ANALELE UNIVERSITĂȚII
"EFTIMIE MURGU" REȘIȚA
ANUL XX, NR. 2, 2013, ISSN 1453 - 7397

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Modulated Field Synchronous Generator for Wind Turbines

This paper presents a modern electromechanical conversion system solution as the modulated field synchronous generator, offering on the one hand, an output voltage with constant frequency in terms of speed variation of the wind turbine and on the other hand an advantage power / weight ratio due to the high frequency for which the magnetic circuit of the electric machine is sized. The mathematical model of the modulated field synchronous generator is implemented in MatLAB modeling language, highlighting the command structure on the transistors bases of the inverter transistors, through which the functioning of the electric machine can be studied, especially in terms of the frequency of the delivered voltage.

Keywords: *modulated field synchronous generator, inverter, mathematic model*

1. Introduction

Besides the classical electric generators, the wind systems appeals to modern energy generation systems, as the synchronous generator with modulated field that offers at the output a voltage with constant frequency, in terms of important variations of the wind turbines speed [4].

The system is based on a three-phase synchronous generator, driven at variable speeds, which produces on the output a three phase / single phase voltage, with precisely controlled frequency of 50 Hz. The machine works in general at high speed (>3000 rpm), generating a voltage with a frequency of at least 350 Hz for a 50 Hz voltage stabilized at the output. These generators have the important advantage that they work in good condition at the coupling with various drive motors and do not require speed control systems.

Another major advantage in the wind application is the power / weight ratio (kW / kg), whose value is convenient due to the fact that the machine is mainly operating at high speeds. It is known that the nominal power of the electric machine, at given size, is dependent on the speed / frequency, which is the reason why the machine dimensioning is done at the frequency of 400 Hz instead of 50 Hz. Therefore, in case of wind generators, the use of synchronous field modulated generators, provides a good solution to the those two problems, namely variable speed drive and reduced weight for a required power, given the mounting on the gondola, suspended at height [6]. Also, the modulated field synchronous generator is characterized by short transient regimes due to a lower weight and lower inertia making possible to track more rapid the wind speed that is constantly changing.

2. Modeling principle of modulated field synchronous generator

If a conventional three-phase synchronous generator with nominal frequency f_g is excited by an alternating current of frequency f_m ($f_g > f_m$) will produce induced voltage of ($f_g + f_m$) and ($f_g - f_m$) frequencies. If by the generator produced three phase voltages, will be, each one, rectified and at the output we will obtain a voltage consisting of a continuous current component, a ripple corresponding the 6 f_g frequency and a rectified sinusoidal voltage, corresponding to the f_m frequency of the form: $U \cdot \sin(\omega_m t)$, where $\omega_m = 2\pi f_m$ [8]. For values of f_g/fm ratio around to 10, the continuous component becomes negligible small and the rectified voltage from the output can be converted in a sinusoidal voltage equal with the modulating frequency f_m, by using a corresponding inverter circuit.

