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SUBSTANTIATION OF ADAPTIVE SELF-ADJUSTING SYSTEM OF AUTONOMOUS WIND POWER INSTALLATION

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Abstract. *These principles of the synthesis of the general structure of an adaptive system electro-mechanical conversion spontaneous flow of wind energy with a selective choices of energy utilization.*

Keywords: autonomous wind power system; adaptive control algorithms and control; selective principle of energy recycling.

I. RELEVANCE

Among the most urgent tasks of improving autonomous wind energy systems is to reduce the energy loss of the wind flow at the stage of Electrical and parametric conversion and energy utilization. We know that this is possible in principle be achieved by the technical implementation of the algorithm a wind turbine at maximum aero-mechanical power factor, value of torque and rapidity, and at the same time adaptive control electricity load is relatively variable power generation.

II. STATE OF THE PROBLEM

There are different types of adaptive control systems and regulation Autonomous wind-energy installations (AWEI). Common general principles of such adaptive systems are flexible logic structures that function [1] for the continuous flow of input and output variables of informative parameters. The maximum installed capacity AWEI achieved, for example, [2] for adaptive control of the process of simultaneous production of electricity and heat. The overall objective of adaptive control AWEI considered [3] maintain to the maximum energy utilization factor variable wind flow from the known graphical dependence on rapidity. Similar principles of adaptive management proposed in [4] with a slightly different structural configuration of algorithms. However, adaptive AVEU as shown in [5], it is necessary to analyze the nature of more informative parameters of the incoming flow of energy, taking into account the inertial parameters of the rotating mass of wind turbine (WT). Also the principles of synthesis structures of self-forming algorithms developed are very general without reasonable methods of energy-efficient electricity load regulation.

III. THE PURPOSE OF RESEARCH

Justification of the adaptive management process fullest acceptance Alternating wind flow mode with optimization of energy utilization.

IV. RESULTS

Informative quality controlling signal current wind flow can be assessed correlation of them with instant energy performance of wind turbines. It is therefore important to analyze the effects of inertia. For example, consider the experimentally recorded combined graphs (Fig. 1) changes in the instantaneous wind velocity and angular velocity of the wind turbine with a diameter of 7 m.

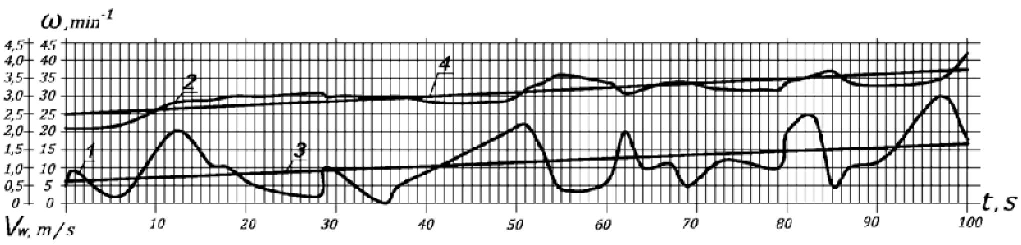

Fig. 1. Combined graphs of instantaneous changes in wind speed (Item *1*) and the angular velocity of the wind turbine (item *2*): *3* is averaged turbine rpm; *4* is averaged wind speed the turbine

The above graph shows that the wind speed is changing every second using stochastic pulses of different amplitude and frequency. The angular velocity WT responds to these changes of instantaneous wind speed with a certain inertia delay. Therefore, we can conclude that the proposed [3] principles of management by maintaining optimum values rapidity of change of the angle of the blades pitch angle technically almost impossible to implement. Given that the electromagnetic torque load current acting in concert with the moment of inertia with increasing WT wind speed and counter at the time of slowdown principle can be considered proportional to the change in stabilization rpm power load for the most rational AWEI

General dynamics of WT can be considered similar to the well-known models of inertial rotating mechanical movement drives. As the wind turbine rotor blade always has a certain moment of inertia J_w, the instantaneous increase in wind speed causes an increase in the angular velocity of the blades with some delay, according to [6] relationship:

$$\omega = \omega_v \left(1 - e^{-\frac{t}{T}}\right),$$

where ω_v is the initial angular velocity of the blades until the instant increase in wind speed; t is time; T is acceleration time constant wind turbine rotating mass, which depends on the moment of inertia of its J_w.

