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Article

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Energy Industry: Effectiveness from Innovations

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ABSTRACT

Putting the energy industry on the way of innovations is a task of utmost importance, whose success will shape up future development and competitiveness of emerging economies to a great extent. Research of the main trends of innovative development of distributed generation demonstrated that they are characterized by high spending both on installation of innovative power equipment and on its creation. Our research of financing in the Russian distributed energy and power engineering demonstrated that the bulk of capital investment is done from companies' own funds, which points to the unaffordability of other funding instruments, credit included. Consequently, the process of creating and using innovations in distributed energy is accompanied by significant investment risks. This scientific research offers an approach to innovations in distributed energy based on coordination of economic interests of innovation process subjects with the aim of optimizing the task of looking for a threshold price through defining and comparing the effectiveness of a novelty for its creators, consumers and the state with the help of an internal rate of return. The use of a business approach to the introduction of innovations in the distributed energy will coordinate the interests of the producer of innovative equipment and the energy company. Such an approach will ensure co-financing of innovation research and development of all subjects of the relations.

Keywords: Innovation Processes, Power Equipment, Power Energy, Heat Energy, Economy, Taxation, Capital Investment, Energy Efficiency, Digital Information

JEL Classifications: E22, G31

1. INTRODUCTION

Distributed energy in the international economy is an objective process caused by general deficiencies of centralized energy, growth of prices for power, stimulation of the use of renewable power sources. The need to supply energy to far-away areas, where construction of large power stations or erection of power lines is not sufficiently justified from an economic point of view is also one of the significant factors. Modern research of special functioning features of distributed energy and innovation management demonstrates that their potential for innovation development cannot be unlocked because of a number of problems of organizational and economic character.

The organizational problems include the absence of working instruments for deployment of modern innovative equipment in distributed energy, the absence of full-scale regulations to standardize functioning of distributed generation (which is typical of the emerging states), a unified notion of distributed energy formalized in legislation as well as a clear classification of the generating facilities, which fall under the category, barriers to access of distributed generation facilities to power networks and to the retail power and capacity markets, etc. The economic problems include the absence of a systemic support of supply and demand for innovations in distributed energy, significant investment risks of creation and introduction of innovations in distributed energy because of their high capital intensiveness and a poor development of a financing instruments system. We may solve the problems by managing the innovation process in distributed generation basing on alignment of interests of consumers of the innovative power equipment for distributed energy (producers of heat and power energy) and its producers at the early stage of the innovation process.

This approach presupposes consideration of the innovation process from the point of view of ‘a full-scale innovation process’. Its functioning should be based on the stages inherent in the innovation process in distributed generation and in power machine-building. At the same time implementation of the approach is conspicuous for the difficulty of organizational and economic interrelations of the subjects under discussion. Management of such processes, which are hard to regulate at methodological and methodic levels, should be done through an organizational and economic mechanism. The organizational and economic mechanism of introducing innovations (further OEM) in distributed energy is defined as a sum total of organizational and economic instruments, levers, methods and forms to increase the effectiveness of innovations in distributed generation based on alignment of interests of the parties.

2. LITERATURE REVIEW

Although there exists a great number of definitions to the term ‘innovations,’ the definition given in the proposed guidelines for collecting and interpreting technological innovation data (The Oslo Manual) is generally recognized: “Technological product innovation is the implementation/commercialization of a product with improved performance characteristics such as to deliver objectively new or improved services to the consumer. A technological process innovation is the implementation/adoption of new or significantly improved production or delivery methods. It may involve changes in equipment, human resources, working methods or a combination of these.”

One of the first scientists who noted that economic development is based on creation and dissemination of innovations were Schumpeter and Kondratiev and Schumpeter is rightly considered to be the founder of the innovations theory. According to his theory, the form and substance of development is regulated by the notion of creating new combinations (Reisman, 2004), which covers five cases:

1. Creation of new output.
2. Introduction of a new production method (manner).
3. Entering a new market.
4. A new source of raw materials.
5. Reorganization of the company.

