TECHNOLOGIES OF THE DISTRIBUTED GENERATION:

EMPIRICAL EVALUATION OF INNOVATIONS ACCEPTANCE[1]

A. V. TRACHUK
Doctor of econ. sci., Professor, Head of Department of Management, Research Manager of the Faculty of Management, FFNEE of the HEE "Financial University at the Government of the Russian Federation", the General Director of the Goznak JSC. Area of scientific interests: strategy and management of company development, innovations, entrepreneurship and modern business models in financial and real sectors of the economy, dynamics and development of e-business, operational experience and prospects for development of natural monopolies.

E-mail: Trachuk_A_V@goznak.ru

ABSTRACT

The estimation of problems and prospects of application of the distributed generation technologies by industrial companies is presented. The concept of distributed generation and composition of technologies included therein are considered, sources of key competitive advantages of using distributed generation technologies are revealed. To analyze the most significant factors of perception of distributed generation technologies by industrial companies, depth semi-structured interviews were conducted with representatives of 8 large industrial companies, questioning of representatives of 69 industrial companies has been carried out. For the analysis, a regression model has been used to determine strength and significance of influence of the selected factors on adoption of a decision by companies on own generation.

For the analyzed companies, the possibility of technical connection, the cost of electricity and perceived benefits are critical factors in taking decisions about the use of distributed generation technologies. The risk factor was insignificant. In in-depth interviews respondents explained this by the fact that distributed generation systems reduce occurrence of listed adverse effects to a minimum. Acquisition of cheap electric and thermal energy, gradual increase in energy capacity, uniformity of investment with rapid production of energy for production and economic needs is possible today due to use of energy-efficient solutions based on distributed generation technologies.

KEYWORDS

ELECTRIC POWER, DISTRIBUTED GENERATION, NEW TECHNOLOGIES, FACTORS OF ACCEPTANCE OF INNOVATIONS, ENERGY EFFICIENCY.

N. V. LINDER
Candidate of Economic Sci., Professor, First Deputy Head of the Department of Management of the FFNEE of the HEE "Financial University at the Government of the Russian Federation". Area of scientific interests: strategy and management of company development, formation of a strategy for development of industrial companies in the context of the fourth industrial revolution, innovation and transformation of business models, dynamics and development of e-business, strategies for developing energy companies under conditions of the fourth industrial revolution, and strategy for Russian companies to enter international markets.

E-mail: NVLinder@fa.ru

INTRODUCTION

Today, the electric power industry is undergoing a radical transformation, the main driver of which is technological innovation, which makes it possible to move to a fundamentally new stage of development. In recent years, there have been changes that led to a review of requirements for generation facilities, network infrastructure and, in general, organization of electricity and electricity markets. Increasing depreciation of the electric power infrastructure, involving of distributed energy resources (including renewable ones) into turnover, changing the role of traditional energy sources and energy carriers, increasing demand for electricity and transforming its quality characteristics, changing consumer behavior patterns – all this requires studying distribution factors of new technologies in the electric power industry for transition to the next energy structure.

The global trend is gradual abandonment of centralized energy supply. Thus, already 12.5% of large producers in the world use their own generating sources. The absolute leader is Denmark, where already more than half of production lines have transited to their own sources. In Russia, such enterprises still make only about 6%. The trend is traced at the level of large consumers, who refuse the electricity received from the UPN one by one in favor of installing their own small (distributed) generation. Accordingly, consumers connected to the UPN at a low voltage level (small and medium-sized enterprises) are forced to bear additional costs associated with the operation of the UPN and suffer a decrease in efficiency due to rising electricity prices.

Two approaches to created imbalance were formed:

- the current situation jeopardizes the continued existence and development of the UPN;
- development of own small (distributed) generation will allow the EES to reach inefficient capacities, reduce fuel consumption during peak hours due to use of electricity from consumer generation, reduce the amount of required and paid reserves, which will increase the efficiency and reliability of the operation of the UPN of Russia.

For example, according to results of a competitive power take-off (CPT) conducted by the System Operator (JSC SO UPN) in September 2016, more than 15 GW were unclaimed in the wholesale market. According to estimates of the System Operator, more than 20 GW will not find demand while maintaining the existing rules in 2018.

The objective of the research is estimation of problems and prospects of application of distributed generation technologies by industrial companies.

THEORETICAL REVIEW

Definition and composition of distributed generation technologies

Distributed energy systems are independent from centralized networks of generating capacities, are designed to generate electricity in close proximity to local consumers, taking into account their specific requests for volumes and consumption profile. Academic studies of the corresponding concept and its aspects began in the 1960s in the UK. The first companies that built distributed power systems opened in the US and Europe in the mid-1980s with the help of venture capitalists. Soon the investment boom began in distributed generation technologies, and the technology vendors market had formed by the end of the twentieth century, the share of distributed generation began to grow at first in the United States and Great Britain, in continental Europe. According to estimates of consulting agencies, the increase in the total amount of generating capacity by 15-25% will be covered by distributed power networks by the end of 2020.

In studies you can find different approaches to the very concept itself. Distributed generation is understood as "generation in a decentralized power system to cover energy needs of isolated (unconnected to main power grids) consumers" [Bauen A., Hawkes A., 2004; Ackermann T., Anderson G., Soeder L., 2001]. Distributed generation considers production of energy "at the level of a distributed network or at the side of a consumer included into the network" [Guan F. H., 2008]. In this case, distributed generation can be used to generate both electricity and heat.

Distributed generation includes not only generation itself, but also distributed energy storage (DESS) systems, price-dependent consumption reduction programs, consumer energy efficiency measures, micro grids and electric vehicles (for example [Frankel D., Wagner A., 2017]). For example, today most of the installed capacity of distributed energy resources in the US is not generation, but a price-dependent reduction in consumption and measures to increase energy efficiency. Only programs of various energy companies in order to reduce electricity consumption during hours of greatest demand can reduce peak consumption (respectively, the need for additional units and network infrastructure) by 5-6%, or by several tens gigawatts. For example, the ConEdison company saved more than $1 billion of investments, which were to expand the network infrastructure in several areas of New York. Instead, the company launched a large-scale program of load reduction for 52 MW at peak hours, its implementation cost $200 million.

Through the auction, the program was contributed with a lot of different measures – from replacing bulbs to more efficient installation of power accumulators from consumers and aggregated management of this equipment.

In Russia, price-based demand management programs are launched for large consumers, but so far only the RusAl company is involved. According to estimates of the Skolkovo Business School Energy Center, if demand management programs are widely spread, the potential for reducing electricity consumption will make 6-10 and 2-3 GW for the first and second price zones, respectively. Together, this is a very significant amount, in a less dense load schedule it will require more than 30 typical combined-cycle power units with a capacity of 400 MW. The energy saving potential is also very high: replacement of energy-consuming equipment with more efficient, reduction of energy losses during transmission

[1] The article was prepared on the basis of the results of the study "Analysis of problems of maximizing benefits and losses of consumers of a unified energy supply system during development of small (distributed) generation models and intelligent energy systems", conducted at the expense of budgetary financing within the framework of the project of the State University's 2017.

and consumption. In 2010, the Government of the Russian Federation estimated the potential to increase the efficiency of final electricity consumption at the level of 30%. And even if this potential is overstated and the realistic part of the potential is already realized, there still remains a significant resource to reduce electricity consumption.

In a more narrow sense, distributed generation is interpreted as construction and operation of sources of electrical (thermal) energy by consumers for their own needs. Excess electricity is sent to a common network. The objects of distributed generation include low-power energy sources up to 25 MW [Hansen C. J., Bower J., 2004; Stennikov V. A., Voropai N. I., 2014]. Co-generation objects (co-generation of electricity and heat) and renewable energy sources (RES) are also attributed to distributed generation [Sellyakhova O., Tarnovskaya O., Fateeva E. et al., 2016]. For example, small-scale power engineering includes objects with a capacity of less than 25 MW [Federal Law 2003]; micro-energy, according to different sources, the ones less than 1 MW.

So, distributed generation implies generation of electricity at the place of its consumption by a lot of consumers who produce heat and electric energy for their own needs, and the surplus is directed to a common network.

In a broad sense, these are objects that are near final consumers, regardless of the fact who owns them. This category embraces:

- *Block-stations* is a source of electrical (sometimes thermal) energy located in the territory or in immediate vicinity of an industrial enterprise and owned or leased by owners of this enterprise. Block-stations are as a rule advantageous since they can function at the expense of by-products of the main production (associated gas or blast furnace gas, etc.).

