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MODERN ASPECTS OF THE DEVELOPMENT OF INFORMATION AND CONTROL SYSTEM IN ENERGETICS

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ABSTRACT: *In the present paper the energy systems are analyzed as an example of the so called large artificial systems. An example of a multilevel system has been considered which is associated with the problem of dispatching active power within the energy system. The advantages of multilevel control as compared to a centralized approach are shown below.*

Construction process of the so called integrated production systems aims at providing functional, information, software, and technical compatibility as well as efficiency of the individual subsystems. In terms of control each information management system, distinguished by a hierarchical structure, consists of three main levels: lowest – field level, the second one – operational and dispatching, and the third level – information level networks.

KEY WORDS: *information and control system, energetics*

Energetic systems, with their variety in equipment, huge amount of sub-systems and complex connections between them, are a natural subject for the application of a multileveled hierarchic approach in the building of their organization and management, including a wide specter of organizational activities, planning, management, building, infiltration, exploitation, support and development of information systems and technologies. With the contemporary organization of the production of electricity and its distribution and allocation through systems for access and transportation, organized by various wholesale companies, some exceptionally elaborate energetic complexes emerge, uniting systems in narrow correlation. Due to the high requirements for reliability and safety of functioning, their management is unthinkable without quick and timely decisions, since possible failures in the energetic system may have serious economical and social ramifications. This demands the development and improvement of new methods when it comes to the organization and management of large energetic systems.

The electro-energetic system is a complex corporative construct, which includes NEC (National Electric Company) and 52 departments in the country, electrical distribution companies, Thermal Power Station "Maritza-East", Nuclear Power Plant Kozluduy. Each of its components represent a complicated complex of different technological means, collectives of people, united in different fields of services, and also includes a number of organizational-structural decisions(rules, servicing, etc.), organizational structure and technology of functioning.

Hierarchy of management in the contemporary electro-energetic system can be represented with a series of prominent levels: European, regional, national, local; through a wholesale object – electrical station, sub-station, network region. Each of these levels is composed of its own internal hierarchy [9].

The low level of management, particularly if an electric station is being considered as a subject of management, has the most strongly emphasized internal hierarchy: *dispatcher management* (commands for commutation switching, correction and control of the work of group and autonomous management systems); common (secondary) automatic management of stations in normal and alert modes (distribution of active and reactive power, regulation of frequency, management of commutation operations, function of anti-alert automatics, adaptation of settings of regulators); group complex regulation, "zero" autonomic regulation, ensuring the assigned carrying out of the technological process of preparation of the energetic system and etc. [5]

Typical for the energetic system is the existence of a complex information structure; hierarchic dependency between the knots of management and in them; colossal in volume streams of information over the communication channels, between the knots of management; correlation between information and processes of its transformation relative to the goals, (which defines the semantic and pragmatic properties of the information); big variety of different information properties, transformers of information (different in their purpose regulators, controllers and etc.; people from different fields of expertise in the knots of management).

The energetic system is an example of the so called *big artificial systems*. In the technical cybernetics the "big artificial system" is called the aggregate of a big number of hierarchically dependent complex subsystems, composed of collectives of people and machines with a certain level of organization and independency, united on the base of an active hierarchy of goals and means of the organization, commonly with energetic, substantial and informational connections for the insurance of the purposeful functioning of the entire system as "a whole".

The means of organization include knots for management, where the process of decision making takes place, and executive organs, realizing the information of the made decision in action, directed to achieving the set goals from the management. Commonly, in the big system, the knots of management and the executive organs represent complex human-mechanic complexes. For the purposes of quantity analysis of the big system, it is necessary for all its defined components to be formalized. Presently, the least studied of them, particularly quantity-wise, are the organization, the hierarchy of goals, the information and the independency, as well as the relations between man and machine, composing the knot of management. In relation to the goals of functionality, the big artificial system must ensure the completion of assigned substantial-energetic processes. But its functionality, development and existence as a whole are determined by the processes of transfer, refinement and transformation of information. Therefore, in the big artificial systems it is productive to separate three aspects: substantial-energetic, economical and informational. With the informational approach and the observation of informational-management systems, each studied system is represented by three levels: field, management, informational – meaning, in an abstract type, it is represented through a hierarchical structure on the lower level, where the technological process sections are located, and on the higher levels, the management knots, connected with the objects of managements and with each other, through channels of the network communication, shift places.

