The main problems and solutions to the management of the electric power system by the example of metropolis power supply

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Abstract. Developments of electric power systems of Russia as well as foreign electric power systems are on the way of the annual complications. This trend can be well observed in the example of the development of electric power systems of large agglomerations - metropolises.

We should also mention that along with this complication new labor-intensive tasks arise - increasing the reliability, improving the management of modes and ensuring the survivability of electric power systems, in this regard, we can distinguish the following factors:

• increasing the number of interconnected power facilities;
• growth of the maximum installed capacity of the power system;
• complication of the electrical network;
• complication of ensuring the required level of controllability of objects;
• increasing of short circuit currents.

Thus, designers of electric power systems often use the principle of multi-factority in their design, which ultimately just affects the complexity of electric power systems, leading to a large number of configurations of network circuits that have different capabilities, properties, technical and economic indicators.

1. Introduction

Since energy supply is one of the primary tasks of life support and life-sustaining activity, it must comply with the highest requirements for its quality and reliability. The most obvious example of an electric power system (EPS) that takes into account all current requirements can be a complex EPS of a metropolis (MP).

Not only at present but also in the near future, high-quality and trouble-free power supply to consumers, will be largely determined by the trends, features and principles of building metropolises' power systems. MP power systems not only cover and coordinate the power supply of the entire city but also effectively synchronize the parallel operation of all power sources, both internal and external. The number of inhabitants of modern metropolises exceeds one million, and the number of cities with a population of more than fifteen million as of 2018 exceeds 15 cities in the world. Thus, metropolises are characterized by the accumulation of a large number of people in a relatively limited territory, very diverse utilities, technologically large and complex volumes and types of production, etc. In this regard, it can be argued that most MPs are deployed in areas with a relatively warm and mild climate, but in general, they are characterized by a variety of environmental conditions.
Consequently, in the development of the electric grid economy and electrical power generating system (EPGS) of MP in present circumstances, the following requirements must be observed - the organization of reliable, sustainable and economic energy supply of MP and the entire infrastructure of giant urban entities.

The most important conditions for achieving this goal are the diversity of energy resources, methods for their receipt, delivery and use in the MP, non-alternative and rigid restriction of violations of ecological interaction with the environment, ensuring stringent requirements for energy conservation and energy efficiency.

The management of the regimes of electric power systems of large agglomerations - metropolises (EPSMP) is becoming ever more complicated every year. The following problems can be identified: territorial extent, a constant increase in the load of consumers, a variety of time ranges of control cycles, restrictions on independent and dependent variables, non-linearity of state equations, increased requirements for accounting settings and the formation of automatic control systems, relative certainty of the initial calculation information. For these reasons, different requirements should be applied to the energy system of MP than to any other energy systems.

The main difference of the metropolis energy system is the presence of a large number of various energy objects: generation, cable and overhead networks, consumers of various reliability categories, which reveals a tendency to increase short-circuit currents and makes it quite a labor-consuming process to calculate PSP settings; significant interconnection of electric, heat and gas supply modes affects a high share of combined production of electric and heat energy; a large number of consumers of the first and second reliability rating, including life-support facilities that do not allow interruptions in power supply, and other equally. Their density in the metropolis is significant.

In a large urban agglomeration, there is a great interdependence between electricity, heat and gas supply. The power system is characterized by a complex topology of the electric network, a high current load of its elements, and a high level of s/c current. Given the above, the time to restore such a power system after an accident should be much less than in a conventional power system. It is necessary that the loss of at least one element of the system leads to the smallest consequences, since in a metropolis completely different requirements for the viability of the energy system. There is also limitedness of the territory. It is especially worth noting that often in modern metropolises there is simply no place for the construction of energy facilities. If generating facilities, apart from modern facilities of renewable energy sources, can still be placed outside the city, then substations supplying such a metropolis cannot. And this is the basis for clearly verified technical, economic and regime calculations, to assess what we are going to build here: a generation, a power load-center substation, or an ordinary, cable or overhead networks, what the capacity of this object or the line capacity should be. These criteria form the main requirements for EPSMP.

The property of metropolis power systems compared to a traditional power system is that with a significant density of the grid and generating complex, this power system can have a wide range of bottlenecks, as well as insufficient equipment with emergency automation systems, which in fact leads to unforeseen emergency situations. For example, an accident in the Moscow EPS in 2005.

