

The Application of Modern Information Technologies for Power Monitoring and Control in Conditions of Distributed Generation

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Abstract—The article is devoted to modern information technologies application in power industry. In the article the structure of intelligent system of monitoring and control of power supply and consumption is proposed. The proposed system is developed for conditions of distributed generation on the basis of alternative and renewable power sources at the enterprises of raw mineral complex. The main factors and regularities which must be considered during monitoring and control of power supply and consumption are detected. The main problems which must be decided for effective functioning of power systems with distributed generation on the basis of alternative and renewable energy sources are defined. The use of wind power installations, solar power stations and micro turbine installations working on following oil gas as sources for distributed generation is proposed in the article. The necessity of use of information technologies of high-speed data transmission for monitoring and control of power supply and consumption modes for conditions of the distributed generation is proved in some publications [1] and here. The basic principles of information and control influence compiling for basic elements of proposed intelligent system are given. The basic directions of data analysis and processing during monitoring and control of power supply and consumption are detected in the area of proposed intelligent system. The actuality of necessity of complex monitoring and control of power supply and consumption is proved in conditions of distributed generation on the basis of alternative and renewable energy sources. The use of the intelligent caching satellite femtocells for mobile communication as the main technology of data transmission is proposed for monitoring and control of power supply and consumption in the conditions of the distributed generation.

I. INTRODUCTION

The technologies and principles of distributed generation for the last 20 years gain the special actuality according to increasing requirements to the level of power saving and efficiency [2]. It is also important for power component decreasing in total cost of produced product in different industries. Nowadays the distributed generation systems are the most effective reserve for the traditional centralized

power supply systems in following cases. The first case is the shut-down of centralized power supply, the second is the inability of centralized systems to provide the demanded level of power supply reliability of most responsible consumers [2]. For example the existing reliability level of Russian Federation centralized power supply systems is lower in comparison to foreign analogs and the bringing of this level into accordance to international standards demands considerable economic expenses. Also the main power consuming industry in Russian Federation is the raw mineral complex, which deposits are allocated in remote regions of Russian Eastern Siberia and Far North. These regions in most cases are not captured by centralized power supply systems, or are captured by them partially without providing the demanded level of reliability. That is why in this case it is reasonable to have reliable reserve power source for supply of most responsible consumers. Therefore the necessity of local alternative and renewable sources complex use is firstly defined by existence of perspective raw mineral deposits in the remote regions of Russian Eastern Siberia and Far North.

The main principle of existing distributed generation technologies is the decentralization of power supply systems with maximum use of local sources [3] and maximum source approach to the consumer in the conditions of absence or considerable remote allocation of the centralized power supply systems [3, 4]. Also the consumer's responsibility level should be considered during developing the distributed generation power system structure. For example the raw mineral complex (RMC) enterprises include the different responsible consumers. The main criterion of this responsibility is the immunity to short time voltage drops and power supply interruptions with saving of technological process continuity and stability. Besides in conditions of RMC enterprises the territorial dispersion of responsible consumers should be considered [2]. The mentioned facts prove the reasonability and actuality of full or partial application of distributed generation technologies and principles at the RMC

enterprises. Also in conditions of RMC consumer's territorial dispersion the problem of effective high speed data transmission to long distance during control and monitoring of power supply and consumption parameters is quite actual too.

The basis of distributed generation principles and technologies is the combined use of various type alternative and renewable power sources. In the conditions of Russian Federation RMC enterprises according to results of theoretical and experimental researches it was detected that the use of following oil gas, wind and solar energy is the most effective under the criterion of power supply reliability and uninterrupted, and under the criterion of energy saving and efficiency.

