Information and measurement technologies for solving problems of energy informatics

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Abstract

The system of statements for defining the problems of using the resources of information and measurement technologies (IMT) for solving the problems of energy informatics in a broad and narrow sense is given. Potential possibilities of using IMT resources are considered, which include: methods of mathematical, computer and physical modeling; methods of carrying out a full-scale experiment with using a priori and a posteriori data; models of research objects (ROs) under various modes of their functioning based on systems of multidimensional deterministic and random functions of time and space; a combination of physical and probabilistic measures to assess the quality of data during receiving, transmitting and processing information; options for the formation of primary information based on interaction of the RO with IMT sensor means; IMT methods, hardware and software, based on the use of modern achievements of science, technology and production. Evaluation of the quality of IMT research results is carried out on the basis of the concept of measurement results uncertainty.

Keywords 1

Energy informatics, information and measurement technologies, signal-to-noise ratio, methods, models, quality evaluation of research results.

1. Introduction

In recent years, scientists from the EU, the USA, China and other developed countries have considered the problems of energy informatics, including the use of information technology to reduce energy consumption, the use of information and communication technologies to improve energy efficiency, to integrate decentralized renewable energy sources into a unified energy system, and others. [1, 2, 3, 4]. Energy informatics is a new discipline, a modern direction of informatics. Solving the problems of energy informatics requires the use of information technologies in other areas. In particular, it is known that methods and means of measurement have always been, are and will be the main tool for understanding the world. The resources of modern IMT are a significant component of information technologies in various areas of informatics, including energy informatics.

This paper discusses the use of IMT resources for solving the problems of energy informatics. It is the methods and means of ICT that make it possible to obtain primary information in the ROs of energy informatics.

The purpose of the work is: 1) to form a system of statements, which makes it possible to formulate the tasks of the IMT for solving the problems of energy informatics; 2) to consider the potential resources of IMT for energy informatics.

ITTAP'2021: 1nd International Workshop on Information Technologies: Theoretical and Applied Problems, November 16–18, 2021, Ternopil, Ukraine
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2. Literature review

The concept of "energy informatics" is receiving a lot of attention from the international scientific community [1, 2, 3, 4]. Most of this community views on energy informatics as a discipline that studies, develops, and applies information and communication technologies, energy and informatics to solve energy problems [1, 5, 6]. At the same time, a large amount of research is focused on technologies that can reduce the consumption of various types of energy [7, 8]. This also applies to climatic problems associated with an increase in greenhouse gas emissions [9, 10, 11], and, as a consequence, the need to create branched sensor networks [12, 13] to monitor the state of air pollution [14, 15, 16], water or soil. Also, deepening the study of energy informatics contributes to increasing the integration of energy systems and information and communication technologies [17, 18, 19, 20]. However, energy informatics does not focus only on energy efficiency and energy conservation. The direction of energy informatics can be more general, which makes it possible to integrate this direction into another disciplines.

3. Main part

First, a simplified scheme of the use of energy and information technology is presented as an illustration of the main ROs of this work, which is shown in Fig. 1.