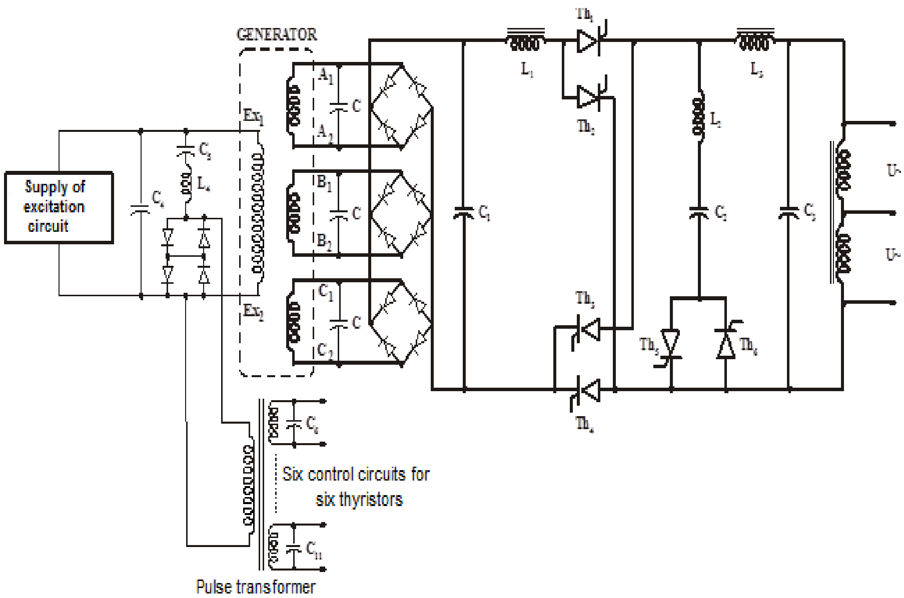

Figure 1. Simplified diagram of the system using the modulated field generator

Figure 1 shows a scheme that is based on a high-speed three-phase synchronous generator and high frequency. The pulse transformer is intended to provide the control pulses both, the main inverter thyristors (Th1 .. Th4) as well as for the extinguishing thyristors (Th5 and Th6)

Considering the performance of power semiconductors, in the modeling of the modulated field synchronous generator, the IGBT transistors can be used in place of thyristors in the parameters imposed by the generator in question. The transistors presents two main advantage in relation to the thyristors, namely does not require extinguishing circuits, ie thyristors and L-C supplementary circuits, having a higher commutation speed helping to reduce the switching losses mainly in schemes that work at high frequencies.

The scheme used for modeling the generator with modulated field and the inverter with IGBT transistors, is presented in figure 2:

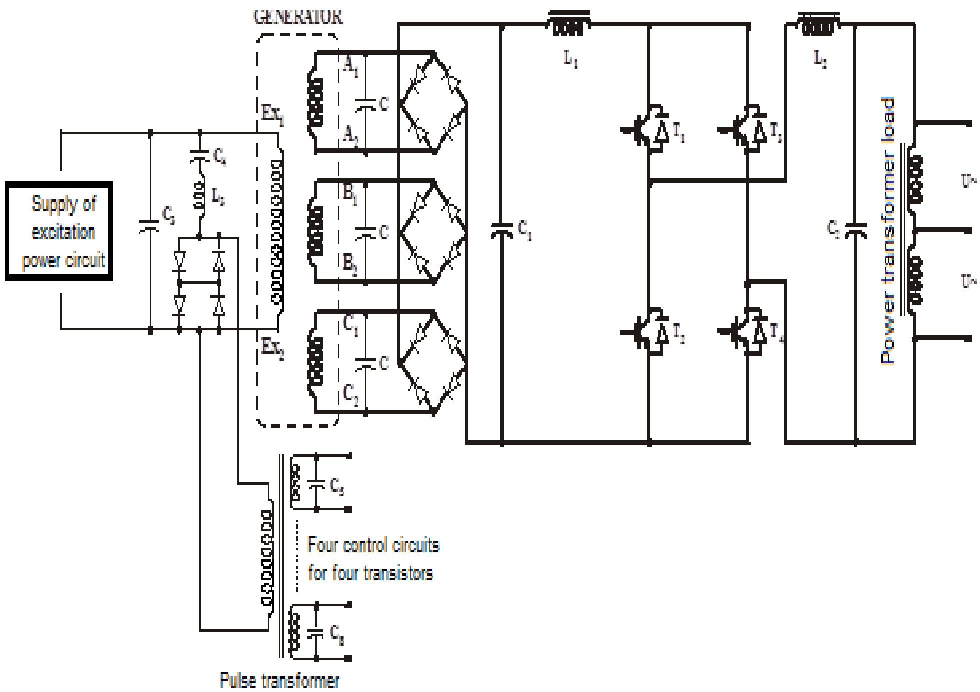

Figure 2. Schematic diagram for modeling the generator with modulated field and inverter with IGBT transistors

There is a noticeable simplified configuration compared to the version with thyristors by reducing the number of static contact, 4 (four) transistors instead of 6 thyristors, simplification of the pulse transformer from 6 (six) to 4 (four) command windings, giving up LC circuits switching with switching role of the auxiliary thyristors.