New combinations of production factors received the name of innovations, while their implementation, according to Schumpeter, belongs to innovative businessmen. In his turn (Abalkin, 2002) in his theory of large trend, cycles (the Kondratiev waves) proved connection between rising and falling cycle waves with the waves of technical inventions. He concluded that a rising wave demonstrates “groundbreaking changes in the technology of manufacturing and exchange, which, in their turn, are preceded by significant technical inventions and discoveries.” In the falling wave, technical discoveries and inventions are especially numerous because “economic depression prompts people to look for ways to make production cheaper, for technological inventions, which would help making manufacturing cheaper.” Later (Schumpeter, 1939) presumed technological innovations as the most important reason behind the large Kondratiev waves.

The development of the wave theory as part of a research into the role of innovations in cyclical development was further reflected in works by Mensch (1971), Chris and Francisco (2002), Hirooka (2004), who singled out technological revolutions or a change in a technical and economic paradigm as a reason behind the change in Kondratiev’s waves.

As part of Russian cyclical school, Glazyev (1993) puts forward the idea that Kondratiev’s waves are based on technological modes, or “groups of technological sums total linked to each other by similar technological links to create reproducing wholes.” At that, we now see the forming of a sixth technological mode. Not to lag behind developed states Russia should have an innovation breakthrough in its development. At that, according to Akayev (2012) care should be taken to channel the flow of innovative technologies of wide use into the traditional economic branches, on which general economic growth depends.” Innovative development of energy, including distributed energy, presupposes creation and introduction of modern highly effective power equipment, including of the equipment based on advanced international experience to ensure safe and effective power and heat supplies to companies and households.

The unlocking of the potential of distributed energy require a comprehensive approach towards management of its technological processes. The innovative management theory sees the innovative process as a “process of turning scientific knowledge into an innovation, which can be perceived as a consequence of events during which innovation matures from an idea to a product, technology or service and is disseminated in practical use.

One of the first innovation models, which appeared in the 50s of the XXth century and dominated the market until mid-60s, was a technology push model, according to which development is pushed by technologies, while the market is a passive consumer of innovations, which only reacts to them by creating demand. It is a simple linear process led by research and development (Gorfinkel 2014). The second approach, a total antithesis to the technological push model, was developed in the second half of the 60s-start of 70s. It says that innovations are initiated by the market and depend on the change of demand (the market pull model). This model existed for a short period of time and became irrelevant as a third approach, or a combined model, appeared, put forward by Rothwell (1994). The characteristic feature of the approach is complementarity of the processes considered in the two previous approaches and abandonment of the linear process.

The fourth approach to innovations includes a chain model of Kline and Rosenberg (1986), which uses a nonlinear principle conspicuous for its feedback links between its processes as the basis. The scientists in their works noted not only the complexity and randomness of the innovative process, but also pointed to the fact that innovations are impossible without accumulation of knowledge at each stage.

The introduction of external suppliers as members of the innovation process into the model is typical of the fifth and sixth models of the innovation process, or a so-called integration and network model of Chesbrough (2003), which is based on the knowledge, which permeates processes not only within companies, but also links between them. The key principles of the fifth generation model are:
1. High organizational and systemic integration;
2. Flexibility of organizational structures, including delegation of power of decision-making;
3. A wide use of research and development;
4. Simultaneous existence of several stages of the innovation process;
5. Reliance on external sources for new ideas and solutions as opposed to the traditional reliance on internal research and development.

On the whole, we can say that technological approaches towards innovation developed along the lines of complicating links and increasing the number of elements. However, empiric research done by Cooper (1983) showed that the bulk of companies use simplified linear models of the innovative process or develop their own models. Despite a large number of models, the question of effectiveness of each model is still open. On the whole, practice points to the impossibility of creating one universal model, which would be equally good for all companies and industries. The current innovation processes in the international energy system are accompanied by the appearance of models of a predominantly network character, which ensure wide international cooperation between energy companies and scientific organizations on a wide range of innovations to find solutions for innovative development of the industry.

A special feature in developed states is a cluster approach to organization of the innovative process. Energy clusters are created with the aim of forming highly competitive production facilities based on large power companies in conjunction with related industries, such as creation of equipment, servicing, personnel training and scientific development. The core of innovations is internal research and development departments of transnational energy companies, which aim at unlocking their own scientific potential and at looking for innovative solutions created by other organizations represented as a rule by various academic organizations.

