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WIND TURBINE WITH HYDROSTATIC ENERGY STORAGE

Catalin CHIOREANU[1], Nicolae CHIOREANU[2]
[1]Universitatea din Oradea, e-mail: Catalin.chioreanu@gmail.com
[2]Universitatea din Oradea, e-mail: nchioreanu@uoradea.ro

***Abstract* —** The paper presents hybrid power equipment that produces two transformations of energy. Wind energy is converted into hydrostatic energy, which is stored in the accumulator. Where necessary, the energy stored on accumulator is converted into electricity.

***Keywords* —** wind turbine, hybrid system, hydraulic variable pump, hydropneumatic piston accumulator, hydraulic variable motor, synchronous electric generator.

I. Introduction

Wind energy is clean and inexhaustible. The main disadvantage of wind power is the randomness of the meteorological phenomenon called wind. The efficiency of wind turbines is acceptable only if the wind speed is more than 3 m/s. To ensure a steady supply of consumers with electric energy necessary to store energy produced by wind turbine. Is evaluated a hybrid power equipment that produces two transformations of energy (Fig. 1). Wind energy is converted into hydrostatic energy, which is stored in the accumulator. Where necessary, the energy stored on accumulator is converted into electricity.

II. Scheme of operation

Wind energy conversion system consisting of (Fig. 1): Turbine Rotor **1**; and Hydraulic Variable Pump **2**. Automatically depending on the wind speed, the flow of hydraulic fluid pumped into the accumulator is adjusted so that the turbine rotor speed is optimal. In this way, wind energy conversion is performed with maximum efficiency [1]. The Measuring Equipment **5** provides the data necessary for regulating the flow from the Hydraulic Variable Pump, and the Nacelle to the wind direction orientation (through Orientation System **4)**.

The main components of the hydrostatic energy conversion into electrical energy (Hydroelectric System called) are: Hydraulic Variable Motor **6**; Synchronous Electric Generator **7**; Hydropneumatic Piston Accumulator **8**; Oil Tank **9**. The flow of the hydraulic fluid fed to the Hydraulic Variable Motor can be varied in such a way that the speed of the Synchronous Electric Generator to be constant (to maintain a constant frequency electric current) [1]. The electric generator Excitation System can be maintained regardless of varying voltage electricity consumption.

Hydroelectric system includes: Electric Transformer **11**, which converts electrical current to the parameters required parameters consumption; Oil Supply System **10** which automatic maintains constant the level of hydraulic fluid in the Oil Tank Buffer; and Thermohydraulic System **12**, which automatic charges the accumulator when stored energy falls below the permissible level (periods of time with little wind or no wind).

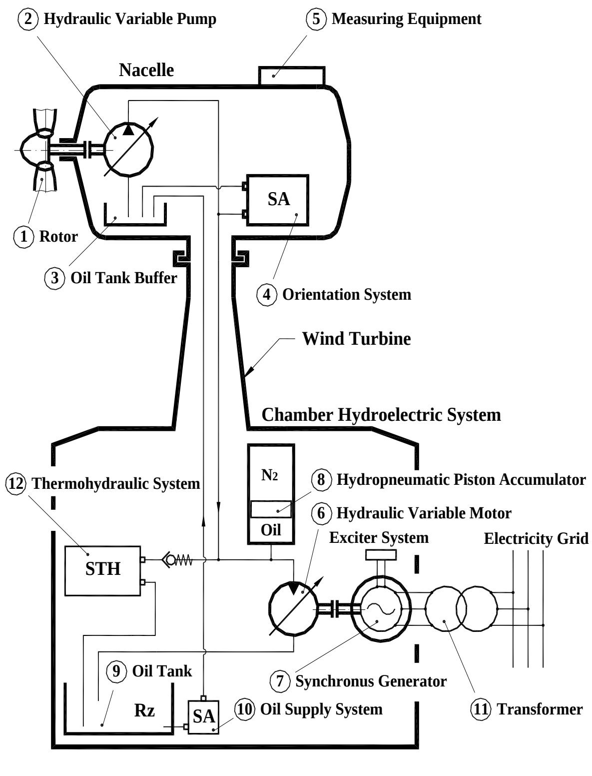

Fig. 1. Wind Turbine with Hydrostatic Energy Storage

Horizontal axis turbine rotor is equipped with multiple palettes (usually three pallets). Profile pallets have a particular form called aerodynamic profile. Thanks to the airflow around the pallet lift phenomenon has occurred. Lift force perpendicular to the direction of air flow, which causing rotation the rotor. In Figure 2 shows the rotor of a wind turbine to high power [2]. The rotor is provided with three blades. The incidence angle of the blades can be adjusted according to wind intensity.