Optimal control of the EPSMP mode is the most important condition for its high-quality operation, first of all, reliability and efficiency. In this connection, the requirements for the energy systems of metropolises include many conditions that cannot be applied to traditional energy systems. So, it is worth to increase the period of development of the scheme and development program from five years to seven, the development of additional sections in schemes and programs with power supply schemes of the power network of 110 kilovolt and above, fuel supply, heat and power supply to distribution networks with a voltage class of 6–35 kV.

The increased requirements are supposed to be applied to the internal high-voltage network of metropolises and its electrical connections with the UES of Russia. For example, the output of electric networks providing communication between the objects of the electric grid economy of the metropolis and the IPS should be at least 20-25% of the total load of consumers of the metropolis.
The energy system of a metropolis must have at least three basic electrical substations with a voltage of 220 kV, connected to other power systems, and also connected for mutual redundancy in the “ring”, which must be equipped with uninterruptible power supplies that provide the substation's own needs during the day or more. At the same time, the total installed capacity of autotransformers of the highest voltage class at one reference substation cannot exceed 20% of the maximum load capacity of a metropolis. In contrast to existing conventional power systems, in metropolises, when designing new and reconstructing existing power facilities, it is advisable to include the most severe design disturbances. For example, simultaneous shutdown of all generators at the power plant, a shutdown of the switchgear of any voltage class at a substation or power plant, simultaneous shutdown of cables of a power network passing through one collector. Thus, in the design of EPSMP it is advisable to use inserts and direct current transmissions.

2. Problems and principles of building power supply in metropolises using new technologies and equipment

2.1 Problems of energy supply of metropolises
Currently, there are a number of cardinal problems in the energy supply of the MP:
- a) lack of generating capacity;
- b) lack of distribution networks at 110 ÷ 220 kV, which bring the power to the concrete MP areas;
- c) unreliability of power supply to consumers of distribution networks of 6 (10) and 0.4 kV;
- d) instability of all three directions - generation, transmission, distribution;
- e) lack of effective consolidation between them and with energy consumption;
- f) unsatisfactory pricing, etc.

From this point of view, the analysis of the listed directions is carried out separately and together. Despite the fact that they are based on competing requirements and conditions, they are generally organically combined and consolidated by the unity of solving the common problem - ensuring reliable power supply to the MP.

Requisite conditions for the modern energy of metropolises are constancy and continuity:
- maintaining all facilities and structures in a healthy state, at the level necessary to meet consumer demands;
- modernization of existing energy facilities;
- development, implementation and effective use of innovative technologies in all aspects of production, transmission, transformation, distribution and consumption of electricity, without exception.

These technologies should not only take into account the current objective need of the MP electric energy complex, but also comply with the advanced evolutionary directions of the domestic and industrial sectors, guarantee indisputable reliability of power supply, comply with environmental safety requirements, be cost-effective, and at the same time fully comply with the requirements and demands of consumers.

2.2 Relocation of power plants in the foreseeable future beyond the lines of the metropolis
The construction of large thermal and nuclear power plants outside the metropolis area agglomeration solves the problem. This is one of the possible ways of developing MP energy. Undoubtedly, this will entail a number of cardinal problems. First of all, this is the creation of "deep entry" systems and the restructuring of the heat supply system. According to many experts, urban thermal power plants need to be radically modernized. Now the problem is being solved by installing and commissioning new effective equipment, CCGT and other technologies.

At the same time, there are problems of building and providing power supply to the border areas of the agglomeration. A striking example of this is the Moscow region, where large sources and consumers of electricity are located in the satellite suburbs of Moscow. Only environmentally friendly sources of energy based on renewable energy resources, including non-traditional individual ones, should work mainly within the megalopolis, especially to solve the problems of providing consumers with heat.
2.3 Expanding the range of distributed generation sources
This direction can be considered as an alternative to the above. These are cogeneration and trigeneration power plants of small and medium capacity that use natural gas as fuel and provide consumers with electricity, heat and cold. They can work independently or together with the main network. In the latter case, an important condition is the optimal combination of joint operation of a particular power plant and network, which allows obtaining the maximum coefficient of primary fuel use and, accordingly, the minimum harmful impact on the environment.

