# Modeling and Analysis of Power Engineering by Using Cognitive Approach

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**Abstract**

Important problem areas of power engineering (by the example of energetics of Georgia) based on the cognitive approach have been determined in the paper. The system analysis with taking into consideration strong and weak properties, risks and chances, environmental, political, legal, social, economic, psychological and other factors has been conducted. The methodology of constructing cognitive models is proposed. As a result of modeling the possible scenarios of development of energetics have been investigated.

**Keywords:** power engineering, selection of scenarios, cognitive map, reciprocal influence of factors, self-development of processes

## Introduction

## Model Representation of Energetics

There are various ways of studying and interpreting realistic situation in power engineering. For example, the development of energetics may be considered in the aspects of political decisions or macroeconomic rules and trends, or technological issues. At the same time psychological factors such as private interests, workers motivation, etc. become very important.

Decision making in management of energetics is difficult due to the following factors:

• Processes being developed inside the energetics are closely interrelated, therefore, it is impossible to choose a single aspect and study it in details; all process inside the system must be studied in complex

• Lack of quantitative information about process dynamics, this forces the qualitative data to describe these processes to be used

• Time-varying (transient) nature of processes, at the same time the nature of change of some process characteristic are often unknown, which makes it difficult to build their quantitative models.

The above-mentioned peculiarities are reason to call such systems as weakly structured ones. Study of these systems by traditional econometric methods is often impossible. The alternative is to apply cognitive structuring of processes and generating of corresponding decisions.

## Definition of the Problem

The cognitive analysis implies the cause-and-effect structuring of process information according to the following scheme (Kosko, B. 1986, Alekseev, N.A 1998):

1. Any event in the system is caused by the movement of material (resources, money, etc.) and non-material (information) flows. Any movement of a flow can be described by a chain of cause-and-effect relations, which represents knowledge of an analysts about processes in the system; the reveal of such flows is the first step in the cognitive analysis of the system under study.

2. Each flow from the selected ones is described by the relevant factors, their integration represent the factor set, in terms of which the process being developed in the system are described.

3. Interaction of factors is considered in terms of cause-and-effect chains describing the movement of each flow.

The strength of reciprocal influence of factors is described by such linguistic variables as “significant”, “normal”, “weak”, etc.

The reciprocal influence of factors is represented by so called cognitive map which in fact is weighted organizational graph of a system being investigated.

When building a cognitive map the following methods may be applied:

1. The analyst builds the cognitive map based only in his knowledge, without using expert’s knowledge and other information; the efficiency of this method depends on the qualification of the analysts, his ability to determine the interrelation between basic system factors. It seems to be the fastest way of building cognitive maps, which at the same time provides confidence.

2. The analyst builds the cognitive maps based on the expert documentation, the advantage of this approach is its flexibility, but, on the other hand, it is rather labor-intensive and requires co-ordination of the experts knowledge

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3. The analyst builds the cognitive map with the help of a group of experts.; the advantage of this method is the aggregation of individual knowledge

4. The analyst builds the cognitive map based on open polls; its advantage is an active dialog with sources of information.

Graphic models of weakly structured systems are built with two purposes:

• More detailed structuring of the system under study

• Using structuring solution of the initial problems within the system under study.

We call factors that represent the essence of the system behavior as objective factors. The control factors (model's "input" factors) are those factors that the analyst can use to control the system processes by applying certain influence signals.

**Model's External Factors**

They are model graph's hanging nodes. They correspond to those environmental factors whose dynamics does not depend on the state of the weakly structured system. Hence, the external factors are not devoted to control the system but to reflect the influence of the environment on the system being modeled.

The problem of controlling model's dynamic consists of selection of such control impacts set which compensate the undesirable results of initial conditions and provide the necessary dynamics of change of the objective factors. When modeling the weakly structured system it is necessary to pass from the graphic model to the time equations when in these equations are represented graph's structural properties. The computer realization of model of such systems implies the initial description in the discrete times intervals.

The initial state of a model is a unity of changes of directions and speeds of all factors in an initial moment of time. Objectives of control (objective vector) are a vector of objective factors, given values of changes of all their coordinates.

**Self-Development of Model's Processes**

Before solving the problem of control, which provides the desired development of processes in the system, it is necessary to analyze the free development of processes (without control impacts) from a given initial state. The structure of the model and initial conditions may happen to be such ones that the free self-development of the system will lead to the desired objective state, i.e. the tendency of changes of objective factors will approach to the desired change tendency. If objective factors move away from the desired tendency then the correction of objective factors by yielding the correspondent control impacts is required.