- *Co-generation plants* (combined heat and power plants) are a combined generation of electricity and heat, increasing the fuel utilization factor (FUF) by an average of 30%. Thanks to this, significant costs and inconveniences in construction and operation of heating systems become acceptable. This is one of reasons why co-generation is widely promoted and encouraged in the West now.

- *Objects of small and medium generation:* gas turbine and gas piston stations, renewable energy source power plants, which are built by consumers [Ryapin I., 2013]. In the Russian practice, the draft definition of small distributed generation was developed following discussions within the meeting of the expert council of the technological platform "Small Distributed Energy" (from 26.06.2012), the meeting of the expert council on energy (small energy section) at the Energy Committee of the State Duma of the Russian Federation (as of 05.07.2012). *"Small distributed power generation is represented by generating facilities with capacity from 1 to 50 MW located in close proximity to a consumer with the possibility of using energy storage systems and SmartGrid technologies. The distributed power engineering includes objects using co-generation energy production technologies and renewable energy sources, i.e. primary energy sources of distributed generation objects, small power plants can be both non-fuel-consuming (they work on solar, wind, wave, geothermal energy and other RES) and fuel-consuming (coal, oil, commercial gas, biomass of various origin serve as fuel).*

Sources of competitive advantages of distributed generation

Distributed generation has a number of advantages in terms of total indexes of reliability, quality and cost indicators as compared to deliveries from the distribution network (the latter remain an alternate option). Independently investing in distributed energy, consumers obviously reduce costs of developing a network complex and a large generation due to a more flexible investment model for responding to changes in dynamics and location of demand. In addition, a set of measures for managing demand and decentralized energy exchange based on distributed energy sources is applied, which also allows to refuse or postpone projects for construction of new capacities and/or large power energy infrastructure.

By its energy efficiency (PF), distributed generation is comparable to large power plants. Due to its proximity to a consumer, it is characterized by relatively lower network losses in distribution of electricity. It can also ensure fulfillment of higher requirements of consumers on availability and quality of energy, reliability of energy supply. Distribution of energy supplies is an important factor in improving energy security since it reduces risks of total blackouts and allows more rapid restoration of energy supply to consumers after natural disasters, catastrophes or cyber attacks, for example. In this sense, the development of distributed sources of energy supply as a new format of energy infrastructure can be compared with the development of information infrastructure based on distributed storage and data processing systems, which eventually became the World Wide Web.

In the literature [You S., Jin L., Hu J. et al., 2015] a new approach to organization of energy systems is called the Internet of energy.

To identify competitive advantages of distributed generation, we analyzed reports of consulting companies, foreign energy centers as well as studies of domestic and foreign authors and identified three groups of main sources of competitive advantages of distributed generation (Table 1).

The combination of distributed power with modern assets management, intellectualization of the network infrastructure, development of consumer services can lead to significant economic effects, including. to limit the growth of prices for electricity in the long term. Development of production capacities and applications of distributed energy stimulates development of management technologies, equipment and services that ensure their most effective use within the power system and energy market, creates a technological basis for emergence of mass active consumers and opportunity to enter the large-scale global market.

Across the world, a significant share of new local capacity is generated by micro generation based on renewable energy sources (primarily roof solar panels, increasingly in combination with storage tanks) and more environmentally efficient mini-co-generation plants. Accordingly, distributed energy is also an effective means of reducing greenhouse gas emissions and preventing climate change. Thus, competitive advantages are highlighted in three areas: economy (for example, limiting increase of electricity prices), management (development of new technologies for managing demand for electricity, equipment and services in companies) and ecology (distributed generation serves to reduce greenhouse gas emissions and prevent climate change).

Table 1.
Sources of competitive advantages of distributed generation

Group	Authors
Economic benefits, including limiting increase of electricity prices	Frankel D., Wagner A., 2017; Berg A., Krahl S., Paulun T., 2008; Trachuk A. V., 2010a; Trachuk A. V., Linder N. V., 2017; Khovalova T. V., 2017
Development of management technologies, equipment and service in companies	Kazemi A., Sadeghi M., 2009; Wu J., 2009; Ipakchi A., Albuyeh F., 2009; Yingyuan Z., Liuchen C., Meiqin M. et al., 2008; Seo H., Park M., Kim G. et al., 2007; Zhang X. P., 2008; Li H., Leite H., 2008; Trachuk A. V., JILinder N. V., Zolotova I. Yu. et al., 2017; Trachuk A.V., 2011; Linder N. V., Trachuk A.V., 2017; Gitelman L. D., Bokarev B. A., Gavrilova T. B. et al., 2015
A mechanism for reduction of greenhouse gas emissions and achievement of global climate change targets	Bhowmik A., Schatz J., Maitra A. et al., 2003; Samuelson S., 2009; Li H., Leite H., 2008; Kumpulainen L., Kauhaniemi K., 2004

Factors of application of distributed generation technologies

Companies will build and use their own generation sources when they realize benefits of their application and will be ready to implement them. Accordingly, it is important to study acceptability of distributed generation technologies and their perception by industrial companies. For this, we studied factors that have the greatest impact on companies' decision to introduce a new technology.

There are not so many studies devoted to adoption of new technologies by industrial companies. The most well-known models of technology adoption factors by companies proposed [Molla A., Licker P. S., 2002; 2005]:

- model POER used to measure intra-organizational factors of adoption of new technologies. This model was proposed to analyze factors of the intra-organizational environment: inclination of employees to adopt new technologies, the system of internal assistance in the company, attitude of employees towards innovation;
- model PEER used for analysis of external factors. The PEER model analyzes factors of competitive pressure in the industry, influence of regulators and technological changes in the industry.

Adoption of new technologies is also affected by specific characteristics, which include speed, reliability, enjoyment of use, control of use process, risk of use [Davis F.D., 1989]. In Table 2, intra-organizational and external factors affecting adoption of new distributed generation technologies by companies, are presented.

Hypothesis 1. Perception of distributed sources of generation by industrial companies is influenced by

- intra-organizational factors:
  a) technical feasibility;
  b) availability of specialists;
  c) perceived risks;
  d) perceived advantage;
  e) the cost of connection;
  f) electricity costs and
- external factors:
  g) market pressure;
  h) pressure of the regulator (government authorities);
  i) technological changes in the industry.

To identify specific characteristics of distributed generation technologies that affect their acceptance by companies, we used results of research [Arndt U., Wagner U., 2003; Picciariello A., Reneses J., Frias P. et al., 2015; Frias P., Gomez T., Cossent R., 2009; Picciariello A, Vergara C, Reneses J. et al., 2015; Dondi P., Bayoumi D., Haederli C. et al., 2002; Ryapin I., 2013; Izadkhast S., GarciaGonzalez P., Frías P. et al., 2016] and identified the most significant specific factors (Table 3).

Hypothesis 2. The decision to switch to use of distributed generation sources is influenced by specific factors:

a) the presence of by-products that can be used as fuel;
b) high efficiency;
c) lack of energy transfer costs;
d) absence of payment for technological connection to electric grids;
e) the existing price ratio for electricity and natural gas;
e) the possibility of changing the amount of generated electric and heat energy when the economic situation changes;
f) reduction of the need for energy transmission over significant distances;
g) increase of the share of the of local energy resources.

Barriers in development of distributed generation in Russia and other countries

For spreading distributed generation in practice, it is important to identify barriers. First of all, we examined barriers for development of distributed generation technologies in foreign markets, and then – on the domestic one.

USA, California. Development of distributed generation in California is closely related to regulatory measures aimed at stimulating production of electricity based on RES. In California, the "Standard of Renewable Energy Sources" (RES) was adopted: energy companies are obliged to annually increase the volume of purchases of electricity produced on the basis of renewable energy according to relevant criteria, not less than 1% of total retail sales of electricity. Currently, California's legislative authorities is developing norms that call for an increase of this index to 33% by 2020.

