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TOPOLOGICAL MODELLING OF THE ENERGETIC SPACE OF THE CHECHEN REPUBLIC

The article is devoted to the geographical aspects of diversity in the energy space of the Chechen Republic. The author has conducted the review of the territorial organization, identified the main problems and marked the preconditions of development. The methodology of geographical study of the diversity of regional energy space is presented in the paper. As further research directions of topology of the energy space of the Chechen Republic, it is important to identify conjugation areas of ecological, socio-economic and technological feasibility of the local power industry development, especially in the rural and mountainous areas. In the language of economic geography, it is required to perform social and electric power zoning of the region.

Key words: *power supply system, cyclic networks, acyclic area, local power industry, resources of renewables.*

Заирбег Атаев. ТОПОЛОГИЧЕСКОЕ МОДЕЛИРОВАНИЕ ЭНЕРГЕТИЧЕСКОГО ПРОСТРАНСТВА ЧЕЧЕНСКОЙ РЕСПУБЛИКИ. *Статья посвящена географическим аспектам разнообразия энергетического пространства Чеченской республики. Проведен обзор территориальной организации, выделены проблемы, отмечены предпосылки развития. Представлена методология географического исследования разнообразия регионального энергетического пространства. В качестве дальнейшего направления исследований топологии энергетического пространства Чеченской республики актуально выявить зоны сопряжения экологической, социально-экономической и технологической целесообразности развития локальной энергетики, особенно в сельской и горной местности. Говоря языком экономической географии − необходимо провести социально-энергетическое районирование региона..*

Ключевые слова: *энергосистема, циклические сети, ациклична зона, локальная энергетика, ресурсы возобновляемых источников энергии.*

Заірбег Атаєв. ТОПОЛОГІЧНЕ МОДЕЛЮВАННЯ ЕНЕРГЕТИЧНОГО ПРОСТОРУ ЧЕЧЕНСЬКОЇ РЕСПУБЛІКИ. *Стаття присвячена географічним аспектам різноманітності енергетичного простору Чеченської республіки. Проведено огляд територіальної організації, виділено проблеми, відзначено передумови розвитку. Представлено методологію географічного дослідження різноманітності регіонального енергетичного простору. В якості подальшого напряму досліджень топології енергетичного простору Чеченської республіки актуально виявити зони поєднання екологічної, соціально-економічної та технологічної доцільності розвитку локальної енергетики, особливо в сільській і гірській місцевості. Говорячи мовою економічної географії, необхідно провести соціально-енергетичне районування регіону.*

Ключові слова: *енергосистема, циклічні мережі, ациклічна зона, локальна енергетика, ресурси відновлюваних джерел енергії.*

Introduction. The Chechen Republic is actively developing nowadays, it is occupied with the implementation of the recovery plan. The region faces a range of problems of social, economic and technical nature, and the energy problem must be identified as one of the basic. Electrical energy industry, according to the author, is one of the most "geographic" objects of research, which is a consequence of the physical specifics of power: the moments of its production and consumption should synchronously coincide. As a consequence, there is rigid connection of the electrical energy industry and the area. Electrical energy industry is a "blood circulatory system" of the territorial organization of society, its mirror copy. Therefore, the detection of the specific topology of the branch space is the important scientific and practical problem and at the same time a subject of research. The article is devoted to the analysis of this problem.

Currently, on the assumption of the analysis of literature, we can say that only power engineers and managers are involved in the study of the topology of the Chechen power supply system [10; 13; 15-16], economic-geographical approach is missing. But spatial approaches, solutions and models are needed. Attempts to build models of development only on the basis of economic, engineering, or management mechanisms are not complete. These decisions should be based on the territorial specifics, but more often they should be determined by its topology.

In the author's opinion, it is the "not embroidered" part of the sectoral programs, it is the goal of the article. Hence the main task of the study: reliability analysis of the topological diversity of the energy space in the region in order to develop composite power supply systems. Modelling of industry space on the principle that management is a continuous modelling and economic and social geography is a constructive in its nature science is in great demand.

