SOURCES OF THE WIND POWER STATIONS

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Annotation
The paper deals with problems of the wind power stations. Describes the basic properties of wind energy. Shows and describes the different types of electrical machines used as a source of electricity in the wind power stations. Shows magnetic fields synchronous generator with salient poles and permanent magnets in the program FEMM. Describes methods for assessing of reversing the effects of the wind power stations on the distribution network.

Keywords
Renewable energy sources, wind energy, wind power stations, electric machines, magnetic fields

1 INTRODUCTION

An important question in the early 21st century is: Where to get the energy at it so people can live, work, travel etc. without restrictions on account absence of electricity? Up to 90 % of consumed electricity comes from petroleum, coal and gas. Bounded amount of fossil fuels and their negative impacts on the environmental forcing people planet Earth, to think about alternative sources of energy. One of the renewable energy sources is wind energy. The conversion of energy flow of wind into electrical energy is implementing in the wind power stations. Wind power stations are in world an important source electrical energy. It is necessary deal with them, because the impact of their operations for transmission and distribution networks with increasing performance of electrical machines causes a change in requirements which must to fulfil that can be connected to the transmission and distribution networks.

2 WIND ENERGY

Wind energy is the kinetic energy of air. Wind energy is an indirect form of solar energy. Earth´s surface sunrays calorify with varying intensity. A result calorify earth´s surface sunrays are to temperature and pressure differences. Approximately 2 % radiates energy of the sun is converted to airflow. Wind speed and direction are given by the rotation of the earth´s surface. Air generally flows from places of higher pressure to places of lower pressure. On the production of electricity is needed the average wind speed greater than (4 – 5) m/s (10 m above the ground). The rule is that at an altitude of 650 m above sea level is the average wind speed 2,5 m/s, which is a low speed [1].

Wind energy is given by the formula for movement matter:

$$E = \frac{1}{2} m v^2 \tag{1}$$

where v is velocity a m is amount that can be expressed by the volume V and density of air ρ:

$$m = \rho V = \rho A s \tag{2}$$

where A is area through which air flows and s is the path, which pass the moving air.

For power flowing through a unit area is valid formula:

$$P_v = \frac{E}{At} = \frac{1}{2} \rho \frac{As}{At} v^2 \tag{3}$$

If we put per a variable v share s / t, so for the *power flowing through a unit area* is valid the following relationship:

$$P_v = \frac{1}{2} \rho v^3 \tag{4}$$

This relationship indicate the fact that wind power flowing per unit area of 1 m^2 is proportional to the cube of the wind speed and air density. At higher speeds is performance large enough to be effectively utilized. If electric power expressed in ratio to wind power, the maximum possible efficiency of the generator will be less than 60 %

(only in theory, in practice about 45 %) [1].

3 SOURCES OF THE WIND POWER STATIONS

Electricity in the wind power stations is produced in the electric generator. The rotational force propeller is transmitted via the driving mechanism to the electric generator. The propeller the wind power station is rotating variable speeds (variable air velocity) and therefore electric power is not constant value. Currently, is the requirement to use a source of electricity that can produce a constant voltage with constant frequency at variable speed.

Sources of electricity used in the wind power stations can be divided according *to the drive*:

- *sources with direct drive* (don´t have gearbox),
- *sources with indirect drive* (have gearbox).

4 SOURCES OF THE WIND POWER STATIONS WITH DIRECT DRIVE

4.1 Multi pole synchronous generator driven directly by the turbine

As a source of the wind power station with direct drive is used synchronous generator with a large number of poles excited actuating current or synchronous generator excited by permanent magnets (Fig. 1).

