

## ON MASS MODERNIZATION OF INSTRUMENT ELECTRIC POWER METERING IN THE REPUBLIC OF BELARUS

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*The spontaneous modernization of instrument electric power metering in the Republic of Belarus, based on the replacement of induction watt-hourmeters by modern electronic microprocessor programmable meters, began 10 years ago. At the end of 1996 the first thirty electronic meters type ALPHA (made by Russian-American joint-venture “ABB Metronics”) were installed in the Belarusian power grid at the cross-flows with the neighboring states. The spontaneous process of installation of different electronic meters in power supply system and industrial enterprises continued up to the year of 2003, when it became clear that it should be brought under industrial or even state control. Therefore, “**The concept of instrument electric power metering in the Republic of Belarus**” White Paper was developed. In 2004 branch requirements to automated meter reading of different types (national, regional, industrial and residential) were elaborated and approved. The result of a number of preparatory measures was the Council of Ministers Regulation N 847 dated 02/08/2005 “**On the introduction measures of automated meter reading in the Republic of Belarus**”. To put the Regulation into effect, the Program of realization efforts on it was elaborated and the above mentioned Concept was approved by the Ministry of Energy. One of the steps of this Program is the creation of an absolutely new Paper – “**Technical Code of Instrument Electric Power Metering in the Republic of Belarus**”. We prove in the article the ideology of the decisions taken and its main principles that form the basis of the elaborated documents and determine the process of mass modernization of instrument electric power metering in the Republic.*

### SOME PREHISTORY

For more than 50 years the instrument metering in the USSR, and later in the Commonwealth of Independent States, has developed on the basis of mass application of single-phase and three-phase one-tariff induction power meters and the methods of local visual meter reading and further manual data processing. In the 1970-s, in order to regulate the consumers’ schedule in the peak hours of the USSR Power Grid by means of economic incentives, a binary tariff system was worked out (charging for the consumed electric energy and the claimed power for the enterprises with the connected power over 750 kVA). Therefore, first automated meter reading (AMR) systems were developed.

Inductive power meters, being quite primitive in construction and monofunctional, could not register the power maximums of consumers working load. Therefore, for the last thirty years the main ideological course of AMR development has become equipping the induction meters with remote-reading pulse sensors that automatically process power impulses of sensor meters at the secondary reading devices – summators or other special computer system. In this direction, dozens types of different systems were elaborated and put into commercial production, and the production of AMR instruments with unit-counting data collecting has become a separate branch of engineering.

At the beginning of the 1970-s, the first electronic power meters appeared in Europe. As distinct from inductive meters, they had a “built-in intellect” for more complicated functions than mere accumulative energy accounting. (The similar meters were also produced then in the USSR, e.g. at Vilnius Metering Technics Plant, at Stavropol Scientific Production Association “Quant”, at Leningrad Electro-Mechanical Plant.) Almost simultaneously the first microprocessors appeared in the USA. But over 20 years passed before microprocessor technology, combined with power metering methods, led to creating programmable multifunctional microprocessor electronic power meters of mass application. Such meters appeared in the expanses of the Commonwealth of

Independent States at the beginning of 1990-s as products of Western technologies, but since the middle of 1990-s their production has already begun at Russian factories, such as Federal State Unitary Enterprise “Nizhniy Novgorod Plant of a name of M.V.Frunze” (1994 – the first Russian commercial electronic single-phase meters) and the Stavropol Concern “Energomera” (1996 -- the first Russian commercial electronic three-phase meters). The first Belarusian one-phase electronic meter was produced by Vitebsk Metering Devices Plant in 1999, and the first three-phase meter – by Minsk private enterprise “Grand System-C” in 2001.

### **FROM PRINCIPLES TO CONCEPT**

The appearance in the market of instrument electric power metering devices of various single-phase and three-phase multitariff electronic meters has put a dilemma for AMR developers: whether to go further by usual way of creating systems with remote unit-counting data collecting from inductive sensor meters or electronic meters with telemetric outputs, or to pass to a new principle of power metering using modern electronic meters. The new important properties of electronic meters, influencing the formation of AMR new principles, are first of all:

a) “intellect”, or multifunctionality, allowing to unite in one meter reading of both active and reactive power in two directions at the same time, measuring energy quality parameters, recording various events and other features;

б) “time sense”, or built-in clock and calendar, giving the possibility to synchronize a meter’s collected data with the data of other meters working in the AMR;

в) “memory”, or storage device, allowing long-term storage of the information for different time periods in the meter’s database and usage of this base as the only certified source of measuring and accounting for further supply of the information to its various users.