The territorial organization of the society in the Chechen Republic. Today the population in the region numbers 1294 thousand people, of which almost 60 per cent are of working age. The average density of settlement is 240 persons per square kilometer, the total area is 16.1 thousand square kilometers, and it is divided into 15 districts. On the basis of differentiation for the development of individual sectors of the economy, the Republic is divided into three zonal grouping regions: central, northern and southern zones [6, c. 60].

I. The northern territory includes part of the Terek-Kuma lowland (dry steppe), three districts. The area is favorable for the development of animal husbandry, vegetable growing, fruit growing and viticulture (picture 1).

II. The central area is the area with the highest economic activity (up to 80% of the population). Here there is a transportation core of the region (an airport, railways and roads, significant electricity transmission lines, gas and oil pipelines). Administratively, it includes the city of Grozny and seven districts. This area is "the pole of growth" of the Republic, with the emerging industrial center along the line of "Grozny – Argun – Gudermes" (the development of the oil refinery complex, time-consuming engineering and transport). Due to the

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agro-climatic conditions this area is of long-standing agricultural development.

III. The southern area is the mountainous area (the northern slopes of the Great Caucasus Mountain Range). The mountain rivers are potential for hydro-power resources, and the natural landscapes for tourism development. The abundance of Alpine pastures has historically predetermined animal husbandry orientation of the area. Administratively, the taxon includes five municipalities.

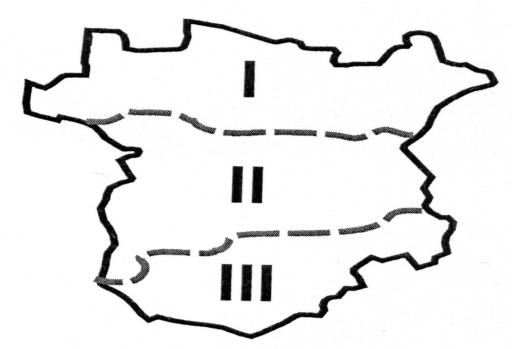

Figure 1. Integrated territorial zonal division of the Chechen Republic *(according to S.A. Lipina, 2007)*
▬ ▬ ▬ ▬ borders of conventional zones:
I. – the Northern Zone (territory); II. – the Central Zone; III. – the Southern Zone.

The Electric Balance of the Chechen Republic. Currently, there are no large energy consumers in the region. The only sector of the economy, which is still kept afloat, is the oil and gas production. The process of recovery of the housing stock, infrastructure and industrial facilities is continuing. The electric balance of the region mainly reflects the household needs of the population and production demand of small businesses. In total, it makes 59 % of the electric balance of the area, industrial consumption does not exceed 4 % (Table 1).

Table 1

Balance, dynamics and forecast of electricity consumption in the Chechen Republic, 2001-2030*

Years	Electricity consumption		Peak load		Number of hours of load usage
	mln. kWh	% from the previous year	MWh	% from the previous year	
2001	793	+61,8	172	-1,2	2816
2002	914	+15,3	233	+35,5	4610
2003	1144	+25,2	248	+6,4	4613
2004	1326	+15,9	287	+15,7	4620
2005	1463	+10,3	296	+3,1	4942
2006	1619	+10,7	343	+15,9	4720
2007	1785	+10,3	370	+7,9	4825
2008	2004	+12,3	414	+11,9	4840
2009	2089	+4,2	416	+0,5	5020
2010	2205	+9,4	437	+5,0	5045
2011	2294	+4,0	464	+6,2	5070
Electrical balance of the Chechen Republic in 2013, %					
Population − 59		Housing and communal services, budgetary insitutions − 28		Industry − 4	
Forecast indicators for electrical balance of the Chechen Republic					
Years	Volume of electric energy, mln. kWh		Commissioning of industrial capacities		Deficit of the power supply system, %
2015	2418		6		In EP and capacity almost 100%
2020	2669		256		In EP and capacity almost 50%
2030	3360		848		Self-balancing of the power supply system

Note: The symbol (*) denotes that the data are presented since 2001, i.e. since the beginning of the end of the war; EP – electric power.

The table contains selected data: [15; 13, c. 9; 15].

