EXPERIMENTAL STAND FOR SIMULATING THE RUNNING OF A LOW POWER WIND STATION

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Abstract This work present an experimental stand equipped with an asynchronous three phase motor with short circuited rotor, coupled to an asynchronous generator with wound rotor. Further to the experimental findings the following conclusions resulted: Depending on the variation of the wind speed and the variation of the load connected to the terminals of the phase windings of the three-phase asynchronous generator, the parameters of the electric energy supplied by the three-phase asynchronous generator can be controlled, by modifying the parameters of the energy supplying the excitation (operating) winding of the three-phase asynchronous generator. It may be affirmed that the three-phase asynchronous motors with wound rotor may be used in the construction of low power wind stations.

Keywords Wind power stations, three-phase asynchronous motor, frequency static converter.

1. INTRODUCION

An experimental stand for simulating the running of a wind power station represents an intermediary stage between the simulation model and the real system. The cost of such a stand is much lower than the cost of a wind power station and its representation for the real system is much more realistic than a numerical simulator. Researchers have developed various types of test stands. They are composed of an electric machine, in general a D.C. motor or an asynchronous three-phase motor that mean the emulator of the wind turbine and a generator coupled to this, that has the role of the electric machine of the wind power station, [1]. The mechanical coupling is on most of the wind power stations during emulation. This coupling between the turbine emulator and generator is really rigid and the motor, as it emulates the turbine, emulates especially the mechanical behavior of the wind power station. This work is also aligned to this principle and presents an experimental stand built with an asynchronous three-phase motor with short-circuited rotor, coupled to an asynchronous generator with wound rotor.

2. DESCRIPTION OF THE EXPERIMENTAL STAND FOR SIMULATING THE RUNNING OF A LOW POWER WIND STATION

The experimental stand for simulating the running of low power wind station was built at the Electrical Machinery Laboratory of the University of Bacau. It is presented in Fig. 1.

The experimental stand shown in Fig. 1 is composed of:

1- Three-phase asynchronous motor with short-circuited rotor, of the following characteristics:
Rated power $P_n = 4$ KW, rated voltage $U_n = 380$ V.A.C., rated speed $n_n = 1485$ rpm, power factor $\cos\varphi = 0.75$

2- Three-phase asynchronous generator with wound rotor of the following characteristics:
Rate power $S = 3.2$ VA, rated voltage $U_n = 380$ V.A.C., rated speed $n_n = 865$ rpm, power factor $\cos\varphi = 0.75$

3- Three-phase autotransformer: $U_1 = 380$ V A.C., $U_2 = (0 \div 380)$ V A.C. , $P_n = 7.5$ KW.

4 – Frequency static converter -1 with the following characteristics: rated voltage $U_n = 380$ V A.C., frequency $(0-100)$ Hz, rated current $I_n = 10$ A used for supplying the three phase asynchronous motor with short-circuited rotor.

5- Voltmeter, $U_n = 500$ V A.C.

6- Ammeter, $I_n = 5$ A

7- Power resistors, $P = 300$ W, $R = 10\ \Omega$

8- Frequency static converter -2 with the following characteristics: rated voltage $U_n = 380$ V A.C., frequency $(0-100)$ Hz, rated current $I_n = 10$ A used for supplying the three-phase winding of the rotor of the three-phase asynchronous generator with wound rotor.

