УДК 517.977 DOI: 10.26102/2310-6018/2020.28.1.031

Управление распределенными энергетическими системами на основе методов оптимизации и экспертных подходов

М.В. Питолин[1], Ю.П. Преображенский[2]
[1]*Воронежский институт МВД РФ, Воронеж, Российская Федерация*
[2]*Воронежский институт высоких технологий, Воронеж, Российская Федерация*

Аннотация: В настоящее время наблюдается развитие различных методов и подходов, связанных с управлением распределенными энергетическими системами. При их использовании требуется сбор большого количества информации. При использовании рейтинговых оценок функционирования энергетических систем возникает ряд проблем. В ходе управления ресурсоэффективностью распределенной энергетической системы существенным является вопрос о принятии рационального решения. При этом важна информация двух видов. Первый связан с формализованным решением задачи с использованием оптимизационного моделирования. Второй основан на экспертном оценивании соответствующих результатов. Такую информации следует объединять, поскольку выбор будет многокритериальным по ресурсному обеспечению. В такой задаче существует множество мониторируемых показателей эффективности работы распределенной энергетической системы. Решение задачи, которая связана одним критерием, большей частью, рассматривается как задача линейного программирования. При этом применяются непрерывные или целочисленные переменные. В данной работе показано, как формируется оценка эффективности распределенных энергетических систем. Разработана оптимизационная модель задачи и сформированы процедуры экспертной оценки управленческих решений. Результаты представленной работы полезны для управления сложными распределенными энергетическими системами.

Ключевые слова: распределенная энергетическая система, оптимизация, экспертная оценка, принятие решений, системный анализ.

Для цитирования: Питолин М.В., Преображенский Ю.П. Управление распределенными энергетическими системами на основе методов оптимизации и экспертных подходов. *Моделирование, оптимизация и информационные технологии*». 2020;8(1). Доступно по: https://moit.vivt.ru/wp-content/uploads/2020/02/PitolinPreobrazhenskiyUP_1_20_1.pdf DOI: 10.26102/2310-6018/2020.28.1.031

Management of distributed energy systems on the basis of optimization methods and expert approaches

M.V. Pitolin[1], Y.P. Preobrazhenskiy[2]
[1]*Voronezh Institute of the Ministry of Internal Affairs of the Russian Federation, Voronezh, Russian Federation*
[2]*Voronezh Institute of High Technologies, Voronezh, Russian Federation*

Abstract: Currently, there is a development of various methods and approaches related to the management of distributed energy systems. Using them requires the collection of a large amount of information. When using rating assessments of the functioning of energy systems, a number of problems arise. In managing the resource efficiency of a distributed energy system, the issue of making a rational decision based on the use of information from two sources is essential: a formalized solution to the problem using optimization modeling and expert evaluation of its results. The need to combine such information is determined by the nature of the multi-criteria choice of resource support in the case of taking into account the set of monitored performance indicators of the distributed energy system in this task. Moreover, in most cases, solving the resource efficiency problem by one criterion reduces to a linear programming problem with continuous or integer variables. This paper shows how the assessment of the effectiveness of distributed energy systems is formed. An optimization model of the problem is developed and procedures for the expert evaluation of managerial decisions are formed. The results of the presented work are useful for managing complex distributed energy systems.

Keywords: distributed energy system, optimization, expert assessment, decision making, system analysis.

For citation: Pitolin M.V., Preobrazhenskiy Y.P. Management of distributed energy systems on the basis of optimization methods and expert approaches. *Modeling, optimization and information technology*. 2020;8(1). Available by: https://moit.vivt.ru/wp-content/uploads/2020/02/PitolinPreobrazhenskiyUP_1_20_1.pdf DOI: 10.26102/2310-6018/2020.28.1.031 (In Russ.).

Introduction

Currently, one can observe the development of distributed energy systems. The rating is considered as an assessment of the analyzed energy systems within the framework of indicators. The rating is the opinion of experts, the assessment of the energy systems on base of quantitative and qualitative analyzes.

There are several approaches that provide opportunities for rating energy systems. Among them are the following: a method for creating a rating using a number of indicators, a cluster analysis method, a matrix analysis method, a score method, a comparative rating method [1, 2]. These methods are not universal. This necessitates an additional search for other approaches.

The paper proposes the development of an algorithm based on optimization and expert modeling, with the involvement of monitoring information.

Optimization-expert modeling in the problem manage resource efficiency on the basis of the monitoring information

When managing the resource efficiency of a distributed electrical system, the problem of making a rational decision is essential. In this case, information from two sources is used: a formalized solution of the problem using optimization modeling and expert evaluation of its results [3, 4].