It follows from the analysis of Table 1 that since 2001 there has been a steady growth in electricity consumption, the increase in demand over the period from 2001 to 2011, was 17.5% and in 2011 it reached nearly 2.3 billion kWh. The internal maximum of the Chechen power supply system load over the period from 2001 to 2011 increased from 172 to 464 MWh (for about 2.7 times). Based on the average annual growth rate of 2% in the period up to 2030, the expected growth (2011 baseline for evaluation) will make: electric energy consumption of 46.5%; load capacity by 44%. The demand for electricity by 2020 will increase to 2.7 million kWh, and by 2030 to 3.4 million kWh. Today, the deficit of the energy system is almost 100% of power generating capacity and energy.

Accordingly, the restoration and reconstruction of the industrial potential of the region is rigidly actualizing the problem of reliable energy supply, which is a precondition for the competitiveness of industrial products. These aspects are reflected in the papers of the power development of the Chechen Republic [15−16].

Power generation. Grozny's central heating and power plants No. 1-3 with total capacity of 489,2 MW were destroyed during the war (1994−1996, 1999−2000). In 2002 generating equipment was totally decommissioned. Now the potential of generation is in the recovery state. Projects for the restoration of Grozny CHP-3 and construction of the cascades of the Argun HPPs are approved. Pre-job designs for construction of a wind farm consisting of 24 wind energy units with a capacity of 1.5 MW each (in total 36 MW) are completed.

Electric network facilities of the Chechen Republic presents a variety of complexes (Table 2). Structurally, the complexes are part of a network of enterprises of JSC "Nurenergo": North, East and West electricity mains.

The backbone electricity mains (voltage ≥ 330 kW) are represented by the transit transmission line – 330 kW with latitudinal extent: Chiryurt Vladikavkaz-2. The supply class of networks consists of transmission lines and 26 PS-110 kW and 75 PS-35 kW. The distribution network is the basis of the configuration of the local energy space (0,4-6,0-10,0 kW).

Table 2

Grid Complexes of the Chechen Republic

Classification of electrical substations, units							
Backbone substations			Supply substations				Total
750 kW	*500 kW*	*330 kW*	*220 kW*	*110 kW*	*35 kW*	*10−0,4 kW*	
—	—	1		26	75	2952*	3054
The length of the lines of electric transmission, km **							
—	—	—	—	1025	1082	9998	12105

The table was compiled on the basis of the information: [6; 10; 13; 16].

Field ties of the power system are implemented through 10 outputs of the transmission lines of different classes. This is the basis of power supply in the region, it is provided by the power and volume exchange from the neighboring power systems: Dagestan, North Ossetia, Ingushetia and Stavropol systems [13]. The network 110 kW divides the region into three isolated districts: PS-330 kW "Grozny" through the transmission line -110 kW provides the supply of the central districts of the Republic; Dagestan power system provides the eastern regions; Ingushetia, North Ossetia and Stavropol power systems ensure the provision of the western regions.

Conclusions on the sectoral section of the region: the power system of the Chechen Republic is scarce, it is steadily increasing in the power and volume of electricity; further depreciation and amortization of funds is expected. As a result, the increase in the energy barriers for the economic development of the region is anticipated. The situation provokes an aggravation of the problem of reliability of power supply of electricity consumers and the need for topological analysis of the service area of the power system.

The methodology of topological segmentation of the grid, the identification of the spatial framework of the power sector of the Chechen Republic, the analysis of the level of power supply reliability. The morphological analysis of the reliability of the territorial organization of power supply is based on the provisions of the mathematical graph theory of O. Ore [7], that is used to organize the spatial mode of control of power systems [5; 8-9; 12].

To implement the geographic approach morphology of transmission lines 35-110 kW of supply class was adopted as the basis for the analysis, and to structure the network entities the proposed by S.A. Tarkhov methodology to describe the topological structure of land transport networks and their morphological dissection into cyclic tiers was used [11, p. 47-53]. The obtained results of the geo-network analysis are presented in Table 3.