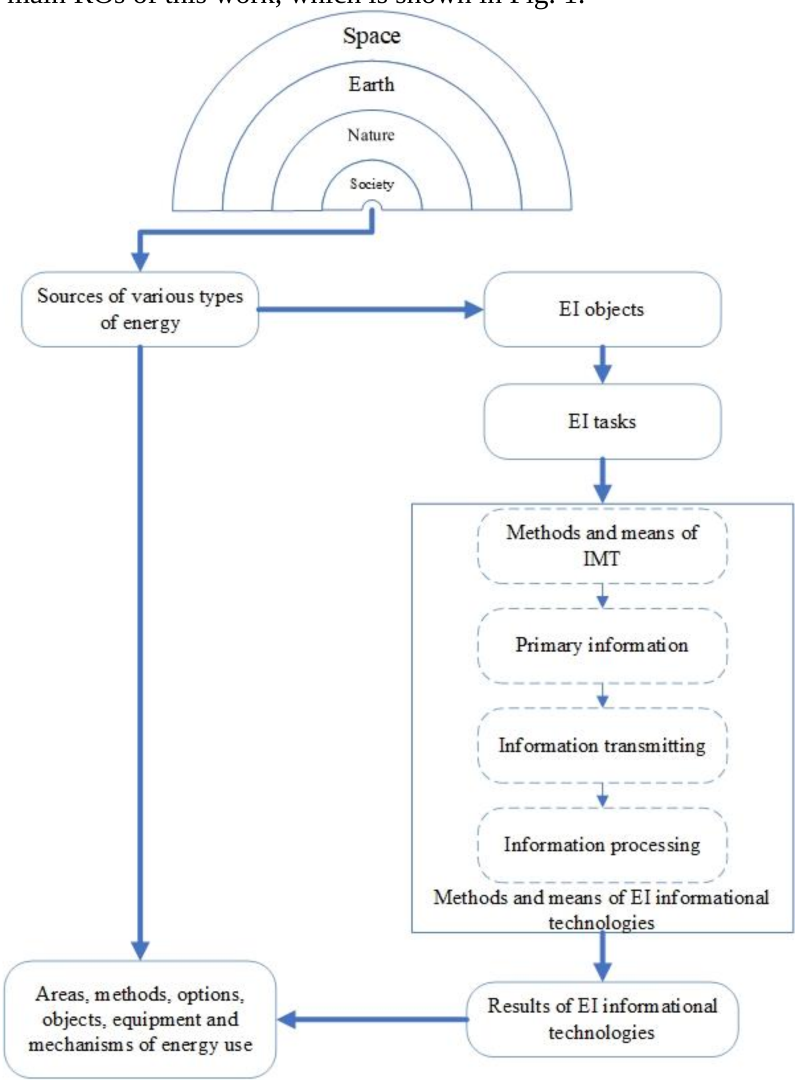

Figure 1: Simplified scheme of using the information of ROs of energy informatics (EI)

3.1. System of statements

To substantiate the tasks of IMT using in solving problems of energy informatics, it was applied a well-known approach. This approach is based on the formation of primary systems of axioms and laws. In the future, this allows them to be used for various kinds of interpretations, formations and definitions. Examples of this are:

- laws of classical mechanics (Newton)
- axioms of probability theory (Kolmogorov)
- laws of information transmission (Shannon)
- equations of electrodynamics (Maxwell)
- laws of thermodynamics and others.

Based on this approach and the results of the analysis of a significant number of scientific, technical and applied publications on cybernetics, informatics, measurements and other types of research, it was formed the following system of statements.

Statement 1. The ROs of energy informatics are the sources of natural and anthropogenic origin of various types of energy and the mode of their functioning in time and space, and power transmission networks to consumers.

Statement 2. Receiving the primary information from ROs of energy informatics is based on the use of methods and means of IMT.

Statement 3. The effectiveness and reliability of the results of solving energy infornatics problems are determined by the software for processing a priori and a posteriori research data based on the methods of mathematical physics, computational mathematics, measure theory, probability theory and mathematical statistics, and measurement theory.

Statement 4. The quality of energy informatics research results is assessed based on the concept of measurement uncertainty, the regulatory framework of which is used by the international measurement community.

Statement 5. The diversity of the primary information of ROs of energy informatics is determined by the action of various energy sources, forming various common variants of signal-interference combinations, while a decrease in the value of the signal-to-noise ratio (<3) significantly reduces the efficiency, reliability and quality of the research results obtained.

In some cases, the following conditional consolidated classification of research problems and tasks is used:

- research in a broad sense;
- research in the narrow sense;

The study of the ROs of energy informatics can be classified based on the application of the proposed system of statements, namely:

- statement 1-4 applies in a broad sense;
- statement 1-5 applies in the narrow sense.

The above system of statements makes it possible to integrate various areas of informatics into the framework of energy informatics and form its concept. An example can be hardware and software systems for receiving, transmitting and processing weather observation data for the purpose of monitoring and forecasting the weather. An example can also be the hardware and software complex of environmental studies (in particular, monitoring of atmospheric air pollution [14]), the global structure of which is being created and developed today.

Let us consider the potential possibilities of using IMT resources to solve the problems of energy informatics.

3.2. Research methods

The capabilities and resources of modern science, technology and production make it possible to implement the following research methods:

- research using the theoretical basis of physical and mathematical models of the ROs and with the use of hardware and software computing facilities and mathematical modeling (simulation);
- physical modeling based on the use of physical models of complex homogeneous and heterogeneous ROs, which includes a reasonable choice of methods and means of IMT research and conducting a modeling experiment;
- experimental study of real ROs based on the use of methods and means of IMT research and carrying out a full-scale experiment.

The given research methods of ROs by methods and mean of IMT are potentially possible for use, but in each specific case, each method can be applied independently. Note that the methods of theoretical research (mathematical modeling) and physical modeling are based on the use of a priori data. On the basis of the method of experimental research, a posteriori data of a full-scale experiment is formed, they are processed and the results of research are formed, which correct and agree on the results of research of mathematical and physical modeling.

