Hybrid Solar Panel Fuel Cell Power Plant

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Abstract - **Authors have worked for several years on stand alone hybrid solar wind turbine power plant for supply telecommunication equipment. The main problem in such installations is how to guarantee power supply all year without interruptions. Weather conditions in Poland provide to breaks in winter and autumn. The paper shows proposition of a new power plant with fuel cell and solar panels. The idea is to generate energy from PV panels as long as it's possible. When there is no sun, energy will be produced by fuel cell. Because of the system will operate rather far from service centres it has to work as long as it's possible without refuelling. Power summation and control algorithm is explained, power electronics converters and control system are described.**

Keywords: **Renewable Energy Sources, Fuel Cells, Control Systems.**

1. INTRODUCTION

In 1998 team of Prof. Dmowski from Institute of Control and Power Electronics built a stand alone hybrid solar and wind turbine power plant. That was an answer to order of one of Polish telecom companies. The power plant has supplied the telecom equipment. The company wanted to have clean energy source. Something what could replace Diesel generators. Particularly in installations placed far from public grid. The power plant had to produce energy all time without any breaks. Block diagram of the power plant is shown in fig. 1.

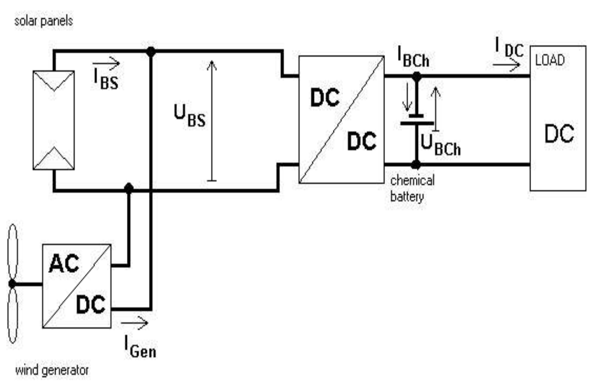

Fig. 1. The block diagram of hybrid solar and wind power plant

A heart of the system is chemical battery. The battery is charged by solar panels and wind turbine. The main idea was to use only solar panels but there are no enough sunny days in Poland. Solar panels could produce enough energy from May to September. But in winter breaks are very often. Fig. 2. shows energy production during all year from the power plant ($P_{obc.}$ means required load power). So the wind turbine was added. But in Poland when there is no sun also there is no wind.

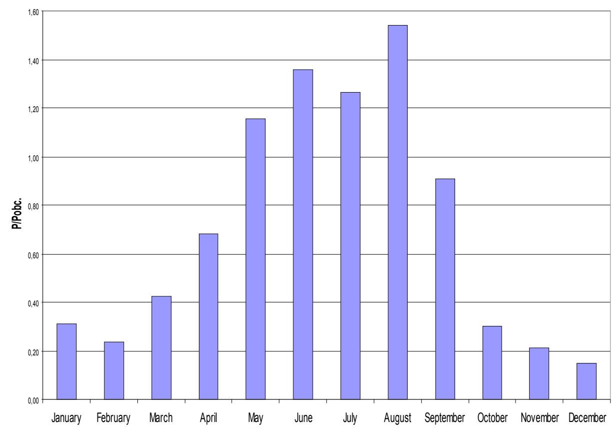

Fig. 2. The power produced by the power plant during year

We decided to replace wind turbine with fuel cell. That solution makes the power plant weather conditions independent. New block diagram is shown in fig. 3. The block representing fuel cell contains also DC/DC converter which takes up voltage level. Voltage conversion is necessary to make collaboration with PV and load supply possible.

