Study the Electrical Power Quality by Controlling Voltage and Frequency, to Attenuate Voltage Perturbations

FLAVIUS SARBU
Department of Engineering and Industrial Management
Transylvania University of Brasov
500036 B-dul Eroilor, nr.29, Brasov
ROMANIA
sfalvius@unitbv.ro

Abstract: This paper presents a model of an islanded mono-phase micro grid powered by renewable energy sources (RES) implemented at laboratory level. The aim of it is to study the electrical power quality by controlling voltage and frequency, to attenuate voltage perturbations (variations, drop-outs, sags, swells, flickers), waveform unbalances and harmonics, power failure and noises (high frequency noises, common mode noises, and spikes). The experimental laboratory model is based on a hybrid structure composed by a micro-hydro turbine (MHT), a wind turbine (WPP) and a photo-voltaic (PV) unit which deliver to consumer's electrical energy of 230V ac in good conditions of system stability.

Key words: electrical power quality, hybrid micro grid, renewable energy sources.

1 Introduction

Power quality, lately, has become a major concern, especially in the case of households, since proper operation of electrical and electronic equipment connected to the electrical network depends in large measure on the quality of electricity supplied to them. From the consumer point of view, quality of electric power is based on delivery of electricity without variations in voltage and frequency. The electrical energy power quality is a concept defined by the Institute of Electrical and Electronics Engineering (IEEE) by the standard IEEE 1100 and represents, in a broad sense, a set of indicators which allow a limit on electrical equipment to operate without loss of performance or service life [1]. The quality of electric power includes two components:

- quality of voltage curve (compared to a symmetrical sine wave);
-quality of service (in comparison with an uninterrupted power supply for a short/long term).

The quality of electricity to a consumer depends on: quality of electricity received (provided), the characteristic of tasks (costs) of its installations and the sensitivity of the equipment defects, disturbances and deviations from the quality indicators. On it, affect the following factors: generating, transport, delivery and consumers. The concept of quality includes mainly energy concepts of performance and longer service life. On the EU documents, since 1997, the concept of energy quality in general and the quality of electricity in particular, falls under sustainable development which has become a political target included in the Maastricht Treaty.

Regarding the Islanded Hybrid Micro-grids (IHM), we cannot speak of a uniform quality and control electricity international standards. Because of this, many issues are reflected in the work of the IEC (International Electrotechnical Commission). In addition to the general recommendations regarding the voltage and frequency, the Commission has drafted a set of regulations, classified by categories of electrical/electronic equipments, etc., which are provided for the basic requirements concerning the quality of electricity.

2 Description of the IHM

Development of an IHM supposed the knowledge of consumer characteristics as well as the characteristics of renewable sources which it feeds. All these informations are used to develop a system management strategy to enshure its stability. Improving the quality of electricity within IHM, involves mainly the voltage & frequency control, unbalances & harmonics compensation and attenuation of flicker and voltage fluctuations. Achieving these goals mainly depends on the IHM structure, types of energy sources involved, the adopted control strategy and the consumer types. The most widely used standard regarding the quality of electrical energy in the power systems, is the international standard IEEE 519-1992, [2].

In accordance with it, for monophase IHM, the rated frequency range is 50Hz ± 2% (49…51 Hz). In normal operating conditions, the average value of the voltage measured at the time of 10 min. must be within a U_n ± 10% band and the rapid voltage fluctuations not exceeding 5% of the rated voltage. The laboratory base structure of the mono-phase (230V/50Hz) IHM is presentef in the Fig. 1.

