The Study of Low Power Wind Turbine Joliet Cyclone

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Abstract – The project aims the study of the wind turbine named Joliet Cyclone with a power of 1 kW, which is located on the Technical University building placed on Centre Street in Cluj Napoca. It is used in several purposes, such as teaching students, for the MA and PhD research and for the popularization among renewable potential investors and local governments.

Keywords – low power wind turbine, alternative energy, wind energy.

I. INTRODUCTION

Briefly, the system operation is as follows: the turbine will generate from the wind energy a 60Vdc voltage at a certain power level, that will charge (with electric current) of a storage battery of 48Vdc; the energy of the battery is converted into alternative energy (230Vca/50Hz) by an inverter of 2.5 kW.

Coupled with the wind turbine, the wind generator is three-phase synchronous with an excitation from the permanent magnets. The link between the generator and the power supply is made by a three-wire cable (three-phases) .

The electricity generated is brought from the wind generator by a three-phase cable.

In this electric panel the cable is connected to the input of the electric arrested, which protect the all installation of any thunderbolts over-tension's arrived from turbine, although the turbine is surpassed in height by the lighting rods assembled on the building.

On this electric panel there are also assembled the DC bars , the fuses and the protection switch.

After the entry into electric arresteds (simultaneously linked towards the table), we go into a protection switch.

This additional protection works when the electronic part of the power supply become inoperable or when the switch S1 is intentionally open .

The switch disconnects the link to the batteries and produces a short-circuit to the generator phases, blocking it by electrical braking. The turbine is further protected from the high wind speeds by the Furlings system, when the turbine rotor deviates from the wind direction.

At the exit of the switch there is the batteries charger, which will be presented below.

The electricity is brought from the charged regulator to the DC bars, which represents a knot that allows both the connection of the batteries and the inverter.

The power of the inverter has not a direct connection with the power of turbine, which can be higher, by taking energy from the batteries. The inverter's input voltage will be 48Vcc, the same with the wind turbine's voltage.

The wind turbines with variable speed (no speed control system) and alternator must be fitted with an electronic load controller, that prevents the turbine's over speed if there is not an electric load (consumer) and if the batteries are charged. The solution is to detect this situation and to connect a load ballast (dump load), usually made of an electric resistance, air-cooled (a natural or forced cooling). The heat produced in this resistance does not recover, it is dissipated into the environment.

In the Figure 1 we illustrate the previous descriptions:

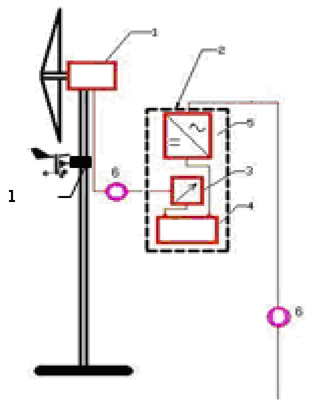

Fig. 1 – The wind turbine used in research:
1 – the wind system, consisting of pillar, wind turbine and wind generator, 2 – a support for accumulator batteries, inverter and charging batteries, 3 – a battery charge controller, 4 - the accumulator battery, 5 - inverter, 6 - electric cables.

II. THE CHECKIMG OPERATION OF THE WIND SYSTEM

The Figure 2 shows an oscillogram of the voltage between the phases of wind generator at a wind speed of 4 m/s.

