Boiko, Olha; Shendryk, Vira; Parfenenko, Yuliia et al.

Article

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Reference: Boiko, Olha/Shendryk, Vira et. al. (2021). Development of expert assessment methods in planning energy supply of buildings with renewable energy sources. In: Technology audit and production reserves 2 (2/58), S. 51 - 54. http://journals.uran.ua/tarp/article/download/230230/229733. doi:10.15587/2706-5448.2021.230230.

UDC 519.812.3:519.816
DOI: 10.15587/2706-5448.2021.230230
Article type «Reports on Research Projects»

Olha Boiko,
Vira Shendryk,
Yuliia Parfenenko,
Petro Pavlenko,
Yevhen Kholiavka

DEVELOPMENT OF EXPERT ASSESSMENT METHODS IN PLANNING ENERGY SUPPLY OF BUILDINGS WITH RENEWABLE ENERGY SOURCES

The object of research is the process of expert evaluation in planning the energy supply of buildings using renewable energy sources. The conducted research is based on the application of system analysis methods to formalize the process of expert evaluation in the planning of an energy system with renewable energy sources. Here were used methods of expert evaluation of characteristics of qualitative criteria, methods of the theory of fuzzy sets and fuzzy logic for the formation of the value of criteria, and methods of estimating the reliability of the expert evaluation. Methods of structural analysis and functional modelling of information systems are used to build structural and functional models of the expert evaluation process. The issue of creating an appropriate information system for planning a power system with renewable energy sources is considered. One of the components of the information system is the unit for evaluating candidate experts. A six-level algorithm of the hierarchical structure of expert selection is proposed. As a result of the algorithm, an expert group is formed. This paper shows the process of narrowing the circle of experts from twenty to three candidates. The list of criteria influencing the choice of experts is formed: length of service, availability of the certificate, the efficiency of decision-making, education. The process of assessing the stability of experts' opinions is shown. It is proposed to use the method of processing the opinions of experts to find the value of the membership functions of qualitative criteria. As a result of the study, a group of three experts was formed, whose opinions are taken into account when choosing alternatives to the energy system. In accordance with the proposed information technology of energy supply planning of buildings using renewable energy sources, an information system in the form of a web-oriented application is proposed. A separate part of the information system is a subsystem for working with experts. The diagram of sequence of actions of the expert and the interface of work with system is developed. The use of the information system allowed to increase the efficiency of questionnaires of experts and decision-making on the choice of the optimal structure of the power system as a whole.

Keywords: *information support for decision-making, hybrid energy system with renewable energy sources, expert evaluation.*

Received date: 23.12.2020
Accepted date: 29.01.2021
Published date: 30.04.2021

How to cite
Boiko, O., Shendryk, V., Parfenenko, Y., Pavlenko, P., Kholiavka, Y. (2021). Development of expert assessment methods in planning energy supply of buildings with renewable energy sources. Technology Audit and Production Reserves, 2 (2 (58)), 51–54. doi: http://doi.org/10.15587/2706-5448.2021.230230

1. Introduction

In the context of a lack of traditional energy sources and an excess of demand for energy resources over supply, the construction of distributed energy systems with renewable energy sources (RES) becomes urgent [1]. Methodological approaches to modeling power systems are studied in works [2, 3]. The problems of energy efficiency of energy systems with renewable energy sources are considered in works [4, 5]. The problems of information support for decision making (ISDM) when planning energy systems with renewable sources are considered in works [6, 7].

When planning energy systems for the maintenance of buildings using RES, it is advisable to develop and use ISDM based on the assessment of alternative combinations of RES. Evaluation can be based on quantitative and qualitative criteria. When determining the quality criteria, it is possible to involve the knowledge of experts. In this case, the tasks of forming an expert group and the development of information support for evaluating alternatives by experts arise.

So, *the object of research* is the process of expert assessment in planning the energy supply of buildings using renewable energy sources.

The aim of research is to develop a methodology for the formation of an expert group and conduct an expert assessment of the qualitative criteria for choosing alternative options for renewable energy sources when planning the energy supply of buildings and its implementation in an information decision support system.