II. BASE FUNCTIONS

The effective functioning of power systems on the basis of distributed generation in the conditions of RMC enterprises requires the solution of the following actual scientific and technical tasks [5, 6]:

- the effective control and monitoring of different energy resources use (the sun, wind and following oil gas energy);
- the power quality improvement and electromagnetic compatibility ensuring [7];
- the development and providing of effective combined functioning modes of alternative and renewable energy sources within the one integrated electrotechnical complex;
- the possibility of parallel functioning of local alternative and renewable sources with the centralized power supply system;
- the adaptivity to electric load diagrams change and power consumption modes variations;
- the ensuring of high-speed effective transmission of data about the power supply and consumption parameters in the conditions of considerable territorial dispersion of power consumers.

For application of distributed generation systems on the basis of alternative and renewable energy sources at full or partial independence of centralized power supply systems and for providing effective methods of control and monitoring of power supply and consumption modes, it is necessary to integrate various functions in the one complex. In this case each of these functions is directed on fixation of certain indicators set.

The realization of two key functions of monitoring and control must be provided by the technical devices, integrated into the complex automated systems of decision-making support. All decisions about monitoring and control strategy should be applied on the basis of complex situations analysis

and prediction of difficult dynamic systems behavior in non-stationary and non-uniform environments [8]. For distributed generation systems on the basis of alternative and renewable energy sources the difficult dynamic system in the non-stationary and non-uniform environment is the set of the following factors:

- the power supply mode from one or several power sources;
- the power consumption mode of one or several functional groups of consumers;
- the current electromagnetic condition;
- the level of power quality and electromagnetic compatibility of electric equipment;
- the current power system structure.

III. THE MAIN FACTORS AND REGULARITIES

When developing the intelligent system of complex monitoring and control of power supply and consumption modes in the conditions of distributed generation it is necessary to consider the significance degree of certain separate technical factors which has the influence on power supply, distribution, transformation and consumption from various power sources. In the conditions of distributed generation from alternative and renewable power sources the following key factors possess the greatest significance degree, which defines the efficiency of complex monitoring and control of power supply and consumption modes:

- the power capacity of each local alternative and renewable power source;
- the presence of especially responsible consumers by criterion of technological process stability;
- the characteristics and parameters of consumer's power consumption mode (load diagram; load factors; harmonic distortion level of current and voltage).

Also during control and monitoring of power supply and consumption modes it is necessary to consider the influence degree and nature of the obvious and hidden regularities on power supply and consumption modes. The results of theoretical and experimental researches conducted in power supply systems of Russian RMC territorial dispersed objects, showed that the most significant regularities in this case are following [2]:

- the character of power supply and consumption modes depending on voltage and current harmonic level in electrical network;
- the dependence of power consumption mode on value and nature of voltage dips, variations and interruptions in electrical network;
- the influence of voltage dips and interruptions value and duration on different consumers functioning

character and power supply and consumption modes stability and reliability;

- the starting characteristics of electric motors in consumer’s electromechanical complexes at various power supply modes;
- the influence of various damages and malfunctions in electrical networks on stability and reliability of power consumption and supply modes.

IV. THE GENERALIZED STRUCTURE OF PROPOSED INTELLIGENT SYSTEM

The generalized structure of power system with distributed generation and proposed intelligent system of complex monitoring and control of power supply and consumption mode is presented in Fig. 1.

In this paper in conditions of electrical engineering the term “intelligent system” means the opportunity of informational and control interaction between power elements by means of modern communication systems. In some publications such term is called “smart” or “smart space” and is applied to internet and data processing technologies. In general both terms are similar. Therefore mentioned term “smart” or “intelligent” can be used in any engineering area.

Fig. 1 shows that the proposed intelligent system controls three main processes: power supply, distribution and consumption [8, 9]. At all specified stages the following procedures are provided:

- the collecting and analysis of information about significant factors and their significance degree;
- the detection of obvious and hidden regularities, their influences on power supply, distribution and consumption processes.

The mentioned procedures allow to form in real time mode the control and information influences and interactions [9] for separate elements of distributed generation system. The results of these procedures depend on current power consumption and supply modes.