3.3. Models class of ROs

Physical and mathematical models are used in a wide range of ROs studies. Each of the models, physical and mathematical, complement each other, and in spite of the fact that they are copies and do not fully correspond to real ROs, the models play a fundamental character in the research. Mostly a more formalized mathematical model is used.

The mathematical model of ROs is a set of knowledge, hypotheses, initial and boundary conditions that have developed behind the a priori research data; written using mathematical objects, terms and symbols in the form of a logically consistent, consistent structure that reflects in time and space the main properties, characteristics of the ROs.

Mathematical models are systems of multidimensional, Hilbert deterministic and random functions, and systems of differential and integral equations. The main characteristics of such models are determined within the framework of the energy (for random - correlation) theory.

3.4. Combination of physical and probabilistic measures

The combination of physical and probabilistic measures is due to the need to assess both the primary data and their quality during the receipt, transmission and processing by methods and hardware and software. Examples of such a combination of measures are discussed in detail in [18].

3.5. Methods for obtaining primary research information

To perform the tasks of using IMT resources during solving problems of energy informatics, three options for the formation of primary information are used in the interaction and interconnection of ROs with the IMT sensor means:

a) RO is a source (generator) of such information;

b) RO is a linear or nonlinear, inertial or inertial, one-dimensional or multidimensional transducer of the impact (signal) acting on the RO, and which is conventionally called test, and the RO is described by a certain transformation operator $Z[\cdot]$;

c) RO is a source, which forms its own, different from the input, reaction (response), and the input signal of action is considered as stimulus.

A schematic representation of this interaction is shown in Fig. 2.

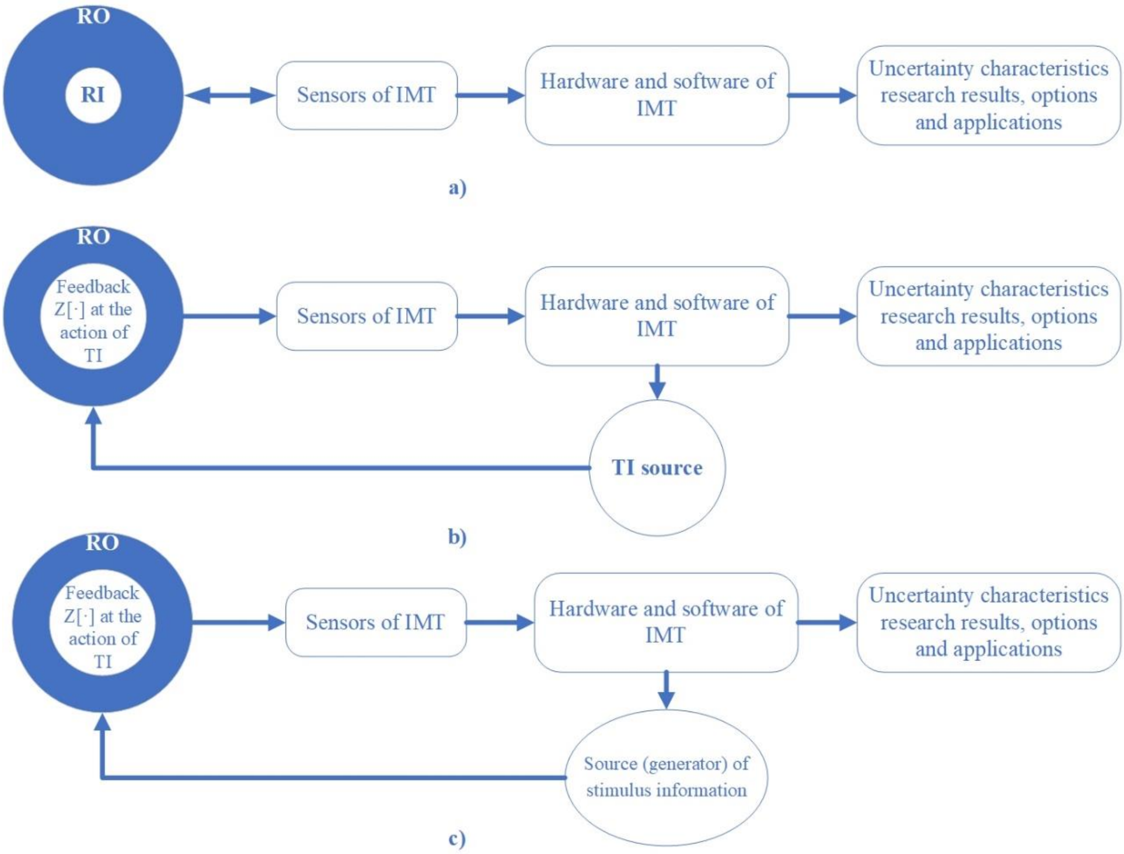

Figure 2: Schematic representation of three options (a, b, c) for the formation of primary research information (RI – research information, TI – test information)

3.6. Hardware and software research tools

To carry out theoretical, modeling and experimental studies of ROs, methods and means of IMT are used, the capabilities and resources of which are based on modern achievements in the development of science, technology and production. Typical tools on IMT include:

- theoretical basis of research using the methods of mathematical physics, mathematical analysis, computational and discrete mathematics, systems and signals theory, measurements theory and others;
- hardware and software of IMT.