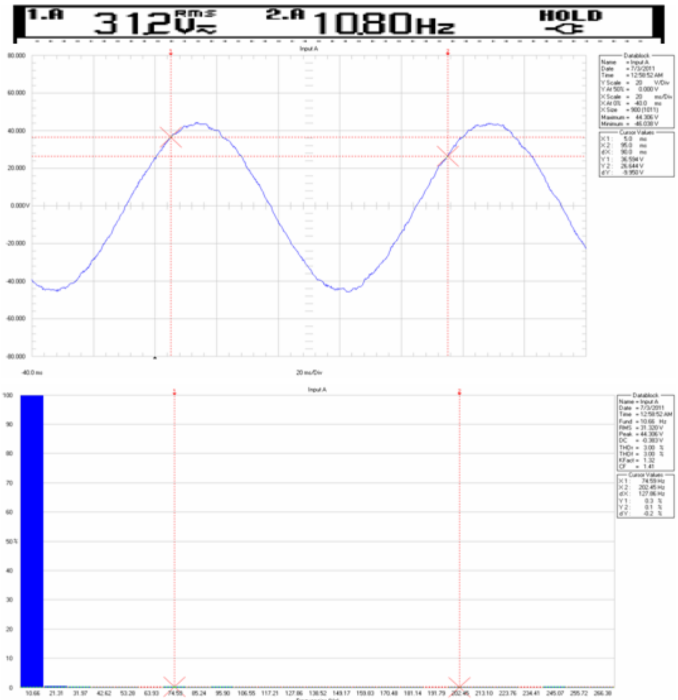

Fig.2 – The Wind Generator Voltage at v = 4m/s

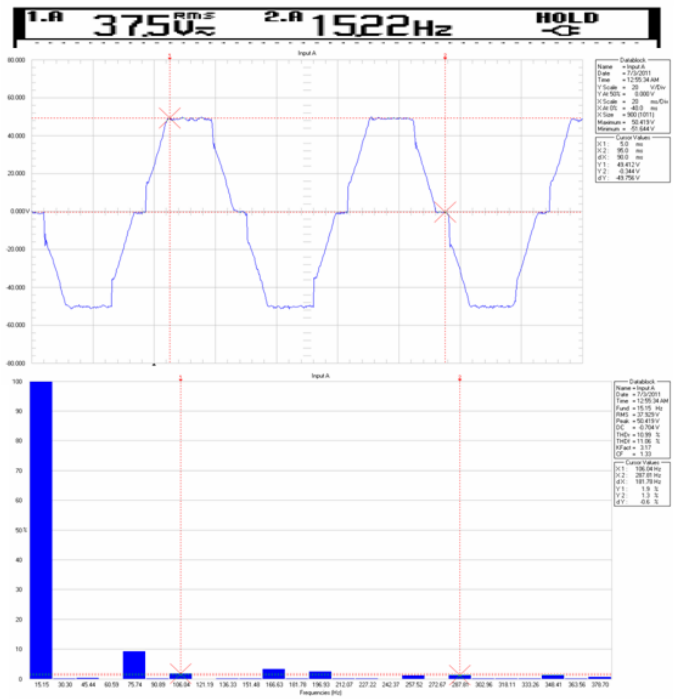

Fig.3 – The Wind Generator Voltage at v = 6m/s

In this chart you can read the following parameters of the wind turbine: the line voltage: 31.2 Vac, the frequency: 10.8 Hz.

These sizes were measured with the network analyzer Fluke 192C.

It can be seen that at this generated voltage, its form is a sinusoidal one, the saturation of magnetic circuit does not turn up and the harmonic analysis of the generated voltage shows a regime indicator THD = 3%, smaller than the allowed (5%). After the implementation of the monitoring system SCADA , these parameters will be available depending the time and they will allow by integration the calculation of the electricity supplied by wind turbines.

The Figure 3 shows an oscillogram of the voltage between the wind generator's phases at a wind speed of 6 m/s. From this chart on can read the following parameters of the wind turbine: the line voltage: 37.5 Vac, the frequency 15.22 Hz.

This time, the form of the voltage is not perfectly sinusoidal is a cut sinusoid, probably due to the saturation of the magnetic circuit. The harmonic analysis of the generated voltage indicates a high number of harmonics (5, 7, 11 and 13) and therefore a THD = 10.99%, higher than that allowed in the public low-voltage network. But this is not important because this voltage will be rectified and AC will be regenerated with a perfect sine wave inverter.

A. The Checking Operation of the Battery Charging Controller

The battery charging controller was adjusted so that at the excell of 58 Vdc voltage after the recover, it acts a switch and it contacts a Dump Load ballast. This is an hysteresis, that means the switch will be disconnect when the rectified voltage drops below 52.5 Vdc.

It was also stipulated that at the disconnect of the normally closed switch is simulating a loss of the charging controller's load, there acts another switch that interrupts the connection between the wind generator and charging controller and put it in short, by braking.

