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Experimental Stand for the Study of a Three-Phase Synchronous Generator with Permanent Super Magnets

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Abstract

This work presents an experimental stand for the study of a three-phase synchronous generator in reverse construction with permanent super magnets. This stand has been built at the Electrical Machinery Laboratory of "Vasile Alecsandri" University of Bacau. Synchronous generators with permanent magnets are used for producing electricity in wind power stations. A synchronous generator of normal construction is composed of two armatures: a fixed armature named stator and a moving one, named rotor; the latter is concentrically located inside the fixed armature. This experiment has used a synchronous generator with permanent super magnets in reverse construction, where the fixed armature named stator is located inside the moving armature, named rotor. With the help of the experimental stand the characteristics of the synchronous generator with permanent super magnets in reverse construction have been determined.

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Keywords: synchronous generator; experimental stand; permanent magnets

1. Introduction

Synchronous three-phase generators with permanent magnets are used for producing electricity in wind power stations [1]. A synchronous generator of normal construction is composed of two armatures: a fixed armature named stator or induced and a moving one, named rotor or inductor concentrically located inside the fixed armature [2]. This work presents an experimental stand for the study of a three-phase synchronous generator in reverse construction with permanent super magnets. The three-phase synchronous generator in reverse construction is composed of a fixed armature named stator, located inside the moving armature named rotor and it has been built at the Electrical Machinery Laboratory of "Vasile Alecsandri" University of Bacau.

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The stator is composed of a ferromagnetic core equipped with a three-phase coil made of insulated copper conductor, properly set on a fixed flange. The rotor consists of a cage made of magnetic steel in whose slots the permanent super magnets of type Neodymium are located, so that their polarity alternates as follows: N-S-N-S, [3]. The cage is fixed inside a housing that can rotate versus the stator through the bearings fixed to the stator shaft. In order to study this synchronous generator an experimental stand has been built at the Electric Machinery Laboratory of "Vasile Alecsandri" University in Bacau. This stand is composed of a universal asynchronous motor coupled through a collet ring clutch to the synchronous generator with permanent super magnets. The universal asynchronous motor is supplied from a single phase source through a single phase A.C. convertor that allow the rpm adjustment within the range (0-2000) rev/min. To the terminals of the three-phase synchronous generator a resistive load is connected between two of its phases. Through the measuring instruments the voltage on the generator terminals and the current intensity through the winding during running at load will be measured. Other projects are using synchronous generators with permanent magnets in normal construction [4], and D.C. motors for driving them. Such experimental stands need D.C. supply sources and involve higher costs for testing the synchronous generators with permanent magnets. By using the universal asynchronous motors supplied from single phase voltage convertors, the costs of the experimental stands are lower. The synchronous generators with permanent super magnets in reverse construction can develop a higher amount of electric energy than the three-phase synchronous generators in normal construction at the same overall dimensions. The experimental stand may be used in various applications with didactic or industrial character.

2. Construction of the Experimental Stand

The experimental stand for the study of synchronous generators with permanent super magnets is shown at Fig. 1 and is composed of: three-phase synchronous generator with permanent super magnets in reverse construction (a), universal asynchronous motor (b), collet ring clutch (c), single-phase A.C. convertor (d), ammeter (e), voltmeter (f), tachymeter (g) and load resistor (h).

