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Monitoring and remote control of a hybrid photovoltaic microgrid

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ABSTRACT

The search of new alternatives for energy supply in island communities has always been a challenge in scientific and social context. In order to attend these communities, in January 2013 a photovoltaic hybrid microgrid project had its beginning at Universidade do Vale do Rio dos Sinos (UNISINOS). This paper presents the characterization and the development of such microgrid, monitored remotely via internet, which allows visualizing the electrical measurements, energy production and performing remote control actions. This work also aims increasing the interaction between students of universities to perform laboratory practices. The system consists of two photovoltaic modules technologies, mono and multicrystalline, totaling 570 Wp, connected to an energy storage bank of 200 Ah in 24 V and a pure sinusoidal inverter of 1 kW to supply AC voltage loads of 220 V. All acquisition components of data, conversion and management system are located in a control cabinet. Currently, the microgrid uses the utility grid as an auxiliary generator, simulating an alternative source of energy, which can be further replaced by fuel cell, biodiesel generator, etc.

Keywords-Hybrid PV Microgrid, Laboratory Practices, Monitoring, Remote Control.

I. INTRODUCTION

One of the fundamental pillars for the development of the economy is energy production. Its scarcity, or lack, brings reflections in search of a fast, reliable output to the energy problem [1]. This fact gives rise to trends in the development of energy production from clean technologies that can attend areas of difficult access with reliability and flexibility [2].

An island community, according to the concept commonly adopted in the electrical area, is the one that is characterized by not being assisted by conventional means of electricity, and therefore the lack of access to this source of energy directly affects the production and consumption processes in day-to-day of their individuals [3].

Considering the relative growth in the consumption of electricity in Brazil, it is necessary to develop an economically viable, reliable and sustainable alternative to assist in serving these communities, as a microgrid [4].

The field of research of PV solar energy is increasing and there are other studies about the hybrid microgrid area. Recent researches bring cases of hybrid microgrid in island communities, controlled by a supervisory and with a central management unit [5-7], other research pursues to improve the power delivery reliability and increase the system efficiency [8, 9].

This paper proposes the development of a remote platform of research and teaching, that allows the interaction of undergrad/grad students, to conduct laboratory practice, based in a photovoltaic hybrid microgrid prototype, installed at UNISINOS, that has the ability of generate, process and store energy, as an alternative supply to the electricity consumption of island communities.

II. SYSTEM DESCIPTION

2.1 The hybrid microgrid

The hybrid microgrid consists of two arrays of photovoltaic modules formed by two monocrystalline modules of 150 WP and two multicrystalline modules of 135 WP, both connected in series. Each array of modules is connected to a charge controller with Maximum Power Point Tracing (MPPT). The two charge controllers are connected into a battery bank of 24 V nominal voltage, connected to an inverter that converts direct current (DC) in alternating current (AC), with of 220 V voltage. The storage bank is loaded through the photovoltaic energy supply system, which also serves to feed a load in a scheme of “24 h X 7 days”, simulating an island community.

A specific controller, based on a free hardware platform - Arduino, performs the management of this hybrid grid. The controller manages the storage back energy entries and the power input to the load, according to the analysis of the state of the equipment/weather [10], and the programming requested by a defined protocol [11]. The auxiliary power system is justified as support in case of several consecutive days without the effective presence of solar energy.

2.2 Monitoring Of the Microgrid

The monitoring of the microgrid current state is performed through a supervisory, with remote access option for any maintenance holders or system updates, enabling their use during practical classes by remote control, through a monitoring platform at the University [5].

The Arduino controller handles all information relating to energy flow and grid management. This processor centralizes all electrical measurements provided by charge controllers, as well as solar radiation measurements obtained by Sunny Sensorbox.

Fig. 1 shows the Arduino controller, responsible for centralizing the system measures peripherals. Fig. 2 shows the diagram of the photovoltaic hybrid microgrid.