9- Oscilloscope: $U_n = 220$ V A.C,

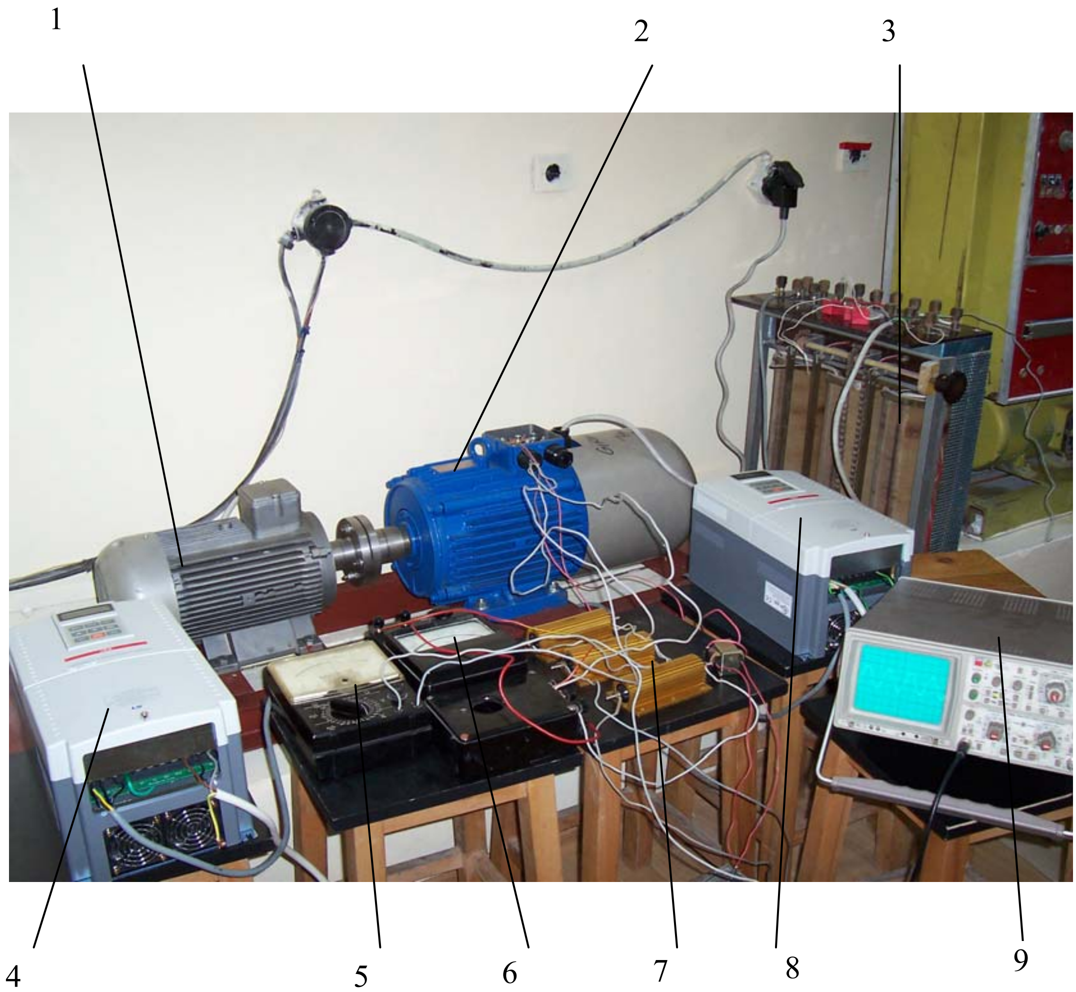

Fig. 1

3. FUNCTIONING OF THE EXPERIMENTAL STAND

The electric diagram of the experimental stand in its final version is presented in Fig. 2. The supply from the A.C. electric network of the frequency static converters is performed by switching the circuit breaker K_0 to its ON position. The short-circuit protection of the two converters is provided through two automatic fuses, $F_1 \div F_3$, and $F_4 \div F_6$ respectively. The three-phase asynchronous motor with short-circuited rotor m_1 is supplied from the frequency static converter -1. The three-phase winding of the m_2 three-phase asynchronous generator rotor, is supplied from the frequency static converter -2 through the autotransformer Tr 1. At the terminals of the stator windings of the three-phase asynchronous generator m_2 the three-phase load resistors $R_1 \div R_3$ and $R_4 \div R_6$ are connected, through the circuit breakers K_1 and K_2. The current intensity through one phase winding of the three-phase asynchronous generator rotor is measured through the current encoder TC_1, and the line voltage that supplies the phase windings of the rotor are measured through the voltage encoder TT_1 .