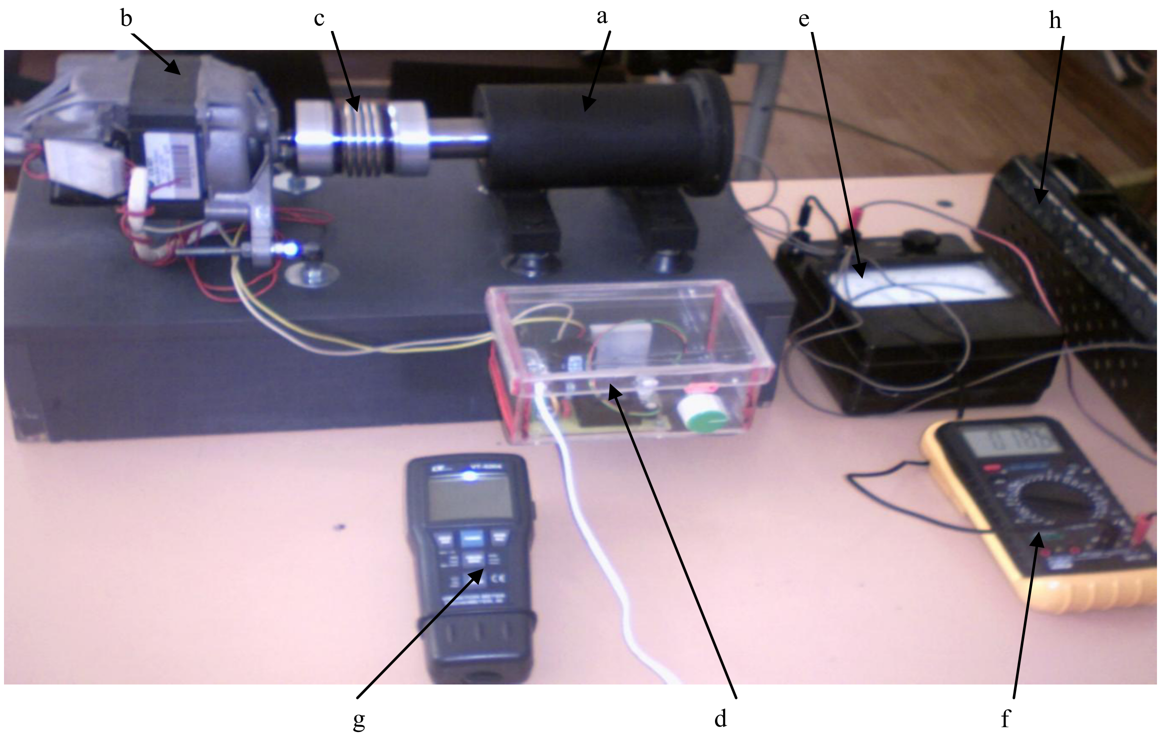

Fig. 1 Experimental Stand.

2.1. Three-Phase Synchronous Generator with Permanent Super Magnets in Reverse Construction

Fig. 2 shows a cross section through a three-phase synchronous generator with permanent super magnets in reverse construction, [5]. The three-phase synchronous generators is composed of a fixed armature named stator (1) and moving armature named rotor, concentrically disposed outside the fixed armature (2). The fixed armature is composed of a ferromagnetic core equipped with an A.C. three-phase winding. The coil groups of the phase windings are STAR connected by means of a disk and the free ends of the phase windings are drawn to the terminal box of the three-phase synchronous generator. The ferromagnetic core and the disk are fixed on a shaft. The moving armature is composed of super magnets and a ferromagnetic core. The three-phase synchronous generator is provided with a protection and shielding housing (5).