Full usage of these opening possibilities became available only in case of rejecting the unit-counting data collecting principle (on the basis of this principle thousands AMR systems had already been put into practice in power supply systems and industrial enterprises of the Commonwealth, first of all in Belarus and Russia) and passing to the principle of data collecting via digital interfaces. Only the digital interface with the corresponding communication protocol allows to address to any piece of diverse information inside the meter, to use all its possibilities in full measure and, moreover, to significantly increase reliability of remote data receiving at the upper AMR levels (after all, if any mistakes in communication channels occur, there is always a possibility of repeated requests of information from the meter’s database).

Passing to new principles of instrument electric power metering has been connected first of all with psychological breaking of the settled stereotypes and solutions. It was not easy for me, as the creator of one of the first in the USSR microprocessor AMR systems (the systems ИИСЭ3 and ИИСЭ4 were produced in thousands at Vilnius Metering Technics Plant from 1984 to 1992) and the apologist of unit-counting data collecting systems, to give up my bygone opinions and comprehend new ways of AMR systems development. One of my first articles on this topic, “Modern principles of automating electric power metering in power supply systems”, in which new approaches to AMR systems creating were clearly declared, was published in Belarusian journal “Automation from A to Z” in 2001—2002 and later in Russian “Electrotechnology News” in 2003 and other journals. I am aware of the fact that it was not easy as well for many Russian AMR manufacturers to reject bygone approaches and pass to “generation next” systems production.

Later “The concept of instrument electric power metering in the Republic of Belarus” was developed on the basis of the new principles. “The Concept” was all ready at the beginning of 2003, but only towards the end of the year 2004, they managed to overcome the resistance of its opponents in the person of the Ministry of Industry. The Ministry officials and the heads of some instrument-making plants turned out to be not ready to the perception of power metering new principles and creation of metering devices according to the Concept. But nevertheless the modern, in spite of out-dating technologies resistance, paved its way to the future.

### FROM CONCEPT TO TECHNICAL CODE

The Belarusian market of electric power metering instruments, as well as the Russian, counts hundreds names of various devices of dozens producers from different countries. Every producer strives to promote its production made according to their own potentialities and certain amount of general requirements, including the standards requirements. If the buyer of metering devices does not have his own policy and clear rules of electric power metering, then he becomes a puppet in the hands of the producers and their representatives, purchasing and using not that he “needs” but what he “is given”. As a result, it may happen that the effect from energy accounting, having been spent considerable amounts of money and efforts on, becomes illusive. In Belarus, according to the Concept and the Program of measures on AMR systems development, about 500 million dollars are to be spent in the nearest future on creating modern energy accounting, and that money must give the wanted effect.

For quality rating of the AMR devices offered in the republic by domestic and foreign suppliers, there have been conducted tests on current transformers, electronic single- and three-phase power meters, and also several AMR systems of different types and producers for domestic customers have been installed and tested on real dwelling objects. The experiments have shown that neither a single meter nor a single AMR system corresponded fully to the requirements of Belarusian standards. Each device has certain weaknesses. To legalize the results of the conducted tests, the regulation *“On branch recommended index of means of electric energy commercial metering”* (approved by the Ministry of Energy on 29<sup>th</sup> April 2005) were developed and the *“Branch recommended index of means of electric energy commercial metering for applying as a component of AMR”* (hereinafter - Index) itself, published already in two editions (the new, third edition being prepared towards autumn) in 2006.

But to reveal the devices discrepancies, it was necessary to form and approve beforehand what is a “must”, that is the requirements to the meters and to AMR system as a whole. These temporary branch requirements were formulated in 2004 and approved by the concern “Belenergy” for four kinds of AMR systems: national (metering interstate and intersystem cross-flows and generations), regional (regional power supply systems), for industrial enterprises and for residential customers. The formulated requirements have allowed influencing the producers of metering devices, demanding that their production possess certain range of properties, be reliable and of high quality. The Index has become one of the methods of such influence, as it includes only those devices from the State register of measuring instruments that correspond to the branch requirements

(with a set of minor remarks that must be removed by the producer during a fixed period of time) and have been tested in the branch evaluation centre or at the experimental objects.

The Principles, the Concept, the Requirements and the Index have become a prelude to elaboration of “Technical Code of Instrument Power Metering in the Republic of Belarus” (hereinafter – the Code). The Code is to become the main document that should define the strategy and tactics of instrument power metering for the future decades regardless any re-structuring in the power supply system and for any groups of consumers. As a basis it must have such regulations that will not become outdated at least within the nearest 10 – 20 years. For this purpose, the Code should head for most modern principles of energy accounting, as well as foresee the future progress in metering techniques. In this respect, the Code is to be considered as an ideal and the main stream of instrument power metering development, and not as a statement of the present unsatisfactory condition in this sector of power industry and economy (though, by definition, the technical code must take into account the historically determined metering practice). Such approach requires careful putting into action, for almost all the existing commercial power accounting systems may become unlawful at once.