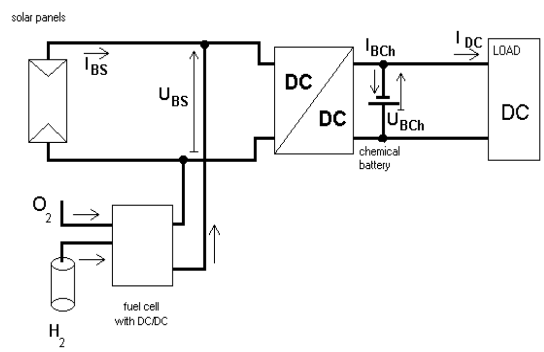

Fig. 3. The block diagram of hybrid solar and fuel cell power plant

2. THE POWER PLANT CONSTRUCTION

The group of engineers lead by Prof. Dmowski from Institute of Power Generation of Warsaw University of Technology is building hybrid solar and fuel cell power plant. Its construction is based on earlier solar and wing unit. Block diagram of the power plant is shown in fig. 3. as it was told above.

Likewise in solar wind system the main part of the power plant is chemical battery. The battery have to supply load during any breaks. It is required by telecom regulations. The battery is charged and load is supplied by solar panels trough standard DC/DC converter which keeps Eurobat conditions. Battery voltage level is set suitable to load. Of course charging by PV is possible only in that time when there is enough sun. When there is no sun fuel cell starts to work instead of PV. Fuel cell is feed by hydrogen. So it is independent of weather conditions. Then fuel cell can produce energy all time when it is required. Parallel connection of those two energy sources allows to supply load all time until it is fuel in tank. Because of the power plant will work rather far from service centres it is very important to make refuelling period as long as it is possible, but not shorter then one month.

Fig. 4. shows equivalent circuit diagram of two sources similar to PV and fuel cell with DC/DC converter. In that circuit load is supplied by that source which has higher voltage. Voltage source V2, inner resistance Rw2 and diode D2 represent fuel cell and source V1, resistance Rw1 and D1 represent PV.

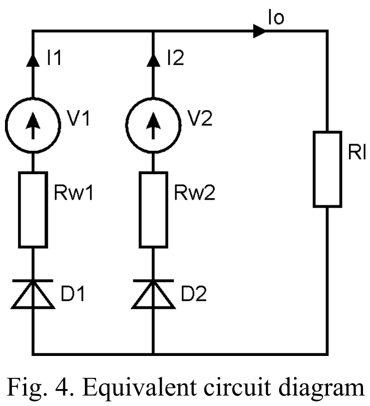

Fig. 4. Equivalent circuit diagram of two parallel voltage sources

As it was explained above, the voltage of fuel cell is regulated by DC/DC converter so it is constant and independent to load. In such situation only V1 changes due to sun intensity and PV characteristics shown in fig. 5. Solar panels produce energy when current I1 is higher then zero. It happens when V1 is higher then V2(1 – Rl/(Rl+Rw2)). In opposition if hydrogen and air pressure is passed to fuel cell, it will automatically start supply load.

