ISSN 2229-5518

Study of a 1.5 kW vertical wind turbine

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Abstract— The aim of this work was the study of a 1.5 kW vertical Wind Turbine, made by Enersud, assembled above the Electronic Engineer Building of the Feevale University. The work consisted in the specifications of the Turbine (shovels), tower and control panel. This wind turbine generates 48 Electric Voltage Tension, connected in a 4-battery of 12V bank, that are connected to a 220 V three-phase inverter, and in its turn, is connected in a bank of resistive charge. The study included, in addition to the specification of the whole device, tests of the wind turbine in operation. In the tests, the wind turbine was unlocked, generating a Voltage greater than 48 V which was charging the batteries. In the output of inverter was generated a three-phase alternating voltage of 220V and frequency of 60Hz.

Index Terms— battery bank, three-phase inverter, vertical wind turbine, weather station.

1 Introduction

THE radiation emitted by the sun that arrives at the Earth combined with the rotation of the planet, are responsible for the displacement in great proportions of the gases present in our atmosphere. When a region of the Earth warms up, the atmospheric pressure in that region decreases and the air rises, thus creating a difference in atmospheric pressure and causing the surrounding, colder air to move from the area of greatest pressure to the area of lowest pressure. The amount of solar radiation absorbed near the Equator is greater than that absorbed at the poles. To prevent the tropics from getting hotter and hotter and the poles getting colder, there is a continuous transfer of energy. Thus, the air from cold surfaces circulates from the poles to Equator to replace the hot air that rises in the tropics and moves through the upper atmosphere to the poles, completing the cycle of heat redistribution on the planet. Although air can move in a vertical direction, the term "wind" is applied only to horizontal movement, parallel to the planet's surface. [1-3]

The use of energy contained in the wind by man is not something new. The development of maritime exploration together with the discoveries of new continents were provided by the use of this form of energy. The first windmills appeared in Persia, around 200 B.C., developed with the purpose of replacing the use of human or animal force in the process of grinding grains and pumping water. The use of this technology arrived in Europe only after the crusades that took place between the 11th and 13th centuries, where soldiers returning from the east brought information about this development. Among European countries, Netherlands was the one that most disseminated the use of this technology, using it mainly for the drainage of flooded lands. The first attempts to harness wind power to generate electricity took place in the late 19th century. However, its use did not prosper due to the industrial revolution and the invention of steam and internal combustion engines that made fossil fuels take over primary source of energy. In the 1970s, after successive increases in the price of oil, wind energy reappeared as an alternative source for the production of electricity through wind turbines. Since then, its use has been strongly expanded and popularized, enabling new developments in this area. [1-3]

The installation of a wind turbine requires prior knowledge of the area where it will be installed. The type of connection of the wind system and the wind profile in the region are the starting points for choosing the equipment that will compose the generator system. Systems called "connected" (grid-tie) are used where there is already an electricity grid, in which the surplus of generated energy is sent to the local grid. "Isolated" systems (off-grid) are used in places where there is no access to the power grid and all the energy generated is then stored in batteries. The characterization of the wind profile through measurements and analysis of wind speed and direction allows to decide in a precise way the best settings for the wind turbine, since these machines have different configurations in relation to the rotor position, shaft position, number of blades, speed of rotation, type of power control, type of tower, among others. [2]

Systems connected to batteries are suitable for applications in locations without access to energy, being a very popular solution in applications of lighting, telecommunication, security and monitoring, water pumping, rural electrification, access to energy in general and backup in systems connected to the network. They have very different characteristics from the systems connected to the standardized network and present a wide market spread throughout the national territory, in urban, rural and coastal areas. Vertical axis wind turbines are characterized by the fact that the wind direction is not an important factor for the successful generation of energy from this equipment. Its main characteristics are the vertical rotor axis and the location of the generator and other components that produce electricity at the base. This type of wind turbine can be fixed to the floor or roof of a building. [2, 3]

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2 Materials and Methods

The main characteristic of the isolated wind power generation system is "self-support" by batteries. The system is not connected to the power grid, storing surplus wind energy in batteries to be used at a time when there is no production. The system can supply household appliances and electronics that use energy directly. The operation of an off-grid system uses equipment such as wind turbine (responsible for transforming wind energy into electrical energy), battery bank (storage of converted electrical energy, allowing its use at any time), charge controller (device that acts in charge management of the battery bank) and the off-grid inverter (converts the energy stored in the batteries into alternating current). [5, 6] Figure 1 presents the operation flow chart of an isolated system.

