Evaluation of Energy-Related Projects in Remote Areas

A. Domnikov, M. Petrov, and L. Domnikova

1 Introduction

The power industry of remote development areas is a specific section of Russia's energy policy. There is a strategic link between energy sector development and the development of new areas. It was the energy that has been helping Russia to expand into new territories for a long time. The key motives were the search for more natural resources and geostrategic organization of its areas. In today's Russia, these processes continue amidst the aftermath of drastic changes in basic social relations and new global challenges. Searching for the national strategy has turned into an intense struggle, which involves both internal and external forces. In this context, the strategic long-term development scenarios, including those for energy development, are determined by the progress and outcome of this struggle [1].

2 The Concept of Methodical Approach to the Evaluation of Energy Projects

Power facilities are characterized by increased capital intensity, a relatively long cycle of creation and subsequent operation, and strong direct and inverse correlations with the nature of development of the serviced territories and power

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consumers. Creation of power facilities in remote development areas, which are mainly located in the Russian Arctic, including the Far North, enhances the specificity of feasibility thereof and influences the design. In this case, the energy sector plays a dual role. Firstly, it serves as a universal infrastructure for development and operation in the new territories and makes it possible to come to these territories and waters with economic purposes. Secondly, those areas of new development that have power resources can become a site for creation of the energy sector as a branch of specialization for the production, transformation, and transmission of energy to the consuming regions.

It is important to look for such relatively cost-effective solutions for the support systems, which would enable to reasonably reduce the energy costs in an adequate, reliable, and safe way. This requirement is a major feature of the design and of application of the economic criteria used for substantiation of the development solutions in this area.

Whereas the energy burden on the economy of a developed territory with developed economic complexes is made of the total energy costs of value-added chains which creates a mechanism for management and limitation of such costs, the areas of new development have no such restrictions and no built-in mechanism of cost management and limitation.

Hence, on the one hand, feasibility of cheaper energy infrastructure within the specified constraints is quite evident. On the other hand, time lags of the infrastructure development can appear longer than expected. It requires the correct configuration of the mechanism for addressing the time factor. It shall be taken into account that during the life cycle of the energy system, the directions of its development may change due to the appearance of new objectives and infrastructure objects, which means increased uncertainty in development of new areas in the North and requires more reserves.

With that said, it can be stated that the economic criteria do not have the highest priority for the infrastructure of new territories in general, including their energy sector, which increases the role of multi-criteria approaches.

In our view, the following principles of criterial consistency in the hierarchy of the systems shall be reckoned as the most important for making decisions on development of the energy system of the remote areas [1]:

- The results of the use of resources invested in the development of the system exceed the bounds of the system (technical, economic, political, logistics).
- It is possible to evaluate the use of these resources only in the context of objectives external to the infrastructure systems.
- Resource constraints of the energy systems depend on the resource potential of the country and region.

Subject to the foregoing, the issues of comparative effectiveness of energy systems, when an economic decision-making criterion is manifested indirectly, have their independent value; this criterion is used to streamline the system at the decision-making stage when its production capacity has been already determined based on well-reasoned scope of needs. For example, the need for energy is set using the initial parameter that is dynamically projected – energy consumption and its structure in terms of energy resources, facilities, and location.

The issue of comparative effectiveness is addressed with the purpose of selecting and ranking project options that meet the restrictions and more preferred criteria. Methodologically, it is important that the comparative effectiveness is considered after forecasting the conditions when the effect of volume indicators defined in the course of time is equivalent to the structure of the consolidated energy needs which in this case can be considered independent of fluctuations in energy costs. Actually, under given conditions of the equivalence of this effect, the issue of comparative effectiveness of the use of resources in the infrastructure system is resolved. The idea is to find a rational trajectory and composition of resources to ensure certain conditions of the effect equivalence.

