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APPLICATION PEM FUEL CELLS IN DISTRIBUTED GENERATION

In this article the laboratory stand for testing the cooperation of three energy sources has been presented. The aspects of the use of PEM cells in distributed generation have been studied. The measurement results of parallel cooperation of the fuel cell with wind turbine and photovoltaic cell have been presented.

SŁOWA KLUCZOWE: PEM fuel cell, distributed generation, electrolysis

1. INTRODUCTION

Energy generation in a distributed system is now a rapidly developing branch of electricity. Distributed generation means small generating units, or objects, connected directly to the distribution network or located near the load. They are not subject to central planning development and disposition of power [1].

Wind turbines operating in the power system are not fully disposable. They require startup reserve sources that could cover the needs of energy in the absence of good weather conditions (suitable wind speed). Photovoltaic systems will have the same problems in the future.

For technological reasons thermal power plants are not suitable to quick changes the power generated at short intervals. The solution to this problem may be PEM (Protone Exchange Membrane) fuel cells.

Fuel cells are electric – chemical devices where direct transformation of chemical energy into electric one takes place. This way of transforming one kind of energy into the other is an essential advantage of fuel cells because it gives an opportunity of reaching high efficiency of energy conversion process which is not limited by Carnot's cycle efficiency. The following advantages of fuel cells can be listed: high efficiency, very low greenhouse gas emission, low level of noise, modular structure, ability to work with low loads, ability of reverse working, very good regulation abilities [2].

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2. PEM FUEL CELLS - OPERATION OPTIMIZATION AND LOAD CHANGE RESPONSE

For the application of PEM fuel cells a virtual power plant of several fuel cells (and other types of power plants) is favorable for the operation due to two main reasons. PEM fuel cells are capable of bearing quick load shifts. However, a change in the supply of the reactant gases is slow. Load shifts may result in short timespans with over- or undersupply of the reactants and therefore reducing the lifetime of a fuel cell [3].

Generally, a fuel cell with modest load changes and constant operation parameters will have a higher lifetime, so one reason for virtual power plants is the possibility of splitting the load over several fuel cells so that each fuel cell can run at optimal operation parameters. The second reason is the distribution of the fuel cell plants will help to generate the energy locally where it is needed, which will reduce transfer losses. Moreover, the generated heat of the fuel cell systems can be used for district heating.

A virtual power plant has various other advantages [4, 5], nonetheless it requires a smart grid for communication between the subsystems and possibly a central power plant control (Fig 2.1). The communication is important to synchronize the decentralized subsystems not only to deal with load change response, but also to transfer status and security information. The market price can also have an influence on the production of a virtual power plant. Additionally it is possible to include the information of weather forecasts or other grid operators to predict the generation of wind and solar so load changes can be prepared in advance. As fuel cells need time to start up this advantage is crucial for the operation management.

For the start process, fuel cell systems based on reformat gas require up to two hours to heat up the reformer. Systems based on pure hydrogen only require a view minutes to start up, but should not run on full load until the system temperature is stabilized at the nominal operation temperature (50-70°C for PEM fuel cells). The heat production of the stacks is enough to heat up the system and excess heat needs to be dissipated to keep the stack temperature stable.

Besides the reactant and thermal operation of a fuel cell system, the electrical operation is rather simple. A fuel cell behaves like a direct current source while the voltage is dependent on the load current and the quality of the fuel cell including aging. The cell voltage will depend on the operation conditions as well as temperature, humidity and pressure of the reactants has a direct influence on the cell voltage. The load current can be changed until the power output is at the required level. However, the virtual power plant approach allows dealing with small power differences of the decentralized systems without this requirement. Therefore, a single system can run at optimal load and stable current.

