**ANNOTATION**

**of the dissertation of Dinmukhanbetova Aigul Zhumageldyevna "Energy saving at power plants by expanding the ring circuits of the OSG", presented for the degree of Doctor of Philosophy (PhD) in the specialty 6D071800 – "Electrical Power Engineering"**

**Relevance**

One of the tasks of the electric power industry is to reduce the under-supply of electricity at power plants. One of the reasons for the under-start is the failures of the circuit elements of open switch gear (OSG) with a voltage of 330-750 kV. The issues of reliability of these schemes were dealt with by Balakov Yu.N., Grudinsky P.G., Guk Yu.B., Dvoskin L.I., Karatun V.S., Misrikhanov M.Sh., Nepomnyashchy V.A., Okolovich M.N., Sinchugov F.I., Tremyasov V.A., Fokin Yu.A., Shuntov A.V., etc.

An analysis of the literature has shown that over the past 50 years, the schemes of the OSG of power plants have remained unchanged and the main direction of their improvement in the world is the replacement of air switches with gas and vacuum ones. The failure rate of gas is 10-35% lower than that of air. The replacement of air switch with gas gives a reduction in the under-supply of electricity by 2,3-8,3% (the assessment was carried out by a tabular-logical calculation method, given in section 2). However, at low temperatures, the gas switch often fail [1], and sometimes this leads to catastrophic consequences, such as the shutdown of a nuclear power plant in the USA in 2018 [2]. At the same time, there is no such problem for air switches that have already stopped producing. In connection with the above, energy saving on the OSG only by developing new switches can hardly be considered very effective. Therefore, the search for ways to increase the efficiency of energy saving at the OSG seems relevant.

**The object of the research** is energy saving at power plants.

**The subject of research** energy saving on the OSG of power plants with ring circuits.

**Connection of the topic of the dissertation with general scientific (state) programs.** The topic is initiative and is related to the implementation of S/B SRW   
№ 66-kmu-2/1 dated 02.24.2021 "Energy saving through the development of outdoor switch gear new schemes of power plants" (IRN AP09058249) within the grant funding of young scientists for scientific and (or) scientific and technical projects for 2021-2023.

**The aim of the work** is to increase the efficiency of energy saving at power plants with ring circuits of the OSG, improving these schemes.

|  |
| --- |
| [1] Dyakov A. Elegazovye switches could not withstand low temperatures // Electric power. Transmission and distribution. – 2011. – №5. – P. 44-46.  [2] Preparing Circuit Breakers for Operation in Cold Weather // <https://www.nerc.com/pa/rrm/ea/Pages/Lessons-Learned> Document. 24.08.2018. |

**To achieve the goal, the following tasks were set and solved:**

– to choose a method for assessing the under-supply of electricity due to the unreliability of the ring schemes of the OSG and improve it;

– to develop an algorithm and a calculation program using an improved method;

– to find a new way of energy saving at power plants with ring schemes of OSG;

– to develop new ring schemes of the OSG of power plants;

– to justify the expediency of their use.

**The validity and reliability of scientific statements, conclusions and recommendations are confirmed by:** competent use of the fundamental provisions of the theoretical foundations of electrical engineering, reliability theory, construction of power plants and relay protection, as well as approbation in the form of publications; obtaining two patents in the republic of Kazakhstan and two in the Russian Federation.

**Scientific novelty of the work:**

1. It is proposed to increase the efficiency of energy saving at power plants with 330-750 kV ring circuits by introducing an additional switch: 1) between the transformer of the block and its two switches; 2) in series to each of the existing ones in the traditional circuit; 3) to the hot reserve in parallel in series (according to the previous method).

2. Mathematically, the expediency of these methods is justified on the basis of the use of the tabular-logical method of calculating the under-discharge of electricity that we have refined.

3. This method is refined by taking into account unstable short circuits on power lines, the imposition of emergency situations and a modern model of the reliability of switches. The calculation algorithm was developed (together with   
A.S. Barukin and D.A. Amirbek).

