

Choosing of the FEC critical objects in model researches of energy security problems and its features

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Abstract. The overall objective of the proposed work is to formulate the main provisions of the approach to the determination of critical objects for the fuel and energy complex within the framework of hierarchical system studies of the energy security problems for the country and its regions. This approach involves the use of a hierarchical system of models, presupposes a preliminary choice of critical objects for energy systems. The approach is focused on the analysis and evaluation of interrelated systems functioning when implementing threats to energy security (in the form of contingencies), requires the accounting for changes in the work of critical objects for industries. To assess the criticality of these objects for the energy complex as a whole, a criterion is proposed for the significance of objects by the most important model indicators.

1 The features of the critical objects choosing in energy security problems researches

Energy security (ES) of the country and its regions is essentially a balance of supply and demand for energy resources [1]. The main content of research tasks to ensure energy security in fact reduced to:

- forecasting the conditions for the functioning and development of energy systems (SE) and the fuel and energy complex as a whole in case of emergency situations caused by ES threats;
- assessment of the energy systems condition in these conditions, the selection of possible directions and measures to prevent or reduce the negative impact of contingencies, taking into account specialized safety measures (reserves and storage).

The most important component of these studies is the identification of energy objects critical to the industries (CO of SE) or FEC (CO of FEC), determination the degree of their criticality in the context of the situations studying. The critical objects are most vulnerable objects, whose disruption of work can cause significant failures in reliable satisfaction of needs [2].

The critical objects is determined within the framework of studies (sectorial or general energy) scenarios for implementing contingencies and possible compensatory measures aimed at adjusting the performance of energy facilities, or on their restructuring. In the case of an abnormal situation, the task of selecting objects whose performance may decrease the efficiency of the system as a whole is solved. When introducing compensatory measures,

objects are determined, despite the inoperability of which, the state of the system as a whole is able to improve. If these objects are classified as critical, they can be deprived of this status. The abnormal situations can be classified into object and territorial, technogenic and functional (by type of disturbance), point and group (by the number of objects of application of disturbances). Compensatory measures, technogenic or functional, can also be applied to individual objects or to their groups.

Energy systems and the fuel and energy complex as complex technical infrastructures in the search for COs can be viewed from three positions. Energy systems in research can be analyzed from the structural and functional point of view, the FEC - from the functional and taking into account the factor of ensuring ES, which is possible only in the case of an analysis of the interrelated work of energy systems. Structural aspect, is connected with the situations of system restructuring, functional aspect is connected with changes in the production characteristics of the objects. The factor of ensuring ES, in turn, is respected with respect to the modeled variants in general.

Accordingly, the following criteria can be used as the selection criteria of the CO:

- structural indicators characterizing changes in the efficiency of the systems functioning as a whole in modeled situations in comparison with their normal mode of operation;
- functional indicators that characterize the effectiveness of the participation of facilities in covering the total demand for energy resources;

- indicators of energy security, whose threshold values can become a criterion for determining the admissibility of modeled situations in terms of energy security providing.

In this case, there is a factor of consistency of the CO (Figure 1) in the sense that the industry CO in the case of determining its criticality for the FEC as a whole

