ELECTRICITY CONSUMPTION DEMAND SIDE MANAGEMENT IN RUSSIA[1]

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ABSTRACT

One of the most modern and effective tools for increasing the energy efficiency at the level of national economies is the electricity consumption demand-side management. The mechanism of electricity consumption demand side management has significant potential to improve energy efficiency for the economy of
Russia, but due to structural characteristics of the UES of Russia the electricity consumption demand side management program is at the stage of the concept development. The model of electricity consumption demand side management for UES of Russia is developed taking into account the structural features of power system. The peculiarities of the economic structure of Russia, influencing the formation of the electric power complex structure of the country are identified. They have been considered in the development of system requirements at the electricity consumption demand side management in the UES of Russia. The basic features are considered the multiple-level system and hierarchical structure, they were studied in the process of developing a model of demand management. The classification of electric power industry entities related to the conversion of electric energy and the influence on the process of electricity consumption demand side management, is developed with the economic interests of each entity within the model of demand management. A model of electricity consumption demand side management, which is based on the hierarchical structure of the demand-side management, covers the whole range of management options and takes into account the peculiarities of demand management at every level of management, is developed. The model allows improving significantly the efficiency of electricity consumption demand side management, to ensure the quality control of the power consumption modes and reliability of power supply of the consumers.

KEY WORDS

ENERGY EFFICIENCY, ELECTRICAL ENERGY CONSUMPTION ELECTRIC POWER INDUSTRY OF RUSSIA, ELECTRIC POWER INDUSTRY ENTITIES OF RUSSIA, REGIONAL ENERGY INDUSTRY, GDP POWER INTENSITY, ELECTRICITY CONSUMPTION DEMAND, DEMAND SIDE MANAGEMENT, UES OF RUSSIA.

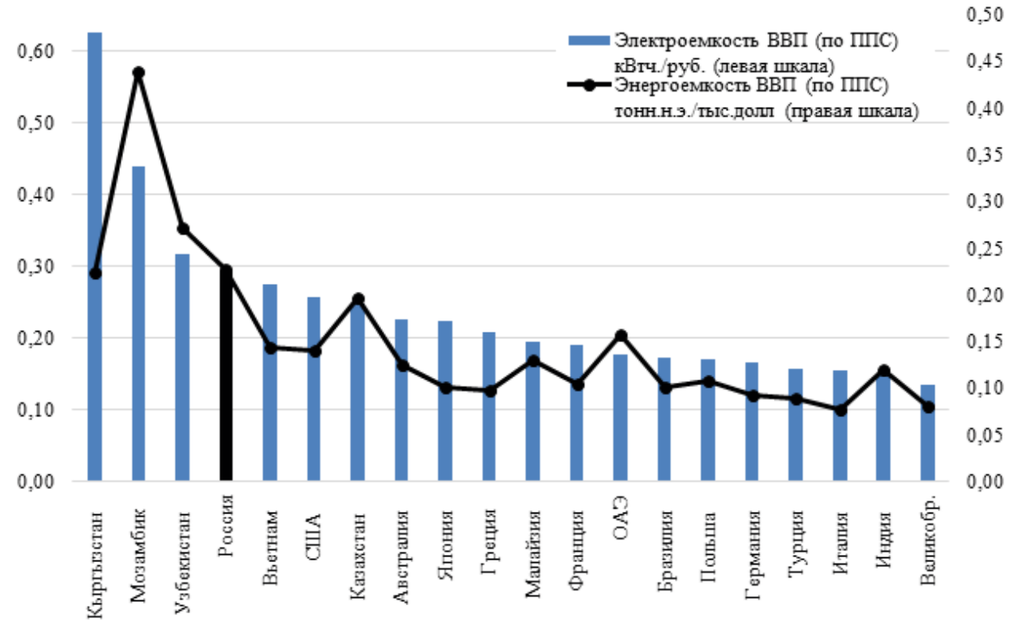
INTRODUCTION

The innovation technological development policy of all developed and developing countries involves the introduction of energy-saving technologies and the improving of energy efficiency. At the level of the national economy, their implementation can significantly reduce the cost of energy consumption without reducing production volumes of goods and services. The costs of energy resources- electric and thermal energy, natural gas, coal and petroleum products are in the cost of each product or service. The increase of the energy efficiency of energy consumption finally will increase the efficiency of all electricity consumers in the national economy.