**New scientific results of the work:**

1 It is shown that during the reconstruction of the OSG schemes with blocks without generator switches, the first and second methods are more efficient than replacing the air switch with a gas-fired one, and the third method is more efficient during construction.

2. New OSG schemes of triangle, pentagon and hexagon have been developed (they are patented).

3. An opportunity has been created to calculate the energy saving efficiency of non-standard OSG ring circuits. The algorithm and the program of the improved tabular-logical method are constructed.

**Practical significance of scientific results:**

1. New OSG circuits with blocks without generator switches make it possible to increase the efficiency of energy saving during reconstruction according to the first method to a greater extent than replacing an air switch with a gas–fired one, according to the second – in a quadrangle and at a voltage of 330 kV in a pentagon (according to the third - when designing power plants).

2. When designing, if we use gas-fired and generator switches, the proposed schemes make it possible to reduce, in comparison with traditional ones, the costs of constructing power plants by 0,3-1,3% according to the first method, 2,2-6,6% according to the second, and 4,1-10,2% according to the third.

3. Replacing the air switch with an elegaz one in the presence of generator switches is more effective only for the "hexagon" circuit with a voltage of 750 kV.

4. The accounting mentioned (in the third point of scientific novelty) makes it possible to clarify the results of calculations using the tabular-logical method by   
5-10%.

**The practical value of the work:**

1. The proposed ring circuits of the OSG, in comparison with traditional ones, make it possible to reduce the cost of constructing power plants with gas-fired and generator switches in blocks during design: by 0,3-1,3% according to the first method, by 2,2-6,6% according to the second, and by 4,1-10,2% according to the third. During the reconstruction, when there are no generator switches, the connection of an additional gas switch between the transformer of the unit and its two air ones will reduce the under-discharge of electricity by 6,3-12,4%, and the replacement of air with gas – 2,3-3,9%.

2. At the same time, the payback of additional capital investments of the proposed schemes is 2-4 months.

3. The new algorithm and calculation program make it possible to calculate the under-output of electricity not only from traditional schemes (like the TOPAS program developed under the guidance of Guk Yu.B.), but also proposed ones and do it a little more accurately.

**To the defense are presented:**

1. New ring schemes of OSG of power plants.

2. Algorithm, program and results of calculations of under-supply of electricity, damage during reconstruction and costs in the construction of traditional and proposed ring schemes of the OSG at power plants.

3. Conclusions from the analysis of the calculation results.

**Approbation of work.** The main provisions of the dissertation were reported at the International Scientific conference "XIX Satpayev readings" (Pavlodar, 2019) and the 37th International Scientific and Practical Conference "Technical sciences: problems and solutions" (Moscow, 2020) and at a meeting of the Toraighyrov University Department of Power Engineering.

**Publications.** The research results have been published in 7 scientific papers, including: 5 publications in publications recommended by the COQAES, including 2 patents of the republic of Kazakhstan, 2 patents of the russian federation and an article in the scientific journal "bulletin of Toraighyrov University"; two publications in the materials of international conferences. in co–authored publications, the applicant's personal contribution is at least 65%.

**The structure and scope of the dissertation.** The dissertation consists of an introduction, three chapters, a conclusion and two appendices. The work is presented on 67 pages of computer text, includes 11 figures, 13 tables. The list of sources used consists of 66 titles.

**In the first chapter** "Methods for calculating the undersupply of electricity in the schemes of OSG of power plants" the traditional ring schemes of OSG of power plants and the main calculation methods based on probability theory are considered. These include: logical-probabilistic (failure tree, probabilistic, tabular-logical), logical-analytical, topological, the method of minimal paths and sections, probabilistic economic – mathematical model, operational reliability. Their features are described, the type of mathematical models for obtaining numerical estimates of reliability indicators is determined.