The need for combining it is determined by the nature of the multicriteriality of the choice of resource support in the case of taking into account in this problem the set of monitored performance indicators of the distributed energy system [5, 6]. Moreover, in most cases, the solution of the problem of resource efficiency by one criterion is reduced to a linear programming problem. It will have continuous or integer variables. If researches will have monitoring information that will lead many indicators [7, 8], it is required to organize the search for the optimally compromise solution of the multicriteria optimization problem. The considered situation will lead to vector criterion.

$$F = \left(F_1, \ldots, F_s, \ldots, F_S\right) \to \max, \quad s = \overline{1, S} \tag{1}$$

The solution of (1) will have the effectiveness. The value of it will lead to the transformation. The operator will used $\Psi = \left(\Psi_1, \ldots, \Psi_s, \ldots, \Psi_S\right)$ on the base of criteria $F = \left(F_1, \ldots, F_S\right)$. Then we have equivalent vector criterion $\Psi(F) = \left(\Psi_1(F_1), \ldots, \Psi_S(F_S)\right)$. That is characterizes the same properties of the control object as F, and defines in the area of acceptable solutions $x = \left(x_1, \ldots, x_i, \ldots, x_I\right) \in \Omega$ the same ratio of non-strict preference O as and vector criterion F :

for any $x', x'' \in \Omega$ takes place $F(x')OF(x'')$ if and only if

$$\Psi(F(x'))O\Psi(F(x'')). \quad (2)$$

The case when the mathematical model of effective decision-making is given by the multi-criteria optimization problem (1). The researches have the particular optimality criteria $s=\overline{1,S}$. It will work for different used criteria, for many problems [9, 10]. The methodical approach for selecting the optimal compromise solution can be reduced to a sequence of the following two procedures:

- selection of the domain of Pareto $\overline{\Omega}$ optimal solutions(not necessarily explicitly), which also includes optimal solutions $x_i^*, i=\overline{1,I}$ obtained from the solution of parametric optimization problems for each of the particular optimality criteria $F_s, s=\overline{1,S}$;
- the introduction of a compromise agreement between the partial optimality criteria $F_s, s=\overline{1,S}$, which allows the search for an optimal compromise solution $x^0 \in \Omega$ using a specially constructed scalar generalized optimality criterion Φ as a function of the partial optimality criteria Φ(F)=Φ$(F_1,\dots,F_S)$, satisfying the condition [11]:

for any $F(x'), F(x'')$ we can see: $\Phi(F(x')) \le \Phi(F(x''))$ if and only if

$$F(x')OF(x'')$$

Thus, introducing the generalized optimality criterion $\Phi(F(x))$ on the basis of the compromise agreement, according to the condition (2), the search for the optimal compromise solution $x^0 \in D$ in the original multi-criteria optimization problem is reduced to the problem of parametric optimization of the following form

$$\min_{x\in\Omega} \Phi(F(x)).$$

In the case where the set $\overline{\Omega}$ consists of a single vector of weight coefficients, the convolution of the vector optimality criterion $F=(F_1,\dots,F_s)$ is reduced to a summation operation with known weight coefficients that implements the additive generalized optimality criterion:

$$\Phi(x)=\Phi(F(x)). \quad (3)$$

The generalized optimality criterion (4) can be used to collapse the vector optimality criterion F only if the partial optimality criteria $F_s, s=\overline{1,S}$ satisfy the following requirements [12]:

- particular optimality criteria $F_s, s=\overline{1,S}$ are commensurate in importance. The researches can assign positive number. The index will show the relative importance of the position in relation to other necessary criteria;
- criteria, that will demonstrate relative optimality $F_s, s=\overline{1,S}$. For them we have the characteristic of homogeneity.

For the generalized optimality criterion (3) is true. It will work for nonconvex domain of feasible solutions Ω. Moreover if we consider functions $F_s, s=\overline{1,S}$, for them we must to check:

- if necessary approach $x^0 \in \Omega$ we consider as effective, and for any $F_s(x^0)>0, s=\overline{1,S}$, What needs to be done next? We will use vector of weight coefficients. It characterized by the optimal solution. Optimization problem is achieved for the approach that will be effective $x^0 \in D$. But we must take into consideration that fixed values in vector with non-zero components ρ, will lead to the optimal result $x^0 \in D$.

Another form of generalized criterion can be represented. It based on optimality for homogeneous partial criteria using the average of the exponential function:

$$\Phi_p(x) = \Phi_p\left(F(x)\right) \tag{4}$$

For any modification of the average power generalized optimality criterion, i.e. for any $-\infty \leq p \leq \infty$ optimal solution of the parametric optimization problem

$$\Phi_p\left(x^0\right) = \min_{x\in\Omega} \Phi_p(x) = \min_{x\in\Omega}\left\{\left(\frac{1}{S}\sum_{s=1}^{S}\hat{F}_S(x)\right)^{1/p}\right\}, \tag{5}$$

it an optimal compromise solution $x^0 \in \Omega$.