A significant hindrance in the development of this direction in Russia is the lack of legislative instruments on joint work and mutual settlements of traditional electricity suppliers, on the one hand, and, on the other, producers (consumers) using distributed generation sources. Moreover, the former are currently actively rejecting and inhibiting the adoption of objective decisions in this direction, in most cases, without taking into account the arguments, assessments and references to the positive experience of the European Union, Asian and American countries. Nevertheless, it is clear that the need for the development of distributed generation is obvious, and the near future time will present itself.

2.4 Concentration of energy production directly inside the territory in existing metropolises
This direction is typical for the organization of the power supply of existing MPs. To a greater extent, in domestic large cities, this is due to the need to organize district heating.

In the examples of building electric networks and power supply systems for the largest Russian cities of Moscow, St. Petersburg, Samara, Yekaterinburg [1], and this regularity can be traced distinctively. In foreign MPs, this trend is manifested to a lesser extent due to the geographical location and, consequently, a milder, warm and hot climate than in Russia.

2.5 Complete solution to the power load-center substation
This is relevant both now and in the future. In other words, in the MP, it is necessary to transport large flows of electricity to power MP consumers from sources located in the agglomeration or at a distance and outside. One of the most well-known solutions for modern EPSMPs, which impose severe restrictions on the dimensions of the switchgear, is power load-center substation at voltages of 110 ÷ 330 kV into the territory of the MP in power consumption centers [2, 3]. At the same time, the possibility of using SWYD is almost completely excluded in new construction.

They not only violate the environment but also increase electromagnetic pollution, both at the industrial frequency and in high-frequency bands, disrupting TV and radio reception, mobile communications, etc. In residential areas, noise effects, such as shots fired when air switches are operating, are also completely unacceptable.

2.6 Creation of modern distribution circuits of a metropolis
Electric networks of the metropolis are created on the basis of innovative principles of their construction: accessibility, outstripping demand for consumption, reliability, environmental friendliness, aesthetics of the urban territory, etc. This problem is considered in the work for the ENEPS of Russian MPs, namely Moscow, St. Petersburg, Yekaterinburg, Samara, as well as characteristic fragments of the power supply of their agglomerations, and, in addition, existing and promising fundamental solutions and schemes that ensure a high level of reliability due to reservation [4].

2.7 Exchange of urban overhead line (OHL) on cable lines (CL)
This major global problem of EPSMP development is solved on the basis of modern types of OHL with polymer insulation (CLP - cross-linked polyethylene, EPR - ethylene-propylene rubber et al.) and CL, which use the effect of high-temperature superconductivity. The use of CL instead of OHL is important due to strict prohibitions and restrictions on OHL in networks of all voltages in the megalopolis and above.

The smaller area of the CL, its greater reliability in comparison to OHLs (if all the necessary conditions for selecting the necessary cables for the transmission of the required power at the design
stage and compliance with the laying technology at the installation stage are met), as well as the absence of supports and hanging wires determine the widespread use of CLs high voltage and ultra-high voltage in the energy systems of large cities, which is observed in the energy systems of the MPs.

At the same time, the cost of constructing a CL of the corresponding voltage class is approximately 15–20 times higher than that equal to it in terms of transmitted power. However, even in spite of this circumstance, CLs based on cables with insulation from CLP are increasingly used [5].

2.8 Short-circuit current limitation in the metropolis ENEPS

In the networks of all metropolises, high levels of SC reach alarming values, being a well-known problem. The situation is made worse by the fact that there are certain difficulties with the serial industrial production of switches, in particular, HV and UHV with tripping currents above 63 kA. The cost of such equipment is more than significant, and their development is unique and still economically unprofitable.

This task is effectively solved when using a complex of relatively new types of electricity-generating equipment and measures, their application is considered in detail [6]. Probably, without their application in the schemes of the long-term development of energy systems of the MP at the level of 2016 ÷ 2020 and further dispensation is almost impossible.

2.9 Implementation of technologies and materials using the HTS effect

These innovations are increasingly being used for cables, in particular, for a power load-center substation and distribution networks, as well as power lines, power transformers, current limiters and other electrical installations and complexes [7].

At voltages of 10–35 kV and an output at the level of traditional of 110–330 kV OHLs in real cases, it is almost irrelevant to them the mutual location of consumers in the metropolis and sources outside of it.