Implementation of the policy of improving energy efficiency at the level of the national economy has the following main effects:

- increase of the competitiveness of the production by reducing the cost for the purchase of energy in the cost structure of products;
- cuts of the budgets of all levels;
- improving the energy security of the national economy;

Fig.1. Energy and electrical intensity of GDP in different countries of the world for



- replenishment of the budget revenues through the export of the energy commodities;
- the maintenance of own hydrocarbon resources;
- the introduction of advanced technologies in production industry

Among all the energy resources the electrical energy occupies a special place. This is the most common energy source in the world, as the large scale production of electricity was established, its transportation over long distances is carried out simply and relatively inexpensively, the electric power can be simultaneously distributed to a large number of consumers, energy carrier is applicable in all climates, and can be converted into other forms of energy: mechanical, thermal and light energy. Efficiency in the electrical energy consumption is a priority in programs of improving the energy efficiency in all countries of the world, including Russia.

The efficiency of energy consumption in general and electricity in particular substantially ranges in different countries. At the level of national economic, the energy consumption efficiency is described as the quotient of the energy intensity divided by the GDP power intensity (Fig. 1). The indicators of the total energy intensity and electrical capacity of GDP are closely interrelated, as most of the energy resources are spent on electricity generation and, consequently, the reduction of the electric capacity naturally leads to a decrease in the total energy.

According to energy and power intensity, GDP of the Russia economy is far behind the developed and even developing countries, due to both natural climatic and geographical factors, and technological and economic factors.

Over the past 15 years, the electric power complex of Russia has undergone some significant changes in order to increase the efficiency of the industry. In 2005– 2007 the electric power industry had been reformed, and resulted in the regional vertically-integrated assets of RAO UES of Russia were divided on the specific types of activity and created the wholesale and retail markets of electricity and power. Since 2009 [Federal Law, 2009] in Russia, at the federal and regional levels, energy saving and energy efficiency standards are being actively introduced to reduce the energy intensity of Russia's GDP by 40% by 2020 compared to 2007.

Despite the transformation, the level of power intensity GDP remains sufficiently high.

Russia is integrating into the global economic space. It is obvious that to improve the competitiveness of the national economy the further systemic changes are required to reduce costs in the energy resources consumption in the national economy and to increase energy security [Karlik A. E., Chernyshev V. V., 2010].

According to the theory of economic cycles, the next sixth cycle (2018-2060 years) will be characterized by a new technological way of development of Nanotechnologies, Biotechnologies, Information Technologies and Cognitive Science (NBIC-convergence) [Kondratiev N. D., 1922].

Currently, domestic and foreign researchers pay much attention to the introduction of the integrated smart grid in the electric power industry, the transformation of the existing management system in the power industry with new technological developments [Technology Roadmap "SmartGrids", 2015; Ten

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Year Network Development Plan, 2014].

In the technology of intelligent energetics, a mechanism of electricity consumption demand side management (ECDSM) is being used. This form of economic interaction of electric power engineering entities with the end consumers of electric energy provides mutually beneficial, economically efficient management of the volume and modes of electrical energy consumption [Gitelman L. D., Ratnikov B. Ye., Kozhevnikov M. V., 2012] ECDSM allows you to align the graphs of electrical loads of end users, thereby reducing costs of the electricity system that arise due to unequal demand.

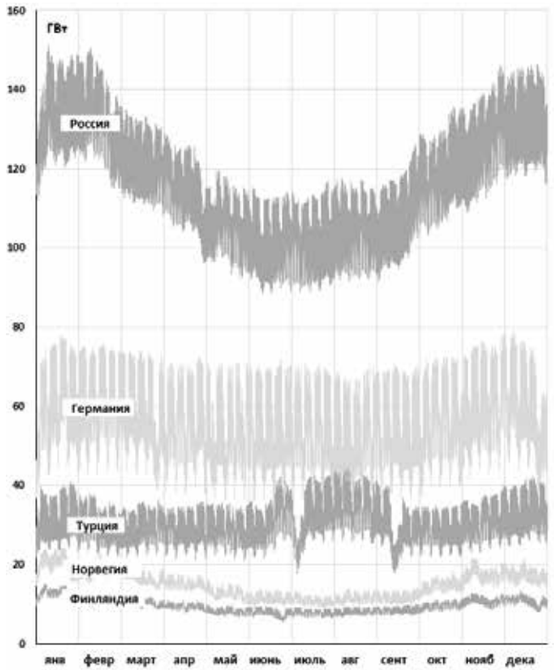
Domestic and foreign researchers have been engaged in the problem of alignment of charts of electric energy consumption demand since the early 1930s, when the united power grid in various countries around the world had being created. [Kukel-Kraievskii S. A, 1938].