The current intensity through a phase winding of the stator of the three-phase asynchronous generator while running at load is measured through the current encoder TC_2, and the line voltage on the phase windings of the three-phase asynchronous generator stator terminals is measured through the voltage encoder TT_2. The output signals from the current encoders and voltage encoders are transmitted to the data collection board of the computer, through the connector X_1. The speed rate of the three-phase asynchronous motor m_1 is measured through the speed encoder m_3. The voltage signal obtained at the output of the speed encoder is passed through an adapting module and sent to the data collection board in the computer through the connector X_1. From the computer, through the data collection board and the connector X_1 the voltage signal that is the reference rate for the frequency static converter -2 is transmitted. In function of the value of this signal the supply voltage of the three-phase winding or the three-phase asynchronous generator rotor will be adjusted. The speed of the three-

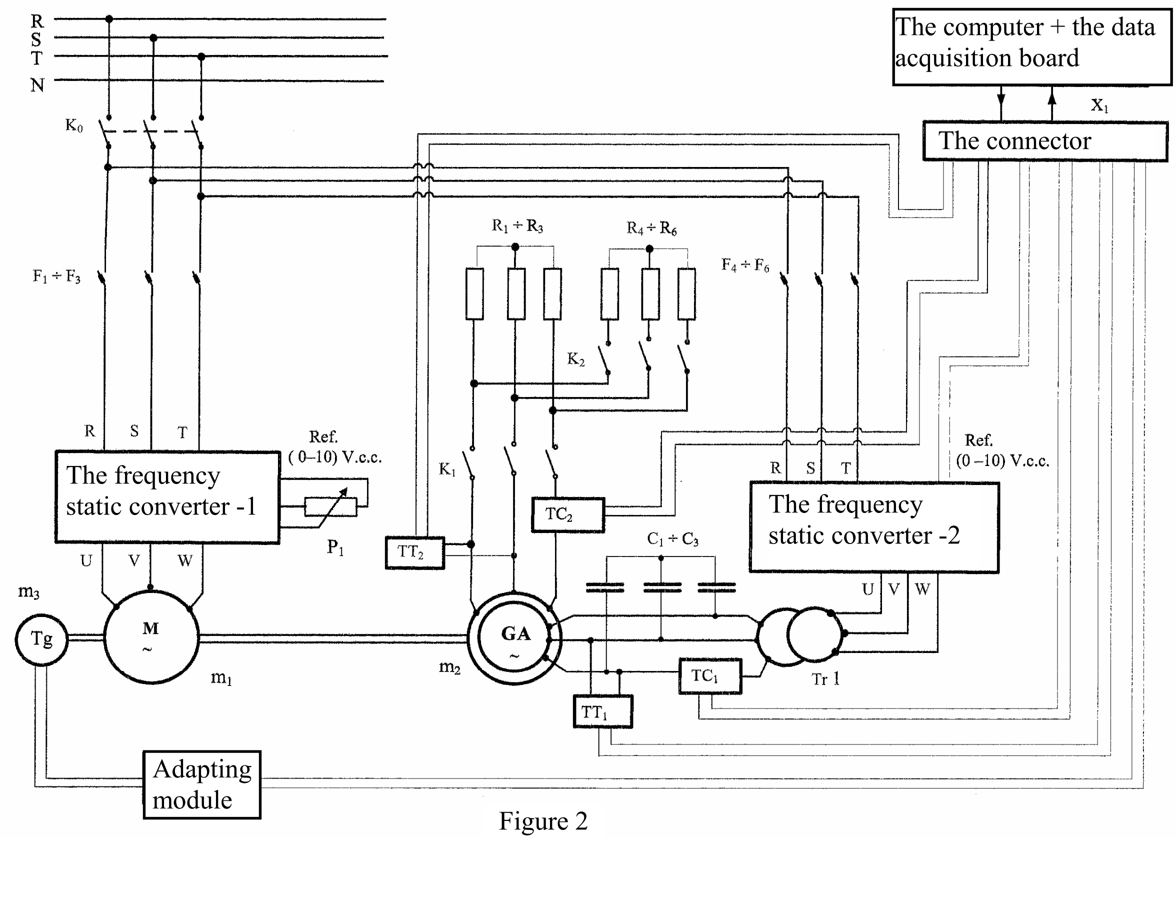

Figure 2

phase asynchronous motor with short-circuited rotor is modified through the potentiometer P_1 that adjusts the reference voltage for the frequency static converter -1. For filtering the voltage harmonics of the supply circuit of the three-phase winding of the three-phase asynchronous generator rotor, the filter composed of the condensers $C_1 \div C_3$ has been used.

4. EXPERIMENTAL FINDINGS

In order to perform the experimental work the test stand in the intermediary design version shown in Fig. 1 has been used. At this stage, instead of the current and voltage encoders ammeters and voltmeters have been used and, instead of the tacho-generator, a portable speed encoder has been used. It is to be mentioned that at this stage the computer equipped with data collection board was not used. The frequency static converter -2 has been controlled through its operator panel. The operator panel of the frequency static converter -2 also displays the value of the supply voltage frequency of the three-phase winding of the three-phase asynchronous