ISSN 2664-9969

2. Methods of research

ISDM for planning the structure of an energy system (ES) with renewable energy sources is provided by using a set of models [8, 9]: collection and processing of information, formation of a set of evaluation criteria, synthesis of alternative ES structures, selection of the optimal ES structure. To determine the optimal configuration of the ES, it is proposed to use the method of expert assessment of alternative options.

The peer review process for planning the ES structure is shown in Fig. 1 in BPMN notation. An expert assessment is proposed to be involved at the stage of assessing alternative ES options with various combinations of renewable energy sources. In general, the assessment of alternative configurations of the ES is carried out according to five qualitative and three quantitative criteria. Quantitative criteria are calculated when calculating technical and economic characteristics: ES construction costs, an indicator of surplus generated energy, an indicator of the likelihood of power loss. The quality criteria include the noise from the installation, the cost of repair and maintenance, the aesthetic appearance of the installation, the influence of the characteristics of the site on the production of electricity [8]. Each criterion is defined as a fuzzy dependence on certain parameters [9], which must be evaluated by experts.

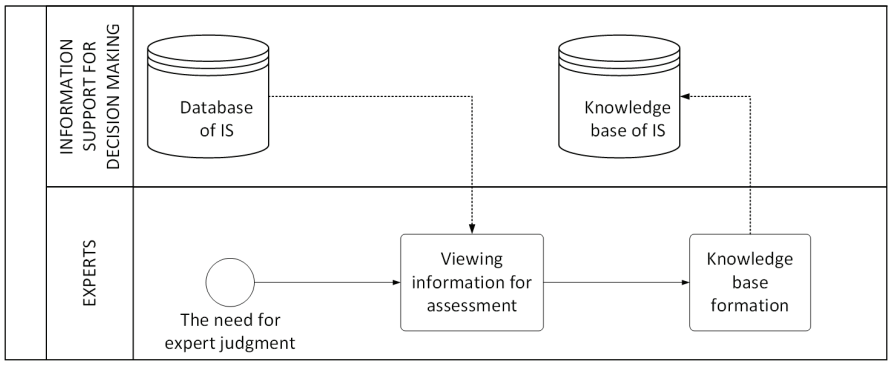

Fig. 1. The process of peer review in planning energy system structures

To calculate the qualitative criteria, it was decided to apply the theory of fuzzy sets and represent them through linguistic variables, as well as to use the method of processing expert opinions to find the value of membership functions [10]:

$$\mu_{L_h}(u_b)=\frac{1}{K}\sum_{k=1}^{K} b_{h,b}^{k}, \qquad (1)$$

where K – total number of experts; $b_{h,b}^{k}$ – opinion of the expert k about whether the element u_b has the properties of a set $b_{h,b}^{k}\in\{0,1\}$. Expert assessments should be binary, that is, describe whether the properties of a fuzzy set are present when determining a quality criterion.

Among the existing methods of conducting expert assessments [11], the one that most satisfies the stated requirement was chosen. Its essence lies in the fact that experts quantify each of the alternatives. The overall score is determined based on the assessments of experts. For example, for the criterion «Influence of the characteristics of the site on the production of electrical energy», experts must assess the parameters that define the terrain and shade of the ES construction site [9].

2.1. Expert group selection method. To implement the selection of a professional group of experts who will conduct the assessment, an algorithm for the hierarchical structure of expert selection is proposed (Fig. 2).

The algorithm consists of the following steps:
– first level – selection of experts for assessment;
– second level – selection of experts for the working group;
– third level – formation of criteria influencing the choice of experts;
– fourth level – selection of expert candidates for the working group;
– fifth level – assessment by criteria that affect the rating of expert candidates;
– sixth level – formation of an expert group of n specialists.

The criteria influencing the choice of experts include work experience in the direction, education, the availability of a certificate in the direction of research and the timeliness of decision-making.

The process of evaluating experts begins with the receipt of a request for consent to be included in the expert group by the candidate. The invitation is sent to the postal address of persons who are specialists in the field of ES design. After giving consent to be included in the list of candidates as experts, the specialist receives a questionnaire of professional qualities.