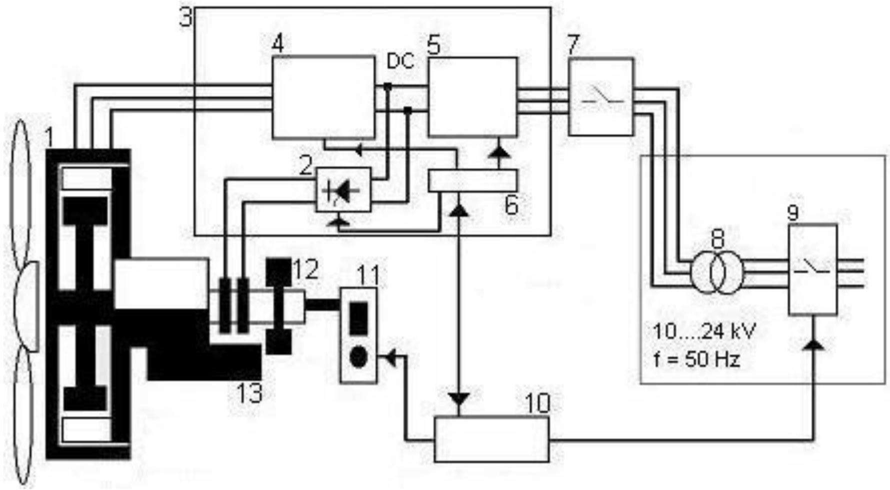

Fig. 1 Multi pole synchronous generator driven directly by the turbine
1 – multi pole synchronous generator, 2 – rectifier excitation, 3 – frequency converter, 4 – rectifier, 5 – inverter, 6 – control inverter, 7 – main power switch, 8 – transformer 0,69/vn, 9 – power switch high voltage (network), 10 – control turbine, 11 – swivelling leaves, 12 – brake, 13 – gripping the rotor

This source is designed so that there is no gearbox and the wind turbine direct driven source variable speed. According to the speed has a induced voltage generator variable frequency and therefore between the network and the generator is inserted frequency converter. Multi pole synchronous generator and frequency converter are large and heavy construction. Nevertheless is loading the gondolas smaller than that of the induction generator with squirrel cage and induction generator fed into the rotor, which have a gearbox. Whole the mast and the gondola are less robust construction and therefore costs are lower.

The basis machine room is a rigid frame on which is the main shaft. On the main shaft is placed a disc brake and at the end of the shaft is located a head propeller. The sheets propeller are mounted in a steel the root with helmet which allows her swivelling around longitudinal axes. In the root of each sheet is located swivelling arm which ensuring the accurate setting angle sheet control device. The shaft rotates directly multi pole synchronous generator because this source does not have the gearbox. Hydraulic unit powered the brake and device for control for the wind motor rotation sheets. The generator is placed in front of the machine room just behind the head propeller. Horizontal shooting propeller to the wind direction is achieved by swivelling machine room with two gearbox located on the frame of the machine room. These two gearbox are driven by electric motors. Pinions two gearbox working with swivelling wheel mounted on top of the mast. Swivelling is controlled by wind electronic winker and controller also protects input the cable into machine room in front of twist.

5 SOURCES OF THE WIND POWER STATIONS WITH INDIRECT DRIVE

5.1 Induction generator with squirrel cage

On Fig. 2 is shows three phase induction generator with slip rings wound rotor or with squirrel cage rotor which is connection to a network and produces electricity in excess of synchronous speed rotor.

