METHODOLOGICAL ISSUES CONCERNING THE QUALITY OF ENERGY SUPPLY

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ABSTRACT

This report examines methodological issues concerning the quality of energy supply. In the scientific sense, this quality is associated with a complete set of natural properties of the product, which determine its usefulness. The quality of energy supply is determined by the reliability of energy supply, by the quality of energy and energy carrier at the consumer side at any given moment of time, that is, when the mode of energy supply to consumers is strictly maintained. Actually, we have to speak about the quality of functioning of energy supply systems. This report formulates the basic objectives of this study of the problem of energy supply quality and ways of solving it.

GENERAL NOTIONS

The quality of energy supply is a many-sided notion. In the general scientific sense the idea of quality is associated with a set of natural product properties, which determine its utility. The utility of a thing makes it a use value. Under the conditions of commodity production use value is the carrier of economic relations between people. This is why quality is an economic category, which governs relations between producers and consumers.

At the same time, use value determines the usefulness of a thing only, regardless of the degree of that usefulness. The notion of “quality” determines the degree of usefulness of a certain object. In a general case, what we understand under the idea of product quality is a combination of properties, which determine the product capacity to meet certain demands in accordance with its purpose.

The quality of a product should be deemed as the most important consumption characteristic, which covers not only its natural/technical properties, but also social properties. While the former point to the absolute usability of a product from the point of view of satisfying a certain demand, the latter point at an area of social relations, which are connected with the production and consumption of the product. The latter circumstance makes it possible to compare the costs run by producers and consumers, which are conditional on the quality of products.

The products of the fuel-and-energy complex (FEC) are fuels, electric and heat energy (further below referred to as thermal/energy resources - TER). Despite the visible distinction between energy products, all of them have a common useful property – it is their ability to perform some work (or to be transformed into the other kinds of energy). This particular feature of TERs provides a rather broad area for their application and interchangeability.

However, in the opinion of the consumer, every single unit of TERs, even within the limits of one of their kinds, is not homogeneous enough in terms of the degree to which energy is capable of being transformed into useful work. It is this degree of usefulness that determines the quality of energy products. It can be characterized by certain parameters. For example, fuel quality is determined by the content of ash, moisture, sulphur and other elements, and in the final analysis, by the calorific value. The quality of electric energy is characterized by the deviations and fluctuations of its frequency and voltage, by the non-sinusoidal form of the voltage curve, by the displacement of the system neutral and by other parameters. The quality of heat energy, depending on the kind of the heat agent, can be characterized by the following parameters: temperature, pressure, enthalpy and others. Therefore, the notion of quality is identical to all the available kinds of TERs, while at the same time those parameters that determine their quality will be different for every individual energy resource (an energy agent).

In order to be able to obtain a deeper penetration into the problem of the TERs quality in the field of economy, it is necessary to proceed from the requirements set by the system-defined nature of relations of the said TERs, which are designed for the production, transformation and distribution of all kinds of fuel and energy between consumers. The functional efficiency of a TER depends upon numerous factors, and among other things, upon the quality of heat and energy resources used at every technological phase. The specific feature of this process lies in the fact that the indexes that characterize the quality of TERs at every phase of transformations are subject to changing. These changes can lead to both an improvement or worsening of energy supply for consumers.

While considering energy products, by applying a system-defined approach, it will not be a difficulty to notice some specific features of their production and consumption. In the first place, it is the continuity of the processes, and, secondly, it is that energy production and consumption coincide in terms of time. The continuous nature of these processes leaves no possibility to reject or eliminate an energy product that does not meet quality standards. Besides this, any interruption of energy supply, will normally bring about a stop of consumers' functioning. The fact that energy production and consumption of coincide in the course of time proves the rigid character of dependence between the production of energy and its consumption mode. These specific features of the heat-and-energy complex (HEC) predetermine the necessity to introduce a new notion – the notion of heat supply quality, which should be understood as reliable energy supply of consumers, in the right amounts and of the required quality, in accordance with a preset mode of its consumption.