For effective functioning of proposed intelligent system of complex monitoring and control of power supply and consumption modes during collection of information about power consumption and supply modes, the analysis of situations development on the basis of received information with formation of power supply system expected model and formation of control and information influence it is necessary to provide the efficient modern high-speed technologies of data transmission on considerable distances.

Power consumption and supply modes are characterized by the set of key parameters and factors which need to be controlled in order to avoid of power supply emergencies

and failures of various duration. In the conditions of the territorial dispersed objects of RMC enterprises these parameters are:

- the factors of electric load diagrams;
- the value and duration of voltage dips and variations;
- the power quality indicators [10];
- the available power from various alternative and renewable power sources.

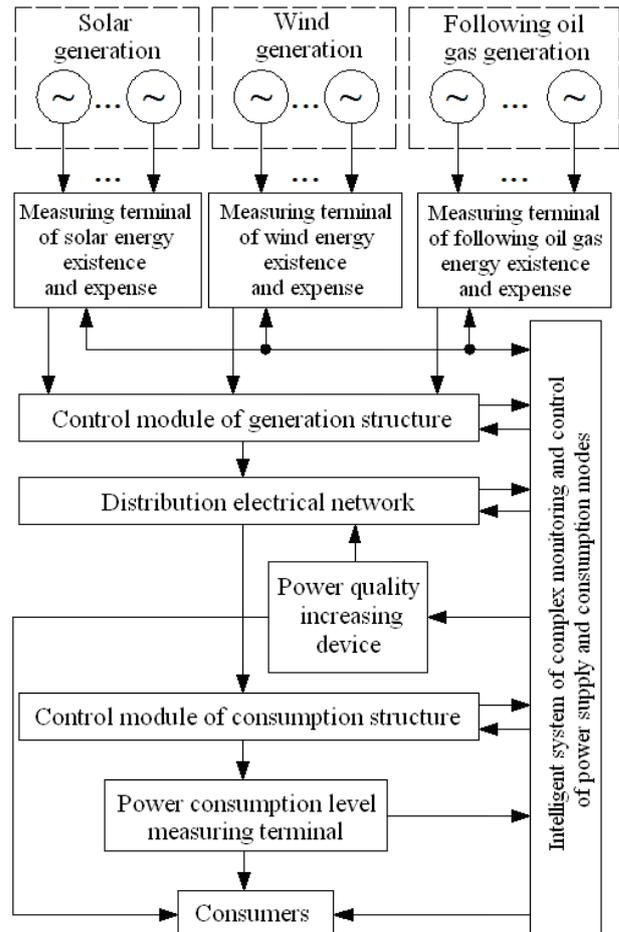


Fig. 1 The generalized structure of power system with distributed generation and proposed intelligent system of complex monitoring and control of power supply and consumption modes

The formation of predicted evaluation of expected power supply system condition on the basis of obtained data analysis [2, 5] includes the following stages:

- the obvious and hidden regularities detection;
- the factors significance evaluation;
- the choice of the most optimum power supply system structure by the selected criterion;
- the base energy source detection for the current modes of power supply and consumption.

In the conditions of RMC enterprises it is necessary to provide the analysis of voltage level and current waveform influence on stability and reliability of electric equipment and consumer's functioning [11]. Also it is important to evaluate the electromagnetic compatibility level of consumers and power supply system [12] with distributed generation. Besides it is necessary to consider the power supply efficiency from the micro-turbines working at following oil gas, solar batteries and wind power installations depending on the set of technical and climatic conditions, structure of electrical network, consumer's responsibility and irresponsibility degree by continuity of technological process criterion.

The formation of control and information influences and interactions is made for power supply system basic elements on the basis of modern algorithms support with use of the theory of phase transformations, fuzzy logic, prediction methods.

The generalized structure of proposed intelligent system of complex monitoring and control of power supply and consumption modes is presented in Fig. 2.

