# INFORMATION-MEASURING SYSTEM FOR CONTROL AND ACCOUNTING OF ELECTRIC ENERGY

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## ABSTRACT

The issues of building an information-measuring system for control and accounting of electric energy based on electronic meters are considered. In the process of supplying consumers with energy, losses of electricity inevitably occur. Voltage fluctuations, the coefficient of non-sinusoidality, the coefficient of asymmetry do not sufficiently characterize the mode of operation of power plants, substations and power lines. Power and energy are among the most important measured quantities characterizing both the load of the power system as a whole and the distribution of load between individual power plants. The principles of construction of measuring power transducers, which form the basis of electronic meters, with the use of frequency-pulse multipliers are analyzed.
**Keywords:** control, accounting, counters, power, losses.

## INTRODUCTION

The amount of electricity consumed is increasing rapidly every year. Electrical energy currently has a direct impact on everyday life, as it is the most versatile type of energy that can be converted into mechanical, thermal, chemical and other types of energy. The growth in electricity consumption is directly proportional to the increase in the number of power consumers. Modern technological processes, developed and already used power receivers are highly sensitive to distortion and interference in the electrical network.

Providing consumers with high-quality electrical energy is one of the priority goals, and therefore the issues of control and accounting, as well as improving the quality of electrical energy, become the most relevant.

Electricity is a rather specific resource for the following reasons:

• production, transmission and consumption of electricity, due to its physical nature, occur almost simultaneously and it is impossible to store (accumulate) it in significant volumes;

• electricity is supplied by many producers to the public electric networks and is instantly consumed from there by many consumers. Therefore, from a physical point of view, it is impossible to determine who produced the electricity consumed by a particular consumer - one can only control the volumes of supply to the general network from each producer and the volumes of consumption from it by each consumer;

• producers generate and supply electric power to the common network exactly in accordance with their obligations, and all consumers consume electric power in total also in accordance with their obligations. But in practice, due to a variety of circumstances, both producers and consumers allow deviations from their obligations; This causes an imbalance between supply and consumption.

In the process of supplying consumers with energy, losses of electricity inevitably occur. Their value determines the efficiency of energy networks and has a significant impact on tariffs. Given the everincreasing cost of energy resources, accounting for electricity losses and their minimization is one of the main tasks for resource supply organizations and consumers [1].

## DATA AND METHODOLOGY

Loads affect the modes of electrical networks and the power system as a whole. The quality of electrical energy in overwhelming cases depends on the modes and nature of consumers. Non-linear loads cause distortion in the waveform of voltage and current.

Quite a significant number of loads are sharply variable. The power consumed by the loads is not constant over time. A periodic change in power leads to periodic changes in the current of the electrical network and voltage fluctuations, i.e. create modulated modes. Some loads (lighting load, single-phase traction loads, etc.) create asymmetry in three-phase systems.

Voltage fluctuations are one of the main indicators of power quality and are a highly undesirable phenomenon. Sometimes they lead to disruption of normal operating modes in power networks. In addition, the occurrence of modulated operating modes leads to an increase in electrical energy losses [2].

Voltage fluctuations, the coefficient of non-sinusoidality, the coefficient of asymmetry characterize only one value (voltage or current), and this is not enough to assess the quality of the regime. In addition, the listed indicators characterize only one type of distortion [3].

In modern power systems, control rooms receive a large amount of information about changes in parameters that characterize the operating mode of power plants, substations and power lines.

Among the most important measured such quantities are power and energy, which characterize both the load of the power system as a whole, and the distribution of the load between individual power plants. In addition, according to their values, it is possible to determine the participation of certain loads in violating the quality of energy.

A modern system for monitoring and accounting for energy consumption needs two types of measuring instruments: electric energy meters and power meters, or a device that performs both functions. In principle, this can be done, since in both devices the main unit is a power measuring transducer. The implementation of such an accounting system based on old measuring instruments is fraught with difficulties.

Increasing the capacity of power plants and transmission lines, as well as improving the culture of operation of power systems and the use of computers and automated control systems for technological processes lead to the need to achieve increased accuracy in measuring power and energy.

Improving the accuracy of power and energy measurements requires taking into account the peculiarities of energy processes in power supply systems in the presence of loads that worsen the shape of the voltage curve and create voltage fluctuations and asymmetry.

The accuracy of measuring the power and energy consumed by the load in the power supply system is determined not only by the accuracy class of the device, but also by the structure of the measuring device, i.e. depends on how much the applied device takes into account the distorting properties of loads.

