

On goal setting in the sphere of Smart Grid

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Abstract: The article focuses on the synthesis of intelligent control systems for the development of power grid complexes. The system approach to designing is formulated, allowing justification of the target function of the project.

1. Introduction

For a long time in Russia, there was an industrial type of power supply for consumers of electrical energy. Power plants were built near large industries, and cities were connected to power supply systems on a residual basis. Simultaneous growth of energy needs from residents and non-residential municipal consumers and its reduction in large-scale industries compels to reconsider the approach to managing the efficiency of electrical systems and complexes (ESCs). In the world practice, modernization of power supply systems to the level of Smart Grid is performed to solve the problem of increasing the efficiency of the balance of generation, transmission and consumption of electrical energy. In this work, Smart Grid is considered as part of the Smart-City system.

2. Research

Management of the efficiency of electrical systems and complexes (ESCs) is aimed largely at improving the quality of life of the population and, therefore, directly related to the problem of sustainable development of cities where the bulk of the population is concentrated. This by default means that in modern terms the innovative development of Smart Grid ESCs falls directly within the scope of Smart-City.

The solution of this class of tasks for large and complex systems (such as Smart-City and Smart Grid) is, first, associated with correct goal setting. There are different conceptual models when developing large-scale urban projects. Their principal difference lies in the question of what is meant by the effectiveness of the system. Today, we can note at least four different approaches to goal setting:

- the goal is a sustainable development of the city (when the rate of development of negative processes is less than that of positive ones) [1-3];
- the goal is a sustainable innovation development (when the efficiency of the system has a positive derivative and grows due to innovations) [4];
- the goal is to maximize the vector performance evaluation in conditions of regulated individual key indicators [5-6];
- the goal is to minimize the risk of failure to meet assumed responsibilities [7-10].

The goal setting refers to the standard procedures in the tasks of managing technological and administrative processes, however, the logic of setting the goal is not always justified. This is usually



associated with either the complexity of the process being serviced or simply with the reluctance to thoroughly understand its specifics, and urban management in this sense is no exception. The article attempts to eliminate the existing gap at least partially.

Solution. Managing complex processes is usually done in the form of a pyramid, the upper level of which declares the challenges caused by changes in the external environment. Challenges are treated as an invitation to action. And the first stage of the work is to assess their importance (i.e., prioritization). Unfortunately, the customer cannot always clearly identify them, so often the contractor must do this work.

The most common approach is the use of private STEP challenges [1] at the top level of the quadruple (tetrad), which characterize the social (S), technological (T), economic (E) and political (P) aspects of the problem, respectively (Table 1).

The social sphere is understood as a sphere aimed, firstly, for the realization of the constitutional rights of citizens and, secondly, for improving the quality of life of the social group of the population for which the system operates.

The technological sphere is focused on the success of exploitation of all types of resources. The modern specificity consists in attracting an unconventional measure - a unit of power, and as a result, the use of the coefficient of efficiency as a numerical indicator of the technological efficiency of the process or system [4].

The economic sphere is the most understandable and methodically worked out type to increase efficiency, the numerical characterization of which can be, for example, the profitability of the system.

As for the political sphere, according to the laws of classical management, it characterizes the success of the competition for markets. A broader interpretation presupposes the growth of the image of either the developer, the owner, or the user of the system.

This point of view is generally accepted, but it is more correct, in our view, to consider the five challenges (pentad) or STEEcP: with the addition of the ecological (resource) aspect (Ec). This fully agrees with the position of Hartmut Bossel who in his report to the Balaton group [2] identifies 6 subsystems in the anthroposphere (Figure 1).