Having accepted the agreement that particular optimality criteria are equivalent criteria, i.e. criteria between which it is impossible to establish priority by importance, thereby we set the same values of weight coefficients:

$$\lambda_s = 1/S \text{, for all } s = \overline{1,S}. \tag{6}$$

For unequal criteria, i. e. criteria for which priority can be established by importance, the values of the weight coefficients are chosen in accordance with their priority (a more "important" criterion should correspond to a greater value of the weight coefficient) so that the search for optimal compromise solutions with the help of parametric optimization is carried out (3). Let us consider a number of compromise agreements based on the information about the minimum Φ_s^{min} and maximum Φ_s^{max} values of particular optimality criteria in the field of acceptable solutions Ω, the values of partial criteria of optimality $F_s(x), s = S$ which are obtained by solving parametric optimization problems [13]. If we accept the agreement that the particular optimality criteria. Researchers say that the minimum and maximum F_s^{min}, F_s^{max} will be located in different parts of the rating scale. For calculating the weights, we can use according procedure. For every private criterion of optimality $F_s(x) > 0$ of the calculated coefficient of relative variation

$$\delta_s = \frac{(F_s^{max} - F_s^{max})}{F_s^{max}}. \tag{7}$$

which determines the maximum possible relative deviation according to the s-th partial criterion of optimality in the sphere of admissible solutions. Then we have additional problems. We have to calculate weight coefficients λ_s. It is necessary to consider the according criteria. They are connected with solutions D for the problem? that are most significant:

$$\lambda_s = \delta_s / \sum_{k=1}^{S}\delta_k, s = \overline{1,S}. \tag{8}$$

Then we combine two expressions (7) - (8). After the considering the problem we can demonstrate that more advisable the minimum value F_s^{min} than F_s^{max}. For the calculation we must use weight coefficient λ_s that is quite few. In $F_S(x) = const$ i.e., $F_s^{min} = F_s^{max}$ we get that $\lambda_S = 0$. With a strong difference in the limit values of S-th partial criterion $\left(F_s^{max} >> F_s^{min}\right)$, the value of the weight coefficient is chosen to be large, since in this case the relative spread coefficient δ_s is close to one. Let all $F_s^{\min} \neq 0, s = \overline{1,S}$. Then, instead of the coefficients of the relative spread δ_i , it is possible to introduce the coefficients of stability of the minimum value in the consideration [14]:

$$\beta_i(x) = \left(F_s(x) - F_s^{\min}\right) / F_s^{\min}, s = \overline{1,S} ,$$

which give information about the deviation of the value of S-th particular optimality criterion calculated in an admissible solution $x \in \Omega$ from its minimum possible value $F_s^{\min}$. For considering the problem the priority of S-th accordingly criterion is in the equation

$$\beta_s(x) \leq \varepsilon_s . \tag{9}$$

In this equation we choose ε_s is selected in some assumption. It is "better" S-th particular criterion. We consider the less select of its value. For the solution of the problem we will consider the compromise. It leads to the criteria of optimization, that we see in loss matrix C. The structure of it show several lines. In them we have optimal solutions. This solutions are bounded by some optimality criterion. And the considered problem is parametric. For columns in considered matrix we have ne necessary criteria for optimization task:

	F_1	F_2	…………..	F_s
x_1^*	0	c_{12}	……………	c_{1s}
x_2^*	c_{21}	0	……………	c_{2s}
.	.	.		.
.	.	.	……………	.
.	.	.		.
.	.			.
x_s^*	c_1	c_2	……………	0

(10)

When we calculate the optimal solution x_s^* we must have necessary criterion. It can be obtained as coefficient c_{dk}. And the index leads to the $k-$th accordingly criterion.

When we consider the criterion, we take into consideration that for diagonal $c_{kk} = 0$, and t $c_{dk} \geq 0$. For solution of the considered task the matrix (10) was considered. We think about it as matrix of payments. For different games we can see it. Two men have the situation with a zero sum. Then each party is reduced. During the consideration we can see that first man will lead to result x_s^* that is optimal. That is the first man have its own net strategy. But we can consider the situation from the point of view the second man. For it the solution of the problem show that we use $k-$th particular criterion of optimality F_s. So the second man have its own net strategy. And when we calculate the elements $c_{dk} \geq 0$, then the man that we consider as first player must transfer fin c_{dk} to the second man. What demotstrates this situation? First man have the better position. The losses are minimized when we use the optimal solution. It can be obtained for the according criteria QF_k, $k = \overline{1,S}$.

