THE DETERMINATION OF THE BALLAST RESISTANCE USED FOR THE CONECTION TO AN EXPERIMENTAL STAND FOR THE STUDY OF THE HYDRO – WIND HYBRIYD POWER (CHHE)

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Abstract - This paper point out some of the experimental determinations that must be made in the achieving of a hidro - wind hybrid system. It highlights the design and implementation of a1 kW ballast resistor and 48 V nickel-chromium wire, with the diameter of 60 three millimeters and connecting cable at the wind turbine by electric panel. Thus, this experimental stand CHHE includes a wind turbine 1 kW, placed on the roof of the Technical University of Cluj Napoca (this place is favorable because the wind has high speeds at great height) and hydro turbine type Pelton 1 kW power. The experimental stand for the study of CHHE hybrid energy system will allow the determination of more experimental conclusive on the impact of the achievement of an energy balance of the physical model.

Keywords: experimental low-power stand, dump load, experimental determinations.

1. INTRODUCTION

The Technical University of Cluj Napoca has an experimental low-power stand (1 kW), because they were considered primarily the costs. This stand is locate in the building of the University, Observatory Street, no. 2. It is used for teaching and research.

The components of the experimental stand are:
- a 1 kW wind turbine instaled on the roof of Technical University of Cluj Napoca,
- a 1 kW Pelton hydro turbine.

In the figure 1 we can see the building where is instalated the wind turbine.

The two physical models (the wind turbine and the hydroelectric pumped storage - CHEAP) are connected to each other (experimental stand CHHE). So, the electricity produced by the wind turbine and stored in the batteries will be used to supply the CHEAP pumps.

Fig.1. The Building UTCN, Observatory Street no. 2 Cluj -Napoca

2. THE FUNCTIONAL DESCRIPTION OF THE EXPERIMENTAL STAND

The experimental stand works as follows: from the wind energy the turbine will generate a voltage of 60 VDC at a certain power level that will load (current) a 48Vcc battery, from here the energy of battery is converted into alternative energy (230Vac / 50Hz) by a 3kW inverter. The energy of the inverter drives a pair of pumps (2x1.1 kW) which action a 1 kW microhidrogenerator, which in turn generates a 24 VDC continuous energy that is consumed as needed.

The water circuit together with pumps, hydrogenerator and tank is a closed one.

The SCADA system follows the operation described above . So, there are measured the energies, the voltages and the currents: from the generator, the battery charger, the inverter and the ballast resistor.

For modeling we purchased a 1 kW wind turbine manufactured by Joliet Cyclone, with three blades, a diameter of 2.7 m, the nominal speed of 9 m / s and the operating temperature falling within from -40 ° C to 60 ° C .

The turbine will generate a voltage of 60 VDC to charge controlly a battery of 48 VDC. The SCADA system will measure the current , the voltage and the energy produced by the wind turbine from DC and the consumed energy as the ballast resistance and the hydroelectric subsystem via the inverter, so it can achieve an energy balance of the physical model of CHHE .

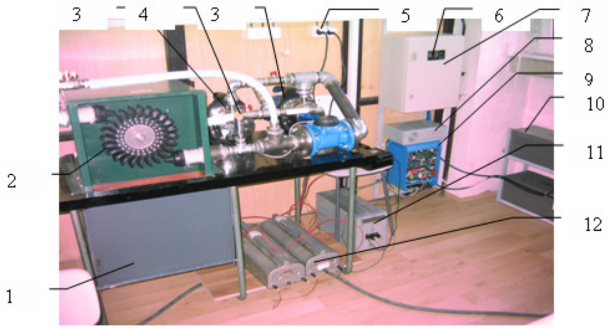

Fig.2. Subsystem wind hydro- physical model CHHE - overview: 1 - water tank; 2 - Pelton hydraulic turbine; 3 - Pump; 4 - digital manometer; 5 - Prize INVERTER OUTPUT; 6 - Remote inverter; 7 - Electric panel ; 8 - Battery charging controller; 9 - Inverter; 10 - Battery; 11 - Dump load; 12 - hydro load resistors.