Development issues for large systems are normally long-term issues, when it is necessary to consider a long optimization period. This is mainly due to both the capital intensity of the systems under consideration and systematicity as such. The planning horizon reflects the aftereffect: forward costs are to be borne to meet the needs of subsequent phases of the system development.

Due to the longtermness, a special role in the behavior of the economic criterion belongs to the time factor, i.e., the need to take into account changes in the relative value of system resources in time. The time factor is taken into account through intertemporal reduction of results and costs.

The methodology for calculation of integrated UNIDO cash flows that is the basis of the entire common practice of investment appraisal, involves the same approach to one-time and ongoing costs and their discounting using the same factors [2]. For the tasks described here, this approach seems inadequate, because it reflects only the value of money over time which is not the decisive factor for the tasks of strategic nature. In this case, private investments may go to the new development regions as an alternative of their application in other regions. Outside of such situation which is still very new for funding new development in this country, universal discounting at the market rate of interest gives distorted indications since it is practically not linked with the value of the resource potential created in the result of the territorial development.

In the North, the importance of adequate development of the energy sector is particularly high due to the harsh climate, territorial remoteness, and increased energy intensity of production. However, for the newly developed territories in the North there is a greater variance in building energy schemes, since isolated solutions based on the use of local fuels are possible. Spot and ribbon development options increase the capabilities for the development of decentralized (distributed) power industry.

For areas of the North, the Nether-Polar, and the Polar Urals lying at the junction of the constituent entities of the Russian Federation, the trans-regional approach is needed which allows to directly compare the energy solutions based on the potential of both Cisuralian and Transuralian entities of the Russian Federation. At the same time, these solutions need to be incorporated in the regional energy strategies, programs, and development schemes. Elaboration of such decisions in the regions is becoming more and more in demand in the modern context.

The regional energy strategy should become the basis for organization of integrated regional power industry development management. This means that implementation of the energy strategy is possible subject to further elaboration and approval of regional and interregional target power industry development programs forming pipelines of interrelated and adequately resourced projects in a number of areas. Such areas include:

- Preparation of conditions for organization of large-scale energy construction with long-term prospects
- Development of cogeneration
- Development of network infrastructure
- Development of local and small-scale power generation
- Energy saving
- Optimization of the fuel and energy balance of the region

Availability of approved programs will enable maximum possible application of incentive mechanisms to encourage energy-generating and energy-consuming entities to invest in energy generation, technological progress, and energy control and ultimately to attract to the regional power industry development the resources of sectors and actors operating both in the region and in the neighboring territories bearing in mind interregional importance and effects of large-scale activities in the energy sector. On the basis of the strategies and programs, initiatives are to be selected, and the state support is to be provided to the projects in the area of energy supply of the region and its individual parts. Scientific engineering and forecasting analytical support of such programs should be based on feasibility reports on energy industry development and on deployment schemes regularly developed by specialized organizations. Based on such schemes systematic design and project development cycles for individual energy facilities shall be arranged. Thereby the contour of integrated management of energy sector development shall be restored and substantially upgraded.

Strategic energy management is based on the principles reflecting the operation and development of any regional system within the Interconnected Energy System (IES) of the macro region of the Urals, Siberia, Northwest, and the United Energy System of Russia. Therefore, the regional energy strategy takes as a premise the priority of the operation of the regional power grid in the interconnected and unified power grids. The system methodology applied to the development of the power industry implies that the substantiation for the development of power generation facilities and backbone electrical networks should assume effective operation of large electric power systems, i.e., the decisions on major energy facilities and system interconnections should be assessed relative to the reference system on the interregional level, in this case, Urals IES or Northwest IES. Absolute priority in managing the development of the power industry belongs to the national level. The unified power system has the highest systemic status in comparison with other infrastructures and possesses all attributes of a large system. Its reproduction as such is the basis of effective development of all business units and the basis of the national security. However, this does not exclude regional management of the power industry development.

