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Control and Research on Blade Vibration of Wind Turbine

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Abstract

This article takes control of fan blade vibration as the main body, introduces a new type of intelligent materials -- Electro rheological fluids, focusing on explain the smechanical and electrical properties of electro rheological fluid explain. The application of electro rheological technology to practical use in the performance of electro rheological fluids, control the occurrence of electro rheological effect, so as to achieve active vibration control effect on leaf and model simulation and eventually realize the effect of blade vibration weakened.

Keywords: *Smart materials, electro rheological fluids and electro rheological technology electro rheological effect, active control*

1. Introduction

Wind power is one of the most competitive and most promising renewable technologies will play an increasingly important role in our energy supply. Study on wind power generation technology which is of great significance will speed the nationalization of large wind power generator in China and propel the development of wind power generation in China [1].

Leaf blades are major components of wind turbine which will take advantage of power wind [2]. Due to fan work in poor conditions, stable blades high centrifugal forces, air force and air exciting-vibration force effect can lead to failure. Failure reasons are high temperature mechanical damage, injury, exposure to high temperature and creep, fatigue and corrosion. Fatigue is one of the most important reasons, it often leads to blade fracture, so research on blade vibration method is of great significance in engineering. There are some more mature vibration reduction technologies, such as honeycomb seal dry friction damping and vibration reduction, the former achieves the propose of reducing vibration by using special structure design, the latter can exacerbate air disturbance, improve the flow of energy consumption and reduce the air vibration. These methods of reducing vibration are obvious, but the effect is limited, and its structure is stable, unable to realize the adjustment of the parameters. In addition, some scholars study applies the vortex measures to improving the stability of the rotor, and use a seal clearance into reverse airflow to reduce rotational flow in the seal clearance. The cyclone only under suitable velocity and flow rate can have the effect of inhibiting vibration, otherwise it will lead to instability of vibration, what's more, the vortex structure is complex, the design calculation is difficult, so the application can't be used universally [3]. There are some issues in leaf protection and operation of the wind turbine. Through the theoretical research on blade failure, electro rheological fluid dampers, vibration acceleration sensor, we can achieve the purpose of vibration

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protection, enabling wind turbine blade vibration reduced, and protection capabilities.

2. Vibration Analysis of Wind Turbine Blades

2.1. Reasons for Blade Vibration

Vibration is one of the most important issues for wind turbine development, with the increasing in size and capacity of wind turbine, wind turbine vibration problems have become increasingly prominent. Therefore, both in the design phase and daily operation and maintenance phase, blade vibration problem cannot be ignored.

2.1.1. Impeller Imbalance: Unbalanced impeller consists of uneven quality imbalances and aerodynamic imbalances. Aerodynamic imbalances are caused by wind turbine blade lift and drag and quality imbalances often caused by great blade manufacturing errors, installation errors, internal water surface fouling or icing, or other causes. According to a study of Wind Guard company as wind turbines in Germany, there are about 20% Imbalances existing in the wind turbine [4] . Imbalance characterized by the consequences of violent vibration of wind turbine, resulting in reliability of the wind turbine, increasing wind turbine noise, shortening the life of wind turbine [5].

2.1.2. Effect of Aerodynamic Force of Blade Change: The aerodynamic forces on the blade can be divided into the lift F_L and resistanceF_D, As in Figure 2.1 below.

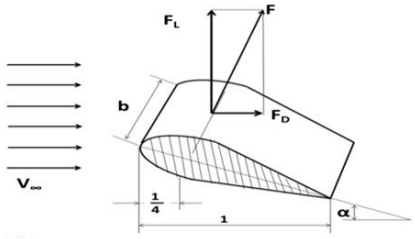

Figure 1. Acting on the Rotor Aerodynamics

Component F_L. With velocity F_D .In parallel, is the drag .With velocity. Vertically, that is, lift;

By the formula:

$$F_D = \frac{1}{2}\rho C_D S V_\infty^2 \quad (1)$$

$$F_L = \frac{1}{2}\rho C_L S V_\infty^2 \quad (2)$$

Style, C_D--Drag coefficient; C_L——The lift coefficient;

P --Air density;

V_∞ --Velocity.

Because the lift force (F_L) and resistance (F_D) the two components are mutually perpendicular, which

$$F_D^2 + F_L^2 = F^2 \quad (3)$$

Therefore, the aerodynamic forces on the blade is stronger with the wind speed increases.

Because the wind wheel diameter is so large, leaves on the upper portion relative to the lower parts of blade can withstand greater aerodynamic forces. During the progress of cycling, the same blade will form vibration because of the cyclic force.