Similarly, reducing the instantaneous wind speed immediately lowers the speed of the blades, but because of the inertia of a period are kept constant momentum. Therefore, the functional circuit stage acceptance of wind energy turbine aero mechanical system can be represented by a standard transmitter link delay (Fig. 2).

Feedback to regulate blades made of the frequency parameters of the turbine. In fact, the link shows the inertial integrated models rapidity WT ratio settings specified angular velocity of the rotating motion and averaged values of instantaneous velocity.

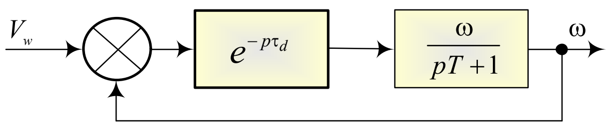

Fig. 2 Functional scheme an inertial system wind turbine

Of input function should be considered a generalized model of turbulent wind speed specified numerical index V_w for performance time, amplitude and spatial non-uniformity.

Thus the coefficient of Z rapidity is not only a scalar function the instantaneous wind speed $Z(V)$, as it has traditionally been considered, but also a function of time $Z(V, t)$. However, determining the exact values of the instantaneous wind speed is technically very challenging because of its temporal and spatial non-uniformity over the entire area of flow turbine. That wind speed to the plane of rotation of the blades has a random nature of temporal and spatial impulses. In modern wind energy is the wind flow pattern was called turbulent wind model. Therefore, the most informative parameters of the mechanical motion of the system is the angular velocity of the wind turbine.

Instantaneous angular velocity is a random function $\omega(t)$, which is a derivative of the primary functions of stochastic wind velocity $V(t)$.

$$\omega(t) = V'(t).$$

Probabilistic characteristics of the derivative $\omega(t)$ стохастичної функції $V(t)$ stochastic function $V(t)$ we obtain directly the characteristics of the original function. The value of the expectation of a stochastic function ω (t) describes the expression:

$$m_{\omega(t)} = \frac{dm_{V(t)}}{dt},$$

where $m_{\omega(t)}$ is expectation of a stochastic function of the angular velocity; $m_{V(t)}$ is expectation function of wind speed to the plane of rotation of the blades.

Stochastic correlation function values of the angular velocity follows the relationship:

$$K_{\omega(t)} = \frac{\partial^2 K_{v(t)}}{\partial t_1 \partial t_2},$$

where $K_{\omega(t)}$ is correlation function of the angular velocity; $K_{V(t)}$ is correlation function of wind speed; t_1, t_2 are neighboring time value of function arguments.

In essence, a stochastic function of the angular velocity of the rotor blade can be considered ergodic process for which the evaluation of the expectation is given by:

$$m_{\omega(T)} = T^{-1} \int_0^T Z(t)dt,$$

where $m_{\omega(T)}$ is evaluation mathematical expectation; T is sustained period of time.

Dispersion of this assessment mathematical expectation follows the relationship:

$$D(m_{\omega(T)}) = 2T^{-1} \int_0^T \left(1 - \frac{\tau}{T}\right) K_{\omega}(\tau) d\tau,$$

where $D(m_{\omega(T)})$ is an estimate mathematical expectation; τ are the time interval between the values of the time argument t_1 i t_2; $\tau = t_2 - t_1$; $K_\omega(\tau)$ is correlation function estimation mathematical expectation.

These evaluation criteria wind turbine motion caused by wind flow with a random pulse temporal and spatial nature of the wind speed is traditionally used for the general operation of wind turbine energy calculations.