The Code has been created in the environment of certain preteritions and presuppositions. Some of them are examined below.

### **THE CODE. WHAT IS IN?**

One of the first ideas that is stated in the paragraph “General Provisions and Requirements” is the notion of electrical energy as merchandise, and not as some free and vital resource, such as air for breathing. This idea may have not been reflected in the Code, but in Belarus there is yet no other document (except for the Concept), where this statement would be clearly defined (“electrical energy as merchandise” is implicit in Civil, Housing, Customs and other codes). The Law on Power Industry, which should possess the appropriate definition, is in stage of development (to be more precise, in the stage of expectation of certain economic conditions). Meanwhile, the whole Code’s strategy is based on the idea that such expensive and high-liquid merchandise as electrical energy is to be under close system control and account at all stages of its technological and economic circle.

The next question arising in the Code is a question of what kind of energy is to be considered merchandise: active, reactive or full? Our energy accounting traditions regard as merchandise only the active energy, for it is this kind of energy that turns into other useful forms of energy in consumers’ electroreceivers. The reactive energy has been always looked upon as interfering by-product. In the times of the USSR for reactive energy generation or compensation they imposed extra-charge or gave discounts to the active energy price. Hot discussion of the topic is still going on and on various journals’ pages as well.

But for the power supply system the reactive energy has always been the unavoidable attribute of energy technological circle, influencing its technological and economic efficiency. Therefore, it would be logical to regard as the merchandise the full energy, the reactive component being merely “the cost of packing” in the merchandise price calculation. In such case, for energy accounting it would be necessary to install everywhere rather expensive full energy meters (about 4 million meters in Belarus and over 60 million in Russia). In the Code they chose the traditional way of active energy metering at all points of account and reactive energy metering at selected points. Nevertheless, it is not excluded that in the long-term future we will have to pass to the accounting of full energy as merchandise.

Traditionally, a power meter has been considered the major and the only metering tool in instrument electric power metering. The particular feature of the new code is a system and global idea of automated power metering, in the context of which the meter is no more autonomous but only an element of the correspondent AMR system. An important element, but just an element. Apart from the meters as primary measuring devices (here also belong current and voltage measuring transformers), there appear in AMR system secondary measuring devices – specialized (such as data concentrators) and generalized (computers and computer networks with AMR correspondent software). The integration of all the above mentioned devices into a complete

metering system is carried out via communication channels. Standard requirements to AMR systems for various power industry objects and energy consumers are formulated in the Code.

Another particular feature of the Code is a system and global idea of applying as an accounting meter microprocessor programmable electronic meter with digital interface and standard open protocol of data exchange via this interface. The Code puts a veto on using for commercial metering the systems with unit-counting data gathering, leaving them only for technical metering with certain reservations though. At present time the unification of digital interfaces protocols of different producers' meters, from the Code's standpoint, acquires especial topicality. Unfortunately, so far every manufacturer develops its own protocol, what for the production consumers creates problems of different meters integrating within an AMR system.

The next Code's fundamental thesis concerns the global usage of principle of electrical energy and power balance for every object of account. The necessity of balance calculation was also mentioned in the former instruction on instrument metering, but at that time they had no means to realize the idea. It is the AMR system only, with the efficient remote data collecting and automated data processing, that can cope with the task of balancing, defining non-balance and revealing energy losses. For reliable and efficient balancing, the former metering methods based on statistics are to be minimized, and the methods of balance account based on direct metering within the AMR system are, on the contrary, to be developed. The Code suggests hierarchical approach to balancing and losses revealing over the objects of account, using for this purpose the data of technical metering as well.

The major aspect of AMR mass applying consists in permanent control over metering capacity and reliability of all the primary and secondary metering devices. Such control warrants timely trouble-shooting in the metering equipment, revealing unfavourable and/or unauthorized external actions on metering devices, and in the long run, it ensures high trustworthiness of instrument power metering and the power system resistance to energy thefts.

Essentially new are in the Code the comprehensive and strong metrological requirements to all metering means, beginning with measuring transformers and ending with the AMR software. The metrological requirements to the measuring devices are differentiated according to the point of account significance, the voltage level and annual load. The Code introduces the difference between the point of measurement and the point of account, which was not present in the earlier documents.

An important moment in creating the AMR under the Code is providing an all-round protection of measuring means and commercial information from unauthorized access. The protection must be consistently carried out both for every single measuring device, and for their communications, including appropriate communication channels protection and the AMR software protection.

The Code pioneers in integrating energy accounting with modern information technologies. Energy engineering acquires new complicated concepts from computer techniques, communications technologies and programming; there appear complex tariff systems and new economic notions. Energy accounting becomes an allied branch of science, synthesizing different fields of knowledge and technics. Therefore, the Code contains a detailed glossary of the essential terms and definitions from all the mentioned disciplines.