Table 2.
Factors influencing the adoption of new technologies by companies

Adoption factors	Research
Intra-organizational factors	
The possibility of technical connection (integration, scalability, remote access, infrastructure, complexity, etc.)	Wu J., 2009; Trachuk A.V., 2010a; Vorozhikhin V., 2013; Volodin Yu. V., Linder N. V., 2017
Availability of specialists	Vorozhikhin V., 2013; Bhowmik A., Schatz J., Maitra A. et al., 2003
Perceived risks (security, investment)	WuJ., 2009; Trachuk AV, 2010 a; Bhowmik A., Schatz J., Maitra A. et al., 2003
Perceived benefits and the need for alternative energy sources	Seo H., Park M., Kim G. et al., 2007; Haas R., Loew T., 2012; Davito B., Tai H., Uhlaner R., 2010; Trachuk A.V., 2011; Volodin Yu. V., Linder N. V., 2017
Cost (transaction fee)	Haas R., Loew T., 2012; Davito B., Tai H., Uhlaner R., 2010; Krivoshapka I., 2013; Volodin Yu. V., Linder N. V., 2017; Berg A., Krahl S., Paulun T., 2008
Expenses	Seo H., Park M., Kim G. et al., 2007; HaasR., Loew T., 2012; Trachuk A.V., 2011; Berg A., Krahl S., Paulun T., 2008
External factors	
Changes in the market that affect the company's decision to use new technologies	Subhes C., 2011; Seo H., Park M., Kim G. et al., 2007; Trachuk A.V., 2010a; Grubb M., Jamasb T., Pollitt M. G., 2008
Decisions of regulators (authorities) affecting the decision of companies on use of new technologies	Subhes C., 2011; Grubb M., Jamasb T., Pollitt M. G., 2008; Davito B., Tai H., Uhlaner R., 2010; Trachuk A.V., 2011; 2010 a
Technological changes in the industry	Subhes C., 2011; Grubb M., Jamasb T., Pollitt M. G., 2008; Trachuk AV, 2011

Three types of barriers for development of distributed generation have been identified:

- technical barriers: technical standards for connection of distributed generation installations to network, testing and certification procedures for equipment used for connection;
- commercial barriers: standard commercial conditions and practice of approving connection with an energy company;
- regulatory barriers: absence of regulated tariffs and incentives for distributed generation [Damodaran A., 2008].

The main barrier to emergence of distributed generation technologies on the market is the lack of standards for connection to the network. To address this issue in 2001, the Californian Public Utilities Commission (CPUC) developed standard connection rules. As a result, generating companies operating on the wholesale electricity market and meeting certain requirements have the right to connect distributed power generation systems to the network.

United Kingdom. Distributed generation systems have been actively developing since the early 1990s. In 1993-1994, the volume of production based on distributed generation in England and Wales was 1.2 GW. At present, this volume exceeds 15 GW. The review prepared by the Office for Gas and Electricity Markets, identified main market failures and regulatory systems:

- imperfection of the legal-regulatory framework: existing laws and regulations have been developed for a system with a centralized electricity production and hamper development of distributed generation;
- the lack of simple and understandable information regarding possibilities of distributed generation [Frankel D., Wagner A., 2017].

Table 3.
The most significant specific factors for companies to take a decision on their own generation

Factor	Research
Specific factors	
The presence of by-products that can be used as fuel	Picciariello A., Reneses J., Frias P. et al., 2015
High efficiency (provided that the generation object is designed to meet needs of specific industrial production in electric and thermal energy)	Picciariello A, Vergara C, Reneses J. et al., 2015
Absence of energy transfer costs	Izadkhast S., Garcia-Gonzalez P., Frías P. et al., 2016
Absence of payment for technological connection to electric grids (if the generation object is isolated from the power system)	Picciariello A., Reneses J., Frias P. et al., 2015; Izadkhast S., Garcia-Gonzalez P., Frías P. et al. 2016
The existing ratio of prices for electricity and natural gas, indicating a high gas potential	Picciariello A., Vergara C., Reneses J. et al. 2015
The possibility of changing the amount of generated electric and heat energy when the economic situation changes	Frias P., Gomez T., Cossent, R., 2009; Izadkhast S., Garcia-Gonzalez P., Frías P. et al., 2016
Proximity of energy production to consumers, reducing the need for energy transmission over significant distances	Ao-Yang H., Zhe Z., Xiang-Gen Y., 2009; Picciariello A., Reneses J., Frias P. et al., 2015
Increase the share of use of local energy resources	Pepermans G., DriesenJ., Haeseldonckx D. et al., 2005

Table 4.
Barriers to development of distributed generation

Barriers	Explanation
Dominance of the traditional industry organization model	Energy solutions are based on a model of centralized electricity generation using transmission and distribution network to supply electricity to consumers
	Institutional structure, rules and regulations, installation requirements and technical standards create more favorable conditions for centralized electricity generation than for distributed generation
	Historically, the cost of electricity was significantly lower compared to other costs than at present, development of alternative sources did not receive an incentive
	Environmental problems gave impetus to development of generating facilities of various capacities based on RES, but did not provide creation of financial incentives
Determining the potential of distributed generation	Information on possibilities of using alternative energy sources is limitedly available for household consumers
	Norms, practical guidelines and certification procedures for suppliers are not harmonized, and their implementation is difficult
	Problems related to regulation, technical aspects and capacity
	Connection of distributed generation causes difficulties, despite existence of regulatory norms
	Micro installations of distributed generation require high installation costs
Profitability of distributed generation	Obtaining permits for use of resources and construction of distributed generation systems require considerable time and money, requirements are significantly overrated for small generation facilities
	The cost of electricity from distributed generation facilities can be higher in comparison with prices for electricity supplied from the network
	The use of new technology can be associated with additional costs and risks
	Energy sales companies are rarely ready to buy excess electricity produced by distributed distribution micro-units
	The payback period of distributed generation systems is too large for residential consumers
Getting investment in distribution networks	Distribution companies may not have sufficient incentives to invest in support of distributed generation

To eliminate barriers to development of distributed generation, it is proposed to implement joint programs under the leadership of the Office for Gas and Electricity Markets and the Department for Business Development, Innovation and Professional Education (BIS). Since 2007, the UK government has been promoting the development of distributed generation. There are fiscal incentives: When introducing the majority of microgeneration technologies, the value added tax is reduced by 5%.

Australia. In the national electricity market, the centralized power supply model for a long time prevailed, small generation and consumption management were used only in the private sector.

A large-scale comprehensive study of barriers and benefits of distributed generation in Australia is presented in a report prepared by the Organization for Scientific and Industrial Research of Australia as part of implementation of the main energy reform program [McDonaldJ., 2008]. So, the authors identify such barriers as imperfection of the legal-regulatory framework, lack of economic incentives for switching to distributed generation facilities, the lack of information about advantages of distributed generation.

Denmark. In Denmark, distributed generation is developing more successfully than in other Scandinavian countries. For comparison: in Norway and Sweden, the capacity of distributed generation units is 1500 kW. There, like in Finland, there are few independent electricity producers, which means there is no need to develop detailed recommendations and requirements for regulation of distributed generation.

In 1980, the capacity of distributed power generation was 1%. The development of distributed generation was mainly promoted by direct regulation, which in Denmark lasts much longer than in other developed countries. The main driving force behind the development of distributed generation is initiatives aimed at increasing the volume of electricity production based on RES in accordance with goals set by the European Commission. In 2002, obstacles to development were considered to be the lack of standards and requirements for connecting distributed generation facilities, the high cost of generating electricity by distributed generation systems and insufficient development of distributed generation market. According to the Ministry of Energy of Denmark, in 2005 about 57% of generating capacity was co-generation (joint generation of heat and electricity) and 31% – renewable energy.

Successful development of the distributed generation sector in Denmark is due to use of the bottom-up approach, which implies close cooperation of a large number of small companies, local authorities and cooperatives [Subhes C., 2011].

Table 4 shows barriers that prevent development of distributed generation in European countries.

Analysis of numerous publications of Russian authors [Trachuk AV, 2011; Sellyakhova O., Tarnovskaya O., Fateeva E. et al., 2016; Klimovets O. V., Zubakin V. A., 2016] revealed barriers to development of distributed generation in Russia:

- the lack of clear and unambiguously interpreted requirements for technological connection of industrial generation facilities to electric network increases the time frame for implementation of projects;
- generating facilities with the capacity of 25 MW or more connected to the network are obliged to sell the generated electricity in the wholesale market (except for cases established by the Government of the Russian Federation). They must buy electricity for own consumption at market prices, paying for transfer services. Owners of distributed generation facilities with a capacity of 25 MW or more are forced to look for ways to obtain confirmation of non-proliferation of the wholesale market requirements for this object (issued by NP Market Council) and remain in the status of a participant in the retail market. In order to avoid the need to be present on the wholesale market, it is necessary to initially build generating facilities with a capacity of less than 25 MW or to plan the isolated operation of generating facilities that will not be connected to the power network;
- The lack of a clear understanding of benefits of industrial distributed generation among stakeholders slows down preparation and receipt of permits.