3. CONCEPT HEADINGS

Taking the current approach to innovation management in distributed energy based on consideration of a "full" innovative process as a basis and taking into account different approaches towards mechanisms forming, we have formulated a comprehensive approach for the development of organizational and economic approach (further - OEA) for introduction of innovations in distributed power generation. The OEA can be transformed from a mechanism of cooperation into a mechanism of influence if necessary. The criterion of such transformation is the inability of the OEA of cooperation to cope with the problems of effective introduction of innovations in distributed generation and agree on incentives for the participants of the innovation process.

This means that an OEA towards introduction of innovations in distributed energy can be defined as a sum total of organizational and economic levers, instruments and methods of creating effectiveness of innovations in distributed power generation basing on alignment of interests of all participants. Taking the proposed comprehensive approach as a basis, we can single out the following key principles of forming the OEA:
1. The principle of focus, where the key goal is a higher efficiency of introducing innovations in distributed energy;
2. The principle of cost effectiveness: the choice of methods, which ensure attainment of goals with the least material and labor costs;
3. The principle of self-organization: A quick reaction towards different changes in the environment, including transformation from the mechanism of cooperation into the mechanism of influence;
4. The principle of science: The need to use advanced scientific methods in assessment of special features of functioning of full innovation process subjects.

One of the key stages of forming an OEA, when its parties cooperate, is the alignment of incentives for producers, subjects of supply, and consumers, subjects of demand. The alignment requires singling out incentives, which are immanent in each subject depending on the aim of the organizational and economic mechanism. The subjects of distributed energy are primarily interested in getting economic profits from introduction and use of innovations. The efficiency of innovations as a ratio of incomes and costs, will depend on the following characteristics:
1. Income means funds received from the sales of heat and power or production costs cuts;
2. Costs mean capital costs - the price of innovations, while production costs are servicing costs, including fuel, water, power.

The subjects of power machine building are interested in getting economic profits from creation and sales (introduction) of innovations. At that, the effectiveness of creation and sales of innovations will depend on the following:
1. Income is money received from the sale of innovative power equipment (a ratio of the price/cost of innovations and sales volumes);
2. Costs: Capital expenditures to develop an innovation and organize production as well as production costs to make innovative power equipment.

At that, coordination of incentives for the subjects of the organizational and economic mechanism can be done through the innovation itself. At that, the key feature of the innovation needed both by the consumer - the subject of demand, and by the producer - the subject of supply, and which can be coordinated is the price/ cost of an innovation as a result of interaction of the subjects. The sales price of innovative equipment is the price/cost of an innovation for its producer, and for the energy producer it will equal part of capital expenditure to buy the equipment. This approach to forming the organizational and economic mechanism of innovations in distributed power generation presupposes the use of the price/cost ratio as the key lever of aligning incentives for creating and introducing of innovations. Thus, a corresponding economic model of innovation price forming lies in the heart of the OEA, which can be used for counteraction of subjects of innovations in the Russian distributed energy. This means that to align incentives of the subjects the price of innovation equipment for its consumer should be defined by its economic efficiency with a simultaneous return on investment for the developer and producer of innovations.

4. STATISTICAL METHODOLOGY

The key indicators used to calculate the efficiency of innovation projects usually are the net present value (NPV), the internal revenue rate (IRR), the profitability index (PI). At that, the NPV is calculated using the formula (1):

$$NPV = \sum_{t=1}^{n} \frac{CFt}{(1+E)^{t}} \qquad (1)$$

Where, E is the discount rate;
CF_t is cash flow during t time.
In its turn, net cash flow can be defined by formula (2):

$$CF_t=EBIT_t-TAX_t+DA_t-IC_t-\Delta WC_t \qquad (2)$$

Where, $EBIT_t$ is income before interest and taxation during t period;
TAX_t is taxes paid during t period;
DA_t is amortization and depreciation during t period;
IC_t is investment costs during t period;
ΔWC_t is working capital replenishment during t period.
In its turn, the PI is calculated using formula:

$$PI = \frac{NPV}{\sum_{t=1}^{n} \frac{ICt}{(1+E)^{t}}} \qquad (3)$$

The discount rate calculated using the weighted average cost of capital (the WACC method) used to calculate the price of all the invested capital is calculated by the following formula (4):

$$WASS= KE\frac{E}{E+D} + KD\left(1\text{-}T\right)\frac{D}{E+D} \qquad (4)$$

Where, K_E - is return on equity calculated under the CAPM method;
E - is the size of shareholder equity;
D - is the size of debt capital;
KD - is the cost of borrowed capital, %;
T - is the corporate tax.

