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TOOL FOR ASSESSING THE LEVEL OF ENERGY SECURITY OF THE DECENTRALIZED POWER SUPPLY SYSTEM FOR ENTERPRISES IN CAMEROON

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The development of the energy system in Cameroon is linked to the electricity supply and demand market. In recent years, the place of development of small and medium-size enterprises has began to have a significant impact on the balance of consumption. The choice of a specific scheme for the operation of a decentralized electricity supply system for enterprises in Cameroon should be based on objective criteria. Depending on the goals of the enterprise, this criterion can be the cost of implementing the project, discounted cash income, profitability growth with a predetermined forecast horizon, and many others. The choice of this criterion is associated with a multi – factor analysis of the goals of the enterprise and the specifics of its functioning, and the set of possible variations of this criterion can be conditionally designated as "Economic criteria". The article presents a tool for determining a comprehensive criterion for assessing the level of energy security of the decentralized power supply system for small and medium-sized businesses in Cameroon. The tasks solved in the framework of the study allow us to develop a system of economic management tools in energy systems. This tool can be widely used in the development of decentralized electricity supply for small and medium-sized businesses that are experiencing problems with the reliability of electricity supply. This will eventually create a more sustainable system for developing this sector of the economy.A characteristic feature of determining the key economic indicator is the dependence on the energy supply system. In one case it can only be revenue, in the second case it can be profitability and revenue, and in the third case profit, revenue and profitability. Perhaps a similar tool can be developed for the energy supply systems of enterprises in other countries.

Keywords: energy security, economic criteria, decentralized power supply system, integrated analysis, small and medium- sized enterprises, integrated assessment tool, fuzzy set theory

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ИНСТРУМЕНТАРИЙ ОЦЕНКИ УРОВНЯ ЭНЕРГЕТИЧЕСКОЙ БЕЗОПАСНОСТИ СИСТЕМЫ ДЕЦЕНТРАЛИЗОВАННОГО ЭЛЕКТРОСНАБЖЕНИЯ ПРЕДПРИЯТИЙ КАМЕРУНА

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Развитие энергосистемы Камеруна зависит от рынка спроса и предложения на электроэнергию. В последние годы существенное влияние на баланс потребления начинает оказывать малый и средний бизнес. Выбор конкретной схемы функционирования децентрализованной системы электроснабжения предприятий Камеруна должен производиться на основе объективного критерия. В зависимости от целей предприятия данным критерием могут выступать затраты на реализацию проекта, дисконтированный денежный доход, прирост рентабельности с заданным горизонтом прогнозирования и др. Выбор критерия сопряжен с многофакторным анализом целей предприятия и специфики его функционирования, а совокупность возможных вариаций данного критерия можно условно обозначить как «экономические критерии». В статье представлена методика определения комплексного критерия оценки уровня энергетической безопасности системы децентрализованного электроснабжения предприятий малого и среднего бизнеса Камеруна. Взвешенная сравнительная оценка уровня энергетической безопасности не может производиться на основе классических методов оценки. В первую очередь, это обусловлено необходимостью использования как статистических, так и экспертных показателей, выделенных в описанной системе. Следовательно, одним из наиболее подходящих для построения методики оценки уровня энергетической безопасности является нечетко-множественный подход. Данная методика должна базироваться на системе экспертных оценок, однако, в отличии от статистических и экспертных методов оценки, она дает возможность учитывать уровень неопределённости посредством использования функций принадлежности ($\mu(x)\in[0;1]$) подмножества заданному множеству. Решенные в рамках исследования задачи позволяют развить систему экономических инструментов управления в энергетических системах. Данная методика может получить широкое применение в системе развития децентрализованного электроснабжения предприятий малого и среднего бизнеса, испытывающих проблему с надежностью электроснабжения. В конечном итоге это позволит создать более устойчивую систему развития данного сектора экономики. Возможно, аналогичным методом может быть разработана методика и для систем энергоснабжения предприятий в других странах.