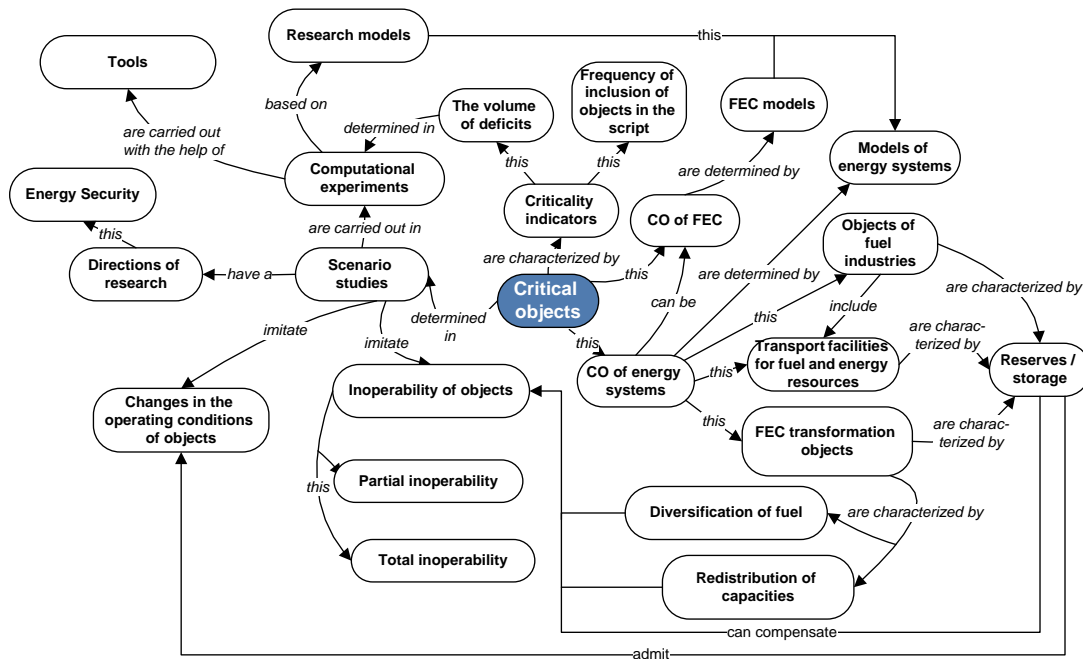


Fig. 1 -. Scheme for the coordination of the selection of CO in energy security researches

can be selected as the COs of the FEC. The possibility of such a choice can be justified by the fact of interconnected work of the branch systems that are the basis of the whole energy system, within the fuel and energy sector. The necessity of proving such a choice is explained by the structural redundancy within the FEC in the form of:

- fuel reserves (coal, gas, fuel oil, diesel fuel);
- volumes of fuel and energy interchangeability among consumers;
- the interchangeability of energy resources in the electric power industry (both by distributing loads between power stations operating on different energy resources, and by changing fuel consumption in dual-fuel power plants);
- reserves of capacity and productivity at the production and transport facilities of coal, gas, fuel oil, electricity and heat;

- reserves (stocks) of gas and oil pipelines throughput. Such a coherence of the multilevel COs gives the right to assert that:

the importance of the same CO for the industry and for the fuel and energy complex can be different, since the branch CO has a more technological (structural) character, the CO of FEC have more system and functional character;

- a list of branch COs can be considered as potential elements of the fuel and energy COs, can be used for calculated conditions in scenario researches of ES;
- the list of the COs of the fuel and energy complex can be more optimal (rational) in quantity and quality in comparison with the list of branch COs.

All this justifies the task of selecting the CO of the fuel and energy complex on the basis of branch COs (regardless of the type of energy systems), the ideology of this task is reflected in Fig. 2.