## CONCLUSION

Thus, the Code, though borrowing some theses from former Belarusian and Russian instructions and regulations, is nevertheless a document of qualitatively different contents and form. The early versions of the document have caused ambiguous reaction among the power engineering specialists. Currently, the fifth edition of the Code is being approved of by power systems, and after that the sixth, probably, final edition will be submitted to the approval of the Ministries and Departments. The document is open to constructive criticism, suggestions and remarks that can be sent both to the editors and the developers: [beltei@rambler.ru](mailto:beltei@rambler.ru) (on this address you can also ask for an electronic version of the Code). The accepted document will become defining in the process of mass modernization of instrument power metering in the Republic for the nearest years (according

to the Program of measures on AMR creating, the process of modernization must be completed by the year of 2012).

## AFTERWORD

*Editor-in-chief of “” journal B. Rubenchik (B.R.) met the author of the article (A.G.) and asked him a number of questions in order to obtain more specific information on the problems concerning the topic under review.*

**B.R.:** *Why has the necessity arisen to develop the Concept and new principles of power instrument metering?*

**A.G.:** The Concept is a system of views, reflecting one's comprehension of a process or a phenomenon. In our situation, the Concept reflects the comprehension of what general organizational and technical principles should underlie the development of electrical energy accounting in the power systems of the republic and for all groups of consumers within the nearest 20 – 30 years.

The main reasons of the Concept creation are connected with the necessity of improving power industry efficiency, reducing its expenses and its adaptation to new market economy. As a result, there arises the necessity of mass replacing the technology of commercial power metering based on inductive meters with manual data reading and accounting by automated meter reading technologies, which are based on electronic power meters, digital interfaces systems and modern communication channels, and use computer networks to store, process, display, control, document and account the produced, transmitted, distributed and consumed energy and power.

The fact is that for the last hundred years the main power metering device in power supply system and among consumers has been the inductive power meter, one of the prototypes of which was invented by Edison as far back as 1881. At present time in Belarus about 4 million inductive power meters are in use, of which 3,5 millions are single-phase and about 500 thousand three-phase ones. Among them electronic meters do not make up even one per cent for the present day. In the new conditions of the sharp rise in price of energy supply and electric power, the coming restructuring of power supply system, passing in the long run to wholesaling and retailing energy markets, transfer of power supply units to complete self-sufficiency, the cross-financing and state subsidizing being ceased, -- the efficiency of account technology based on inductive meters has abruptly fallen.

In the first place this is due to significant measurement errors in inductive meters, and the errors increase in the operational process during intercalibration interval, moreover, in practice the interval is often not observed because of the limited resources of power supply services. The researches have shown that due to metal deterioration and attrition wear of electromechanical meter, its relative error becomes negative and increases annually, depending on the meter's actual load, by 1-1,5%. If when calibrating and adjusting the meter, e.g. of class 2, its error is put in the power system laboratories as “plus”, and during the first two years such meter works in favour of the power system (by the way, this feature of inductive meters has been regarded as “an advantage” by some apologists of the traditional metering), though all the following years, up to the time of a scheduled calibration, it works in favour of the consumer, in particular, after 8 years of its operation its error in favour of the consumer can rise up to 8-10%.

A specific investigation of Main State Energy Supervision Authority of the Russian Federation, carried out in Moscow region as far back as 1994, has shown that according to their metrological performance, rejected as defective were 40% of three-phase inductive power meters with the operation time 1–3 years, 46% with 4—10 years operation time and 51% with 11—16 years. These figures are even more sizeable for single-phase meters: 33% for 1—3 years, 56% for 4--10 years, 64% for 11--16 years and 97% for 17-21 years. According to mass metrological verifying, carried out in electric department of the Republic Unitary Enterprise “BrestEnergy” in 2005, rejected as defective are up to 30% of domestically produced single-phase meters after 8 years of operation and up to 45% of three-phase inductive meters after 4 years of operation (and the error of the meters increases up to the average of 6--7%, and with certain items up to 50%). For the sake of fairness, it should be noted that certain foreign meters kept their error in class even after 50—60 operation years.

It should be noted that inductive meters error and, therefore, power systems losses resulting from consumers' energy under-account increase sharply when the real load falls down to the level of 5-30% of the rated load, what often happens in practice. Earlier, at the times of cheap energy and the common Soviet Union's “stock”, the abovementioned errors were not paid proper attention to, as everything was written off to this “stock”. The situation has changed with the division of the “common stock” in the post-Soviet area,

the appearance of independent states, ownership separation and its new patterns appearance. It has been yet aggravated with the sharp load drop in power system as a result of industrial economic recession of many years. Thus, to keep disregarding such important drawback of inductive meters meant to bear costs. At the same time, in the middle of 1990-s there appeared mass electronic meters devoided of such drawback (I would like to remind you, that the first electronic meter appeared in Europe in 1972, but then it was too incomplete and expensive for the mass application).