The information, circulating in the system, may manifest itself in three forms: informative – directed with priority from the objects of management to the relevant management knots; managerial – in reverse direction; transformational – defining the regularities of behavior of the management knot and the algorithm of functioning of its individual elements [2, 6].

The management knots transform the informative data into managerial with the help of the transformational information, contained in the algorithms and the structure of the management knot. The different sections of the technological process are considered as generators of primal informative information. As it moves up the hierarchy, the information gradually gets synthesized, transformed in the different management knots and arrives in the main management knot on the top of the hierarchy. Using the acquired informative information, this knot generates managerial information, which gets more detailed as it moves down to the lower knots. The smaller the volume of the necessary higher knot information to form managerial information in the ”i” knot, the more autonomous this knot is.

To achieve the goals of management, it is of great importance that only the necessary (valuable) information reaches the respective knots. That is why in the informational-managerial systems, the semantic and value statistics of the information are displayed with priority. The management of complex technological processes, like the energetic, always happens in an environment of lacking of information. This is mainly caused by the fact that in the management knots in these systems, representing a unification of people and machines, these systems are only partially observable, partially manageable and partially knowable.

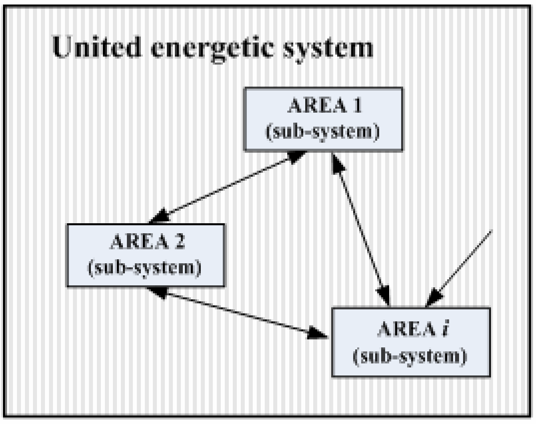

Figure 1

A classical example of a multi-leveled hierarchic system is the problem with dispatching of active power in the energetic system (fig. 1)

The system is divided in *n* correlated sub-systems. Usually, the boundaries of the respective areas are chosen in a way that each one of them represents a separate association or company.

Each area has a series of generator stations and a big variety of consumers, but as long as the transfer of electrical energy between the areas is a major interest, it can be assumed, that each area is characterized only by the following parameters:

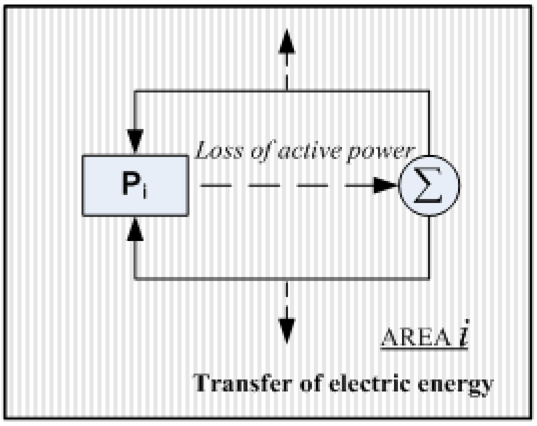

Figure 2

– C_i – load up (full) in area i ;
– X_i – active power, generated by the elements in area i ;
– Y_i – loss of active power in area i ;
– U_i – transfer of powers through the energetic lines, connecting area i with the other areas.

With a set load, the loss in the i area depend on the power, generated in the area itself, as well as on the transfer of powers, meaning Y_i is a function of X_i and U_i.

(1) $$Y_i = P_i(X_i, U_i)$$

The equation, defining the balance of powers can be written in the following way:

(2) $$P_i(X_i, U_i) + C_i - U_i + X_i = 0.$$

There can be an *n* amount of equations of this kind. Also, the transfer of powers between the individual areas must be balanced:

(3) $$U_1 + U_2 + \ldots U_n = 0$$

Equation (2) describes the sub-processes, and equation (3) – their relation.

