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Determining the Generalized Efficiency Index of the Hybrid Energy Source Energy Consumption Object

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ABSTRACT: In this article, the share of renewable energy sources in the product unit and its impact on energy efficiency are studied in the assessment of the efficiency of energy use in the enterprise. An industrial enterprise is taken as an object of energy consumption, and it is proposed to evaluate its energy (heat and electricity) consumption in the form of a single hybrid energy source. The ranking order of the components of the generalized efficiency indicator of the energy consumption object and the values of the weighting coefficients were developed based on "Expert assessment" and the Fishburn formula.

KEY WORDS: Energy consumption object, hybrid energy source, environmental index, energy resource utilization indicator, quality indicator, source efficiency, economic efficiency indicator, transmission efficiency, Expert evaluation, Fishburne.

I.INTRODUCTION

In recent years, the use of renewable energy sources (RES) in the energy supply system has been increasing in order to increase the efficiency of energy use in production enterprises. These changes cause certain problems in evaluating the efficiency of energy use of the enterprise. For example, when using renewable energy sources in an enterprise, the amount of energy consumed per product unit does not change, and energy efficiency is considered unchanged. However, the use of renewable energy sources reduces the use of primary energy resources and the amount of environmental pollution, that is, increases the energy efficiency index [1]. When determining energy efficiency, it is necessary not only to calculate the efficiency of energy devices, but also to reduce the considerable of the use of fuel and energy resources in the enterprise. Currently, alternative energy sources (solar heaters, solar photoelectric plant, wind power plant, etc.) are installed in energy consumption facilities, and diversification of the energy source is being carried out. Such consumer objects can be considered as a small autonomous micro-energy network consisting of a hybrid energy source, energy transmission and energy consumers (Fig1). In this case, it is assumed that "electricity and heat energy received by the enterprise from the centralized network is produced in a micro power plant or heat source on the territory of the enterprise." That is, it is considered that "the waste coming out of the network power plant or regional heat center due to the consumption of the enterprise is directly removed from the enterprise." Acceptance of energy consumption objects in such a composition allows to determine the impact of energy consumption in the enterprise on the environment, and complex assessment of its energy efficiency.

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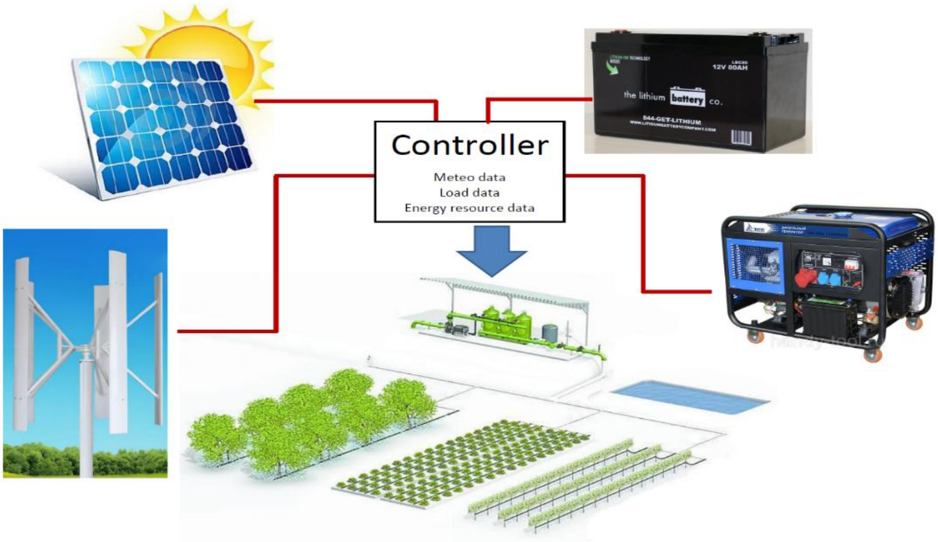

Fig1. Structural energy devices of the hybrid energy source energy consumption facility

The development of a comprehensive efficiency indicator that covers all factors affecting energy efficiency in an enterprise allows to classify different enterprises according to energy efficiency. For this, all stages of the energy use process should be covered in the energy consumption object (ECO). We assume that the process of energy use in the enterprise is carried out according to the scheme shown in Fig 2. That is, the type and amount of fuel energy resource (FER) used in the calculation of energy efficiency, energy production, transmission and consumption processes are covered.