Table 3

Morphology and Metric Cycles of the Electric Power Supply of the Chechen Power System (35–110 kW)

Morphology and metric of cyclic supply networks	Cycle indexes	Number of cycles	Outputs of the power transmission lines outside the region
The main frame of supply electrical grid (tier)	8	8	10

From the content of Table 3 it is implied that the first and the only topological tier of transmission lines forms the main skeleton of the cyclic network, it is revealed by a circular crawl along the outer periphery of all cycles of the regional energy system (8 cycles), having at least one common vertex or edge with the outer border of the frame. This is the area of greatest development, it outlines the area of relatively guaranteed supply. Thickening of cycles is the vector of "space compression", it reflects the main development bands of the region with multi-functional transportation harnesses. Thus, the 110 kW power transmission lines diverge "in rays" from the main sites of generation of power systems: PS-330 kW "Grozny"; CHPP-4 (Argun); PS-110 kW. The territorial combinations manifest themselves as morphological formations in the main skeleton of eight cycles and as their elongation along the federal-aid highways: Grozny – Argun – Gudermes. Thus, the cyclic networks in the Chechen Republic are present only in the central zone (see Picture 1).

The rest of the supply grid 35-110 kW potential operates in the open-loop mode, it is an acyclic area of the region, indicating the low level of centralization and, a priori the power supply system reliability. This thesis requires validation at the local level of organization of the energy space; to do this we used the method of selection of the type of managing networks structure [12, p. 14].

The joined geo-network analysis shows that a strictly centralized type of managing structure with very low reliability level of energy supply is characteristic of a zone of dominance of tree networks, and it constitutes more than 90% of the area of the region. Accordingly, the main part of the republic, in case of a breakdown in the power system (including the neighbouring regions), is an area prone to inversions and exacerbation of energy problems under the cascading scenario ("the ripple effect").

Meanwhile, the territory itself is a substrate not only of problem initiation but also of searching ways of its solution on the principle that the economy is a constant spatial modelling.

Modelling of energy space of the Chechen Republic is a mutual accompaniment of vertical space centralized grid by horizontal integration of local systems [1, p. 31]. Therefore, the problem of increasing the reliability of energy supply due to the increase of complexity of the morphological type of managing structure can be solved. In the case of expansion of the network of power transmission lines and the growth of the number of cycles, the number of topological tiers of the network also increases. Then, a strictly centralized management system of supply grids type is replaced by a mixed one, the main cyclic skeleton almost reaches the administrative borders of the region, and the frame of the power system takes the form of conditionally duplex territorial organization.

The basis of the first level of the energy space is constituted by cycles of centralized supply network. The second level is a set of combined local cycles, which are focused on energy carriers of different nature and have a connection with the JSC "Nurenergo" via the distribution network.

In practice, the growth of topological diversity is a consequence of this spatial structure: "Mutual complementation of tendencies of centralization and decentralization of power systems is the ability to increase the actual variety of forms of territorial organization of power supplies and diversity of functions" [1, p. 28].

In such a model, the local energy system can "close" consumers at the local network cycle and its potential of small-scale generation. The individual choice of mutual complementation schemes depends on the specifics of the locality content.

As generating foundation for local energy systems high hopes are put on the construction of small gas turbine central heating and power plants (GTP – CHPP). The comprehensive scientific research institute of the Russian Academy of Sciences has developed proposals for the use of energy distribution stations for the region [15]. But functioning of small GTP- CHPP of domestic production requires gas pressure of not less than 2.5 MPa [4, p. 9]. Therefore, the development of gas turbine technology is possible only in those network systems of the region, where there are gas pipelines, but it is limited and morphologically can be expressed as *linear-nodal type of local energy systems development*.

The development of local power industry based on gas-piston engines adapted to run on gas pipelines of urban and rural gas supply network option is more interesting (0.3 to 1.2 MPa). Gasification is implemented even if the settlement numbers only 20-30 houses [14]. The development of small power engineering on the basis of such technologies in the Chechen Republic can be recognized as a promising direction, although it has its own spatial restrictions and limits (areal-nodal type of local grids).

However, under any scenario, the development of small thermal power industry its dependence on exhaustible resources is continuous. Energy prices will rise, and the stake only on the development of gas technology dramatically increases the dependence of power industry from the dynamics of gas price band. In this regard, the ideas of mass development of local energy systems based on local resources of renewable energy sources – RES are being revived, which contributes to the spread of *areal (universal) type of local energy systems*.