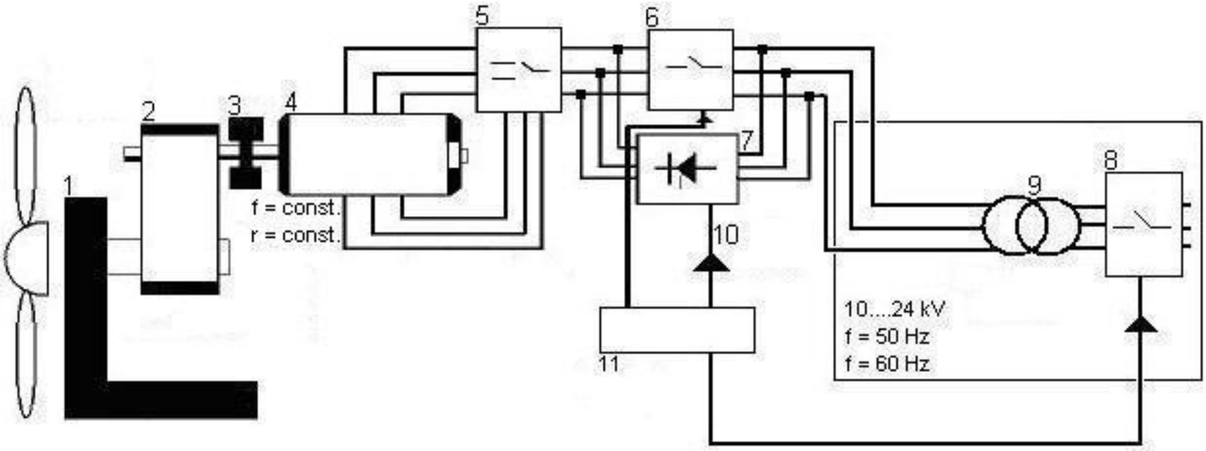

Fig. 2 Induction generator with squirrel cage
1 – gripping the rotor, 2 – gearbox, 3 – brake, 4 – induction generator, 5 – power switch generator, 6 – main power switch, 7 – rectifier excitation, 8 – power switch high voltage (network), 9 – transformer 0,69/vn, 10 – starting motor, 11 – control turbine

These machines operate with a small negative slip within a few percentage, so the operation is bound to constant speed. The wind turbine regulate the speed of the generator via a gearbox in excess of synchronous constant speed. This construction allow operation the wind power stations in a narrow speed range. Certain improvements meant application of generators with selectable number of poles, for example with the number poles 4, 6, 8 reaching three synchronous speed videlicet 1500, 1000 and 750 rpm. You can also expand the regulatory scope if into the rotor ring induction machine will to include resistors. These types of induction generates are characterized by the need to compensate power factor through capacitor battery. These sources are relatively inexpensive but less efficiently. They are used in older types the wind power stations.

5.2 Induction generator fed into the rotor

Induction generator fed into the rotor is currently the most used source of wind power stations. On production the electricity is used the slip rings induction generator with wound rotor, which is fed into the rotor slip performance from the frequency converter and the stator is directly connected to the network. This source is operated beside the different speeds of the rotor turbine thus at different wind speeds. Voltage regulation and frequency provides frequency converter feeding to the rotor. This generator wind power stations is working in a range from 30 % of the synchronous speed generator to 150 % speed, which is very favorable range. Therefore is the most extended source wind power stations despite the high price of frequency converter whose power need not be dimensioned at full power generator but on smaller according to the required range regulation speed of the generator. To accelerate the speed turbine induction generator fed into the rotor require gearbox. It can be used in the performance of several MW.

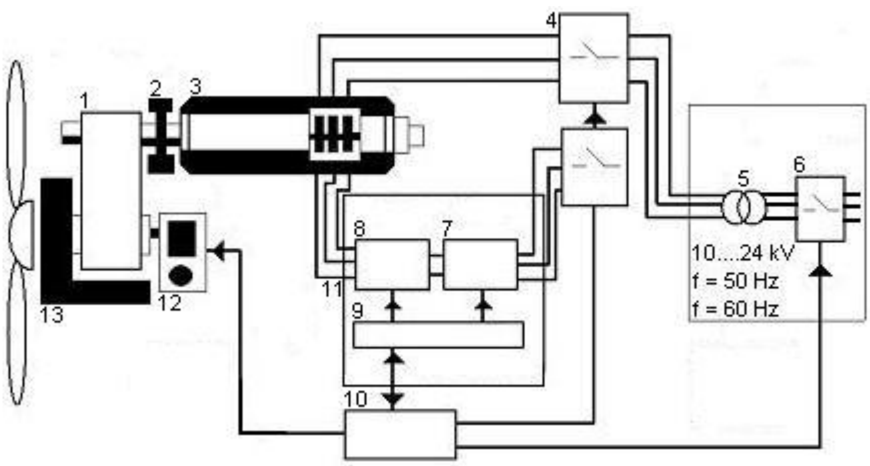

Fig. 3 Induction generator fed into the rotor
1 – gearbox, 2 – brake, 3 – induction generator, 4 – main power switch, 5 – transformer 0,69/vn, 6 – power switch high voltage (network), 7 – rectifier, 8 – inverter, 9 – control inverter, 10 – control turbine, 11 – frequency converter, 12 – swivelling leaves, 13 – gripping the rotor

5.3 Commutator motor fed into the stator

Three phase commutator motor fed into the stator is a classical source of electricity, which is suitable for smaller the wind power stations.

