

THE POWER CONTROL OF THE MULTIPOLE DOUBLE FED INDUCTION WIND GENERATOR

DAUDZPOLU ASINHRONĀ VĒJA ĢENERATORA JAUDAS PLŪSMAS VADĪBA

Guntis Dilevs, *student Mg. sc. ing.*

Riga Technical university
Power and electrical engineering
Kaļķu street 1, LV-1050, Riga, Latvia
Phone: +371
e-mail: guntis.dilevs@gmail.com

Edgars Jakobsons, *student Mg. sc. ing.*

Riga Technical university
Power and electrical engineering
Kaļķu street 1, LV-1050, Riga, Latvia
Phone: +371
e-mail: edgars.jakobsons@inbox.lv

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Introduction

Nowadays the use of wind energy is developing in the direction of large and medium wind generators, which are able to work in parallel with the grid or independently. The most common solution for such systems is a direct-drive synchronous generator, which provides high efficiency and installed power factor [1].

A conventional induction generator possesses a number of advantages – such as high reliability and stability when working to the power grid [2]. However, it also has some significant disadvantages – e.g. the low efficiency and power factor when the number of pole pairs is greater than ten. They are impossible to use as direct driven wind generators for small and medium wind turbines. Accordingly, the direct driven generators are based on synchronous machines with controlled or permanent magnet excitation systems [3].

In this project we overview the practical application of multipole induction machines as generators for small and medium wind turbines. In the considered model all the windings are placed on the stator and the rotor is tooth-like with no windings.

1. Special features of the multipole induction generator with a single-phase secondary winding

Figure 1 shows the construction diagram of an induction generator whose primary (A – X, B – Y, C – Z) and secondary (a – x) windings are situated in the slots of stator 1. Accordingly rotor 2 is tooth-like and has no windings. Each tooth 3 of rotor 2 corresponds to one pole pair. The total number of teeth can be rather big, which does not lead to enlargement of winding coils of the stator and, therefore, of the magnetizing current. The secondary winding is single phased and is also placed in the stator's slots. In the secondary circuit capacitors and electrical devices (load) $R_{L1} - R_{L5}$ are arranged. The secondary winding plays a major role in magnetizing the system and reducing the losses of the electrical machine. The system requires neither brushes nor slip-rings.

Owing to the single phase secondary winding the number of coils in the stator is limited. In this case, at the number of pole pairs equal to 22, there are four coils in each phase. The primary windings, A-X, B-Y and C-Z, are situated in pole extensions 4. Each pole extension between two slots can have up to five smaller teeth with a step t_{zp} , which is equal to the step t_z for the teeth on the rotor.