Ключевые слова: энергетическая безопасность, экономические критерии, децентрализованная система электроснабжения, комплексный анализ, малые и средние предприятия, методика комплексной оценки, теория нечетких множеств

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Introduction

Cameroon is currently destabilized in terms of many aspects of business infrastructure. The result of this destabilization is an increase in the consequences of the implementation of possible risks, and, consequently, a significant increase in the probability of suspension or complete termination of the company's activities. Thus, the energy security of the scheme of functioning of the decentralized power supply system (DPSS) of enterprises is no less significant than the economic effect of its implementation. However, at the moment, there is no universal criterion of energy security (ES) developed in science. This fact is due to the fact that the specified criterion is complex and is determined by a set of many factors, significantly differentiated depending on the object of research [2].

Purpose of research: development of a tool for a comprehensive assessment of the level of energy security of a decentralized power supply system.

Object of research: decentralized power supply system for small and medium-sized enterprises in Cameroon, experiencing problems of unreliability or complete absence of a centralized power supply system.

Subject of research: energy security of possible schemes for managing energy supply to enterprises.

Tasks:

1. Identify the main factors, determining the energy security of small and medium-sized businesses in Cameroon;
2. Based on the identified factors, propose a set of indicators for assessing the energy security of small and medium-sized businesses in Cameroon;
3. Develop a tool for determining the values and units of measurement of the proposed indicators;
4. Based on the theory of fuzzy sets to build a tool for assessing the level of energy security of the enterprise.

Research methods

For the purpose of developing the tool for assessing, first of all, it is necessary to determine the factors that influence the ES of the implementation of the scheme of functioning of the DPSS of enterprises in Cameroon. A complex analysis allowed us to identify the following macro factors that affect the ES of energy supply systems of enterprises in Cameroon:

1. *The scale of the company's activities*. This factor determines the possibility of exclusively independent energy generation [2]. In the absence of this possibility, the company is forced to cooperate with other enterprises in the region, which significantly reduces the level of ES, due to the increment in the system of potentially uncontrolled subjects of management decision-making. The influence of this factor can be expressed by the following indicators:

1.1. *The Ratio of the company's annual revenue to the cost of implementing the project to build a DPSS*. This indicator reflects the ability to independently ensure the implementation of the project. The vector of impact on ES is positive. Reference designation is – $I_{1.1}$. The units of measurement are *percentages*.

1.2. *The Ratio of the average annual volume of working capital of the enterprise to the average annual cost of ensuring the operation of the proposed power supply system*. The mechanism of influence of this indicator is comparable to the previous one. Vector of impact on energy security is positive. Reference designation is – $I_{1.2}$. The units of measurement are *percentages*.

2. *The business sector of the company*. This factor primarily determines the possibility of independent production of fuel, which is the main energy carrier in the framework of the considered energy supply system of the enterprise [4]. Also, this factor reflects the specifics of energy consumption. The influence of this factor can be expressed by the following indicators:

2.1. *The Proportion of required fuel provided at the expense of productive activities*. This indicator reflects the ability to independently provide the power supply system with the necessary amount of energy. The vector of impact on ES is positive. Reference designation is – $I_{2.1}$. The units of measurement are *percentages*.

2.2. *The ratio of the energy intensity of the main production processes to auxiliary ones*. This indicator reflects the conditional risk of stopping production activities as a result of accidents and breakdowns of the proposed power supply system [4]. The decrease in this indicator determines the increment of the possibility of redistributing energy capacity and, as a result, ensuring the stability of the main production processes. The vector of impact on ES is negative. . Reference designation is – $I_{2.2}$. The units of measurement are *percentages*.

3. *Geographical location of the company*. Since Cameroon is geographically heterogeneous in terms of distribution of energy resources, as well as in terms of urbanization, the influence of this factor cannot be ignored [15]. The influence of this factor can be expressed by the following indicators:

3.1. *The average distance to energy resources*. This indicator determines the ability to meet the company's demand for raw materials needed for energy generation in a timely and sufficient manner. The vector of impact on ES is negative. Reference designation is – $I_{3.1}$. The unit of measurement is kilometers.

3.2. *Conditional transport availability of energy resources*. This indicator is an expert indicator and determines the labor intensity of delivery of raw materials needed for energy generation. The vector of impact on ES is positive. Reference designation is – $I_{3.2}$. Units of measurement are points.

4. *Climate influence*. This factor reflects the influence of climatic conditions in the region of operation of the enterprise on the process of generating energy in the power supply system. The influence of this factor can be expressed by the following indicators:

4.1. *Conditional index of the influence of the environment*. This indicator is expert and reflects the level of aggressiveness of the region's environment in relation to the energy generation process within the proposed energy supply system. The vector of impact on ES is negative. Reference designation is – $I_{4.1}$. Units of measurement are points.