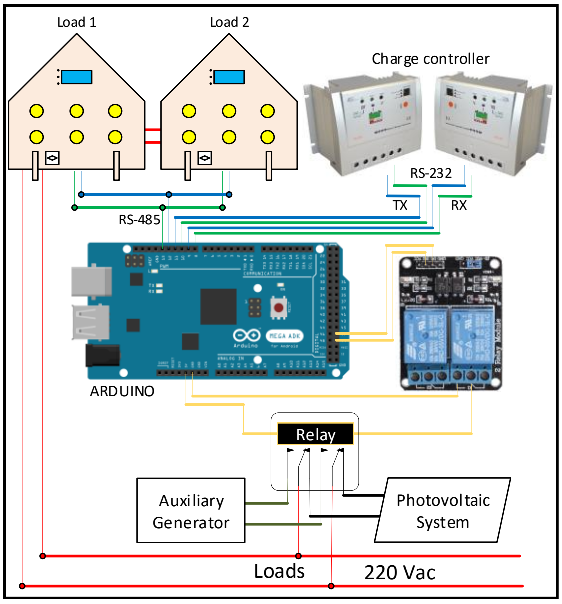

Figure 1 - AT mega 2560 Arduino [13] and peripherals

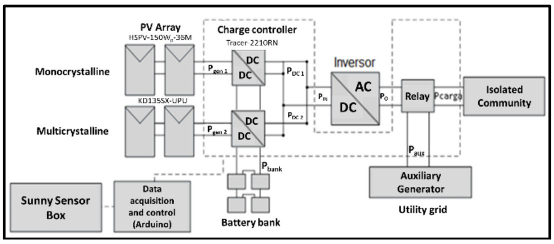

Figure 2 - Hybrid microgrid diagram

2.3 PV array details

In this hybrid microgrid are used two independent PV arrays. The first, composed of two monocrystalline modules, supplying electric power P_{gen1} (Power generation 1), and the second by two multicrystalline modules providing P_{gen2} (Power generation 2), (i.e., (1a; 1b), where I_{ger1} and I_{gen2} represent the electrical current, and V_{ger1} and V_{gen2} are PV array voltages.

$$P_{gen\,1} = I_{gen\,1} V_{gen\,1} \quad (1a)$$
$$P_{gen\,2} = I_{gen\,2} V_{gen\,2} \quad (1b)$$

Each array is connected to a charge controller, respectively generating an output power P_{DC1} and P_{DC2} responsible for loading the storage bank P_{bank} and supply electric power to the inverter Pin, (i.e., (2a; 2b), where η_{MPPT} represents the maximum power point tracing efficiency of the charge controller.

$$P_{DC1} = P_{gen\,1}\eta_{MPFP} \quad (2a)$$
$$P_{DC1} + P_{DC2} + P_{bank} = P_{in} \quad (2b)$$

The inverter input power is expressed by (i.e., (3a; 3b), because the controllers, the storage bank and the inverter input are on the same electrical potential. The inverter converts the electric power (P_{in}), received as direct current, to alternating current (as electric power P_o). Under normal conditions of work, the power delivered to the load (P_{load}) is fully supplied by the inverter, (i.e., (4). However, when the battery bank is in a critically low level, the system controller (Arduino) turns off the inverter output and activates the auxiliary power (P_{aux}) to supply the load, (i.e.,(5).

$$V_{DC1} = V_{DC2} = V_{bank} = V_{in} \quad (3a)$$
$$P_{in} = (I_{DC1} + I_{DC2} + I_{bank})\, V_{in} \quad (3b)$$
$$P_{in} = \eta_{inv} P_o = P_{load} \quad (4)$$
$$P_{aux} = P_{load} \quad (5)$$

III. RESULTS

3.1 The Pv System Installation

The photovoltaic modules support are fixed in the building, taking into consideration the best place to avoid shading, as shown in Fig. 3.

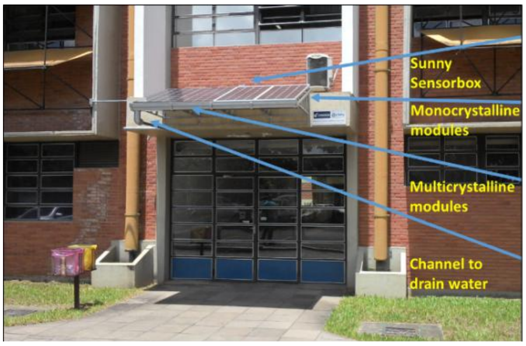

Figure 3 - Photovoltaic modules

Fig. 4 shown the energy conversion and control panel installed in the laboratory. In front of this, we simulated the charge of the system by a series of lamps that are programmed to switch at a set time, simulating a house, as shown in Fig. 5.

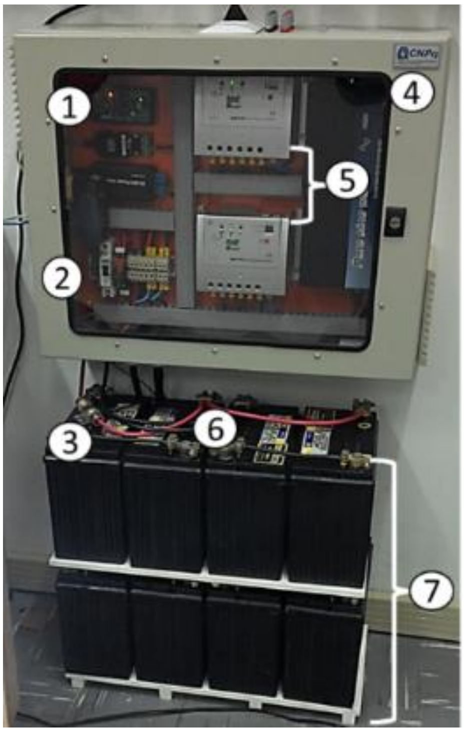

Figure 4 - Energy conversion and control panel

On Fig. 4, the numbers mean: 1-Arduino controller, 2-Breaker and terminals, 3-Fuse, 4-Sinusoidal inverter 1000W, 5-MPPT Charge Controller, 6-Power cables, 7- Battery bank- 24 V / 200 Ah.