Based on this, it can be assumed that the problem of dispatching of active power in a unified energetic system lies in the need to be able to define, on all lines, the power X_i and the volume of transfers U_i where the value of the produced electric energy would be minimal. For that purpose, the function $F_i(X_i)$ is introduced, called function of value of generation in each of the areas with power X_i. Then the overall value of the generated power will be:

(4)
$$F(X_1,.....X_n) = F_1(X_1) + ... + F_n(X_n)$$

The problem with optimal dispatching is reduced to a minimization of example (4), provided that the variables $X = (X_1,.....X_n)$ and $U = (U_1,....U_n)$ satisfy the equations of balance (2) and (3). It can be noted that after equation (3) the number of the independent values U_i is $n-1$. The problem can be solved through the use of single-computer configuration on the base of the so called full centralization, or on the base of a dual-leveled hierarchy of the computer system.

With the dual-leveled hierarchic approach each area has a respective computer for solving the task of dispatching and also has a central management computer. This organization is displayed on figure 3. The problem with finding the optimal distribution of the production and the transfer of power is solved with the help of a dual-leveled system with an organizational hierarchy.

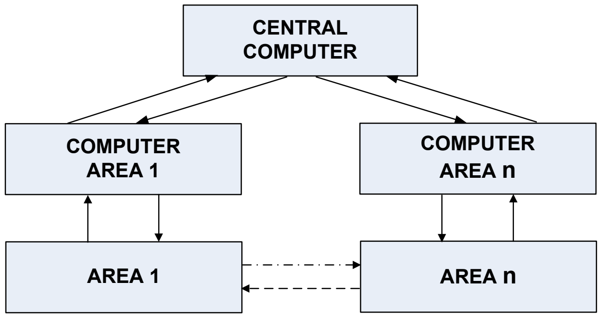

Figure 3

The task and goal of each hierarchic organization is connected with the solving of the problem with minimization. In relation to this raises the question how is this task supposed to be distributed between the computers of the different areas and the central computer. For the purpose, a common approach is developed, based on the so called principle of prognostication of relations, used for distribution of tasks between the separate computers, composed of the following. The computer for the i-area solves the task for minimization of $F_i(X)$ in relation to X_i by execution of example (2). Then the value of U_i^α is set by the central computer. The task of the central computer comprises of the definition of a support level of transfer, meaning U_1^α,..., U_n^α. If the transfer is conducted under this condition, the local optimum will simultaneously be global as well. When the difference between the support level of transfer (defined by the central computer) and the actual transfer exceeds the levels of the predetermined boundaries, the new support transfer is defined through an iteration process between the central computer and the ones for the different areas.

The multileveled management (in the examined case – dual-leveled hierarchic system) is preferred in comparison to the centralized approach, due to a number of reasons of technical, economical and exploitational nature. The more significant of these are:

1. Dispatching is executed faster (with less necessary machine time) and with lower cost to the memory. The volume of the resources is determined by the size of the system and the software of the central computer, which serves as a coordinator in this case.

2. The system is less sensitive about changes in the structure of relations – changes that can be either of deterministic or random nature. Therefore the change in the conditions in just one area causes a shift in only one of the tasks (local) that are being solved. With the centralized "single-area" approach these changes can be localized and usually it becomes necessary to change the solving program for the entire system (it is examined as a whole).

3. In the area centers, there are usually computer systems, solving other technical and exploitational tasks. In that case the central computer is just added for the purposes of dispatching coordination and for other goals on the level of the entire system, for example – for the preparation of requests for transfer of energy it needs to be reminded that one area can be relevant to a few companies. That leads to a series of specific administrative and legal problems, for the solving of which the dual-leveled management system is preferred.

In accordance with the principles of the liberal energetic market, the consumers strive for signing contracts for quantities of energy that are maximally close to their expected consummation and the manufacturers strive for producing quantities, equal to the contracted ones. In accordance with the necessity of separate logging of the production and consummation of the different independent entities, the building and development of a singular information system for measurement, research, storing and refining of the necessary information is more than required. NEC begins to develop a large scale information system of that kind in year 2000, simultaneously with the restructuring of the company [6]. It is in accordance with the contemporary information systems in the utility business, connected with their complex hierarchic structure with network communication, based on an aggregate of mutually connected and related sub-systems.

The contemporary approach for ensuring a functional, informational and program-technical compatibility and efficiency of the individual subsystems lies in the building of the so called *integrated systems* in the production in the broadest sense. From a management view point, each informational system with a hierarchic structure is composed of three fundamental levels. The lowest level is the so called *field level*, composed of networks for communication of programmable controllers (PLC) with intelligent devices – sensors, measurement devices and actuating mechanisms. In energetics, the field level is built on the base of intelligent static completely programmable electricity meters, devised for marketing and control measurement in networks for high, average and low voltage. Utilized are electricity meters with accuracy class of 0,25 with serial communication ports, responsive to IEC 62056 (COSEM/DLMS communication protocol). An important specificity of the field networks is the real time functioning and the necessity of maintenance of remote, limited in time relations between the subsystems of the different management systems.