Modern technical means of control and metering of electricity should:

- provide with the necessary accuracy accounting of consumed electricity;
- control the consumption of electricity in individual industries, technological installations, etc., i.e. carry out technical control;
- issue the necessary information for the dispatcher to manage electricity consumption or carry out automatic regulation of electricity consumption;
- ensure control and fixation of the increase in the levels of the permitted power consumption limit;

- to control the quality of electricity;
- document the necessary information.

## RESULTS

A structural diagram of an information-measuring system for monitoring and accounting for electrical energy based on electronic meters has been compiled. It is shown that with a rational construction of the system, the accuracy of determining the required parameters is practically determined only by the accuracy of the electric energy meters used, which are based on measuring power converters. A necessary element of these converters is a device for multiplying voltage and current values. The analysis of the principles of building multiplier MD devices showed that, given the widespread use of microprocessor tools in control and accounting systems for electric energy, the construction of digital MDs when using and expanding the functionality of linear converters of the frequency-time group is of considerable interest. The issues of constructing an MD for measuring electric power in single-phase and three-phase circuits based on a voltage-to-frequency converter with impulse feedback are considered in detail. The advantage of this circuit of the measuring power transducer over others lies also in its speed. The formation of instantaneous power is carried out during the clock period with virtually no transient process. Theoretical studies have shown that the device fully meets the requirements for a class 0.5 meter.

## DISCUSSION

The structural diagram of the information-measuring system for monitoring and accounting for electric energy is shown in fig. 1.

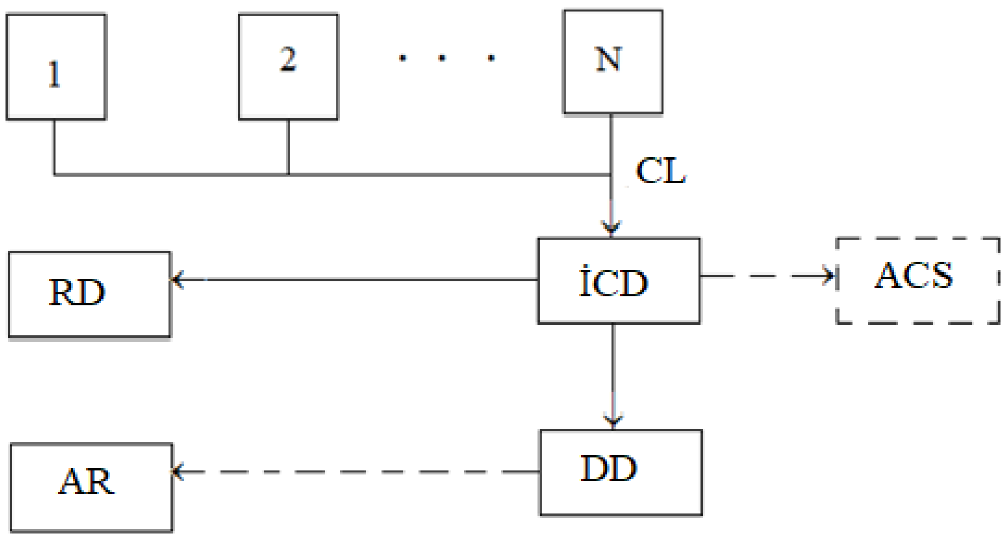


Fig. 1. Structural diagram of the information-measuring system.

Direct communication channels are provided here from meters 1, 2, ..., N to the information and computing device of the ICD system, therefore the latter is suitable for compactly located enterprises with the transfer of information via CL communication lines from meters-sensors. For subsequent processing of information, access from the ICD of the system to the automated control system ACS, the registration device RD, the dispatcher DD device and the automatic load regulator AR is provided.

With the rational construction of the ICD system, the accuracy of determining the required parameters is practically determined only by the accuracy of the electric energy meters used and the cost of their output pulses.

As for the metering of electric energy, it seems appropriate, if necessary, to supplement the system with a separate structural branch with the release of information to the RD (printing, registration) and an ACS computer or micro-computer for calculating the final indicators of the quality of electric energy.

Despite the fact that it is possible to use induction meters in information and measuring systems, the most suitable measuring devices are electronic electricity meters.

