Information system for decision-making support with resources allocation between geographically remote objects within a production association

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Abstract. In this article, we discuss the issues of creating an information system for decision-making support for the task of resources rationing at geographically remote objects within a production association. The article contains the problem statement and the algorithm for solving the problem of redistributing quotas for production resources between separate remote objects (structural divisions) of a production association, settlement of payments between them, which allow reducing total costs for the entire association.

1. Introduction
Currently, Russia is on the threshold of a new stage of transformation. The country has accumulated serious economic problems related to both strict centralization and administrative monopoly during preceding decades and to the actual progress of reforms. Variety and complexity of economic changes make it necessary to identify the most effective forms and methods of state regulation. Promotion of competition and antitrust regulations are extremely important for Russian economy and mechanisms for regulating competitive relations are gradually becoming one of the priorities in economic reforms [1-3].

Conducting competition and antitrust policies against big corporations should be based on theoretical knowledge and methodological approaches to industrial organizations. Any economic entity is characterized by the desire for monopolistic power and expansion of its market share, therefore, acquisition and strengthening of market power is accompanied by establishing control over the factors that determine the activity of an Enterprise or a production association. For the sake of preserving the market power and controlling the market situation, actions that restrict competition can be performed, which significantly distorts the action of market forces, leads to irrational distribution of public resources, and negatively affects economic activities of all market participants and, as a result, economic well-being of the society. Excessive concentration of economic power can become a threat
to independent decision-making. Thus, it contradicts with the foundations of democratic structure of
the society.

Development of competition rules and regulation of competitive relations in the society are carried
out based on the principles developed by the antitrust policy. Transition to a market-based system of
relations is an integral part of the antitrust policy, which is currently considered as one of the priority
tasks for development of the Russian economy.

In this regard, we propose an approach that allows regulating the relationship between individual
remote objects (structural units) of a production association in terms of resources allocation. Its
relevance is due to the fact that the present situation does not allow to fully receive economic benefits
(no penalties for timely delivery of resources, the possibility of rapid reallocation of resources to other
market participants) for all structural divisions. At the same time, one of the main reasons is that all
economic operations are carried out with mandatory participation of the parent company, which does
not allow to fully use all the advantages of the market economy (free commodity-money relations,
rational use of material and labor resources, motivation to increase labor productivity) and hinders
development of the entire production association [4-6].

In this paper, the proposed approach to resources distribution for geographically remote objects
within a production association is considered on the example of electricity distribution.

Today, the situation is as follows: a parent company makes a request for energy consumption,
indicating planned volume of electricity consumption for each hour. Then, every hour, the difference
between the actual consumption and the declared consumption is calculated, and a fine is charged for
the difference between these indicators. An additional penalty is imposed for exceeding a 5%
difference between these indicators.

The way out of this situation can be such an option when contracts will be directly signed between
generating companies (suppliers) and electricity consumers. Such market conditions will allow
mutually beneficial agreements, which will cause a decrease in penalties paid for deviation of actual
electricity consumption from declared volumes [7-9].

The purpose of this work is to develop a mathematical and information support system for decision
support in order to regulate the relationship between individual remote objects (structural units) of a
production association - consumers of electricity.

2. Problem statement

One of the possible solutions to the problem of regulating the interaction between the subjects of the
electricity market is to implement a possibility of signing bilateral agreements between them, which
will reduce overall costs by generating profits under the terms of such agreements.

We will formalize the task of redistributing electricity consumption quotas between separate
divisions of a production association. The diagram of material and information flows on the scale of a
wholesale regional electricity market is shown in figure 1.

Let the region consist of $N$ Enterprises (structural divisions), each of which consumes the following
amount of electricity: $Q_i(t), \ i = 1, N$; where $Q_i(t)$ - functional dependence of electricity volume
for the $i$-th Enterprise, $i = 1, N, \ t = 0,24$ hours.

The following values of quotas for electricity consumption are set for each Enterprise $Q_{lim}^i(t)$,
which are formed based on the requests of the Enterprises and the capacity of the generator.

The task of electricity reallocation is formulated as follows: it is required to reallocate electricity
quotas in such a way that the cost of purchasing the necessary amounts of electric for individual
market participants in the interests of the entire region has a minimum value.
Figure 1. Scheme of material and information flows on the wholesale market scale (ASCME - automated system for control and management of electricity).