Lift force is calculated by the relationship [3]:

$$F_z = C_z \cdot \rho \cdot \frac{w_0}{2} \cdot A \quad [N] \tag{1}$$

where: C_z is the coefficient of lift; ρ is the density of air in kg/m^3; w_0 is flow speed air (wind speed) in m/s, A is the lift surface of the palettes, in m^2.

Lift coefficient value C_z depends, of the form and finish of palettes surface, of the value of the incidence angle, of the flow regime of the air flow, etc.

Fig. 2. Rotor Wind Turbine [2]

Wind speed w_0 varies randomly over time, $w_0 = w_0(\tau)$, which can be obtained by statistical processing of meteorological data [4].

Turbine power output is calculated by the relationship:

$$P_t = M_t \cdot \omega \quad [W] \tag{2}$$

where: M_t is torque developed at the rotor shaft in $N \cdot m$; ω is the angular speed of the rotor in rad/s.

It is noted that the power turbine varies with the time, just as the wind speed: $P_t = P_t(\tau)$.

The energy produced by wind turbine in a certain time interval T [s], is calculated from the relationship:

$$E_t = \int_0^T P_t(\tau) \cdot d\tau \quad [J] \tag{3}$$

In conclusion, the energy produced by wind turbines varies randomly over time. To ensure a steady supply of energy to consumers, it must be stored.

The hydraulic pump is powered by the wind turbine, which discharged hydraulic fluid in the accumulator. Hydraulic pump capacity can be adjusted. Figure 3 shows a hydraulic variable axial piston pump [5].

Hydraulic pump flow is variable and is calculated by the relationship:

$$Q_p = \eta_t \cdot \frac{P_t}{p_h} \quad [m^3/s] \tag{4}$$

where: η_τ is total efficiency; P_t is wind turbine power, in W; p_h is the discharge of hydraulic fluid pressure, in Pa.

Fig. 3. Hydraulic Variable Axial Piston Pump [5]

Actuation of the synchronous electric generator is made by the hydraulic motor. Hydraulic motor capacity can be adjusted. Figure 4 shows a hydraulic variable axial piston motor [5].

Fig. 4. Hydraulic Variable Axial Piston Motor [5]

Synchronous generators can be: with electric or permanent magnet excitation. In synchronous generators with electrical excitation, coils of the electric excitation circuit (placed on the rotor) are supplied with direct current by means of a system of brushes and slip rings fixed to the shaft of the generator. Power supply can be through a rectifier that converts alternating current power, of the DC. In Figure 5 shows the synchronous generator of a wind turbine to high power [2].

Fig. 5. Synchronous Generator with Electrical Excitation [2]

In synchronous generators with magnetic excitation, source excitation is the permanent magnets located on the rotor. In Figure 6 shows the synchronous generator with magnetic excitation [2].

Fig. 6. Synchronous Generator with Magnetic Excitation [2]

In conclusion, the hydraulic motor - synchronous electric generator produces an electric current quality indifferent how consumption varies.

III. High capacity hydropneumatic accumulators

Size of hydraulic accumulator is determined based consumption and the wind speed over a period of time.

Main parts of hydropneumatic piston accumulator are, cylinder and piston. The piston is separating component the liquid of the gas, and during operation has a reciprocating motion. To increase the volume of stored liquid, cylinder can be connected to one or more gas bottles. Figure 7 shows the structure constructive of hydropneumatic piston accumulator without bottles and figure 8 shows a hydropneumatic piston accumulator with bottles [6].

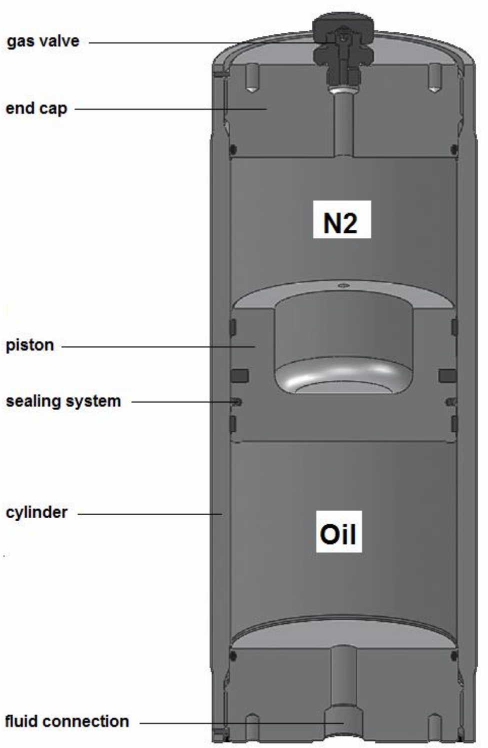

Fig. 7. The constructive structure of hydropneumatic piston accumulator [6]

Size of accumulator is denoted by V_0. Pre-charge pressure p_0 to piston accumulators is equal to the minimum operating pressure p_1 (pre-charging the accumulator is drained), result: $p_1 = p_0$, $V_0 = V_1$. Also, the charging and discharging processes at high capacity accumulators are slow thermal processes that can be considered isothermal evolves.

