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Integrated modeling and simulation of wind power generation system based on PVDF piezoelectric thin film[1]

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Abstract. PVDF piezoelectric film wind power generation technology is attracting more and more attention because of its high efficiency and practicability. And it has a wonderful development prospect. This paper is devoted to the study of PVDF piezoelectric thin film wind power generation technology, starting with analyzing its operation mechanism, and comparing the difference of fixed pitch, pitch and PVDF piezoelectric film wind power. Finally it selected the doubly fed PVDF piezoelectric film as the scheme: it's in the stage of low speed pitch adjustment pursuit of maximum wind energy capture, and achieve the independent regulation of stator output constant frequency and active and reactive power by controlling the rotor side power when it is in high wind speed. This paper analyzes the basic operation characteristics, points out the advantages of PVDF piezoelectric film generator that AC motor cannot match; studies the steady-state circuit and power balance, and the establishment of the state equation; realizes decoupling of the stator active and reactive power control, which makes the motor control simple. The research of this paper has promoted the development of wind power industry.

Key words. Wind power generation, PVDF piezoelectric film, doubly fed induction generator, modeling, simulation.

1. Introduction

The process of industrialization in the world has led to an increase in energy consumption and emissions of harmful chemicals. Thus caused climate anomalies, disasters, and many malignant diseases. And the energy and environmental issues become the two major issues [1–3]. The crisis caused by the energy problem and the increasingly prominent environmental problems make us recognize that the development of clean and renewable new energy is an objective need for the protection

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of the ecological environment and the protection of sustainable development [4]. At present, in the development of renewable energy of wind power generation has the most potential, and the generation cost decreased gradually, and technically mature, which forms a new industry, has become the power system structure relative to the fastest growth of new energy power generation [5–6] Therefore, the research of wind power generation technology is of great significance [7]. The paper makes an analysis the basic operation characteristics, shows the advantages of PVDF piezoelectric film generator that AC motor cannot match; studies the steady-state circuit and power balance, and the establishment of the state equation; realizes decoupling of the stator active and reactive power control. The research has promoted the development of wind power industry [8–9].

2. Methodology

MATLAB 6.5/Simulink software is used to build the simulation model of each part of the system, and the simulation of the system was carried out.

The mathematical models can be expressed by the equations:

$$M_{\mathrm{w}} = \frac{\pi}{2} p c_1 w \,, \tag{1}$$

$$C_{\mathrm{p}} = 0.5 \left(\frac{rC}{L} - 0.022B - 2 \right) \mathrm{e}^{-ti\theta} \,, \tag{2}$$

$$\frac{\mathrm{d}M}{\mathrm{d}t} = \frac{1}{T(M-U)} \,, \tag{3}$$

and

$$\frac{\mathrm{d}W}{\mathrm{d}t} = \frac{1}{C(M-U)} \,. \tag{4}$$

Here, C is the piezoelectric stress constant, M is piezoelectric strain constant, B is the electric field strength, T and U are piezoelectric constant matrix and transpose matrix, L is the inductance and C_{p} is the circuit capacity.

The optimum operation principle of PVDF piezoelectric film wind turbine is depicted in Fig. 1.

The PVDF piezoelectric film wind curve is depicted in Fig. 2.

According to Fig. 2, when the wind speed changes, as long as the speed of the wind wheel is adjusted, and the tip speed ratio $\lambda_{\max} = \lambda$ is kept the same, the maximum wind power can be obtained, which is the best operation principle of the wind turbine.

The simulation models of all parts of the wind power system are built up using the software Matlab 6.5/Simulink 5.0 and simulation experiments are done, whose results show that the models are proper and the VSCF wind power system has good operating performance.