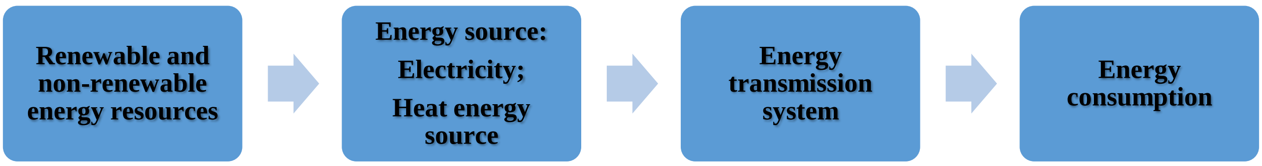

Fig2. Scheme of the stages of the energy use process in the enterprise

II. EXPERIMENTAL PART

The efficiency indicator that summarizes the efficiency of energy use in the enterprise is developed based on the following principles of energy saving:

1. Rational use of fuel and energy resources in energy production and reduction of the considerable of their use;
2. The total efficiency of the energy source and the energy transmission system should be maximum or waste should be minimal;
3. Environmental damage or environmental impact index in energy production should be minimal;
4. Minimal total costs (cost of energy) per unit of energy in energy production.

Based on these principles, we determine the efficiency indicators of the hybrid energy source energy consumption object (HES ECO). In order to generalize all performance indicators into a single indicator, the indicators must be in a dimensionless (relative) unit. Indicators we define indicators that describe the efficiency of the stages shown in Fig 2.

1. The efficiency indicator of the use of energy resources of a hybrid energy source is determined by combining the indicators of electric and thermal energy sources. In this case, both types of energy are converted into one unit: kWh or t.c.f unit. The expression for calculating this indicator is as follows:

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$$K_{eru} = 1 - \frac{W_{er}+Q_{er}}{(W_{er}+Q_{er})+(W_{RES}+Q_{RES})}, \quad (1)$$

Here: W_{er} and Q_{er} – electricity and thermal energy produced at the enterprise from fuel energy resources, kWh; W_{RES} and Q_{RES} – electricity and heat energy obtained from renewable sources at the enterprise, kWh.

This indicator shows the volume of "clean" energy obtained without using FER in the energy consumed by the enterprise [2]. For example, if the indicator $K_{er} = 0.55$, it means that 55% of the energy consumed by the enterprise was obtained from RES without using FER.

2. Efficiency of the hybrid energy source. This performance indicator is also combined in this order. That is, the efficiency of all energy devices is summarized in the following form, bringing electrical and thermal energy into one measurement unit (kWh or t.c.f.):

$$K_\eta = \frac{\sum_{i=1}^{i} W_i \cdot \eta_i + \sum_{k=1}^{k} Q_k \cdot \eta_k}{\sum_{i=1}^{i} W_i + \sum_{i=1}^{i} Q_i} =$$
$$= \frac{(W_1\cdot\eta_1+W_2\cdot\eta_2+\cdots+W_i\cdot\eta_i)+(Q_1\cdot\eta_1+Q_2\cdot\eta_2+\cdots+Q_k\cdot\eta_k)}{(W_1+W_2+\cdots+W_i)+(Q_1+Q_2+\cdots+Q_k)}, \quad (2)$$

Here: W_i and η_i are the electric energy produced by the electric power plants in the enterprise and their efficiences; Q_k and η_k –are the thermal energy produced by the thermal energy devices in the enterprise and their efficience.

This indicator determines the average efficiency of total energy (renewable and non-renewable) devices in the production of energy consumed in the enterprise.

3. The environmental impact indicator of an energy-consuming objectis summarized in the following order. The damage to the environment for all energy devices operating on different fuels (natural gas, coal, gasoline, etc.) in the hybrid energy (electricity and heat) source is determined by the following expression:

$$C_{eco.\Sigma} = \sum m_i \cdot C_{o.i} = m_1 \cdot C_1 + m_2 \cdot C_2 + \ldots + m_i \cdot C_{o.i} \quad (3)$$

Here: $m_1 - i$ – the amount of harmful substances released into the environment during the year by electric and thermal energy sources using different types of fuel, Tn; $C_{o.i}$ – i-the value of the amount of environmental damage (or the amount spent to compensate for the damage) of 1 ton of harmful substances released by the fuel-burning power plant.