**Basic Part**

**Principles of Determination of Cognitive Modeling Factors and Interrelations between them in Power Engineering**

Energetics as a production system operates in certain environment and interrelates with its various subjects, such as the government, regions, international partners, state and commercial organizations, etc. The environment changes its state and conditions which creates additional difficulties and risks to the energy economy. For purposeful development of the energy economy it is necessary to develop new tools to represent such difficulties and risks. When studying the problem situation the great importance has also a human element (in this case the management of the production system), that is, the internal understanding of current situation in the system (the picture "Model of the World"). The "Model of the World" [Alekseev, N.A.(1998), Kulinich A.A (2010)] contains set of grounds, perception of special valuable and practical principles which the subject uses in his managerial activity of generating impacts for development of situations.

When constructing the "Model of the World" not only the "picture of the present" is created, but the future of development of the energy economy is considered as well. Hence, the "preventive" research may be used for creation of the space of possibilities, which we can use in one of the method of perception - modeling.

The cognitive modeling, which is the continuation of representing processes, allows us to explore the space of opportunities of the energy economy development. Using the cognitive modeling the "Compact model of the World" can be constructed. Here non-significant factors are isolated and are excluded from the consideration.

When determining the basic factors the main criteria are:

• Mechanisms that support the purposeful development of the energy economy in the conditions of interactions with environment

• Interests and expectations of participants of aroused problem situation

In the cognitive modeling each factor is determined by its influence on other factors. This type of interaction allows the interests and expectations of participants to be taken into account.

The interaction between factors can be positive, when growth (reduction) of a factor causes growth (reduction) of other related factors, or negative, when growth (reduction) of a factor causes reduction (growth) of other related factors.

As a result the development of the energy economy is represented by interactions of basic factors of the so called cognitive map, whose nodes are unambiguously associated

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with factors and arcs represent the connections between factors.

**Development of Model of Interaction between Energy Sectors with other State Subjects**

The development of this model begins with the building of the cognitive map that represents the real situation. Various factors of development of the energy economy can be considered: for example, political decisions or macro economic rules and trends, or social conditions in the society. On the basis of the built cognitive map the self-development of the system is being modeled. The goal is revealing the positive tendency in the development of the energy economy. With the aid of cognitive modeling it is possible to fix the evolution of the situation consisting of 2 components:

• Self-development of the situation , that is, the free development

• Control of development of the situation determined by the selected control objective

**Factors of the Cognitive Factors which Characterizes the Situation "Today"**

In this situation the following problems can be selected:

• In the control of energetics the strategic interests of the country are not determined

• Extremely hard situation in energetics from the point of security

• Financial state of is anxious

All above-mentioned aspects create many unsolved problems for the fuel and energy complex. These problems are very critical for the country because they generate social tension in the society and reduction of living standards of population.

**Internal Factors of the Energy Economy**

Financial and production activity of energetics is based on the following: energetics at the expense of rather modest turnover means receives energy. Then the complex makes realization of energy to customers. They are generation objects, energy transmission, distributive companies, wholesale market, dispatching services. Each of them represents independent juridical person. For their normal functioning and reproduction the full financial flows are necessary.

The analysis shows that many factors influence the process: commercial losses, technical losses ( above the standard), technical failures, lack of turnover means, increased expenses, low collection of payments for energy consumed, etc.

**External Factors of the Energy Economy**

The successful functioning of energetics is impossible without the impacts from the outer world (social, economic, political, etc.) On cognitive maps these impacts (direct or indirect) can be expressed by means of a "boundary layer" and "outer field".

In the completed model the external factors, which represent other subjects of the country and governmental influence on the fuel and energy complex, are very important not only during the analysis of the current situation, but for the prediction of the behavior of the system. These factors are: social situation in the country, economic situation, tax situation, political situation, etc.

**Cognitive Map of a "Boundary Layer"**

**Determination of Degree of Reciprocal Influence of Factors Characterizing the Situation "Today"**

The unity of an internal field, a boundary layer and external fields creates the complete field of factors of the fuel and energy complex. In an interdependency matrix immediate relations between factors are presented. The columns and rows of the matrix correspond to the factors of the cognitive map, and numerical values at the intersection of an i-th row and a j-th column show hose weights and direction by which i-th row influences on the factor of the j-th column. To describe the reciprocal influence of factors the set of linguistic variables such as "strong", "moderate", "weak", and etc., is used. The numerical values of linguistic variables are reflected on the closed interval [0, 1] as follows: "very weak" – 0.1, "moderate" – 0.3, "significant"- 0.5, "strong"- 0.7, "very strong"- 1.0. The direction of influence is determined by its sign: a positive one, when growth (reduction) of a factor also will cause growth (reduction) of another related factor, and a negative sign, when growth (reduction) of a factor will cause reduction (growth) of another factor. For example, the moderate (-0.3) reduction of the second factor "Tax Benefits of the Fuel and Energy Complex" causes the growth of first factor "Tax Values". That is, the more is the tax benefits, the less are taxes, the more is "profit", the more is" turnover means". This relation is reflected by the values of coefficients 0.2 and so on (filling matrices is done by experts)