2.10 The development of transmission and distribution networks of the metropolis

It is very difficult to develop electric networks on the territory of existing MPs [8]. First of all, in conditions of high-density development and penetration of the city by various types of communications in some cases, it is practically impossible to place and build substations and power lines, since this requires withholding of significant territories from circulation. High-cost, but effective from all points of view, high-temperature superconductivity (HTS) and polymer CLs can be called as possible ways [9, 10]. As an alternative, we can offer sources of distributed generation using gas-piston and gas-turbine installations, although they, like the well-known diesel generators, are suitable as backup and are preferred in cogeneration and trigeneration complexes. Moreover, if strategic investors can provide financing for these works and purchase equipment, then to overcome other restrictions (environmental, historical, organizational, etc.), even using the latest equipment and technologies state guarantees and effective administrative support of city structures are needed.

2.11 Introduction and development of inserts and direct current transmissions

EPSMP, which are becoming more complex every day, require high-quality supervisory monitoring. Therefore, along with the above mentioned, to enhance supervisory monitoring of AC systems, power management using direct current transmission can be the introduction of a ring or power lines creating a “torn” ring of direct current transmissions with a hierarchical submission system, which will serve a regional power grid or a local center of electricity consumption, for example, a metropolis, using controlled AC to DC converters, in the form of a system of a variety of points of supply/consumption of electricity. Such a system would allow one to make a very stable operation of the grid according to the scheme: a network of alternating current - direct current - alternating current, which at the same time would provide full control over the supply of electricity to all supplied loads, while at the same time providing power control in all incoming and outgoing power lines of alternating current and/or direct current.
According to the considered options for the use of direct current transmissions and DC converting substations, the implementation of measures to improve supervisory monitoring can be represented by the following options:

- a direct current transmission system will allow to “decouple” the local alternating current network from the surrounding alternating current system, where there is an alternating current electric power consumption center with many local alternating current electric loads and one or more distribution network supply lines serving a lot of local alternating current electric loads. Also, there may be a detachable AC load. At least one remote generation producing electricity AC power to a local AC consumption center and/or to a remote AC electrical load via an AC power transmission line, and between the local AC power consumption center and the remote power generating station and the remote electric load, at least partially there is a ring or an incomplete ring of direct current power lines having a plurality of direct current electric loads connected to it.

The DC power line ring provides isolation of AC electricity received from a remote power station from a local AC power consumption center. The first set of AC/DC converters that are electrically connected to a ring of DC power lines that is external to the local AC power consumption center is designed to convert AC power from a remote power plant to DC power that flows through a ring of DC power lines and to supply this DC power to at least, on some other loads from the set of DC electrical loads on the ring of DC power lines. The second set of AC/DC converters, which are electrically connected to a ring of DC power lines, is designed to convert DC power from a ring of DC power lines to AC power, which is directed to both local AC electrical loads and remote electrical loads.

One or more runs of the distribution network in the local AC power consumption center are electrically connected to the ring of DC power lines through the second plurality of AC/DC converters to supply AC power to the local AC power consumption center while decoupling all local electrical AC loads from a remote power station. A power line that is external to the local AC power center is electrically connected to the ring of DC power lines through the second plurality of AC/DC converters for supplying AC power to remote electrical loads, all local AC electrical loads being unleashed from this power transmission operation.

- many DC-to-DC converters have been introduced in pre-defined locations on the DC power line ring to provide decoupling, which are designed to decouple from faults on the DC power line ring, preventing interference to the system operation or complete disruption of the system due to these faults.
- at least one local AC power generator is electrically connected to the AC power consumption center through a ring of DC power lines.
  - AC electric power produced by a remote power plant is transferred to the local electric network via a power line selected from the group of power lines consisting of high voltage (HV) or ultra-high voltage (UHV) lines, and it can be overhead or cable.
  - controlled AC / DC converters direct electricity that is planned to be transferred from a remote power station instead of a distribution located remotely from a local AC power center through a ring of DC power lines.
- at least the system includes one DC power source located at a local AC power consumption center that is electrically connected to the ring of DC power lines. The ring of DC power lines provides isolation of DC power sources from AC electrical loads and provides supervisory control of DC sources.
- in the local AC power consumption center, there are many different distributed sources of DC power generation that are electrically connected to the ring of DC power lines. The ring of DC power lines provides isolation of DC power sources from AC electrical loads and provides supervisory control of DC sources.
- power source converters are AC to DC converters.
- in the local center of AC electricity consumption, there are many different distributed sources of DC electricity generation, which are electrically connected to the ring of DC power lines and are selected from the group consisting of fuel cells, micro turbines, solar photovoltaic batteries, batteries and DC electric micro grids current. The ring of DC power lines provides isolation of DC power sources from AC electrical loads and provides supervisory control of DC sources.
- The second ring of DC power lines, designed to be used as a backup, which is connected to the system and passes along a similar, but on an adjacent route.