Soviet scientists were among the first who had started to study the problems of alignment of the load curves of electricity consumers in the electric power systems. Since then, the electric power industry has changed significantly: the efficiency of power plants was improved, the coefficients of maneuverability were increased, the power supply dispatching process was developed, however, the task of alignment of charts of electric demand within the UES has still been relevant.

RESEARCH METHODOLOGY

In many countries programs of electricity consumption demand side management are applied in everyday practice.

Рис. 2. Почасовые графики нагрузки электропотребления за 2016 год (масштабы сохранены)



In our country, the introduction of demand management is at the stage of concept development. By itself, the problem of alignment of the graphs of the electricity consumption demand is particularly relevant because the overall electrical energy consumption and the volatility of electrical energy consumption demand is significantly higher than in Germany, Turkey, Norway, Finland, within both a year, and month. The demand for electrical energy consumption is characterized by a significant increase in the cold season and decrease during the summer months. For comparison: in Norway and Finland at the annual chart, the power consumption is distributed more proportionally both in summer and in winter. A high volatility level of demand for electrical energy consumption in Russia is observed in the daily section.

Thus, introduction of ECDSM mechanisms in Russia is due to:

- high GDP power intensity;
- significant scale of energy consumption;
- the high volatility of annual, weekly and daily demand for electricity consumption;
- a significant proportion of industrial consumers in the structure of national electricity consumption.

In the development and implementation of ECDSM mechanisms the specificities of the economic structure of Russia should be taken into account:

- multi-level organizational structure of management;
- a large number of regions that are substantially different in terms of economic development and mutual economic relations;
- the vast distances between separate territories;
- widely varying climatic and geographical characteristics of the time zones;
- high variation in industrial structure of regional economy and the resource endowment;
- a significant amount of electric power engineering entities involved in the process of conversion of electricity and having divergent economic interests in the process of energy supply.

Features of economic system of Russia are also determined by the characteristics of the electric power complex of the country:

- the individual parameters of the demand for electrical energy consumption in the regional section; a significant number of electricity consumers, operating under UES;
- the complex organizational structure of the processes of production, transmission, distribution and marketing of electric energy;
- a large number of electric power engineering entities, at different levels of management;
- a combination of market and regulatory mechanisms at various levels of electricity prime cost formation;
- differentiation of tariffs for energy supply;
- the close relationship of the electric power complex with related industries.

Features of economic system of Russia and the structure of the electric power complex determine the factors that should be taken into account in the process of developing a system of demand management in Russia (table. 1).

Because of the hierarchy of demand control system each higher level of management is associated with lower due to the peculiarities relating to the variables and the parameters of the demand volatility, which, in turn, are associated with many factors, for example, with the number of consumers, sectoral structure of consumption, individual factors that influence the parameters of demand. We propose a hierarchical structure of ECDSM (Fig. 3).

HIERARCHICAL STRUCTURE OF DEMAND MANAGEMENT

We consider a level of electric energy consumers as a basic. It takes into account the individual characteristics of demand from each consumer, factors influencing the demand, the volume of demand, volatility of demand, conditions of supply etc.

According to the hierarchical structure, the electric energy consumer level is below the regional level. Regional levels of electric energy consumption are determined via the local peculiarities of the demand changes, the value, the organizational and sectoral structure of the regional demand for electrical energy consumption, as well as criteria of reliability ensuring of the supply modes at the level of regional energy system (RES) [Baev I. A., Solovieva I. A., Dziuba A. P., 2015].

At the hierarchical structure, the regional level of consumers is below the level of united power grids. The levels of united power grids take into account the volatility features of electrical energy consumption demand, the periods of growth and decline, demand structure, the criteria providing the reliability of the supply modes at the level of the united power grids (UPG).