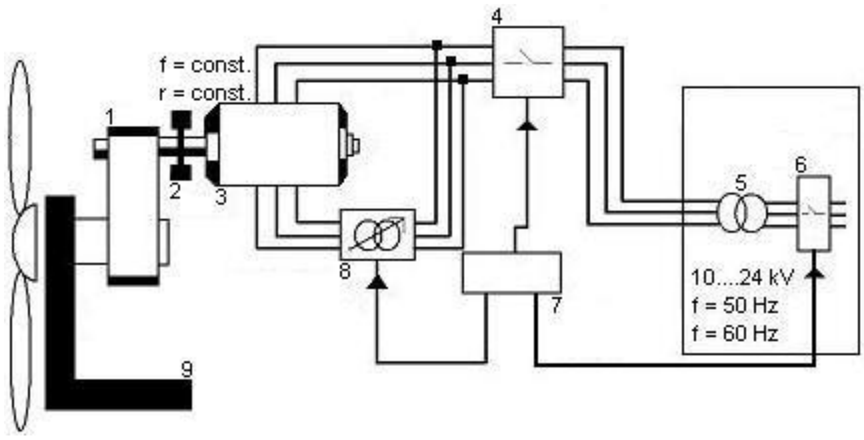

Fig. 4 Commutator motor fed into the stator
1 – gearbox, 2 – brake, 3 – commutator motor, 4 – main power switch, 5 – transformer 0,69/vn, 6 – power switch high voltage (network), 7 – control turbine, 8 – variable transformer, 9 – gripping the rotor

Commutator machine have similar generators area of operation as the induction machine. To its operation needs gearbox. Power control can be done by regulating the output voltage regulating transformers (may be located on the base plate mast) which to feed rotor induction machine by means of servomotor. Also are need of capacitor batteries for power factor compensation because the commutator source to provide active power to the network and simultaneously drawn from the network the reactive power. Commutator sources do not need electronics, are cheap and reliable operation is good. In the past were made to several 100 kW (200 – 400 kW), at the present can work in some older types of small wind power stations [2].

6 MAGNETIC FIELDS SYNCHRONOUS GENERATOR

Magnetic fields are solved using the program *Finite Element Method Magnetics (FEMM)* in synchronous generator with salient poles and permanent magnets. FEMM is a set programs on solve static and low frequency magnetic fields. These programs usually solve problems in two dimensional and axial symmetrical environment. FEMM is divided into three main parts namely:

a) *Preprocessor* (geometric construction; the definition of material properties and boundary conditions – Dirichlet, Neumann and Robin boundary condition),
b) *Solver* (calculation equations to obtain values of the magnetic field),
c) *Postprocessor* (graphic section that shows the resulting magnetic fields) [3].

Synchronous generator is drawn in the Preprocessor program FEMM so that were see the slots stator, armature poles with permanent magnets and air gap between stator slots and permanent magnets. In the Preprocessor is to the top and bottom of the cut synchronous generator specified Dirichlet boundary condition, which says that the magnetic field lines do not pass boundary solutions. After running section Solver is of the cut synchronous generator divided into many triangles (the triangulation), which is very important when solution with finite element method. Then make calculations based on the finite element method. After calculations graphic section Postprocessor shows the distribution of the magnetic field.

Input and calculated the basic parameters synchronous generator with salient poles and permanent magnets which are the basis for solving the magnetic fields are as follows:

- D = 4 m – average generator
- m = 3 – number of phases
- q = 1 – number of slots per pole and phase
- $2p$ = 150 – number of poles

- $\delta = 3$ mm – air gap between stator slots and permanent magnets

The total number of stator slots is given by:

$$Q = N_d = 2p.m.q = 150.3.1 = 450 \tag{5}$$

Then for the poles distance stator slots is valid:

$$\tau_p = \frac{\pi.D}{2p} = \frac{\pi.4}{150} = 0{,}083 \text{ m} \tag{6}$$

Pole width is determined by the equation:

$$b_p = 0{,}73.\tau_p = 0{,}73.0{,}083 = 0{,}061 \text{ m} \tag{7}$$

Ratio of equations (6) and (7) we get the equation for pole coverage:

$$\alpha_p = \frac{b_p}{\tau_p} = \frac{61{,}15}{83{,}77} = 0{,}73 \tag{8}$$

6.1 Synchronous generator with salient poles and permanent magnets in no-load condition

In the program FEMM is a no-load condition characterized by a zero current that passes through stator slots which means that of the cooper windings in the stator slots is replaced by air. On the poles armature are located permanent magnets NdFeB (Fig. 5).