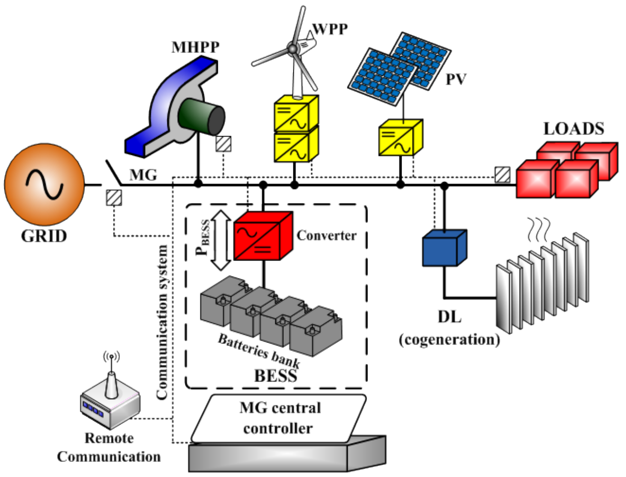


Fig. 1 Structure of the mono-phase IHM

It contains a microhydro turbine (MHPP) with synchronous generator (SG-5.5kW/1500 rot/min), a wind turbine (WPP) with permanent magnet synchronous generator (PMSG-2 kW/400 rot/min) connected by a ballast load (BL-4.5kW), a photovoltaic pannel (PV-0.6 kW) and a low power resistive load (DL-1.5 kW).

On the d.c. circuit part, as storage electrical energy device is used a set of gelly-lead batteries in total of 120V/26 Ah. The power of the converter to supply batteries is of 3kVA.

The IHM management is provided by smart meters, rapid and reliable systems of communication, automated systems and computer control of decision-making and implementation of quality services rendered to customers.

For a similar configuration, the theoretical and computer simulations have been presented in [3, 4]. In this paper are presented aspects related of laboratory experiments.

3. Laboratory experiments

Are considered the following experiments:

- ***MHPP turns on and SG connecting at IHM***

At no load starting of MHPP, a linear adjustment of loading turbine from 30% to 80% is imposed, as shown in Fig. 2.

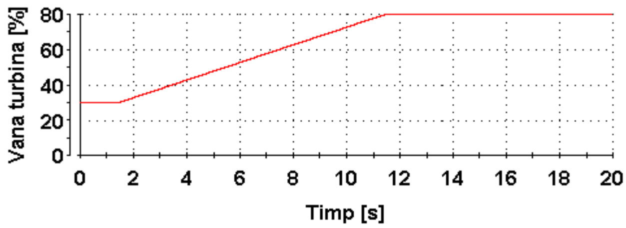


Fig.2 Loading of MHPP

In this case, all the active power loads the SG because the only load is the BL and its dissipated power is controlled by the intermediate of frequency controller, as depicted in Fig. 3.

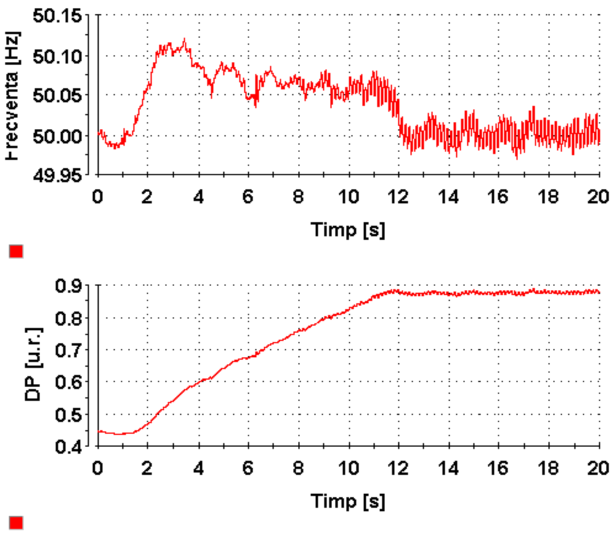


Fig. 3 MHPP frequency and frequency controller response

Results that frequency is maintained in a very narrow range of ±0.5Hz for the all time of transients, being stabilized at the rated value of 50Hz only after the SG loading. All this time, because of the frequency controller action, the voltage is kept quite constant. The balance of active powers within the MHPP (on SG and BL) is presented in the Fig. 4.

