Methodological approach to simulation and choice of ecologically efficient and energetically economic wind turbines (WT)

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Abstract. Use of wind energy is related to one of the prospective directions among renewed energy sources. A methodological approach is reviewed in the article to simulation and choice of ecologically efficient and energetically economic wind turbines on the designing stage taking into account characteristics of natural-territorial complex and peculiarities of anthropogenic load in the territory of WT location.

1. Introduction

Practical use of renewable energy sources (RES) is growing in many countries of the world. Leading place among them is taken by wind turbines (WT), capable of generating a lot of electrical energy for consumers of various sizes from single plants to group united into networks (wind power station) [1-15]. Main advantages of WT are inexhaustibility of wind energy, relative ecological safety of the obtained energy and possibility of location on any territory. The drawbacks, limiting wide use of WT, include narrow range of use of speed characteristics of wind from 2 to 15 m/sec, unstable work due to changes of wind direction, long payback term of the plant [16-23]. Further progress of WT development, in our view, shall be based on optimization of WT management through simulation of the process of electrical energy production.

Under the modern conditions of WT development a necessity arises of development of criteria for choosing of plant and optimization of the technology of electrical energy production [24-35]. Research of the most widely used in practice methods for evaluation and choice of optimal parameters of WT with consideration to necessary volumes of the produced energy and location of the facility allowed to find their drawbacks:

- necessity of preliminary setting of certain type of equipment;
- absence, sufficiently, of energetic characteristics of equipment on the assumption of peculiarities of complex impact on the state of environment and comfort of living of the population in the area of location of WT.

Presently in relation to existing variety of WT arises a necessity of management of the process of choosing of type of the turbine based on the principles of energetic economy and ecological efficiency [19-21]. Under the term «energetic economy» we understand the share of energy (useful energy) used by WT in relation to total wind potential of the territory. Under the term «ecological efficiency» we understand the degree of decrease of negative factors (noise, vibration, etc.), influenced by WT on the environment after its installation on a certain territory. The method suggested by us allows to simulate
the process, i.e. to calculate the variants of choosing of technologies of transformation of wind energy into the electric with the help of WT.

2. Materials and Methods

Main aim of our research is provision of the possibility to manage the process of transformation of wind energy into the electric one on basis of simulation of the choice of optimal technologies of WT under the principles of energetic economy and ecologic efficiency. Such a methodological approach allows to choose the most ecologically efficient and energetically economic technology. For realization of the goal it is necessary to solve the following tasks:
- carry out system analysis of natural and climatic factors and landscape characteristics of the territory of location of WT;
- determine parameters describing main characteristics of WT;
- carry out mathematical description of resulting evaluation criteria of the process: ecologically efficient and energetically economic;
- choose the most ecologically efficient and energetically economic technology on basis of the calculated resulting criteria;
- work out a procedure of choosing technologies for obtaining of electrical energy and choosing of constructive plants of WT.

3. Results

Thus, the mentioned simulation is based on the procedure we offer including the following main stages.

On the first stage natural and climatic characteristics and landscape peculiarities of the territory of location of the construction are grouped by type of landscape, including surface roughness, wind potential calculation of the territory in the speed interval from 2 to 13 m/sec taking into consideration evaluation of average annual and average monthly wind speed, time of wind gust formation, number of hours of prevailing wind direction. Aggregate of these parameters determines, in the end, the aggregate wind power \( W_1 \) per the unit of area perpendicular to the direction of wind flow on the researched territory.

On the second stage by the power demanded by the consumer \( W_2 \) various variants of plants are chosen (by types of WT). For each type of WT technical characteristics and ecological parameters are determined. Technical characteristics of the plant: wind wheel diameter, mast height, type of axis of rotation, number of blades and materials they are produced of, screw pitch. Ecological parameters of WT impact characterizing ecological safety in the area of the facility location: mechanical noise, vibrations, infra-sound, wear-resistance of the construction and its elements.

On the third stage characteristics are previously chosen on the second stage types of WT are compared, choosing plants by minimal values of losses of wind specific energy \( \Delta W_i \), capable of providing the power necessary for the consumer:

\[
\Delta W_i = W_1 - W_2 \cdot \Delta W_i
\]

Output-input ration

\( \Delta W_i \) – are losses of wind specific energy, \( W_i \).

On the fourth (final) stage out of the plants passing the third stage of choosing one is chosen optimal by ecological efficiency and energetic economy. On this stage we suggest ecological efficiency and energetic economy as resulting criteria for WT.

At that we suggest to make the choice of optimal WT by ecological efficiency on basis of this parameter by formula:

\[
E_{\text{eff}}^{\text{WT}} = \frac{(A_1 - A_2)}{A_1} \cdot 100\%.
\]

where \( A_1 \) – is the level of impact of a certain ecological factor on the state of the territory without WT; \( A_2 \) – is the level of impact of a certain ecological factor on the state of the territory taking into consideration WT impact.
In case if several variants of WT shall have the same values of ecological efficiency the further choice if optimal WT is suggested to be carried out by values of energetic economy of each reviewed variant on basis of calculation of energy output index of WT as a criterion for evaluation of energy economy:

\[ E^{\text{WT}} = \frac{W_2}{W_1} \cdot 100\% , \]

where \( W_2 \) is used (transformed) by WT specific wind energy («useful energy»), \( W_1 \) – is full specific wind energy on the reviewed territory («consumed energy»), \( W \).

4. Conclusions

Thus, the procedure offered by us allows to choose ecologically efficient and energetically economic WT on the stage of designing taking into account characteristics of natural and territorial complex and peculiarities of anthropogenic load on the territory of WT location.

As the result of the research carried out we have suggested the procedure of choosing of the technology of transformation of wind energy into the electrical one and selection of constructive characteristics of WT on basis of simulation of various variants of such technologies, and also choice of optimal parameters of WT based on principles of provision of maximum values of ecological efficiency and energetic economy. At that, starting with the third stage, if as the result of choosing only one WT is left, the implementation of further stages is not necessary and choice of optimal WT culd be concluded on the corresponding stage of the procedure.

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