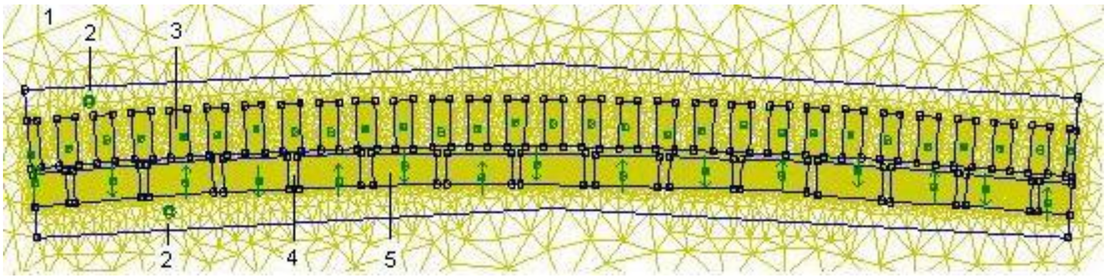

Fig. 5 Triangulation region for no-load condition
1, 3, 4 – air, 2 – iron, 5 – permanent magnets NdFeB 32 MGOe

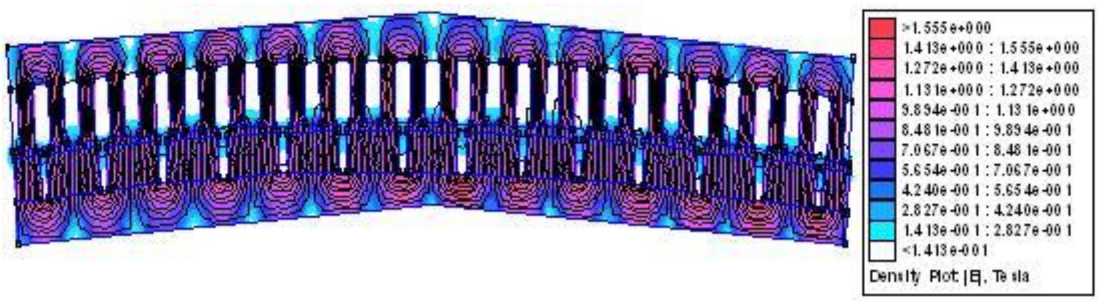

Fig. 6 The magnetic field map in no-load condition

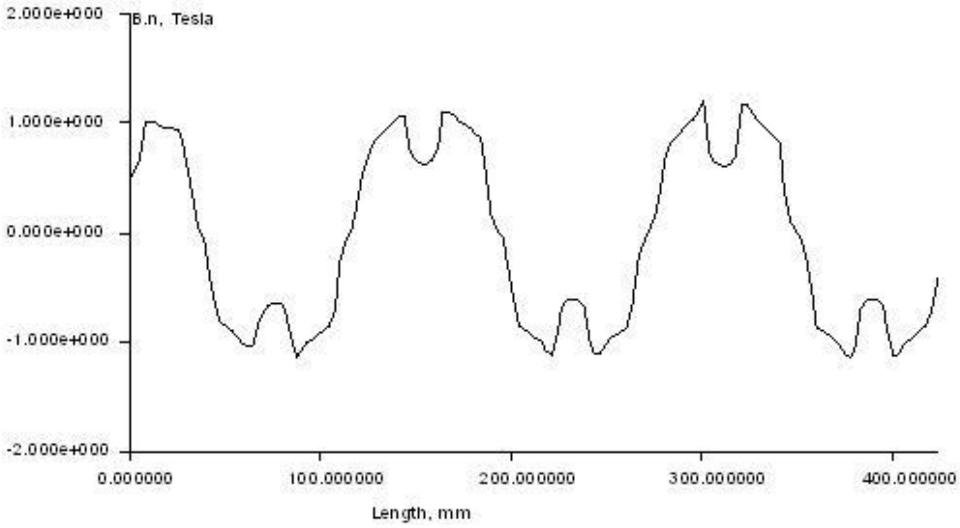

Fig. 7 The normal component of magnetic flux density in no-load condition

6.2 Synchronous generator with salient poles and permanent magnets in loaded condition