The MatLAB / Simulink [9] model of the principle scheme presented in Figure 2, is shown in Figure 3.

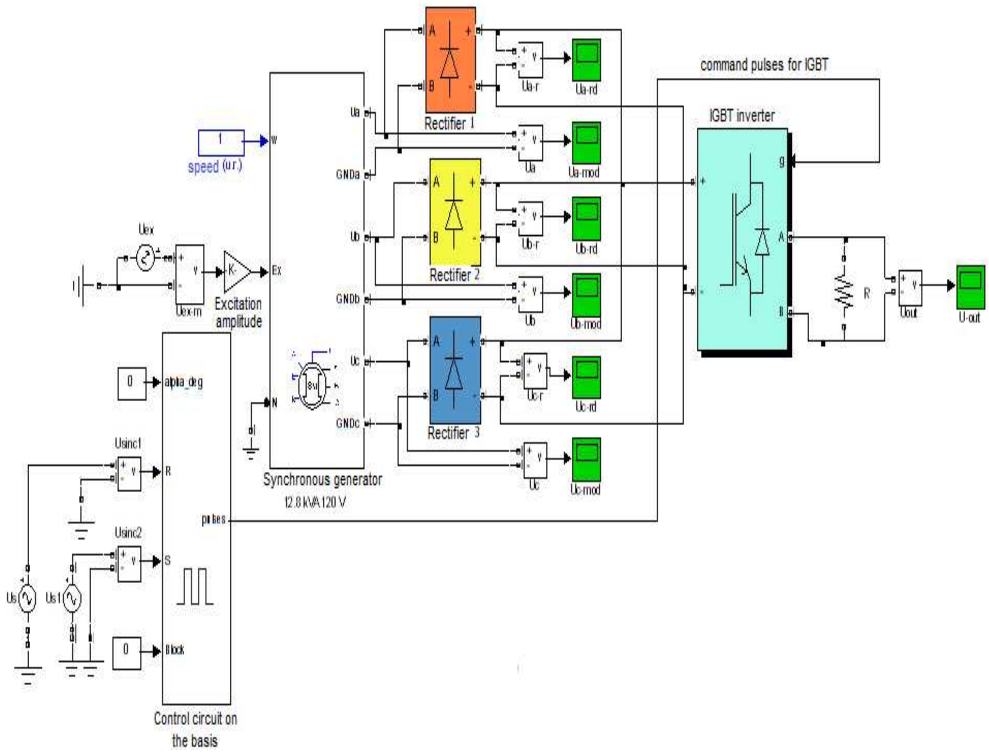

Figure 3. MatLAB / Simulink model of the principle scheme from Figure 2

The model is based on a three-phase synchronous generator, provided by the SimPowerSystem package from the Simulink environment [7], which adapts to the electromagnetic parameters of the considered synchronous generator. To model the synchronous generator with modulated field, its excitation circuit is powered from an AC voltage source U_{ex-m}, of imposed voltage and 50Hz frequency. The voltages obtained from the three phase windings are rectified by bridge rectifier: 'Rectifier 1', 'Rectifier 2', and 'Rectifier 3' whose outputs in DC are connected in parallel and feed the input inverter with transistors 'IGBT Inverter'. The inverter output is connected to a single phase consumer R, which is supplied with a 50Hz frequency voltage, equal to the supply voltage of the generator excitation circuit.

In Figure 4 we notice the role of the command circuit to provide control signals synchronized with the supply voltage of the excitation circuit, so that the inverter provides to the load a voltage of the same frequency with respect to the excitation voltage.