METHODOLOGY OF THE STUDY

To analyze the most significant factors of perception of distributed generation technologies by industrial companies, we conducted the study in two stages:

- *Qualitative stage*:
  - o conducting in-depth semi-structured interviews with representatives of 8 large industrial companies in order to determine interrelations between factors and decision to build their own generation and additionally justify the development of a questionnaire that allows analyzing factors that are most significant for a positive solution;
  - o Determination of nonparametric Spearman correlation coefficients (ρs) for the ranked data in order to recognize significant connection between the model components, the selection of specific characteristics of factors for further testing;
- *Quantitative stage*:
  - o drawing up a questionnaire and questioning representatives of industrial companies (69 companies, Table 5);
  - o Formation of regression model has been used to determine strength and significance of influence of the selected factors on taking a decision by companies on own generation.

At the next stage, an index was calculated for the main internal and external factors affecting the decision to build own generation by summing up references to individual items from the questionnaire (Table 6). Similarly, the frequency of mention of specific factors is calculated (Table 7). Then nonparametric Spearman correlation coefficients ρs were calculated for the ranked data. To recognize the relationship between components of the model, the significant correlation coefficient should exceed the threshold value of 0.50.

Description of variables

At the quantitative stage of the study, statements of the questionnaire that measured the most significant factors, were formulated. Respondents were asked to answer the question: "How much do you agree with statements below?" The degree of consent was assessed on the Likert scale from 1 to 7 points (1 – "completely disagree", 4 – "I do not know, I agree or disagree," 7 – "completely agree") (Table 8, 9).

To measure the "technical feasibility" factor, we took a scale with two questions. They are designed to determine whether the company has the ability to establish distributed generation objects taking into account the existing infrastructure. To assess the "perceived advantage" factor, the higher efficiency of distributed generation than the services of the Unified National Electrical Network, was estimated. The factor "costs for construction and installation of sources of distributed generation" was measured using two issues that characterize the need to redeem construction of own generation in the medium term.

In order to measure external factors affecting the adoption of distributed generation technologies, three groups of issues are involved. Market pressure was measured in accordance with the answers to questions about competitive pressure, comparison of used technologies. Technological changes in the industry were measured as an assessment of how possible to repair equipment and to ensure equipment operation during peak hours of workload. The regulators decisions significance was assessed on the basis of confidence and there are no administrative obstacles, but there is support for the introduction of distributed generation.

Similarly, a questionnaire was developed in order to analyze the specific factors for the adoption of distributed generation technologies (Table 9).

Description of the data analysis procedure

Reliability coefficients (Cronbach's alpha) were first evaluated for all variables measured on the basis of scales of several questions during the analysis. The calculated coefficients corresponded to the recommended minimum level of reliability - 0.75 (see Table 8, 9). The factor analysis was carried out by the main component method for 9 questions describing the four aspects of intra-organizational factors and 6 questions describing three aspects of external factors on the next stage.

An analysis of specific factors affecting the adoption of distributed technologies by companies network extension was conducted using 15 questions. In total, four specific factors shows 73.8% of the variation in the company's answers to questions, which corresponds to recommendations of 70% explaination of the variation in structural models.

Factor analysis based on the method of principal components with orthogonal rotation revealed the presence of four intra-organizational factors and two factors of the external environment, which described a total of 72.8% variation in questions. The values of these factors were used to form the final set of factors that influence the adoption of distributed generation technologies by companies and which were included in the regression analysis.

The results of factor analysis were used in order to calculate the influence of factors on the perception of distributed generation technologies by companies:

$$Z_i = \beta_0 + \beta_1 T_i + \beta_2 RK_i + \beta_3 UR_i + \beta_4 COST_i + \beta_5 C_i + \beta_6 MARK_i + \beta_7 TR_i + \beta_8 GR_i + \varepsilon_i \quad (1)$$

где Z_i – the indicator of adoption of distributed generation technologies by companies (binary variable, where 1 – distributed generation technologies are accepted for company use, 0 - not accepted); T_i – possibility of technical feasibility for the use of distributed generation units; RK_i – perceived by companies risks associated with the usage of distributed generation technologies; UR_i – company's perceived advantages of using distributed generation technologies; $COST_i$ – primecost of own electricity; C_i – зcosts of construction and installation of distributed generation sources; $MARK_i$ – давление рынка, влияющее на принятие технологий распределенной генерации; TR_i – technological changes in the industry, promoting acceptance of distributed generation technologies; GR_i – decisions of regulators (authorities), affecting the decisions of companies about use of new technologies for distributed generation.

An analysis of specific factors of perception of distributed generation technologies by companies was carried out according to the following model:

$$Y_i = \beta_0 + \beta_1 PRDOD_i + \beta_2 KPD_i + \beta_3 USE_i + \beta_4 EASE_i + \beta_5 SEC_i + \beta_6 CON_i + \beta_7 ECO_i + \varepsilon_i \quad (2)$$

where Y_i – indicator of distributed generation technologies perception by companies (binary variable, where 1 – distributed generation technologies are accepted for use by the company; 0 – are not accepted); $PROD_i$ – presence of by-products that can be used as fuel; KPD_i – high efficiency; USE_i – ono energy transfer costs; $EASE_i$ – absence of payment for technological connection to electric networks; SEC_i – existing price relation for electricity and natural gas indicates a high gas potential; CON_i – energy production occurs in close proximity to points of consumption, which leads to a decrease of need for energy transmission over significant distances; ECO_i – ability to vary the amount of generated electrical and heat energy when the economic situation changes.

Standardized and non-standardized regression coefficients were determined using the maximum likelihood method. Non-standardized coefficients were used to test hypotheses, and

Table 5.
Characteristics of companies in the sample: control variables

Characteristic	number of companies	
	abs. un.	rel., %
Sector		
Industry	61	92
HUS	8	8
Life of the company, years		
Less than 5	11	16
5–10	17	25
More than 10	41	59
Number of staff, people.		
From 500 to 1000	4	5
From 1001 to 1500	19	28
More than 1500	46	67
Proceeds from sales, million rubles.		
Less than 50	9	8
From 50 to 500	21	35
More than 500	39	57

Table 6.
Mention of intra-organizational and external factors of perception of distributed generation by companies

Factor	the mention share, %
Intra-organizational factors	
The possibility of technical connection and use (integration, scalability, remote access, infrastructure, complexity, etc.)	61,6
Availability of specialists	19,3
Perceived risks (security, investment)	45,9
Perceived benefits and the need for alternative energy sources	76,3
Cost of electricity	74,1
Expenses for construction and installation of sources of distributed generation	81,5
External factors	
Changes in the market that affect the company's decision to use innovation	62,7
Decisions of regulators (authorities), affecting decisions of companies on the use of	96,3
new technologies Technological changes in the industry	73,5

Table 7.
Mention of specific factors of distributed generation technologies

Factor	the mention share, %
The presence of by-products that can be used as fuel	41,5
High efficiency (the generation object is designed taking into account needs of specific industrial production in electric and thermal energy)	48,4
Absence of energy transfer costs	58,9
Absence of payment for technological connection to electric grids (if the generation object is isolated from the power system)	79,4
The price of natural gas is lower than that of electricity	42,6
The possibility of changing the amount of generated electric and heat energy when the economic situation changes	41,2
Energy production in close proximity to places of consumption and a reduction in the need for energy transmission over significant distances	34,6
Increase the share of use of local energy resources	55,6

Table 8.
Indicators for measuring acceptance characteristics of distributed generation technologies by industrial companies