Nitrogen volume at maximum operating pressure p_2, is calculated from the relationship:

$$V_2 = V_0 \cdot \frac{p_1}{p_2} \quad [m^3] \qquad (5)$$

The maximum volume of liquid that can be stored hydraulic accumulator is calculated from the relationship:

$$\Delta V = V_0 \cdot \left(1 - \frac{p_1}{p_2}\right) \quad [m^3] \qquad (6)$$

where: V_0 is the accumulator size, in m^3; p_1 is minimum operating pressure, in Pa; p_2 is maximum operating pressure, in Pa.

The accumulators of bottles, the maximum volume of liquid that can store is equal to size of accumulator, result: $\Delta V = V_0$, and the volume bottles $V_B = V_2$.

The volume bottles, is calculated from the relationship:

$$V_B = V_0 \cdot \frac{p_1}{p_2 - p_1} \quad [m^3] \qquad (7)$$

where: V_0 is the accumulator size, in m^3; p_1 is minimum operating pressure, in Pa; p_2 is maximum operating pressure, in Pa.

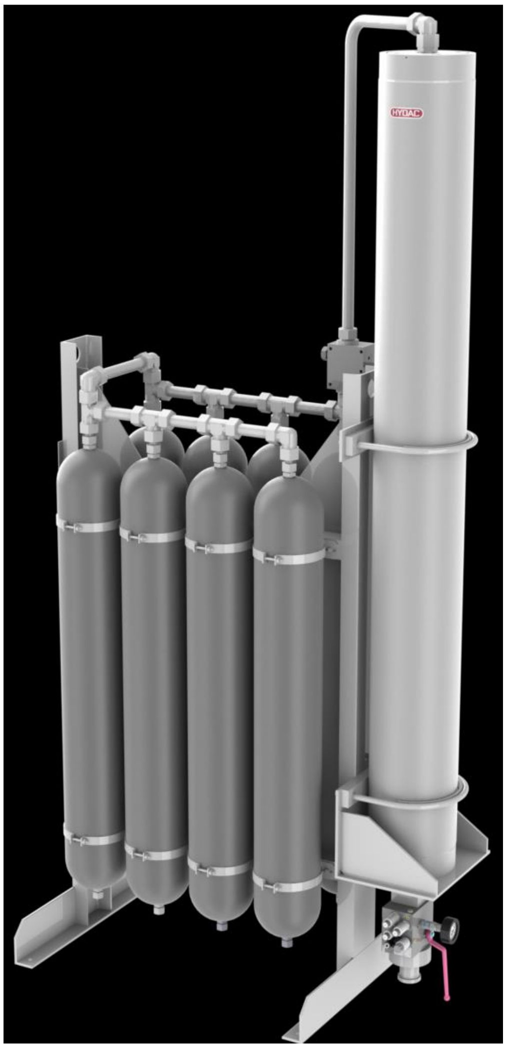

Fig. 8. The hydropneumatic piston accumulator with bottles [6]

The maximum hydrostatic energy the accumulator can store is calculated from the relationship:

$$E_h = \int_{V_2}^{V_1} p \cdot dV \quad [J] \qquad (8)$$

where: V_1 is maximum volume of the accumulator, in m^3; V_2 is minimum volume of the accumulator, in m^3; p is pressure of the accumulator, in Pa.

In conclusion, hydropneumatic piston accumulators have the capacity to store a large amount of energy that can cover the consumption of in periods of time with little wind or no wind.

IV. Conclusion

The new type of wind turbine converts wind energy into electrical energy efficiently regardless of varying consumption. The system is automatic and highly flexible. He has a grid that can power continuously regardless of varying consumption, all the necessary electricity (for lighting, heating, industrial, etc.) for an individual consumer or a limited group of consumers. The power grid system can be provided with the ability to connect with other electrical grid (with individual electrical grid of other wind turbines or national electrical grid).

References

[1] N. Vasiliu, Daniela Vasiliu, I. Seteanu, Victoriţa Rădulescu, *Mecanica fluidelor şi sisteme hidraulice. Fundamente şi aplicaţii Vol. II*. Bucureşti, Editura Tehnică, 1999.

[2] www.windpower.org

[3] N. Chioreanu, S. Chioreanu, *Motoare termice neconvenţionale pentru automobile*. Oradea, Editura Universităţii din Oradea, 2006, pp. 67-104.

[4] Mariana Deliu, Ghe. Deliu, *A simple method to estimate the wind potential of a region.* RECENT Journal, Vol. 8, no. 2 (20), July 2007, Transilvania University of Brasov, Romania.

[5] https://www.boschrexroth.com/en/xc/products/product-groups/industrial-hydraulics/index

[6] http://www.hydac.com/de-en/products/hydraulic-accumulators/accumulator-stations.html