3. MODELING RESISTANCE BALLAST (DUMP LOAD)

In the case of the wind turbines with variable speed (there is no system that adjusts the speed) and alternator, there should be used an electronic controller for the load, which is designed to prevent turbine over speed when there is not an electrical load (consumers) and the batteries are charged. It will be necessary to identify this situation and to connect a dump load (load ballast) . This dump load is usually carried out in air-cooled electric resistor (naturally or forced). As show the Figure 3, the dump load will be connected in circuit with the switch K2 and the heat that it produces is not salvage.

The sizing of the dump load will be made at the maximum voltage:

$$U_{CC,max} \cong 1{,}1\ V_{CC} \cong 55\ V_{CC} \tag{1}$$

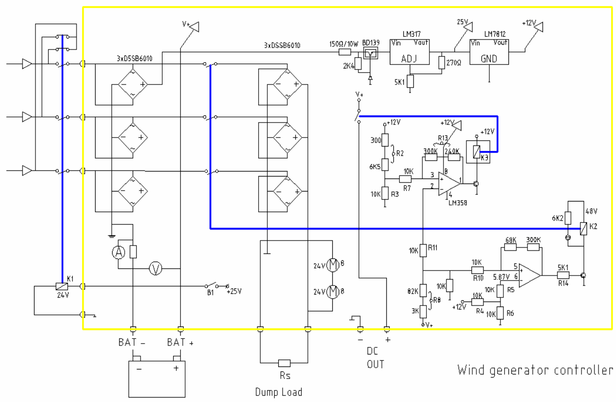

Fig.3. Battery Charger

To protect the generator when is wind, because it would not race, the power of loads will be taken P_R = 1000 W.

Using the formula:

$$P = U \cdot I = \frac{U^2}{R}, \tag{2}$$

we calculate the resistance R :

$$R = \frac{U^2}{P} = \frac{55^2}{1000} = 3.02\,\Omega\,. \tag{3}$$

We neglect the variation of the resistance in temperature, because we estimate a heat of $\Delta\theta \approx 500°C$, if the cooling is natural (outdoor) .

We made checking calculations and if we find a higher heating, the solution adopted is the switching to the forced cooling, that we will resize so that we have $\Delta\theta \le 500°C$.

The material chosed for the resistance is the alloy Cr - Ni 60 (Cr20Ni60Fe20) having the following characteristics:

- resistivity: $\rho = 1.1x10^{-6}\ \Omega m;$
- density: $\rho^{`} = 8.2x10^3\ Kg/m^3$
- maximum temperature: $\theta_m = 1075°C;$
- admissible specific power: $p_s = 1.4x10^4 W/m^2.$

The load resistance was achieved with a round wire, spiral on the ceramic surface (Figure 4).

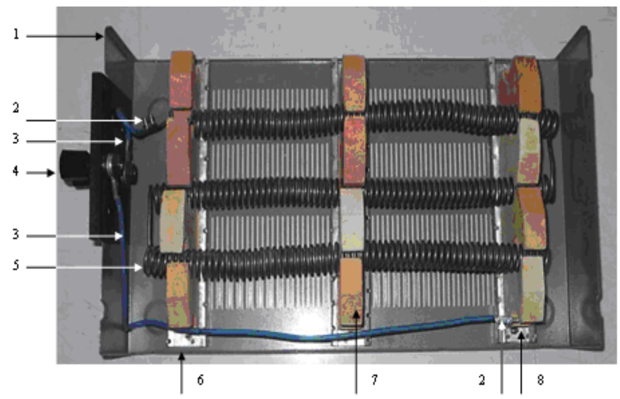

Fig.4. The load resistance: 1 - housing; 2 - clamp connection; 3 - wire connection; 4 - Connection terminals; 5 - wire resistive twisted; 6 - guide rail; 7 - ceramic pieces; 8 - fasteners.