Notation	Dimension	Source	Kronbach Alpha
	In-house characteristics *Possibility of technical connection* *(integration, scalability, remote access, infrastructure, complexity, etc.)*		
T_1	Our company has an understanding of what types of distributed generation are most suitable and applicable to our business	Wu J., 2009; Trachuk A.V., 2010a; Vorozhikhin V., 2013; Volodin Yu. V., Linder N. V., 2017	0,79
T_2	Our company will connect to distributed generation objects if existing systems can be configured to use them		
	Perceived risks (security, investment)		
RK_1	Our company will connect to distributed generation facilities, if this will improve safety and efficiency of our energy system	Wu J., 2009; Trachuk A.V., 2010a; Bhowmik A., Schatz J., Maitra A. et al., 2003	0,79
RK_2	Our company will switch to distributed generation if risks of using its own energy sources are not high		
	Perceived benefits and the need for alternative sources of electricity		
UR_1	Our company will switch to its own generation, if it is confident that they meet all the needs of the technological cycle	Seo H., Park M., Kim G. et al., 2007; Haas R., Loew T., 2012; Davito B., Tai H., Uhlaner R., 2010; Trachuk AV, 2011; Volodin Yu. V., Linder N. V., 2017	0,92
UR_2	Our company will switch to its own generation, if we can use our by-products as fuel		
	Cost of electricity		
$COST_1$	Our company will switch to its own generation, if the cost of electricity is lower than other alternative options	Haas R., Loew T., 2012; Davito B., Tai H., Uhlaner R., 2010; Krivoshapka I., 2013; Volodin Yu. V., Linder NV, 2017; Berg A., Krahl S., Paulun T., 2008	0,91
$COST_2$	Our company will switch to its own generation, if it allows us to have additional sources of income from the sale of electricity to the network		
	Expenses for construction and installation of sources of distributed generation		
C_1	Our company will switch to its own generation, if the cost of installing and building own generation sources will redeem within 5 years	Seo H., Park M., Kim G. et al., 2007; Haas R., Loew T., 2012; Trachuk AV, 2011; Berg A., Krahl S., Paulun T., 2008	0,93
C_2	Our company will switch to its own generation, if construction and use of sources of own generation do not significantly increase the cost of manufactured products		
$MARK_1$	Our partners are pushing us to use our own sources of energy generation, as this will significantly reduce the share of electricity costs in the structure of cost of our products	Subhes C., 2011; Seo H., Park M., Kim G. et al., 2007; Trachuk A. V., 2010 a; Grubb M., Jamasb T., Pollitt M. G., 2008	0,86
$MARK_2$	Products produced at domestic enterprises are sometimes not in position to compete with foreign analogues due to high share of energy resources in production costs, imperfect production technologies and waste of energy resources		
	Technological changes in the industry		
TR_1	Our company will switch to its own generation, if maintenance and repair can be carried out in an open area and do not require significant material and human resources.	Subhes C., 2011; Grubb M., Jamasb T., Pollitt M. G., 2008; Davito B., Tai H., Uhlaner R., 2010; Trachuk A.V., 2011; 2010a	0,76
TR_2	Transition of our company to sources of distributed generation is associated with inability to provide necessary electricity demand at remote sites, at sites where there are frequent interruptions in centralized power supply, in situations where peak loads on power system are sufficiently high.		
	Decisions of regulators (authorities), affecting decisions of companies on use of new technologies		
GR_1	Our company will switch to its own generation, if commissioning such plants will require significantly fewer approvals of controlling authorities	Subhes C., 2011; Grubb M., Jamasb T., Pollitt M.G., 2008; Трачук А.В., 2011	0,78
GR_2	Our company will switch to its own generation, if commissioning of such facilities will be supported by authorities		

Table 9.
Specific factors for decisions making about on own generation

Factor	Desig-nation	Measurement	Source	Cronbach's alpha
Presence of by-products that can be used as a fuel	$PROD_1$	We have by-products and consider it as the possibility of switching to distributed generation technology	Walczuch R., Van Braven G., Lundgren H., 2000; Ao-Yang H., Zhe Z., Xiang-Gen Y., 2009	0,78
	$PROD_2$	We do not have by-products, but this is not a decisive factor for the transition to own generation		
High efficiency (under condition that the generation object is designed с учетом to meet the needs of specific industrial production in both electrical and thermal energy)	KPD_1	The efficiency of distributed generation technologies in cogeneration mode reaches 90% or more, which makes the transition to these installations cost-effective	Ao-Yang H., Zhe Z., Xiang-Gen Y., 2009; Walczuch R., Van Braven G., LundgrenH., 2000	0,81
	KPD_2	Reliability of power supply and high quality of energy are critical for the uninterrupted operation of equipment and exclusion of technical stops at large-scale construction projects		
	KPD_3	An additional argument in favor of autonomous generation is the possibility to use the energy of the exhaust gases of turbines turbines in order to produce heat, which can significantly increase the overall efficiency of the power		
Absence of energy transfer costs	USE_1	The use of distributed generation technologies makes it possible to obtain stable high-quality electricity without the cost of transmission of electricity	Davis F. D., 1989; Walczuch R., Van Braven G., Lundgren H., 2000; Ao-Yang H., Zhe Z., Xiang-Gen Y., 2009	0,77
	USE_2	The use of distributed generation technologies in industry is an exceptionally effective means of saving costs and solving problems of current waste resources use.		
Absence of payment for technological connection-technological connection to electric grids (if the generation object is isolated isolated from the power system)	$EASE_1$	Energy supply from centralized sources is becoming more expensive and unreliable. The use of decentralized energy energy supply systems can be easier and more promising in production	Davis F. D., 1989; Walczuch R., VanBraven G., Lundgren H., 2000; Ao-Yang H., Zhe Z., Xiang-Gen Y., 2009	0,89
	$EASE_2$	Today due to the use of energy-efficient solutions based on small and microturbines became possible to obtain cheap electric and thermal energy, to increase gradual in energy capacity, to invest uniformly with the rapid obtainment of energy for production and economic needs		
The price for natural gas is more attractive than for electricity	SEC_1	Annually, more than 100 billion cubic meters of energy-containing gases are burned all over the world, which are waste products of any production. In the mining regions there are no opportunities for transportation and processing of gases accompanying oil released during its extraction. This makes an attractive transition to own generation.	Davis F. D., 1989; Walczuch R., Van Braven G., Lundgren H., 2000; Ao-Yang H., Zhe Z., Xiang-Gen Y., 2009	0,86
	SEC_2	The technology of fuel combustion in burner can of the turbogenerator provides a low level of emissions into the atmosphere, which makes the technology of distributed generation environmentally friendly.		
The ability to vary the amount of generated electrical and heat energy under condition of the economic situation changes	ECO_1	The dual-mode controller allows to monitor the status of the electrical network and, in case of a fall of the external network, to put the installation into an autonomous mode. Thus, distributed generation technologies can be used in order to power an uninterruptible power system without unnecessary costs for connection to electrical networks	Ao-Yang H., Zhe Z., Xiang-Gen Y., 2009	
The production of energy in close proximity to the points of consumption and, consequently, energy transmission need reduction over significant distances	CON_1	Gas turbine power plants using associated gas as fuel are located in close proximity to oil production places. According to this, there is a need for construction of gas gathering facilities, pipelines, compressor stations	Davis (1989); Walczuch R., Van Braven G., Lundgren H., 2000; Ao-Yang H., Zhe Z., Xiang-Gen Y., 2009	0,88

Table 10
Acceptance of distributed generation technologies by companies: the impact of intra-organizational characteristics and environmental factors

Independent indicator	Hypothesis	Coefficient	
		Non-standardized	Standardized
Constant $β_0$		0,191 (0,0134)	
In-house characteristics			
Technical feasibility (integration, scalability, infrastructure, complexity, etc.) T_i	1 (а)	0,264*** (0,098)	0,281***
The perceived risks (security, investment) RK_i	1 (в)	0,166*** (0,015)	0,185
The perceived benefits and need for alternative sources of generation UR_i	1 (г)	0,451** (0,104)	0,454**
Cost of electricity $COST_i$	1 (д)	0,598*** (0,062)	0,599***
Costs for construction and installation of distributed generation sources C_i	1 (е)	–0,387*** (0,209)	–0,385***
External environmental factor			
Market pressure $EASE_i$	1 (ж)	–0,196** (0,118)	–0,394**
Technological changes in the industry TR_i	1 (з)	0,153 *** (0,201)	0,254***
Decisions of regulators (authorities) affecting companies' decisions on the use of new technologies GR_i	1 (и)	–0,393 *** (0,023)	–0,194***
Corrected R^2	—	0,709	
Number of observations		69	
* $p < 0{,}10$; ** $p < 0{,}05$; *** $p < 0{,}01$. Standard errors are given in brackets.			

standardized ones were used to determine the factors that had a greater impact on adoption of distributed generation technologies by companies.

RESULTS OF THE STUDY

The influence of factors on the adoption of distributed generation technologies

Regression analysis showed the influence of various factors in the adoption of distributed generation technologies by companies (corporate internal characteristics and environmental factors), as well as the influence of specific factors (Table 10-12). We evaluated the influence of these independent variables on the adoption of distributed generation technologies with help of the maximum likelihood method. In general, the results of the regression analysis confirmed the hypotheses of the study. Models based on equations (1) and (2) were able to explain 63% of the variation of intra-organizational and external factors in the adoption of distributed generation technologies by companies and 57% of the variation of specific factors.