$$\min_{1 \leq l \leq s} \max_{1 \leq k \leq s} c_{lk} = \min_{1 \leq l \leq s} \max_{1 \leq k \leq s} \left| \frac{F_k - F_k\left(x_l^*\right)}{F_s^*} \right| .$$

When we consider this problem, the men show the agreement. It is based on according criteria for optimization. The illustration of the loss matrix (10) has features. We can not see saddle point in it structure. But we must solve the problem. Optimization for solution can be reached on the base of combination This combination have in strategy the first man: $\mu_l \geq 0, l = \overline{1,S}, \sum_{l=1}^{S} \mu_l = 1;$ and the second man: $\lambda_k \geq 0, k = \overline{1,S}, \sum_{k=1}^{S} \lambda_k = 1.$ So we must to calculate probabilities μ_l. Then they are will bigger for x_l^*. But this solution is correlates with small values in coefficients c_{lk}. During the solution of the problem we see for probabilities λ_k and the considered criteria F_k, another situation for c_{lk}. They will grow. For the optimization task in this paper we base o Churchman-Akof method. The main characteristic of it is that we have logical ordering. In the steps of the algorithm we must consider systematic check of the expert's judgments. For the correct solution of optimization problem they analyze relationship of preference $k-$ private criterion. It is calculated between another criteria $(F_{k1}, F_{k2},..., F_s)$.

1. Linear ordering of partial optimality criteria is carried out $F_k, k = \overline{1,S}$ in order of decreasing their importance by using the ordinal scale of natural numbers (index 1 is assigned to the particular criterion with the greatest importance, and index S - to a particular criterion with the least importance): F_1 F_2,..., F_s.

2. Partial criterion of optimality F_s score matching $\mu_s = 1$. Then, using a nonlinear scale of orders, assign different numbers to the estimates μ_i reflecting the expert's judgments about the relative importance $i-$ private criterion, observing the condition: $\mu_{i-1} > \mu_s$ $i = S, S-1,...,2.$

3. Considering columns one through ($S-2$) From top to bottom of Table 1, called the table of options for a logical choice, the expert fixes his judgments. The relationship is considered. It corerelates with the left (x) and right part of it. Then in this step of solution we make a replacement from sign V, to >. Then we come to the expression of inequality, that is x is strictly more respectable than y. In another situation we have sign <. Then the opposite happens, 0 more will be preferable. We can see the situation for sign ~ . We use such approach when x is equivalent to y. For considered variants, all of them we can see in the table of options. For example: x> y or x ~ y, can be shown in according column.

Table 1 – Table of options for logical choice
Таблица 1 – Таблица вариантов логического выбора

1		2		.	$(S-2)$	
x	y	x	y	.	x	Y
$F_1 v$		$F_2 v$	$F_3 + F_4 + \cdots + F_S$	.	$f_{S2} v$	$F_{S-1} + F_S$
$F_1 v$	$F_2 + F_3 + \cdots + F_{S-1}$	$F_2 v$	$F_3 + F_4 + \cdots + F_{S-1}$	.		
..	……………			.	….	…………
$F_1 v$	$F_2 + F_3$	$F_2 v$	$F_3 + F_4$	.	View finished	
Move to the second column		Move to the third column		.		

We can see ratio $F_k \vee F_{k-1} + F_{k-2} + \cdots F_S$. What does it mean? Expert prefer criterion F_k. The choose of it is strictly. It is This is true if we compare with other different options $(F_{k-1}, F_{k-2}, \ldots, F_S)$.

4. Then we use grades $\mu_i, i = \overline{1,S}$ that obtained in the second step. This values will used

in the consideration of logical choice. Further , we go to step 3. But the initial value will be $(S-2)$. So we have the cycle. The column in the corresponding matrix will be viewed from bottom to top. Finally, let us move from left to right and go to the right side. In this case, we must focus on the fulfillment of the conditions described below:

$$\mu(x) > \sum_s \mu_s(y), \text{if } x > y; \mu(x) > \sum_s \mu_s(y), \text{if } x < y;$$

$$\mu(x) > \sum_s \mu_s(y), \text{ if } x \sim y,$$

that the expert makes an inadequate decision in the course of his reasoning. Moreover, he focuses on the selection matrix associated with logical reasoning. During consideringt each subsequent relationship, we will go to the necessary μ_s' .

