ISSUING THE PATTERN OF THE DOUBLE SUPPLY ASYNCHRONOUS MACHINE USED IN AN ELECTRICAL WIND POWER STATION

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Abstract: The wind energy belongs to regenerating energies. It results from [1] that currently 80% of the new wind power stations are equipped with asynchronous machines with double supply. (MADA). This work is establishing the simplified mathematical pattern of an asynchronous machine with double supply and orientation by the stator flow. Through using the SIMULINK program, in the MATLAB environment, the block diagram has been determined the simplified pattern of an asynchronous machine with double supply and orientation by the stator flow.

Keywords: asynchronous machine with double supply, wind power station, mathematical pattern.

1. INTRODUCTION

The intensive usage of fossil fuels has significantly modified the CO_2 level in the atmosphere and led to a general heating of the Earth because of the glasshouse effect. The temperature increase of the Earth in future would facilitate the melting of the icebergs in the polar regions. Further to the analysis of these aspects, the following problems come up:
-The limited amount of energy resources, considering that more than 90% of the world average energy consumption comes from fossil fuels.
- Various form of pollution: chemical, thermal, etc.

One of the solutions to the problems of above consists of exploiting new energy sources, such as:: solar energy, geo-thermal energy, wind energy, tide energy, nuclear energy, etc. It can be asserted that researches in the field of the wind power stations are now under full development.

2. THE FUNCTIONING PRINCIPLE OF A WIND POWER STATION

The wind energy belongs to the regenerating energies. The aero-generator uses the kinetic energy of the wind for driving its rotor shaft. This energy is transformed into mechanical energy. That in its turn, is transformed into electricity through the generator mechanically coupled to the wind turbine. This mechanical coupling can be done either directly, if the turbine and the generator have speed rates of the same range, or through a speed multiplier. The wind power stations with horizontal shaft are the most usual, since their aero-dynamic efficiency is higher than the vertical shaft wind station efficiency, they are less submitted to important mechanical requirements and costs are lower. The elements composing a horizontal shaft wind power station are shown in Fig.1. Their detailed presentation is shown in [6]. The horizontal shaft wind power stations are also divided into two categories: Wind power stations with fixed speed rate and wind power stations with variable speed rate. Two types of electrical machines are used in the structure of the wind power stations: synchronous machines and asynchronous machines. From [1] it results that currently 80% of the new wind power stations are equipped with double supply asynchronous machines (MADA). For this reason, a MADA of a variable speed type wind power station has been selected for study. A wind power station using a MADA allows obtaining the maximum power starting from a certain wind speed, through optimizing the specific speed λ and minimizing the mechanical requirements of the wind turbine during the wind blows. The specific speed λ is given by the ration between the tangent/surface speed of the pallet extremities and the wind speed. The mechanical power recovered by the wind turbine is eventually converted into electrical power conveyed to the electrical network by means of the stator and rotor windings.