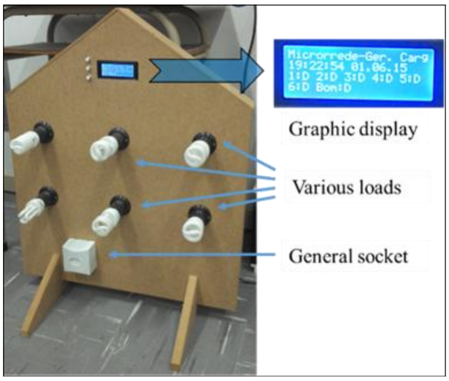

Figure 5 - Control charge and graphic display

3.2 Monitoring System

The monitoring equipment was carried out via a remote access over the Internet, which allows access to all system parameters. This equipment also provided physical view of the components by cameras, as shown in Fig. 6.

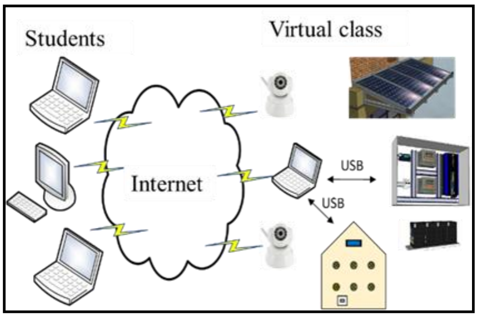

Figure 6 - Monitoring system

3.3 PV system operation

The results were obtained considering a single standard charge (computer), with information extracted directly from the controller charge and Sunny Sensorbox. In this step, the use of an auxiliary power source has not been necessary. The sampling interval was 30 seconds.

Fig. 7 shows a graph of the output voltage of the PV arrays. It is possible to see in this graph, that there is a natural fluctuation in the value of the output voltage in function of the irradiance and MPPT system charge controller. The irradiance that the modules are exposed and the temperature in the center of the panel modules are illustrated in Fig. 8.

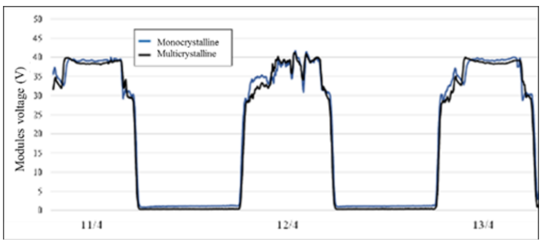

Figure 7 - Output voltage of the PV modules connected in charge controllers

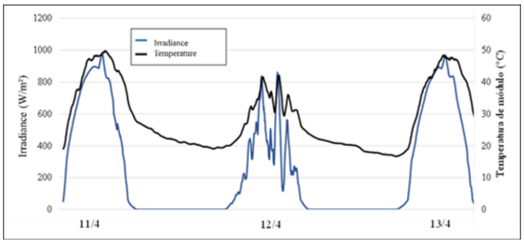

Figure 8 - Irradiance and module temperature

Fig. 9 shows when the battery bank enters its state of full charge. After a few minutes in this state, the storage bank is subjected to a float voltage, guaranteed by the charge controller.

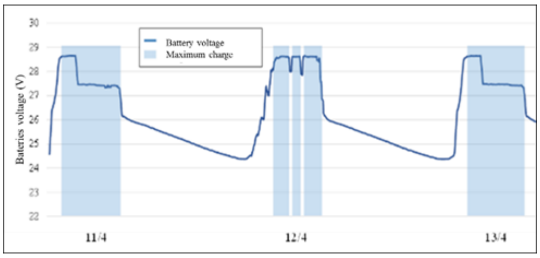

Figure 9 - Voltage and charge status of the storage bank

IV. CONCLUSION

Was observed, through electrical measurements obtained by the acquisition system that the microgrid is working properly. Monitoring and system control over the internet shows up an important tool to be used at Universities, providing greater interaction between students, facilitating the learning of this technology through the subjects taught, inside and outside the institution. The improving of technologies, which help students to learn about alternative energies, are important to increase its use and incentivize the application of new ways to teach, interesting and helpful to teachers and students. Therefore, the incentive to studies that cover this area could get the advance that Universities need. The next step of this research will assemble practical experiments in a virtual environment, using all available resources, as a control charge with a home island standard program..

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