**B.R.:** *I guess, it is not the only reason for the necessity of the inductive meters replacement with the electronic ones?*

**A.G.:** You are quite right. Apart from their metrological drawbacks, the inductive meters have some fundamental functional restrictions. In the new conditions of struggling for energy costs reduction and power industry efficiency improvement, the role of economic incentives has increased and particularly the role of tariff systems.

From the very beginning of its appearance the inductive meter has been oriented for one-tariff system of accounting and payment for the generated/consumed electrical energy, that is the payment for the energy consumed as a progressive total for the account period. This tariff allows consuming the energy at the same conditions regardless of day or night time, days off or holidays, seasons of the year. As a result of natural human rhythms the maximum energy consumption steadily corresponds to the most active period of the morning (industrial maximum) and the evening (residential maximum) hours, with the downfalls at night time, resting hours and days off. Such synchronous unevenness of the load profile of a great number of consumers has caused additional expenses for the power system. There has arisen the necessity of creating peak generating supplies at thermoelectric power stations, covering the peak loads and, adversely, unloading generating supplies at the hours of load downfall, that has caused additional fuel consumption and fast energy equipment deterioration.

To solve these problems of power systems uneven profiles, in 1968 in the USSR double-rate tariff was introduced for big industrial enterprises that meant the basic payment for the claimed capacity in the peak hours of the power system and the additional payment for electrical energy. It was back then when there appeared the problem of two-tariff accounting on the base of inductive meters that were not fit for recording the maximum power. For new tariffs accounting there were developed special accounting systems (AMR systems), and the meters were equipped with built-in pulse transducers that communicated to the system the meter's speed and the data were further used for power calculation.

The inductive meters replacement with the electronic ones to a great extent changes the opportunities of creating and using various multi-tariff systems for the purpose of regulating the power system load profile. At the same time the consumer's energy expenses can be reduced owing to flexible tariffs that take into account the peculiarities of energy consumption of this or that typical group consumer. Multi-tariff systems based on the usage of modern multi-tariff electronic meters change the communication style between the power system and the consumer from the administrative to the economic one, and this is of great importance for regular interaction of the power system and the consumers.

The power system of the Republic is characterized by uneven load profile created by all the energy consumers. Usually for the power system peak covering hydroelectric and pumped-storage power stations are used (as, e.g., in Lithuania) that are not present in Belarus. Therefore, the only effective instrument for load covering in the Republic is regular interaction with the consumers through the tariffs and appropriate systems of control and account.

**B.R.:** *What is the use of applying electronic meters with the digital interfaces particularly?*

**A.G.:** The Concept and Technical Code emphasize that commercial energy accounting must be based not simply on electronic meters, but on the meters with the stored data base of measurements and the access to this data base through digital interfaces. The principle of pulse transmission of energy increments in the meter (whether it is inductive or electronic one), used in most today's AMR systems, in the long run should be eliminated as being uncertain and unreliable. The loss of pulse increments in the process of their transmitting from the meters to the upper AMR level cannot be filled up. This fact lowers the accuracy and reliability of the commercial information and lessens the value of wide functional features of electronic meters that can show most varied information through digital interfaces and not only current energy and power reading. The digital interface allows repeated referring to the information stored in the meter; this eliminates communication channel influence onto the information trustworthiness.

**B.R.:** *What is the importance of the communication channels in the AMR systems?*

**A.G.:** The accounting technology based on inductive meters used episodic manual data pickup from the reading scale and their further recording in the registration book or the data base for storage and accounting. When there have appeared the AMR systems with the remote impulse collection of data on the

energy increments from the meters onto special systems of account (summaters, controllers), two kinds of communication channels came into being: two-wire communication channels from the meters to the systems (they were considered as part of measuring channel) and the communication channels from the systems to the AMR upper level computers (upper level channels). The requirements to the measuring channels were the transmission of the current impulse 10-12 mA with 10Hz frequency, and the requirements to the upper level channels using digital data transmission varied a lot. In the capacity of such channels were used leased and switched telephone lines, high-frequency communication channels, radio channels etc.

The Concept and the Technical Code permit using for the purpose of digital data transmission from the meters or systems of account to the AMR upper level a wide range of digital interfaces and channels including the above-named as well as cellular, satellite, rf modem and other communication channels, the Internet among them. The recommended transfer rate is 9600 bps and more. The aim of using communication channels is to avoid manual data pickup replacing it with the remote one, to provide time synchronization at all control points and minimization of delays in collecting current reading data. At the same time, in certain cases it is allowed to use portable control panels and palmtop or briefcase computers for data collecting from the systems of account (but not from separate meters). Such solution should be looked upon as intermediate, temporally permissible due to certain economic or other reasons.