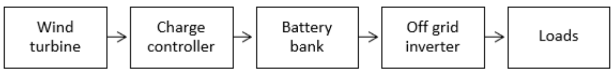

Fig. 1. Energy generation flowchart in an isolated system.

2.1 Wind Turbine

A RAZEC 266 wind turbine was used in this study. This wind turbine is Darrieus H type, which is suitable for urban areas, because it presents low rotational speed, very poor noise level and is adequate for turbulent winds and with variable direction, characteristic of the site was the turbine was mounted (Fig. 2). The RAZEC 266 turbine has been developed to meet energy needs, depending on wind speed, a middle-class residence or demands such as telecommunication stations, water pumping, public lighting of condominiums or residential, among others, and can be applied to insulated systems (use of batteries) and connected to the network by power inverters. [6, 7]

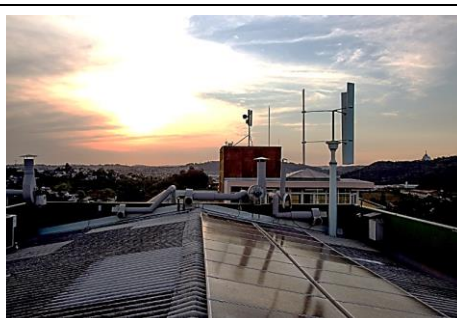

Fig. 2. Top of Green Building in Feevale University.

The main specification of the vertical wind turbine has described in Table 1.

2.2 Charge controller

The charge controller is a very important component of the system. Its function is to prevent the battery overload, and to block the reverse current. The charge controller is usually added sensors such as voltmeter, ammeter, wattmeter, so that the information can be read and verified. The charge control, in most controllers is made through the modulation of voltage by the varying width of pulses CC, better known as PWM (pulse width modulation), where basically is defined intervals between the maximum level of voltage in the output of the Controller and the value of 0 volt, thus controlling proportionately the amount of load that will be sent to the batteries and other equipment [7]. The charge controller used in the project is produced by the same manufacturer of the wind turbine and it was showed in Fig. 3.

TABLE 1
Wind Turbine Specifications

Specification	Value
Model	RAZEC 266
Manufacturer	ENERSUD
Rotor diameter	2.0 m
Height of paddles	2.66 m
Power at 12 m/s	1500 Watt
Number of paddles	3
Starting speed	2.5 m/s
Starting Torque	0.3 Nm
Speed control	Stall and electromagnetic brake
Magnetic System	Neodymium (permanent magnet)
Output voltage	24/48/220/400 V

Fig. 3. Inside view of charge controller

2.3 Battery bank

The function of the batteries is to store the energy generated by the wind turbine that, because it is a power generation where energy production can vary both in potential, and in quantity. Therefore, it becomes difficult to maintain the level of output of the system stable. Thus, it is used of battery associations, which accept a variation in their supply, but maintains a stable the output voltage level. The most recommended type for use in power generation systems are stationary batteries [8]. Stationary batteries feature a deep energy discharge and can be used in UPS/nobreak, PBX, telephone switchboards, signaling, emergency lighting, solar power, wind power, remote monitoring, alarms, electronic surveillance, electrical substations, banks, telecommunications, databases and other [9].

ISSN 2229-5518

The stationary batteries used was Freedom DF 4001 were designed so that the effects of the corrosion of the poles and the expansion of the plates do not impair their performance and to support the existing efforts during their transport and handling, avoiding electrolyte spill. The main specifications are describeb in Table 2. The stationary battery is a maintenance-free battery, so it does not need to replenish water or electrolyte during its lifetime. This model of batteries is designed for a lifetime of more than 4 years at a temperature of 25 ºC and P20% discharge depth. The batteries were interconnected to form a 48V battery bank shown in the Fig. 4. [9]

TABLE 2
BATTERY SPECIFICATIONS

Specification	Value
Voltage	12 V
Fluctuating voltage	From 13.2 to 13.8 V @ 25 ° C
Load/equalization voltage	From 14.4 to 15.5 V @ 25 ° C
Weigh	59.90 kg
Dimensions (length, height, width)	530 x 280 x 246 mm