- DC power transmission system, providing isolation of the local AC power transmission network from the surrounding AC power system, and it comprises a local AC power consumption center in which there is a plurality of AC electrical loads, an AC distribution line supply line serving a plurality of AC electrical loads, and a local DC power consumption center in which there is a plurality of DC electric loads and DC distribution network supply line serving a variety of DC electrical loads. One remote power station provides at least a supply of AC power to a local AC power consumption center. A ring of direct current power lines having a plurality of direct current electrical loads connected thereto is located at least partially between the local AC and DC power consumption centers and the remote power plant. A ring of DC power transmission lines provides isolation of AC power received from a remote power plant from local AC and DC power consumption centers. The first plurality of AC/DC converters that are electrically coupled to a ring of DC power lines that is external to the local AC power center is for converting AC power received from a power plant to DC power and for providing DC power transformed in one of the AC/DC converters for at least some other loads of the plurality of DC electrical loads on the ring of the DC power lines. The second plurality of AC/DC, which are electrically connected with the ring to a local center electricity consumption of DC power lines AC, designed to convert DC power from the ring transmission lines DC to AC power for its supply to the electrical loads AC. The run line of the AC distribution network in the local AC power consumption center is electrically connected to a ring of DC power lines through a second set of AC/DC converters to supply AC power to the local AC power consumption center while providing isolation of all local electrical loads from the remote power plant. The run line of a DC distribution network in a local DC power consumption center is electrically connected to a ring of DC power lines through a second set of AC/DC converters to supply DC power to the ring of DC power lines.

- The local AC power transmission network contains a variety of distributed DC power generation sources that are electrically connected to a ring of DC power lines. The ring of DC power transmission lines provides isolation of DC power sources from AC electrical loads and provides dispatching control of DC power sources.

A method for providing isolation of a local AC power transmission network from the surrounding AC power system according to one of the proposed options includes a system that has an AC power consumption center with multiple AC electrical loads, one or more supply lines of the distribution network that serve multiple local AC electrical loads, and at least, one remote power plant for supplying AC power to the local AC power consumption center. The method contains the following operations: between the local AC power consumption center and the remote power plant, at least a partial ring of DC power lines is placed, which has a set of DC electrical loads connected to it, and by means of a ring of DC power lines, the AC power received from the remote power plant is separated from the local AC power consumption center. Convert AC power received from a power plant to DC power and provide it for at least some other loads from the set of DC electrical loads on a ring of DC transmission lines.

Converting DC electric power from the ring of DC power lines to AC electric power is carried out, and AC electric power is supplied to a local center of AC electric power consumption, while isolation of all local AC electric loads from a remote power station is ensured.

- In pre-defined locations on the ring of DC power lines, many DC-to-DC converters are installed to provide isolation, which are designed to isolate faults on the ring of DC power lines, preventing system failure due to these faults.

The processes described above are shown in figure 1 and figure 2.
Figure 1. Distribution of electricity based on the use of remote production and consumption centers.

To analyze the proposed options, you can use the 14-node IEEE test circuit (figure 3). The scheme, due to the irregularity of network indicators in different areas, whether it is the district’s energy system or metropolis, will not vary.
The proposed test scheme consists of two areas: the first - have a deficit of generated capacities (nodes 3, 4, 5) and the second - have an excess of generation (nodes 1 and 2).

The main purpose of mode calculations is to determine their parameters that characterize the conditions under which network equipment and its consumers operate. The results of calculations of network modes are the basis for evaluating the quality of electricity issued to consumers, the validity of the considered modes in terms of operation of network equipment, as well as identifying optimal conditions for power supply to consumers.