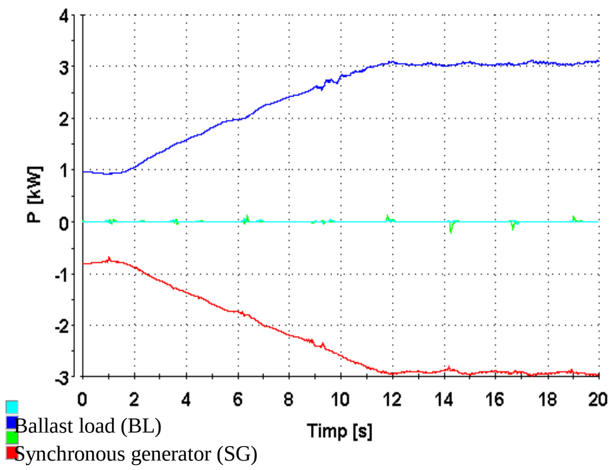
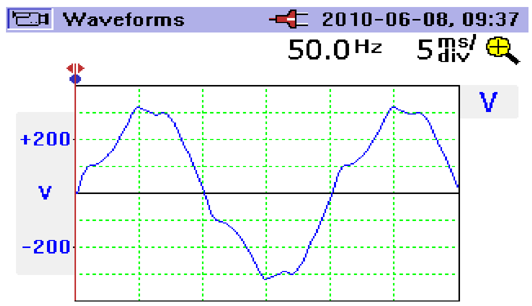
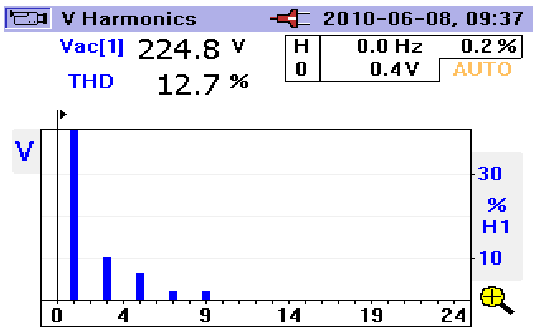


Fig. 4 Active powers within the MHPP

It is noted that at the end of transients, the GS delivers approximately 3kW power totally absorbed by the SB. In the Fig. 5 are presented the IHM voltage waveform and its harmonics.



a) Voltage waveform



b) Voltage harmonics

Fig. 5 IHM voltage waveform and its harmonics

We can note that the voltage waveform are quite sinusoidal with a convenient harmonics content.

- ***Connecting/disconnecting the load***

With the MHPP loading turbine at 80%, the IHM is tested at transient operating mode by consumption changing.

This is obtained by connecting/disconnecting within the IHM a resistive load of 1.5kW. It results, as shown in the Fig. 6, some deviations (0.5Hz) in the frequency from the rated value of 50Hz.

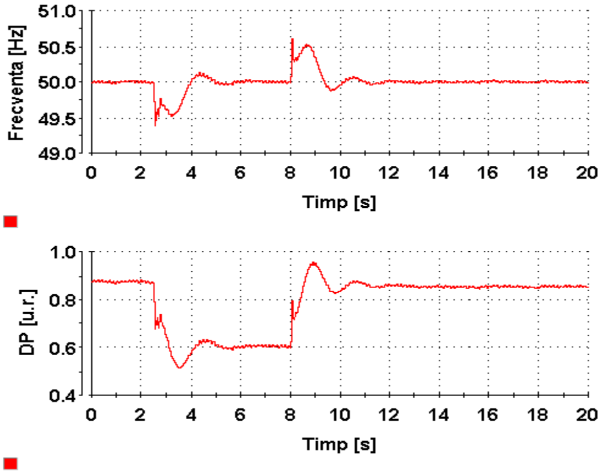


Fig. 6 IHM frequency and frequency controller response

In this case, the time of transients is approximately of 2s. During this time the voltage within IHM is quite sinusoidal at 230V.

- ***Connecting to the IHM of wind turbine***

It starts from the previous case conditions (MHPP loading turbine at 80% with a 1.5kW load connected in the IHM). In this situation the WPP starts rotaing the PMSG until the rated rotation (as reference one) and rated frequency of 50Hz (see Fig. 7).