The indicator of the environmental impact of an energy-consuming object is determined by the ratio of environmental damage to the total product produced in the enterprise from the following expression.

$$K_{eco.im} = \frac{C_{eco\Sigma}}{P_\Sigma} = \frac{C_{eco.e} + C_{eco.he}}{P_\Sigma} \quad (4)$$

It can be seen from this expression that as the amount of damage to the environment increases, the impact indicator also increases and the efficiency decreases. Inversely proportional to this indicator, the variable indicator is taken as an efficiency indicator and is determined from the following expression:

$$K_{eco.ef} = 1 - \frac{C_{eco.\Sigma}}{P_\Sigma} \quad (5)$$

Here: $C_{eco.\Sigma}$ – the amount of damage caused to the environment by the hybrid energy source during the year; P_Σ – the value of the product produced during the year.

4. The economic efficiency indicator of the hybrid energy source is determined by summing the indicators of electricity and heat sources with the contribution of energy production costs in the production of a unit product from the following expression:

$$Z_{0.e.th} = \frac{Z_{e.t}+Z_{th.t}}{P_t} = \frac{Z_{e.th.g.t}}{P_t} \quad (6)$$

Here: $Z_{e.t}$ and $Z_{th.t}$ – are the total expenses spent for the production of electricity and heat energy in the enterprise during the year, million soums.

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The inverse of this indicator is the coefficient of economic efficiency of energy production in this enterprise and is calculated from the following expression:

$$K_e = 1 - \frac{Z_{e.th.g}}{P_t} \tag{7}$$

5. The efficiency of the energy transmission system determines the efficiency of energy delivery to the consumer. One of the important indicators of the energy supply system is the ability to transmit energy with minimal waste. This indicator is determined by the sum of waste in energy transmission in the enterprise from the following expression:

$$K_\eta = \frac{W_g - \Delta W_{\Sigma w}}{W_g} \tag{8}$$

Here: $W_g$andW_c −energy produced at the enterprise and received by consumers, kWh; $\Delta W_{\Sigma w}$ −is the sum of losses in energy transmission, kWh.

Quality coefficient of delivered energy. Electricity is high-quality energy, and the efficiency of energy transmission is also determined by providing consumers with high-quality electricity. Therefore, when determining the generalized power quality indicator at the output of the electric transmission network (ETN), only the power quality indicators adjusted by the ETN devices are taken into account. This indicator is determined from the following expression:

$$K_q = \prod_{n=1}^{n} K_n = K_1 \cdot K_2 \cdots K_n = K_{sin} \cdot K_{\Delta U} \cdot K_{sim} \tag{9}$$

Here: K_{sin} −the voltage sinusoidality coefficient, $K_{\Delta U}$ − the voltage deviation coefficient, K_{sim} −the voltage summetry coefficient.

III. RESULTS AND DISCUSSION

Summarizing the obtained indicators, we determine the comprehensive energy efficiency indicator of HES ECO:

1. Coefficient of use of energy resources of ECO. This coefficient is equal to the coefficient of use of energy resources of the hybrid energy source. That is:

$$K_{ECO} = 1 - \frac{W_{er} + Q_{er}}{(W_{er} + Q_{er}) + (W_{RES} + Q_{RES})}, \tag{10}$$

2. General efficiency coefficient of energy devices of ECO. This coefficient is equal to the sum of the total efficiency in energy production and transmission.

$$K_{\eta.ECO} = K_{\eta.g} \cdot K_{\eta.t} \tag{11}$$

3. Environmental impact coefficient of ECO. This coefficient is equal to the coefficient of the hybrid energy source's environmental impact.

$$K_{ECO.eco} = \frac{C_{c.\Sigma}}{P_\Sigma} = \frac{C_{c.e} + C_{c.th}}{P_\Sigma}, \tag{12}$$

4. The energy quality coefficient of ECO is equal to the quality coefficient of electricity transmission:

$$K_q = \prod_{n=1}^{n} K_n = K_1 \cdot K_2 \cdots K_n = K_{sin} \cdot K_{\Delta U} \cdot K_{sim}$$

5. The ECO's economic efficiency indicator consists of the sum of economic efficiency indicators at all stages of the energy use process. That is:

$$K_e = K_{ec.pr} + K_{ec.tr} + K_{ec.con} = 1 - \frac{Z_{pr} + Z_{tr} + Z_{con}}{P_t} \tag{13}$$

Here: Z_{pr}, Z_{tr} and Z_{con} − costs in energy production, transmission and consumption processes; P_t − the value of products produced in an enterprise in one year.