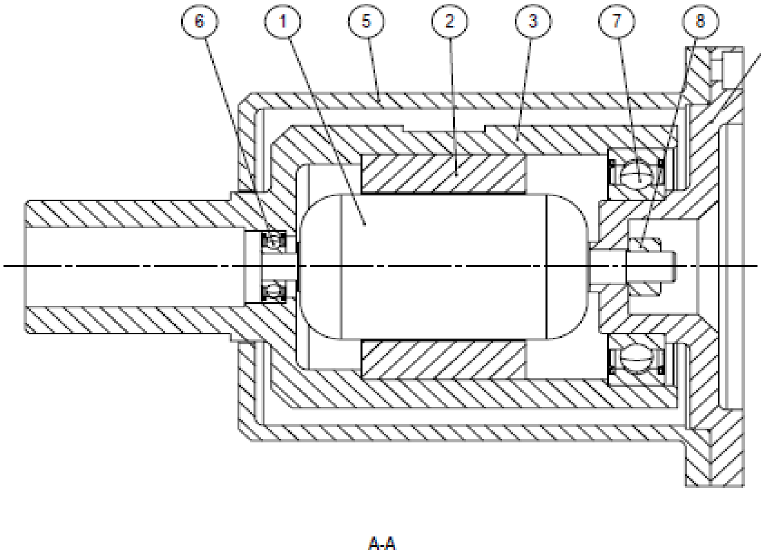

Fig. 2. Cross Section through the Three-Phase Synchronous Generator.
1- stator, 2-rotor, 3-rotor case, 4-ring, 5-protection housing, 6-bearing 607 2Z, 7-bearing 6007 2Z, 8-hexagonal nut

Fig. 3. Generator Stator.

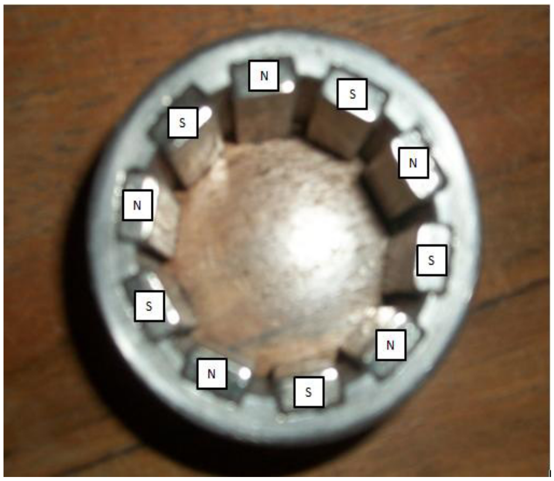

Fig. 4. Generator Rotor .

The stator of the three-phase synchronous generator with permanent super magnets is shown at Fig. 3. The stator shaft is fixed to the ring (4) through the hexagonal nut (8). On the stator shaft the bearings (6) and (7) are mounted,

for supporting and driving the rotor in its rotation motion. The rotor of the three-phase synchronous generator is presented at Fig. 4. It is composed of the case (3) inside which the permanent super magnets are fixed. The permanent super magnets are of type Neodymium. The polarity of the permanent super magnets alternates, so that a hetero polar rotor results.
The characteristics of a permanent super magnet are, [6]:

- Pole surfaces: 40 x 10 mm
- Material: NdFeB (Neodymium Iron Boron)
- Layer type: Nickel (Ni-Cu-Ni)
- Power: approx 8 Kg, approx 78,5 N
- Weight: 15,2
- Manufacturing method: sintered
- Magnetizing: (Grade) N42
- Maximum running temperature: 80 °C
- Temperature (Curie): 310 °C
- Residual magnetism: Br 12.9-13.2 kG 1.29-1.32 T
- Power of the coercive field bHc: 10.8-12.0 kOe 860-955 kA/m
- Power of the coercive field iHc: ≥12 kOe ≥955 kA/m
- Energy being produced: (BxH) max 40-42 MGOe 318-334 kJ/m3

2.2. Universal Asynchronous Motor

The universal asynchronous motor (b) is of industrial type C.E.SET.MCA 38/64 -148/ALA1 and has the following characteristics: rated power = 335 W, rated voltage 220 V.A.C., rated current 1.5 A and rated rpm = 3000, [7]. The shaft of the universal asynchronous motor is coupled to the shaft of the three-phase synchronous generator with permanent super magnets through a collet ring clutch (c). The single phase asynchronous motor is supplied from the single phase A.C. convertor (d) that allows the modification of the rotation speed.