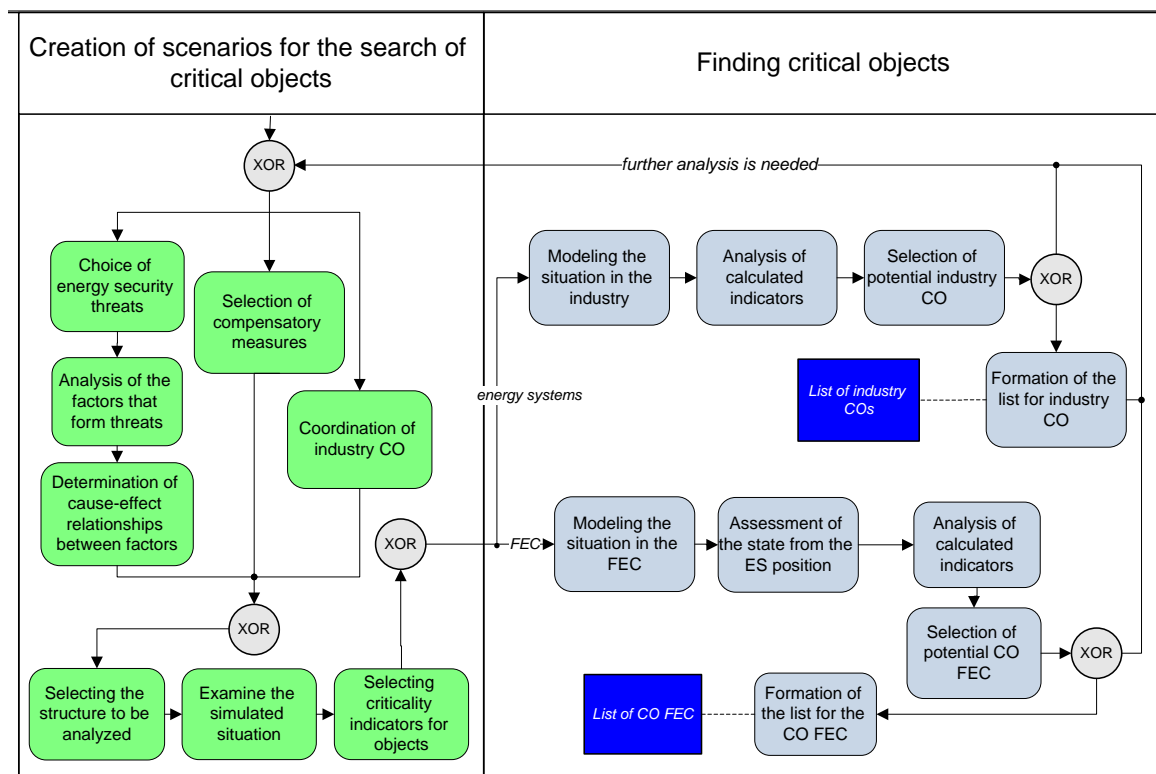


Fig. 2 - The ideology of the selection of the CO for the fuel and energy complex on the basis of branch COs

2 Methodical approach to the determination of critical objects for FEC on the basis of critical objects for industry

An approach is proposed for obtaining the CO of the fuel and energy complex on the basis of a pre-formed set of branch COs, taking into account the requirements of the ES. This approach is focused on the use of diurnal models of fuel and energy complex functioning. At the same time, the list of Cos of energy systems may not coincide with the list of fuel and energy complex objects depending on the degree of structural detailing of sectorial models and the degree of aggregation of objects in the fuel and energy complex models. This is a feature of the implementation of the proposed approach.

Wherein:

1. The CO of the FEC can become:

- either directly by the sectorial COs in the case of proving their significance for the fuel and energy complex as a whole, provided that the degree of detail of the objects at the sectorial and complex level is identical;
- or aggregated fuel and energy complex objects, including dedicated sectorial CO, also under condition that this object is significant for the functioning of the fuel and energy complex as a whole.

2. The choice of the CO of the fuel and energy complex should be carried out on the basis of the permissible from the standpoint of energy security positions. Only in this way is it possible to take into account the requirements of the ES. It is provided by modeling contingencies caused by ES threats, as well

as through the use of ES indicators to evaluate and select the calculated conditions of the fuel and energy complex. At the same time, the assessment should be made on a large scale at the level of the country, which is mainly due to the need to obtain a single complex assessment of the state, regardless of the strategy of the analysis (states can be assessed by one indicator, step by step, or by a generalized integral indicator). For the evaluation of the ES level, the following indicators can be used [3]:

- share of the dominant type of fuel in the structure of the consumed boiler fuel;
- the ratio of the volume of shortage of energy resources in the country as a whole to the total demand for them;
- the ratio of the daily total reserves of boiler-furnace fuel at the beginning of the heating period to daily consumption;
- in case of realization of the threat of cooling, an indicator of the level of potential provision of consumers under the conditions of growing demand for energy resources.

3. The assessment of the importance of sectorial COs for the fuel and energy sector as a whole should be based on a system indicator that characterizes the contribution of the sectorial CO to the relative assessment of states according to one model indicator. In the case of the analysis of states over a set of model indicators, a convolution of the numerical values of the set of system indices formed in this case should be provided. Model indicators should be relative at the same time, be considered at the country level. It can be considered:

- shortage of energy resources (deficits);

- the level of the storages using;
- the level of production capacity using in the fuel and energy complex.

4. The selection of CO for the FEC from the list of pre-assessed by the above-mentioned indicator of sectorial COs should be made by experts taking into account the specifics of the tasks to be performed.