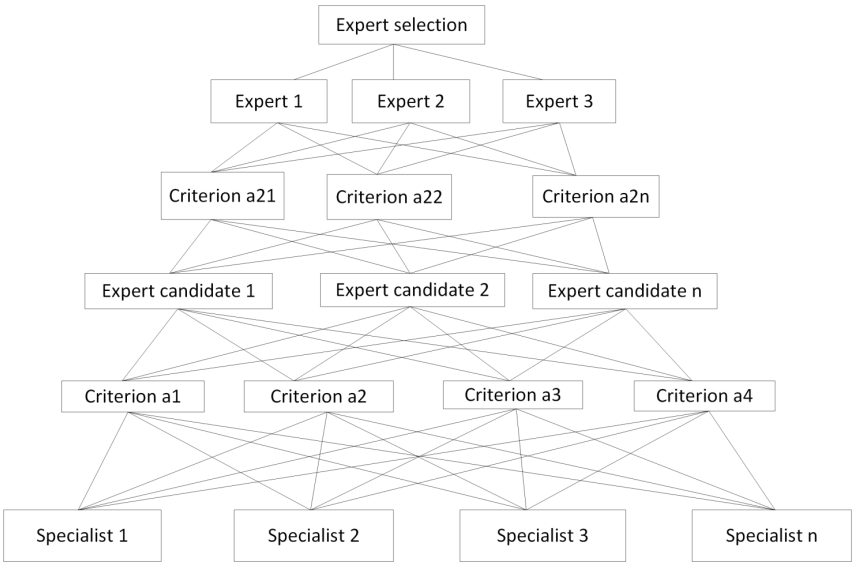

Fig. 2. Hierarchical structure for the selection of experts

According to the algorithm proposed above, the information system selects 10 experts who will be considered as candidates for inclusion in the expert group. At the next stage, candidates receive a confirmation letter and data for authorization in the system. Selected candidates conduct an initial assessment of the alternatives against qualitative criteria. After a specified period of time, the candidates for experts re-evaluate the alternatives according to the same criteria in order to determine the stability of their judgments. The calculation of the indicator of stability of experts' judgments is carried out using the paired comparison method, which is presented in [12]:

$$k_{ui} = \frac{(K_{ij})_H - (K_{ij})_n}{n(m-1)\cdot m}, \quad (2)$$

where $(K_{ij})_H$ – quantitative value of the advantage of the j-th object according to the judgments of the i-th expert as a result of the initial examination; $(K_{ij})_n$ – quantitative value of the advantage of the j-th object according to the judgments of the i-th expert as a result of repeated expert assessment, respectively; n – quantitative value of the selected expert candidates; m – quantitative value of the objects of examination. The formation of an expert group from candidates is carried out according to the results of ranking expert candidates according to the value k_u – a comprehensive assessment of the significance of the j-th expert's judgment.

The result of the application of the proposed method is the formation of an expert group of three people, which will deal with the tasks of assessing the criteria for influencing the choice of alternative ES options for renewable energy sources.

3. Research results and discussion

The process of conducting an expert assessment of qualitative criteria for choosing alternative renewable energy sources is presented using a sequence diagram (Fig. 3).

The expert begins the work on confirming the request from the system administrator. The next step is to register in the expert assessment subsystem through the web interface, go to the main page and authorize. The expert is invited to fill out the criteria evaluation forms on the web page of the expert evaluation subsystem. The data entered by the expert is stored in the database.

An example of the page for entering expert information is presented in Fig. 4, *a*. The entered data through the system interface are entered into the database according to Fig. 1.

On their basis, the values of the qualitative criteria are calculated (formula (1)) and according to the model for determining the optimal ES configuration [8], the final result becomes available to the user through the interface in Fig. 4, *b*.