The field networks are the basis for the building of the so called management systems with network communication NCS (Net-worked Control Systems). These are systems in which the managerial and end devices such as sensors, transformers, actuating mechanisms, controllers, and operational stations and so on, are connected in a network and each of them represents a knot, a respective station in this network and communicates with the rest through a network environment. The use of field networks significantly simplifies the integration of devices from different manufacturers, as well as the diagnostics, the tuning and the general exploitation of the management systems with network communication. The field networks have two major functions in the management systems with network communication: transportation of incoming/outgoing data (management information) from and to the end devices – sensors, actuating mechanisms, signalizations, local controllers and so on; transfer of other information, not directly related to the management, such as configuration parameters [3, 4].

The functional compatibility of the devices in the field networks is defined by the specifications through the means (unifying) of the physical connection to the network; diagnostic type matter, most commonly light conducting indicators; possibilities for adding and respectively removing of devices from the network without powering down and without the reestablishment of communication, automatic diagnostics and configuration of the apparatus part.

A huge variety exists with the field networks, characterized with their specifications: Device Net, Profibus, SDS, Lou Works, Modbus and so on.

The network of second (operative-dispatcher) level is designed for transfer of technological programs, coordinating and managing information for the controllers, connected to the respective aggregates, installations, machines. On this level the communication is intense, with memory that is small in size, but with heightened requirements when it comes to soundproofing, safety and work in real time. This stems from the fact that the transferred data is delivered for management of constant processes in real time. Usually, on lower level, different field networks [1, 8] function.

For the management level, the simplified programming and automatic network configuration are typical. Unified network software and controllers from various manufacturers are used. In a network of this level, many outlines and discrete managerial structures can be implemented – for logical management, for emergency signalization and blocking and so on. Mutual replaceability of the functional blocks, manufactured by different firms in the same standard is achieved. The networks of management level are characterized with speed of data transfer of 10-12 Mbit/s, with flexible management of incoming/outgoing data and automatic configuration, which is why they are used for building of open systems for control and management.

The third level in the hierarchy is represented by the networks from the *information* level. These networks are characterized with high conductivity and are designed for transfer of massive amounts of information. Typical for this level are the global management tasks regarding company, branch and so on. The major problems here are connected with the volume of the transferred information and the speed of transfer due to the high requirements for fidelity and security. So far, however, an approach for defining an applied layer in the networks on level management is lacking with the informational level. This layer is responsible for defining the semantics of the delivered information. Most wide-spread in the modern systems on this level is the specification known as Ethernet. The main prerequisite for this are the computers in the office equipment in LAN networks of the type Ethernet and the fast development of the global network Internet. These networks of informational level meet all the requirements of the OSI (*Open Systems Interconnect Basic Reference Model*) model and use protocols, which cover all layers – from the applied to the physical. The modern programmable commutators and technical improvements such as Fast Ethernet allow the building of more and more efficient informational-management systems [3].

Doubtfully, there is clearer example for the spiral evolution of the prices than the development of the researches and the practical work on the optimization and optimal management in the energetics and the material manufacturing. Not long ago, this problem was the main research subject in the field of automatic management. The goal was the complex automation and optimization and the results were presented as far too optimistic. The hopes were not fulfilled and the researches were directed to solving of separate, isolated tasks, solved in different methods and through different means. The term "complex optimization" was abandoned. Evidently none of the research centers of the leading companies had any critical mass to solve such a complex task, that is dependent on the hardware, software, mathematic methods, knowledge of management process and last, but not least – the approach for the presentation of the managerial information, in order for the optimal decisions to be taken. Today the informational-management systems include elements from different levels: sensors, managerial and communicational devices with an apparatus part and program controlling, human-machine interface sub-systems for connection with the managing business systems. The use of communicational networks as a mean of integration of sub-systems is a spreading tendency, allowing the use of different devices without supervision from the manufacturer, while maintaining full functionality. Due to this, the standards for the informational – management communicational networks will continue to be a major factor for their development, the major characteristic of which is the use of open specifications and architectures for their building.

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