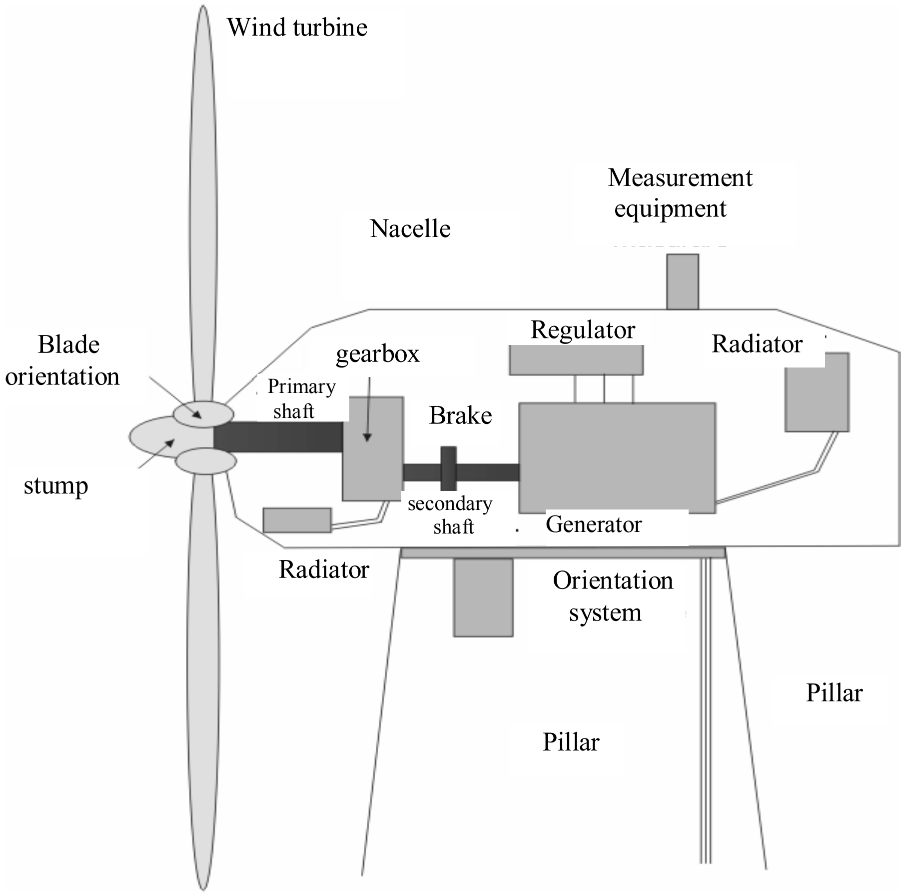

Fig. 1 The structure of an electrical wind power station

3. THE PATTERN OF THE DOUBLE SUPPLY ASYNCHRONOUS MACHINE (MADA) WITH ORIENTATION BY THE STATOR FLOW

Since the electrical machines are sinusoidal, they are defined through their module and phase. As such, they can be represented in a bi-dimensional reference systems The reference being chosen here for modeling the asynchronous machine with coiled rotor is a system related to the machine stator.(with fixed axis). This reference system is illustrated through the axes α_f and β_f in Fig. 2. The conversion of the electrical machines to this reference system with the starting point from the reference system associated to the three stator windings is done while crossing and exchange of axes (the Park transformation). The particularity of the asynchronous machine with double supply consists of having two currents that can be directly controlled, i_{rd} and i_{rq} as well as two currents, indirectly controlled: i_{sd} and i_{sq}. From $[4]$ the system of differential equations of the machine results:

$$\frac{d\phi_{1d}}{dt} = u_{1d} - R_1 \cdot i_{1d} + \phi_{1q} \cdot \omega_1 \quad (1)$$

$$\frac{d\phi_{1q}}{dt} = u_{1q} - R_1 \cdot i_{1q} - \phi_{1d} \cdot \omega_1 \quad (2)$$

$$\frac{d\phi_{2d}}{dt} = u_{2d} - R_2 \cdot i_{2d} + \phi_{2q} \cdot \omega_2 \quad (3)$$

$$\frac{d\phi_{2q}}{dt} = u_{2q} - R_2 \cdot i_{2q} - \phi_{2d} \cdot \omega_2 \quad (4)$$

In case of the flow orientation, the MADA pattern being obtained is simplified and the resulting control device is simpler as well. The vector control of this machine has been conceived with the orientation of the Park mark for which the component of the stator flow by the q axis to be zero: $\phi_{1q} = 0$. A simplification of the asynchronous machine equations has been obtained through considering the homo-polar components zero:

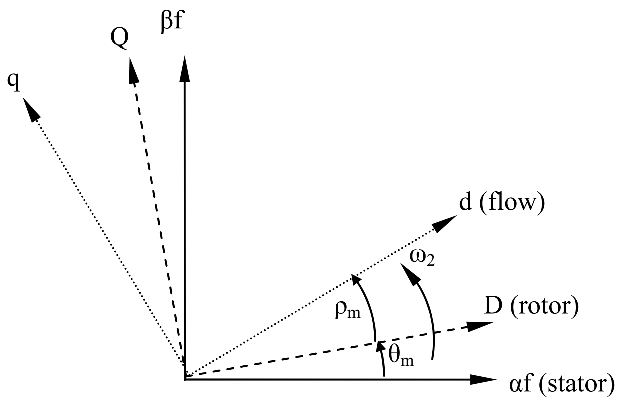

Fig. 2 Systems of reference axes of the asynchronous machine

$$\frac{d\phi_{1d}}{dt} = u_{1d} - R_1 \cdot i_{1d} \quad (5)$$

$$u_{1q} = R_1 \cdot i_{1q} + \phi_{1d} \cdot \omega_1 \quad (6)$$

$$\frac{d\phi_{2d}}{dt} = u_{2d} - R_2 \cdot i_{2d} + \phi_{2q} \cdot \omega_2 \quad (7)$$

$$\frac{d\phi_{2q}}{dt} = u_{2q} - R_2 \cdot i_{2q} - \phi_{2d} \cdot \omega_2 \quad (8)$$