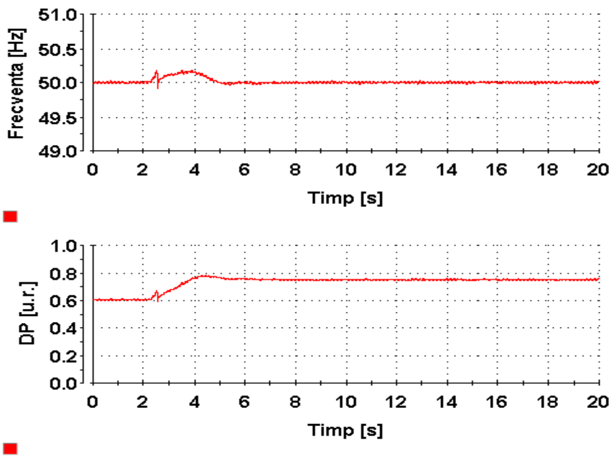


Fig. 7 IHM frequency and frequency controller response

The WPP delivers electricity in the IHM and through the converter, the microgrid voltage and frequency are increasely controlled until the rated values (see Figs. 7, 8).

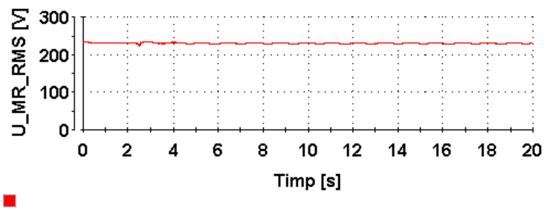


Fig. 8 IHM constant voltage

After connecting to the IHM, the wind turbine unit is increasely loaded with a smoothing power ramp of 0.5kW/s in order to avoid turbine mechanical shocks and sudden power fluctuations in the grid. Thus, the converter output power stabilizes at a value of wind speed.

- ***Random profile of wind speed***

In this case, it starts with the MHPP loaded at 80% with a load of 1.5kW and the WPP connected within the IHM. As random profile of wind speed (5...9 m/s, for a period of 100s), is considered the waveform depicted in the Fig. 9.

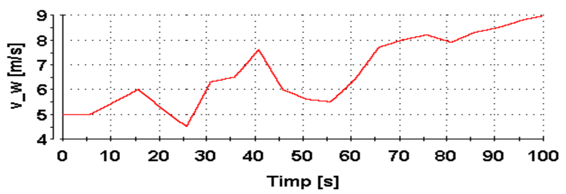


Fig. 9 Random profile of wind speed

It is seen that, during the operation, the frequency of IHM remains virtually constant at the rated value of 50Hz and the frequency controller shall act accordingly to ensure the stability of the system (see Fig. 10).

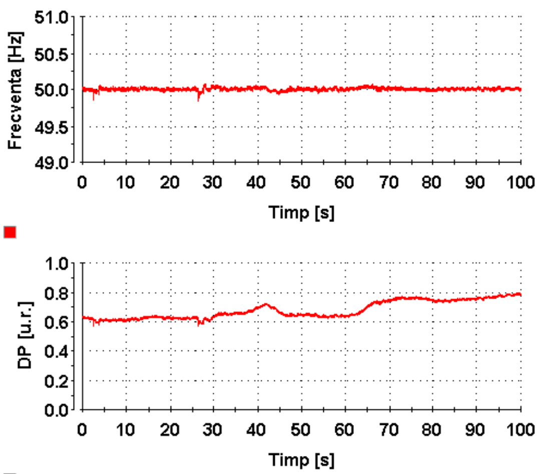


Fig. 10 IHM frequency and frequency controller response

The active power controlled by the WPP dc-ac converter is changed depending on the PMSG rotation and on the wind speed.

5 Conclusion

This paper presents problems relating to the integration of renewable energies within the IHM as smart structures, from the perspective of issues related to the quality and energy of the environment.

These issues have become a reality in continuous expansion in the EU countries.

Taking into account that electric power quality is in fact a very current problem for all categories of consumers, the author presents some laboratory tests regarding the mono-phase IHM powered by renewable energy sources.

Are reviewed practical aspects on the variations in voltage/frequency and continuity which are the main factors that affect the smooth functioning of the installations and equipment for all consumers, including those households.

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