After the analysis of the essential operating characteristics, this work presents a study on the steady equivalent circuit and the power flow. Five-order-state equa-

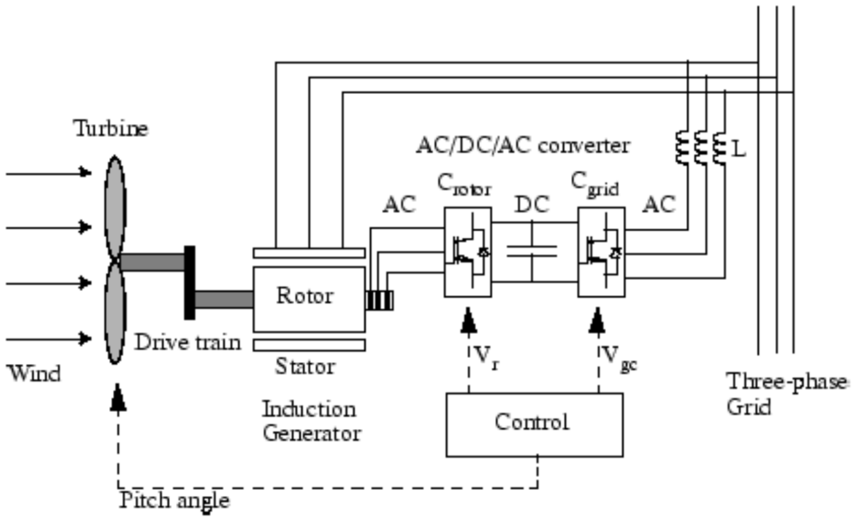

Fig. 1. Wind turbine simulation model

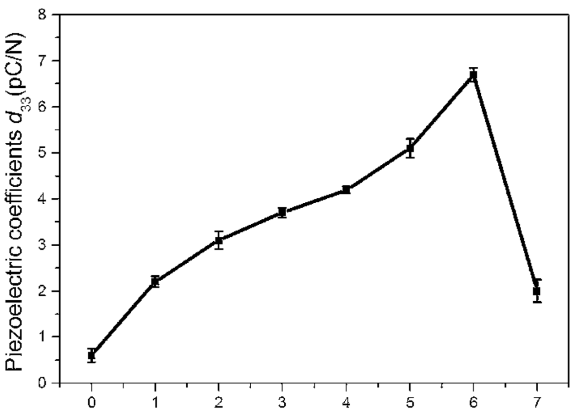

Fig. 2. PVDF piezoelectric film wind curve

tions in the M-T-0 reference frame are deducted in detail and the stator flux-oriented vector control system is built to decouple the stator active and reactive power regulations and make controlling of the motor more simple.

The main circuit structure is depicted in Fig. 3.

Matlab 6.5 software (MICROTEK Simulink/Power System Blockset model) was set up to model single-phase positive and negative rectifier circuit.

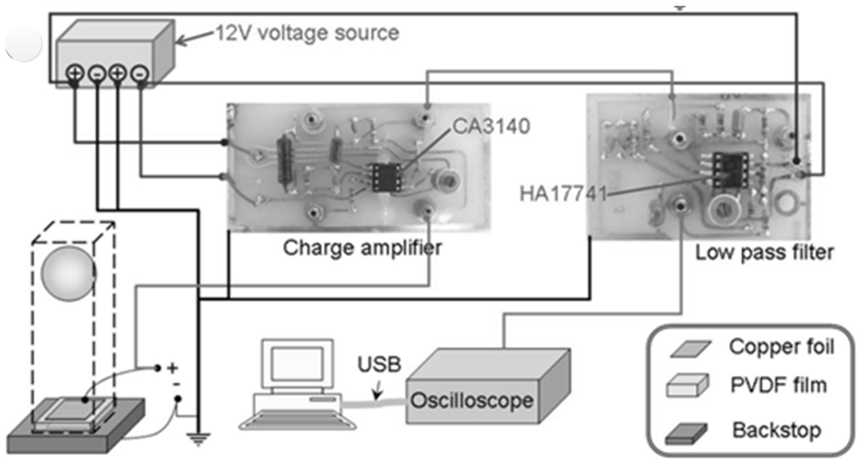

Fig. 3. Main circuit structure of system

3. Result and discussion

3.1. Simulation results of a wind turbine

Technical parameters of the model of G52-850 kW wind turbine are listed in Table 1, and the wind farm parameters are shown in Table 2.