2.3. Single Phase A.C. Convertor

The single phase A.C. convertor is a commutation instrument where the electric circuit is shut off and switched on without mechanical contacts. For this purpose semiconductors are used (thyristors, triacs). The advantages from using single phase convertors are: high reliability, silent and vibration free running, short commutation time, low control power, availability for disconnecting the circuit while the current goes through zero (thus avoiding the occurrence of commutation overvoltage upon the switching off of the inductive loads), as well as high frequency commutations. The single phase A.C. convertors may be built with two thyristors in anti-parallel connection with one triac or a diode bridge and one thyristor. In case of a purely resistive load, the current has the same shape of time variation as the voltage. The single phase A.C. convertor (d) being used is manufactured by the company S.C. Redresoare S.R.L. Giurgiu in Romania. The single phase voltage from the supply source is rectified through a diode bridge, type 1PM8. The continuous voltage resulting at the output of the rectifier bridge is filtered through a condenser. The winding of the single phase motor is connected to the collector of a power field effect transistor model IRFP 460 and is supplied from the continuous voltage produced by the rectifier bridge. The transistor IRFP 460 is controlled through pulses of variable frequency by means of an inverter transistor model TLP 250. The variable frequency pulses for the control of the inverter transistor TLP 250 come from an oscillator fitted with the integrated circuit LM 393. The pulse frequency can be modified through a potentiometer.

2.4. Measuring Instruments

The measuring instruments being used have the following features: ammeter (e): rated current In=5A, digital voltmeter (f): maximum rated voltage = 1000 V.A.C., the tachymeter (g) with laser radiation used for measuring the motor rpm is of type VT – 8204 and measures the rpm without direct contact within the range (10 …. 99.999) rpm with an accuracy of ± 0.05%. The load resistance (h) has the characteristics: R= 30 Ohm, In= 5 A.

3. Running of the Experimental Stand

The electric diagram of the experimental stand is shown at Fig. 5. The stand is supplied from a source of 220 V.A.C. The speed of the three-phase asynchronous motor is adjusted through the single phase voltage convertor by means of the potentiometer P. The speed of the single phase asynchronous motor is measured with the contactless tachymeter. At the terminals of the synchronous generator a load resistor is connected between two of its phases. By means of the measuring instruments the voltage and intensity of the current in the windings will be measured while running at load, at various rpm values of the motor that drives the synchronous generator rotor.

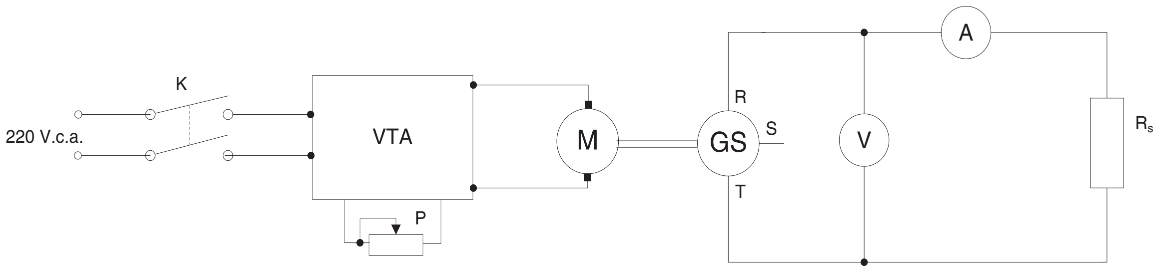

Fig. 5 Electric Diagram of the Experimental Stand.

4. Experimental Findings

With the help of the experimental stand the following characteristics of the synchronous generator with permanent magnets have been drawn out.

4.1. The diagram of idle running of the three phase asynchronous generator, U=f(n) where U is the voltage measured at the terminals between two phases of the generator and n is the speed of the synchronous generator. The resulting values are presented in Table 1 and the diagram of this characteristic is shown at Fig. 6.