Tabulation 1
Factors to be considered in the system of ECDSM in UES of Russia

Factor	Level of the social and economic processes	Level of electric power complex
The administrative and economic system of Russia	Regional structure of administration in the territory of constituent entities of the Federation	Features of tariff regulation in the territory of each constituent entity of the Federation
The hierarchical structure of the electric power complex	Influence of Executive authorities of Federation entities on electric power industry	Specificity of regional management in the electric power industry
Features of Russian regions geography	The distance between the regions and mutual economic relations	The length of the transmission lines, climate pattern, structure of fuel supply
The interests of all actors involved or indirectly associated with the process of conversion of electric energy	The economic interests of equipment manufacturers, transport and supporting infrastructure, and environmental specifications	The interests of the suppliers of fuel and raw materials, the manufacturers, the enterprises, the transport infrastructure, the electricity and heat consumers
The interests of all categories of electric energy consumers	The restriction of tariffs growth for all categories of consumers	The balance electric power infrastructure interests
The interests of management entities at all levels	The change in the cost of electricity at various levels	Changes in the demand structure of electrical energy consumption for different categories of consumers of electric energy
Economic characteristics of the regions and territorial entities	The level of social and economic development and the structure of territorial unit economy	The structure of electrical energy consumption of territorial units
Account of fuel characteristics of the electricity production in the Russia regions	Fuel supply of the generating capacities of territorial units	Structure of fuel balance of territorial units
Structural features of electricity consumption at each level of management	Structure of electric energy consumers and economic consequences of electricity consumption demand side management for each category of electric energy consumers	Electric energy consumption by different categories of consumers: population, industrial and transport companies, etc.
Technological and economic relationships between the regions	The impact of demand management on the energy systems of the related territorial entities, connected with the electrical communication and the power consumption modes	Systematic relationship between territorial entities and the unity of the electric energy consumption modes
Economic features of forming the cost of electric energy at each level of management	Social and economic consequences of the decisions made in each region	Tariff policy in the regions, and particularities of the price formation on the electric energy wholesale market
The connection of electric power industry with related industries at each level of management	The economic impact of electricity consumption demand side management for each region taking into account the individual economic and structural features	The interests of energy commodities and equipment suppliers
The system reliability of Russian UES	Ensuring the quality and reliability of the energy supply of consumers	Maintenance of equipment at nominal modes including repairs and reserves
Technological sustainability of Russian UES	Ensuring a reliable energy supply of economy	Prevention of accidents and the timely provision of fuel
Economic and energy security	The preservation of jobs in the electric power complex	Fuel supply and preservation of the required reserve of the power and generating powerful capacities in the grid
Socio-economic, technological, power development of Russia in the short, medium and long-term periods	Opportunities for socio-economic development of regions	The development of the UES of Russia, the connection of new electric energy consumers, the expansion of existing production capacities

The levels of united power grids are below the level of the Unified energy system of Russia, which is determined by the degree of volatility, periods of growth and decline of electrical energy consumption demand, the criteria of reliability ensuring of the power supply modes at the level of the UES and ensuring the parallel work of UES of Russia with energy systems of foreign States.

CLASSIFICATION OF ELECTRIC POWER INDUSTRY ENTITIES

On the basis of the developed hierarchical structure of the electricity consumption demand side management in Russia the authors carried out the classification of the electric power industry entities, which are classified according to their participation in the processes of the conversion of electrical energy and the impact on the electricity consumption demand side management (table. 2). Cost reduction on electric energy consumption could potentially lead to a massive effect on the national economy level, but not all of the electric power industry entities are interested in reducing the cost of electric energy. Mainly in reducing the cost of electric energy are not interested:

Fig. 3. The hierarchical structure of the electricity consumption demand side management

- electric energy providers: their profit directly depends on the revenue for the electricity supplied;
- representatives of the grid infrastructure (their tariffs on electric power transmission are linked to a common level of tariffs on electricity consumption, the decrease of which would have the negative impact on the dynamics of the annual indexation of transmission tariffs);
- energy supply companies (indexing dynamics of the sales markups is tied to the general level of tariffs on electricity consumption).

The economic interests of other electric power industry entities influencing the conversion of electric energy and the demand management will not be infringed during the implementation of the ECDSM mechanism and the reduction of the prices for supplied electric energy.