The simulation of distributed generation technologies acceptance by companies (Table 10) showed that the technical feasibility (β = 0.264, p <0.05), the comparative advantage of using distributed generation (β = 0.451, p <0.10), the cost of electricity (β = 0.598, p <0.10) positively affect the adoption of distributed generation technologies. The perceived risks (β = 0.166, p = 0.01) have no significant effect on the growth in the number of distributed generation users. Expenses for the construction and installation of distributed generation sources "(β = -0.387, p <0.10) have a negative impact on the decision to use distributed generation technologies.

The decisions of regulators have a significant impact on the distributed generation technologies (β = 0,393, p <0,05) adoption by companies among the external factors. Market pressures and technological changes in the industry have a slight negative impact on the adoption of distributed generation technologies by companies. Thus, technical feasibility, comparative advantage and the cost of electricity are the main factors in the growth of companies number using distributed generation in the sample studied. Table. 11 shows the results of regression analysis of the specific factors influence on the process of adopting distributed generation technologies. The content of the hypotheses is given above.

All specific factors had a positive effect on the distributed generation technologies adoption by companies with an error probability of p≤0.05. Factors had the following coefficients β:

- EFFICIENCY: $β = 0{,}324$ ($p < 0{,}01$);
- Absence of energy transfer costs: $β = 0{,}378$ ($p < 0{,}05$);
- absence of payment for technological connection to electric networks: $β = 0{,}321$ ($p < 0{,}05$).

At the same time, the existing ratio of prices for electric energy (β = 0.016, p> 0.10) and the possibility of changing the volumes of generated electric and thermal energy in case of some changes in economic situation (β = 0.163; p> 0.10) did not make a significant influences.

The results of the analysis of barriers of distributed generation adoption

According to the regression analysis, the costs of building and installing sources of distributed generation, the decisions of regulators (authorities) affecting the decisions of companies in cases of new technologies usage, and market pressure have a negative impact on the decision to switch to their own sources of electricity.

We conducted semi-structured interviews with 14 experts who are members of NP Market Council in order to understand barriers that form a negative impact of these factors. Further, we reduced the barriers mentioned by experts and the frequency of their mention in Table. 13. The index for the main barriers of distributed generation development is calculated by summing up references to individual items from the questionnaire. The identified barriers allow us to formulate measures for the development of industrial distributed generation in Russia at the federal level.

CONCLUSIONS AND APPLICATION OF THE RECEIVED RESULTS

Hypothesis testing results

Hypothesis 1 described the factors influencing the distributed generation technologies perception by companies. The hypothesis is partially confirmed for intra-organizational factors:

a) the possibility of technical connection ($β = 0{,}264$; $p < 0{,}05$);
d) perceived benefits ($β = 0{,}451$; $p < 0{,}01$);
e) the cost of electricity ($β = 0{,}598$; $p < 0{,}05$), and environmental factors: (i) the regulator's decision ($β = 0{,}396$; $p < 0{,}05$).

The negative influence on adoption of distributed generation technologies is rendered by:

e) costs of construction and installation of distributed generation sources ($β = –0{,}387$; $p < 0{,}01$);
g) market pressure ($β = –0{,}196$; $p < 0{,}01$).

The hypothesis is not confirmed for the factors:

h) perceived risk ($β = 0{,}166$; $p < 0{,}01$);
i) the possibility of changing the amount of generated electrical and thermal energy ($β = 0{,}153$; $p < 0{,}01$)

According to hypothesis 2, the perception of distributed generation technologies by companies is influenced by specific factors.

This hypothesis is partially confirmed for general factors:

b) the presence of by-products that can be used as fuel ($β = 0{,}421$; $p < 0{,}01$);
d) high efficiency ($β = 0{,}324$; $p < 0{,}10$);
e) absence of costs for energy transfer ($β = 0{,}316$; $p < 0{,}01$);
h) absence of payment for technological connection to electric networks ($β = 0{,}363$; $p < 0{,}01$).

The influence of factors is not confirmed:

g) the existing price ratio for electricity and natural gas ($β = 0{,}016$; $p < 0{,}01$);
h) the possibility of changing the amount of generated electrical and thermal energy ($β = 0{,}163$; $p = 0{,}45$);
k) Decrease of need for energy transmission over significant distances ($β = 0{,}211$; $p < 0{,}01$).

Table 11
Adoption of distributed generation technologies: the impact of specific factors

Independent indicator	Hypothesis	Coefficient	
		Non-standartized	Standartized
Constant $β_0$	—	0,216 (0,031)	—
The presence of by-products that can be used as fuel	2 (б)	0,421 *** (0,023)	0,419***
High efficiency (the generation object is designed taking into account the needs of specific industrial production in both electric and thermal energy)	2 (г)	0,324*** (0,127)	0,327*
Absence of energy transfer costs	2 (д)	0,378** (0,212)	0,381***
Absence of payment for technological connection to electrical networks (if the generation object is isolated from the power system)	2 (з)	0,321** (0,041)	0,323
The price of natural gas is more attractive than for electric energy	2 (ж)	0,016*** (0,091)	0,009***
The possibility of changing of generated electric and heat energy amount due to economic situation changes	2 (и)	0,163* (0,037)	0,168*
The production of energy in close proximity to consumption points and, consequently, the reduction in the need for energy transmission over significant distances	2 (к)	0,211*** (0,009)	0,209***
Corrected R^2	—	0,628	
Number of observations	—	69	
* $p < 0{,}10$; ** $p < 0{,}05$; *** $p < 0{,}01$. Standard errors are given in brackets.			

The analysis model proposed by us is successful, describes the various factors in the adoption of distributed generation technologies by companies. Standardized coefficients not only allow testing hypotheses, but can also be used to compare the effects of various characteristics of distributed generation installations on the likelihood of their acceptance by companies.

Thus, in order to decide about its own generation by companies, the main factors are the possibility of technical connection (β = 0,421), the perceived advantages (β = 0,363), the cost of electricity (β = 0,324) and the decision of regulators (β = –0,309). Consequently, the possibility of technical connection, the cost of electricity and the perceived benefits are critical factors in deciding on the use of distributed generation technologies for the analyzed companies. The risk factor was insignificant (β = 0,209), while carrying out in-depth interviews with the company, this fact was explained by the fact that distributed generation systems reduce the occurrence of the listed adverse effects to minimum. Today due to the use of energy-efficient solutions based on distributed generation technologies became possible to obtain cheap electric and thermal energy, to increase gradually power capacities, to invest uniformly and to product fast energy for industrial and household needs.

LIMITATIONS OF THE STUDY

We did not interview the entire amount of Russian companies because of limited data collection capabilities. Nevertheless, our sample of companies is representative by sector, revenue from sales and size of companies. Also researchers can analyze the factors of adopting distributed generation technologies on a larger sample of companies. The results of the sampling study confirm the feasibility of a comprehensive assessment of the factors of distributed generation technologies acceptance. Within the framework of this study, the identified factors - intra-organizational, external and specific - were measured empirically and used to analyze the adoption of distributed generation technologies by companies. The qualitative stage of the research allowed us to make initial conclusions about the significance of certain aspects of the adoption of distributed generation technologies. Thus, in accordance with the results of the analysis of the theoretical base, it was empirically confirmed that making the distribution of generation by companies, the greatest value was the cost of electricity and technical compatibility at the qualitative stage of the study. The majority of respondents named these aspects as the most important ones.