5. *The status of the regional networks*. This factor reflects the stability of regional networks and the dependence of the enterprise on this conditional value [14]. The influence of this factor can be expressed by the following indicators:

5.1. *The Ratio of the time of power failure due to accidents to the calendar time for the previous year*. This indicator reflects the stability of the energy distribution system. The vector of impact on ES is negative. Reference designation is – $I_{5.1}$. The units of measurement are *percentages*.

5.2. *Wear coefficient of the regional energy distribution system*. This indicator reflects the projected period of increasing risk of reducing the stability of the energy distribution system. The vector of impact on ES is negative. Reference designation is – $I_{5.2}$. The units of measurement are *percentages*.

5.3. *Conditional index of the company's dependence on the regional energy distribution system*. This indicator is an expert indicator [12]. The vector of impact on ES is negative. Reference designation is – $I_{5.3}$. Units of measurement are points.

6. *Environmental legislation*. This factor is the most complex, and reflects the specifics of the legitimization of the project under study and the level of state support for the chosen method of energy generation. The influence of this factor can be expressed by the following indicators:

6.1. *Conditional index of regulatory voltage*. This indicator is expert and reflects the complexity of legitimizing the proposed energy supply system. The vector of impact on ES is negative. Reference designation is – $I_{6.1}$. Units of measurement are points.

The presented system of indicators is multidimensional, primarily from the point of view of the studied consequences [2]. The strength of the influence of the considered indicators on the possible result is expressed by the specific gravity which can be distributed evenly, at the primary level (Fig. 1).