Firstly, in the energy sector, there is a technological possibility and feasibility for using small capacity and local (stand-alone) systems. Secondly, the regionalization of the economy has led to concentration of significant development resources on the regional level. And, thirdly, these processes take place against the background of weakening of the country's power industry management as a result of economic reforms. The regions in these circumstances cannot be guaranteed adequate power supply status "from above."

In the North, the effective energy sector development is possible through a combination of capabilities of large- (systemic) and small-scale (mostly distributed) energy generation. The main prerequisites for this are the focal character of loads and significant demand for heat in the development areas. In both cases, cogeneration of electricity and heat makes economic sense.

The strategic development priorities for a distributed energy sector in the new development territories are no less important. Historically, this type of facilities performed the role of pioneer energy industry in the Far North and equivalent territories. In the areas with available natural and associated gas, the bases of the energy sector were gas turbine installations with unit capacity up to 16 MW, while in other regions were diesel generators using motor fuel. In the course of the development of new territories, the growing power loads were routinely connected to centralized sources, namely, the district energy systems.

In the areas currently the segment of distributed power generation is rapidly growing. It is based on energy sources, constructed and operated by consumers. Solutions are becoming more competitive in the situation of accumulated underdevelopment of the large power industry and the growth of the tariff burden on the economics of the consumers, on the one hand, and improvement of technological capabilities of small (distributed) power industry on the other hand. Practically, the most significant overlapping of the opportunities of the large and small power generation today appears to be a set of heat and electricity cogeneration technologies.

3 Performance Evaluation of Cogenerating Power Plants

The preliminary analysis of the business processes related to the performance evaluation of cogenerating power plants revealed that the following four options out of all abovementioned ones are the most promising in terms of their efficiency [3]:

1. Modernization of cogenerating power plants with the replacement of the worn-out elements, which are mainly used in the areas with high temperatures and pressures

2. Re-equipment of cogenerating power plants while preserving their existing dimensions
3. Expansion of the existing cogenerating power plants through installation of additional cogeneration CCGT units in the new main buildings
4. Construction of new cogenerating power plants based on CCGT units equipped with solid fuel gasifiers

In general, assessment of economic efficiency requires additional calculations with the use of modern mathematical tools of fuzzy set theory, which allows solving multi-criteria problems and eliminates the inconsistency between some indicators when choosing the best variant for development of a cogenerating power plant. This multi-criteriality may be considered as a manifestation of uncertainty connected with the conditions of development and future operation of a cogenerating power plant [4–6].

To solve this problem, we have developed a general method of multi-criteria analysis, which consists of the following steps [3, 5]:

- Identification of admissible alternatives among many options (at this stage we select the most preferable development alternatives, which satisfy the conditions of the problem being solved)
- Definition of a set of criteria (objectives), which may help to solve the problem
- Determination of the criteria for evaluation of feasible alternatives in exact numerical values, interval (fuzzy) numbers
- Compromise allocation (a set of compromises may be applied only to the options for which the best combination of all criteria cannot be found);
- Application of the fuzzy set theory for identification of the non-dominated set of alternatives, which may determine their effectiveness
- Analysis of the calculation results, adoption of decisions

Comparison of the options, which may be applied to cogenerating power plants, was performed on the basis of the integrated suite of software facilities developed by the authors and used for the fuzzy multiple criteria analysis [7–10].

The calculations were performed within a predetermined range of possible changes in the weight coefficients talking into account certain groups of criteria. The increment range was 0.25.

Figures 1, 2, and 3 show the results of the multi-criteria analysis, performed with the use of mathematical tools of fuzzy set theory, and hierarchical grouping of the alternatives by the degree of their non-domination depending on the weight coefficients.