This category of quality will not have any real sense, unless the system is capable of providing energy supply without interruptions, at least. In the real sense one should speak about energy supply reliability as a complex of properties which characterize the ability of the system to maintain all its parameter values in the course of time and perform the required functions within the limits of preset modes and operation conditions. Normally, reliable functioning implies that the system is uninterruptible, durable, that it is fit for repairs and maintainable. In the energy field these features are complemented by its readiness for operation, survivability and safety. Requirements concerning reliability are a keystone for the creation of any technical systems.

Under the idea of energy quality one should understand an assemblage of properties that govern its suitability to meet certain demands in accordance with its purpose. In some instances, in order to have a more complete description of energy quality, it becomes necessary to procure information about the quality of the energy carrier, too. This is of a particular importance for describing the quality of thermal energy, whose carrier can be represented by any kind of matter, which can be in any aggregate state and which, consequently, possess not only different physical/chemical properties, but also different thermodynamic properties.

Of no lesser importance for the description of energy supply quality are data on the modes of delivery and consumption of energy. A mode in this case is deemed as a change of energy agent flows and parameters, as its dependence from time and other conditions within the calculation period. And in particular, this refers to changes of energy consumption parameters in the process of time, e.g., by the hour, by typical 24-hour periods or depending on some other conditions, e.g., the weather conditions.

Therefore, it is not only quite important to be able to generate energy, but it is essential to be able to reliably supply consumers with this energy at a given moment of time. The problems of reliability and quality of energy supply are interconnected and they must be solved as a combination. This means that from the methodological point of view, it is necessary to investigate the quality of energy supply as a specific category, which reflects the entire set of TEC's useful properties and its products. There can be no doubt that, in order to be able to solve this problem of energy supply quality in its full scope, a system-based approach must be applied, under which energy quality should be examined as a set, covering the complete energy chain, starting from energy resources and ending with energy consumers.

The problem of energy products quality has been the subject of investigations by both Russian and foreign experts for quite a long time. Yet, no kind of general concepts of energy supply quality have been formulated until now. Despite all this**,** quite a lot of the theoretical theses and concepts that have been elaborated are really quite applicable not only for the appraisal of energy products quality, but also for the assessment of the quality of functioning of complex technical systems.

APPRAISAL OF THE QUALITY OF FUNCTIONING OF AN ENERGY SUPPLY SYSTEM.

Taking into account the above-mentioned theses, and in order to analyze the energy supply problem, first and foremost it will be necessary to single out from the multitude of available properties those that determine use value. The said use value and as a consequence, the energy supply quality are determined generally by the reliability of energy supply, by the quality of energy and energy carrier at the side of the consumer at any given moment of time, that is, if the mode of energy delivery to consumers is maintained in any case. Actually, one should speak about the quality of energy supply system functioning.

It is recommended to assess complex technical systems with the help of the functioning quality index, which can be presented in the following form [3]:

$$\mathbf{F_x(t) = F[X(t)]}\,, \qquad (1.1)$$

where $\mathbf{X(t)}$ is the vector of the mathematical model of system functioning at moment t.

The value $\mathbf{X_i(t)}$ – it can serve to assess the state of the i-th element of the system. For example, if an element operates, then $\mathbf{X_i(t)=1}$, while in the opposite case $\mathbf{X_i(t)=0}$. Therefore, it is possible to consider, e.g., the regularity (the lack of interruptions) of system operation. If the state of the system changes in a random manner, the quality of system functioning will be presented by the mathematical average of distribution of the random function $\mathbf{F_x(t)}$ at the moment $\mathbf{t}$.