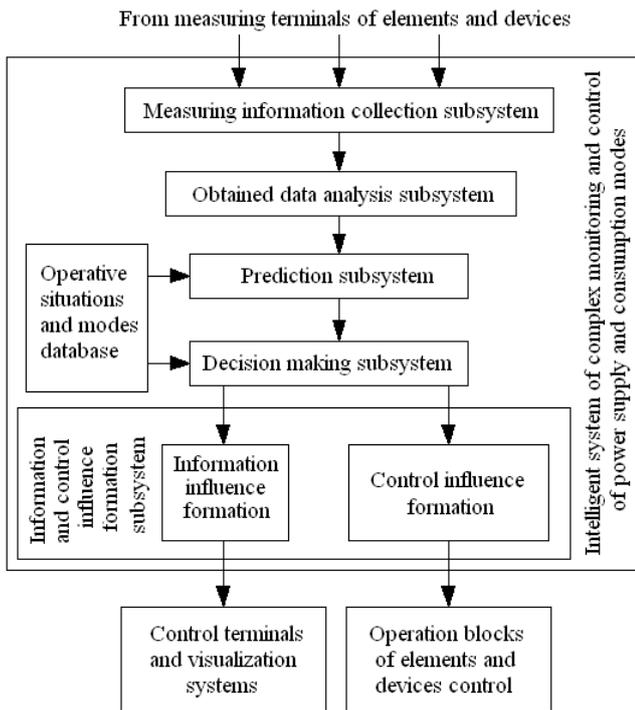


Fig. 2. The generalized structure of proposed intelligent system of complex monitoring and control of power supply and consumption modes

The structure proposed in Fig. 2 reflects all main stages of above mentioned control and monitoring of power supply and consumption modes in the conditions of the distributed generation for RMC enterprises objects. Depending on technological objects specifics and functioning modes the proposed generalized structure can

be completed with necessary elements and subsystems [9], but general principle remains constant, because the proposed system has two main functions: control and monitoring. For both mentioned functions it's necessary to collect, analyze and save information about power supply and consumption. Also similar structure is applicable to other technical systems.

The proposed structure can be realized and organized by means of different type modern digital communication systems on the base of most effective platforms.

V. THE INFORMATION TECHNOLOGIES FOR PROPOSED INTELLIGENT SYSTEM

As information technologies for formation of control and information influences and interactions it's the most effective to use the intelligent caching femtocells for mobile communication with use of satellite transport channels.

Nowadays at the organization of mobile networks as the transport communication channels from reference network to base stations the satellite communication channels are often used. The use of satellite channels is the unique decision in the presence of the following scenarios:

- the need of the mobile network organization in case of considerable distance between reference network elements and base stations expansion places;
- the absence of necessary engineering infrastructure in the expansion place: oil and gas industry territorial dispersed camps, remote regions, mineral deposits, etc.;
- the difficult land relief and weather conditions (for example, highlands), not allowing to provide year-round reliable wire or wireless (for example, radio relay) transport network to reference stations;
- the need to adjust of emergency mobile communication in emergency situations, accidents or in military operations zones;
- the need of the temporary reference stations and transport network organization at mass actions: concerts, sports meets, etc.;
- the need to organize cellular communication on large moving objects: cruise liners, trains.

The transport network via satellite channels is used generally in situations when other decisions are not physically possible, or not completely economically profitable. For example, in the remote region where the mobile network is developed, the number of subscribers can be very much insignificant in comparison with the cost of creation necessary classical transport wire or wireless infrastructure for delivery to this region of a mobile traffic.

Note that the satellite segment of transport network is the key element of transport network infrastructure. By the

nature, the satellite channels have a number of disadvantages: limited capacity, high cost of given traffic, small scaling opportunities at overloads, etc. These disadvantages are aggravated upon transition to high-speed 3rd and 4th generation's networks, with high requirements for user's service quality level. The separate and very important problem is video information (more than 50% of all mobile traffic today) and web traffic (30% – 40%), consequently operators incur considerable expenses. Also the operational and capital cost increasing is observed: not only on expensive infrastructure maintenance, but satellite channels payment too. Thus, limited opportunities of such channels especially adversely affect on peak loading that leads to subscriber's service impossibility with demanded quality level.