generator rotor. The manner of parameter variation of the electric energy supplied by the three-phase asynchronous generator has been followed up, in function of the wind speed variation and variation of the load connected to the terminals of the phase windings of the three-phase asynchronous generator stator. For keeping constant the parameters of the electric energy furnished by the three-phase asynchronous generator it will be acted on the values of the parameters of the energy that supplies the rotor three-phase winding, that is the excitation (operating) winding of the three-phase asynchronous generator.

4.1 Experimental Findings upon the variation of the Wind Speed

The speed (rpm) of the three-phase asynchronous motor m_1 will be successively adjusted at the rates $n = 1052$ rot/min, $n = 1187$ rpm, $n = 1354$ rpm. The value of the load resistors $R_1 \div R_3$ will be kept constant. The frequency of the excitation voltage of the three-phase windings of the asynchronous generator rotor will be modified, so that to keep constant the parameters of the electric energy furnished by the asynchronous generator through the terminals of the three-phase winding of the stator. The values being obtained are stated in Table 1.

Table 1

n [rpm]	1052	1187	1354
f_{ex} $[Hz]$	18	15	12
U_{ex} $[V]$	33	27	22
I_{ex} $[A]$	12.6	12	11.6
U_2 $[V]$	300	300	300
I_2 $[A]$	2.51	2.51	2.51

4.2 Experimental Findings upon Load Variation

4.2.1. The speed of the three-phase asynchronous motor m_1 will be adjusted at the rate $n = 1100$ rpm.

The slip s of the three-phase asynchronous generator will be: $s = \frac{n_1 - n}{n_1} = \frac{1000 - 1100}{1000} = -0.1$. The frequency f_2 of the voltage that is obtained on the output of the three-phase asynchronous generator should be equal to 50 Hz. The frequency of the supply voltage of the excitation (operating) winding of the three-phase asynchronous generator is determined through the relation: $f_{ex} = |s| \cdot f_2 = 0.1 \cdot 50 = 5$ Hz. The load resistors $R_1 \div R_3$ will be set on the maximum value. More trials will be done, by decreasing the value of the load resistance. The values being obtained are stated in Table 2.

Table 2.