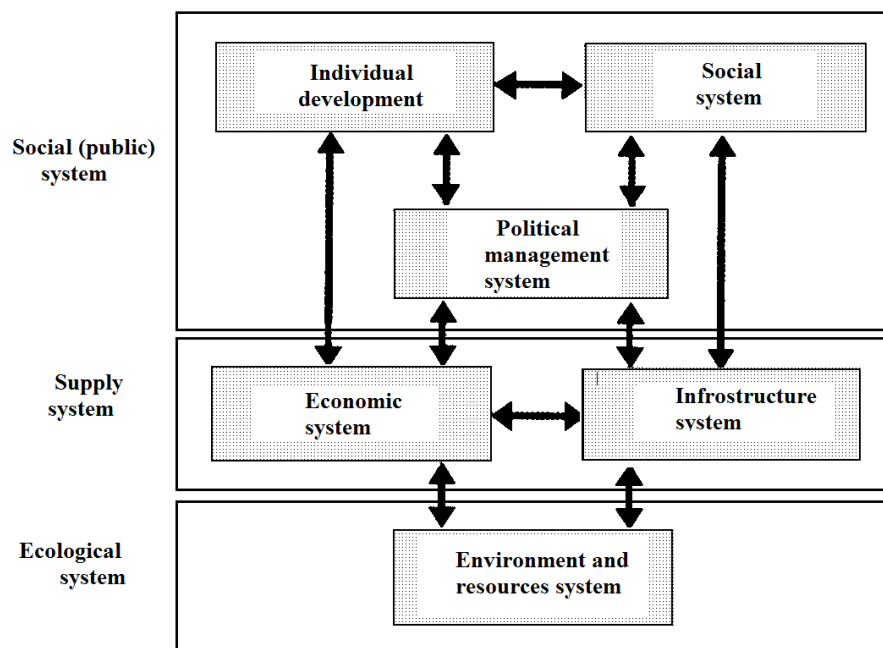


Figure 1. Six main subsystems of the anthroposphere [1].

The specificity of these subsystems is summarized in Table 1.

Table 1. Main subsystems of the anthroposphere.

No.	Name	Identifier	Content
1	Individual development	IR	Individual potential expresses the potential of a competent individual action.
2	Social	SP	Social potential means the ability to constructively manage social processes and their use for the benefit of the common system.
3	Political management	PP	Management potential (professional skills of the government, administration, business and management circles).
4	Infrastructure	IP	Infrastructure potential is the stock of constructed facilities, including cities, roads, water supply systems, schools and universities, etc.
5	Economic	EP	Production potential for the implementation of all economic activities.
6	Environment and resources	RP	Potential, representing reserves of renewable and non-renewable resources of materials, energy sources and biosystems, including the ability to absorb waste and regenerate.

Note: the economic subsystem of H.Bossel combines 2 blocks: technological and economic.

So, we identify 6 subsystems, the level of development of which predetermines the success of the urban development. These subsystems are interlinked with 5 key performance indicators (*KPIs*) as follows:

- KPI_1 - social performance (includes subsystems of individual development and social);
- KPI_2 – technological performance (technological block in the economic subsystem);
- KPI_3 – economic performance (economic block);
- KPI_4 – ecological performance (environment and resources subsystem);
- KPI_5 – political performance (a subsystem of political management).

Key indicators KPI_i are typically formed, as a result of which dimensionless quantities are formed ^

$$g_i = (KPI_i - KPI_{i \min}) / (KPI_{i \max} - KPI_{i \min}).$$

The standardized key indicators g_i predetermine the structure of the goal function (GF), which is a vector (generalized) estimate.

A generalized performance estimate is usually considered [13] either as a convolution or in the form of a weighted sum

$$\varphi = \sum_{i=1}^n \lambda_i \cdot g_i, \quad (1)$$

or as a weighted product

$$\varphi = \prod_{i=1}^n g_i^{\lambda_i}, \quad (2)$$

where λ_i - weight coefficients corresponding to the normalization condition $\sum_{i=1}^n \lambda_i = 1$;

g_i - normalized individual performance indicator.

The estimate (2), as we see, is more stringent than (1), since the zero equality of any g_i nullifies the estimate ϕ itself, therefore, the ratio (1) is often used.

There are two principal questions: what is the significance (weight λ_i) of each component, and which of them are the most priority? Such questions arise before any responsible party in the sphere of Smart-City. Of course, the customer of the executed project (program) must answer them. It is necessary to note with regret that the city administration, which by its status is competent to form "weights", has not yet indicated its position, so the decision will be entirely determined by the experience, professionalism and boldness of executors.

Formally, the "weights" and the priority of challenges can be estimated by the Analytic Hierarchy Process (AHP) proposed by T. Saati [10]. As a rule, the initial data for such analysis is formed by experts, and the final processing is performed by software, for example, MPRIORITY 1.0 [11], which implements the AHP. An example of such an analysis is given below (Figure 2). Of course, one can disagree with it, remembering, however, that, firstly, a plausible model is still better than no model at all, and, secondly, the result obtained depends on the specific nature of the problem being solved. Each problem has its own matrix of "weights".