**B.R.: *What role is assigned to computer processing of the metering data?***

**A.G.:** The first systems of remote energy accounting worked out in the middle of 1970-s could autonomously perform the complete functions of collecting, processing, displaying and documenting the reading data. For this purpose they had built-in or remote displays, control panels, printing devices. Since the middle of 1980-s such systems have been connected to small computers in order to improve data processing, displaying and documenting performance. Since the beginning of the 1990-s for this purpose have been used personal computers based on microprocessor devices.

At present the AMR systems are built as two- or three-level systems having electronic meters at the lower level, special systems of account (controllers) at the medium level and computers or computer networks at the upper level. Computers have become and will stay the essential part of AMR in the future, taking the "lion's share" of the functions that were earlier carried out by medium level systems of account. Thereby, these systems will transform into simpler devices of data collection and transmission (data concentrators). Most functions of energy data processing, control, management, displaying, documenting and accounting are transferred to computer level.

Thus, the Concept and Technical Code preset the main organizational and technological directions, in the framework of which commercial energy accounting should develop in the future. The epoch of inductive meters and the related principles therein passes over, being replaced by the epoch of energy accounting based on high information technologies. Of course, it is difficult to carry out such a large-scale transition at once, there should be a certain transition period, the duration of which depends on the particularities of power industry demonopolizing and restructuring, the formation in it of ownership rights and providing appropriate investments in accounting reorganization.

The above-mentioned documents describe in detail the main general principles of automating energy accounting that must be followed in order to provide the creation of effective AMR systems for power system units and power industry markets.

**B.R.: *Could you dwell on the principles in particular?***

**A.G.:** I will name them, giving a brief comment, in the order they are presented in the corresponding Part of the Concept.

1. The principle of "measuring everything what is necessary and economically feasible". It is common knowledge that in power system electrical energy is measured at far from all points where it should be done. As a result, many important values such as amounts of losses in power networks are not measured, but calculated according to the approved procedures that contain a lot of rather relative statements. At one's wish, manipulating the loss factors, they can get any supposedly well-grounded amounts of standard losses that are included into tariff and provide salaries and profits to power industry. But if you have direct balance measurements of losses with the meters, there will appear quite different figures that can exceed standard losses by several times. Russia and the Ukraine have already experienced it. Without direct measurements it is rather difficult to estimate the actual state of affairs and take correct decisions.

2. The principle of "long storage of the initial energy accounting database with metrological certification at the measuring point". It is the base for providing identity of measurements as the information in this case comes to all the entities concerned from the same source. This very principle also guarantees information reliability and trustworthiness (with the reliable meter), its total correspondence to the energy progress in the control point.

3. The principle: “geographically distributed databases of the electronic meters information must be synchronized with the current time zone”. This principle ensures the measurements identity in the actual process of energy consuming and receiving reliable time-matched power and energy reading. The mistiming in a large-scale AMR system should not exceed 3 seconds. With a view to ensuring national safety it is prohibited to use American GPS network and such receivers.

4. The principle of “tariff meter features allowing to use both the existing tariffs and the forward-looking ones that differ from the working ones in a larger number of tariff zones”. The meter’s lifetime is defined as 30 years. During this period tariffs should change and not only once. The meter must allow new tariffs realization by way of it reprogramming, but not replacement, what is not provided in most models of currently produced meters.

5. The principle of “physical digital interface of the meter that must belong to the international standard interfaces class (de facto or de jure) and the logical interface (the protocol) that must be open and have a full unambiguous consistent description in the national language of the Republic of Belarus”. It is prohibited to use in the AMR systems the meters with the secret proprietary protocols and all the more the ones not having a documentary description of the protocol. The AMR systems should not be dependent on the dictates of a certain firm – the equipment supplier. The openness of the protocol allows, at the early stages of AMR designing, to carry out the comparative analysis of various producers meters according not only to their technical features, but also telecommunicational ones and thus make a more reasonable choice of the AMR equipment. The existing electronic meters of various producers as a rule possess different physical and logical interfaces; this creates significant difficulties for the users to combine these devices in the framework of their AMR systems. Interfaces and protocols unification is the problem number one for electronic meters manufacturers.

6. The principle: “the agent’s AMR system is built on the base of corporate computing network (CCN), the server or working stations of which via appropriate communication channels receive metrologically certified data either directly from electronic power meters or from AMR medium level data concentrators”. The main function of the concentrator consists in concentrating the meters data and multiplexing the communication channel with CCN. If a high-speed broadband communication channel is used and there is no necessity to calculate the balance of energy immediately at site, at the object of account (e.g., not serviced substation) the data concentrators may be left out as a redundant part of AMR system. In certain cases CCN can be replaced by a personal computer.