In a formalized form, the problem statement is to find the minimum of the target function:

$$F_{opt} = \min \sum_{j} \sum_{k} s_{jk} \cdot \tilde{Q}_{jk},$$  \hspace{1cm} (1)

subject to the following constraints:

$$\sum_{t=1}^{N_1} Q_j(t) \leq Q_{gen},$$ \hspace{1cm} (2)

$$\sum_{k} \tilde{Q}_{jk} = \tilde{Q}_j, \quad j = 1, N_1,$$ \hspace{1cm} (3)

$$\sum_{j} \tilde{Q}_{jk} = \tilde{Q}_k, \quad k = 1, N_2,$$ \hspace{1cm} (4)

The reserves of quota sellers have, as well as the amount of electricity to be purchased by Enterprises, are determined by the formulas:

$$\tilde{Q}_j = \sum_{t=0}^{24} Q_j(t) - Q_{j}^{lim}(t), \quad j = 1, N_1;$$ \hspace{1cm} (5)

$$\tilde{Q}_k = \sum_{t=0}^{24} Q_k(t) - Q_{k}^{lim}(t), \quad k = 1, N_2.$$ \hspace{1cm} (6)

Here: $s_{jk}$ - contractual cost of transferring the rights to consume one kilowatt of electricity by the $j$-th entity to the entity under the number $k$; $N_1$ - number of entities that have reserves for selling of unspent electricity balances (potential sellers); $N_2$ - number of subjects who want to purchase electricity consumption rights from sellers (potential buyers), $N_1 + N_2 = N$; $\tilde{Q}_{jk}$ - the number of megawatts that the $k$-th entity can additionally consume by purchasing the consumption rights from the $j$-th entity; $Q_j$ - the amount of electricity that the $j$-th entity can transfer; $Q_{gen}$ - the amount of electricity generated for the production association.
If actual amount of electricity consumed by individual entities during the day exceeds the capacity of quota sellers, these entities will be penalized with a fine for exceeding this amount of electricity.

In this setting, the task of redistributing electricity consumption quotas between the subjects of the region (1) – (6) is similar to the task that is known in the literature as the transportation problem [2]. It belongs to the class of linear programming problems and the simplex method is used to solve it. Based on the characteristics of relationships between sellers and consumers, the problem is solved once an hour or 24 times a day.

In order to obtain the most reliable information about electricity demands at each Enterprise, we have proposed an information and logic model (ILM) for decision-making support, which allows each consumer to form a request and determine the required amount of electricity based on the characteristics of Enterprise’s operation. This may take into account equipment load at different times of the day, seasonal temperature fluctuations, market value of energy resources and availability of qualified personnel.

In general, an ILM for decision-making support for determining the volume of electricity ordered by each consumer is a combination of sets of data and relationships between them in the form of rules. A separate production rule contained in the knowledge base consists of two parts: the antecedent and the consequent. An antecedent is a rule premise (conditional part) and consists of elementary sentences connected by logical strings “and”, “or”. A consequent (result) includes one or more sentences that express either a certain fact or an indication of a certain action to be performed [10-12].

Thus, an IML can be represented by the following tuple

\[ M = (d_1, \ldots, d_i, \ldots, d_N, p_1, \ldots, p_j, \ldots, p_S) \]  

In turn, the rules included in the model are built as follows:

if ... (conditions are met), then ... (implementation of a consequence), in a formalized form, is described as follows:

\[ p^r : \text{if } \left( d_1 \cdots d_i \cdots d_N \right) \left( A_1 \cdots A_i \cdots A_N \left( d_1 \cdots d_i \cdots d_N \right) \right) \text{ then } \left( d_1 \cdots d_i \cdots d_N \right), \]  

where \( M \) - ILM operator; \( d_1, \ldots, d_N \) - set of ILM data; \( p_1, \ldots, p_S \) - set of rules; if - designation of “if” condition; then - designation of “then” consequence; \( A_1, A_i \in \{ =, >, \geq, <, \leq, \neq, - \} \), \( i = 1, n \) - arithmetic operator; \( Z = \{ z_1, \ldots, z_n \} \) - logical operator; \( d_1, \ldots, d_N \) - model's input and output data correspondingly; \( Z^k = \{ z_1^k, \ldots, z_n^k \} \) - multiple values of an antecedent \( d_i \); \( z_i^k \in \{ z_1^k, \ldots, z_n^k \} \) - value of a consequent \( d_i \); \( n \) - number of conditions; \( \kappa \) - rule index.