The Chechen Republic has huge potential of hydropower and wind energy. The widespread use of wind for generating electricity is effective with average annual wind speed of at least 5 m/s [1-3]. In the republic this figure is higher. According to preliminary estimates, gross hydro power potential is 10-14 billion kWh on large rivers (Terek, Argun, Sharo-Argun and others) and another 1.4 billion kWh on small rivers. Economically reasonable share of resources reaches a value of 3.1-5.0 billion kWh, which exceeds the projected needs of the region. Reserves of thermal waters of the republic are equivalent to the consumption of 1 million tons/year of oil [6, p. 91]. The possibility of helioenergy is under study (265 days of sunshine a year).

General analysis of the situation allows to express the following judgments: geographically favorable com-

bination of the availability of energy issues and economic resources of RES is viewed in the zones of the republic. Large-scale use of renewable energy sources should be organized in areas where lack of energy reduces the general level of the population's sustainment. Thus, any model of economic development of the Chechen Republic in its energy basis is "bound" to socio-ecological imperative, accordingly, we can define the main directions of the use of renewable energy:

1. The sparsely populated part of the Chechen Republic (the Northern and Southern zones) limits the feasibility of large-scale network. The connection to a centralized network is inefficient, if the average daily consumption is equal to or less than 2 kWh/day per person. In such areas, the functioning of local energy systems is almost the only way to solve the energy and social problems of consumers. The socio-economic aspect of "topogenesis" is brought to the forefront, and the territorial aspect of such a range allows to join an acyclic zone with poor network connectivity, areas of "focal" settlement.

2. As a result of high depreciation of networks, the reliability of energy supply decreases, the share of energy losses during transportation increases, frequency of emergency situations and disconnections rise, etc. Socio-economic losses have time lag. This is the situation when the infrastructure aspect of the arrangement of "topogenesis" dominates. The problem can be solved by combining local and centralized power system. In this scheme, small power plants are the main source of electricity generation for the service area of the local power system, which has weak links with the centralized system. The inclusion of small generators under the scheme of the modular segments in the overall power system can improve energy saving performance for the total range of effects, including the option of reliability. Renewable power industry in addition to fuel economy plays the role of a backup power system.

3. In recreational and protected areas (reserves, sanctuaries, national parks), it is also wise scheme combining both local and centralized power systems. In this case, the local energy system will carry a base load, and the centralized one – its transitive part. Then, it solves the technical problem of optimization of the output parameters of the power plants on the basis of the resource RES. Low-temperature needs of the population as a technological process does not require output parameters variations in a wide range. The effect of the use of renewable energy for water lift and irrigation is characterized by the same parameters. The option is valid for all cases, when the focus is on the environmental aspect of "topogenesis".

4. The fourth direction is promising to "topogenesis" on the principle of "growth pole" (the Central zone). The scheme of the local power system provides for the operation of small generation module as an integral part of a centralized power system. This maximally optimizes the elasticity of production with high reliability of the supply system itself and at the same time leads to increase of synergy effects as a result of this synthesis ("the ripple effect"). The coupled power system is especially promising for areas with rapidly increasing demand for energy (suburban areas, cost-effective agricultural organizations, deluxe cottage settlements, zones of mass conversion to electric heating and so on). The place of local and centralized electric power systems in the graphics of load will depend on the specific conditions of the area, demand rate in seasonal and daily dimensions, the current level of energy prices, etc.

It is obvious that the above mentioned directions do not exhaust the variations of the target use of RES in the region. The actual range of efficient operation of renewable energy is more diverse in needs and capabilities of its satisfaction. It is obvious that measures of large-scale involvement of the resources of RES in the total energy balance should be a priority in the regional strategy. And the general algorithm of research in the sphere of modelling of multilevel energy space of the Chechen Republic actualizes the necessity to solve a number of related tasks:

1. The zoning of the region on energy consumption of the territory, taking into account the real level of the energy needs of the population (according to the criterion really delivered power and actually used amount of energy, and not by the conventional statistical approach).