From $[4]$, the following expressions of the stator currents will be obtained:

$$i_{1q} = -\frac{L_h}{L_1} \cdot i_{2q} \tag{9}$$

$$i_{1d} = \frac{\phi_{1d} - L_h \cdot i_{2d}}{L_1} \tag{10}$$

These stator currents are replaced in the equations of the direct components of the rotor flows $[4]$:

$$\phi_{2d} = \left(L_2 - \frac{L_h^2}{L_1} \right) \cdot i_{2d} + \frac{L_h}{L_1} \cdot \phi_{1d} = L_2 \cdot \sigma \cdot i_{2d} + \frac{L_h}{L_1} \cdot \phi_{1d} \tag{11}$$

$$\phi_{2q} = L_2 \cdot i_{2q} - \frac{L_h^2}{L_1} \cdot i_{2q} = L_2 \cdot \sigma \cdot i_{2q} \tag{12}$$

where σ is the dispersion coefficient between the windings d and q:

$$\sigma = 1 - \frac{L_h^2}{L_1 \cdot L_2}$$

By replacing the expressions of the direct components of the stator currents (9 and 10) in the equations (5 and 6) and then the expressions of the direct components of the rotor flow (11 and 12) in the equations (7 and 8), it will result:

$$u_{1d} = \frac{R_1}{L_1} \cdot \phi_{1d} - \frac{R_1}{L_1} \cdot L_h \cdot i_{2d} + \frac{d\phi_{1d}}{dt} \tag{13}$$

$$u_{1q} = -\frac{R_1}{L_1} \cdot L_h \cdot i_{2q} + \omega_1 \cdot \phi_{1d} \tag{14}$$

$$u_{2d} = R_2 \cdot i_{2d} + L_2 \cdot \sigma \cdot \frac{di_{2d}}{dt} + \frac{L_h}{L_1} \cdot \frac{d\phi_{1d}}{dt} - L_2 \cdot \omega_2 \cdot \sigma \cdot i_{2q} \tag{15}$$

$$u_{2q} = R_2 \cdot i_{2q} + L_2 \cdot \sigma \cdot \frac{di_{2q}}{dt} + L_2 \cdot \sigma \cdot \omega_2 \cdot i_{2d} + \omega_2 \cdot \frac{L_h}{L_1} \cdot \phi_{1d} \tag{16}$$

The equations (15 and 16) allow the rotor currents to be determined:

$$\frac{di_{2d}}{dt} = \frac{1}{L_2 \cdot \sigma} \cdot \left(u_{2d} - R_2 \cdot i_{2d} + \omega_2 \cdot L_2 \cdot \sigma \cdot i_{2q} - \frac{L_h}{L_1} \cdot \frac{d\phi_{1d}}{dt} \right) \tag{17}$$

$$\frac{di_{2q}}{dt} = \frac{1}{L_2 \cdot \sigma} \cdot \left(u_{2q} - R_2 \cdot i_{2q} - \omega_2 \cdot L_2 \cdot \sigma \cdot i_{2d} - \omega_2 \cdot \frac{L_h}{L_1} \cdot \phi_{1d} \right) \tag{18}$$

The electromagnetic torque is established with the help of the relation:

$$M_{em} = p \cdot \left(\phi_{1d} \cdot i_{1q} - \phi_{1q} \cdot i_{1d}\right) \tag{19}$$

Through an orientation of the stator flow so that $\phi_{1q} = 0$, a simplified expression will be obtained:

$$M_{em} = p \cdot \phi_{1d} \cdot i_{1q} \tag{20}$$

The current i_{1q} cannot be controlled directly, but, using the equation (9) the component of the rotor current is input to the expression of the electromagnetic torque:

$$M_{em} = -p \cdot \frac{L_h}{L_1} \cdot \phi_{1d} \cdot i_{2q} \tag{21}$$

4. RESULTS OF THE SIMULATION

For simulation the SIMULINK program in the environment MATLAB has been used. The simulation was done for an asynchronous machine with double supply having the following rated parameters: $[1]$: $P_n = 15$ KW, $n_n = 1440$ rot/min, $M_n = 100\ N \cdot m$, $U_{1n} = 220$ V, $U_{2n} = 220$ V, $I_{1n} = 32$ A, $I_{2n} = 2.5$ A, $R_1 = 0.17\ \Omega$, $R_2 = 0.2\ \Omega$, $L_1 = 0.05$ H, $L_2 = 0.05$ H, $L_h = 0.045$ H, p=2. Based on the equations 13,14, 15,16 and 21, Fig. 3 shows the SIMULINK block diagram of the simplified pattern of the double supply asynchronous machine with orientation by the stator flow. The mathematical pattern being obtained will be used in the structures of vector controls of the double supply asynchronous machine used in the structure of the wind power stations.