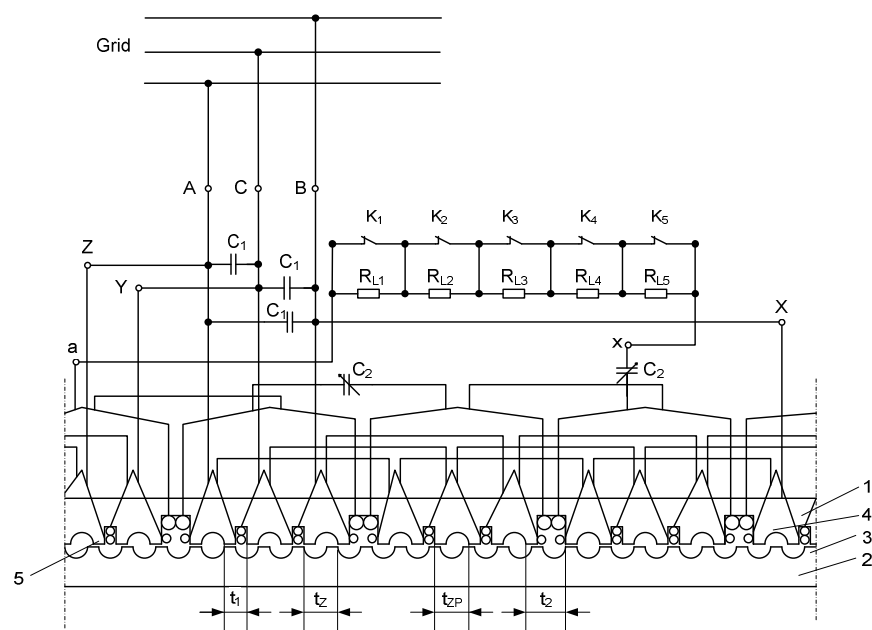


Figure 1. The construction diagram of the induction generator with primary and secondary windings on the stator: A-X, B-Y, C-Z – primary windings; a-x – secondary windings; 1 – stator; 2 – rotor; 3 – rotor teeth; 4 – pole extension; 5 – teeth on the pole extension; C_1 , C_2 – capacitors in the primary and secondary circuits; $R_{L1} - R_{L5}$ – controlled secondary load resistance; t_Z , t_{ZP} , t_1 , t_2 – stator and rotor tooth steps; $k_1 - k_2$ – NC contacts

The practical application of the single-phase secondary winding is that it simplifies the transfer of energy to the load. At rotation the rotor teeth change their location with respect to the stator pole extension – from teeth to grooves, which, in turn, cause a periodical change in the magnetic conductivity from maximum to minimum. The conductivity of the K -th pole extension can be described by a Fourier's periodic function series [4] as

$$\lambda_k = a_0 + a_1 \cos(Z_R \alpha - \varphi_k) + a_2 \cos 2(Z_R \alpha - \varphi_k) + a_3 \cos 3(Z_R \alpha - \varphi_k) + \dots + a_v \cos v(Z_R \alpha - \varphi_k) \quad (1)$$

To avoid the total harmonics distortion (THD), the width of stator's teeth has to be $t_Z/3$, and the groove between the teeth should be calculated assuming the radius of $t_Z/3$ [4]. Accordingly, equation (1) can be rewritten as

$$\lambda_k = a_0 + a_1 \cos(Z_R \alpha - \varphi_k) \quad (2)$$

where

- a_0 is the constant magnetic conductivity of the pole extension;
- a_1 is the amplitude of first harmonics of a pole extension's magnetic conductivity;
- Z_R is the number of rotor teeth (pole pairs);
- φ_k is the phase angle.

The periodic change in magnetic conductivity causes a periodic change in the magnetic-flux linkage, which means the generation of energy transferred to the power grid and to the secondary load.

2. The power control of multipole double fed induction generator

To increase value of the current in the secondary circuit and power generated to the grid from the primary circuit, the operating mode of the induction generator has to be close to the resonance mode. This mode can be achieved by switching the capacitors in secondary circuit, which total capacity equals

$$C = \frac{10^6}{4\pi^2 f_1^2 L_2 s^2} \quad (3)$$

where

- f_1 – the frequency of the power grid;
- L_2 – the impedance of the secondary winding;
- $s = (n_1 - n)/n_1$ – slip.

For the prototype of the generator the impedance $L_2 = 0,222$ H, which together with its active resistance $R_2 = 1,5$ ohm, provides sharp curve current resonance in secondary circuit. That is why the capacity of the secondary circuits and resistance of the secondary load should be controlled due to achieving maximum output power $s = - (1,0 \dots 1,1)$. The capacity for this generator changes in a wide range. According to (5) the limits of the capacity $C_2 = 1540 - 37 \mu\text{F}$ and the resistance $R_2 = 0 - 16,5 \Omega$.

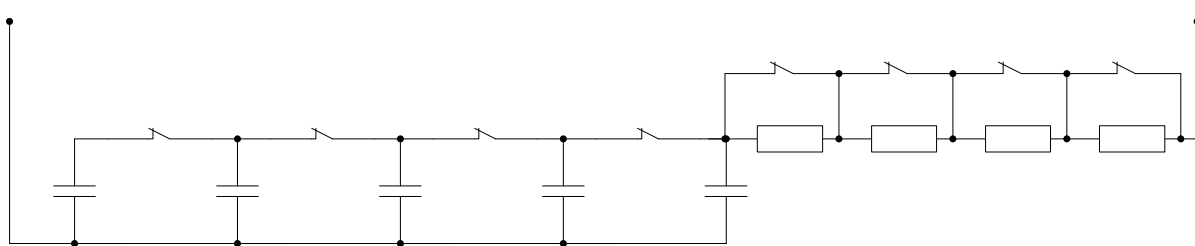


Figure 2. The principle of commutating the secondary circuit into five steps

In the Figure 2 is shown the option of controlling the parameters in the secondary circuit into five steps. Unfortunately this cause major power fluctuations when slip $s = (-0,14..-1,11)$. That kind of power fluctuations are not allowed for the power generation.