The CAPM discount rate used to calculate the price of equity capital of the company is calculated by the following formula (5):

$$CAPM=R_F+\beta_L ERP \qquad (5)$$

Where, R_F - is a risk-free rate of return calculated using the yield of 20-year U.S. treasuries.
ERP - is a premium on the risk of investment in shareholder equity; it is calculated using yield data on U.S. treasuries and the Standard and Poor's 500 index.
β_L - is a leveraged coefficient of a beta company. When calculating a discount rate for companies, which are not traded on a stock exchange, the coefficient is calculated by recalculating the beta-leveraged coefficient for the industry to the financial leverage using the Hamada formula (Hamada, 1972).

One the whole, we can note that calculation of a discount rate should be scientifically grounded by the participants, while it should reflect the specifics of projects under consideration fully. Basing on the goal of the created OEA the threshold price of innovation P as a leverage to align the incentives should exceed the highest effectiveness of the innovation introduction project in distributed energy F devel calculated by formula (6):

$$F\ devel\ (P)=IRR\ max \qquad (6)$$

Where, F devel (P) is the effectiveness of innovation equipment installation;
IRR max is the internal rate of return of F devel project.

At that, the threshold price of the project should ensure the effectiveness of innovations in distributed energy calculated using the formula (7):

$$F\ devel\ (P)=IRR\ devel \geq E\ devel \qquad (7)$$

Where, E devel is a discount rate of F devel project.

But the aforementioned criteria of the threshold price can result in the creation and installation of equipment, which is worse than that already existing by its technical parameters (primarily by the degree of efficiency), but whose cost can be recovered thanks to the cheapness of the technologies used. At the same time, such a situation can be negative because of the use of old technologies, which will provoke higher energy consumption in the country as well as a consistent technological lagging of the hi-tech industries behind other states. This is why we should use the criterion of innovation as well as when aligning incentives for producers and consumers. Since an innovation is the launch of a new, or a significantly improved product (goods, service) or a process, a new sales method or a new organizational business method, a method of working place or external relations, one of the criteria is a better efficiency of new innovative equipment compared to the equipment of competitors.

5. RESULTS

International experience shows that creation of test-rooms and certification centers are also important for innovative development of energy technologies. Internationally, there are several large research centers and laboratories - the Technical University of Denmark, the High Tech Campus in the Netherlands, the NEL. National Engineering Laboratory in

Great Britain, the National Renewable Energy Laboratory, the U.S.A., state Colorado, and several others. This is why, to avoid possible losses when applying levers, choosing the direction of state support in the form of support to the producer or consumer of innovations, we should be guided by a profit to costs ratio. At that, the OEA should be adaptable and changeable, which can be achieved by adjusting the threshold price. This approach to innovation management in distributed energy allows us to develop an economic model to align incentives for all the interested parties taking into account the organizational and economic mechanism of innovation introduction in distributed energy.

Large power companies are not currently interested in comprehensive development of distributed energy of their own because centralized supplies mean distributed energy margins are smaller than those of large power firms (if we consider comparable technologies) due to its lower efficiency rate. For instance, gas turbines for gearing gas compressors for gas compressor units and и power generators installed at heat and power stations of small and medium capacity (GGT) GGT10 MW have an efficiency rate of 35.5% and a capital cost per unit of $1,300/kW, while the efficiency rate of GGT-110 MW amounts to 36% and capital cost per unit to $900/kW).

