The Connection of a Micro-hydropower Plant to an Experimental Electrical Network

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Abstract— The paper describes the connection of a micro-hydropower plant to a 24 V experimental smart grid. The principle of the proposed design consists in improving the stability of the current grid and enabling maximum exploitation of the electric energy produced by renewable sources (hydroelectric stations, photovoltaics, wind power plants). In this respect, the authors present a very important module to the renewable sources connection and change the current flow direction.

This module, denoted as Control Block, serves both to dispatch the energy to the grid and to charge the smart grid batteries. In order to secure correct operation and functioning of the Control Block, the authors applied a step-up converter and designed a special step-down converter.

1. INTRODUCTION

The authors describe the connection of a micro-hydropower plant to an Experimental Electrical Network (E.E.N.) [1]. The principle of the proposed design consists in improving stabilization of the current grid and enabling maximum exploitation of electric energy produced by renewable sources (hydroelectric stations, photovoltaic, and wind power plants) [2, 3]. In this respect, the authors present a very important block for change the direction of a current flow [4]. It is very useful block for the connection of a micro-hydropower plant to a smart grid, see Chapter 3. This paper presents also the measured characteristics of our micro-hydropower plant, see Chapter 4.

2. EXPERIMENTAL ELECTRICAL NETWORK

Small power plants utilizing renewable energy sources are connected to a grid. Some of these power plants are shown at the Automation Laboratory, Brno University of Technology, where the E.E.N. is located. Firstly, there is a PV panel and small wind power plant which are situated on a roof of the building. The micro-hydropower plant must be placed in other locations from practical reasons. But the performance of micro-hydropower plant is measured and information about power is send to our laboratory via a GPRS data logger. In E.E.N. is this information used for physical model of renewable energy sources (RES). Physically RES is the voltage control current source [1] Produced energy is stored in batteries and in the hydrogen container.

The physical realization of the E.E.N. is presented in the Fig. 1. The figure shows renewable sources (hydroelectric stations, photovoltaic, and wind power plants) connection to the smart grid. While the thick lines represent the material and energy flows, the thin lines indicated communication links. Each power control source communicates with the CompactRIO and LabView control system physically through the input/output circuits available via the wired connections in the laboratory.

The resources supplying energy to the E.E.N. describing in this paper are a water turbine and solar panels. Each of these elements supplies approximately 200–500 W peak to the E.E.N. Given the simplicity of the physical realization, the safety experiments, and the low cost, the E.E.N. works with 24 V DC. Very important part of the E.E.N is the Control Block 1 (CB1).

3. CONTROL BLOCK 1

Control block 1 denoted as CB1 serves both to dispatch energy to the grid and to charge the smart grid batteries. In order to secure correct operation and functioning of the CB1, the authors applied a step-up converter and designed a special step-down converter.

The first mode of CB1 enables to charge the local 12 VDC batteries (whose voltage may range between 11 VDC and 14.5 VDC depending on the battery charge status). The batteries are charged via a DC/DC converter, which behaves like a current source. The 24 VDC smart grid is used as the supporting source. The DC/DC converter is controlled depending on both the current sensed by

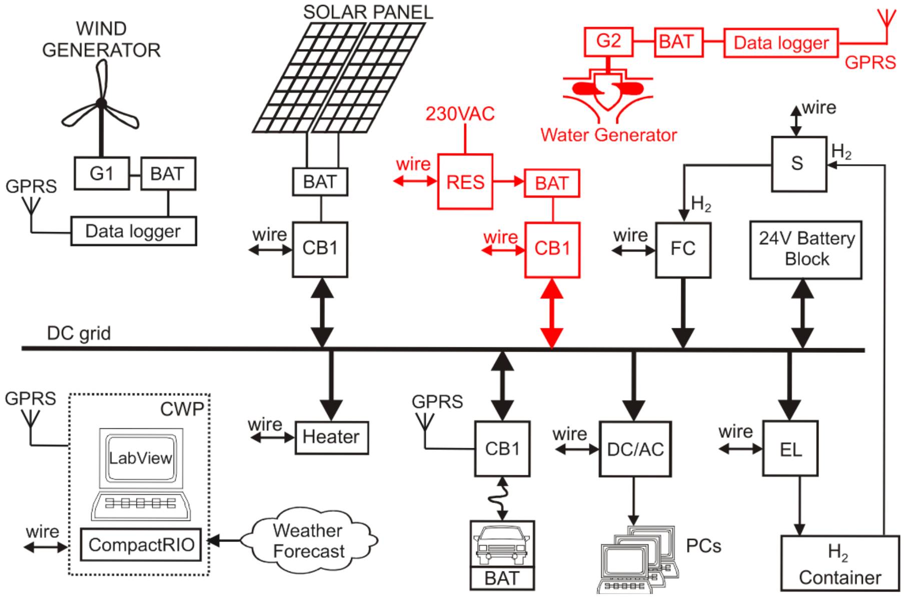


Figure 1: Block diagram of the experimental electrical network: **CB1** — Control Block 1, **BAT** — accumulator of DC energy, **RES** — physical model of remote energy source, **S** — valve to switch and control the hydrogen flow to the fuel cell (FC), **EL** — electrolyzer, **FC** — fuel cell, **G1** — wind turbine generator 24 Vss, 160 W, **G2** — water turbine generator 230 V, 50 Hz, 500 W, **Heat** — electric heater, **Container**: metal-hydride container of hydrogen, **CWP** — control work place.