A tabular-logical method was chosen for a comparative assessment of the under-output of electricity in the schemes of OSG. Its advantage is the ability to take into account all types of possible accidents leading to short and long interruptions of power supply and extensive testing. The disadvantages of this method are taking into account only stable short circuits (unsuccessful ARA) on power lines and not taking into account the imposition of emergency situations, the use of a simplified model of switch failure, in which all switch failures are reduced to failures of the "short circuit in both directions" type, as well as the inability to assess under-start in non-standard OSG circuits.

The elimination of these shortcomings made it possible to improve the method. On the basis of this, a new algorithm and a program for calculating the under-discharge of electricity in the schemes of the OSG of power plants (together with A.S. Barukin and D.A. Amirbek) were built.

The chapter substantiates the possibility of reducing the under-supply of electricity by introducing an additional switch into the OSG circuit.

**In the second chapter** "Energy saving by inserting a switch between an element of the ring circuit and its switches" the efficiency of energy saving by traditional ring circuits of the OSG and the possibility of increasing them by connecting an additional switch between the transformer of the unit (or power line) and its switches is evaluated – the first method. The work of traditional OSG schemes in normal and repair modes is considered in detail. The results of calculations of under-supply of electricity and costs for the construction of power plants are presented, taking into account the reliability of the considered traditional schemes. For the improved schemes, a similar calculation was performed, which required consideration of new modes. At the same time, in the formulas for determining the effect of energy saving, i.e. reducing damage during reconstruction and costs during the construction of the proposed schemes, in comparison with traditional ones, the cost of additionally introduced switches and land is taken into account. It is shown that the replacement of air switches (AS) with gas-fired switches (GS) in the traditional circuits of a quadrilateral, pentagon and hexagon gives a reduction in the under–discharge of electricity with blocks having a generator switch by 4,5-8,3%, and without them – 2,3-3,9%, and in the triangle circuit up to 1%. Connecting an additional AS (GS) between the transformer of the block and its existing AS in the ring circuits of the OSG with a voltage of 750-330 kV without a generator switch in the blocks is more efficient than replacing the AS with GS. A similar connection on the line does not have an effect in energy saving.

It is shown that the use of the tabular-logical method improved by us makes it possible to refine the results of calculations of under-output of electricity in traditional OSG schemes by 5-10%.

**In the third chapter** "Energy saving by doubling and tripling the switches in the ring circuits of the OSG" new schemes are considered with the connection of an additional switch in series to each of the existing ones in the traditional (second method) and with the connection of the switch to the hot reserve in parallel with two consecutive according to the previous method (triangle and pentagon patented) – the third method; with the connection of two additional switches: one sequentially to each of the available ones, and the second one between the block (line) and his (her) two switches (the hexagon is patented). The modes of their operation are described, and the results of calculations for reducing the under-supply of electricity, the damage from this under-supply and the costs of constructing power plants are presented.

A comparative analysis of the developed and traditional schemes for energy saving efficiency showed that: in ring circuits without generator switches in blocks, reconstruction according to the first method is more effective than replacing explosives with GS, and according to the second – in a quadrangle and a voltage of 330 kV in a pentagon. Reconstruction using GS in the traditional scheme with AS can lead to a reduction in damage by 6,3-12,2% according to the first method, 3,5-9,8% according to the second, and the replacement of AS with GS – 2,2-3,8% (table 1 on page 7). When constructing power plants, the third method can give the greatest reduction in costs 4,1-10,2% (table 2 on page 8).

**The results of the work are as follows:**

A new direction is proposed to increase the efficiency of energy saving on open switchgears (OSG) of power plants, in which additional switches are introduced into the circuit.

1. The research was carried out on the basis of comparing the results of calculations of energy saving in the ring circuits of the OSG according to a well-tested and improved by us (together with Barukin A.S. and Amirbek D.A.) tabular-logical method. The improvement consists in taking into account unstable short circuits on power lines, taking into account the imposition of emergency situations and a modern model of the reliability of switches, as well as in the development of an algorithm and calculation program that make it possible to calculate the energy saving efficiency of not only traditional, but also new OSG circuits.