On loaded condition each third slot stator passes a zero current which means that of the cooper windings in the stator slots is replaced by air. Between these slots are two slots which are loaded current with a current density + 5 A/mm^2. Between other slots which passes a zero current are two slots with a current density - 5 A/mm^2. On the poles armature are located permanent magnets NdFeB (Fig. 8).

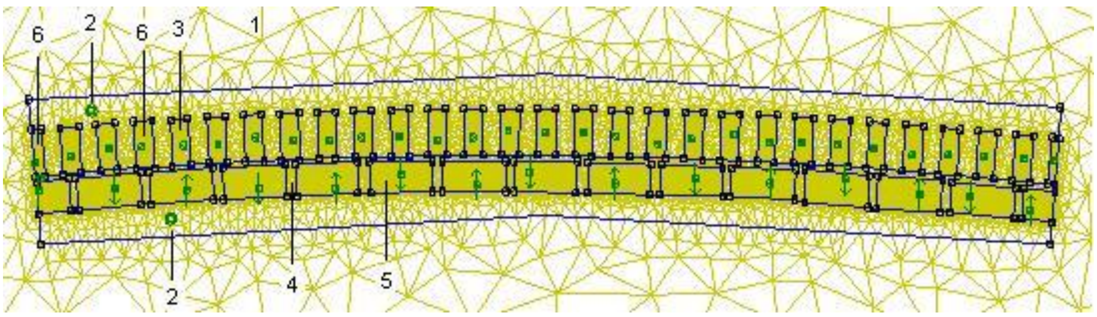

Fig. 8 Triangulation region for loaded condition
1, 4, 6 – air, 2 – iron, 3 – cooper, 5 – permanent magnets NdFeB 32 MGOe