The classification of electric power industry entities proves once again that the demand management model in the UES of Russia should take into account the interests of all electric power industry entities, particularly those whose profits depend on the revenues for the supplied electric energy. Introduction of ECDSM technology allows to obtain a considerable effect on the national economy level. If the economic interests of the part of electric power industry entities do not coincide with the goals of the implementation of demand management system, their participation should be strictly regulated by the executive authorities of appropriate levels.

The basis for demand-side management technology is the economical motivation of the electric energy consumers to the reduction of the electrical energy consumption. In our opinion, the economic criterion is one of the incentives to adopt solutions to reduce the consumption of energy resources.

ECDSM MODEL IN RUSSIA

To implement the ECDSM model it's need to develop mechanisms of economic incentives for electricity consumers to reduce the volatility of the demand, that ultimately should facilitate alignment of graphs of power consumption in various periods in the levels of RES, UPG, UES and parallel operation of UES of Russia with energy systems of foreign States.

The proposed ECDSM mechanism (Fig. 4) has planning levels of demand management (the level of electric energy consumers, the level of the regions, the level of united power grids and the level of the unified energy system). At each level of management the individual peculiarities of functioning of the demand management system are taken into account, the levels of demand management constitute a hierarchical system. It is expected to organize the demand management, to stimulate the demand management and to control it . These steps should be implemented with the participation of all electric power industry entities (table. 2).

Electricity consumers. End users are economically encouraged to manage the demand, the organizational mechanism of ECDSM is implemented, the individual characteristics of consumer demand are taken into account, and the demand management in different periods is conducted.

Regions of Russia. Regional characteristics, influencing the demand-side management are taken into account: peculiarities of the regional demand volatility, the specific structure of electric

Tabulation 2

Classification of electric power industry entities

Entity	The reduction in electricity rates for consumers	The introduction of a mechanism of demand management	In fluence on the demand management process at the legislative level	Demand management on the electricity consumption
The regulatory infrastructure of the energy markets				
NP “Sovet rynka” (NPO “Market Council”)	—	+	+	–
OAO "Administrator torhovoi sistemy" (JSC "Trading System Administrator")	—	+	+	–
The infrastructure of the dispatching processes of the electrical energy conversion				
AO "Sistemnyi administrator YeES" (JSC "System operator of UES")	—	+	+	–
United Dispatching Offices	—	+	+	–
Regional Dispatching Offices	—	+	+	–
Regulatory infrastructure of electric power at the level of the UES				
Ministry of energy of the Russian Federation	+	+	+	–
Federal Antimonopoly Service	+	+	+	–
Regulatory infrastructure of electric power at the level of the regions				
Regional executive authorities in the energy sector	+	+	+	–
Regional executive bodies in the area of tariff regulation	+	+	+	–
Electric energy providers				
Wholesale generating companies	—	—	+	–
Territorial generating companies	—	—	+	–
Entities of retail generation	—	—	+	–
Electrical grid infrastructure				
Federal grid company	—	—	+	–
Interregional distributive grid company	—	—	+	–
Regional grid companies	—	—	+	–
Power supply companies				
Regional guarantee suppliers	—	—	+	–
Independent power supply companies	—	—	+	–
Electricity consumers				
Major subjects of the wholesale market	+	+	—	+
Large consumers of electricity in the retail market	+	+	—	+
Medium and small electricity consumers	+	+	—	+
Population	+	+	—	+
Export-import organizations				
JSC Inter RAO UES	—	—	+	+