B. The Checking Operation of the Storage Battery

The battery's voltage was measured before initial operation and on obtained a value of 48 V_{dc}. After its maximum load capacity, indicated by the fact that at the smallest presence of the wind (the turbine's startup), the Dump Load starts and its voltage is at 56V_{dc} comes into dump their load and voltage was 56 V_{dc}. Under a voltage of 44 $V_{dc,}$ the inverter arrives at the emergency operation - Low voltage.

C. The Checking Operation of the Inverter

We adjusted a maximum value of the inverter's current at 15A and we realized that the over current protection acts in case of the surpassed value.

III. THE HOMER MODEL OF THE WIND TURBINE

A. Presentation Model

The experimental stand presented in this chapter will be further simulated by HOMER simulation software developed by National Renewable Energy Laboratory NREL U.S..

The components of the model are:

- the wind subsystem of 1 kW;
- the deap cycle batteries;
- the Victronics frequency converter;
- the DC-bars (48 V_{dc});
- the AC-bars(230 Vac, 50 Hz).

The physical model of the wind turbine is mounted on the building of UTCN, on the Centre Street, in Cluj Napoca, at an approximate distance of 30 m above the ground and near the top of the Feleac hill (elevation ~ 430 m). However, in this location, the wind speed has not an high annual average. For this reason, when there is wind, the produced electricity will be stored in the battery pack and, by inverter, it will be used about 3 hours / day (10.00 AM - 13.00 PM) in the laboratory for the performance tests with the hydro subsystem of the hydro wind hybrid stand.

B. The HOMER Wind Subsystem

The Figure 4 shows the characteristic pattern of the Homer wind subsystem.

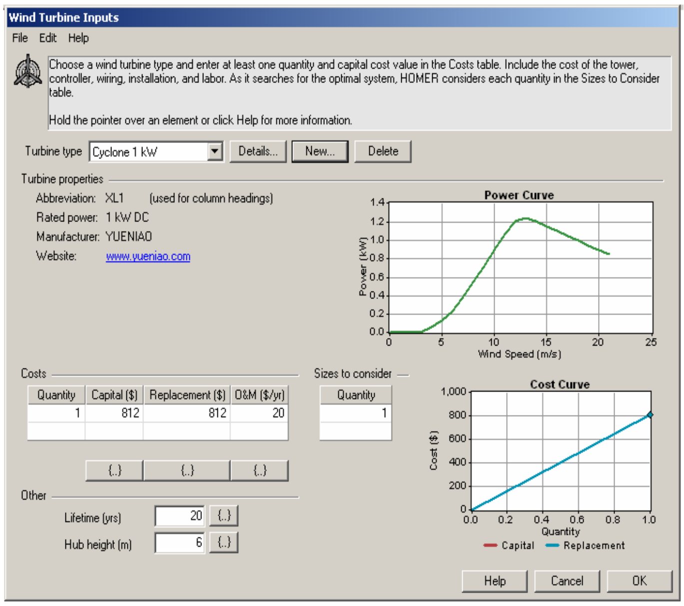

Fig. 4 – The HOMER wind subsystem

For this modeling we considered the Joliet Cyclone wind turbine of 1 kW at an affordable price of $ 800.

C. The HOMER MODEL for the Batteries

The battery is composed of 4 AGM (absorbent glass material) batteries with a capacity of 200 Ah 12V (BAT412201080). This kind of battery can withstand 200 cycles of charge / discharge when the battery is fully discharged and 900 cycles if only download up to 30%. It results that the battery management is very important for the life of those products. The model battery is presented in the Figure 5.