5. For refined values $\mu_s', s = \overline{1,S}$ we have the following situation. They are not connected to μ_s , obtained in the second step, calculate the weighting coefficients of the relative importance of the partial optimality criteria $F_3, i = \overline{1,s}$:

$$\lambda_s = \mu_i' / \sum_{k=1}^{S} \mu_k', s = \overline{1,s} .$$

Evaluation of expert procedure

The work of expert have the first step. It will form of the group. In this group we can see different people. For solving such task some researches show the snowball method. The procedure of the method assumes the known number of initial participants of the expert group. $P_0 -$ "Core expert group." Among them, a survey is conducted to identify their views on possible candidates for the expert group, then let each $d-$ the respondent calls $m_1(d)$ persons, among which $p_1(d) \notin P_0$. As a result of the first round of such a survey, we get: $P_1^0 = P_0 + \sum_{i=1}^{P_0} p_1(d) = P_0 + P_1,$ where $P_1 -$ the number of new individuals named in the first round. Then the process continues, revealing on each $k-$ step set: $P_k^0 = \sum_{j=0}^{k} \sum_{i=1}^{P_0} p_j(d).$

If taken as unknown $(D+1)-$ the number of all participants in the expert group, the number of persons called by each interviewed candidate, then for the case of complete uncertainty, when any m persons from D may be called a candidate (excluding himself), we are likely to be named L new faces based on combinatorial considerations:

$$P(L) = \frac{C_{D+1-P_0}^{L} C_{P_0-1}^{m-L}}{C_D^m},$$

where L varies from 0 before m . The resulting distribution is a hypergeometric, expectation of a random variable $p'-$ numbers of new faces:

$$M(P') = m(N+1-P_0)/D.$$

We equate the expectation of the sample mean: $M(P') \approx \frac{1}{P_0}, \sum_{d=1}^{P_0} \mu(d),$

where $\mu(d) = 1-$ if $d-$ candidate from P_0 calls the person not entering P_0 and 0- otherwise. Hence, an approximate estimate of the possible number of candidates:

$D^* = \dfrac{mP_0(P_0-1)}{mP_0 - \sum_{d=1}^{P_0}\mu(d)} + 1$. Based on the primary set of experts obtained, for example, using the snowball method, we can distinguish groups of non-conflicting experts, "clans" of experts. To determine the competence of experts, a “test” method can be applied or peer evaluations of experts can be used. The essence of the latter method is as follows: each expert fills in a matrix $A = \|a_{ij}\|$, each element of which is an integral assessment of competence $j-$ an expert with the help of $j-$ an expert. If the division of experts into groups ("clusters") is set $G_1,\ldots,G_q$, then, using the average value of competence assessments by groups as measures of the “conditional” competence of an expert, we have:

$$u_i = \frac{1}{n_s}\sum\nolimits_{i\in G_s} a_{ij},$$

where n_s- number of experts in the group G_s. Denote $\Delta_j^{(H)}-$ lower bound. It will be in the confidence interval for the mean u_j. If for given thresholds *a* and *b* it turns out $u_j < a, \Delta_j^{(H)} < b$ then $j-$ the expert is considered incompetent in the group G_s With $u_j \geq a$ и $\Delta_j^{(H)} \geq b$, the expert is considered competent in the group G_s This method allows you to leave in each "clan" sufficiently competent experts in the relevant field. Expert assessments are also applied, the use of which should take into account the fact that "if it is human nature to make mistakes, then first of all when trying to evaluate oneself." A measure of the consistency of expert assessments may be the coefficient of concordance:

$$W = \frac{\sum_{i=1}^{n}\Delta_i^2}{\left[\sum_{i=1}^{n}\Delta_i^2\right]_{\max}},$$

introduced by M. Kendall. As a quantity Δ_i^2 consider the difference of the sum of ranks σ_i attributed by experts $i-$ object, and the average value of such a sum σ_{CP} Number n determines the number of objects of expert ranking. Magnitude varies from 0 to 1. With $W=0$ There is no consistency between the assessments of various experts, and with $W=1$ the consistency of expert opinions is complete. There are other estimates of the consistency of expert estimates. So we have the group of experts. Then we go to the next step. We choose approach for group expert assessment. There some parts in it: organization of procedure for group expertise, processing the results of examinations, management decision making.

Formation of models of an integrated assessment of the performance of objects of distributed electrical systems in which we can see the monitoring information. We must have approach for integral assessment Y. How does it work? The researches use transformation of monitoring data. Then it is necessary to consider specific management objectives. At the end step the integral assessment model must be developed. The researches use structural identification method. The rationing indicators Y_s is considered.

To solve the first problem of the structural identification goal of management, it is advisable to assess the possibility of using variants of the model structure of the global target multicriteria optimization function, allowing to determine the optimal-compromise management solution (Table 2). Let us analyze the conformity of the models.