7. The principle: “the databases of AMR main level meters must have full or partial backup in CCN database of a corresponding agent, be periodically filled up and stored therein for a long time (years)”. This principle allows to increase AMR vitality, data trustworthiness in the long-term outlook, as well as to provide comprehensive short-term and long-term analysis and the forecast of energy supply processes.

8. The principle: “the AMR software should correspond to the metrological characteristics of its hardware and have unauthorized access protection using standard security means (access passwords, protection keys, event records)”. In particular, the software must identify and verify the access agents, terminals and communication channels.

9. The principle of “the impossibility for the AMR system to solve problems of industrial control systems and telemonitoring dispatcher control systems”. AMR and other systems, though they are all real-time systems (pseudo-real, to be more exact), but they differ a lot not only in their objectives, but also in the time discontinuity and control intervals. At the same time AMR systems can produce additional information to industrial control systems and telemonitoring dispatcher control systems. These features are defined first of all by communication channels traffic.

10. The principle: “the communication channels type and traffic should conform to the problems being solved at the upper level of the agent's AMR system”. As it was mentioned above, the recommended transfer rate for AMR communication channels is not less than 9600 bps. The communication channels can be specially created for the AMR system or be separated for the AMR requirements from communication channels designed for operating with the agent’s other engineering systems.

There may have been formulated a larger number of the principles, but these just listed ones have come from the main practical problems and determine the general directions of their solving.

**B.R.:** *The creation of large-scale AMR systems in power systems and for the consumers demands, as you said, considerable capital investments. But what is then the efficiency of the AMR systems themselves?*

**A.G.:** The objects of automating energy accounting in power system are power generating sources, power networks and their branches and various groups consumers. Each structure object of the energy sector incurs certain expenses for AMR creation, so the results of capital investments should be estimated in such a

way that they be recompensed in an acceptable period of time. In Belarus there are two categories of participants in the process of energy sector functioning: the energy supplier, having at its disposal power generating sources, power and distribution networks and the consumer, having with the supplier the differentiation point of balance belonging of energy sector elements at one or more levels of power networks voltage. Each of these categories as an independent economic entity operates in the common production process – energy consumption. The important result of their joint co-operation is regular interactions consisting in:

- reducing the peak loads in control time intervals of power system coincident load schedule with day and night time, week and seasons regulation of energy and power consumption;
- modes combined optimization at the load nodes in voltage, active and reactive power.

The above-listed regular interactions give to the energy supplier the following results:

- postponement of generating supply entering to 60 thousand kW or 42 million USD (if to calculate 700 USD of investments for a Watt of installed capacity) with the reduction of peak loads (about 6000 MW for Belarusian power system) by 1% and 210 million USD in total with the reduction of peak loads by 5% (by 300 MW);

- the reduction of fuel rate for power generating with day and night regulation of load schedules (thorough investigation of this reduction volumes is to be carried out according to every consumer group); at first, we can assume the possible fuel rate reduction by 5% of the actual consumption. For the republic power system this will be 15 g/kW-h or with the year's volume of 26 billion kW-h will provide the economy of 39 million USD annually;

- the reduction of active power losses transferring to reactive, with the modes joint optimization at the load nodes of voltage, active and reactive power (the main result can be got from the right choice of power output and the installation places of backing devices that provide keeping the appropriate voltage mode); if the total active energy losses, as a result of joint optimization, reduce by 1% (260 million kWh per year) and the energy tariff equals 0,04 USD/kWh, the result will be 10,4 million USD per year.

As a result of regular interactions with the energy supplier, the consumer may count on the reduction of the energy tariff differentiated in time zones in non lesser amount than power system economy from load regulation, i.e. the average of 5-7%, if such regulation is provided by special regulating measures (the regulator consumers may have a much higher effect that the figures above).

The extra effects of AMR application will be the results provided by each of the Parties “Supplier-Consumer” on their own, independently of regular interactions. Such results are:

- energy losses reduction following up full coverage of all energy accounting levels with high-accuracy AMR measuring instruments both at the supplier's structure objects and the consumer's ones; the losses reduction and their sources identification will provide the possibility to give a real evaluation of economic indexes of the parties work and stabilize these indexes at a reasonable level, the economy being, as a rule, over 1% of energy output, i.e. over 0,26 billion kWh, or 10,4 million USD;

- reduction of energy specific consumption in the engineering process and in intensive power units by means of energy consumption analysis in various operating modes applying AMR; the analysis of energy consumption of both power generating sources for the auxiliaries and industry aggregates (electric motors, electric furnace, refrigerators electrical equipment, electrified transport etc.) can reveal, under different estimates, up to 5-15% possible energy consumption economy, and if calculate for 1 million kW with 5000 hours of usage per year and the average tariff of 0,04 USD/kWh, it will give the economy of over 200 million USD per year, without taking into account the modernization expenses for the revealed low-profit electrical installations (and even the expenses being 80% of the calculated possible economy, the cost effectiveness on this part will equal over 40 million USD annually).