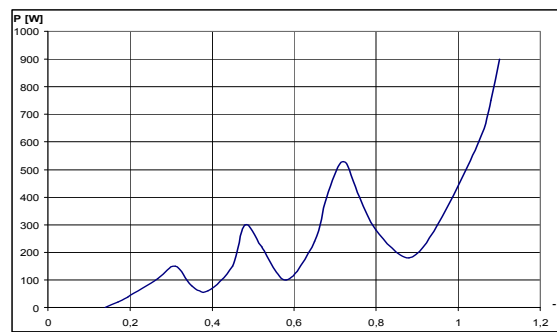


Figure 3. Power collected from the secondary circuit by five step capacitor system

If the amount of capacitor steps are increased to ten, then it is possible to decrease the fluctuation for about 2 times. This can be used as an example of making a control model for this generator. According to that the slip jumping from one step to another increases 1,23 times. It is possible to make a row of slip values for each step: -0,172; -0,212; -0,260; -0,32; -0,354; -0,484; -0,596; -0,733; -0,901; -1,108.

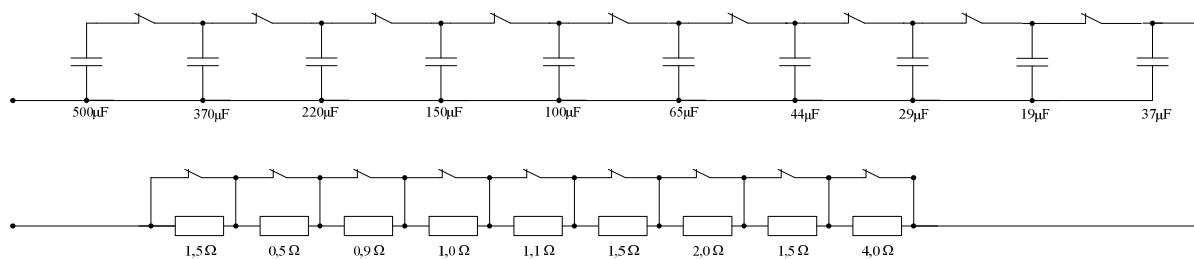


Figure 4. The principle of operating the secondary circuit into ten steps

In the Figure 4 is shown the circuit diagram for the secondary circuit. The capacitors and resistors of the secondary load are divided into ten steps. The step values of the capacitors should strictly follow together with the frequency in the secondary circuit in each step.

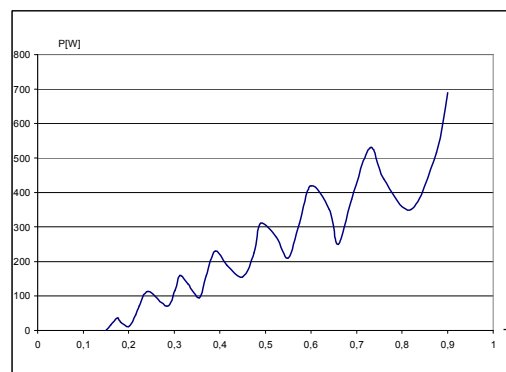


Figure 5. The curve, which shows the power collected from the secondary circuit by ten step capacitor system

The control of the frequency $f_2 = f_1 s$ is done by a microprocessor, which switches the capacitors according to the value of the f_2 . The frequencies for switching the capacitors are as follows. If frequency f_2 in the secondary circuit increases the commutation for next step should be handled at these values 7, 10, 12, 15, 18, 22, 27, 33, 41, 50 Hz. If it decreases then it should be done at these values 49, 40, 32, 26, 21, 17, 14, 11, 9, 6 Hz. In the Figure 5 is shown an example of the capacitors and resistors in secondary circuit, which are used for the prototype multipole double fed induction generator. From the calculations it is seen that the capacity of the capacitors is rather big, especially for the generators with comparatively increased power. That is why it is more reasonable to use the semiconductor devices (e.g. IGBT transistors) instead of the capacitors. The fluctuations of the power then will be rather small [6].