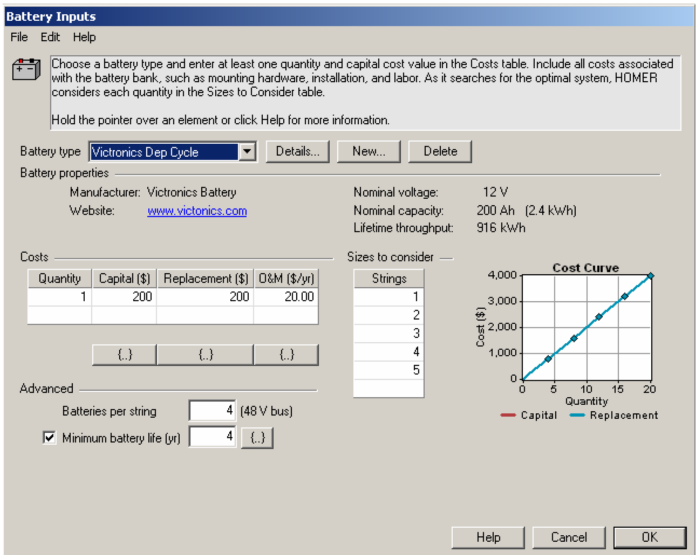

Fig. 5 – The HOMER model of the Batteries

D. The HOMER Model of the Frequency Converter

The choosing of the converter was predominantly based on the power engine which was to be operated (Pconverter > Pengine), the number of the supply voltage phases, the supply voltage, the ambient conditions, the operating mode, the command mode etc. We chose a 3 kW frequency converter with characteristics seen in Figure 6.

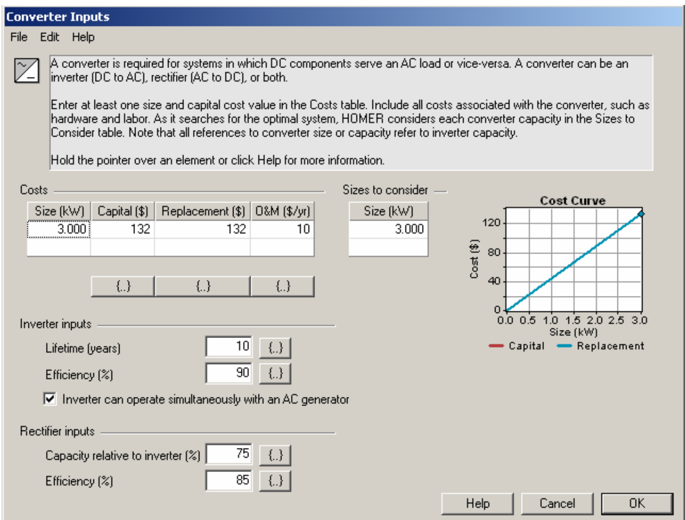

Fig. 6 – The HOMER model of the frequency converter

In Figure 7 on presents the simulation results considering two criterions: the average cost of electricity produced ($ / kWh) and the number of batteries required depending on wind speed.

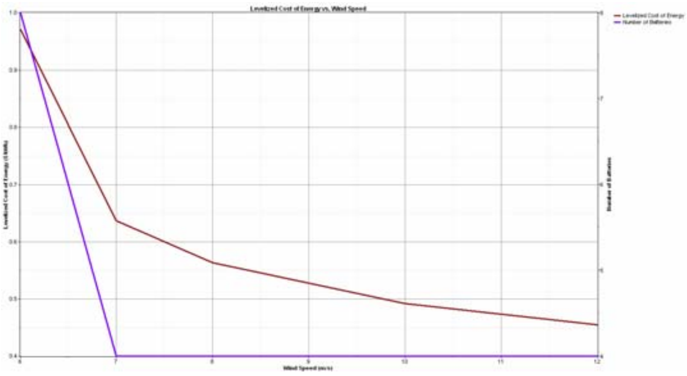

Fig. 7 – The number of batteries and energy costs on the basis of wind speed

As we can see the cost of the produced electricity will decrease with increasing wind speed. Also, at an annual average wind speed of less than 7 m / s, we need eight lithium-ion batteries. The reasoning is that at the lower average speeds, the wind turbine is not large enough to provide directly a part of the load and the part which have to be stored. We can see also that in low wind speeds both system cost and the cost of energy values are quite high.

CONCLUSIONS

It was made a functional low-power physical model hydro-wind hybrid system, useful for educational purposes and master students and PhD research.

Simulation of dynamic solution designed and built, and an economic analysis of low-power physical model realized.

The results of simulations show that the proposed model for the study of the dynamic behavior of a low wind power system is very close to the real model. This model can be integrated with a hydro energetic model to obtain hydro-wind hybrid system model.

An economic analysis of the experimental stand CHHE using HOMER software, developed by NREL in the USA, it was also made.

We In order to validate the results of simulations for case studies or small-scale physical model some experiments were made in laboratory.

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