We calculate :

$$d = 0.74\left[\left(\frac{P_r}{U}\right)^2 \cdot \frac{\rho}{p_r}\right]^{1/3} = 0.74\left[\left(\frac{1000}{55}\right)^2 \cdot \frac{1.1x10^{-6}}{1.3x10^4}\right]^{1/3} \approx 3\,mm\,,$$

where:

$$p_r = 1.3 \cdot 10^4 \frac{W}{m^2} \le p_s = 1.4 \cdot 10^4 \frac{W}{m^2}\,. \tag{4}$$

The length of the line will be :

$$l = \frac{P_R}{\pi \cdot d \cdot p_r} = \frac{1000}{\pi \cdot 3 \cdot 10^{-3} \cdot 1.3 \cdot 10^4} \cong 8.16\,m\,. \tag{5}$$

We choose: *D=23 mm*

$$l_{sp} = \pi \cdot D = 3.14 \cdot 23 = 72 \text{ mm} \qquad (6)$$

$$N_{sp} = \frac{l}{l_{sp}} = \frac{8.16}{72 \cdot 10^{-3}} \cong 120 \qquad (7)$$

The location will be made on 3 columns of spirals , each of them having :

$$N_{col} = \frac{N_{sp}}{3} = \frac{120}{3} = 40 \ spires\ . \qquad (8)$$

The length of a column is $L_{col} = 400$ mm.
Step:

$$t = \frac{L_{col}}{N_{col}} = \frac{400}{40} \cong 10 \ mm\ . \qquad (9)$$

Thus, the space between the two spires is:

$$\Delta = t - d = 10 - 3 = 7 \ mm\ . \qquad (10)$$

Checking the temperature that the resistor is operating:

$$\Theta_{rm} = 100 \cdot \sqrt[4]{\frac{P_r}{\varepsilon_{rp} C_n A_{ef}} + \left(\frac{T_0}{100}\right)^4} - 273 = 100 \cdot \sqrt[4]{\frac{1000}{0.65 \cdot 5.77 \cdot 0.053} + \left(\frac{273}{100}\right)^4} - 273 = 571^{\circ} C\ , \qquad (11)$$

where:

- $\varepsilon_{rp}=0.65$, emissivity resistor;
- $A_{ef} = \alpha_{ef} \cdot \pi d l = \alpha_{ef} \cdot \pi \cdot 3.5 \cdot 10^{-3} \cdot 14 = 0.34 \cdot 153.86 \cdot 10^{-3} = 5.3 \cdot 10^{-2} \ m^2;$
- $T_0 = 20 + 273 = 293^{\circ} \text{K}$.

We note that the heating deviation from the indicated value is 51 ^{0}C $(\approx 9\% \leq 10\%)$, so the calculations are no longer resume.

4. CONNECTING CABLE WIND TURBINE – ELECTRIC PANEL

The model of the wind generator coupled with the wind turbine is three-phase synchronous type with excitation from the permanent magnets. The connection between the generator and the power supply is ensured by a three-wire cable (3 phases). The cable section depends on the value of the current supplied by generator - 15A. In this case the cable length is critical to sizing, so it ensures the voltage drop on cable less than 5 %.

We estimate a length of 30 m, the cable section shall be taken:

$$s = \frac{I \cdot L}{100} = \frac{15 \cdot 30}{100} = 4.5 \text{ mm}^2, \qquad (12)$$

formula is an empirical one. The chosen cable is insulated PVC 3 x 6 mm² section.

The current related the cable which links the charged regulator and the batteries will be $I_{dc} = 21$ A. In this situation, because the cable is shorter, it will consider only the heating of the cable:

$$s = \frac{I_{dc}}{J_{ad}} = \frac{21\text{A}}{2\text{A}/\text{mmp}} \approx 10 \text{ mm}^2 \qquad (13)$$

5. CONCLUSION

The physical model developed, low-power hydro-wind hybrid system, is useful to the students for educational purposes, master and PhD research.

Were performed in laboratory experiments to validate the results obtained from simulations for the case study or small scale physical model.

It was designed and built a ballast resistor of a1 kW ballast resistor and 48 V nickel-chromium wire 60 three millimeters in diameter and connecting cable size wind turbine - electric panel.

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