Conclusions

The research was targeted at extension of the practical application of directly driven induction machines in the wind turbines. For small powers (400 – 500 W) it is possible to use a generator with 8..10 pole pairs and a squirrel cage rotor. The conventional design cannot provide increasing output power with simultaneous decrease in the number of pole pairs. In the proposed low-speed induction generators all windings should be placed on the stator, with a tooth-like windingless rotor. To increase the output power of such a generator it is recommended to use a double fed system. The number of pole pairs in a generator can reach ≥ 50 . The research was done for a 52-pole induction machine with three-phase primary and one-phase secondary windings, and with tooth-like unwound rotor. The results have shown that with such a machine a reliable power generation and high efficiency can be achieved.

References

1. Daskova J., Kamolins E., Levins N. Multipole directly driven wind generators. Latvian journal of Physics and Technical sciences, Nr.4, 2004.gads. pages 41 – 47. (in Latvian)
2. The new generation of wind energy converters. Pitch Wind Systems AB, Sweden, 2001.
3. Enercon grid properties and wind farm managemant, Enercon, Hamburg, 2002. 15 pages.

4. Levin N., Serebriakov A., Electrical machines and drives, 3.ed, Electrical drives based on the motors with static windings, Riga 1976, 192 pages.
5. Dilevs G., Levins N., Pugachevs V., Ribickis L. Double fed induction generator. Patents application P – 03 – 101, 20.09.2007, 8 pages.
6. Levin N., Pugachev V., Ribickis L., Zhiravecka A., Contactless multipole Doubly-Fed Asynchronous Generator for Windmills. Electrical Power Quality and Utilisation, Journal Vol. XII, No. 2, 2006. 5 pages.

Dilevs G., Jakobsons E. The power control of the multipole double fed induction wind generator

The project concerns the practical applications of multipole induction machines as generators for small and medium wind turbines. Such a multipole generator should be built in a way that the primary and secondary windings are placed on the stator, and the rotor is tooth-like without windings, with each tooth equivalent to one pole pair. The most reliable design is that with a single-phase secondary winding, which provides efficient control of the generator. The secondary winding gives an opportunity to increase the output power above the nominal within the increase of the wind speed. The power flow of this generator is separated in two parts. The power generated from the primary winding is directly transferred to the power grid. But the power which is generated by the secondary winding can only be transferred to the secondary load, which does not require constant frequency. The resistance of the secondary load should change according to the rotation speed of the shaft. The secondary voltage increases – the resistance of the load also increases. The principle of controlling the power of the secondary load is that the current in the secondary winding does not increase above the nominal.

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Дилев Г., Якобсон Э. Управление мощностью многополюсного асинхронного ветро генератора

Предлагается использовать многополюсные асинхронные машины в качестве прямоприводных генераторов в ветроустановках малой и средней мощности. При большом числе пар полюсов следует применять конструкции, когда и первичная и вторичная обмотки расположены на статоре, ротор зубчатый без обмоток, где каждый зубец определяет пару полюсов. Наиболее просто и надёжно такая задача решается при однофазном исполнении вторичной цепи, обеспечивающей эффективное управление режимами работы. С помощью вторичной цепи возможно увеличивать отдаваемую мощность генератора выше номинальной. Мощность генератора возможно разделить на две части – мощность первичной обмотки и мощность вторичной обмотки. Мощность генерируемая первичной обмоткой отдаётся на общую сеть, а мощность вторичной обмотки возможно отдать на независимую от частоты нагрузку. Сопротивление вторичной нагрузки должно меняться пропорционально частоте вращения генератора. Основное условие: при коммутации вторичной нагрузки необходимо, сохранять величину вторичного тока близкой к номинальной.