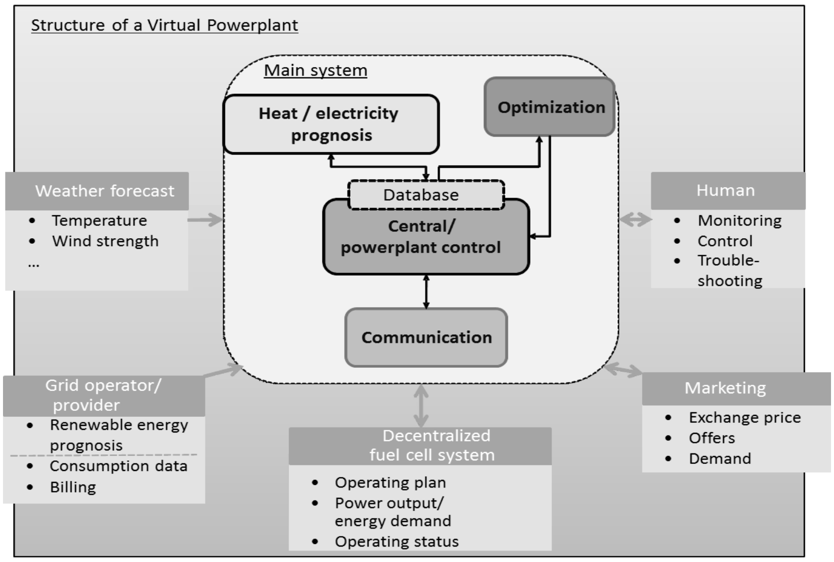

Fig. 2.1. Structure of a virtual power plant showing connections to external systems

3. COOPERATION OF PEM FUEL CELLS WITH WIND TURBINE AND PHOTOVOLTAIC CELLS

Figure 3.1 shows a block diagram of the system which includes, wind turbine, photovoltaic cell, fuel cell and electrolyzer. There are two possibilities for energy flow. First option is feeding elecrolyzer with wind turbine and solar cells. Second option is parallel cooperation of fuel cell with both renewable energy sources.

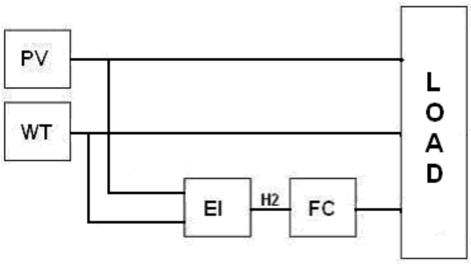

Fig. 3.1. A block diagram of the test system

The first purpose of the test is to obtain information about the time of produce of specifc value of hydrogen by feeding electrolyzer with renewable energy sources. The second purpose of the test is to get information is fuell cell can work in parallel with chimeric energy sources as wind turbine or photovoltaic cell and cover momentary deficits of produced power.

3.1. Laboratory stand

In Figure 3.2 laboratory stand has been presented. Thanks to the stand it is possible to determine the characteristics of the three energy sources - fuell cell, photovoltaic cell, wind turbine as well as their cooperation.

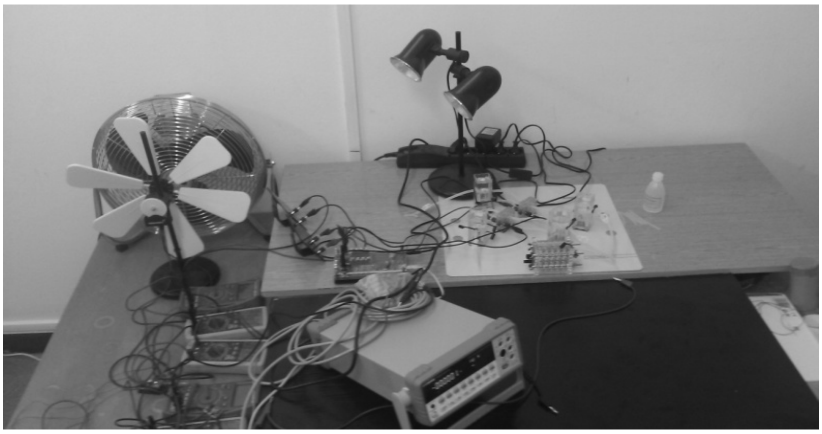

Fig. 3.2. Laboratory station

3.2. Wind turbine and photofoltaic cell feeds the elektrolyzer

In Figure 3.3 a block diagram of the test system has been presented. The measurements were made at three operating points of the system. Operating points means points of intersection of the external characteristics of energy sources with the external characteristic of the electrolyzer. Figure 3.4 shows the external characteristics of the system components.