2. It is proposed to increase the efficiency of energy saving at power plants with 330-750 kV ring circuits by introducing an additional switch: 1) between the transformer of the block and its two switches; 2) in series to each of the existing ones in the traditional circuit; 3) to the hot reserve in parallel in series (according to the previous method). The expediency of using these methods is mathematically justified.

3. New OSG schemes of triangle, pentagon and hexagon have been developed (they are patented).

4. During the reconstruction, all new OSG circuits with blocks without generator switches make it possible to increase the efficiency of energy saving by the first method to a greater extent than replacing an air switch with a gas one, by the second – in a quadrangle and at a voltage of 330 kV in a pentagon (by the third - when designing power plants). Replacing the air switch with a gas one in the presence of generator switches is more efficient than using the proposed schemes, only for the hexagon circuit with a voltage of 750 kV.

5. When constructing an electric power station (EPS), the proposed schemes make it possible to reduce, in comparison with traditional ones, the costs of the first method by 0,3-1,3%, the second – 2,2-6,6%, and the third – 4,1-10,2%, if you use gas and generator switches. At the same time, the payback of additional investments in the proposed schemes is 2-4 months.

6. When planning the reconstruction of the ring circuits of the OSG at the power plant, the EPS staff should consider the possibility of using the results of the work under item 4, and design organizations when calculating the costs of the construction of the EPS – the results under item 5, since in both variants, for most EPS, the efficiency of energy saving is significantly higher than with a simple replacement of an air switch with a gas one.

Table 1 – Reduction of under-supply of electricity (W) and damage during reconstruction (D) for ring circuits by replacing the air switch (AS) with a gas switch (GS) and when connecting additional switches