2.1.3. Influence of Tower Shadow Effects: With uniform rotation of the wind wheel, Tower shadow effect will cause the blades and wind turbines to generate cyclic, periodic change of force can result in blades or rotor vibrations. Although the amplitude of vibration is small, but if the vibration frequency is close to or the same as the natural frequency, so many side effects will appear soon.

2.1.4. Wind Direction Fluctuations and the Effects of Wind Ripple: Wind is often characterized by variability, due to the influence of change factors such as solar radiation, wind direction; wind speed is changing every day or even every hour. Such a change in wind direction and wind speed will produce a fluctuating aerodynamic, resulting in vibrations.

2.2. Blade Vibration Measurement and Analysis

2.2.1. The Basic Process Of Blade Vibration Measurement: Vibration test technology consists of sensor devices, such as measuring equipment in the working process of the important components of displacement, velocity, acceleration, frequency, such as exercise, to understand the dynamic performance of the mechanical equipment or structure, such as inherent vibration mode and natural frequency, damping, and stiffness characteristic parameters, such as technology [6].

The basic process of blade vibration detection is signal acquisition, signal transmission and conversion, signal analysis and processing and signal display. Wind turbine blades sensors on vibration signal and converts the signal into electrical signal outputs, acquisition card will be transferred to the electrical signals , which can be converted into digital signals, will eventually signal transmission to the computer for analysis after the vibration signal detection which is in the form of waves or data directly to show it. Entire vibration testing process as shown in Figure 2.2 shows:

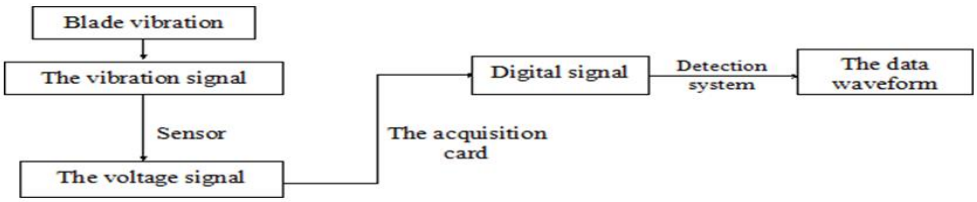

Figure 2. Blade Vibration Detection Process

2.2.2. Vibration Analysis of Blade: Vibration signal analysis is will be collected by the vibration of the original signal to the corresponding mathematical processing, making it useful for vibration fault forms such as graphics or table. Commonly used method of signal analysis with time domain analysis and frequency domain analysis.

Time domain analysis is by observing the time course of the vibration signal, is a kind of vibration signal analysis of measuring method. Getting a lot of information, using time domain analysis of measured signal will not cause leaks and distortion, thus can more just show the characteristics of the signal.

Frequency domain analysis of mechanical fault diagnosis is one of the most widely used in signal processing methods, with the occurrence and development of fault, it can often cause the changing structure of the signal frequency. Frequency

domain analysis method is frequency spectrum analysis method, and spectrum analysis is the purpose of the complex time waveform by Fourier decomposed into several single harmonic component to study, in order to obtain the frequency of the signal structure as well as the various harmonic amplitude and phase information, frequency domain analysis to get the final result is spectrum diagram, periodic and quasi periodic signal after frequency spectrum analysis was the discrete spectrum, non periodic signal and random signal after getting the continuous spectrum, frequency spectrum analysis for continuous spectrum, using the concept of "spectral density" [7].

2.2.3. Analysis of Blade Vibration Frequency: With pro-e establish the entity model and analysis, on the choice of unit type, according to the characteristics of blade, SHELL181 element, including SHELL181 element to fit to have a certain thickness of thin shell structure is analyzed [8], fixed line of modal analysis was carried out on the primitive, the blade is obtained the first ten order modes, results show that the main vibration mode of the blade waving and shimmy, have a stronger ability to resist torsion. As shown in table 1 and Table 2:

Table 1. Parameters of Each Cross Section of Blade

Section number	Twist angle (in degrees)	String length (unit: m)	Distance between sections and root (unit: m)
1	30	1.96	3.4
2	18.8	2.41	6.3
3	12	2.63	8.39
4	12.5	2.5117	9.7
5	7	2.2706	13.5
6	5.5	2.0297	16.8
7	3.5	1.7888	19.5
8	2	1.5476	23.4
9	0	1.3070	26.6
10	-2	1.0660	29.9

Table 2. Natural Frequencies of Blade (Hz)

Number of modal	1	2	3	4	5	6	7	8	9	10
Natural frequency	0.2824	0.7633	1.6523	3.1735	4.0384	6.1851	7.732	9.4668	11.042	12.739

1, 2 order vibration mode mainly, 3 order to order vibration mode 7 is a combination of shimmy, waving, order from 8 to 10 levels of vibration can be seen in the form, it is the blade twist, waving, shimmy results under the action of, so the blade under the condition of high frequency vibration mode is complicated, in order to show that the vibration of the blade's main form for waving and shimmy, waving the blade, the worst in order 1, 2, obvious vibration [8].