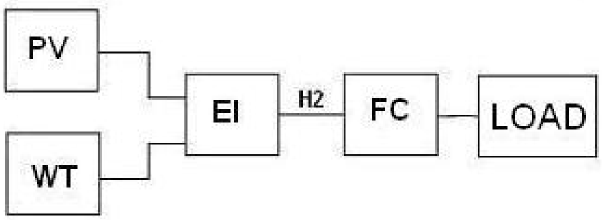

Fig. 3.3. A block diagram of the test system

The electrolyzer was first powered by wind turbine, second was powered by photovoltaic cell and finally from both sources at the same time. Value of the irradiance was 1200 W/m2, and wind speed value was 5.2 m/s. The time in which 20 cm^3 of hydrogen was produced was measured.

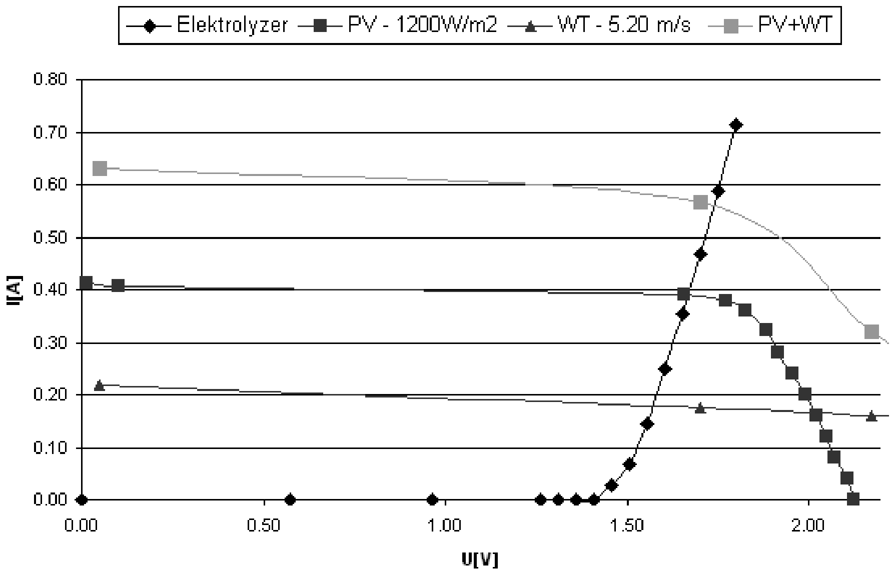

Fig. 3.4. External characteristics of the electrolyzer, the wind turbine and photovoltaic cell

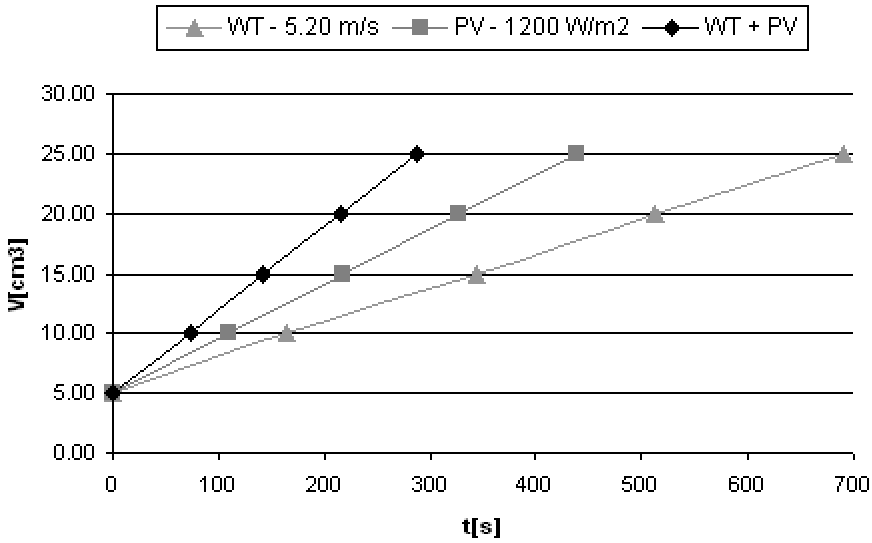

Fig. 3.5. The results of measurements

Figure 3.5 shows the results of measurments. Providing more power to the electrolyzer will reduce the time of production of a specific volume of hydrogen.