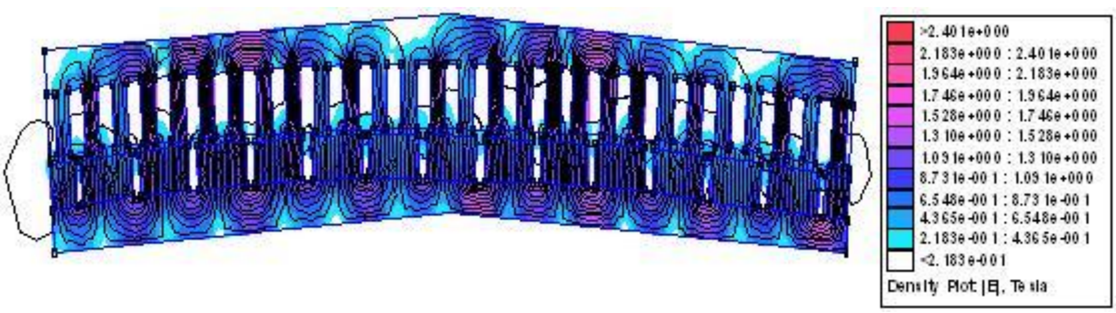

Fig. 9 The magnetic field map in loaded condition

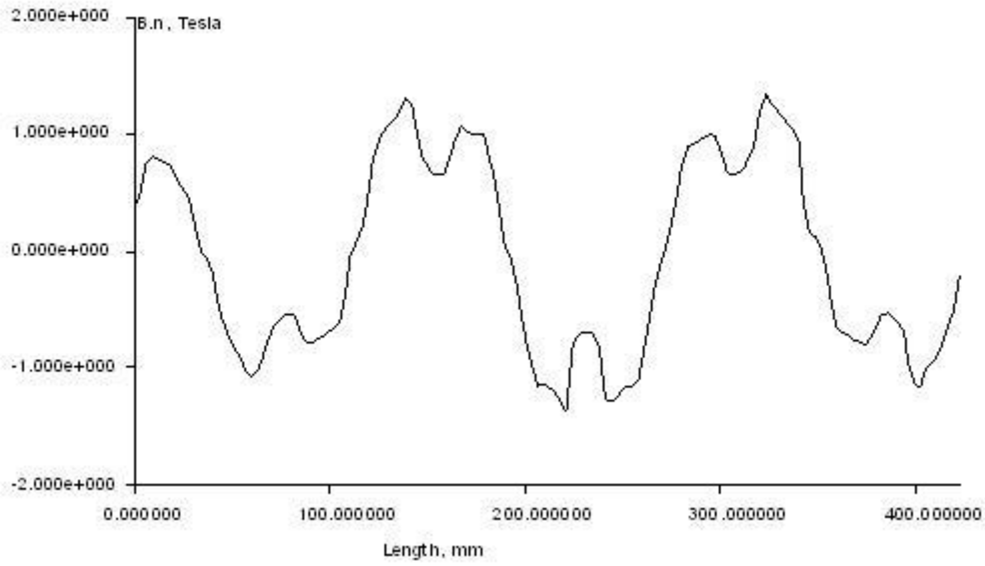

Fig. 10 The normal component of magnetic flux density in loaded condition

6.3 Armature reaction synchronous generator with salient poles and permanent magnets

The only difference in the armature reaction compared with loaded condition in program FEM is that permanent magnets are replaced by air (Fig. 11).

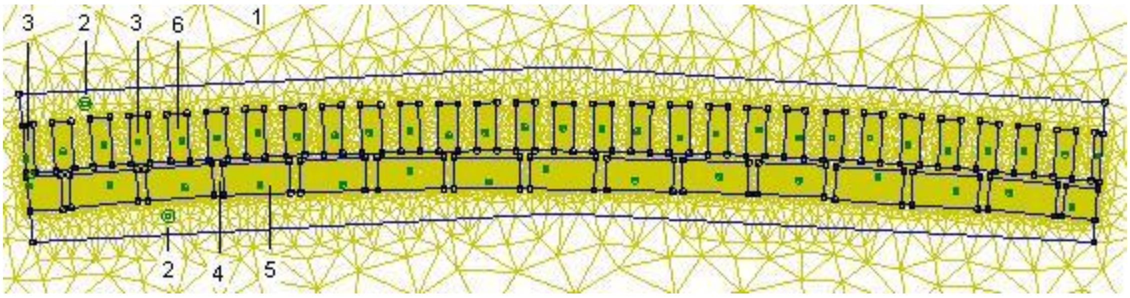

Fig. 11 Triangulation region for armature reaction
1, 3, 4, 5 – air, 2 – iron, 6 – cooper