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| OSG scheme | U,  kV | PБЛ, МVt | W, 106 kWh/year | | AS to GS, % | | AS (GS)  the transformer of the unit and its two AS, % | | Serial  connection  of the AS (GS) to the AS, % | | W, 106 kWh/year | | AS to GS, % | | AS (GS)  the transformer of the unit and its two AS, % | | Serial  connection  of the AS (GS) to the AS, % | |
| AS | GS | ΔW | ΔУREC | ΔW | ΔУREC | ΔW | ΔУREC | AS | GS | ΔW | ΔУREC | ΔW | ΔУREC | ΔW | ΔУREC |
| **Blocks with a generator switch** | | | | | | | | **Blocks without a generator switch** | | | | | | | |
| quadrilateral | 750 | 1200 | 327 | 304 | 7,1 | 6,6 | (0,6) | (0,3) | 9,1 (11,4) | 8,5 (11) | 2444 | 2375 | 2,8 | 2,7 | 8,7 (9,5) | 8,6 (9,4) | 9,5 (10) | 9,4 (9,8) |
| 800 | 201 | 189 | 5,8 | 4,9 | (0,8) | (0,4) | 7,5 (9,8) | 6,6 (9) | 1568 | 1525 | 2,7 | 2,6 | 8,7 (9,5) | 8,6 (9,4) | 9,4 (9,9) | 9,3 (9,7) |
| 500 | 800 | 221,3 | 203 | 8,3 | 7,5 | (2,9) | (2,7) | 12,3 (12,8) | 12 (12,2) | 1460 | 1421 | 2,7 | 2,6 | 6,1 (6,5) | 6 (6,5) | 7,2 (7,4) | 7,1 (7,3) |
| 500 | 99 | 93 | 6,1 | 5,4 | (1,9) | (1,6) | 9,3 (9,8) | 8,4 (9,2) | 786 | 764 | 2,8 | 2,7 | 7 (7,7) | 6,9 (7,7) | 8,2 (8,4) | 8,1 (8,2) |
| 300 | 38,7 | 36,6 | 5,4 | 3,7 | - | - | 7,1 (7,7) | 4,7 (6) | 333 | 323 | 3 | 2,8 | 7 (8,1) | 6,8 (8) | 8,7 (8,9) | 8,4 (8,6) |
| 330 | 300 | 45,1 | 42,4 | 6 | 4,9 | - | - | 12,5 (12,7) | 11 (11,6) | 330 | 318 | 3,5 | 3,4 | 7,6 (8) | 7,5 (7,9) | 9,5 (9,8) | 9,3 (9,5) |
| the pentagon | 750 | 1200 | 309,1 | 291 | 5,9 | 5,2 | (0,3) | - | 6,2 (9,4) | 5,5 (8,8) | 2454 | 2388 | 2,7 | 2,6 | 8,2 (9,1) | 8,1 (9) | 7,4 (8,3) | 7,3 (8,1) |
| 800 | 196,2 | 184,8 | 5,8 | 4,7 | (0,6) | (0,1) | 6,3 (9,5) | 5,1 (8,4) | 1563 | 1521 | 2,7 | 2,6 | 8,2 (9,2) | 8,1 (9) | 7,4 (8,3) | 7,2 (8,1) |
| 500 | 1000 | 255 | 238,8 | 6,4 | 6,1 | (1,6) | (1,5) | 7,1 (8,3) | 6,7 (7,9) | 1903 | 1856 | 2,5 | 2,4 | 5,8 (6,3) | 5,8 (6,3) | 5,5 (6) | 5,5 (5,9) |
| 800 | 184,6 | 176,3 | 4,5 | 4,1 | (3,4) | (3,2) | 7 (7,8) | 6,3 (7,4) | 1500 | 1466 | 2,3 | 2,2 | 5,8 (6,4) | 5,8 (6,4) | 5,7 (6) | 5,6 (5,9) |
| 500 | 91 | 86,6 | 4,8 | 3,9 | (2,1) | (1,7) | 7,1 (8,1) | 5,8 (7,2) | 786 | 765 | 2,7 | 2,6 | 7 (7,9) | 6,9 (7,5) | 6,9 (7,5) | 6,3 (7,3) |
| 330 | 300 | 37,4 | 35,5 | 5,1 | 3,4 | - | - | 8,4 (10,4) | 6,7 (8,7) | 332 | 321 | 3,3 | 3,1 | 7,5 (8) | 7,4 (7,9) | 8,3 (8,7) | 8,1 (8,3) |
| hexagon | 750 | 1200 | 485,5 | 452 | 6,9 | 6,4 | (1,1) | (0,8) | 1,1 (4,7) | 0,6 (4,2) | 3916 | 3762 | 3,9 | 3,8 | 10,8 (12,3) | 10,7 (12,2) | 2,7 (4,6) | 2,7 (4,5) |
| 800 | 304 | 284,5 | 6,4 | 5,5 | (1,4) | (1) | 0,7 (4,2) | - (3,3) | 2491 | 2394 | 3,9 | 3,8 | 10,9 (12,4) | 10,7 (12,2) | 2,7 (4,6) | 2,6 (4,5) |
| 500 | 800 | 311 | 287,5 | 7,5 | 7,1 | (3,7) | (3,5) | 5,6 (8,1) | 5,1 (7,8) | 2219 | 2142 | 3,5 | 3,4 | 7,7 (8,8) | 7,7 (8,8) | 2,1 (3,6) | 2 (3,5) |
| 500 | 140,8 | 133 | 5,5 | 4,8 | (2,6) | (2,3) | 5,1 (7,4) | 4,1 (6,7) | 1211 | 1170 | 3,4 | 3,3 | 8 (9,1) | 7,9 (9,1) | 5,5 (6,4) | 5,4 (6,3) |
| 300 | 56,4 | 53,1 | 5,8 | 4 | - | - | 5,1 (7,8) | 2,7 (6) | 506 | 488 | 3,4 | 3,2 | 7,6 (9,1) | 7,5 (9) | 6,8 (7,6) | 6,5 (7,4) |
| 330 | 300 | 62 | 58,4 | 5,8 | 4,6 | - | - | 8,4 (9,2) | 7,2 (7,9) | 500 | 481 | 3,9 | 3,8 | 8,3 (9) | 8,2 (8,9) | 7,2 (7,6) | 7 (7,4) |