3.3. Fuel cell parallel cooperation with wind turbine and photovoltaic cell

In Figure 3.6 a block diagram of the test system has been presented.

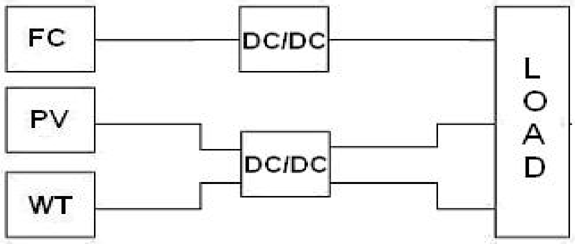

Fig. 3.6. Measuring system - block diagram

Voltage and current signals were registered using a multimeter. The DC/DC convertes were gave a constant value of voltage which was 2.5 volts. Shunt resistors were used for the measurement of current signals. During the recording voltage and current signals, intensity of solar radiation and wind speed was changed. In Figure 3.7 the recorded signals have been presented.

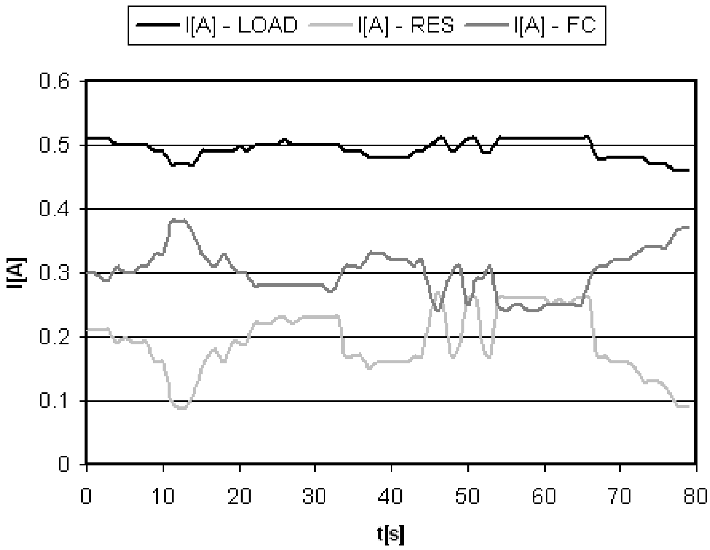

Fig. 3.7. The results of measurements - the current signals

Dark gray signal represents the current flowing from the fuel cell and light gray signal represents current flowing from wind turbina and photovoltaic cell. The sum of the currents is represented by the black signal. The initial operating point was established at the 0.2 ampere from renewable energy sources and 0.3 ampere from the fuel cell. After 10 seconds renewable energy sources were disabled and the current from the fuel cell with a value of 0.37 ampere has been generated. After the next 5 seconds, renewable sources restarted - the current value from the fuel cell went back to the earlier value, the system was stabilized and the current value of the load was again 0.5 ampere. After next 15 seconds the main light source was turned off. The value of current from photovoltaic cell has decreased to the minimum. The fuel cell changed the operating point and generated bigger current. Thanks to this the current value of the load was constant. After a while, the main light source has been switched on and off, then it was switched on and off again and then switched on. Thanks to the fuel cell the value of current of the load was 0.5 ampere. Wind turbine and photovoltaic cell were disabled at the end of the test. The fuel cell generated a maximum current and recording of the measured signals were completed.

The fuel cell can work in parallel with renewable energy sources and cover momentary deficits of produced power

4. CONCLUSIONS

The tests performed let us draw the following conclusions:

– Virtual power plants allow the combined operation of several fuel cell systems and other sources and will manage the load change response.
– Providing more power to the electrolyzer will reduce the time production of a specific volume of hydrogen.
– The fuel cell can work in parallel with renewable energy sources and cover momentary deficits of produced power.

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