Table 2 – Illustration of structures for models of integral estimation
Таблица 2 – Иллюстрация структур для моделей интегральной оценки

Option designation	Identification of model	Types of models in mathematic
1	2	3
Struct. 1	Additive convolution with variable weights	$Y = \sum_{s=1}^{S} \lambda_s \hat{y}_s$, where $\hat{y}_s$ – normalized values of monitoring indicators, λ_s – weighting factors that meet the conditions $0 \le \lambda_s \le 1, \sum_s^S \lambda_s = 1$.
Struct. 2	Additive convolution with constant weights	$Y = \frac{1}{S} \sum \hat{y}_s$
Struct. 3	Average power convolution	$Y = \left(\frac{1}{S} \sum_{s=1}^{S} \hat{y}_s{}^u \right)^{1/u}$, where $-\infty < u \le \infty$
Struct. 4	Geometric mean convolution	$Y = \frac{1}{S} \left(\prod_{s=1}^{S} \hat{y}_s \right)$
Struct. 5	Multiplicative convolution	$Y = \prod_{s=1}^{S} \hat{y}_s$
Struct. 6	Logical convolution on the principle of "maximum risk"	$Y = \max_{1 \le s \le S} \hat{y}_s$
Struct. 7	Logical convolution according to the principle of "maximum caution"	$Y = \min_{1 \le s \le S} \hat{y}_s$

In Table 3 we can see the key objectives. They based of different management tasks. We can chose rationale way for the adequacy of options for the structures of the integral assessment model.

All considered models operate with normalized values of monitored indicators $\hat{y}_s$. The choice of the according method we use for structural identification. It will be for second step. Then we solve another problem. We study the effect of individual approaches. We must apply them correctly, depending on the observed situation and managing resource supply. The next step is related to the fact that an approach based on parametric optimization will be used. The weighting coefficients can be determined. For example, we have the situation of using the structure 1. It is according to the model. In the course of solving the next step of the analyzed problem, we need to select the appropriate characteristics in the model. Finally, we carry out the construction of models of interest: formed by ranking sequences; formed on principle of extreme values of the indicators during the consideration of statistical samples.

Table 3 – Illustration of adequacy for considered integral assessment structures
Таблица 3 – Иллюстрация адекватности для рассматриваемых интегральных структур оценки

Problem of management, and we use monitoring data	Main used management objective	Option structures models	The adequacy of the task and objectives of management
Information that we use	Increasing the importance of components of a distributed hydro system	Struct. 4 Struct. 5 Struct. 1	Reflects the according effect of the impact of achievements in one direction on other
Significance Management	Improving the efficiency of calculations in promising areas through rational optimisation	Struct. 3 Struct. 6 Struct. 7	Reflects the varying degrees of priority of achievements in individual areas.
Development Management	Achieving the necessary resource efficiency	Struct. 1 Struct. 2	Strengthens the importance of promising areas

Calculation of the potential of components in a distributed electrical system with using an integrated assessment

By using the shown above approach we can select basic models of integrated assessment. Then we consider the characteristics of integrated assessment of components of distributed electrical system. The work of it is analyzed from the point of view the effectiveness development during resource support. We based on combined technique. It includes monitoring information that treats in obtaining the necessary mode of distributed electrical system: excluding after-effects; with limited aftereffect; with prediction. In case of determining the potential of a distributed electrical system π_i statistical samples are used in the form without consequence y_{tsi} current time period τ^1. Magnitude π_i calculated on a given interval (O, P) using the integral estimation model. Along with models of rank sequences and additive convolution of indicators $y_{tsi}, i=\overline{1,I}, s=\overline{1,S}, t_s=\overline{1,T_S}$ considered the combined option. In this case, the most significant indicator is selected for each direction. $y_s, s=\overline{1,S}$ and calculated by approximating the rank sequences y_i continuous scale α with values on the interval $[A,O]$. We based on its normalizing with use of indicators $\hat{y}_{si} = \alpha\left(i_s^{/}\right)$. The next step is connected with calculation π_i. For it we use additive convolution $\pi_i = \sum_{s=1}^{S} \lambda_s \hat{y}_{si}$, here we use designation

λ_s – weights. Then we consider the option of limited aftereffect. For it we take into the consideration that monitoring information related to different periods. We consider time interval τ_2, and current time τ_1. Morover, it is necessary to calculate some indicators that we see from $s=\overline{1,S}$ directions

$$\tau_1 - s^{\tau_1} = \overline{1.S^{\tau_1}}, \tau_2 - s^{\tau_2} = \overline{1.S^{\tau_2}}.$$