Resuming mentioned above, it is possible to develop certain requirements to the reference stations expanded on remote location and connected to operator network kernel through satellite communication channels:

- the orientation to connection through "narrow-band" satellite communication channels;
- high speed of expansion;
- low power consumption;
- considerably smaller cost in comparison with macro-base stations;
- the protected cabinet, installation simplicity and convenience;
- high reliability, network further work possibility in case of separate base stations failure;
- ease of scaling and new elements addition;
- considerable load reduction opportunities of the "top" satellite communication channel (at the expense of caching, transcoding, etc.);
- opportunities for management and traffic optimization in a mobile network for the purpose of subscribers service quality improvement at the specified loading level and taking into account users tariff rafts;
- opportunities for data flow automatic adaptation to channel conditions and loading level taking into account tariff rafts of users.

The proposed intelligent caching satellite femtocells for mobile communication meet all mentioned requirements, providing mobile communication existence at connection to reference or transport network via satellite channels.

The satellite intelligent femtocells represent the hardware-software complex, allowing to provide a cellular network covering in that place where it is necessary, and adapted for connection to provider's reference and transport network through satellite communication channels. The main advantages of this system are following:

- the highly protected version with key modules double hardware duplication, and state and working capacity automatic remote control;
- the compact configuration and use of universal Intel™ processors allowing considerably reduce the whole system power consumption;
- the use of intelligent caching and video transcoding specialized subsystems in real time mode on the basis of the latest Intel™ technologies that allow considerably (up to 70%) reduce load of the "top" satellite communication channel;
- the use of advanced techniques of control and traffic optimization in the mobile network, allowing to increase service quality and visual perception quality on subscriber's devices;
- the use of the latest methods of data flows automatic adaptation to the channel conditions, loading level, subscriber's tariff plans with the purpose to increase service quality and decrease network load;
- the traffic volume decrease in the "top" satellite channel by 70%;
- the radio segment load decrease by 30-40% at peak loading time;
- the visual perception quality improvement of content with reduction of video stop probability at reproduction (so-called rebufferization) by 3-4 times, reduction of web pages loading time by 2-3 times;
- one femtocell in the maximum packaging is capable to serve 2000 subscribers at the same time at the total traffic amount in 10 - 2000 Mbps.

The proposed intelligent system of complex monitoring and control of power supply and consumption modes in comparison with existing developments has several advantages: the opportunity of combined control and monitoring of solar, wind and followed oil gas energy amount, the opportunity of combined control and monitoring of power supply modes from different types of alternative and renewable power sources, the opportunity of combined control and monitoring of power supply quality level from solar, wing and following oil gas station, the opportunity of combined control and monitoring of available power capacity of solar, wing and following oil gas station, the operative control and monitoring of responsible and non- responsible consumers quantity.

Thus, in the conditions of distributed generation systems development and the complex application of alternative and renewable power sources (wind, solar and following oil gas power), the creation of the effective intelligent system of complex monitoring and control of power supply and consumption modes which is one of key factors of power saving and efficiency level increasing, with application of

femtocells as modern and effective technologies of data transmission is actual.

VI. CONCLUSION

The necessity of proposed intelligent system of complex monitoring and control of power supply and consumption modes creation in conditions of distributed generation on the basis of alternative and renewable energy sources is proved.

During researches the generalized structure of power system with distributed generation and proposed intelligent system of complex monitoring and control of power supply and consumption mode is developed. The most significant regularities were detected for effective control and monitoring of power supply and consumption modes in conditions of distributed generation. Also in the conditions of the territorial dispersed objects of raw mineral complex enterprises the key parameters and factors which characterize the power consumption and supply modes are determined. The generalized structure of proposed intelligent system of complex monitoring and control of power supply and consumption modes is developed.

The intelligent caching femtocells using for mobile communication with use of satellite transport channels for proposed intelligent control and monitoring system is proposed.

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