Thus, the actual analyzed element in the selection of the COs of the fuel and energy complex is the calculated states of the fuel and energy complex, in the formation of which changes are made in the characteristics of the functioning of the objects. In this case, the search for the CO includes the following steps. First, using the ES indicators, a set of FEC states is defined. Then, the significancy of the selected FEC states is determined by the relatively model parameters taking into account the priority of the sectorial systems. Further, on the basis of the obtained state estimates, the importance of sectorial COs for the fuel and energy complex as a whole is determined using a special system indicator. This indicator characterizes the relative importance of a particular CO for a particular model parameter. The coefficient of significance for the i^{th} object is determined from the j^{th} index by the following formula

$$ZO_i^j = \frac{\sum_{k=1}^n ZS_k^j}{\sum_{l=1}^m ZS_l^j} \quad (1)$$

$j = \overline{1, p}$, where

ZO_i^j – the importance of the i^{th} object on the j^{th} indicator,

ZS_k^j – estimations of states with inclusion of the i^{th} object on the j^{th} indicator,

ZS_l^j – estimates of all states with respect to the j^{th} indicator,

n – the number of states evaluated with respect to the j^{th} state with the inclusion of the i^{th} object;

m – the total number of states, estimated by the j^{th} index,

p – number of analyzed indicators.

A generalized scheme for searching critical objects for the fuel and energy sector within the framework of the proposed approach is shown in Fig. 3.

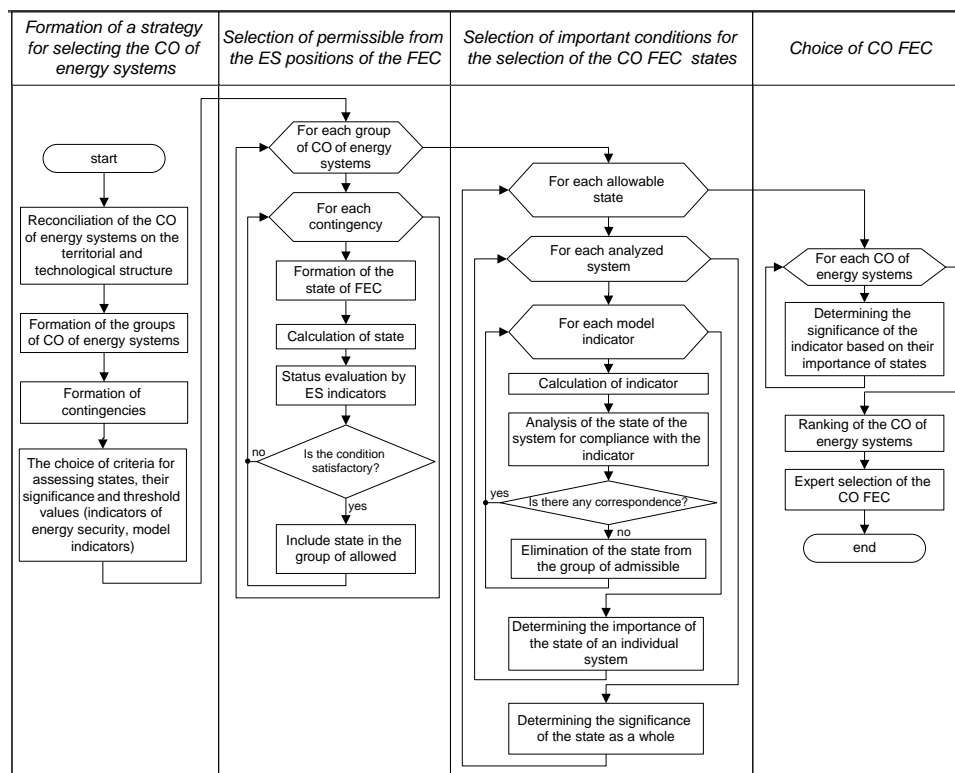


Fig. 3 - Scheme of selection of the COs of the fuel and energy complex on the basis of sectorial COs.