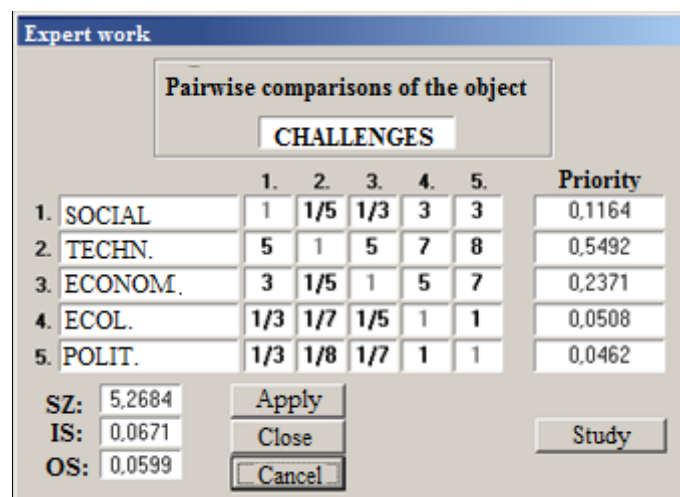


Figure 2. Estimation of weight coefficients.

Based on the data obtained, a Pareto chart is constructed and an ABC analysis is performed (Figure 3), whose goal is to identify priority areas that determine ~ 90% of success.

Priorities are those areas whose ranks fall into the region A + B. This means that not all individual indicators g_i , but only the most significant ones can be in the objective function. This explains the fact that researchers form the final list of individual performance indicators in different ways. So, in our case, these are studies aimed at increasing the technological and economic efficiency of the process.

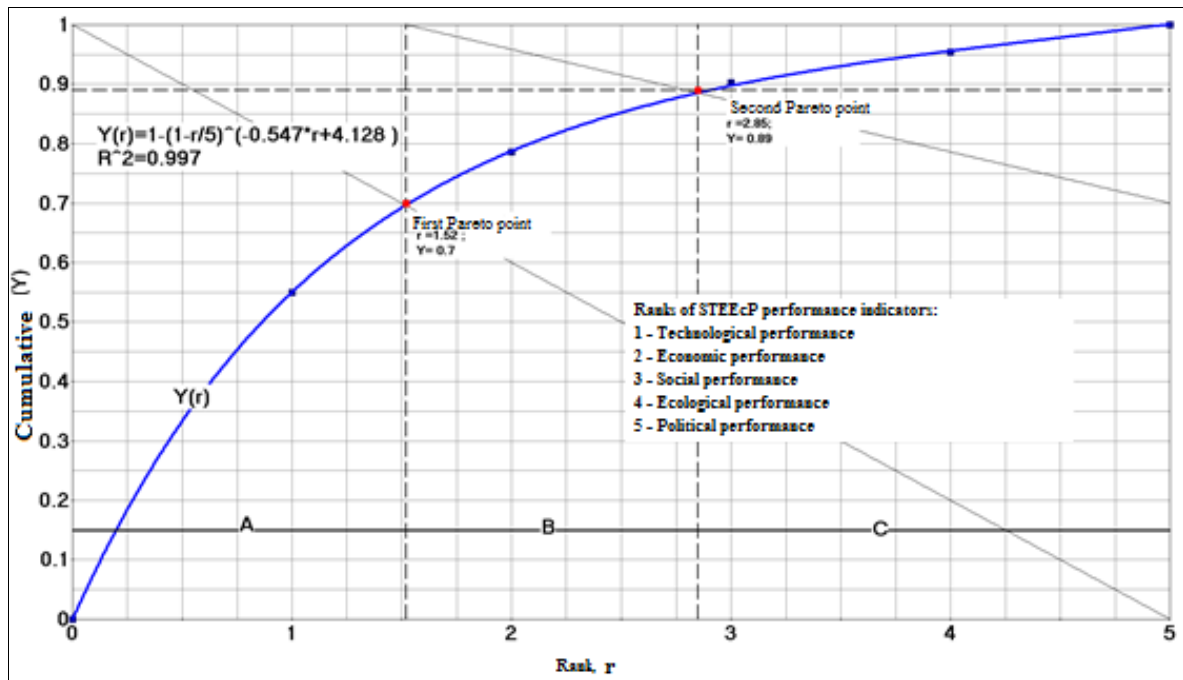


Figure 3. "Pareto" ABC analysis for STEEcP-indicators.