The inverter is the key equipment to make the double-fed motor VSCF operate so the 6-pulsed AC-AC inverter, (cycloconverter) is selected as the exciting power supply. Through processing the interface between the inverter and the generator, this paper builds up the mathematical model of the inverter by analyzing its main configuration of the circuit, the method of cosine crossing and the producing of trigger pulses. Power characteristic curve and parameters of wind turbine are depicted in Fig. 4.

Table 1. Technical parameters of wind turbine

Rated power	850 kW	Hub height	55 m
Impeller diameter	52 m	Swept area	2124 m^2
Rated wind speed	13 m/s	Safe wind speed	50–70 m/s
Speed range	14.6–30.8 rpm	gearbox ratio	1:61.74

Table 2. Wind farm parameters

Air density	1.04 kg/m^3	Average speed	8 m/s
Wind frequency spacing	2 rad/s	Gap range	2000 m
Surface roughness	0.004	Max. wind speed	20 m/s
Maximum gradient wind speed	15 m/s	Distance between turbines	>260 m

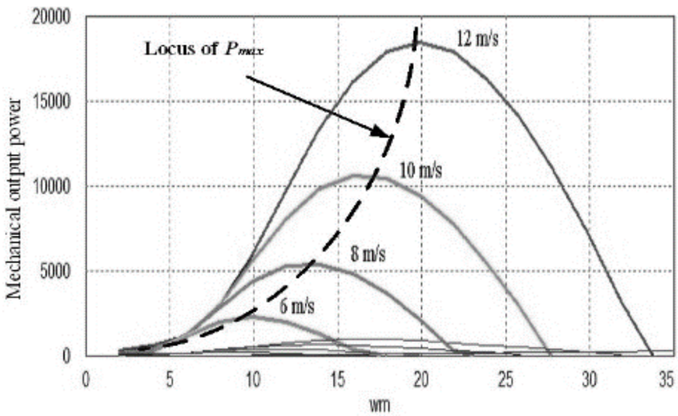

Fig. 4. Power characteristic curve and parameters of wind turbine

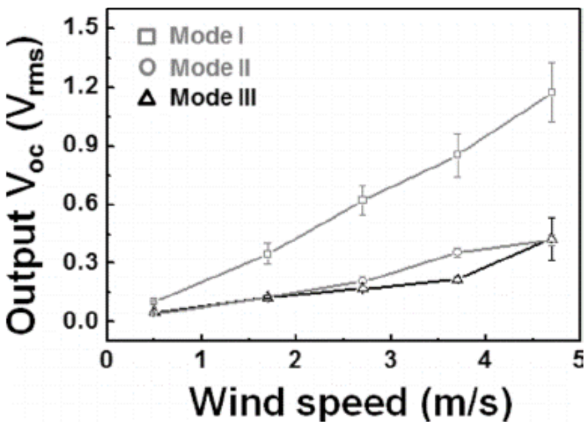

Fig. 5. PVDF piezoelectric film wind speed

Figure 5 is the power characteristic curve and parameter curve of PVDF piezoelectric film wind speed. The highest value is reached when it is about 6 seconds.

3.2. Output curve of frequency converter

Let the control voltage amplitude be 100 V and frequency 10 Hz. Then the effective value of cycloconverter fed power supplied by excitation transformer is 100 V, frequency 50 Hz and load inductance $L = 0.07$ H. Figure 6 shows the load voltage of the cycloconverter, the voltage between the two neutral points and the load current waveform.

From the simulation process it can be seen that the cycloconverter is a highly nonlinear system, containing 36 thyristors, cosine wave generator, synchronous trigger pulse generator, commutation logic control module, the system model of complex structure, and large amount of feedback.