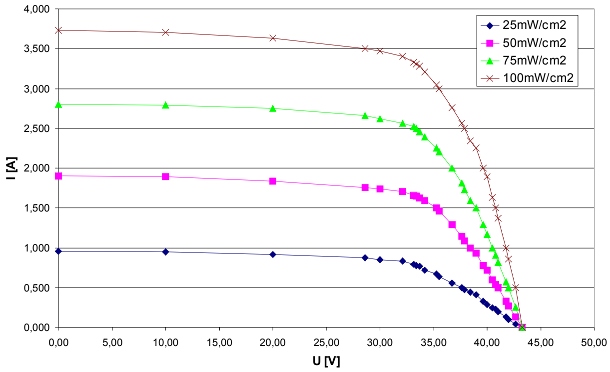

Fig. 5. Solar panel characteristics

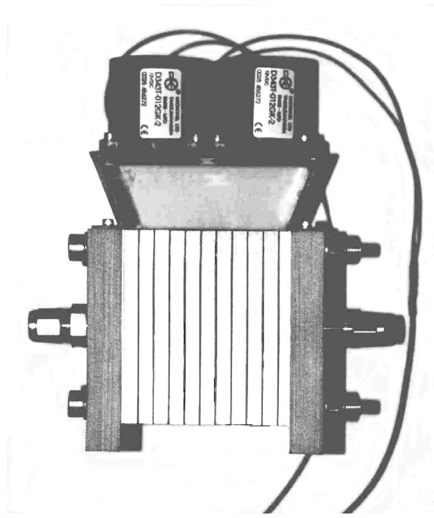

Fig. 6. Fuel cell used in the power plant

Experimental hybrid solar and fuel cell power plant will be build with two 110W PV (fig. 5.) connected in parallel, 50W small demonstrative fuel cell shown in fig. 6. Its characteristics are shown in fig. 7. Two car chemical batteries are used as chemical battery. All system is controlled by microprocessor controller described below.

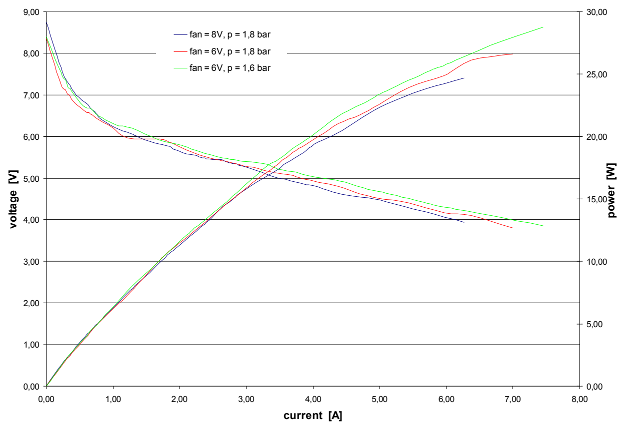

Fig. 7. The fuel cell characteristics

3. THE DC/DC CONVERTER FOR THE FUEL CELL

According to the outer characteristic curve, the voltage drop during operation is very high and strongly depends from the current. So if we want to supply any load, an additional power converter is needed. We've proposed the simple topology of the boost converter without transformer (fig.8).

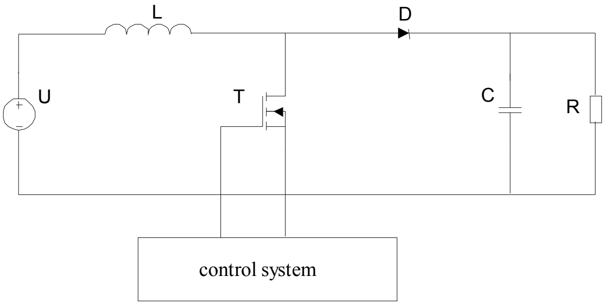

Fig. 8. Boost converter

Main disadvantage of this topology is non-continuous ripple current drawing from the fuel cell (fig 9) and great switching loses.

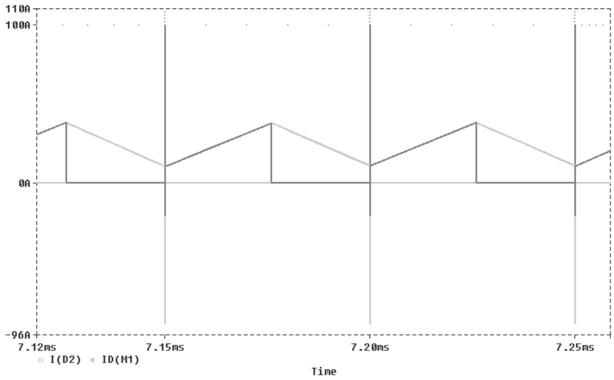

Fig. 9. Non-continuous current of the boost converter

To improve these characteristics and still using the very simple circuit we've proposed the following topology (fig. 10).