The initial data in the calculation of the modes of electric networks are the known capacities of consumer substations, the voltage values of power supplies or substations of systems that receive energy through electric networks from power plants, as well as the parameters and interconnection of network elements, on the basis of which the calculated equivalent circuit is compiled. In this case, the characteristic features of the network and the purpose of the calculations, which may be design or operational, are taken into account. It should be noted that in most cases the load in such calculations seems to be constant active and reactive powers. Nevertheless, there are examples when the calculation of the regime is carried out when the loads are taken into account by constant resistances and static voltage characteristics.

Losses as well as reactive power generation take place in the electric network line. The difference between reactive powers at the beginning and end of the line depends on the ratio of losses and reactive power generation.

The result of the computer calculation is the following results (tables 1 - 3):

Table 1. Node data.

| No | Type | Unom | cap+ | Voltage | Load power | Load generation | Limits the generation |
|----|------|------|------|---------|-------------|---------------------|----------------------|
|    |      | kV   | ind- | phase (deg.) | module (kV) | P MWt | Q MVar | P MWt | Q MVar | Qmax. MVar | Qmin MVar |
| 1  | 3    | 230  | -    | 0.00     | 243.80     | -    | -      | 232.39 | -      | 16.55      | -         |
| 2  | 2    | 230  | -    | -4.98    | 240.35     | 21.70 | 12.70  | 40.00  | 43.56  | 50.00      | 40.00     |

Figure 3. 14-node IEEE test circuit.
### Table 2. Legs data.

| In | Final | R, Om | X, Om | (cap + ind -) | Ktr  |
|----|-------|-------|-------|---------------|------|
| 1  | 2     | 10.2500 | 31.3009 | 0.0998      | -    |
| 1  | 5     | 28.5819 | 117.9882 | 0.0930      | -    |
| 2  | 3     | 24.8577 | 104.7261 | 0.0828      | -    |
| 2  | 4     | 30.7402 | 93.2733  | 0.0643      | -    |
| 2  | 5     | 30.1266 | 91.9825  | 0.0654      | -    |
| 3  | 4     | 35.4483 | 90.4749  | 0.0242      | -    |
| 4  | 5     | 7.0622  | 22.2762  | 0.0000      | -    |
| 4  | 7     | 0.0000  | 105.8105 | 0.0000      | 0.511247 |
| 4  | 9     | 0.0000  | 276.2604 | 0.0000      | 0.515996 |
| 5  | 6     | 0.0000  | 115.8037 | 0.0000      | 0.536481 |
| 6  | 11    | 12.5611 | 26.3045  | 0.0000      | -    |
| 6  | 12    | 16.2548 | 33.8309  | 0.0000      | -    |
| 6  | 13    | 8.7483  | 17.2282  | 0.0000      | -    |
| 7  | 8     | 0.0000  | 23.2958  | 0.0000      | -    |
| 7  | 9     | 0.0000  | 14.5488  | 0.0000      | -    |
| 9  | 10    | 4.2069  | 11.1751  | 0.0000      | -    |
| 9  | 14    | 16.8103 | 35.7578  | 0.0000      | -    |
| 10 | 11    | 10.8511 | 25.4013  | 0.0000      | -    |
| 12 | 13    | 29.2167 | 26.4341  | 0.0000      | -    |
| 13 | 14    | 22.6055 | 46.0256  | 0.0000      | -    |

### Table 3. Network mode parameters.

| In | Final | Qin,MVar | Pin,MVar | In,A | Pfinal,MWt | Qfinal,MVar | Ifinal,A |
|----|-------|----------|----------|------|------------|-------------|---------|
| 1  | 2     | 156.88   | -20.4    | 374.65 | -152.59    | 27.68       | 372.51  |
| 1  | 5     | 75.51    | 3.85     | 179.05 | -72.75     | 2.23        | 179.20  |
| 2  | 3     | 73.24    | 3.56     | 176.13 | -70.91     | 1.60        | 176.29  |
| 2  | 4     | 56.13    | -1.55    | 134.89 | -54.45     | 3.02        | 134.53  |
| 2  | 5     | 41.52    | 1.17     | 99.77  | -40.61     | -2.10       | 100.13  |
| 3  | 4     | -23.29   | 4.47     | 58.93  | 23.66      | -4.84       | 59.56   |
| 4  | 5     | -61.16   | 15.82    | 155.82 | 61.67      | -14.20      | 155.82  |
The modern electric power industry was created thanks to the tremendous efforts of many processing systems. Systems based on innovative types of electrical equipment and methods for controlling the regimes of large power generations.