Table 12

The frequency of mentioning barriers of distributed generation barriers extension

Barrier	Mention , %
Expenses for construction and installation of distributed generation sources	
Existing electricity transmission tariffs together with wholesale market rules prevent investment in distributed generation in cases where the electric capacity of the generating set is 25 MW or more	74,8
The sale of heat for district heating is considered uneconomic in Russia due to low prices set by the state	66,5
Uncertainty about future prices for fuel and electricity and the possibility of conclusion of a treaties	45,9
Decisions of regulators (authorities) affecting companies' decisions on the use of new technologies, certainty regarding future prices for fuel and electricity and the possibility of contracting	
Uncertainty about possible changes in the legal framework may be an obstacle to investments in distributed generation	74,1
The process of obtaining permissive documentation for medium and high power generation facilities takes a long time in Russia	37,9
The lack of unified technical requirements for technological connection to the power grid. The process is long, the connection fee is often very high	71,5
The absence of a unified policy regulating the development of industrial distributed generation, and the conflict of interests of the concerned parties concerned creates obstacles in the negotiations for obtaining permits	44,7
Energy service companies operating under a tolling contract are required to obtain a special permit for the use of gas for commissioning	49,1
Market pressure	
According to the legislation of the Russian Federation, contracts for the supply of electricity are considered invalid until the commissioning of the installation, which increases the risks of the investor	52,9
Industrial enterprises may face a shortage of their own personnel, competent in the field of energy. There is a need to establish professional contacts, to share experiences and to attract external experts and attracting external experts	50,7
It may not be possible to agree on sufficient natural gas limits to be issued by OAO Gazprom at a low regulated price for the generating unit	39,7

REFERENCES

1. *Volodin Yu. V., Linder N. V.* (2017). Tariff policy and cross subsidization in electricity and heat energy // Business strategies. № 1. P. 37-47.
2. *Vorozhikhin V.* (2013). Organizational and economic mechanisms of energy development. Saarbrücken: LAPLAMBERTAcademicPublishing. 245 p.
3. *Gitelman L.D.* (2013). Economics and business in the power industry. Moscow: Economics. 432 p.
4. *Gitelman L.D., Bokarev B.A., Gavrilova T.B. etc.* (2015). Anti-crisis solutions for regional energy. Economy of the region. № 3. P. 173-188.
5. *Dolmatov I., Zolotova I.* (2015). How much is the excess power of the generators costs? // Power Market. № 8.P. 21-28.
6. *Zhuravleva S.N., Popov K.A., Lisitsyn I.M* .(2014). The development of the pricing system in the construction of electric power facilities // Reliability and safety of energy. № 15. P. 42-49.
7. *Krivoshapka I.* (2013). Distributed generation in Russia: a competitor to a large energy industry or a way to get into the pocket of consumers? // Energy and Industry of Russia. No. 5 (217).
8. *Klimovets O.V., Zubakin V.A.* (2016) Methods for assessing the effectiveness of investments in own generation under risk conditions // Effective Anti-Crisis Management. № 2 (95). P. 78-84.
9. *Linder N.V., Trachuk A.V.* (2017) Influence of cross-subsidization in electricity and heat power engineering on the behavior of participants in the wholesale and retail electricity and heat markets // Effective Anti-Crisis Management. No. 2 (101). p. 78-86.
10. Oboskalov V.P, Panikovskaya T. Y. Energy Consumption Management in a Competitive Electricity Market// FGBUN "Institute of Energy Systems. A. l. Melentyev, Sib. ord. RAS. URL: http: //www.sei.irk. com / symp2010 / papers / RUS / S4-14r.pdf.
11. *The main results of the operation of power facilities in 2015* (2016) / Ed. A. V. Cherezov. M. 72 p.
12. *Ryapin I.* (2013) Risks of the "big" electric power industry: the consumers leave for independent provision with electricity as a result of the shortcomings in the reform / Energy Center of the Moscow School "Skolkovo". M. 117 p.
13. *Sellyakhova O., Fateeva E.* (2012) Cross subsidization and the social norm of power consumption // Effective Anti-Crisis Management. No. 6. (75). p. 32-79.
14. *Stennikov V.A., Voropai N.I.* (2014). Centralized and distributed generation is not an alternative, but integration. // Bulletin of the Russian Academy of Sciences. Power engineering. № 1.p. 64-73.
15. *Sellyakhova O., Tarnovskaya O., Fateeva E. and others* (2016) Virtual power station // Energorynok. № 2 (137). p. 43-50.
16. *A. Trachuk* (2010a) Reforming the electric power industry and developing competition. M .: Master. 280 p.
17. *Trachuk A.V* .(2010 b) Risks of growth in concentration on the electricity market // Energorynok. № 3. P. 28-32.
18. *Trachuk A.V* .(2011) Reforming of natural monopolies: goals, results and directions of development. Moscow: Economics. 320 p.
19. *Trachuk A.V., Linder N.V.* (2017) Cross subsidization in the electric power industry: approaches to modeling the reduction of its volumes // Effective Anti-Crisis Management. No. 1 (100). p. 24-35.
20. *Trachuk A. V., Linder N. V., Zolotova I. Y. etc*(2017) Cross subsidization in the electric power industry: problems and solutions. St. Petersburg.
21. *Fuel and Energy Complex of Russia - 2015* (2016) // Analytical Center under the Government of the Russian Federation. URL: http: // ac.gov.ru/files/publication/a/9162.pdf.
22. *Khovalova T.V* .(2017). Modeling the efficiency of the transition to own generation // Effective Anti-Crisis Management. No. 3 (102). P. 44-57.
23. The Federal Law "On Electric Power Industry" from March 26, 2003 No. 35-FZ // ConsultantPlus. URL: http: // www.consultant.ru/document/cons_doc_LAw_41502/.
24. Assessment of Demand Response and Advanced Metering (2010)/Federal Energy Regulatory Commission, Washingtonю
25. *Arndt U., WagnerU.* (2003) EnergiewirtschaftlicheAus wirkungeneinesVirtuellenBrennstoffzellen-Kraftwerks// VDI-Berichte 1752, VDI-GET-FachtagungStationäreBrenn stoffzellen am 01./02.04.2003. Düsseldorf: VDI–Verlag. S. 165–179.
26. *Ao-Yang H., Zhe Z., Xiang-Gen Y.* (2009) The Research on the Characteristic of Fault Current of Doubly-Fed Induction Generator // Asia-Pacific Power and Energy Engineering Conference; 27–31 March 2009. P. 1–4.
27. *Berg A., Krahl S., Paulun T.* (2008). Cost-efficient integration of distributed generation into medium voltage networks by optimized network planning // CIRED Seminar 2008: SmartGrids for Distribution. P. 1–4. URL: http://ieeexplore.ieee.org/document/4591855/.
28. *Bhowmik A., Schatz J., Maitra A. et al.* (2003). Determination of allowable penetration levels of distributed generation resources based on harmonic limit considerations // IEEE Transactions on Power Delivery. Vol. 18, № 2. P. 619–624.
29. *Bresler St. F.* (2009) Demand Response in the PJM Electricity Markets // PJM. Vol. 32, № 6. P. 1306–1315.
30. *Carley S.* (2009) Distributed generation: an empirical analysis of primary motivators // Energy Policy. Vol. 37. P. 1648–1659.
31. *Damodaran A.* (2008) Strategic Risk Taking: a framework for risk management. New Jersey: Pearson Prentice Hall. 388 p.
32. *Davito B., Tai H., Uhlaner R.* (2010) The smart grid and the promise of demand-side management // McKinsey & Company. URL: http://www.calmac.com/documents/MoSG_DSM_VF.pdf.
33. Demand Dispatch – Intelligent Demand for a More Efficient Grid (2011)/National Energy Technology Laboratory //U.S. Department of Energy Office of Electricity Delivery and Energy Reliability. URL: https://www.netl.doe.gov/File%20Library/Research/Energy%20Efficiency/smart%20grid/DemandDispatch_08112011.pdf.