I_{ex}	10	10.4	11	11.8	13
U_{ex}	17.5	17.5	17.5	17.5	17.5
I_2	1.7	2	2.45	2.9	3.55
U_2	275	260	245	210	175
P_{ex}	175	182	192.5	206.5	227.5
P_G	467.5	520	600.25	609	621.25

4.2.2. The speed of the three-phase asynchronous motor m_1 will be adjusted at the rate $n = 1200$ rpm.

The slip s of the three-phase asynchronous generator will be: $s = \frac{n_1 - n}{n_1} = \frac{1000 - 1200}{1000} = -0.2$. The frequency f_2 of the voltage that is obtained on the output of the three-phase asynchronous generator should be equal to 50 Hz. The frequency of the supply voltage of the excitation (operating) winding of the three-phase asynchronous generator is determined through the relation: $f_{ex} = |s| \cdot f_2 = 0.2 \cdot 50 = 10$ Hz. The load resistors $R_1 \div R_3$ will be set on the maximum value. More trials will be done, by decreasing the value of the load resistance. The values being obtained are stated in Table 3.

Table 3

I_{ex}	11.6	12	12.8	14	16.8
U_{ex}	27	27	27	27	27
I_2	2.05	2.45	2.9	3.7	4.65
U_2	340	325	290	260	220
P_{ex}	313.2	324	345.6	378	453.6
P_G	697	796.25	841	962	1069

4.2.3. The speed of the three-phase asynchronous motor m_1 will be adjusted at the rate $n = 1300$ rot/min.

The slip s of the three-phase asynchronous generator will be: $s = \frac{n_1 - n}{n_1} = \frac{1000 - 1200}{1000} = -0.3$. The frequency f_2 of the voltage that is obtained on the output of the three-phase asynchronous generator should be equal to 50 Hz. The frequency of the supply voltage of the excitation (operating) winding of the three-phase asynchronous generator is determined through the relation: $f_{ex} = |s| \cdot f_2 = 0.3 \cdot 50 = 15$ Hz. The load resistors $R_1 \div R_3$ will be set on the maximum value. More trials will be done, by decreasing the value of the load resistance. The values being obtained are stated in Table 4.

Table 4

I_{ex}	12.4	13	14	16	19.4
U_{ex}	37	37	37	37	37
I_2	2.35	2.75	3.3	4.05	5.75
U_2	380	370	340	310	260
P_{ex}	458.8	481	518	592	717.8
P_G	893	1017.5	1122	1255.5	1495

The shape of the voltage signal U on the output terminals of the three-phase asynchronous generator is shown in Fig. 3.

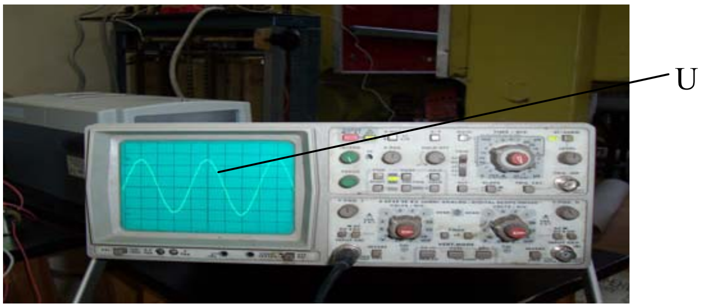

Fig. 3

5. CONCLUSIONS

Further to the experimental tests, the following conclusions have resulted: In function of the wind speed variation and the variation of the load connected at the terminals of the phase windings of the stator of the three-phase asynchronous generator, the parameters of the electric energy furnished by the three-phase asynchronous generator can be controlled by modifying the parameters of the supply energy of the excitation (operating) winding of the three-phase asynchronous generator. Along with the increase of the wind speed, the frequency of the supply voltage of the excitation winding of the asynchronous generator will also be increased, in order to keep constant the frequency of the voltage that will be obtained on the terminals of the phase windings of the three-phase asynchronous generator. Upon the increase of the load connected at the terminals of the three-phase asynchronous generator the rate of the supply voltage of the excitation winding of the three-phase asynchronous generator will be increased, in order to keep constant the value of the voltage on the terminals of the three-phase asynchronous generator. Through adequate software implemented on the structure of the test stand as shown in Fig.2, the performances of the three-phase asynchronous generator m_2 could be verified in real time. In the end, it may be affirmed that the three-phase asynchronous generators with wound rotor can be used in the construction of the autonomous low power wind stations.

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