3. Blade Vibration Control and Research Programmes

3.1. Electrorheological fluids and Electrorheological Technology

Electrorheological fluid which belongs to sol can control the nature by being applied voltage to. By electric fields, electrorheological fluid is composed of zero electric field at the time of the liquid to viscose solid, increasing damping has great ability to resist shear. When removed the electric field, electrorheological fluid changes from solid to liquid. It takes only a few milliseconds, its response time and change is reversible, the two big advantages determines the possibility of its practical application, many countries have attached great importance to this research.

3.2. Mechanical and Electrical Properties of Electrorheological Fluid to Vibration Control Strategy

Electrorheological Effect (Electrorheological Effect ERE for short) refers to a certain features of the fluid, it is through the effect of the applied electric field to control the nature, namely when by electric fields, the fluid is composed of zero electric field at the time of the liquid to viscose solid, shear resistance ability of the damping increase greatly; When removed the electric field, electrorheological fluid changes from solid to liquid. This fluid is the Electrorheological fluid (Electrorheological Fluids for ERF).

In practical engineering applications, when the vibration amplitude exceeds the set value, the vibration signal through the vibration sensor, computer receives the sensor signal, according to the strength of the vibration signal to the controller action instruction, to realize to control the size of electrorheological fluid applying an electric field, so as to realize the electrorheological technology for vibration active control and decrease the vibration of the blade [9].

3.2.1. The Mechanical Control of Electrorheological Fluids: Control device are made of the current electricity rheological fluid, fluid movements are generally classified into flow patterns, extrusion, and shear mode 3 kinds.

Flow patterns: the fixed electrode, the electrorheological fluid can flow between two electrodes, general engineering in two typical of concentric cylinder device, or device using multilayer concentric cylinder type, alternate for positive and negative electrodes.

Extrusion model: the electrode movement process, the fluid will be the role of squash and stretch, in addition, the electrorheological fluid exchange between the two electrodes (extrusion or flow into), will be affected by shearing action. This model which is recently proposed can be used for vibration control.

Shear mode: due to the rotation or translation between two electrodes, the electrorheological fluid between the two electrodes will be the effect of shear. If two electrode adopts the translation method, then can be made into linear damper. If two electrode adopts the rotation method, it can be made into type torsional vibration damper.

In the process of actual application, the main applications of electrorheological fluid shear load working condition. With Bingham plastic body, describing shear constitutive relation for:

$$\tau = \mu\tau_b + \eta_\gamma \quad (4)$$

Type of γ as the shear rate, η for plastic viscosity [10].

3.2.2. Effect of Shear Rate Γ Of Shear Stress: For ordinary fluid, can have the following formula is true:

$$\tau = \mu \frac{d\mu}{dy} \text{ (Of which: } \mu = con) \quad (5)$$

Namely: $$\tau \propto \frac{d\mu}{dy} \quad (6)$$

Of which: τ--For fluid shear stress;

μ--The relative shear rate in a fluid;

y --As the gap between the two electrodes.

By the above formula, the shear stress is on the electrorheological fluid an important factor that affect the performance. A group in a specific field of the shear rate and shear stress under the curve as shown in Figure 3 [9].

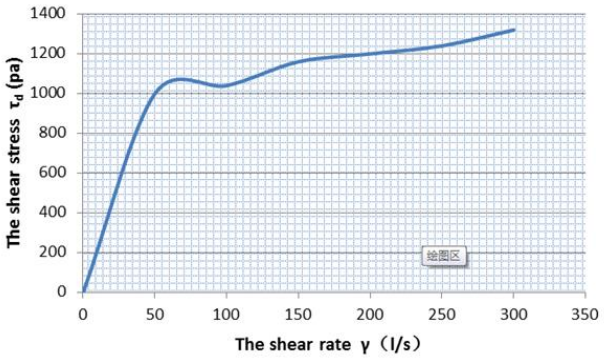

Figure 3. Specific Relationship between Electric Field Shear Rate and Shear Stress Curve

3.2.3. Blade Vibration Control: Induction of electro rheological effect of electro rheological fluid produced is the direct cause of the applied electric field, and electric field intensity and apparent viscosity and shear stress increases, the decisive factor, from a large number of experiments, with increasing of electo-rheological fluid's shear stress, the relationship between electro-rheological and field strength E is:

$$\tau = AE^n \quad (7)$$

A and n is the coefficient that the materials' component and the related to the field of fluid.