**Modeling of Self-Development Scenario in the Energy Economy (Scenario "Today")**

This scenario is based on observation of changes in the system (in fact, it is the task of exploitation). It is possible to obtain a situation that satisfies requirements of development of the fuel and energy complex. Then the conclusion is that the intervention in the process of operating of the

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system. These results of modeling

answers, in fact, the question "What can happen in future, if "today" tendency will hold out?" In this case the following must be entered in the model:

- interdependency matrix
- initial values of factors

The initial tendencies represent the current situation in the fuel and energy complex. They are given in the form of linguistic variables.

The concrete values of linguistic variables are given according to the poll of experts in 10-point scale and 3 – positional tendency scale: growing "+1", unchanged "0" and decreasing "-1".

**The First Scenario –"today"**

The starting data of the model (values of the factors) are selected on the basis of the current crisis in the energy. The model corresponds to the self-development scenario.

The results of modeling are given below. This situation is represented by the first scenario. The factors to be observed or objective functions and their predictions are given on the graph. The yellow colored rectangles show the initial tendencies, the red colored ones - objective tendencies that correspond to the desired development of the situation, and blue colored ones- the predicted results tendencies:

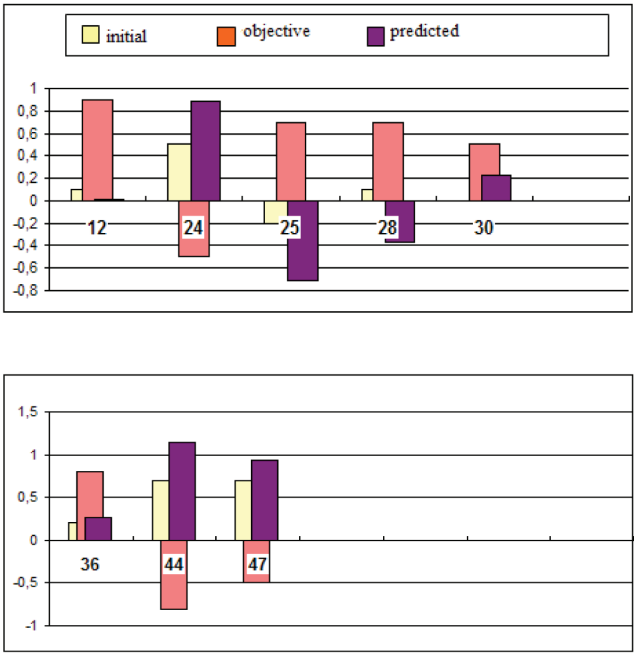


***Figure 1:*** *Graph of the results (First Scenario)*

| | |
|---|---|
| 12. profit from sales | does not change |
| 24. shadow turnover | significantly increased |
| 25. efficiency of energetics | significantly decreased |
| 28. ecological security | moderately decreased |
| 30. rehabilitation | slightly increased |
| 44. corruption | strongly increased |
| 47. social tension | strongly increased |

As the results show, in the condition of self-development the situation is not only improved, but, on the contrary, became significantly worse and became the source of new problems. In particular, the 12-th factor is the collection of payment for the consumed energy and it decreased compared with the today collection (it is contrary to desired dynamics of changes); the 24-th factor, the shadow turnover, is increased; the 25-th factor, the efficiency, is decreased; the 28-th factor, ecological security, is decreased; the speed of change of the 30-th factor is insufficient; the 44-th factor, the level of corruption, is increased.

**First Scenario's Conclusion**

All the above – said makes it necessary to intervene radically in operation of the fuel and energy complex, to change significantly the strategy and tactics of its development. That implies the use of the second modeling option (modeling of controlling development of the fuel and energy complex).

**Modeling Using Control (on the Basis of the Starting Scenario "Today Situation")**

The controlling factors from the list of existing ones were selected. Predictions for not only variants were obtained, but for the set of accepted variants, each of which is determined by concrete values of controlling parameters (these are selected according to experts' knowledge).

The factors selected as controlling ones:

- 2 - tax benefits in the fuel and energy complex
- 6 - turnover means of the fuel and energy complex
- 8 - commercial losses
- 12 - profit from realization
- 17 - tariff on electric power
- 30 - ecological security in the fuel and energy complex
- 33 - state order
- 34 - level of participation in transnational unions
- 37 - demand on electric power
- 43 - state grants for the fuel and energy complex
- 49 - export of peak
- 50 - level of legislative base in the fuel and energy complex

- The factors 2, 6, 8, 12, 17, 33, 34, 43, 50 provide

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the governmental control.

