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CLASSIFICATION OF VERTICAL-AXIS WIND POWER PLANTS WITH ROTARY BLADES

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Abstract—*The goal of this paper is to increase the efficiency of using alternative energy sources, namely: to analyze the ways of controlling the angular position of the wind turbine blade. The object of analysis are the wind turbines with a vertical axis of rotation, the subject of analysis is justification for the use of adjustable blades in a vertical-axis rotor. Critical analysis of various methods blade angle control of the wind turbine has been carried out and task of active and passive control systems design for the vertical-axis wind turbine rotor blade angular position has been solved.*

Index Terms—Vertical-axis wind turbine; blade control; active and passive control systems; control algorithm on the fuzzy controller.

I. INTRODUCTION

Wind power in the last few decades in a number of countries has been developed into separate branches of energy farms that successfully compete with traditional energy. The main attention is paid to wind power plants (WPP) of medium and high power as part of distribution and transmission networks. However, the world market of small wind power plants is also dynamically developing at the expense of mass consumers, including low-rise buildings, farms, fishing cooperatives and hunting grounds, remote monitoring systems, road lighting systems, telecommunications equipment and other autonomous consumers of electric power. As a result, an important scientific and technical challenge is the effective use of wind potential, which lies in not only improving the aerodynamic characteristics of wind turbines but also in increasing the productivity of wind turbines as a whole.

The main characteristic on which performance of a wind turbine depends is the coefficient of wind energy use (WEUC) is the ratio of the mechanical power of the wind wheel to the total power of the incoming wind flow passing through the swept area of the wind turbine. Thus, the increase in WEUC in all operating modes of the wind power plant by improving the various methods of power management is relevant.

At the present stage of the development of science and technology, electrical systems based on renewable energy sources consist of a large number of interrelated elements and subsystems. To study such systems, a fairly powerful mathematical apparatus is usually required, based on the use of computing resources of electronic computers and its implementation by appropriate software.

In renewable energy, energy sources can not ensure the permanence of the generated power, so in such systems, the accumulation of generated energy is required for its subsequent delivery to the consumer, when necessary.

A wind turbine with a vertical axis of rotation can be divided into:

– wind turbines with constant geometry of the wind wheel;

– wind turbines with variable geometry of the wind wheel.

In this paper considered a wind turbine that operates at a variable speed with a change in the set angle of the wind wheel blades or a change in the geometrical dimensions of the wind wheel.

II. PROBLEM STATEMENT

One way [1] to adapt the properties of a wind wheel to changing wind conditions can be called a wind turbine power control method by changing the set angle of the blades or the geometric dimensions of the wind wheel. The application of this method involves the use a wind wheel design in which automatic modification of the aerodynamic surfaces leading to a change in the aerodynamic characteristics of the wind wheel in accordance with the varying wind speed is possible. Such a design usually requires the wind turbine to be equipped with various units to carry out the control function.

The advantages of the method:

– application of the mechanized design of the wind wheel allows the most complete use of wind energy in a wide range of operating speeds;

– this method allows to provide aerodynamic regulation of the wind turbine power, providing the most favorable operating conditions including ensuring the protection of the wind power plant generator from excessive power in the conditions of strong winds.

Disadvantages of the method:

– such a method requires the use of complex control system for mechanical devices and units in a wind power plant to allow wind wheel aerodynamic surfaces geometry change;

– the application of mechanical devices and units to change the wind wheel aerodynamic surfaces geometry leads to a decrease in the reliability of the wind power plant design and increases the maintenance need in during the wind turbine operation;

– design complication of the wind turbines leads to an increased cost of both the wind power plant and operating spendings, which adversely affects the economic efficiency.

III. Problem Solution

There are the following systems for angular position of the wind turbine blade adjustment:

1) Passive:

– systems for setting the angular position of the blade by directing to the wind flow;

– wind wheel geometry change control systems.

2) Active:

– electric drive orientation system;

– fuzzy logic control systems for changing the angle of blade jamming. Consider each of these systems.

To control the vertical-axis wind turbine with a Darrieus H-rotor [2] (Fig. 1b) a blade rotation around its vertical axis is most commonly used. The turning mechanism can be controlled by a centrifugal regulator located on the main vertical shaft or an electrohydraulic drive. Regulation by omission of the wind flow past the wind turbine blade system is implemented with Musgrove rotor (Fig. 1c). In this case, each pair of half-blades from the vertical position can fold in a horizontal position. The introduction of additional resistance on the wind turbine can be introduced using different kinds of brake flaps, including the turn of the entire rear part of the blade profile. Another method of aerodynamic braking uses an asymmetrical fixation of each blade with a rotor in its central part by means of a horizontal torsion (Fig. 1b). In the case of an increase in the speed above the nominal speed, the blade rotates around the horizontal axis of the torsion under the action of centrifugal forces and twists the torsion, deviating from its vertical position. The inclined position of the blade (deviation from the vertical position) causes an increase in its aerodynamic resistance.