In modern wind power for assessing local wind power potential is often used regardless of differential recurrence wind speeds on the ground in distribution Weibull. However, all known stochastic models recurrence wind speed can not be used in the automatic control system of wind turbines as sufficient prior information. Furthermore angular velocity of wind turbine in turn also depends not only on the wind speed, but also of the electromagnetic torque of the generator, which operates in variable load, so to get an accurate mathematical model of multiple stochastic functions impossible. Because it is necessary to analyze possible scenarios of system states given the dynamics of change of instantaneous wind speed (Fig. 1). Obviously, similar to the nature of the motion of the gas flow, estimated values of the Reynolds criterion, you can type indicator temporal and spatial non-uniformity of wind speeds before the wind turbines. This criterion is needed to select the combination of models of algorithms. Next, you need to give mathematical model of motion of the system for the extreme values of these parameters. Therefore, the most rational way of synthesis configuration self-structured adaptive AWEI be considered a combination of wind interaction models with models of wind turbine, generator and load.

The most rational way to present a technical level is the use of an adaptive control system self-adjusting type. It was therefore proposed a generalized structural model AWEI where energy consumers are divided into two types varying load under stochastic variable and operational-regulated facilities. Other traditionally-called ballast now feel more energy utilization adaptive load (EUAL). This block scheme of the adaptive AWEI shown in Fig. 3.

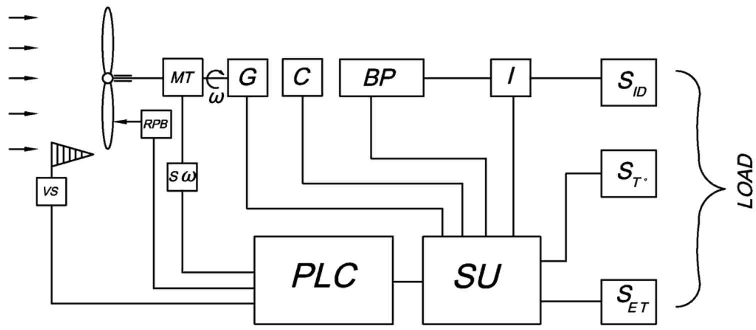

Fig. 3. Structural and technological scheme of AWEI with adaptive power control different type of load: *MT* – mechanical transmission; *G* – generator; *C* – semiconductor converter; *BP* – battery pack; *I* – inverter; *PLC* – programmable logic controller; *SU*– switching unit; *VS* – wind speed sensor (anemometer electricity); *RPB* – regulator position of the blades; $S\omega$ – RPM sensor (electrical tachometer); S_{ID} – stochastic variable load of industrial and domestic type; $S_{T°}$ – adaptive-controlled thermoelectric load; S_{ET} – adaptive-controlled electro-technological load

In this scheme forward and backward linkages are made through a programmable logic controller between different groups of load and wind turbine and generator unit. This controller has a double structure, which contains analytical computing device and automatic control device. The principle of adaptive load control is adjustable changing the type and power depending on the adopted EUAL variable power WT and instantaneous power-stochastic variable load. And EUAL also divided into priority groups for parameters regulated power supply and connected to the system after different numbers of consecutive stages parametric energy conversion, priority is given to those who meet the requirements of electricity passing the cascade transformations directly from the generator. For example, heat accumulators heaters can be connected directly through the switching unit to the power generator and electrode electrolysis system can be connected after the rectifiers.

The principle of operation of the developed adaptive control systems and energy-efficient load control algorithm AWEI written schematically (Fig. 4).

The work of the algorithm is described below in steps:

Step_1. Run the system begins with the transition to the initial state: battery packs (BP); regulator position of the blades (RPB); generator (G) and switching unit (SU) and transition to step_2.