The quality characteristic of system functioning is determined by the goals it should meet. The task of an electric supply system is the reliable supply of consumers with energy in required amounts and of required quality in accordance with a preset functional mode. This is why the function reflecting the quality of energy supply can be presented in the form of a functional, whose arguments are the parameters of energy supply parameters. The complex index of energy supply quality can be presented in the following form:

$$\mathbf{F_x(t) = \sum_{j=0}^{m} P[q_j]\prod_{i=1}^{n} P[(K_{i\,min} \le K_i \le K_{i\,max})_j \mid (q_j \ge Q)]} \quad (1.2)$$

where **j=1;m** are the possible states of an energy supply system;

P[q_j] is the probability that the system will be in condition j, which is characterized by its throughput $\mathbf{q_j}$;

P[(К $_{imin}$ ≤ K_i ≤K_{imax}|(q_j ≥ Q)] – is the probability that the i-th indicator of energy quality $\mathbf{K_i}$ will remain within the preset limits, while the throughput $\mathbf{q_j}$ will correspond to the energy consumption mode Q;

i=1;n – is the number of indexes of energy quality under consideration.

The value of this functional presents an integrated evaluation of energy quality. In such a case as the characteristic of the system functioning quality we should adopt the mathematical average of distribution of the energy, which was received by the customer in accordance with the load schedule, the quality indexes being within admissible limits. A complex index determines the possibility of maintaining energy supply quality, which fact will secure direct transition towards the quantitative evaluation of energy supply quality. To this end, it is necessary to find the average of distribution of energy, which the customer can receive with the preset indexes of quality and within the required mode:

$$\mathbf{E_f = E\,F_x(t)} \quad (1.3)$$

where E – is energy consumed during the period being examined and when there are no violations of energy supply quality.

In energy supply systems the following cases will be in accordance with this statement: 1) in case of a break of energy supply, this value will then be the quantity of energy which the customer did not receive or 2) it will be that quantity of energy, which was received, but of improper quality, used up by the customer during a fixed period of time.

The quality of heat supply in a heat supply system can worsen as result of heat supply interruptions, due to the non-delivery of the required heat quantity (insufficient heating) or due to enforced delivery of a surplus heat quantity to the consumer (overheating). This means that in the capacity of the heat system functioning quality we should adopt an hourly (monthly or yearly) heat flow, which is defined as a difference between the rated flow ($\mathbf{Q_r}$) and the actually delivered flow ($\mathbf{Q_f}$). This difference does determine the heat quantity which was either delivered in excess **(+ΔQ)** or undelivered **(-ΔQ)**, as a result of overheating or insufficient heating (due to interruptions of heating):

$$\mathbf{\pm\Delta Q = Q_r - Q_f} \quad (1.4)$$

Therefore, the possibility of assessing the quality of energy supply as a quantity will be secured.

For this purpose it is necessary to know in what way any worsening of energy supply quality will affect the consumer. These statements fully agree with a general sort of understanding of the physical/mathematical model of energy supply system functioning.

A SYSTEM-BASED APPROACH TO THE PROBLEM OF SECURING THE QUALITY OF ENERGY SUPPLY

In the scientific/practical sense the energy supply problem in terms of its quality should be regarded as a system of mutually linked problems, whose solutions are to be directed at the development of efficient ways of securing the quality of energy supply. It is recommended to investigate a broad range of subjects covered by these problems in three main areas, as follows:

1. Development and improvement of indexes and norms concerning the quality of energy supply.
2. Development and improvement of methods for the determination of economic losses when the quality of energy supply worsens.
3. Development of a comprehensive system of measures aimed at improving the quality of energy supply for consumers.

All these directions contain both technical and economic issues, among which the following points are the most important:

- Determination of indexes and norms concerning the quality of energy supply, energy agents and energy;
- Development of methods to determine the extent of damage due to lower energy supply quality for different consumers;
- Investigation of dependences between the quality of energy supply and the efficiency of functioning of the entire system of FEC, starting from the generation to the functioning consumption of energy;
- control over the quality of energy supply, including aspects like rational organization, planning, incentives, supervision, regulation, etc;
- development and introduction of a system of measures that can secure the quality of energy supply for consumers.

Thus, in order to be able to secure the quality of energy supply, it is necessary to develop both theoretical and practical methods of solving these problems.

Taking into account the specific nature of energy generation, which is reflected in the uninterrupted character of the process of generation, transmission and consumption of energy, and in order to be able to solve the problems that were set, it is necessary to apply a system-supported approach.