It identifies four main stages of the selection of the CO of the fuel and energy complex on the basis of sectorial COs:

1. The stage of forming a strategy for selecting the CO of the fuel and energy complex, within the framework of which at the expert level:
 - the technological and territorial level of representation of sectorial COs in the modeled

territorial-production structure of the fuel and energy complex is coordinated;

- groups of coordinated COs of energy systems are formed for their subsequent inclusion in modeled situations;
- analyzable threats of energy security are selected, for them non-standard situations are formed;

- a set of criteria for assessing the states (indicators of ES, relative model indicators) is formed, the significance of the criteria, their threshold values is determined.

2. The stage of permissible from the ES positions of the fuel and energy complex states selection, at which for each group of industrial objects in the conditions of realization of emergency situations, possible states of the fuel and energy complex are formed and calculated. These states are analyzed for compliance with the level of the country's EBS in general with the help of previously selected ES indicators.

3. The stage of significant FEC states selection, consisting in the evaluation of previously selected states for each analyzed relative model index.

4. Stage of the CO formation for the fuel and energy complex, which includes an assessment of the significance for the facilities based on the analyzed model indicators, the subsequent expert selection of the sectorial COs, which are important for the fuel and energy complex.

Detailing of the work on the selection of the COs of the fuel and energy sector on the basis of sectorial COs in the framework of the model calculations of the fuel and energy complex is considered in the next section of the article.

3 Technique of fuel and energy complex functioning models application in the selection of the COs for FEC

Complex scenario calculations in determining the CO of the fuel and energy complex within the framework of the proposed approach should be based on the territorial-production models of the fuel and energy complex functioning. These models include the main industry blocks that imitate the interrelated work of industry objects in varying degrees of territorial and technological detail. In the temporal aspect, as applied to the task of selecting the COs of the fuel and energy complex, they are oriented to the daily cut, since, in the case of more significant time intervals, the consequences of the failure of the operation of the sectorial facilities for the fuel and energy complex are generally leveled.

Technically conducted on the models the experiments are traditionally represented by the processes of data preparation and verification, by the procedures for the formation and calculation of various options for the operation of the fuel and energy complex, by the analysis of calculated situations, possibly using by the additional calculated indicators. At the same time, the starting point in the studies is the annual balanced version of the model, on the basis of which daily variants are subsequently formed (the average daily variant and diurnal variants with perturbations). Such a chain of work with model variants is justified by the composition and level of

presentation of statistical and analytical industry information, especially with regard to external supply of energy resources, the relative ease of balancing the annual indicators. Correction coefficients used for obtaining daily variants are either formed by experts from the specifics of the situations analyzed, or are calculated by presence of the monthly reports from industry companies.

With regard to the task of selecting the COs taking into account the factor of ES providing, three types of diurnal versions of the model must be consistently formed: the average daily balanced version, the maximum version of the load of energy facilities, and the options for implementing contingencies with maximum utilization of industrial objects. In the latter two cases, when deficits arise, activation of model mechanisms for reserving and diversifying energy resources is required. In case of formation of variants with contingencies, additional accounting of changes in the work of groups of critical industrial objects is necessary, which allows to determine the criticality of these facilities for the fuel and energy complex as a whole in conditions of ensuring the requirements of the ES.

The conceptual scheme of working with models of fuel and energy complex functioning in the selection of the COs of the fuel and energy complex within the framework of the main stages of the proposed approach is shown in Fig. 4.

The details important for this scheme, debugging the basic annual version of the model, are represented by the following sequence.

1. Debugging of the electricity and heat block, including preparation of data on stations (or their groups) and boiler houses (or their groups), namely:

- conversion of data on fuel consumption;
- definition of technological characteristics of equipment of stations and boiler-houses (their capacities, volumes of heat and electricity supply on separate types of fuel);
- balance control of the release of converted resources and fuel consumption (verification of specific fuel consumption) within stations and boiler houses;
- adjustment of external electricity flows;
 - balance heat control in entities, electricity in the country as a whole.

2. Debugging of the fuel supply block, including:

- determination of mandatory fuel demand for the territories based on the total and energy needs of the regions;
- if necessary, the breakdown of the compulsory fuel demand by entities for specific categories (for example, for the needs of the population and industry)
- possible correction of the data in the event of a lack of balance on fuel consumption in the subjects;
- correction of external supplies of fuel;
- analysis of transmission capacities of transport subsystems for fuel.