Table 2 – Results of calculations of W and costs (C) for the construction of EPS for traditional and proposed schemes with GS

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| OSG scheme | Traditional | | | | The proposed first scheme is P1, the second P2, the third P3 with blocks with a generator switch (without them) | | | | | | | | | | | |
| U,  kV | PБЛ, MVt | WTR, 106 kWh/year | ЗTR, 109 tg/ year | GS between the transformer of the unit and its two GS, P1 | | | | Serial connection  of the GS to the GS, P2 | | | | the GS in the hot reserve is parallel to the sequential GS, P3 | | | |
| WР1, 106 kWh/year | ΔУREC  % | ЗР1, 109 tg/year | ΔЗР1,  % | WР2, 106 kWh/year | ΔУREC, % | ЗР2, 109 tg/year | ΔЗР2,  % | | WР3, 106 kWh/year | ЗР3, 109 tg/year | ΔЗР3,  % |
| quadrilateral | 750 | 1200 | 304 | 447 | 304 | - | 448 | - (7,2) | 274 | 9,3 | 417,5 | 6,6 (7,7) | | 262 | 406 | 9,1 (8,3) |
| 1000 | 242 | 363 | 242 | - | 364 | - (7,2) | 220 | 8,4 | 341 | 6 (7,7) | | 211 | 333 | 8,3 (8,2) |
| 800 | 189 | 287 | 189 | - | 288 | - (7,1) | 172 | 8,3 | 270 | 5,9 (7,6) | | 165 | 264 | 8,1 (8,2) |
| 500 | 800 | 203 | 296 | 199,3 | 1,3 | 292,5 | 1,2 (4,4) | 186 | 7,3 | 279,5 | 5,6 (4,9) | | 184 | 277,2 | 6,4 (5,1) |
| 500 | 93 | 153 | 92,6 | - | 152,5 | 0,3 (5,1) | 86 | 6,7 | 146,3 | 4,4 (5,7) | | 85 | 145 | 5,2 (5,9) |
| 300 | 36,6 | 74 | 37,2 | - | 75 | - (5,2) | 34 | 5,2 | 71,6 | 3,3 (5,9) | | 33 | 71 | 4,2 (6,1) |
| 330 | 300 | 42,4 | 77 | 44 | - | 79 | - (4,6) | 38,3 | 8,6 | 73 | 5,2 (5,9) | | 37,2 | 72 | 6,6 (6,3) |
| the pentagon | 750 | 1200 | 291 | 438 | 292 | - | 440 | - (7,1) | 265 | 8,3 | 412,3 | 5,9 (7,2) | | 252,6 | 401,7 | 8,5 (8,2) |
| 1000 | 236,3 | 362 | 237 | - | 363 | - (7) | 215 | 8,1 | 340,8 | 5,8 (7,2) | | 205,4 | 332 | 8,2 (8,2) |
| 800 | 184,8 | 288 | 185 | - | 289 | - (7) | 168 | 7,9 | 271,4 | 5,7 (7,1) | | 161 | 265 | 8 (8,1) |
| 500 | 1000 | 238,8 | 357 | 234,8 | 1,6 | 353 | 1,1 (4,4) | 223 | 6,4 | 341 | 4,5 (4,6) | | 218 | 336,5 | 5,7 (5) |
| 800 | 176,3 | 271,7 | 173 | 1,7 | 268,5 | 1,2 (4,4) | 165 | 6,1 | 260,3 | 4,2 (4,6) | | 163 | 258,4 | 4,9 (5) |
| 500 | 86,7 | 148,5 | 86 | 0,2 | 148,3 | 0,1 (5,1) | 80,6 | 6 | 142,6 | 4 (5,4) | | 79 | 141,5 | 4,7 (6) |
| 330 | 300 | 35,5 | 71,2 | 37 | - | 72 | - (4,6) | 33,2 | 4,8 | 69 | 3,1 (5,5) | | 32,4 | 68,3 | 4,1 (5,8) |
| hexagon | 750 | 1200 | 452 | 667 | 451,4 | - | 668 | - (8,9) | 435 | 3,1 | 651 | 2,4 (2,7) | | 382 | 599 | 10,2 (12,3) |
| 1000 | 366,5 | 548 | 366,2 | - | 549 | - (8,9) | 353 | 3 | 535 | 2,4 (2,7) | | 310,5 | 493,5 | 10 (12,3) |
| 800 | 284,5 | 433 | 284,3 | - | 433 | - (8,9) | 274,5 | 2,6 | 423,4 | 2,2 (2,6) | | 242,2 | 392 | 9,5 (12,3) |
| 500 | 800 | 287,5 | 428 | 282 | 1,7 | 422,5 | 1,3 (5,6) | 275,8 | 3,7 | 416,3 | 2,7 (1,6) | | 259 | 400 | 6,5 (7,6) |
| 500 | 133 | 223 | 132 | 0,4 | 222 | 0,4 (5,9) | 126,6 | 4,1 | 216,6 | 2,8 (3,9) | | 121 | 211 | 5,4 (7,4) |
| 300 | 53,2 | 109 | 54 | - | 110,4 | - (5,7) | 50 | 3,7 | 106,6 | 2,6 (4,7) | | 48 | 104,6 | 4,3 (7,1) |
| 330 | 300 | 58,4 | 111 | 61 | - | 113 | - (5,1) | 54,5 | 5,3 | 107,2 | 3,4 (4,5) | | 48 | 104,7 | 5,6 (6,9) |
| The payback of additional capital investments of the proposed schemes is 2-4 months | | | | | | | | | | | | | | | | |