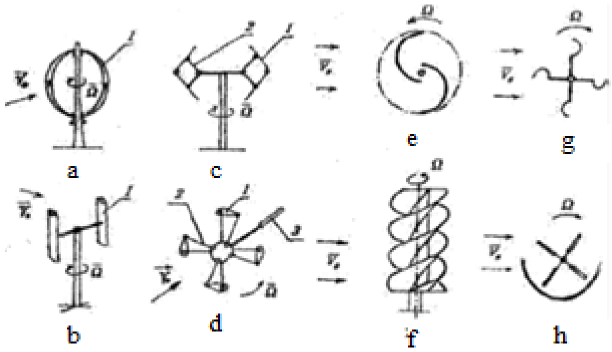

Fig. 1. Orthogonal vertical-axis wind turbines: (a) is the Darrieus rotor; (b) is the H-type rotor; (c) is the Masgrove Rotor (in a half-folded position) with a variable position of the blades; (d) is the "zhiromill" rotor (top view) with a variable angle of blades installation: 1 is the blade, 2 are blades position control mechanism; 3 is the weather vane (e) is the Savonius rotor (top view); (f) is the cup rotor (anemometer, top view); (g) is the screw rotor; (h) is the plate rotor with a screen, carousel (top view)

The algorithm for changing the blade jamming angle was proposed in the work [3]. The process of implementing fuzzy control is reflected in Fig. 2.

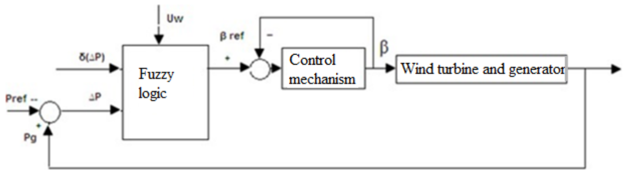

Fig. 2. Block diagram of the controller with the fuzzy logic-based algorithm for changing the blade jamming angle of the wind turbine

The input and output functions are shown in Fig. 3. From Fig. 2 it is seen that the proposed algorithm is based on power deviation from the nominal value ΔP:

$$\Delta P = P_{\text{ref}} - P_g,$$

$$\delta(\Delta P) = \Delta P_n - \Delta P_{n-1},$$

where P_{ref} is the nominal power value; P_g is the measured value of the generator power.

Table I shows the rules for input and output variables.

TABLE I. Rules of Fuzzy Inference

u_m	PS					PM					PL				
ΔP	NL	NS	ZE	PS	PL	NL	NS	ZE	PS	PL	NL	NS	ZE	PS	PL
δΔP															
NL	NL	NML	NM	NM	PS	NL	NM	NM	NS	PS	NML	NM	NS	NS	PS
NS	NL	NM	NS	PS	PM	NML	NM	NS	PS	PM	NML	NM	NS	ZE	PS
ZE	NML	NS	ZE	PS	PML	NM	NS	ZE	PS	PM	NM	NS	ZE	PS	PM
PS	NM	NS	PS	PM	PL	NM	NS	PS	PM	PML	NS	ZE	PS	PM	PML
PL	NS	PM	PM	PML	PL	NS	PS	PM	PM	PL	NS	PS	PS	PM	PML

In the proposed fuzzy system, nine fuzzy sets are used: NL is the negative large; NML is the negative medium large; NM is the negative medium; NS is the negative small; ZE is the zero; PS is the positive small; PM is the positive medium; PML is the positive medium large; PL is the positive large.