At the same time recent innovative power units for distributed energy with a variable speed of generator, unlike the traditional technologies with a permanent speed used in centralized energy, ensure good power quality regardless of the speed without undermining efficiency while changing relative capacity. We have compared economic efficiency of two options of construction of a power station to understand the future of innovative technologies in distributed energy. Under the innovative option, a GGT-80 MW works mainly in a nominal condition, while distributed generation facilities regulate capacity within 24 h with a possibility of a full halt when loading reaches 50%. But the question whether additional costs are returned thanks to a potentially lower fuel consumption remains open. The additional costs of the innovative option include higher capital investment as well as additional spending on servicing the distributed energy units. However, power machine-building technologies are developing to increase automation and ensure a wider use of software, which make servicing costs of low capacity facilities comparable with those of high capacity generation units. This means that if we presume that all other costs are conditionally equal in our options we have to understand the possibility of return on the additional capital costs.

Our calculations show that the economy of fuel in the innovation option and our efficiency rates allow investors to have a return on a $38.6/kW difference in capital costs within a year. Consequently, output costs of $1,000/kWВт for GGT-110 and GGT80 units and $1,300/kW for GTT-10 units mean that the lower fuel consumption ensure a return on additional costs within 7.77 years: ($1,300/kW – $1,000/kW)/$38.6/kW (Appendix 1).

However, if we discount the figure at F devel of 14% (the discount rate is calculated similarly to the F devel project) and plan the project for 15 years, the additional capital costs will have no return. The difference in capital costs should not exceed $237/kW to make an innovative project effective (IRR devel ≥ 14%).

The use of OEA experience of innovations in distributed energy may help the producer of innovative equipment and the power company to align their interests. At that, the power company should not only be the consumer of innovations, but also an investor in the creation of innovative equipment becoming, in fact, the core of the mechanism.

6. DISCUSSION

Smart grid technologies. Smart Grid Technologies are the most promising and quickly developing area of distributed power. One of the first approaches to the smart grids definition was taken by the U.S. Energy independence and security act of 2007 (110th Congress Public Law 140. U.S. Government printing office), which outlined the key features of smart grids:

1. Use of digital information and inspection technologies to enhance reliability, safety and effectiveness of power grids.
2. Optimization of transmission and loading of grids in conditions of full cyber security.
3. Introduction and integration of distributed energy, including renewable resources.
4. Development and introduction of demand response for power.
5. Use of automated interactive technologies, which help optimize work of devices and domestic appliances.
6. Installation and integration of power accumulators and lead management.
7. Provision of a client with timely information and control over parameters.
8. Development of connectivity suite standards for equipment switched to the power grid.

According to a definition of the Institute of Electrical and Electronics Engineers of the European Union, a smart grid is a fully integrated self-regulated and self-repairing system with a network topology, which includes all types of generating sources, trunk grids (including interstate system-forming power transmission lines), local distribution networks and all types of consumers and power energy accumulators managed by a single grid of data management devices in real time.

The function of a power grid built on the smart grid principles is transmitting not only power, but also information. In this case the consumer, apart from energy, receives the following opportunities of interaction with the power system:

1. More flexible tariffs,
2. Power consumption planning,
3. Becoming a power supplier (if conditions are met, the consumer can sell power produced by his power sources: wind mills, solar batteries, accumulators, etc.) and as a consequence cut power costs.

The bulk of developed countries as well as many emerging states have embarked on smart grid projects covering a wide spectrum of problems and tasks in recent years. The largest and most comprehensive smart grids projects are now implemented in the U.S.A., China and the European Union. In Russia, the development of smart grids is reflected in the smart grid with an active-adaptive network concept. A smart grid with an active-adaptive network is a system, where all subjects of the power energy market (generation, grids, consumers) take an active part in transmission and distribution of power. The active-adaptive network plays an important role in a Smart Grid with an Active-Adaptive Network as a technological infrastructure of power energy, which endows the smart grid with totally new qualities. At that, the Smart Grid with an Active-Adaptive Network technologies ensure totally new power supply concepts, including microgrids and virtual power stations. Microgrids are low-capacity grids with sources of distributed generation, accumulators and managed loading (heaters and conditioners).

One of the most important features of the grids is their ability to switch into an isolated state automatically in case of emergency and to restore connection with the grid after repairs. Consumers of such systems can both buy power from a distributor and sell excess power ensuring the best power supply schedule.