Step_2. Verification of compliance with the nominal charge BP. If corresponds – status-level SU «charger – BP» disconnected and SU connect BP to stochastic variable-load industrial and domestic type (S_{ID}) and transition to step_4. Otherwise – SU connect charger to BP and transition to step_3.

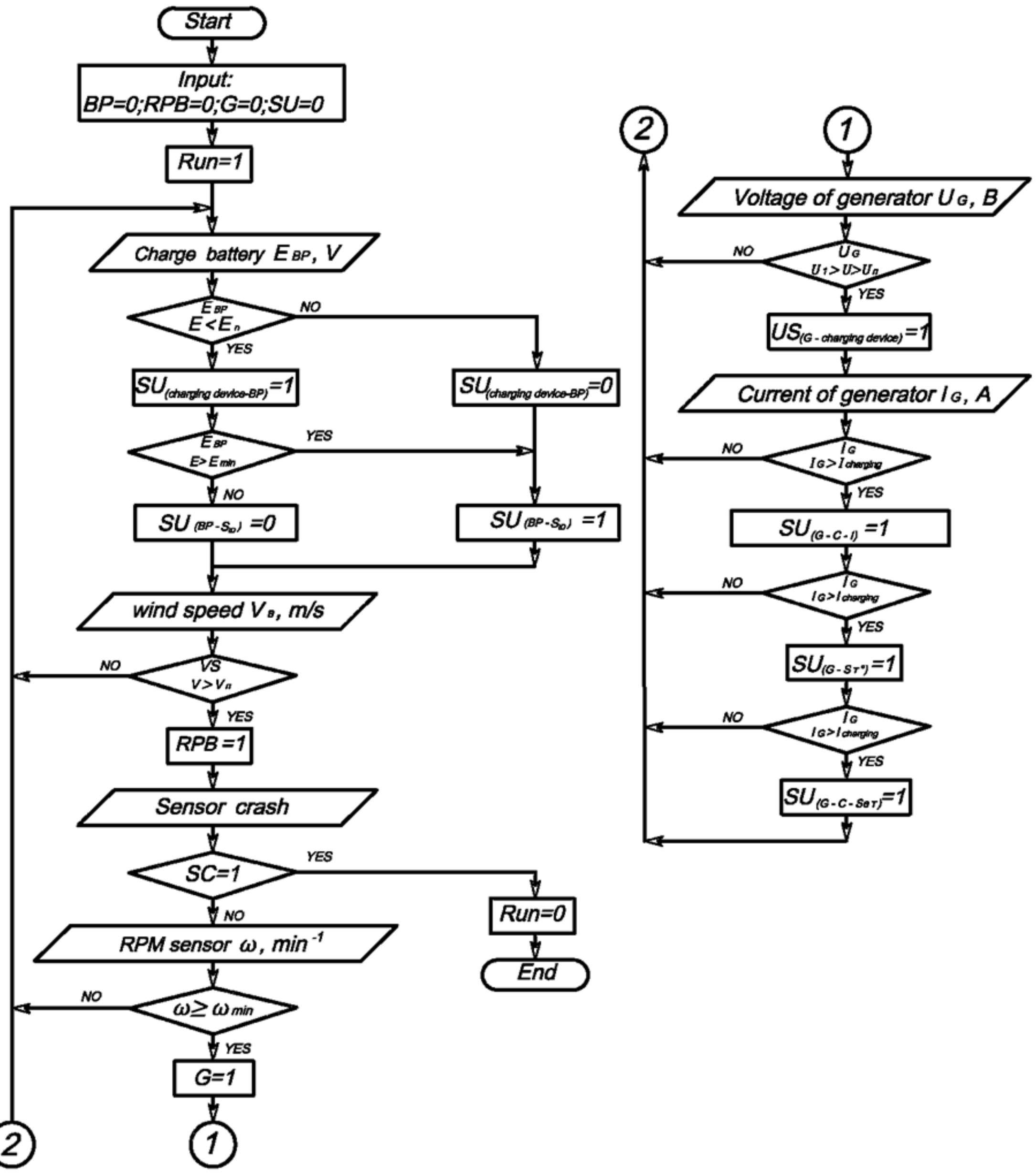

Fig. 4. The general scheme of the algorithm operation AWEI system with adaptive power adjustment heterogeneous load

Step_3. Verification of compliance with the nominal charge BP. If corresponds – SU connect BP to S_{ID} and transition to step_4. Otherwise – status-level SU: «BP – S_{ID}» disconnected and transition to step_4.