The basis of electronic energy meters is measuring power converters. Electronic active energy meters are built on the basis of a power converter with subsequent integration of its output value in accordance with the dependence

$$W = \int_{t1}^{t2} Pdt \,. \qquad (1)$$

One of the possible structural diagrams of such a counter is shown in Fig. 2,

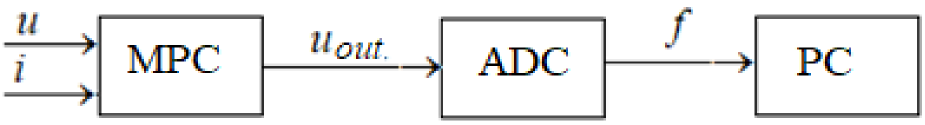


Fig. 2. Structural diagram of an electronic active energy meter

where MPC is a measuring power converter; ADC - analog-to-digital converter with frequency-pulse output; PC - pulse counter. The output value *Uout* is proportional to the active power P. Using the ADC, this value is converted into a pulse frequency *f*, which is proportional to the power P. The output pulses of the ADC are counted (integrated) by the PC pulse counter. Therefore, the PC readings are proportional to the active energy W.

As mentioned above, the basis of electric energy meters is power measuring transducers. The operation of active power converters is based on the implementation of the dependence

$$P = \frac{1}{T}\int_{0}^{T} uidt \,, \qquad (2)$$

where P is the measured power; T is the period of current *i* and voltage *u* on the load.

It follows that the necessary element of the converter is a device for multiplying the values *u* and *i*.

The analysis of the principles of building multiplier MD devices showed that, given the widespread use of microprocessor tools in control and accounting systems for electric energy, the construction of digital MDs when using and expanding the functionality of linear converters of the frequency-time group is of considerable interest.

The reason for this is both the simplicity of digital measurement and further processing of frequency and time-pulse signals, and the accuracy and noise immunity sufficient for practice of integrating converters of the measured value into the pulse frequency or into the time interval.

Research in the direction of expanding the functionality of methods and tools for converting measuring information, analysis and synthesis of the structures of converters of the class under consideration have shown that the most appropriate in terms of ease of implementation and ensuring sufficiently high metrological characteristics, the principle of constructing MD is to use the functionality of linear voltage-to-frequency converters (VFC ) and voltage per time interval (VTI).

The presented material discusses in detail the issues of constructing an MD for measuring electric power in single-phase and three-phase circuits based on a voltage-to-frequency converter with pulse feedback (VFC FB).

The advantage of such converters is the independence of the transformation function from most parameters and nodes.
The converter parameters do not depend on the capacitance values in the integrator circuit and the reference voltage and are determined only by the ratio of the summing resistances of the integrator $R_1$, $R_2$ and the stability of the feedback pulse area $U_0t_0$. In addition, since this converter integrates the input signal, the noise contained in the input signal is reduced. Such converters can provide a sufficiently high conversion accuracy [4].
The multiplication operation in the MD, built on the basis of a linear VFC FB, is performed by providing a hyperbolic relationship between the duration of the feedback pulse and the input voltage [5].
As is known, the pulse frequency of linear VFC FB is determined by the dependence of the form

$$f = \frac{R_2}{U_0 t_0 R_1} U_x \ , \qquad (3)$$

where $U_0$ is the amplitude, $t_0$ is the duration of the feedback pulse.
By providing certain functional dependencies between the input voltages and the FB pulse parameters, it is possible to create various functional ADCs of the frequency-pulse conversion.
In particular, by providing a hyperbolic dependence between $t_0$ and $U_x$, it is possible to build a functional pulse-frequency converter on the basis of the VFC under consideration, which makes it possible to perform the operations of multiplying and squaring the input signal.
The structural diagram of the MD, built on the basis of this converter, is shown in fig. 3.
In this scheme, the hyperbolic dependence of the FB pulse duration on the input signal is provided by sweeping the latter with a hyperbolic voltage.