During the consideration of sets we can calculate $\pi_i^{\tau_1}$, or

$$\pi_i^{\tau_1\tau_2} = \lambda^{\tau_1}\pi_i^{\tau_1} + \lambda^{\tau_2}\pi_i^{\tau_2}, \quad (11)$$

here we have some designations for weights $\lambda^{\tau_1}, \lambda^{\tau_2}$. By these values we can determine the priorities of time intervals. It will demonstrate in assessing the positive move of the considered organization. The technique of calculating positive move of a distributed energy system for according characteristics is use the set of statistical values y_{ts} [15]. We have the variant when the prediction is carried out. In this step we must have numerical characteristics. In them i – demonstrates sampling (for the value $m(y_{si})$, that we expect. Also, if we use the statistical approach we need standard deviation $\sigma(y_{si})$. By calculation of it the indicator y_s can be calculated $i=\overline{1,I}$ $\sigma(y_s)$:

$$\pi_i = \sum_{s=1}^{S} \lambda_s (y_{si} - m(y_{si})) \frac{\sigma(y_{si})}{\sigma(y_s)}. \quad (12)$$

For the step where we use monitoring information it is necessary to consider several time periods $k=\overline{1,K}$. So it leads to the combination of the values $y_{si}(\tau_k), s=\overline{1,S}$. In practice we have the situation when it is possible to calculate prognostic value of positive move. This is characterized by the half years before the consideration of the analyzed time is begun.

For the solving of the problem it is necessary to use the integral estimation model (11). In such variant we must normalize the values of the considered indicators:

$$\hat{y}_{si}(\tau_k) = \begin{cases} \dfrac{y_{si}(\tau_k) - y_s^{gr}}{y_s^{max}(\tau_k) - y_s^{gr}} & if\ y_s(\tau_k) > y_s^{gr}; \\ 0, otherwise. \end{cases}$$

here y_s^{gr} – is considered the designation as prediction for indicator y_s;

$y_s^{\max}(\tau_k)$– show the extreme indicator for the case when we choose $y_{si}, i=\overline{1,I}$ in k period of the time

For calculation of prognostic values, we must use the base definition (11). It depend on the differentiation of each indicator $\hat{y}_{si}$: $\pi_i(\tau_k) = \sum_{s=1}^{S} \lambda_s \hat{y}_{si}(\tau_k)$. For this class of social systems – time series of individual indicators $\hat{y}_{si}(\tau_k)$ possess certain properties: monotony and gradual change over time. These properties are determined by the inertia of educational systems. During the consideration, these time series are heterogeneous. How does it work? We can see it from the differ in the rate of change of indicators $\hat{y}_{si}(\tau_k)$. We consider the characteristics for functions and the need for their changes. During such analysis we proposed to build a prognostic estimate. We construct it in the form of a sum of polynomials of various degrees $v=\overline{0,V}$, where the value of the degree of a polynomial: $\pi_i(\tau_k) = \sum_{s=1}^{S} \lambda_s \sum_{v=0}^{V} \gamma_{v_s} \delta_{v_s} Y_{v_s}(\tau_k)$, where $Y_{v_s}(\tau_k)$– time functions $\left(Y_0(\tau)=1, Y_1(\tau)=\tau, Y_2(\tau)=\tau^2,..., Y_v(\tau)=\tau^v\right)$; γ_{v_s} – participation factors $Y_v(\tau)$ in a mathematical time series model $\hat{y}_{si}(\tau_k)$ and determined by expert,

$$\gamma_{v_s} = \begin{cases} 1, \text{ if function } Y_{v_s} \text{ includes a time series model } Y_{v_s}(\tau_k), \\ 0, \text{ otherwise ;} \end{cases}$$

δ_{v_s} – are designated as coefficients, that constructed by the exponential smoothing technique. During calculation we use the values of the time series $\hat{y}_{si}(\tau_k)$ for time periods from 1 to k. On the next step the forecast value for the time period $k+k_1$ is defined as follows $\pi_i\left(\tau_{k+k_1}\right)=\sum_{s=1}^{S}\lambda_s\sum_{v=0}^{V}\gamma_{v_s}\delta_{v_s}Y_{v_s}\left(\tau_{k+k_1}\right)$. The combination technique to assessing the potential allows determining the criterion for the distribution of resources. It have some differences from the previously proposed in [11, 12]. We have to two components: the potential of the distributed energy system based on the monitoring results and the corresponding GHS using expressions (11) and (12).