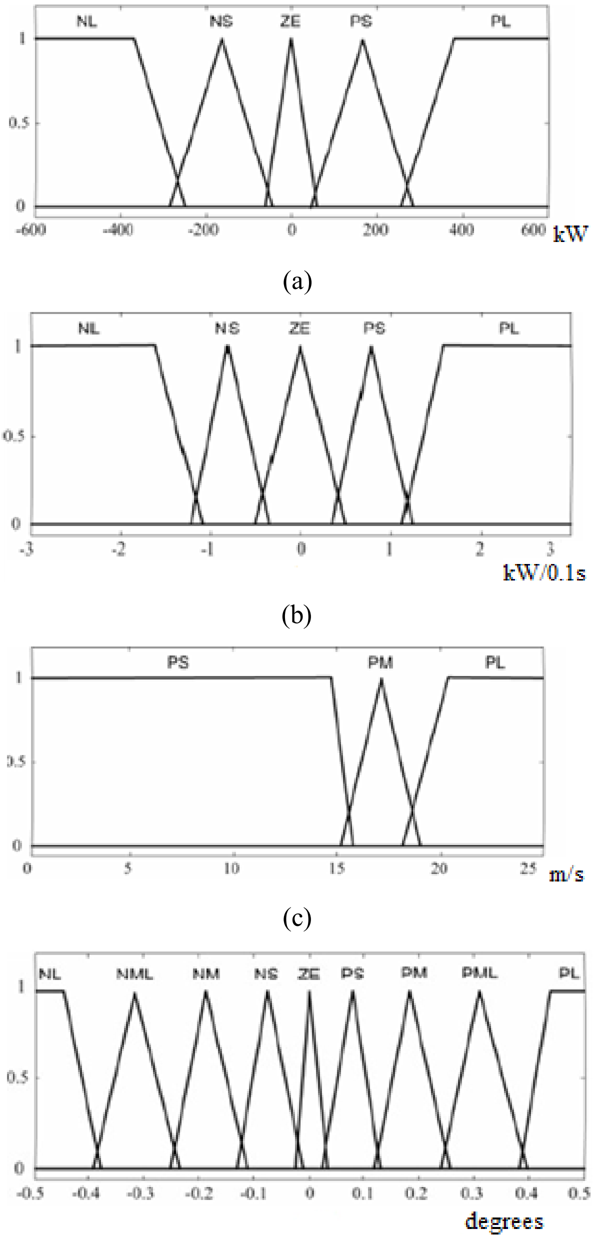

Fig. 3. Membership functions for variables: (a) input power error signal; (b) power gradient input signal; (c) the input signal of wind speed; (d) the output signal of changing the blade angle

For a more accurate understanding of the rules, let's comment on some of them (without taking into account the wind speed)

1) If ΔP and δ (ΔP) are large negative, the output power is greater than the nominal power value and the amplitude of power change increases. Therefore, it is necessary to reduce the jamming angle.

2) If ΔP is negative large and δ (ΔP) is a positive large, then the output power is higher than the nominal, but the amplitude of its change decreases, so the change in the jamming angle will be small.

Studies of the proposed algorithm have shown that its use at high wind speeds reduces the load on the wind turbine components.

IV. Conclusions

Analysis of various control systems for vertical-axis wind generator blade angular position was performed.

The main methods of optimal wind power plant control aimed at energy optimization by obtaining the optimal wind wheel rotor speed are analyzed. The use of any one of them depends on the envisaged control objective and on the information availability on system parameters and feedback. Some of these methods are potentially more flexible, and their shortcomings can be reduced to some extent.

Therefore, this topic is topical and requires further research.

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В. М. Синєглазов, І. С. Швалюк. Класифікація вертикально-осьових вітроустановок з поворотними лопатями

Метою роботи є підвищення ефективності використання альтернативних джерел енергії, а саме проведення аналізу способів керування встановленням кута лопаті вітрогенератора. Об'єктом аналізу є вітроустановки з вертикальною віссю обертання, предметом аналізу – обґрунтування використання регульованих лопатей в вертикально-осьовому роторі. Проведено критичний аналіз різних способів керування положенням кута лопаті вітроустановки та вирішено задачі з розробки активних та пасивних систем керування положенням кута лопаті ротора вертикально-осьового вітрогенератора.

Ключові слова: вертикально-осьова вітроустановка; контроль лопаті; активні та пасивні системи керування; алгоритм керування з використанням нечіткого контролера.

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В. М. Синеглазов, И. С. Швалюк. Классификация вертикально-осевых ветроэнергетических установок с поворотными лопастями

Целью роботы является повышение эффективности использование альтернативных источников энергии, а именно проведения анализа способов управления положением угла лопасти ветрогенератора. Объектом анализа являются ветроустановки с вертикальной осью вращения, предметом анализу – обоснования использования регулируемых лопастей в вертикально-осевом роторе. Проведен критический анализ различных способов управления положением угла лопасти ветроустановки и решено задачи по разработке активных и пассивных системы управления положением угла лопасти ротора вертикально-осевого ветрогенератора.

Ключевые слова: вертикально-осевая ветроустановка; контроль лопасти; активные и пассивные системы управления; алгоритм управления с использованием нечеткого контролера.

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