Field effect to electro rheological effect, namely, when the field strength E below a certain value, that there is no electro-rheological effect, generally, when the field strength is strong than a value, strong to a the dispersed particle kinetic energy greater than the Brownian motion of particles, a large number of particles field formed connections in the direction of the poles "chain" in an electric and bunched between chains, have a significant ER effect.

Generally, under the conditions evaluated that the critical electric field Ex is greater than Brownian motion, the expression is:

$$E_x \approx \sqrt{k_B T/(\beta^2 \gamma^2 \varepsilon_f f_v)} \quad (8)$$

In the formula: K_B--Glass-Boltzmann constant;

T --The temperature of external;

γ--The particle of RADIUS;

f_v-- The volume ratio of dispersed particles phase;

ε_f-- The dielectric constant of basic liquid.

When E < EC, there is no obvious electro rheological phenomenon, when ES > E >EC, ER effect has a sharp change; when E>ES, roughly the present $\tau = K (E - ES)$ trend; The growth of the shear stress and field strength E roughly linear relationship. When the field strength increases, it can greatly enhance the electro rheological effect; When the insulating ability stronger than fluid on the spot, the fluids will be breakdown, this value is limited to 3 kV/mm or so commonly [9]. The curve of shear stress and the electric field strength as shown in Figure 4:

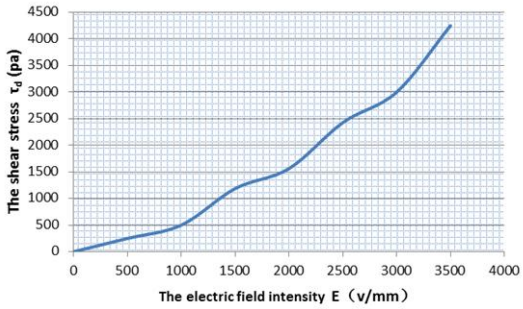

Figure 4. Relationship Between Shear Stress and Electric Field Strength Curves

4. The Simulation

According to the research of the electro rheological effect on technology, use electro rheological fluid performance, control the occurrence of electro rheological effect, to the main control effect of blade vibration.

In this paper, application of wind farms 3 mw doubly-fed wind power unit data, application of electro rheological technology of vibration control method, application of Mat lab software, under the condition of the initial disturbance of the first two order vibration simulation, through the control of the simulation before and after, to illustrate the effectiveness of the above control strategy.

Through simulation, we can get control before and after blade vibration corresponding curve is as follows, Control before and after the system diagram as shown in Figure 5, Figure 6:

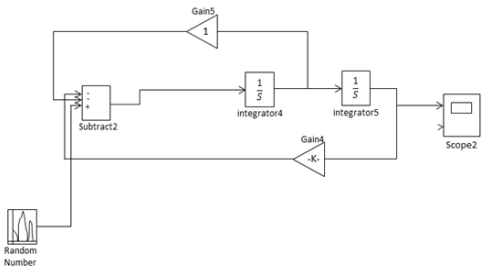

Figure 5. Control System Diagram

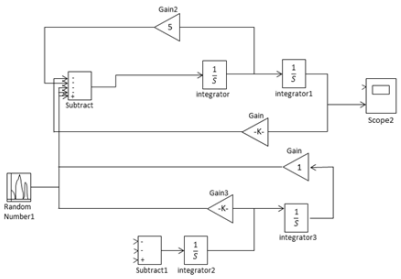

Figure 6. Control System Diagram

Blade vibration response curve before and after obtained through simulation of control are as follows:

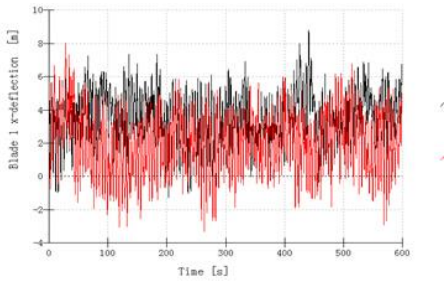

Figure 7. Vibration Response Curve of Cantilever Beam End Points Before and After

As that can be seen from the diagram, prior to control vibration that under random loading conditions, imposed after the active control of a cantilever beam system significantly decreased the amplitude of vibration, about vibration control strategy discussed in this chapter are very efficient.

5. Concluding Remarks

Based on the analysis of the vibration causes, forms of vibration and monitoring of wind turbine blades, based on vibration control for wind turbine blades the analysis of mechanical and electrical properties of electro rheological fluid, using the study of electro rheological fluid, the simulation results show that using electro-rheological fluid vibration of the blade itself has weakened.

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