Fig. 4. Inside view of charge controller

2.4 Inverter

The inverter is that perform the conversion of the continues electric current stored in batteries for a standardized alternating current according to the final specification, normally alternate current. There are basically 3 types, synchronous, isolated and multifunctional inverter [8]. The synchronous inverter uses the conventional electrical network as a storage system, that is, when there is plenty of energy it is possible to inject energy into the conventional network, so it can be sold to the city's energy distribution company, provided that the project has been approved, and all requirements and equipment are in accordance with the company's standards. The contrary is also valid, if there is need, power of the conventional network can be consumed if the system is unable to meet the requirement of the project. The SA sign output provides pure sine wave [7]. The isolated inverter converts the continuous current power (CC) stored into the batteries for alternating current (CA). Output signal can be transformed into square wave, modified sine wave and sine wave. The multifunctional inverter aggregates the functions of the synchronous and isolated inverter. Connected to the battery bank, installation distribution and conventional electrical network [8].

The static inverter is intended to convert continuous current supplied by a source of accumulators, in alternating current of 115/220v-60hz. Among the most frequent applications we can mention the use of appliances, electronic equipment, Refrigerators, including motors, etc., through a battery bank. The operating principle is based on electronic circuit, with adjustable switching control with voltage control and frequency that excites a transformer elevator. Fig. 5 shows the inverter used.

Fig. 5. Three-phase inverter

2.5 Resistive load

For the tests of the generator, the system has a bank of resisting loads of 7.5 KW (Fig. 6) which can be connected in various ways in different potencies.

Fig. 6. Resistive load bank

2.6 Monitoring system

The monitoring of output power of each module of the three-phase inverter are performed by a Web Box manufactured by Tecnomaster. The Table 3 describes the main specifications of the system and Fig. 7 shows the Web Box mounted in a case and installed, in which it can be seen that it is connected to a computer and a TV and

TABLE 3
OFF-GRID INVERTER SPECIFICATIONS

Specifications	Value
Nominal voltage	48 V
CC Input	41 to 48 V
AC Output	220 V, 60 Hz, 3 phases
Power	2.5 KVA
Output wave	Modified sinusoidal PWM system

Fig. 7. Monitoring system

2.7 Mini weather station

The monitoring of incident solar radiation, wind speed, humidity and temperature is carried out by a mini weather station. The anemometer used was the RK100-02 reference type of the Hunan Rika Electronic Technology Co, the irradiation sensor used was a sensor based on a 50 x 33 mm monocrystalline silicon crystal solar cell supplied by ENERPRO company. The DHT11 sensor was also used to capture humidity and temperature. The shows the station mounted on the roof of the Feevale University Green building.

Fig. 8. Mini weather station

The monitoring system is installed in the same building that the wind turbine. An electric circuit was built to acquire the signals generated at the mini station via cable, where from two microcontrollers, the data are processed and recorded and shown from a display. The microcontrollers used is a ATtiny85 in the weather station and a Atmega328P-PU in the show display. Figure 9 show the data acquire system of the mini weather station develop by the Feevale University students.

3 Results and Discussions

The proposed system was assembled at the Feevale University, according to the schematic diagram of Figure 1 where it can be observed that the generator sends the power to the controller that feeds the batteries (48 V), these transfer the power to the three-phase inverter (3 2.5 kW inverters each phase which totals 7.5 kW with output voltage of 220 V), which feed a resisted load of 7.5 kW used to simulate consumption loads.

Fig. 9. Mini weather station DAQ

The generator has been unlocked and performed some tests. In these tests it was verified that the output of the controller of the generator generated voltages greater than 48 V (battery bank), which carried these batteries. It was not possible to check the rated power (or the maximum), because, until now, the speed of the winds could not be determined. In the output of the inverter, tensions were also measured, which remained in 220 V (three phases). It was also connected to the resisting cargo bench and some powers were measured, always below the nominal power of the generator, which is 1.5 kW.

4 Conclusions

The system of the generator (wind turbine, charge controller, battery bank, inverter and load bank) was successfully installed, generating electric power of 220 V three-phase and frequency of 60 Hz. It was not possible to check income or performance relationships once that it has not yet been installed the anemometer, with which it would be possible to observe the speed of the winds and thus to conduct empirical studies.

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