A logical result of the selection of priority g_i is the list of necessary indicators of the process since each indicator g_i is predetermined by the set of measured parameters (indicators x_{ij}) inherent only in it. Interconnection of g_i and x_{ij} is inherently a model of an individual, standardized indicator of effectiveness $g_i = F(x_{ij})$. Identification of these models is one of the main tasks of the project.

Creation of models $g_i = F(x_{ij})$ allows designing the goal function of the project (see relation (1)), aimed at achieving maximum performance ^

$$\varphi = \max \sum_{i=1}^n \lambda_i \cdot g_i = \max \sum_{i=1}^n \lambda_i \cdot F(x_{ij}) \cdot \quad (3)$$

If we consider Smart Grid (SG) as a subsystem of Smart-City, then it inherits all the specifics of the goal setting for the city in the methodological plan. The difference is only in the nomenclature of indicators x_{ij} and, as a consequence, in models $g_i = F(x_{ij})$.

Smart Grid as a management object. It is quite obvious that SG belongs to the class of large systems in which several subjects interact in their interests (Figure 4). Their main attributes determined by regional and functional features in the example of the Tyumen region are shown in Table 2.

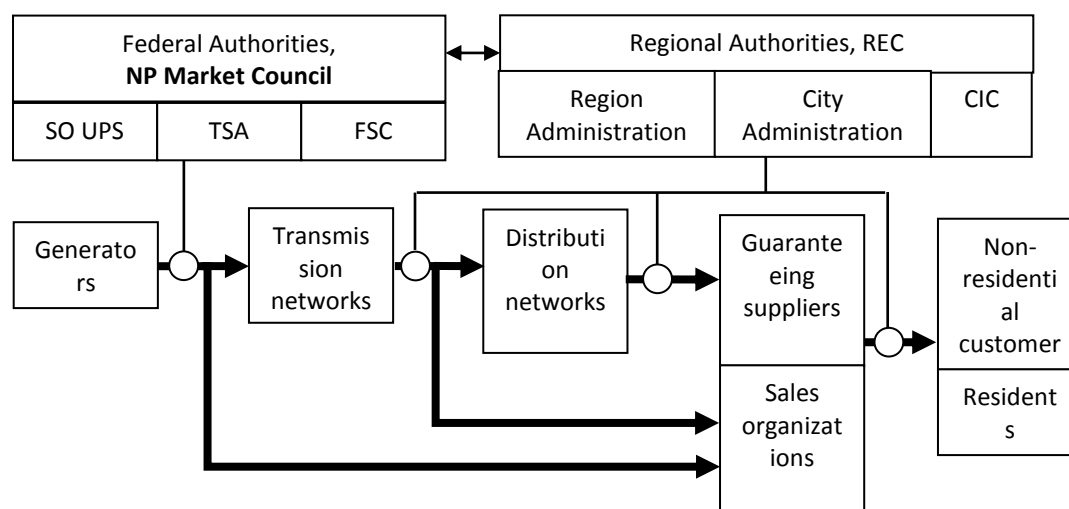


Figure 4. System structure.

The nature of the interaction of subjects. On the chart, thick lines show the flows of electricity and power, thin lines - information and financial flows. It is necessary to specify that the power here is a reserved quantity of electrical energy, and the electric power is the amount of electrical energy consumed.

Energy flows: Generators create electricity and power and transfer them to the wholesale market. Electricity and power are obtained by guaranteeing suppliers and energy sales organizations either directly or through network organizations. Suppliers provide electricity and power to consumers in the required quantities with the required technological parameters. Due to the peculiarity of electrical energy, it is consumed at the moment exactly as much as is produced.

Information flows: The wholesale market for electricity and power (WMEP) is managed by the Federal authorities through the Non-Profit Partnership Market Council (NP Market Council), and retail market (RMEP) - through regional authorities represented by the Regional Energy Commission (REC). The operational dispatching management is performed by the System Operator of the Unified Power System of JSC "SO UPS" or other entity of operational dispatch management of network organizations or guaranteeing suppliers.