**PUBLICATIONS**

1. Kletsel M.Ya., Barukin A.S., Dinmukhanbetova A.Zh. Analysis of the methods for assessing the reliability of schemes of outdoor switchgears of electrical stations and substations // Mater. international conference of young scientists, undergraduates, students and schoolchildren "XIX Satpayev readings". – Pavlodar 2019. – Vol. 21. – P. 71-74.

2. Bogdan V.A., Kletsel M.Ya., Barukin A.S., Dinmukhanbetova A.Zh. An open switchgear of an electric station with two generator-transformer units and three lines // Patent No. 2713447 RF. publ. 05.02.20, Bul. No. 4. – 9 p.

3. Dinmukhanbetova A.Zh. The choice of a method for calculating the reliability of the circuits of the ORU of electric stations // Technical sciences: problems and solutions: collection of articles on Mater. XXXVII International Scientific and Practical Conference – Moscow: Internauka, 2020. – Р. 102-108.

4. Bogdan A.V., Kletsel M.Ya., Barukin A.S., Dinmukhanbetova A.Zh., Kaltaev A.G. An open switchgear of an electric station with a generator-transformer unit and two lines // Patent No. 2744474 of the Russian Federation. publ. 10.03.21, Byul. No.7. – 9 p.

5. Barukin A.S., Dinmukhanbetova A.Zh., Kletsel M.Ya., Melnikov V.Yu. Open switchgear of an electric station with three generator-transformer blocks and three lines // Patent No. 35130 RK. publ. 09.07.21, Bul. No. 27. – 5 p.

6. Barukin A.S., Dinmukhanbetova A.Zh., Kletsel M.Ya., Lenkov Yu.A. An open switchgear of an electric station, made according to the pentagon scheme // Patent No. 35131 RK. publ. 09.07.21, Bul. No. 27. – 5 p.

7. Kletsel M.Ya., Barukin A.S., Dinmukhanbetova A.Zh., Amirbek D.A. Influence of reliability of elements of ring circuits of electric power stations on under–discharge of electricity // Scientific journal "Bulletin of Toraighyrov University", Power series No. 1. – Pavlodar 2022. - Р. 99-110.