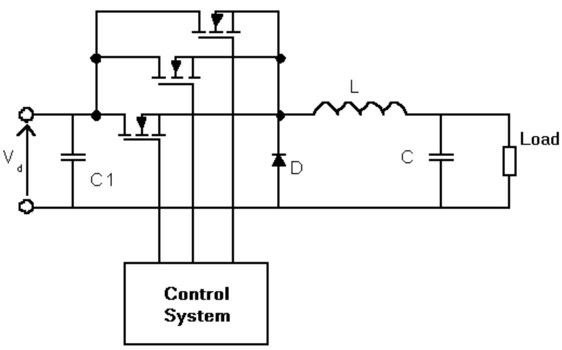

Fig. 10. Multi-switch topology of the boost converter

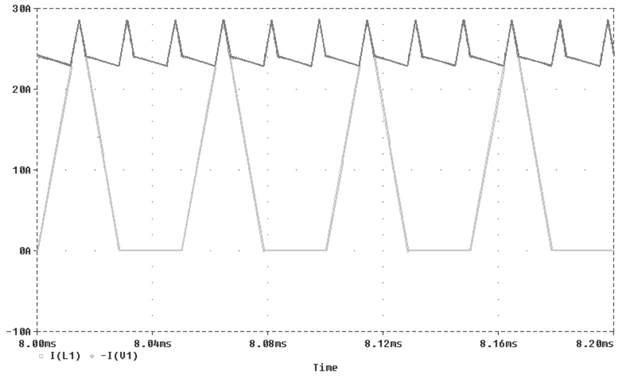

Fig. 11. Current from multi-switch topology

The control circuit of this converter turns on every single transistor branch with the time delay to minimizing the switching loses and draw continuous current from the fuel cell. This topology allows us to use smaller transistors with the same power output as traditional boost converter (reducing of the costs). The efficiency of power conversion is higher due to reduced switching loses. The ripples in the input current are smaller and the switching frequency can be greater so the input filters are less complicated and smaller and lighter. The possible damage done to one of the transistors do not brake the current flow to the load (redundancy).

On the fig. 12 there is a photo of used multi-switch converter with the internal microprocessor controller and on the fig. 13. there is an input current.