Financial flows: The commercial operator of the WMEP is the Administrator of the wholesale electricity market trading system JSC "TSA"; calculations of requirements and obligations of wholesale market participants, JSC "SO UPS" and JSC "FSK EES" is carried out by the Financial calculation centre JSC "FSC". As for the RMEP, calculations are made with the network organization through the Calculation and information centre (CIC) or directly.

Table 2. Attributes.

No.	Subject	Names of organizations; Name of the department on the example of the Tyumen region	Functions	Key performance indicators (KPI)	Source
1.	Generator	OJSC Fortum Tyumen TPP-1	Generation of electricity. Sale of electricity.	<i>KPI</i> – profitability <i>Restrictions:</i> Reliability. Quality. Safety.	[14]
2.		OJSC Fortum Tyumen TPP-2			
3.		PJSC "Sibur" Tobolsk TPP			
4.	Network	JSC "SO UPS" ODU of the Urals - Tyumen RDU	Operation- dispatching control	<i>KPI</i> - profitability <i>Restrictions:</i> Reliability. Quality.	[16]

5.		PJSC "FSK EES" - MES of Western Siberia - Southern PMES		Safety. Availability.	[17]
6.		PJSC "Rosseti" - Tyumenenergo	Electric power transmission	Price-dependent consumption.	[18]
7.		LLC "Corporation STS" - PJSC "SUENCO"			[19]
8.		JSC "EK Vostok" - SC "Tyumenenergosbyt"			[20]
9.	Sales and Distribution	PJSC "Gazprom" - OJSC "Mezhregionenergosbyt" - JSC "TEK" OJSC	A guaranteeing electricity supplier. Purchase and sale of electricity.	<i>KPI</i> - profitability <i>Restrictions:</i> Reliability. Quality. Availability.	[21]
10.		"Siburenergomanagement"			[22]
11.	Regional administration	Regional Energy Commission of the Tyumen Region	Management of the electricity market. Development of investment programs. Coordination of the development of the power grid infrastructure, generating capacities. Tariff formation.	<i>KPI</i> - economy <i>Restrictions:</i> Productivity. Reliability. Quality. Safety.	[23]
12.		Department of Housing and Communal Services of the Tyumen Region	Development of the power industry of the Tyumen region	Availability.	[24]
13.		Department of Municipal Economy	Checking the readiness of power supply organizations for the heating season		[25]
14.	Consumer	Residents		<i>KPI</i> - economy <i>Restrictions:</i> Reliability. Quality. Safety.	
15.		Non-residential customers	Power consumption	<i>KPI</i> - profitability <i>Restrictions:</i> Reliability. Quality. Economy. Safety. Price-dependent consumption.	

3. Results and discussion

The analysis of Table 2 showed that in the field of performance management of the power system there is virtually no systemic paradigm and, as a result,

- missions of subjects are not formulated;
- there is no conceptual model of the process of providing a service to a consumer;
- goal functions of subjects are not formulated;
- there are no mathematical models of key performance indicators;
- there is no engineering algorithmic support for the process of network performance management;
- work of the organisation to maintain market equilibrium is non-transparent.

From the positions of the system approach, two aspects are principal today:

- conditions for achieving the agreed optimum between the interacting subjects [26];
- mechanisms for achieving the optimum and regulation of market equilibrium.

These tasks, in accordance with their status, should be carried out by the Regional Energy Commission. By variation of tariffs (prices), it must find a reasonable compromise between the five subjects (see Figure 4): generators, network, sales, consumers and city administration. Unfortunately, it was not possible to find a transparent solution to this problem in accessible sources.

4. Conclusion

The formalization of the problem, in our opinion, assumes an analytic assignment of the goal function of each subject $J_i(\mathbf{x})$ (here \mathbf{x} is a vector of control parameters) followed by maximization of the weighted criterion $J = \sum_{i=1}^5 \lambda_i \cdot J_i$ with respect to \mathbf{x} . Unknown weights λ_i are usually determined on

the basis of the Lagrange principle [26].

Using the system approach will make it possible to introduce the necessary logic into the development of the conceptual model of the Smart Grid project, and, as a result, increase the chances of success.

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