34. Demand Side Response: A Discussion Paper (2010)/OFGEM. London.
35. *Davis F. D.* (1989) Perceived use fullness, perceived ease of use and user acceptance of information technology // MIS Quarterly. Vol. 13, № 3. P. 319–340.
36. *Dondi, P., Bayoumi D., Haederli C. et al.* (2002) Network integration of distributed power generation // Journal of Power Sources. Vol. 106. P. 1–9.
37. Estimating the Costs and Benefits of the Smart Grid. A Preliminary Estimate of the Investment Requirements and the Resultant Benefits of a Fully Functioning Smart Grid (2011)/The Electric Power Research Institute. Palo Alto.
38. *European Technology Platform SmartGrids* (2010). Brussels. URL: www.snartgrids.ur/documents/SmartGrids_SDD_FINAL_APRIL2010.pdf.
39. Evaluating Policies in Support of the Deployment of Renewable Power // IRENA. URL: http://www.irena.org/DocumentDownloads/Publications/Evaluating_policies_in_support_of_the_deployment_of_renewable_power.pdf.
40. *Frankel D., Wagner A.* (2017) Battery storage: The next disruptive technology in the power sector // McKinsey. URL: https://www.mckinsey.com/business-functions/sustainability-and-resource-productivity/our-insights/battery-storage-the-next-disruptive-technology-in-the-power-sector.
41. *Frias, P., Gomez T., Cossent R. et al.* (2009) Improvement in current European network regulation to facilitate the integration of distributed generation // Int. J. Electr. Power Energy Syst. Vol. 31. P. 445–451.
42. *Faria P., Vale Z.* (2011) Demand response in electrical energy supply: An optimal real time pricing approach // Energy. Vol. 36. P. 5374–5384.
43. *Flick T., Morehouse J.* (2011) Attacking Smart Meters // Securing the Smart Grid: Next Generation Power Grid Security. Boston: Syngress. P. 211–232.
44. *GB Demand Response. Report2 Strategic Issues and Action Planning* (2011) // KEMA, Commissioned by the Energy Network Association. URL: http://www.energynetworks.org/modx/assets/files/electricity/futures/smart_meters/KEMA_CUE_Report_Strategic_Issues_and_Action_Planning_March20 11.pdf.
45. Global trends in renewable energy investment (2013)/UNEP Collaborating Centre, Frankfurt School of Finance and Management. Frankfurt am Main. URL: http://fs-unep-centre.org/system/files/globaltrendsreportlow-res_0.pdf.
46. *Grubb M., Jamasb T., Pollitt M. G.* (2008) Delivering a Low Carbon Electricity System. Technologies, Economics and Policy. Cambridge: Cambridge University Press. 536 p.
47. *Gudi N., Wang L., Devabhaktuni V.* (2012) A demand side management based simulation platform incorporating heuristic optimization for management of household appliances // Electrical Power and Energy Systems. Vol. 43. P. 185–193.
48. *Haas R., Loew T.* (2012) Die Auswirkungen der Energiewende auf die Strommärkte und die Rentabilität von KonventionellenKraftwerken // nachhaltigkeitsbericht. URL: http://www.nachhaltigkeit.wienerstadtwerke.at/fileadmin/user_upload/Downloadbereich/Haas-Loew-Auswirkungen-Energiewende-auf-Energiemaerkte2012.pdf.
49. *Hansen C. J., Bower J.* (2004) An economic evaluation of small-scale distributed electricity generation technologies/Oxford Institute for Energy Studies. Oxford, 2004.
50. *Hogan W.* (2010) Demand response pricing in organized wholesale markets/IRC Comments, Demand Reponse Notice of Proposed Rulemaking. FERC Docket RM10-17-000. URL:https://sites.hks.harvard.edu/fs/whogan/Hogan_IRC_DR_051310.pdf.
51. Implementation Proposal for The National Action Plan on Demand Response: Report to Congress Prepared by staff of the Federal Energy Regulatory Commission and the U. S. Department of Energy (2011) // Office of electricity delivery & energy reliability. URL: https://www.energy.gov/oe/downloads/implementation-proposal-national-action-plan-demand-response-july-2011
52. *Ipakchi A., Albuyeh F.* (2009). Grid of the future // IEEE Power and Energy Magazine. Vol. 7, № 2. P. 52–62.
53. *Jasim S. Kunz C.* Erneuerbare Energien im Strommarkt. Renews Kompakt // Agentur für Erneuerbare Energien. URL: http://www.unendlich-viel- energie.de/media/file/276. AEE_RenewsKompakt_Strommarkt_dez13.pdf.
54. *Jiang B., Fei Y.* (2011) Dynamic Residential Demand Response and Distributed Generation Management in Smart Microgrid with Hierarchical Agents // Energy Procedia. Vol. 12. P. 76–90.
55. *Kazemi A., Sadeghi M.* (2009). Distributed generation allocation for loss reduction and voltage improvement // Power and Energy Engineering Conference, 2009. APPEEC 2009. Asia-Pacific.
56. *Kumpulainen L., Kauhaniemi K.* (2004). Analysis of the impact of distributed generation on automatic reclosing // Power Systems Conference and Exposition, 2004. IEEE PES. P. 603–608.
57. *Li H., Leite H.* (2008). Increasing distributed generation using automatic voltage reference setting technique // IEEE PES General Meeting – Conversion and Delivery of Electrical Energy in the 21st Century, 2008 IEEE. 20 Jul 2008–24 Jul 2008. P. 1–7.
58. *Lujano-Rojas J. M., Monteiro C., Dufo-Lopez R. et al.* (2012) Optimum residential load management strategy for real time pricing demand response programs // Energy Policy. Vol. 45. P. 671–679.
59. *Markets* (2010)/Mossavar-Rahmani Center for Business and Government, John F. Kennedy School of Government Harvard University. Cambridge, MA.
60. *McDonald J.* (2008) Adaptive intelligent power systems: active distribution networks // Energy Policy. Vol. 36. P. 4346–4351.
61. *Mietzner D., Reger G.* (2005) Advantages and disadvantages of scenario approaches for strategic foresight // International Journal of Technology Intelligence and Planning. Vol. 1, № 2. P. 220–239.
62. *Modelling Load Shifting Using Electric Vehicles in a Smart Grid Environment: Working paper/OECD/IEA.* (2010) // IEA. URL: https://www.iea.org/publications/freepublications/publication/modelling-load-shifting-using-electric-vehicles-in-a-smart-grid-environment.html.
63. *Molla A., Licker P. S.* (2002) PERM: A Modelof e-Commerce Adoption in Developing Countries // Issues and Trends of Information Technology Management in Contemporary Organizations/Ed. M. Khosrowpour. Seattle: Idea Group Publishing. P. 527–530.
64. *Molla A., Licker P. S.* (2005) Perceived e-Readiness Factors in e-Commerce Adoption: An Empirical Investigation in a Developing Country // International Journal of Electronic Commerce. Vol. 10, № 1. P. 83–110.
65. *National Action Plan on Demand Response* (2010)/Federal Energy Regulatory Commission, Washington.
66. *Pontikakis D., Lin Y., Demirbas D.* (2006) History matters in Greece: The adoption of Internet- enabled computers by small and medium sized enterprises // Inf. Econ. Policy. Vol. 18. P. 332–358.
67. *Pepermans G., Driesen J., Haeseldonckx D. et al.* (2005) Distributed Generation: definition, benefits and issues // Energy Policy. Vol. 33. P. 787–798.
68. *Picciariello A, J. Reneses, P. Frias, L. Söder* (2015). Distributed generation and distribution pricing: Why do we need new tariff design methodologies? // Electricpower systems research. Vol. 119. P. 370–376.
69. *Picciariello A., Vergara C., Reneses J. et al.* (2015). Electricity distribution tariffs and distributed generation: Quantifying cross-subsidies from consumers to prosumers // Utilities Policy. Vol. 37. P. 23–33.
70. *Izadkhast S., Garcia-Gonzalez P., Frías P. et al.* (2016). An aggregate model of plug-in electric vehicles including distribution network characteristics for primary frequency control // IEEE Transactions on Power Systems. Vol. 31, № 4. P. 2987–2998.
71. *Samuelson S.* (2010). Development and Analysis of a Progressively Smarter Distribution System // CSI RD&D Grant Solicitation Package: PV Grid Integration. UC–Irvine Advanced Power and Energy Program/PG&E. Leiden, theNetherlands 9–11 September 2010.
72. *Seo H., Park M., Kim G. et al.* (2007). A study on the performance analysis of the grid-connected pv-af system // Proceeding of International Conference on Electrical Machines and Systems. Toronto, Ontario, Canada 1–3 November 2007/TheInstituteofElectricalandElectronicsEngineers, Inc. Toronto.
73. *Subhes C.* (2011) Bhattacharyya Energy Economics Concepts, Issues, Markets and Governance/University of Dundee. London: Springer. 645 p.
74. *Wu J.* (2009). Control technologies in distributed generation system based on renewable energy // 3rd International Conference on Power Electronics Systems and Applications.20–22 May 2009/PESA. URL:http://ieeexplore.ieee.org/document/5228652/.
75. *Walczuch R., VanBraven G., Lundgren H.* (2000) Internet adoption barriers for small firms in the Netherlands //Eur. Manag. J. Vol.18. P. 561–572.
76. *Yingyuan Z., Liuchen C., Meiqin M. et al.* (2008). «Study of energy management system for distributed generation systems // 3rd International Conference on Deregulation and Restructuring and Power Technologies. P. 2465–2469. URL: http://ieeexplore.ieee.org/xpl/mostRecentIssue.jsp?punumber=4511470.
77. *You S., Jin L., Hu J. et al.* (2015). The Danish Perspective of Energy Internet: From Service-oriented Flexibility Trading to Integrated Design, Planning and Operation of Multiple Cross-sectoral Energy Systems // ZhongguoDianjiGongchengXuebao. Vol. 35, № 14. P. 3470–3481.
78. *Zhang X. P.* (2008). A framework for operation and control of smart grids with distributed generation // Power and Energy and Society General Meeting-Conversion and Delivery of Electrical Energy in the 21st Centuryю Pittsburgh. P. 1–5.