7. CONCLUSION

The priority directions of scientific development on the whole and in energy production in particular should be as follows:

1. Creation and deployment of module-based technological equipment for new construction and transfer of existing heat power sources to a co-generation basis;
2. Development of renewable power technologies as well as multifunctional energy complexes for autonomous power supplies in regions, which are not connected to centralized power grids;
3. Introduction of effective technologies of power and heat power supplies based on renewable energy sources;
4. Production expansion and use of new types of fuel produced from various types of biomass;
5. Development of small power in areas of decentralized power supplies to improve the effectiveness of local energy sources, to reduce imports of light oil products.

The following directions of innovative development could be singled out in the distributed energy:

1. Higher effectiveness of existing technologies of distributed energy based on heat engines as well as a wide introduction of cogeneration technologies.
2. Higher effectiveness of solid fuel technologies.
3. Development of renewable energy technologies.
4. Creation and introduction of smart grid, micro grid technologies.

These directions are of critical importance for further development of international energy, which is to be based on a comprehensive approach to development and use of energy sources, their diversification, which will undoubtedly entail changes in the energy balance. In particular, micro grids will become parts of a unified energy system. Power from micro grids will flow to the consumers and back to the system depending on demand and supply allowing the consumer to adjust power supplies in accordance with its needs. Development of this direction may increase effectiveness not only of distributed energy, but of the country as a whole. In particular, the costs of smart grid technologies introduction in the U.S.A. from 2010 to 2013 amounted to about $18 billion. The estimates of costs necessary for implementation of the technology differ. The Electric Power Research Institute of the U.S.A. Estimates the spending at $338-$476 billion within a 20-year period, including $82-$90 billion on transmission systems and substations, $232-$339 billion on distribution systems, and $24-$46 billion on the consumer systems. Consulting company Brattle Group estimates overall investment in smart grid development at about $900 billion until 2030.

Taking into account the scale and technological features of Russia's power system, preliminary capital investment in the development of smart grids with a heavy upgrade of existing infrastructure and distribution network, power infrastructure of energy consumers, as well as dispatch control systems may amount to 2.4–3.2 trln rbl until 2030. This means that successful implementation of the directions depends on two key factors: The ability of distributed energy subjects to introduce innovations and the ability of power machine-building to create innovative power equipment.

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APPENDIX

Appendix 1: Forecast of cash flows from installation of power equipment (turbo-power unit-10 MW), mln rbl

Financial	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Income from sales	0.0	350	382	413	430	447	465	484	503	523	544	566	589	612	637
Material (spare parts) costs	0.0	−124	−133	−142	−148	−154	−160	−166	−173	−180	−187	−194	−202	−210	−219
Wages	0.0	−10	−11	−11	−12	−12	−13	−13	−14	−14	−15	−16	−16	−17	−18
Costs total	0.0	−27	−29	−30	−31	−33	−34	−35	−37	−38	−40	−41	−43	−45	−46
Taxes	0.0	−13	−25	−36	−56	−78	−80	−82	−85	−87	−90	−107	−111	−116	−120
Cash flows from operating activities	0.0	175	184	194	183	171	179	187	195	204	212	208	216	225	234
Investment in equipment and other assets	−789	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Net operating capital growth	0	−27	−1	−2	3	4	−1	−1	−1	−1	−1	0	−1	−1	−1
Cash flows from investment	−789	−27	−1	−2	3	4	−1	−1	−1	−1	−1	0	−1	−1	−1
Discount rate for calculation period, %	14	14	14	14	14	14	14	14	14	14	14	14	14	14	14
Discount coefficient for flow at start of period	1	1.14	1.30	1.48	1.69	1.93	2.19	2.50	2.85	3.25	3.71	4.23	4.82	5.49	6.26
Net cash flow	−789	149	183	192	186	175	177	185	194	202	211	207	215	223	232
Discounted cash flow	−789	131	141	130	110	91	81	74	68	62	57	49	45	41	37
Discounted cash flow on accrual basis	−789	−658	−517	−387	−277	−186	−105	−31	37	99	156	205	249	290	327

Our own calculations based on data from http://www.npo-saturn.ru/?sat=55