Results

To select the structure of the criteria for making management decisions on the establishment of parameter values, a comparative analysis of the capabilities of several models of integrated assessment of the efficiency of distributed energy systems is carried out. As alternative structures of the model (Table 1) consider the additive convolution variable (structure 1) and permanent (structure 2) weighting factors, and alternative ways of rationing is based on rating order in the ranking order of the translated discrete scale $i_s^{/} = \overline{1, I_s^{/}}$, where $s=\overline{1,S}$ – the performance of system components y_s, $y_s^{/}$ - the rating of *i*-th component of the *s*-th indicator and by conversion in a dimensionless form a single continuous scale [A,O]. Comparative analysis is carried out by means of a computational experiment. The following key indicators *s*=(1,3) were considered (1): y_1-energy characteristics (average power); y_2-research activities (income from research and development activities per employee); y_3-infrastructure (total area of premises per employee). Comparison of rating $i^{/}$ and expert rating $i^{//}$ by value (determined that its highest value corresponds to the model 2, so in the future it is advisable to use such a model mainly to assess the potential of distributed energy systems.

Conclusion

The paper presents optimization and expert modeling for the problem related to the management of resource efficiency of distributed energy systems based on monitoring information. The results of the calculation based on the developed algorithm are presented.

ЛИТЕРАТУРА

1. Jamil F. On the Electricity Shortage, Price and Electricity Theft Nexus. *Energy Policy*. 2013;54:267-72.
2. Con Edison (ConEd). 2013. «Demand Management Incentives». http://www.coned.com/energyefficiency/demand_ management_incentives.asp.
3. Energy Storage Association (ESA). Community Energy Storage. 2014. http://energystorage.org/energy-storage/ technology-applications/community-energy-

storage.
4. Wood E. Princeton University's Microgrid: How to Partner, Not Part from the Grid. 2014. Microgrid Knowledge. http://microgridknowledge.com/princeton-universitys-microgrid-partner-part-central-grid/.
5. Groefsema H., van Beest N.R.T.P. Design-time compliance of service compositions in dynamic service environments. *Int. Conf. on Service Oriented Computing & Applications. 2*015:108-115.
6. Groefsema H.: Business Process Variability: A Study into Process Management and Verification. PhD thesis. 2016.
7. Object Management Group. Business Process Model and Notation, version 2.0. http://www.omg.org/spec/BPMN/2.0/, last accessed 2019/02/10.
8. Weber I., Xu X., Riveret R., Governatori G., Ponomarev A. Mendling J. Untrusted Business Process Monitoring and Execution Using Blockchain. *BPM 2016, LNCS 9850*. 2016:329-347.
9. Bertone G., Deisenroth M. P., Kim J. S., Liem S., de Austri R. R. Welling M.. Accel-erating the BSM Interpretation of LHC Data with Machine Learning. arXiv preprint arXiv:2016;1611.02704.
10. Albert S. Lutakamale, Shubi Kaijage. Wildfire Monitoring and Detection System Using Wireless Sensor Network: A Case Study of Tanzania. Wireless Sensor Network. 2017;9:274-289.
11. Odu G.O., Charles-Owaba O.E. «Review of Multi-criteria Optimization Methods – Theory and Applications». *IOSR Journal of Engineering (IOSRJEN)*. 2013;3:1-14.
12. Sorokin S.O. Optimization modeling of the functioning of the system of homogeneous objects in a multidimensional digital environment. *Modeling, optimization and information technologies*. 2018;6(3):153-164. Доступно по: https://moit.vivt.ru/wp-content/uploads/2018/09/Issue_3(22)_2018.pdf.
13. Orlova D.E. Stability of solutions in ensuring the functioning of organizational and technical systems. *Modeling, optimization and information technologies.* 2018;6(1):325-336. Доступно по: http://moit.vivt.ru/wp-content/uploads/2018/01/Orlova_1_2_18.pdf.
14. Pekka Neittaanmki, Sergey, Repin and Tero Tuovinen (Eds.). Mathematical Modeling and Optimization of Complex Structures; Series: Computational Methods in Applied Sciences. *Springer International Publishing AG.* Switzerland. 2016.
15. Rios L.M. and Sahinidis N.V. Derivative-free optimization: a review of algorithms and comparison of software implementations. *Journal of Global Optimization*. 2013;54:1247-1293.

ИНФОРМАЦИЯ ОБ АВТОРЕ / INFORMATIONS ABOUT AUTHORS

Питолин Михаил Владимирович, кандидат технических наук, доцент, Воронежский институт МВД РФ, Воронеж, Российская Федерация.
e-mail: pmv_m@mail.ru

Mikhail V. Pitolin, Candidate of Technical Sciences, Associate Professor, Voronezh Institute of the Ministry of Internal Affairs of the Russian Federation, Voronezh, Russian Federation.

Преображенский Юрий Петрович, кандидат технических наук, профессор, Воронежский институт высоких технологий, Воронеж, Российская Федерация.
e-mail: petrovich@vivt.ru

Yury P. Preobrazhensky, Candidate of Technical Sciences, Professor, Voronezh Institute of High Technologies, Voronezh, Russian Federation.