I hope the above list and evaluation of the expected efficiency of AMR introduction are sufficient. At further stages the components can be specified and given a more detailed ground. AMR system creation will require up to 500 million USD, apart from the expenses on primary metering devices (here are included work expenses, equipment and communication channels modernization costs, designing corporate computing network, the software). The supposed introduction period is 5 years, thus, the creation of a full-scale AMR system shall require 100 million USD per year. The annual profit of AMR application, judging from the above evaluation features, can be in total 141,8 million USD (if the savings on costs, related to the postponement of additional generating sources construction for the total output of 60MW, should be distributed for 5 years).

So, even the safety reduction factor being 0.5, the annual economic benefit from the AMR system introduction will equal up to 71 million USD. It should be noted that to get the benefit all the AMR created information must be properly used. This sets to the AMR management personnel and users a certain range of

requirements related to their qualification and ability of taking decisions on the base of accurate reliable operative information. The AMR effect is defined, on the one hand, by the management personnel competence and, on the other hand, the entirety and completeness of the AMR system (a fragmentary AMR should give a lesser benefit).

**B.R.: *In what way do the Concept and Technical Code differ from the AMR documents being developed or used in Russia and the Ukraine?***

**A.G.:** There is no state concept on AMR systems in the Ukraine. They have the following approach to energy accounting: “There is the State Register of measuring devices, and in particular, electrical energy measuring devices. Everything included in the Register is allowed for the application in the market of commercial energy accounting. Specific solution of this or that commercial energy accounting system is individually coordinated with the power-supplying entity.” Since the State Register contains hundreds types of power meters both inductive and electronic ones, and there are dozens companies in the market suggesting their special solutions, so in the Ukraine’s different areas those solutions are being carried out that have been lobbied in the interests of a specific company. As a consequence there is a “zoo” of solutions, the absence of measurements unification, compatibility, comparability and identity.

The similar situation is in Russia in all its regions and energy systems. Every region has its own firms with their special approaches and solutions, various meters, systems and protocols. There is no unified hierarchy, nor state technical policy concerning metering devices, it only being partially filled up with the documents approved and elaborated by the nonprofit partnership “Trade System Administrator”. The heads of the Russian power industry note that the expenses on AMR creation, maintenance and service are going to increase and will reach 10% of “Energo” corporations market production. At the same time the existing AMR insufficiency and ineffectiveness, not able to reveal the sources of losses, lead to transport energy losses of 25% of market production in 20 regions and 35% in 7 regions.

Until very recent times Belarus has had the same situation as in Russia and the Ukraine. The first attempt to overcome the situation, clearly define from the position of the state the further direction of commercial electrical energy accounting development has been the Concept. Its ideas have their further development in the Technical Code. In view of Belarusian power industry compactness and controllability there is a hope to reach this controllability in the creation of new and forward-looking AMR systems for all the power system units and the created energy market in the near future.

**B.R.: *Is there anything you would like to add at the end of the interview?***

**A.G.:** I would like to point out that the creation of commercial AMR for power systems constituent entities and consumers must become not a new-fashioned idea, but the work based in the first place on the economic advisability. Beside that, one should take into consideration that commercial AMR shall lead to the creation of technical accounting AMR systems, or technical AMR, and their large scale will to a great extent exceed the commercial AMR scale. Only when you have an advanced technical metering in all the entity’s sectors, you can reveal all its unproductive energy losses, eliminate them and thereby reduce power and financial expenses. In this connection I suppose that inductive power meters and the pulse method of remote data collection from these meters will keep their positions in technical accounting for a long time still. Although in the long run electronic meters and digital interfaces have no alternative.

And one more thing. One should realize that in the framework of the AMR system the electronic meter is no more the only metering device, but just the element of the accounting system. As a result, the functions can be re-distributed between the AMR different elements, the standard functions and even the appearance of the meter being greatly transformed. For example, it may be transformed into a “black box” with the access to its information not through the electronic indicator board (it may be absent), but through the remote data concentrator or any other group device. Such solutions do already exist, in particular, within the AMR for residential customers. And the last. Electrical power AMR systems should be created in such a way that they could be developed into (or combined with) the systems of complex energy carriers accounting (electric power, water, heating, gas etc.). The future belongs to automated systems of complex energy carriers accounting.