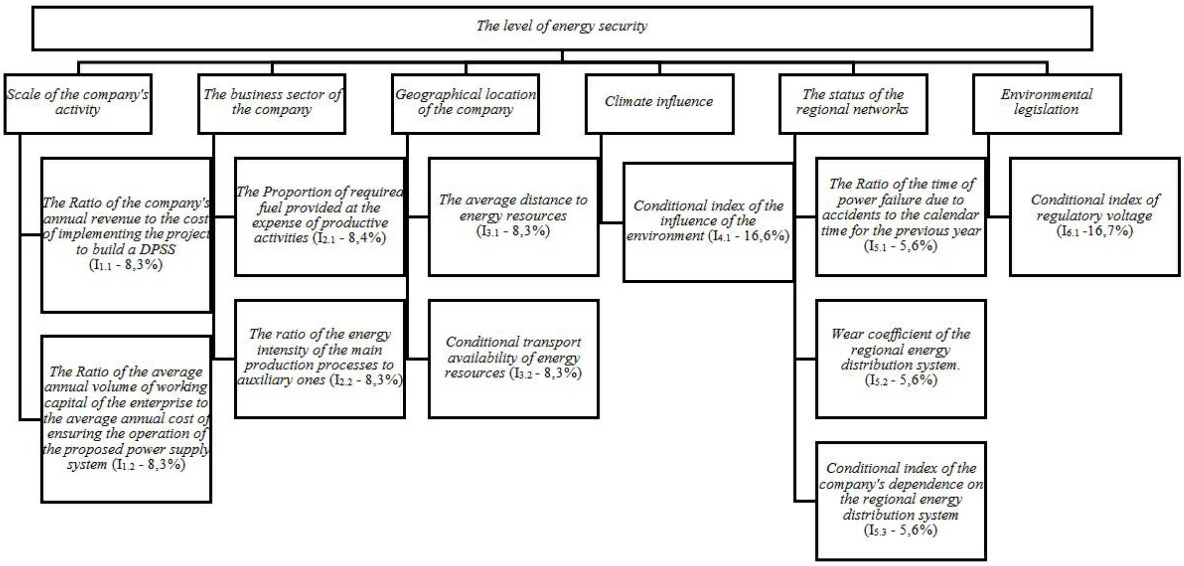

Figure 1. Distribution of specific weight of indicators

A weighted comparative assessment of the level of energy security cannot be made on the basis of classical tools. First of all, this is due to the need to use both statistical and expert indicators identified in the described system. At the same time, the complexity of the research object determines the need to allocate fuzzy evaluation intervals that allow describing the degree of confidence of the expert in the conclusions made. Therefore, one of the most suitable tool for assessing the level of energy security is the fuzzy multiple approach. This tool should be based on a system of expert assessments, however, in contrast to statistical and expert assessment tools; it makes it possible to take into account the level of uncertainty by using the functions of belonging ($\mu(x) \in [0;1]$) of a subset to a given set. The founder of applying the theory of fuzzy sets to describe economic processes is doctor of Economics Nedosekin A. O. In the framework of his doctoral dissertation "Methodological foundations of financial activity modeling using fuzzy multiple descriptions", the author offers an algorithm for evaluating a complex economic indicator using fuzzy set theory [1]. This algorithm is the basis for building a tool for assessing the level of ES.

Result of research

The algorithm of forming fuzzy multiple classifiers includes the definition of factors, identification of linguistic variables, the base term set, the definition of the carrier of linguistic variables, and the calculation of partial and integral indicators.

Within the framework of the tool, 1 integral linguistic variable is identified "the Level of the energy security criterion of the energy supply system (I)". The base term set for this criterion has 2 subsets:

1. Unacceptable level of ES of the power supply system;
2. Acceptable level of ES of the power supply system.

This integral indicator is the resulting indicator of the tool. For each particular indicator, a linguistic variable is also formed «the value of a particular indicator (In.n). The base term set for these indicators has 5 subsets each:

1. Unacceptable value for indicator;
2. Low indicator value;
3. Average value of the indicator;
4. High indicator value;
5. Indicative value of the indicator.

The standard five-level 01-classifier is selected as a classifier for particular indicators. In the classifier, the segment of the real axis [0;1] (01-the carrier) acts as the carrier of the linguistic variable. To describe the type of subsets of a term set, a system of five membership functions is introduced that characterize the degree to which a segment of carrier values belongs to a given subset (Table 1).

Table1. System of fuzzy-multiple classifiers of particular indicators

Indicator	T- numbers {Y} for values of a linguistic variable				
	Unacceptable value for indicator	Low indicator value	Average value of the indicator	High indicator value	Indicative value of the indicator
$I_{1.1}$	(0.4; 0.4; 0.6; 0.8)	(0.6; 0.8; 1; 1.2)	(1; 1.2; 1.4; 1.6)	(1.4; 1.6; 1.8; 2)	(1.8; 2; +∞; +∞)
$I_{1.2}$	(2.5; 2.5; 3; 3.5)	(3; 3.5; 4; 4.5)	(4; 4.5; 5; 5.5)	(5; 5.5; 6; 6.5)	(6; 6.5; +∞; +∞)
$I_{2.1}$	(0; 0; 10; 20)	(10; 20; 30; 40)	(30; 40; 50; 60)	(50; 60; 70; 80)	(70; 80; 80; 80)
$I_{2.2}$	(100; 100; 100; 80)	(100; 80; 70; 60)	(70; 60; 50; 40)	(50; 40; 30; 20)	(30; 20; 10; 10)
$I_{3.1}$	(300; 300; 300; 275)	(300; 275; 250; 225)	(250; 225; 200; 175)	(200; 175; 150; 125)	(150; 125; 100; 0)
$I_{3.2}$	(1; 1; 2; 3)	(2; 3; 4; 5)	(4; 5; 6; 7)	(6; 7; 8; 10)	(8; 10; 10; 10)
$I_{4.1}$	(10; 10; 10; 8)	(10; 8; 7; 6)	(7; 6; 5; 4)	(5; 4; 3; 2)	(3; 2; 1; 1)
$I_{5.1}$	(+∞; +∞; 20; 17)	(20; 17; 14; 11)	(14; 11; 8; 5)	(8; 5; 3; 1)	(3; 1; 0; 0)
$I_{5.2}$	(100; 100; 100; 80)	(100; 80; 70; 60)	(70; 60; 50; 40)	(50; 40; 30; 20)	(30; 20; 10; 10)
$I_{5.3}$	(10; 10; 10; 8)	(10; 8; 7; 6)	(7; 6; 5; 4)	(5; 4; 3; 2)	(3; 2; 1; 1)
$I_{6.1}$	(10; 10; 10; 8)	(10; 8; 7; 6)	(7; 6; 5; 4)	(5; 4; 3; 2)	(3; 2; 1; 1)