Table 1. Resulting values of U (voltage at the terminals) and n (speed of the synchronous generator)

U (volts)	8	10	15	18	21	27	33	38	45
n (rpm)	522	586	765	898	1083	1380	1652	1933	2220

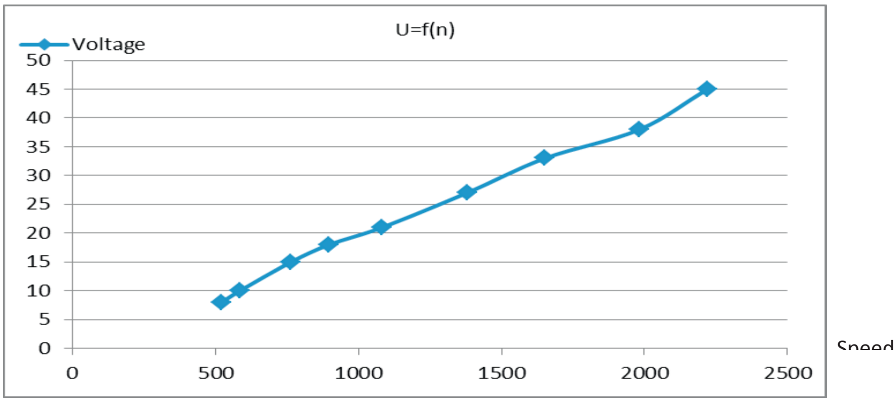

Fig. 6. Diagram of idle running of the three phase synchronous generator .

4.2. The load running diagram of the three phase synchronous generator U = f(I), where U is the voltage on terminals measured between two phases of the generator and I is the current intensity through the load resistor R_s

and through the respective windings at a constant value of the generator rotor rpm, n= 2536 rev/min. The resulting values are shown at Table 2 and the diagram of this characteristic is shown at Fig. 7.

Table 2. Resulting values of U (voltage at the terminals) and I (current intensity)

U (volts)	21,4	17,3	12,2	7	1
I (A)	6,5	7,5	8,25	9	10

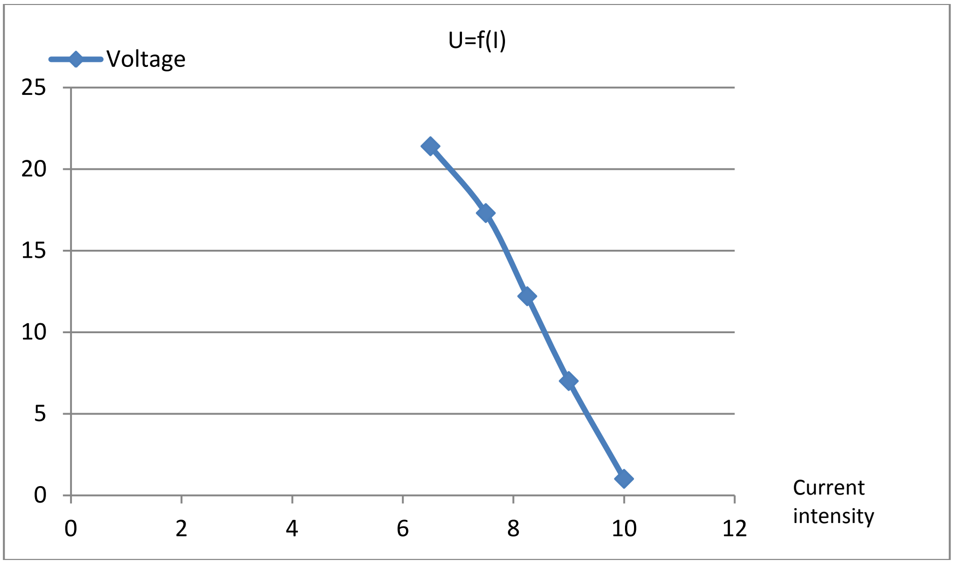

Fig. 7. Diagram of load running of the three phase synchronous generator.

5. Conclusion

Synchronous generators with permanent super magnets are an important alternative to the usage of synchronous machines in the construction of low and medium wind power stations for producing electricity. The advantages of using the synchronous generators with permanent super magnets compared to the usage of synchronous generators with excitation winding are: the lack of rotor losses due to the usage of permanent super magnets, generation of a rotary field of high value by the permanent super magnets, approximately linear running characteristics and higher effectiveness. In perspective, synchronous generators with permanent super magnets may be built, with smaller armature gap, in order to increase the generator power for the same overall dimensions

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