that Hydrogen and fuel cells together have the flexibility to adapt to the diverse and intermittent renewable energy sources available [1], and that is the reason there were chosen to integrate a RES power generation unit.

Several studies on different configurations of RES power units and their management strategies were developed worldwide [2], [3], [4], [5]. Given the specific local particularities of RES, researches addressing their inclusion in more manageable power systems, taking into account the balances between the supply and the demand in each point are ongoing in the National Hydrogen and Fuel Cell Center (NHFCC), at National R&D Institute for Cryogenics and Isotopes Technologies Ramnicu Valcea, Romania.

2. Method

A concept of a power generation system integrating solar and wind energy inputs with short- term energy storage on rechargeable batteries and long- term energy storage utilizing hydrogen produced by water electrolysis was designed to meet the load power requirements. The system, whose block diagram is shown in Fig.1 and overview in Fig. 2, was made and put into service at NHFCC.

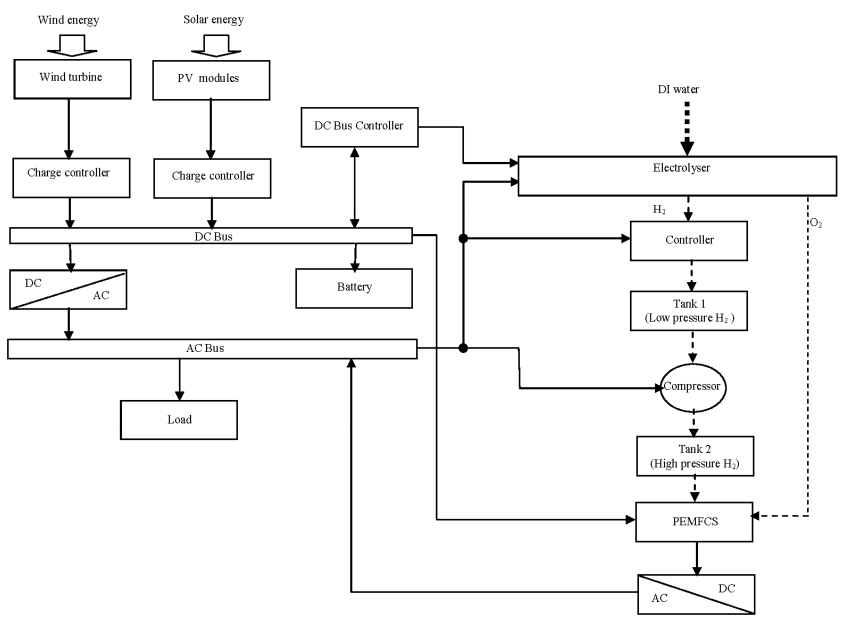

Fig. 1. Block diagram of the Peack Power Management Unit (PPMU)

The RES system consists of 10 photovoltaic (PV) modules able to provide 1800W electric power in standard conditions of irradiation and temperature (1,000 W/m^2 with AM 1.5 light spectrum and 25^0 C), and a vertical axis wind turbine of 600 W rated power at 12 m/s rated wind speed. The generated energy charges a stack of 6 sealed gel batteries, having 400Ah / 2V and low self discharging rate. The surplus energy supplies a polymer electrolyte membrane (PEM) electrolyser producing 2 lpm (liters per minute) of Hydrogen at adjustable pressure to 7 bar. The gas is filling a 10 l low- pressure tank from which is then extracted and compressed in a high pressure 10 l storage tank, by means of a compressor, to a maximum pressure of 150 bar, for subsequent use in a 500 W proton exchange membrane fuel cells stack (PEMFCS) in case of lack of energy from RES.

Fig. 2. Overview of the PPMU

In the initial state the high pressure storage tank was charged with 1500 l of hydrogen. Following the battery status, the Peak Power Management Unit (PPMU) was operated as follows:

- if the battery voltage, V_{bat}, is 9.6 V≤ V_{bat} ≤10.8 V, the load was „off" and the battery was charged by the RES power and, if not available or insufficient, by the PEMFCS, using the stored hydrogen, with all system components „off", excepting the charge controllers and the boost converter (this situation could occur only accidentally);
- usually, at the system startup, for 10.8 V< V_{bat} ≤14.4 V, the load is „off" and the battery is charged the same manner as previous;
- in normal operation, for 10.8 V< V_{bat} ≤ 13.5 V, the load is „on" and the battery is charged from RES power or PEMFCS, as appropriate. If an excess RES power is available, it will supply the electrolyser in order to restore the hydrogen reserve;
- if V_{bat} < 9.6 V or V_{bat} > 14.4 V, the system has to be „shut down", because the battery is damaged, respectively over- charged.