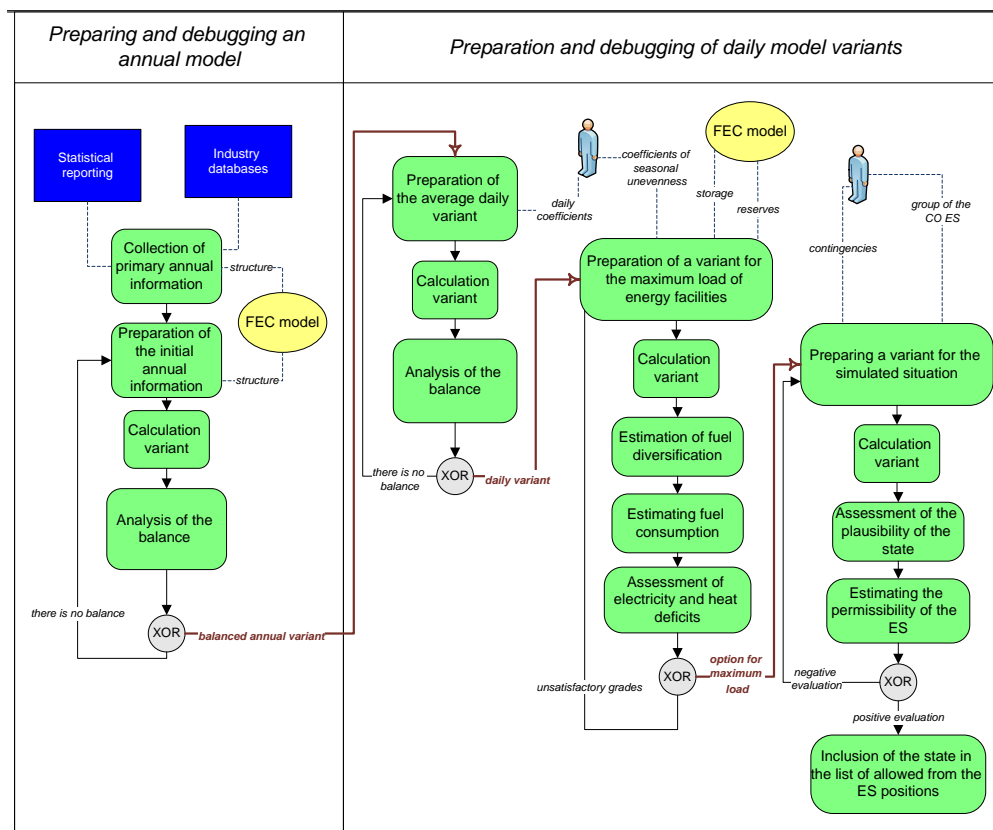


Fig. 4 - The scheme of work with models of functioning of fuel and energy complex at a choice COs for FEC on the basis of industrial COs

3. The balance estimate for all types of resources without taking into account their stocks.

4. Carrying out model calculations, during which should be analyzing:

- correctness of the initial information;
- "locked-in" energy resources, determination the causes of their occurrence;
- fuel deficits in the areas associated with functional insufficiency of transport subsystems, or with imbalance of own production capacities and needs in case of isolation of the territory;
- deficits of final types of energy resources, the reasons for their occurrence (non delivery of primary fuel and energy resources, technological insufficiency of transportation facilities);
- the degree of occupancy of production facilities in the fuel and energy complex.

This analysis is carried out in stages for each of the industries. The results of this analysis are the annual version of the model, balanced for all types of energy resources.

4 Conclusion

The paper outlines the features of the selection of critical facilities in the fuel and energy complex on the basis of the list of the COs of energy systems in researches of the ES problems. The methodological provisions for determining the COs of the fuel and energy complex have been developed, and the criteria for their selection have been presented. The scheme of

the coordinated selection of the COs is justified, the indicators and the scheme for determining their significance with the use of models for the functioning of the fuel and energy complex are proposed. In the future, it is planned to carry out experimental calculations on the proposed methodological provisions for the formation of the list of COs for FEC.

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