Agriculture, science, education, as well as other aspects of the population's life.

The electric power industry as the basic branch of the economic mechanism of Russia must meet the following requirements and ensure the sustainable development of all areas of the economy: industry, agriculture, science, education, as well as other aspects of the population's life.

The modern electric power industry was created thanks to the tremendous efforts of many generations. To date, the electric power industry should provide:

- Standard quality and reliability of electricity consumers;
- Prompt connection of new consumers to the electric grids and providing them with the required capacity, which ensures generally reliable development of the Russian economy;
- Reducing the risk of emergency disturbances, including the development of major system accidents;
- Reduction of direct and indirect losses from lack of electricity supply.

The target of the development of the modern electric power industry in Russia is the implementation of innovative types of electrical equipment and methods for controlling the regimes of large power systems based on the new capabilities of power regulating devices, measurement and information processing systems. This circumstance is especially relevant for power systems of large MPs. Under

### 3. Result and discussion

Considering the analysis, we can recommend possible solutions to problems related to the supply of electric and heat energy to the metropolis:

1. The growth of investments in the development of energy systems of the MP in general, including the financing of generation development programs.
2. Optimization of the control system due to the construction of inserts and direct current transmissions.
3. Construction of new and modernization of existing power facilities, including the use of 20 – 35 kV networks.
4. Energy management as a variant of the rigid demand management model.
5. Further development of distributed generation based on renewable sources.
6. Switching in cities to selling electricity at market prices, rather than through subsidy programs.

At the same time, environmental factors related to environmental pollution and stimulating global warming have already acquired special importance and will become more and more significant. For this reason, in almost all the world’s MPs, when developing a strategy and tactics for the development of energy, along with the creation of new large sources, the growth trend of renewable energy sources and tight control of electricity demand are clearly visible.

Thus, in modern conditions, organizational, technical, economic and financial aspects of designing and large-scale implementation of promising advanced, innovative environmentally friendly energy technologies, processes and electrical equipment are of significant importance in matters of the power industry of metropolises.
current conditions and midterm the population, as well as the main production, cultural, scientific, technical and other resources of the country are concentrated in and around MPs.

To ensure the normal functioning and further successful development of the infrastructure of an MP and centered around resources, it is necessary to be able to provide energy in the required volumes to all existing consumers and to connect and provide electricity to new consumers.

In such conditions, the following requirements are imposed on MP power systems, which will only become tougher in the future:

- the readiness of the electric grid infrastructure to ensure the operation of the wholesale and retail electricity markets, accession of new generating capacities and consumers;
- the reliable operation of power facilities and, as a result, reliable power supply to consumers;
- the profitability of functioning and development;
- the personnel safety and reduction of negative impact on the environment.

The energy systems of MPs, formed, built and implemented today according to traditional principles, are highly likely to not be able to fully meet the requirements that they will have to meet in the short term, which determines the need for a transition to the innovative directions of their development that are formulated above.

All these circumstances complicate the provision and maintenance of the required level of reliability of MP energy systems. It becomes obvious that the construction of traditional outdoor SWYD and OHLs in such conditions is in most cases impossible.

4. Conclusions
1. The problems of the development of EPSMP are directly related to the vitals of MP, the most important of which are the population and communications.
2. Modern metropolises are characterized by a complex of problems of the energy trilemma, which includes: energy, environmental safety and free access to energy, and energy resources in the ENEPS.
3. The electric power industry of a metropolis must be considered taking into account the specifics of regional entities - medium and small villages located in close proximity to the metropolis and forming its agglomeration.
4. We can state a steady trend of decreasing energy, environmental and economic efficiency in the conditions of the predominant use of traditional organic fuels for the energy supply of the metropolis.
5. Among a large number of basic principles and principles of the formation of the ESSE of a metropolis at present and in the near future, we can distinguish: the construction of large thermal and nuclear power plants outside the metropolis area; the complete solution to the power load-center substation problem; the creation of modern distribution networks of MP; the expansion of the complex of distributed generation sources; an exchange of urban OHLs on CLs; short-circuit current limitation in the metropolis ENEPS; the implementation of technologies and materials using the HTS effect and others.

6. The effective development of the electric power industry of the MP is determined by the development and adoption of decisions based on a set of the latest technologies and the use of innovative devices both in the present and in the future.

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