In this case, the generalized efficiency coefficient of HES ECO is determined by adding the efficiency indicators that make it up with the following expression:

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$$K_{mex} = \sum_{n=1}^{n} \alpha_i \cdot K_i, \tag{14}$$

Here: the order number of the $n-$efficiency coefficient of the energy-consuming object; $\alpha_i -$the weight coefficient determining the level of significance of the indicator; $i-$ efficiency coefficient is the sequence number in the sequence

It is important to determine the order of the queue when summarizing indicators. In this case, the weight coefficients of important indicators will be larger. The next important issue is determining the values of the weight coefficients of the indicators. In determining the level of significance of indicators, "Expert evaluation" or methods of differentiating them based on some criterion are often used. Based on their experience, experts rank and justify the indicators according to their importance. In this assessment, based on the conclusions of 5 experts, the indicators were ranked as follows:

1. Indicator of economic efficiency of ECO–K_e
2. General efficiency of energy devices of ECO - K_η
3. Coefficient of environmental impact of ECO - K_{eco}
4. Coefficient of use of energy resources of ECO - K_{er}
5. Energy quality coefficient of ECO - K_q

At the next stage, indicators are checked for significance based on technical or economic criteria. To do this, each indicator is changed to the same value, and the weight of technical (for example, wastage) and economic (for example, the amount of costs) changes are compared and ranked according to the results. The analysis of the results showed that the above ranking order is correct.

At the next stage, the values of the weight coefficients of the indicators are determined. The ranking order of the indicators and the values of the weighting coefficients were determined using the methods "Determining the average evaluation of experts", "Sorting the criteria according to the level of importance", "Hierarchical analysis" and "Fishburn formula". With the participation of experts, the following values of weight coefficients were calculated in the methods of "Determining the average assessment of experts", "Sorting the criteria according to the level of importance":

$$K_{HES} = \sum_{n=1}^{n} \alpha_i \cdot k_i = 0.3 \cdot K_e + 0.25 \cdot K_\eta + 0.2 \cdot K_{eco} + 0.15 \cdot K_{er} + 0.1 \cdot K_q \tag{15}$$

By determining the values of the weighting coefficients in this order of ranking based on the Fishbren formula, we get the following expression:

$$K_{HES} = \sum_{n=1}^{n} \alpha_i \cdot k_i = \frac{5}{15} \cdot K_e + \frac{4}{15} \cdot K_\eta + \frac{3}{15} \cdot K_{eco} + \frac{2}{15} \cdot K_{er} + \frac{1}{15} \cdot K_q, \tag{16}$$

The α_i-weight coefficients in this expression were determined by the Fishbren method from the following expression:

$$\alpha_i = \frac{2(n-i+1)}{n(n+1)}, \tag{17}$$

Here: $n-$the sequence number of the efficiency coefficient of the energy consumption objects; $\alpha_i -$the weight coefficient determining the level of significance of the indicator; $i-$efficiency coefficient is the sequence number in the sequence.

VI.CONCLUSION

1. The generalized efficiency indicator of the hybrid energy source of the energy consumption object was developed.
2. The efficiency indicator of the energy transmission system of the energy consumption facility and the energy consumption process was developed.
3. On the basis of the effective indicators presented in the dimensionless unit, a generalized efficiency indicator of the energy consumption object was developed.
4. The order of ranking the constituents of the generalized efficiency indicator of the energy consumption facility and the values of the weighting coefficients were developed based on "Expert assessment" and the Fishburne formula.

REFERENCES

[1] F. Nadi, A.Hepbasli, "Evaluation of Sustainability of a Prune Production Process from Farm to Fork Approach based on Thermodynamic Principles and Actual Operational Data", International Journal. Global Challenges, 210007, 2022.
[2] KorzhovV.Yu., "Energy saving and energy audit", Journal. "Simplified accounting",pp. 43-48, 2013.
[3] N.N. Sadullaev, M.O. Gafurov., "Assessment of the impact of the industrial enterprise on the environment by determining the integrated (generalized) energy efficiency performance indicator", AGRITECH-VIII 2023 E3S Web of Conferences 390, 06018, 2023.
[4] N.N. Sadullaev, M.O. Gafurov., "Determination of the complex (generalized) energy efficiency index of the industrial enterprise", Scientific journalDevelopment of science and technology, Volume 2pp. 214-218, 2-2023.
[5] N.N. Sadullaev, M.O. Gafurov., "Determination of the Complex Energy Efficiency Indicator of an Industrial Enterprise", Journal JisuanjiJichengZhizaoXitong/Computer Integrated Manufacturing Systems. Volume 28(11), pp. 883-890 2022.