Step_4. Check the wind speed according to the desired starting value WT. If signal corresponds – RPB the transition into the working position and to step_5. Otherwise – return to step_2.

Step_5. Diagnosis of sensor crash. If the emergency signal goes – forced braking WT and the transition to step_6. Otherwise – transition to step_7.

Step_6. Turn off all systems.

Step_7. Verification of compliance with the rotation frequency to the desired starting value WT. If corresponds – G transition in the operating position to step_2.

Step_8. Check the voltage from G according to the required size BP. If corresponds – status-level SU: «G – charger» disconnected and transition to step_9. Otherwise – return to step_2.

Step_9. Check the current from G according to the required size BP. If signal corresponds – status-level SU: «G – converter – inverter» connected and transition to step_10. Otherwise – return to step_2.

Step_10. Check the current from G according to the required size BP. If corresponds – status-level SU: «G – adaptively controlled-load» connected and transition to step_11. Otherwise – return to step_2.

Step_11. Check the current from G according to the required size BP. If corresponds – status-level SU: «G – adaptive-controlled electro-technological load» connected and return to step_2. Otherwise – return to step_2.

BP is connected to power consumption in one of three modes: rapid, normal or regular, depending on the degree of battery discharge. If the generated power exceeds the charging capacity of the battery, the connection is made alternate channels of direct supply of the first group of loads through the inverter and energy utilization, initially load the less tightly regulated power supply options.

In the case of reducing power energy stochastic variable load in constant power generation is connected EUAL next group.

As EUAL provided technological energy consumers who are not strictly regulated by an electrical requirements, the electromechanical system with a minimum number of stages of conversion adopted wind energy and therefore higher overall efficiency AWEI, that has higher energy efficiency. Depending on the ratio of installed capacity of heterogeneous load adaptive control scheme AWEI (known quantitative indicators for energy losses in the stages of the parametric conversion of electricity after the generator) according to theoretical calculations can improve the overall energy efficiency of 35 - 40% of auto engines.

V. Conclusion

1. The immediate value of the instantaneous wind speed can not be considered informative indicator of sufficient quality to implement adaptive control algorithm using optimal rapidity.

2. The principle of stabilization rpm wind turbine implementation of adaptive change in load power should be considered as one of the most efficient methods for AWEI.

3. The most rational way of synthesis of energy efficient structure automatic control AWEI modern technical level is the use of an adaptive search engine without self-adjusting type.

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В. М. Синєглазов, В. В. Козирський, М. І. Трегуб, О. С. Василенко. Обґрунтування адаптивної самоналагоджувальної системи автономної вітроелектричної установки

Розглянуто принципи синтезу загальної структури адаптивної системи електромеханічного перетворення спонтанного потоку вітрової енергії із селективними варіантами енерго-утилізації.

Ключові слова: автономна вітроенергетична система; алгоритми адаптивного керування і регулювання; селективний принцип енерго-утилізації.

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В. М. Синеглазов, В. В. Козырский, Н. И. Трегуб, А. С. Василенко. Обоснование адаптивной самонастраивающейся системы автономной ветроэлектрической установки

Рассмотрены принципы синтеза общей структуры адаптивной системы электромеханического преобразования спонтанного потока ветровой энергии с селективными вариантами энерго-утилизации.

Ключевые слова: автономная ветроэнергетическая система; алгоритмы адаптивного управления и регулирования; селективный принцип энерго-утилизации.

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