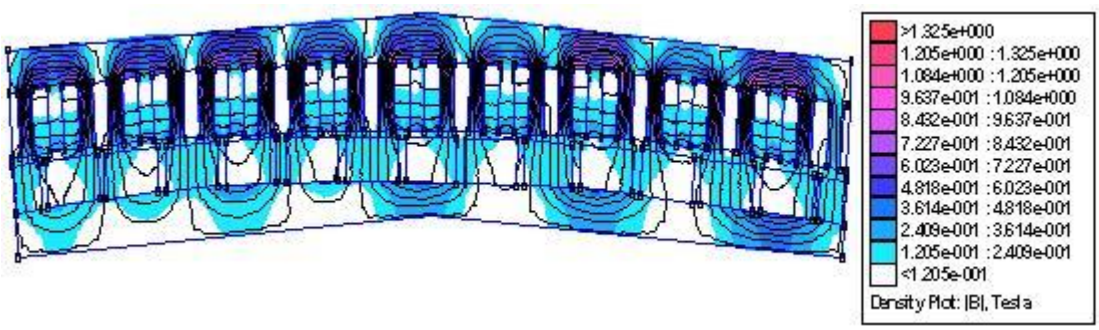

Fig. 12 The magnetic field map for armature reaction

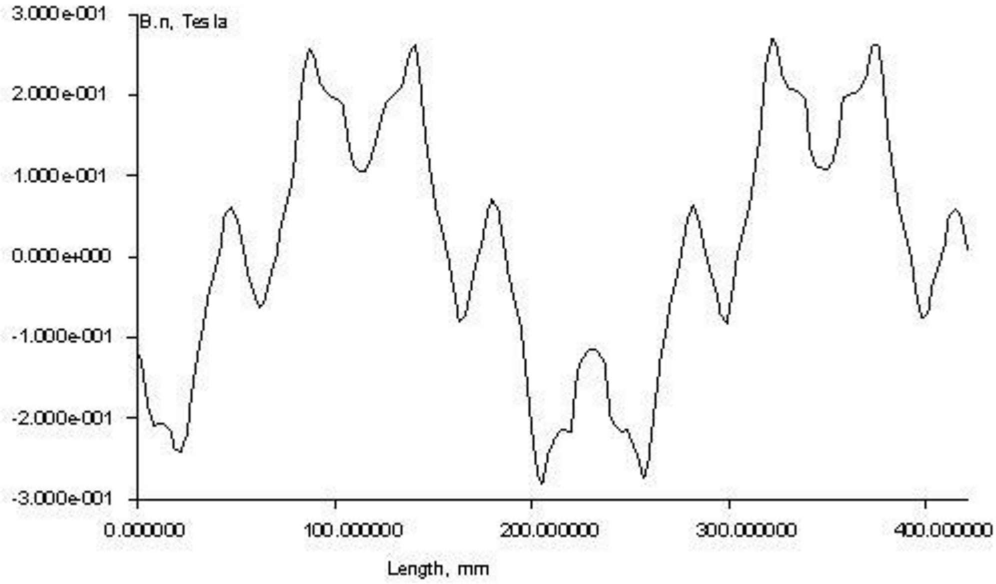

Fig. 13 The normal component of magnetic flux density for armature reaction

7 ASSESSMENT OF REVERSING THE EFFECTS OF THE WIND POWER STATIONS IN THEIR CONNECTION TO THE DISTRIBUTION NETWORK

For the assessment of reversing the effects (change voltage, flicker, harmonic currents, influencing signal mass remote control) connecting of the wind power stations to the distribution network can be used:

- *calculation method,*
- *simulation method.*

The calculation method involves a mathematical model of the network with characteristic input quantities such as cable length, cable cross section, resistivity, reactance, short-circuit power network, apparent power, loss of short and short voltage transformers. Output variables are the maximum possible connected outputs performances, changes voltage, flicker, changes the phase angle of impedance network and harmonics currents. The calculation method is based on the condition of neutral power factor attached source which saying that *cos* φ = 1. The disadvantage this method is that it can be solved only simple connected network with limited number resources.

Algorithm s*imulation method* is based on the calculation method and therefore also works with condition the neutral power factor attached source (*cos* φ = 1). However this method allows to solve various operating states networks (simulation with power switches, possibility backup power) as well as the deployment more sources with the possibility giving a new parameters into these sources. Therefore it is more convenient, faster and provides greater variability compared with a calculation method to achieve the desired (optimal) installed power of the wind power stations which have be connected into the distributions systems.

The result of calculation method and simulation method for the assessment feedback influences (change voltage, flicker, harmonics currents, influencing the mass remote control devices) for of connecting wind power stations to the distribution network according to [4] is that:

- voltage in the network low voltage slightly exceeds the tolerance what can be eliminate a more range of values of power factors,
- voltage in the network high voltage according to the calculation method does not exceed the allowed values but according to simulation method slightly exceeds values what can be eliminate by increasing conductors cross section in the critical section a power lines high voltage,
- flicker may in the network low voltage slightly exceeds the tolerance but in the network high voltage is in the tolerance,
- excessive production of harmonic currents in the wind power stations connected to the network low voltage can not be evaluated but the results of calculations and simulations in the network high voltage can be found in [5],
- signal the mass remote control in the network low voltage and in the network high voltage is not influenced.

Further comparison of the above methods and results which are divided according to the voltage levels in examined connection the distribution system are given in [4].

8 CONCLUSION

On the production so called green energy contribution in addition to other renewable energy sources also the wind power stations. Currently used by modern advances (in household or in industry) are largely dependent on continuous supply of electricity. Therefore, can the wind power stations difficult to replace classical energy sources such as for example nuclear power stations. However in the future can be the wind power stations important additional source of electricity.

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