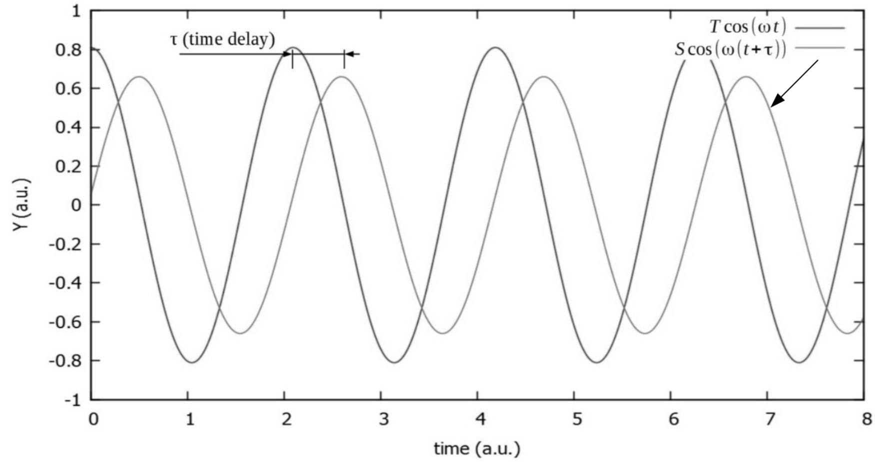

Fig. 6. Two-phase load current waveform

3.3. Simulation model of doubly fed induction generator

The stator-oriented vector control of doubly fed generator is given. The structure diagram is shown in Fig. 7, and the simulation model is similar to the block diagram, no longer tired. Before the dynamic control is implemented, the motor is in a steady state, and the following initial conditions can be determined by the equation of state of the generator.

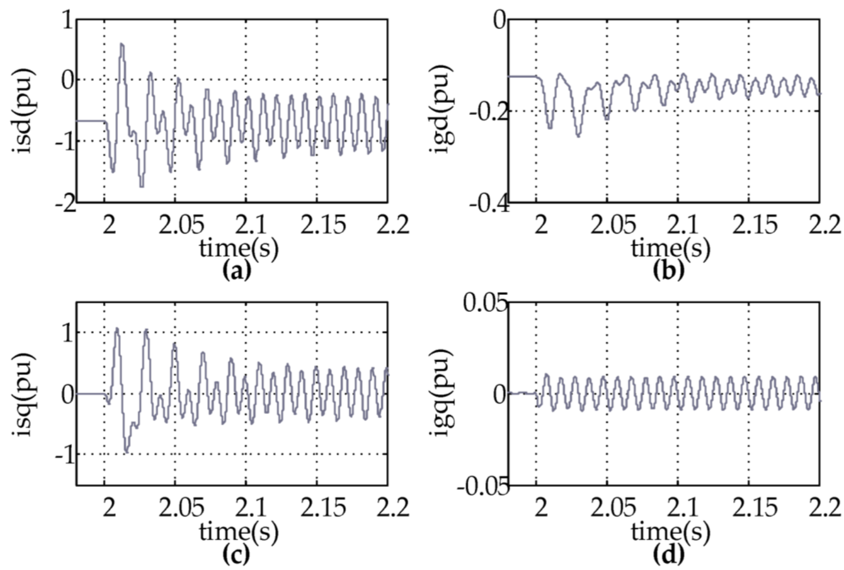

Fig. 7. Structure diagram of the doubly fed induction generator

The double-fed generator, who is superior to a general AC one in many aspects, and it is the hard core of the wind power system. After the analysis the essential operating characteristics, this thesis makes a study on the steady equivalent circuit and the power flow. Five-order-state equations in the M-T-0 reference frame are deducted in details and the stator flux-oriented vector control system is built to decouple the stator active and reactive power regulating and make controlling of the motor more simple.

4. Conclusion

This paper presented an research on PVDF piezoelectric thin film wind power generation technology, starting with analyzing its operation mechanism, and comparing the difference of fixed pitch, pitch and PVDF piezoelectric film wind power. Finally selected the doubly fed PVDF piezoelectric film as the scheme: it's in the stage of low speed pitch adjustment pursuit of maximum wind energy capture, and achieve the independent regulation of stator output constant frequency and active and reactive power by controlling the rotor side power when it is in high wind speed.Above all, the way can get a better effect in wind power generation comparing with other ways.

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