These classifiers can be represented as trapezoidal membership functions, where the ordinate axis indicates the values of membership functions (from 0 to 1), and on the axis of the abscissas – terms. In this case, the upper base of the trapezoid corresponds to the expert's absolute confidence in the reliability of the classification, and the lower base characterizes the confidence that no other values of the interval (0;1) do not fall into the selected fuzzy subset. The side faces of the trapezoid reflect the fluctuation of the expert's judgment about the belonging of a particular segment on 01 – carrier to a particular term. There are 5 nodal points: {0,1; 0,3; 0,5; 0,7; 0,9}. Based on the results of calculating each of the particular indicators, their values are recognized by the criterion $\lambda ij \in [0;1]$. This indicator correlates the values of individual indicators with the values of 01 – carriers:

$$\lambda_{ij} = 1 - \frac{X_i - a_3^*}{a_4^* - a_3^*}$$

where a_3^* and a_4^* are the t-numbers of the I-th subset of the term set.

Based on the results of recognizing the values of particular indicators, integral indicators are calculated:

$$I = \sum_{1}^{10} p_j \times r_j \times \lambda_{ij} .$$

Where p_j are the node points of the 01 carrier:

$$p_j = 0{,}9 - 0{,}2 \times (j - 1) .$$

Where j is the number of subsets of the base term set.

The resulting integral indicator is recognized in accordance with two selected term sets, the boundary value:

1. Unacceptable level of energy security of the power supply system – (0; 0; 0.4; 0.8).
2. Acceptable level of energy security of the power supply system – (0.4; 0.8; 1; 1).

If the project under consideration does not reach the acceptable level of energy security, regardless of the size of the potential economic effect, it is rejected. Fig. 2 shows a comprehensive assessment of the level of energy security of the decentralized power supply system for enterprises in Cameroon.

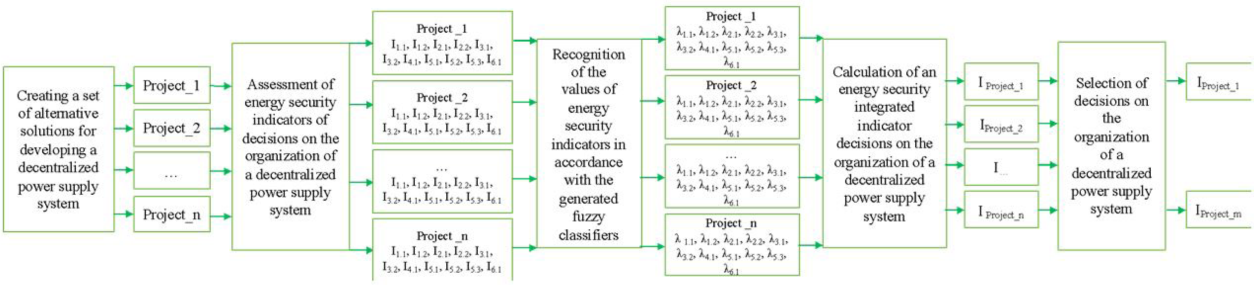

Figure 2. Tool of comprehensive assessment of the level of energy security of the decentralized power supply system (m < n)

Implementation of it will provide an additional tool for managing the development of the fuel and energy complex of the country as whole and individual regions with significant potential for using biofuels. Such an example can be the energy complex of Cameroon. The tool proposed by the author can be used to determine the energy supply management system and select the type of generating source from the point of view of providing a comprehensive solution to maximize energy security and minimize economic costs. The use of fuzzy set theory will increase the level of validity of the applied solutions.

Conclusions

The tasks solved in the framework of the study allow us to develop a system of economic management tools in energy systems. This tool can be widely used in the development of decentralized electricity supply for small and medium-sized businesses that are experiencing problems with the reliability of electricity supply. This will eventually create a more sustainable system for developing this sector of the economy. Perhaps a similar tool can be developed for the energy supply systems of enterprises in other countries.

The authors see the addition of the energy security criterion to the economic efficiency criterion as areas for further research. Consistent application of these criteria will allow for the final selection of the management decision based on the selected indicators of economic efficiency based on the assessment of the energy security indicator. A characteristic feature of determining the key economic indicator is the dependence on the energy supply system. In one case it can only be revenue, in the second case it can be profitability and revenue, and in the third case profit, revenue and profitability.

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