3.7. Assessment of the quality of research results

Each study in the field of energy informatics ends with an assessment of the quality of the obtained results. The assessment procedure is very diverse, has a wide range of complexity and is determined by the research objective.

In one case, the result is an answer of the question “yes or no” (for example, a control problem), in the other, the result is used to justify the tasks of a new study (for example, to determine the dependence of the probability of signal detection under the influence of interference on the signal-to-noise ratio (SNR)). The given example of signal detection under the influence of interference is one of the complex problems of radiolocation, hydroacoustics, other branches of science and technology, and, accordingly, energy informatics, for the solution of which appropriate information support, hardware and software modules of technical systems are used. The complexity of taking into account the dependence of the characteristics of signal detection under the influence of interference on the signal-to-noise ratio (SNR) is due to the fact that it has a more general definition in energy informatics:

$$SNR \sim \frac{\text{energy of the RO's information signal}}{\text{energy of the total interference signal}}.$$

In practice, it is difficult to find the meaning of such a relationship because:

- ratio is the ratio of two signal fields as multidimensional functions of time $t \in T$ and space $\left(x, y, z\right) \in R^3$, and in the general case, a random variable $\omega \in \Omega$;
- signal fields of the ROs and interference do not apply separately, but are manifested additively or multiplicatively by their combination;
- energies of the ROs' signal field and interference change differently in the hardware and software modules of the research systems.

The problem of signal detection under the influence of interference is important for a wide range of industries, and is transformed into a number of independent tasks, the solution of each of which is based on a specific signal-interference situation.

The principle of integration of various knowledge systems into informatics makes it possible, within the framework of energy informatics, to use the well-known method of the concept of measurement uncertainty for the quality assessment of research results. This concept is widely used by the international community, has a regulatory framework that is used by each country.

4. Discussion

Naturally, the development of energy informatics requires appropriate integration in the use of information technologies, including IMT. IMT are integral part of almost all information technologies. Therefore, the urgent task is to consider in more detail the use of IMT resources during solving the problems of energy informatics. In this paper, ROs are the objects of energy informatics, and for their research methods and hardware and software of IMT are used.

First, a system of statements was presented that adapts the use of IMT resources to solve the problems of energy informatics. This is a well-known approach to the formation of relevant disciplines and directions based on the application of a system of axioms and laws. The problem of energy informatics is conventionally divided into 2 options: in a broad and in a narrow sense. The first option includes all the problems of energy informatics, which does not use the signal-to-noise ratio in its research. The second option takes into account the signal-to-noise ratio, which significantly affects the research results, and, accordingly, their reliability and efficiency. The paper also discusses in detail the potential possibilities of using IMT resources in solving problems of energy informatics.

5. Results

1. The given system of statements, which, by analogy with the well-known approach to the formation of the corresponding areas of knowledge based on the use of systems of axioms and laws, makes it possible to form tasks, obtain and evaluate the results of research by methods, hardware and software of IMT for ROs.

2. A number of characteristic features of IMT are considered, including:

- theoretical, modeling and experimental methods as the main research methods for ROs of energy informatics for various modes of their functioning in time and space;
- physical and mathematical models of ROs using systems of one-dimensional, multidimensional, deterministic and random functions of time and space;
- combination of physical and probabilistic measures in research;
- methods for obtaining primary information based on the interaction and interconnection of the ROs with sensors means of IMT;
- methods and hardware and software of IMT, based on the use of modern achievements of science, technology, production;
- assessing the quality of research results using the characteristics of their uncertainty based on the concept of uncertainty, which widely used in the world.

6. Acknowledgments

The work is supported by “Development of models, methods and methodology for determining the state of industrial structures according to the data of monitoring system with forecasting the residual resource” (2021-2025, 0121U110307), “Development of methods and ways to improve the environmental efficiency and durability of chimneys of heat power plants. Stage 2” (2021, 0121U109243), “Development of a system for monitoring the level of harmful emissions of TPP and diagnosing the equipment of power plants using renewable energy sources on the basis of Smart Grid with their collaboration” (2019-2021, 0119U101859) which are financed by National Science of Ukraine.

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