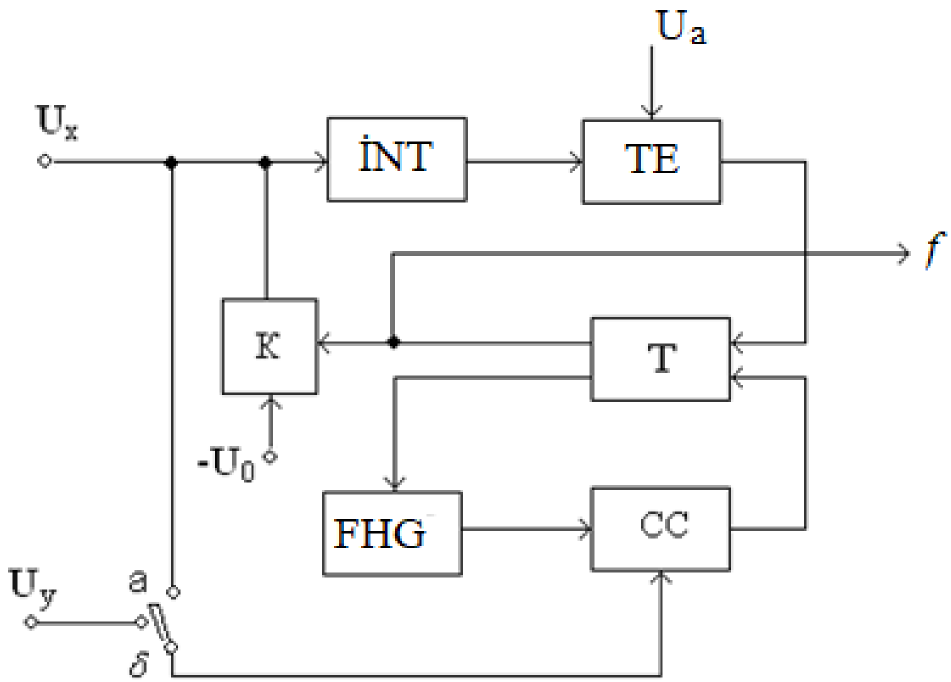


Fig. 3. MD scheme based on a functional pulse-frequency converter, where
INT - integrator; TE - threshold element; FHG – functional generator of hyperbolic form;
CC - comparison circuit; K - key; T-trigger

In the initial state, the switch K is open, only $Ux$ is supplied to the inputs of the INT integrator and the comparison circuit CC (the switch is in position a).

At the moment, the output signal INT reaches the actuation level $U_a$, the state of the trigger T switches. As a result, the key K closes and the functional hyperbolic voltage generator (FHG) is turned on. Upon reaching output signal $U_f(t)$ FHG level $Ux$, CC returns T and FHG to its original state. The process is then repeated periodically.
Taking into account the law of voltage change FHG

$$U_f(t) = \frac{K_g}{t} \quad , \qquad (4)$$

the FB pulse duration is

$$t_0 = \frac{K_g}{U_x} \quad , \qquad (5)$$

where $Kg$ is a constant coefficient.
Taking into account (4) in (3), we obtain the following transformation function:

$$f = SU_x^2 \quad , \qquad (6)$$

where S is the static transfer coefficient of the converter.
When the switch is set to position *b*, the frequency of the output pulses will be proportional to the product of the voltages $U_x$ and $Uy$, i.e.

$$f = SU_xU_y \quad . \qquad (7)$$

The number of converter pulses per period will be proportional to the active power.
The most characteristic unit of this converter is the FHG, which is included in the pulse FB assembly. FHG can be built by dividing the constant voltage by the linearly changing voltage; on an integrating amplifier with an FB circuit, which includes a linear semiconductor resistance with a quadratic characteristic; based on the summation of functions that are members of a power series, etc.
From the point of view of ensuring high accuracy of formation $U_f(t)$ and ease of implementation of FHG, it is of interest to use the principle of modeling functions by expanding into a series of the simplest signals. In this aspect, the use of the method of approximating the modeled dependence by exponential functions deserves attention.

## CONCLUSIONS

Providing consumers with high-quality electrical energy is one of the priority goals, and therefore the issues of control and accounting, as well as improving the quality of electrical energy, become the most relevant.
Automation of electricity metering and control is an important means of improving energy efficiency. Loads affect the modes of electrical networks and the power system as a whole. The quality of electrical energy in overwhelming cases depends on the modes and nature of consumers.
The most important measured quantities characterizing both the load of the power system as a whole and the distribution of the load between individual power plants are power and energy.
Despite the fact that it is possible, to use induction meters in information-measuring systems, the most suitable measuring devices are electronic meters of electric energy, which are based on measuring power converters.
An increase in the capacity of power plants and transmission lines, as well as an increase in the culture of operation of power systems and the use of computer technology and automated control systems for technological processes require an increase in the accuracy of measuring power and energy, which is determined not only by the accuracy class of the device, but also by the structure of the measuring device.

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