2. The typing of the system of settlement in the region by the criterion of real territorial changes in the density of settlement, the dominant type of settlement, the population, and not statistically generalized indicators (with access to micro-level of locality).

3. The zoning of the region in terms of the concentration of economic resources of renewable and non-renewable energy sources, formed by them geographically favorable combinations, that identifies potential opportunities and schemes of their involvement in the overall energy balance.

4. The zoning of the region on the capabilities of the territorial combination of local and centralized energy supply systems based on renewable and non-renewable energy sources.

The foregoing judgments are estimative, but they allow to speak about a wide variety of opportunities of the energy space for the modelling of composite power systems. The modern Chechen Republic is the truly "untilled field" for study and engineering.

The conclusions can be formulated in the form of a number of theses:

1. The energy deficit of the Chechen Republic is almost 100% in the power and volume of electricity. The deficit steadily increases, further depreciation and amortization of fixed assets can be expected. As a result the growth in energy barriers for economic development of the region can be anticipated.

2. The geo-network analysis of the electric power system shows that the acyclic area of the region has a very low reliability of supply (90%). The main part of the republic, in the case of a breakdown in the power system (including the neighbouring regions), is the area prone to exacerbation of energy problems under the cascading scenario ("the ripple effect").

3. Mutual accompaniment of the tendencies of centralization and decentralization of the power systems is the opportunity to increase the actual variety of forms of territorial organization of power supply and diversity of functions. In the zones of the republic the favorable

territorial combination of the availability of energy problems and potential economic resources of RES is confirmed. Measures of large-scale involvement of the resources of renewable energy into the total energy balance should be a priority in the regional strategy.

4. As further research directions of topology of the energy space of the Chechen Republic, it is important to identify conjugation areas of ecological, socio-economic and technological feasibility of the local power industry development, especially in the rural and mountainous areas. In the language of economic geography, it is required to perform social and electric power zoning of the region.

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Summary

Zairbeg Ataev. TOPOLOGICAL MODELLING OF THE ENERGETIC SPACE OF THE CHECHEN REPUBLIC.

The Chechen Republic today is occupied by the implementation of the recovery of the economy, where the energy problem is one of the basic. Power industry itself is a very "geographical" object of study, which is a consequence of the physical specifics of electric power: the time of its production and consumption must simultaneously coincide. As a result, there is rigid connection of power industry and the area; it is a "circulatory system" of the territorial organization of society.

The investigation of the topology of the Chechen power system is carried on only by power engineers or managers, the economic-geographical approach is missing. Attempts to build models of development only on the basis of economic, engineering, or management mechanisms is not complete and must rely on the territory, its topology. Reliability analysis of the topological diversity of the energy space in the region is the very part of the sectoral issue which is not "worked out".

The power system of the Chechen Republic is in deficit, and the deficit is steadily growing, alongside with depreciation and amortization of fixed assets. Consequently, there is increase in the energy barriers for the economic development of the region. The situation provokes an aggravation of the problem of security of supply, the need for topological analysis of the service area of the power system. Geospatial analysis shows that 90% of the area of the Republic, in case of a failure in the power system, is an area of acute energy problems. But the territory is not only the substrate of the emergence of the problem, but also of the looking for ways of its solution on the principle which states that the economy has a constant spatial modelling.

Modelling of energy space mutually complements the vertical of a centralized power system space with the horizontal integration of local energy systems. The specific choice of the complementation schemes depends on the specifics of the locality content.

The development of gas turbine technologies is possible only in those network complexes, which have cross-country gas pipelines; it is limited and morphologically can be expressed by line-nodular development type of local energy systems. Small-scale power generation based on gas-piston engines is a promising direction, although it has its own spatial restrictions and limits (area-nodular type of local grids). Only the mass development of local energy systems based on resources of renewable energy sources contributes to the spread of areal (universal) type of local energy systems.

As a further research direction of topology of the energy space of the Chechen Republic it is crucial to detect suitable development areas of the directions of power industry combination. In the language of economic geography, it is required to perform social and electric power zoning of the region.

Key words: power supply system, cyclic networks, acyclic area, local power industry, resources of renewables.