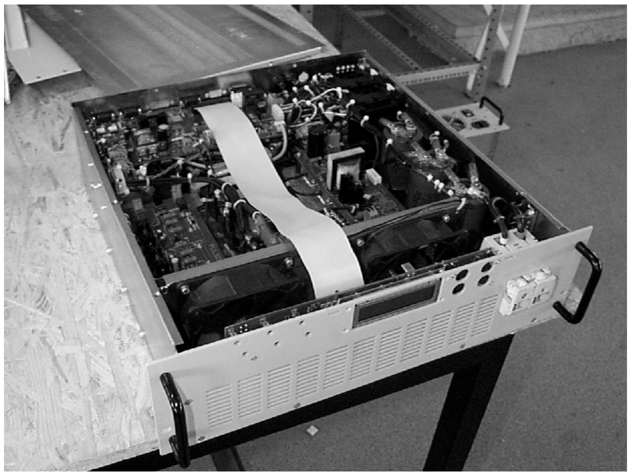

Fig. 12. Multi-switch DC/DC boost converter

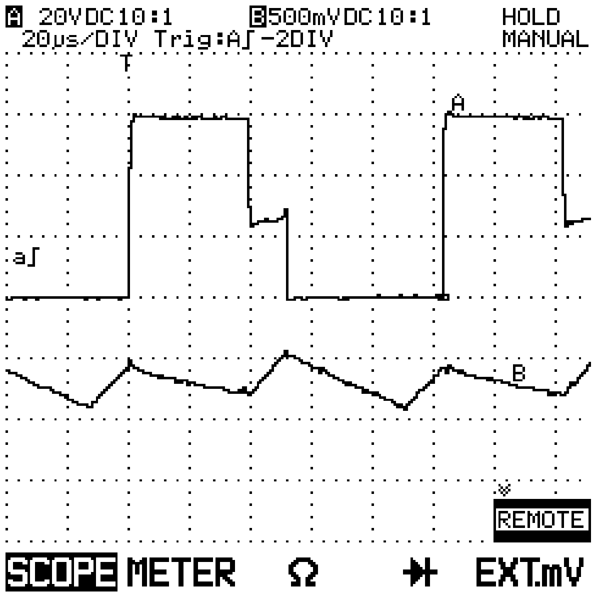

Fig.13. Input current with 2 operating branches

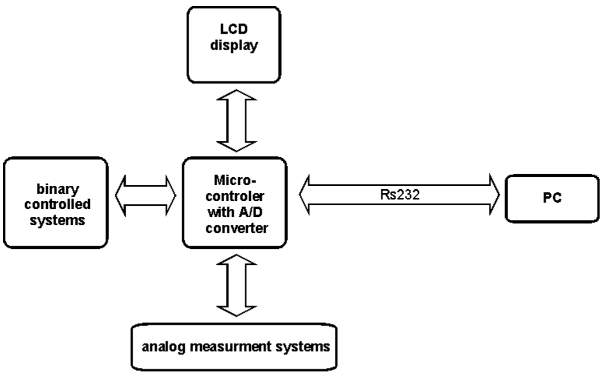

Fig. 14. The controller block diagram

4. CONTROL OF THE POWER PLANT

The power plant is controlled by microprocessor unit shown in fig. 14. The controller measures all important data such as battery current and voltage, load current, PV current and voltage, time and date. Those parameters are necessary for service in order to avoid any breaks and damages. So they have to be stored and then sent to operator by telephone or RS.

The second group of controlled parameters is connected to fuel cell (FC). To operate fuel cell it is necessary to know parameters listed below:

- FC current,
- FC voltage,
- FC temperature,
- hydrogen pressure or hydrogen flow,
- state of hydrogen valve,
- state of air fan (compressor),
- state of switch between FC and its DC/DC converter.

The controller has three tasks connected to FC: turn on and turn off the FC to work, protect FC from damage during operation.

PEM fuel cell cannot be loaded without fuelling because it provides to membrane damage. So it is very important to turn on and turn off the FC in proper way. Fig. 15 shows start procedure and fig. 16 stop procedure.

Fan on
Set fan voltage to 1V
Hydrogen flow on
Wait 1 minute
Set load to 1A
Wait 15 minutes
Set fan voltage to operating level
Set load to operating level

Fig. 15. Start procedure

Load off
Wait 2 minutes
Hydrogen flow off
Fan off

Fig. 16. Stop procedure

When the FC works it is very important to keep its temperature in proper range. Our fuel cell could operate up to 45ºC. If FC's temperature is too high the controller have to increase air flow to cool it or stop it for some time.

5. CONCLUSIONS

The main reason to build described system is to supply stand alone telecom system using renewable energy sources. So the power plant has to produce energy independent of any weather fluctuations. That could be obtained by using two sources. Weather dependent solar panels and weather independent fuel cell. Such installation can give energy all time and do not produce any pollutants. In the other hand, problem with the fuel cell is limited tank capacity. So because of solar panels do not need fuel, using both sources permits to maximise refuelling period. In comparison to solar power plant energy production (fig. 2), described hybrid installation will give power as it is shown in fig. 17, where P_0 means required load power.

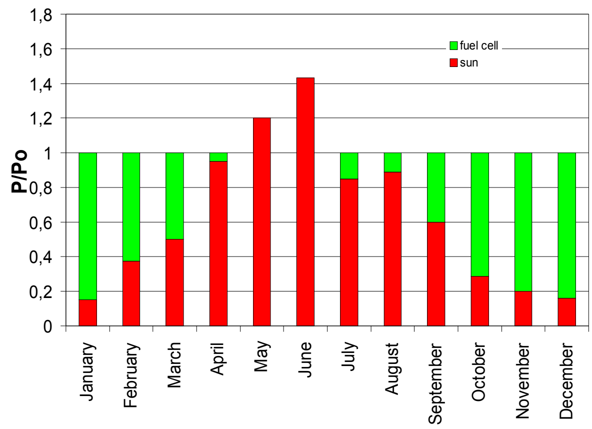

Fig. 17. Hybrid solar and fuel cell power production

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