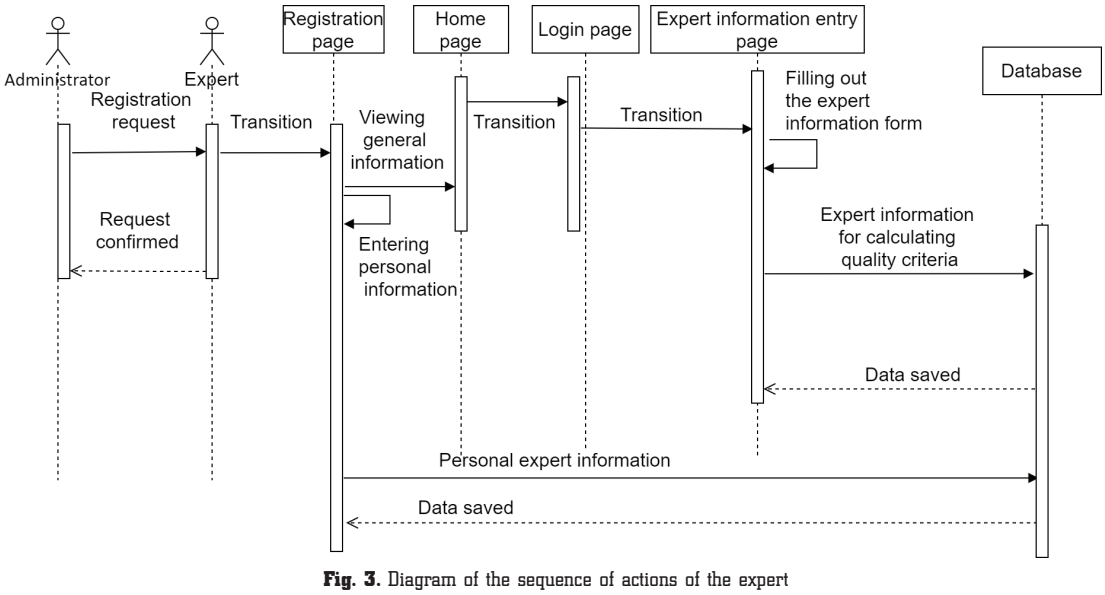

Fig. 3. Diagram of the sequence of actions of the expert

a *b*

Fig. 4. An example of an information system interface:
a – page for entering criteria characteristics by experts; *b* – page for presenting the results of the information system

ISSN 2664-9969

4. Conclusions

To assess alternative solutions for choosing the optimal structure of the energy system when conducting an expert assessment, a method for forming an expert group is proposed. A list of criteria influencing the choice of experts has been formed, as a result of the analysis by the self-assessment method, a rating of experts and an expert group are formed. An assessment of the stability of experts opinions was carried out using the method of pairwise comparison, which made it possible to create software tools to reduce risks when assessing alternative options for the power system.

The proposed method was tested on the example of forming a group of three experts to assess the qualitative criteria that affect the choice of ES components for renewable energy sources. The software implementation of the proposed method is a subsystem for conducting an expert assessment with a web interface, which is an integral part of the planning information system of the ES structure for renewable energy sources. The introduction of the peer review subsystem made it possible to increase the efficiency of decision-making when choosing the optimal ES structure.

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Olha Boiko, *PhD, Department of Computer Science, Sumy State University, Sumy, Ukraine, ORCID: https://orcid.org/0000-0001-8557-2267, e-mail: o.boiko@cs.sumdu.edu.ua*

Vira Shendryk, *PhD, Associate Professor, Department of Computer Science, Sumy State University, Sumy, Ukraine, ORCID: https://orcid.org/0000-0001-8325-3115, e-mail: v.shendryk@cs.sumdu.edu.ua*

Yuliia Parfenenko, *PhD, Associate Professor, Department of Computer Science, Sumy State University, Sumy, Ukraine, ORCID: https://orcid.org/0000-0003-4377-5132, e-mail: yuliya_p@cs.sumdu.edu.ua*

Petr Pavlenko, *Doctor of Technical Sciences, Professor, Department of Mechanics, National Aviation University, Kyiv, Ukraine, ORCID: https://orcid.org/0000-0002-2581-230X, e-mail: petrpav@ukr.net*

Yevhen Kholiavka, *Department of Computer Science, Sumy State University, Sumy, Ukraine, ORCID: https://orcid.org/0000-0002-9841-7909, e-mail: e.p.kholiavka@gmail.com*