With a relatively wide range of weight values in different groups of criteria (0.25–0.5), including the case of equal probability of these groups, the most effective was the option, which involved expansion of the cogenerating power plant through addition of a CCGT unit. Compared to other business processes, the same option has the greatest degree of non-domination in terms of energy saving and environmental protection (with the weights of these criteria equal to one). Under the same conditions, the second option is construction of a new cogenerating power plant on the

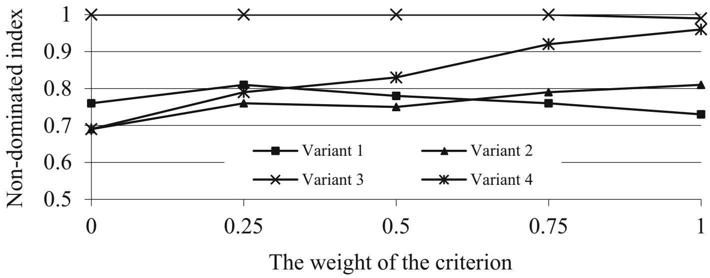

Fig. 1 Ranking of the alternatives by the energy criterion

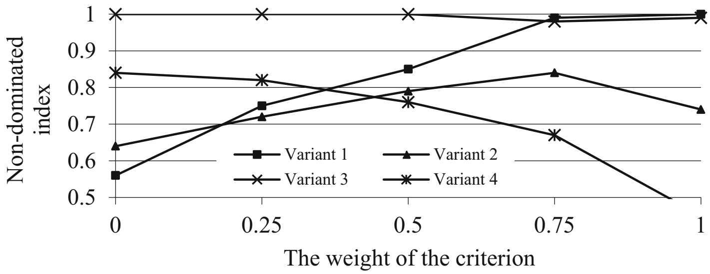

Fig. 2 Ranking the alternatives by the economic criterion

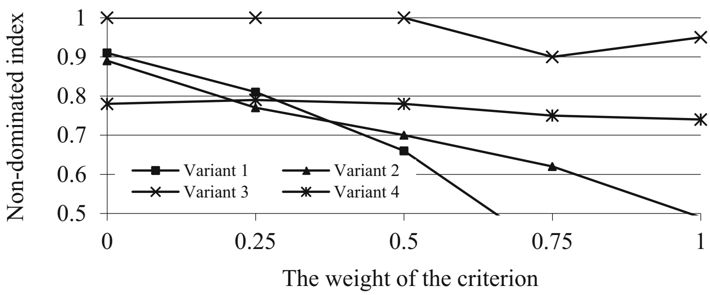

Fig. 3 Ranking the alternatives by the environmental criterion

basis of a CCGT unit equipped with a solid fuel gasifier. The analysis shows that the lower rank of this option may be explained by the following reasons: as for the energy criterion, by the significantly smaller volumes of power generation in the initial stage (due to longer construction period), and as for the environmental criterion, by the need in additional alienation of land. With the increase of the economic criterion weight (0.75–1), the equipment modernization becomes the most effective business process, which is also the best investment solution.

The result of multi-criteria analysis shows that the most effective are options 1 and 3. The choice between these alternatives may be made based on the existing strategic and tactical plans adopted by the management entities responsible for the development of the centralized cogeneration system.

4 Conclusion

The economic and technological development priorities in production of combined heat and power energy in remote areas were assessed with the use of mathematical tools of fuzzy set theory. The results of this analysis are as follows: (1) taking into account a short-term perspective, for the centralized cogeneration systems, the most preferable will be extension of the residual operation life of the main equipment; but in terms of a long-term perspective, it seems to be more effective to expand the existing plant capacities through construction of additional CCGT units, which will remain competitive under the conditions of seasonal fluctuations in the consumer heat load; (2) for distributed power generation systems, re-equipment of the existing boiler stations with additional installation of CCGT units proved to be the most competitive option. Electric capacity of such power plants will cover the annual needs in hot water supply for consumers, while the plants will be able to work in economy mode during the non-heating season. It was established that in the remote areas, which possess local fuel resources (waste wood, agricultural wastes, etc.), it is feasible to use high-performance gas-producing cogenerating power plants equipped with internal combustion engines.

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