The data acquisition and control system is realized with NI FieldPoint modules and is based on LabView software platform, which allows realizing a user friendly interface, centered on the synoptic scheme presented in Fig. 3 A.

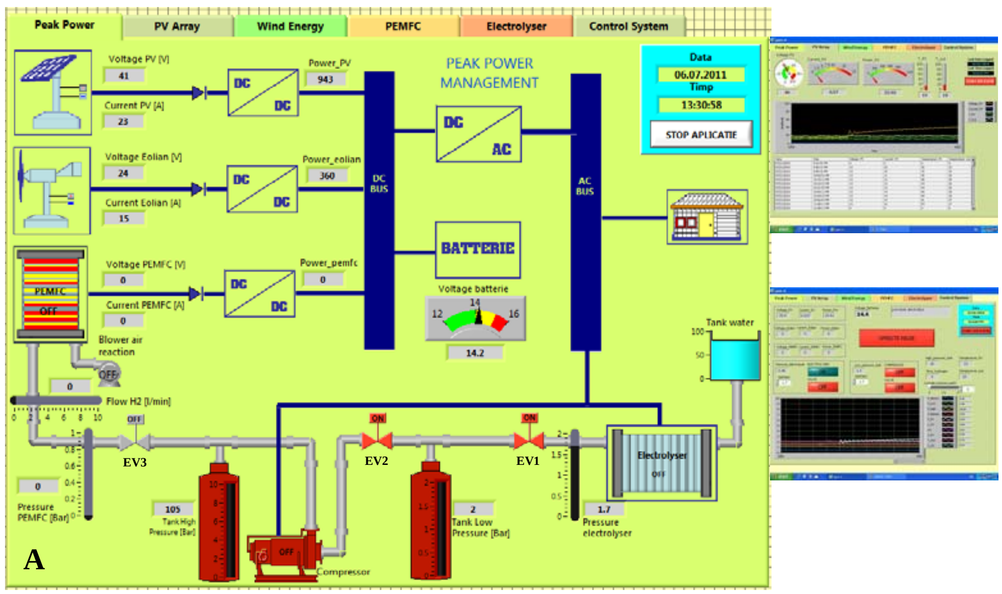

Fig. 3. Print screens of the PPMU software

Sub- routines (as an example, two of them – PV array and Control System, are presented as small pictures in Fig. 3) called from the main program are managing the operation of the PPMU subsystems. The management strategy adopted to the surplus RES power using for Hydrogen production by water electrolysis in the PEM electrolyser is presented in the logic diagram of Fig. 4.

The electrolyser starts when the load is connected and the three solenoid-valves (EV1, EV2, EV3 in Fig. 3 A) on the hydrogen line are closed.

Consequently, the hydrogen dowry is built up in the low pressure tank, in function of the electrolyser pressure value, P_L. The filling of the high pressure tank is made with hydrogen extracted from the low pressure tank and then compressed. In order to minimize the on-off working regime of the electrolyser and the compressor, a hysteresis band between a Low Limit (LL) and a High Limit (HL) was assigned to the pressure set point (SP).

3. Results

The PPMU was preliminary tested over 4 month (may- august 2011), for an uninterrupted operation of 122 days. The average values for the solar energy, wind speed and temperature for each month are presented in Fig. 5.

