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APPLICATION OF HYDROMECHANICAL CONSTANT-SPEED DRIVES IN A WIND POWER GENERATION SYSTEM

MIKHAYLOV, M[axim]; KOPYCHEV, V[ladimir]; LARCHIKOV, I[lya]; KOPAEV, S[ergey]; CVETKOV, V[ladimir] & STAZHKOV, S[ergey]*

Abstract: *Wind power is one of the most promising power industry. Increased energy and economic efficiency of wind generators are the main objective of their creation. The use of hydromechanical constant-speed drives is a promising line of development of wind energy. These drives are designed for stepless conversion of variable speed on the input shaft to the constant speed on the output shaft and its sustaining. This will get rid of the massive and expensive elements in the system of energy generation, reducing its weight and dimension, in order to reduce of the producting and operating costs.*
Key words: *wind power, mechatronics, hydraulics, control systems*

1. INTRODUCTION

Nowadays number of world's resources of traditional energy resources is severely limited. It (this) will lead to serious energy problems in the near future. Alternative energy sources such as wind power acquire a large role in the situation. The total capacity of all turbines in the world increased 6 times from 2000 to 2009 (http://www.gwec.net, 2009) and amounted to 157 GWt (Strube, 2010). Now leaders in recycling wind power are the U.S. (35 GWt), Germany (25.8 GWt) and China (25.1 GWt) (http://www.ewea.org, 2007).

Wind turbines are high-tech systems and the process of their creation is full of complex science and engineering problems. Creators of wind generators constantly struggle to improve energy efficiency and economic installations.

The system converting mechanical energy of wind turbines rotation in to electricity (generation system) is the main component turbine and determines its effectiveness. The system is designed to convert non-constant wind energy in conditionally constant electrical energy. The main problem and task of wind energy is the realization of this process with maximum efficiency. The design of modern wind turbine bases on synchronous generators. They generate a non-constant voltage and non-directly connected to the network. The alignment of electricity running through power electronics. But this electronics has some major drawbacks: high weight, size, cost and complexity.

The design of the majority of wind generators on the basis of synchronous generators includes a mechanical multiplier with 3-4 stages. The manufacturing of multiplier requires a high-quality alloys and high-precision surface processing. This problem led to the creation of a system of energy transfer without the use of multiplier - "direct drive". This scheme has one big plus - a minimum of moving parts. But the scheme has some drawbacks. First, the mechanical alignment speed wind turbine is missing. Secondly, the generator must be very large, as its shaft rotates at a speed of wind turbines. More recently the engineers have proposed an alternative design of energy transfer in wind generators - "multibrid". This scheme is based on a single-stage planetary multiplier which is located between the wind turbine shaft and generator shaft. It is important that the medium-generator has acceptable dimensions. However mechanical alignment of speed is lacking here as well.

2. PROPOSED SOLUTION

The disadvantages of the options considered design forced engineers to find new and more effective solutions. At the same time reducing complexity, weight and dimensions of the components is a basic condition for maintaining high efficiency of wind generator. The required effect can be the use of hydromechanical constant-speed drive (HMCSD). This drive is designed for stepless conversion of variable speed on the input shaft in a constant speed of output shaft and its maintenance. The output shaft can be directly connected to the input shaft of generator. Consequently it provides an opportunity to generate a constant voltage. The input shaft can be attached to the shaft of wind turbine through one-speed multiplier (e.g. in "multibrid" system).

The power part consists of input shaft, 3-stage differential and output shaft which are connected by kinematic transmissions. In the process of work, variable torque provided by the wind turbine is converted in the constant moment by dint of differential. This moment enters to the shaft of generator. The executive hydraulic circuit is designed for practicing the required gear-ratio of the differential and for increase transferred moment. The hydraulic circuit includes the unregulated hydraulic motor and the regulated hydraulic pump. The hydraulic machines are connected with elements of the differential. They close the base mechanism and create the 2-stream hydromechanical transmission. Application of hydraulic drive significantly improves the specific power of a drive compared to multi-stage mechanical transmissions of similar size while sustaining high efficiency (Babaev et al., 2000).

3. DESIGNING OF HMCSD

3.1. Design process

Creating of HMCSD is based on the International Scientific-Educational Center BSTU-FESTO "Synergy" of the Baltic State Technical University (St.-Petersburg, Russia).

The HMCSD is a classical mechatronic system, so the design is conducted with the application of concurrent design of mechatronic systems. Constructing a mechanical differential is the first stage of design. Construction involved the creation of cinematic schemes of differential, layout of gears and development of 3D computer model of differential. Simulation allowed optimizing the layout and minimizing the size of differential. Design of hydraulic circuit executed in parallel with the construction of mechanical parts. The circuit consists of unregulated axial piston hydraulic motor and regulated hydraulic pump with an inclined cylinder block. As a result hydraulic circuit and a differential were structurally combined in a single drive.

The calculation of mechanical and hydraulic characteristics of developed differential and hydraulic circuit has been made in the next stage of design. The calculation was performed on the basis of input data: the speed of input shaft must be changed from 600 to 1800 rpm, the speed of ouput shaft should be equal to 1500 rpm with an accuracy of 4%. The speeds of differential gears and shaft speeds of regulated hydraulic pump and unregulated hydraulic motor were determined based on the calculated gear-ratios. The speed of regulated hydraulic pump varies in the range from -3000 to 3000 rpm, the speed of unregulated hydraulic motor varies from 1218 to 3653 rpm. The parameter of regulating of hydraulic drive (circuit) is calculated on the basis of speeds values. Its value is in the range from -2.46 to 0.82. The dependence of regulating parameter of input shaft speed was determined using the method of polynomial approximation. The calculations of dynamic characteristics of drives will be calculated at the final stage.