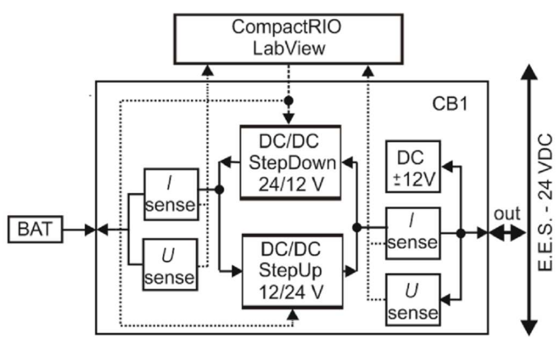


Figure 2: A block diagram of the Control Block 1.

a HY10 sensor and the voltage determined on a divider; the current and the voltage are measured at the CB1 input. The applied DC/DC converter is a special Linear Technology circuit controlled by a D/A converter via the LabView environment.

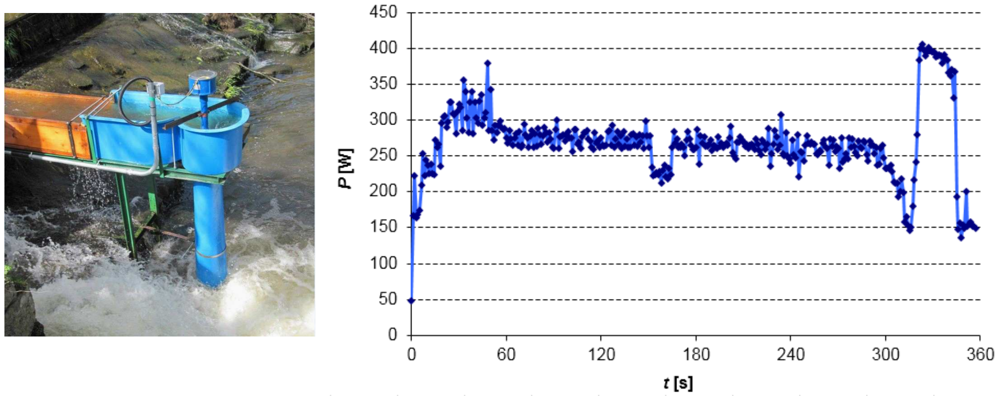
The second mode of CB1 allows power the 24 VDC smart grid from local 12 VDC batteries. For this purpose, we used a step down DC/DC converter, whose output voltage is controlled via LabView. In general terms, the controlling is performed through a D/A converter in CompactRIO; the output of the converter is connected to the controlling input of the changer. Here, the controlling is also realized depending on the output current and voltage, and sensor types similar to those applied within mode 1 are utilized.

Mutual switching between the two modes is performed using the LabView controlling interface; thus, the activity of only one converter (the step-up or the step-down) at a given moment is secured.

4. MONITORING OF MICRO-HYDROPOWER PLANT

A micro-hydropower plant has also been included in our E.E.N.. The capable of generating the maximum power of 500 W. For modeling of the E.E.N., it is very important to monitor the performance of the hydroelectric plant. The performance depends on the amount of water in the weir; this amount is proportional to the level h in the weir, which is used as the water source for the hydropower plant.

Figure 3 left shows our micro-hydropower plant and the right-hand side Fig. 3 shows a six-hour power recording. The regulator should keep the harmonic network voltage at 230 V and maintains the frequency of 50 Hz. It is possible to connect any load (and also a charger) to the output of the regulator.



(a) (b)

Figure 3: (a) Micro-hydropower plant, (b) six-hour power recording.

5. CONCLUSIONS

In this paper the connection of a Micro-Hydropower plant to an Experimental Electrical Network was presented. A new module, Control Block 1 — CB1, was designed. Then the paper presents the output power characteristics of our experimentally micro-hydroelectric power plant. This characteristic can be suitably utilized in the modelling of an E.E.N..

As the output power of a micro-hydropower plant markedly depends on the weather, With increasing precipitation, the water level in the weir of the station will rise, thus improving the output power of the turbine. For the six-hour power recording see Fig. 3.

The micro-hydropower plant can be connected directly to the grid loads via a regulator; alternatively, the energy can be stored in batteries. Data-loggers are located in the stations to transmit the measured output power data to an SQL server. In the future, the data could be used to support the entire process of modelling the functions of an E.E.N..

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