Depending on the evolution of the generator speed drive over time, the system behavior can be studied by simulation in terms of phase modulated voltage, the rectified modulated phase voltage and from the consumer power supply frequency point of view [5].

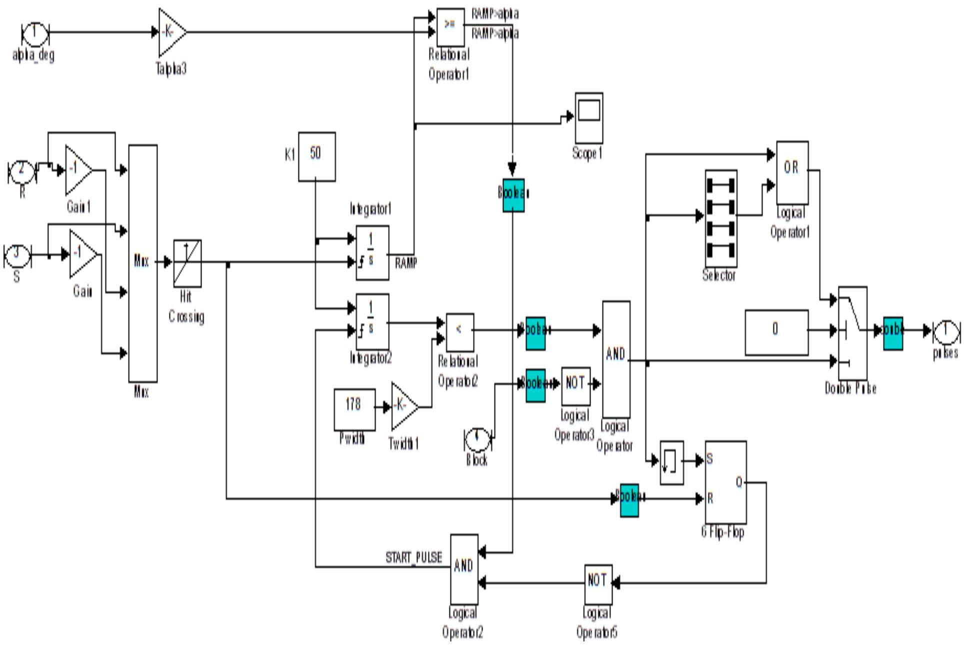

Figure 4. Command structure circuit on transistors base

3. Conclusions

Using modulated field synchronous generator for wind turbines constitutes a modern version of energy production, alongside the use of permanent synchronous generators. The study by modeling and simulation, demonstrated the system ability to maintain constant the frequency of the output voltage in terms of wide limits variation of the driving speed. The modulated field synchronous generator has shown benefits on operation in a wide range variable speed, short term transient regimes, a low inertia thanks to a small magnetic circuit and consequently a reduction of weight, important when installing the gondolas at height.

References

[1] Babescu M., *Vehicule electrice hibride*, Ed. Politehnica, Timisoara, 2009

[2] Babescu M., *Surse statice de energie electrica*, Ed. Politehnica, Timisoara, 2007.

[3] Boldea I, *Variable speed generators*, CRC Press, Taylor & Francis Grousp, 2006.

[4] Cimpoeru A., *Encorderless Cector Control of PMSG for Wind Turbine Applications*, Aalborg University, Institute of Energy Technology, 2010.

[5] Enrique L. Carrillo, *Modeling and simulation of permanent magnet synchronous motor drive system*, University of Puerto Rico, 2006.

[6] Gary L. Jhonsons, *Wind energy systems*, Manhattan, KS, 2006.

[7] Nahome Alemayehu Ayehunie *MultiPhase Permanent Magnet Synchronous Generators for Offshore Wind Energy System*, Norwegian University of Science and Technology, Department of Electric Power Engineering, 2011.

[8] Paunescu D., Babescu M., *Analiza matematica a dinamicii masinilor electrice*, Ed. Politehnica, Timisoara, 2005.

[9] http://ctms.engin.umich.edu/CTMS/index.php?aux=Home

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