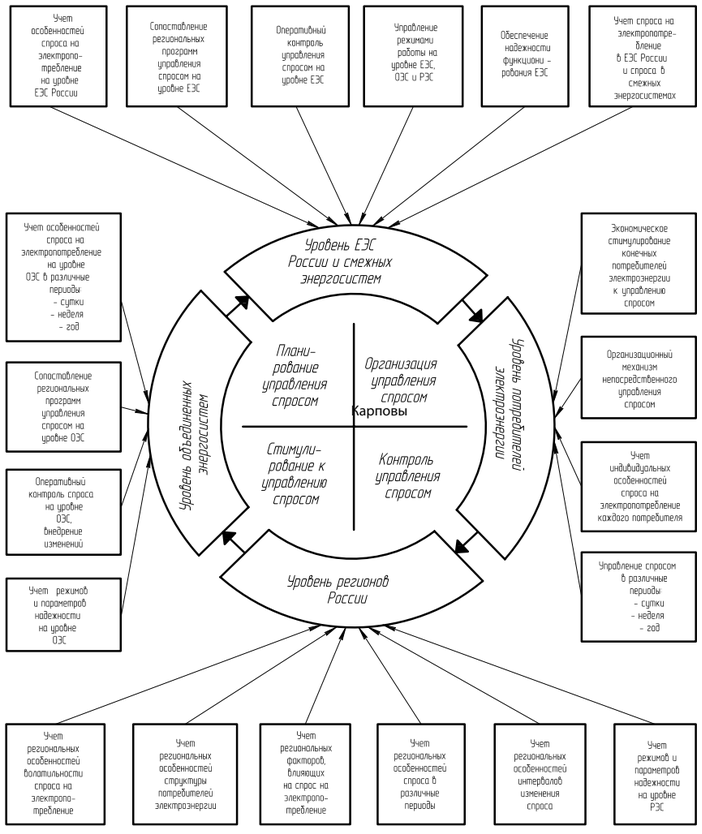
Note: "+" – the influence of the electric power industry subject; " – " – absence of influence of the electric power industry subject.

energy consumers, the regional factors influencing the demand, demand characteristics in certain periods, the operation modes of the regional power system are taken into account, the analysis of the reliability parameters of the power supply in the process of ECDSM at the end-consumers level is conducted.

United power grids. The peculiarities of electricity consumption demand side management at the level of the power systems in different periods are taken into account, the programmes of demand management at the level of UES are matched to programs of lower levels, the demand at the level of the UPG is operatively controlled, the organizational adjustments are performed, the modes of UPG operations are considered, the parameters of of power supply reliability in the process of ECDSM in the levels of regional power systems are analyzed.

Unified Energy System of Russia. The features of the electrical energy consumption demand at the level of the UES must be taken into account, the programmes of demand management on the directly preceding management level are matched to the UES level, the operational control of demand management at the UES level is performed, the operation modes of the UES in Russia are taken into account, the parameters of reliability of power supply in the process of ECDSM at the levels of the united and regional energy systems are analyzed, the electric energy consumption in the UES of Russia is taken into account, the work of the national energy system is monitored in parallel with power systems of foreign States.

Fig. 4: ECDSM MODEL IN RUSSIA



CONCLUSIONS

Current economic conditions are characterized by the development of intelligent technologies and their introduction into all spheres of economic activities. One of the most modern and effective tools for increasing the energy efficiency at the level of the economy is of ECDSM, its mechanisms today are widely used in most advanced countries of the world.

Over the past 15 years the electric power complex of Russia has undergone extensive changes, but the efficiency of energy consumption is far from the level of most developed and even developing countries. In the current economic conditions it is obvious that to increase the competitiveness of the Russian economy the further systemic changes aimed at reducing costs of energy resources in national economy are required. The ECDSM programm in Russia is at the stage of the concept development that is determined by the organisational complexity of the ECDSM in Russia. The revealed features of the economic structure of Russia and the specific characteristics of Russian nelectric power complex structure are the basic platform for the development of a general model of ECDSM in the UES of Russia. The developed model and the mechanism cover all levels of management and all functions of ECDSM in the economic system of the country. This should facilitate faster and more effective implementation of ECDSM in Russia.

Comparison of the parameters of the demand for electricity consumption in Russia and other countries demonstrates the significant potential of cost reduction of electricity consumption by balancing the demand for electricity consumption. The set of requirements to the ECDSM system in Russia is developed and the hierarchical management structure is proposed that allows to consider the characteristics of the different levels of electric energy consumption demand, to identify inter-level relationships and to increase the effectiveness of the demand management model in general.

ECDSM model should harmoniously consider the economic interests of all entities related to the process of electricity conversion, and strictly regulate the interests of the entities that impede the implementation of demand management technology. The developed model is based on the hierarchical structure of ECDSM, it covers the whole range of management options and takes into account the peculiarities of demand management at every level of management, allows to significantly improve the effectiveness of ECDSM, providing quality control of electrical energy consumption modes and reliability of power supply for consumers.

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