- The 30th controlling factor provides actions according to the Kioto protocol.

-The factors 39 and 49 represent actions reflecting participation of the Georgian fuel and energy complex in transnational unions.

The starting data of the second scenario correspond to the today situation. The model correspond to the control scenario (parameters to regulate crisis situation are determined).

The results of modeling (the second scenario) are shown below

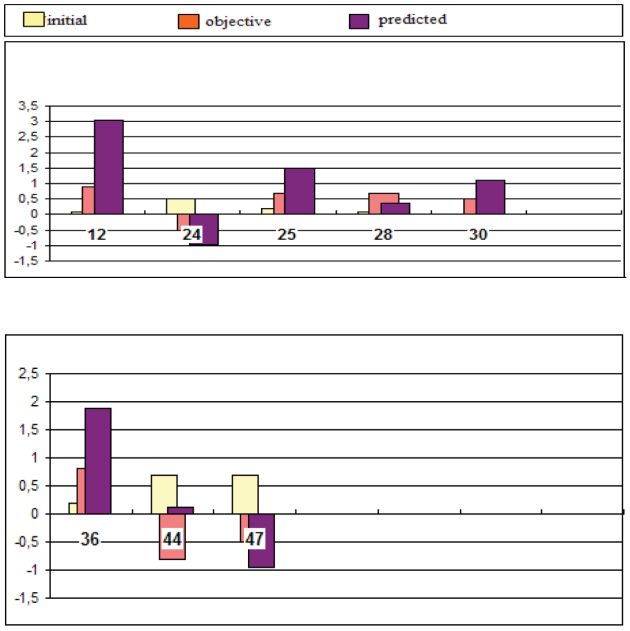


***Figure 2*** *Graph of the results (Second Scenario)*

| | |
|---|---|
| 12. profit from sales | strongly increased |
| 24. shadow turnover | strongly increased |
| 25. efficiency of energetics | strongly increased |
| 28. ecological security | moderately decreased |
| 30. rehabilitation | strongly increased |
| 44. corruption | strongly increased |
| 47. social tension | strongly increased |

**Second Scenario's Conclusion**

The second scenario shows that the Georgia has to participate more intensively in various transnational unions. It shows also that the governmental intervention must be strengthened (of course, if it is compatible with the market economy principles and if there is analogue in the world practice) . The membership of the Georgia in the international energy system guarantees that the intensification of the governmental control is not contrary to the market economy principles.

**Modeling of the Self-Development in the Good Starting Conditions**
**(Scenario "Tomorrow")**

For this scenario modeling of self-development of energetics was conducted. The relevant values of factors and tendencies of stable successful countries were selected as initial factors.

**The Third Scenario**

The starting values of parameters were selected with accordance of their desirability.

The graph of results of modeling is given below:

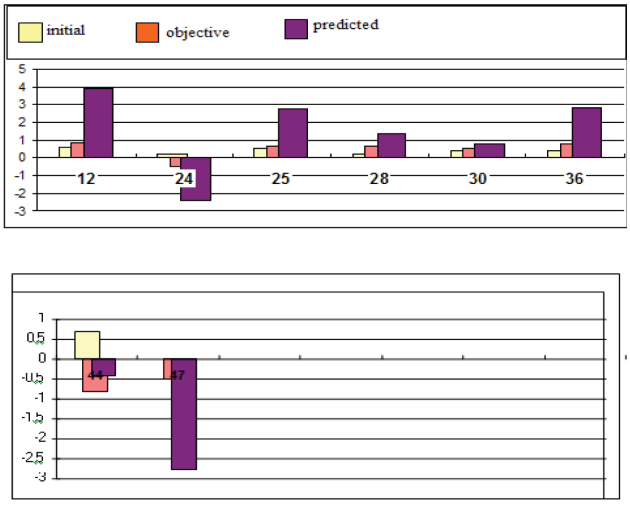


***Figure 3*** *Graph of the results (Third Scenario)*

| | |
|---|---|
| 12. profit from sales | strongly increased |
| 24. shadow turnover | strongly decreased |
| 25. efficiency of energetics | strongly increased |
| 28. ecological security | moderately decreased |
| 30. rehabilitation | strongly increased |
| 44. corruption | moderately decreased |
| 47. social tension | strongly decreased |

**Third Scenario's conclusion**

As one can see, the results are very good and their economic action principles are based on monetary development theory.

**Conclusions**

The comprehensive system analysis of power engineering (by the example of Georgia) with taking into consideration various environmental, political, legal, social, economic and other factors has been conducted. The methodology of constructing cognitive models is proposed. As a result of modeling the possible scenarios of development

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of energetics have been investigated. On the basis of the conclusions of 3 scenarios considered recommendations on further possible development of energetics are proposed.

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