5. CONCLUSIONS

The structure of the electrical wind power stations includes currently double supply asynchronous machines in a percentage of 80%. This work determines the simplified mathematical pattern of a double supply asynchronous machine, with orientation by the stator flow. Through using the SIMULINK program in the MATLAB environment, the block diagram of the simplified pattern of the double supply asynchronous machine with orientation by the stator flow has been determined.

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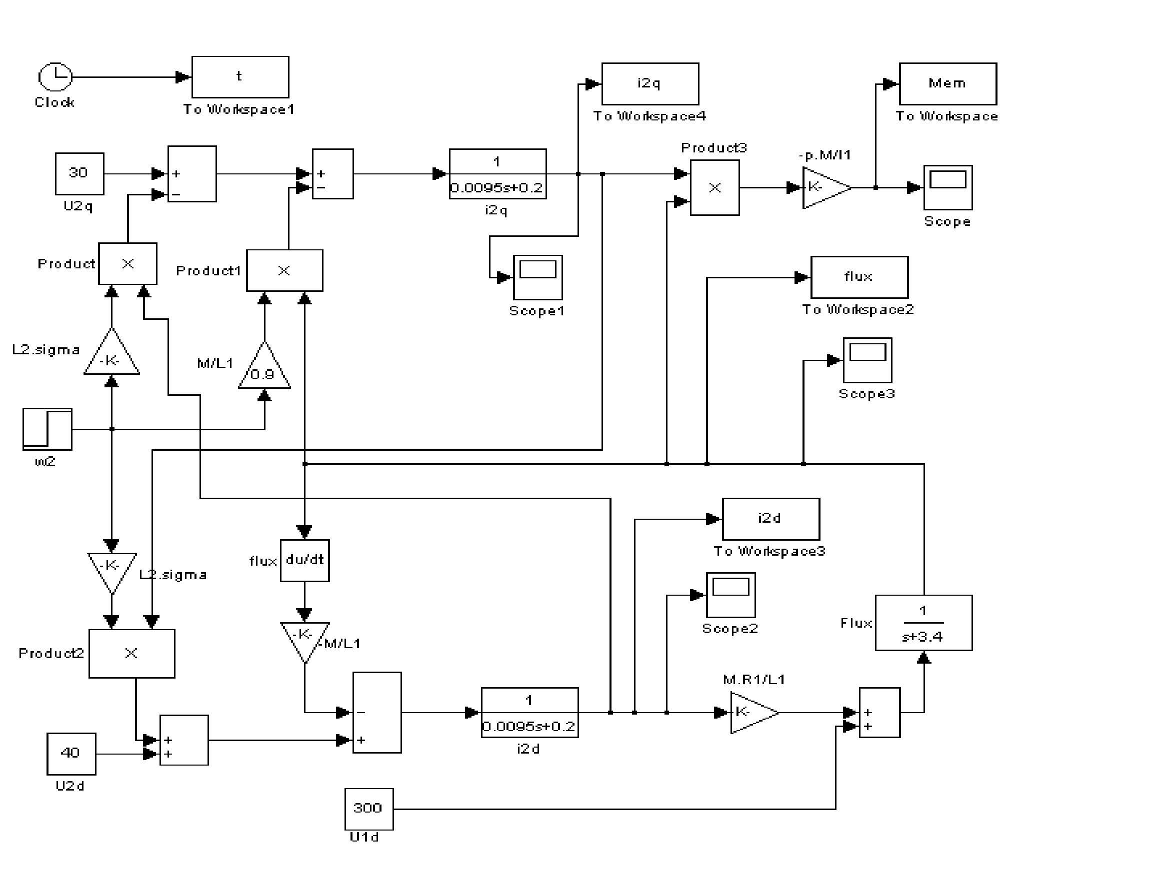

Fig. 3. The SIMULINK block diagram of the double supply asynchronous machine simplified pattern