A specific type of ILM (7) – (8) is determined based on specific features of technological processes for producing target products at each Enterprise.

3. Software implementation of the approach
To solve the problem of regulating the relations between the Enterprises (structural divisions of the production association) - market participants, the authors have developed the relevant software, where Visual Basic programming environment is used as the basic software environment.

To store information, a relational data representation model was chosen, which is a set of hardware and software tools designed for creating, maintaining and using databases and is implemented using the Microsoft Access DBMS (Database Management System).

The following information is stored in the database: generator’s capacity; values of distributed and redistributed amounts of electricity at the Enterprises, the cost of purchased / sold quotas, etc.

The software environment of the CLIPS (Language Integrated Production System) expert system is used to implement the the ILM. CLIPS includes a full-fledged object-oriented COOL language (Classroom Object-Oriented Language) for expert systems [3].
4. Results and discussion

The developed software was tested on the example of test data from individual industrial Enterprises that form the production association. Market participants include 10 companies: JSC "Tambov plant "Revtrud", JSC "Tambov plant "October", JSC "Plant " Tambovapparat", etc.

| Table 1. Results of test calculations for redistribution of electricity consumption quotas. |

|                  | Enterprise 1 (JSC "Tambov plant Revtrud") | Enterprise 2 (JSC "Tambov plant October") | Enterprise 3 (JSC "Plant Tambovapparat") |
|------------------|--------------------------------------------|--------------------------------------------|-------------------------------------------|
|                  | Clock                                      | Clock                                      | Clock                                     |
|                  | 1  | 2  | 3  | 1  | 2  | 3  | 1  | 2  | 3  |
| Application, MW/h| 170| 1810| 168| 54 | 49 | 51 | 87 | 80 | 83 |
| The fact is, MW/h | 172| 185 | 165| 50 | 50 | 51 | 84 | 79 | 85 |
| Number of resources for receiving /transmitting, W/h | -2 | -4 | 3 | 4 | -1 | 0 | 3 | 1 | -2 |
| Penalties for deviations from the request, Rub | 654 | 1309 | 982 | 1309 | 327 | 160 | 982 | 327 | 654 |
| Contract price, Rub/MWh | 322 | 325 | 324 | 322 | 325 | 324 | 322 | 325 | 324 |
| Number of resources after redistribution, MW/h | 0 | -4 | 0 | 2 | 0 | 0 | 3 | 0 | 0 |
| Amount of profit / loss after redistribution, Rub | 0 | 1300 | 165 | 644 | 0 | 0 | 966 | 0 | 0 |
| The initial amount of the fines, Rub | 2947 | 1797 | 1964 |
| Total amount of fines, Rub | 1465 | 644 | 966 |

As a result of solving the problem of electricity quotas redistribution for each Enterprise, information about the size of purchased / sold quotas, their cost, and the size of penalties for exceeding the allowed amounts is provided in graphical and tabular form. Table 1 contains the results of test calculation for the JSC "Tambov plant "Revtrud".

At various times, a plant can buy or sell a certain amount of electricity. During the period under consideration, the JSC (Joint-stock company) "Tambov plant "Revtrud" is subject to a fine for deviation from the declared volume. It can be seen from the calculation results presented in table 1 that the company would have been fined for 2947.14 rubles before distributing its resources and for 1465.24 rubles after redistribution. For other Enterprises (Enterprise 2 and Enterprise 3), we see (table 1) similar results in reducing fines: 1797.755 - 644 for Enterprise 2 and 1964.76 - 966 for Enterprise 3. These numbers, representing results from the Enterprises 3 confirm the efficiency of using resources within the production Association.

As a result of solving the problem for a certain period of time, each company is issued a report on the actual volumes of electricity consumption and costs for mutual settlements with other companies for purchasing / selling of electricity.
Conclusion

In this paper, the authors formulated the problem of redistributing the quotas for production resources between separate remote objects (structural divisions) with a production association, proposed an algorithm for its solution, as well as implementation of mutual settlements between them, which allows reducing the overall costs in the interests of the entire association.

Thus, the approach proposed by the authors makes it possible to normalize electricity consumption on the scale of the production association, which fully meets the needs of individual market participants, as well as regulate their relationships within the framework of current legislation of the country.

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