3.2. Scientific problem

The results analysis of calculation speed of regulated hydraulic pump has shown that it passes through the dead-zone speeds. The hydraulic pump changes its direction of rotation when passing through the zone. The whole flow of fluid into the pump goes to compensation of fluid leakage at the boundaries of the zone that leads to the pump stop. It cannot compensate for leakage inside the zone. Speed on the output shaft decreases in the period of time when the pump goes through the dead-zone. This leads to a "failure" of output shaft speed and, consequently, the rotation speed of generator. Identify boundaries of dead-zone has compelled the recalculated speed of unregulated hydraulic motor on the linearized mathematical model of hydraulic drive. Volume losses of regulated hydraulic pump during the process of work were taken into account in this calculation. The dependence of volume losses on pressure in the pump cavity was found in an experimental manner and processed with the help of polynomial approximation.

The generator speed retires beyond the speed limit at a time when the pump speed in the range from -30 to 50 rpm. But this calculation does not give the exact values of dead-zone because some real factors were not included in the formulas. The speed of output shaft has a value that is lower than the rated speed at 3.2% in the working range and it is valid.

The problem of dead-zone is the subject of a thorough scientific research. The main issue is the behavior regulated hydraulic pump at its passing dead-zone. Consequently, the boundaries of this zone must be defined more precisely. Methods of overcoming the dead-zones must be developed on the basis of data. But only a real experiment may provide such data. The Research stand for conducting this experiment was established on the basis of the International Scientific-Educational Center BSTU-FESTO "Synergy". The stand consists of a HMCSD, electric motor, combined with hydraulic drive (simulated wind turbines), and an electric generator.

3.3. Control system

The control system of HMCSD is designed in parallel with the mechanical and hydraulic parts. The main element of control system is the industrial controller based on the signal MCUs Silicon Laboratories (Mikhaylov et al., 2009).

The signals from the rotation sensors (incremental encoders) of input and output shafts of HMCSD transmitted in the control system. The control signals are formed depending on the data signals in accordance with the calculations. In addition, the system receives signals from pressure sensors. They are the basis for calculating the adjustment which is introduced into the control signal. The control signal comes to electrohydraulic executive unit that regulates the pump. The electrohydraulic executive unit may be designed on the basis of: proportional hydraulic distributor with a round valve, electrohydraulic distributor with a flat valve or electrohydraulic converter type "nozzle-shutter". The minimum dead-zone of electrohydraulic executive unit is the main criterion for his selection. The experiment showed that the electrohydraulic distributor with a flat valve has the best characteristics. His dead-zone reached 9.3% of total operating range. The electrohydraulic executive unit regulates the angle of inclination of block cylinders pump. The angle of inclination of block cylinders is monitored the angle sensor (absolute encoder). The signal from the sensor allows adjusting and maintains the angle of inclination of block cylinders in accordance with the control signal based on the PID algorithm.

The main task of control system is to maintain a constant speed of output shaft of HMCSD. This system should provide compensation of dead-zone and volume losses in the regulated hydraulic pump. The software for control system will be developed based on the calculated mathematical dependencies.

3.4. Planned research

The experiment on the stand HMCSD will be held in several stages. The first step is to test the ability of control system to maintain a constant speed output shaft in the working speed range with a given accuracy. The next step is to search for and testing of method of compensation "failure" speed of drive in the dead-zone in the regulated hydraulic pump. The experimental data will serve as a way for the formation of its compensation. This method will be implemented with the help of designed control system. The final phase of research will be the identification and correction of accuracy to maintain speed of drive for the entire speed range input shaft by means of designed control system.

4. EXPECTED RESULTS

The result of design and research work should be a finished HMCSD in the form mechatronic system. This drive should provide the required accuracy to maintain speed on the output shaft in all speed range input shaft. The data of experiments consider being of high practical value. In the first place they need for develop ways to compensate the dead zone in the different types of hydraulic drives. Secondly they form the basis for a unified approach in designing drives for wind generators with different capacities. In general this will significantly improve the efficiency of designed drives and reduce the cost of their designing and manufacturing.

5. CONCLUSION

The use of hydromechanical constant-speed drives is a promising line of development of wind energy. This will get rid of the massive and expensive elements in the system of energy generation (precision multistage multiplier, rectifier on the power electronics base), reducing its weight and dimension, in order to reduce of the producting and operating costs.

6. REFERENCES

Babaev, O.M.; Ignatov, L.N.; Kistochkin, E.S. & Cvetkov, V.A. (2000). *Hydromechanical power transmissions,* Mechanical engineering, St.-Petersburg, Russia

Mikhaylov, M.; Kopaev, S. & Stazhkov S. (2009). The automated neural-network control system of the hydraulic constant-speed drive, *Proceedings of the 20th International DAAAM Symposium,* Katalinic, B. (Ed.), pp. 1605-1606, ISBN 978-3-901509-70-4, Austria Center Vienna, Vienna, Austria, November 2009, DAAAM International Vienna, Vienna

Strube, O. (2010). Global Wind Installations Boom, *Available from:* http://www.renewableenergyworld.com *Accessed:* 2010-03-10

*** (2009) http://www.gwec.net - The Global Wind Energy Council, *Accessed on: 2010-06-05*

*** (2007) http://www.ewea.org - The European Wind Energy Association, EWEA Annual Report 2007, *Accessed on: 2010-06-17*