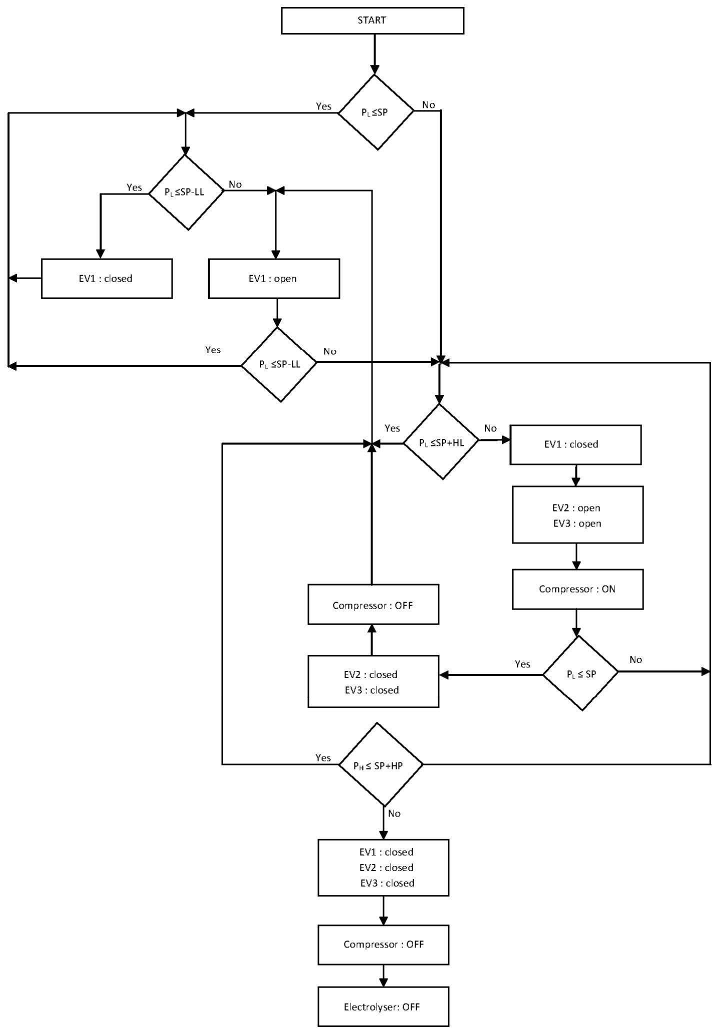

Fig. 4. Logic diagram of the strategy for the use of the excess RES power

The electricity request was on the energy to power a lighting system of 12 eco- bulbs of 20 W each, for 8 hours a day, and it was constant throughout the 4 months (1.92 kWh).

The RES power average cumulative intake over 8 hours was 985 W. Besides the power supply for its functional components, the system provided the necessary power for a daily 8 hours functioning of the 240 W lighting system (the load). At the test end, the pressure on the high pressure hydrogen tank was 78 bar, which means the presence of 780 l of gas.

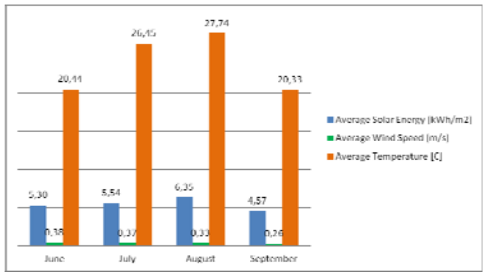

Fig. 5. The average values of solar energy, wind speed and temperature for each month

4. Conclusions

The PPMU which is about was implemented in a region characterized by medium solar radiation and rare winds, its structure including a wind turbine only for demonstrative purposes. In the system design the costs of the equipments was an important criterion.

The tests will be continued by implementing some different strategies in the system management, in order to optimize its performances and develop an integrated control strategy. This strategy will take into account to ensure the smooth flow of the power in the system, by the continuously as possible operating of the PEMFCS and the electrolyser, with no frequent start-ups and shut- downs, which would increase the system maintenance costs and shorten its life. The tests will also lead to getting the input data for an optimal selection of the system components capacity (e.g. required nominal power level, battery capacity, electrolyser nominal hydrogen flow), allowing to minimize the material costs.

R E F E R E N C E S

[1]. *** Hydrogen Energy and Fuel Cells – A vision of our future (Final Report of the High Level Group) – EUR 20719 EN, 2003

[2]. *D.B. Nelson, M.H. Nehrir and C. Wang,* , “Unit Sizing and Cost Analysis of Stand- Alone Hybrid/ Wind/ PV/ Fuel Cell Power Generation Systems”, in Renew Energy, vol. 31, 2006, pp. 1641-1656.

[3]. *E.M. Nfah, J.M. Ngundam, R. Tchinda,* “Modelling of Solar/ Diesel/ Battery Hybrid Power Systems for Far- North Cameroon”, in Renew Energy, vol. 32, 2007, pp.832-844.

[4]. *Y. Himri, A.B. Stambouli, B. Draoui, S. Himri*, “Techno- Economical Study of Hybrid Power System for a Remote Village in Algeria”, in Energy, vol. 33, 2008, pp. 1128-1136 .