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Control and analysis of breakdowns of overhead transmission lines (6 – 500 кV) in the Middle Volga region

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Abstract— **The paper is devoted to the problem of technological breakdowns in the Middle Volga electric power networks. The analyses given in the article help to generalize the obtained data, reveal the extent of breakdowns and estimate the effect of systematic and seasonal factors in reference to electric power network. This provides the possibility of using the achieved results to work out organizational and technical measures to eliminate and prevent the causes for different forms of technological breakdowns with the aim of increasing the operating efficiency of the power network and its operating reliability, and to reduce the number of breakdowns in the electric power networks.**

Index Terms—**electric networks, overhead transmission lines, technological breakdowns, systematic and seasonal factors, short-circuit, intensity of breakdowns, organizational and technical measures.**

I. INTRODUCTION

Contemporary electric power objects and power systems are extremely complex. The quantity of units of equipment, units, components, and elements, technological and functional connections between them in the electric power system is calculated by tens of millions. It is obvious that the possibility of the failures of elements or disturbance in the functional connection between them in such complex technological systems one cannot underestimate. Moreover, one cannot exclude the cases of number of successive failures, which can lead to the chain or cascade development of failures process.
One of the most important responsibilities and tasks performed by electrical engineers and, in particular, inspectors involved in failure preventing work is to guarantee reliable and safe work of the electrical units, to conduct united technical policy in the sphere of failure preventing activities, control and investigation into of technological breakdowns, correct estimation of the obtained data, development and realization of measures aimed at the prevention and elimination of technological breakdowns.

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II. FAILURE PREVENTING MEASURES

The analysis of causes and prerequisites of technological breakdowns, statistical indices of failure rate is the base for the system estimation of the equipment's condition and level of its operation necessary for making the decisions aimed at increasing the service effectiveness of the electrical units. The effectiveness of failure preventing activities will be achieved only by the observance of the previously thought-out system of the measures of the blocking action of technological breakdown causes (Fig. 1).

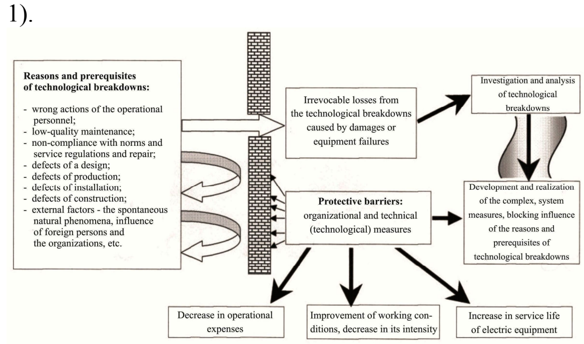

Fig. 1. The block diagram of failure preventing activities.

Represented in Fig. 1 block diagram [of 1] failure preventing activities works rather well, when there is an understanding that there is a case of failure and one knows the algorithm of how to avoid the repetition of similar events.
Hence it follows that precisely the investigation and the subsequent analysis of the occurred technological breakdown in the work of electric power objects are indispensable conditions of the acquisition of knowledge, which will serve as the foundation for decision making by the selection of one or other corresponding failure preventing measures.
The technological breakdowns that occurred in 6- 500 kV electrical networks of the Middle Volga region were selected using company's data base from "Analysis of the investigation of technological breakdowns in the operation of equipment and electrical objects" within the period from 2002 to 2006. During this period in accordance with company's instruction "The instruction on investigation and calculation of technological breakdowns in the operation of power systems, power stations and boiler, electrical and thermal networks" [of 2] more than 1000 cases of technological breakdowns were recorded.

III. DISTRIBUTION AND SEASONAL NATURE OF TECHNOLOGICAL BREAKDOWNS

From the above mentioned it follows that we have a distribution of technological breakdowns on the basic elements of electrical networks: overhead transmission lines (67%), cable transmission lines (3%), power substations (30%) (Fig. 2) [of 3-5].

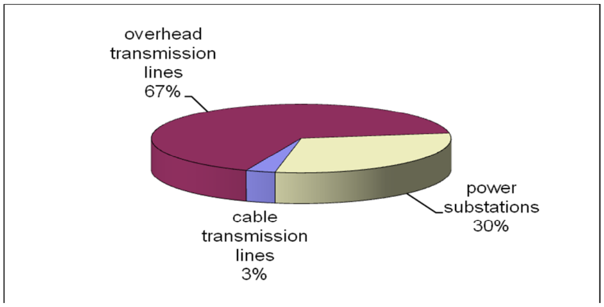

Fig. 2. The distribution of technological breakdowns among the basic elements of electrical networks

The majority of technological breakdowns (67%) occurs at the 6 - 500 kV overhead transmission lines of the Middle Volga region.
The intensity of occurrence of breakdowns in the electrical networks has the seasonal nature (Fig. 3) [of 6].

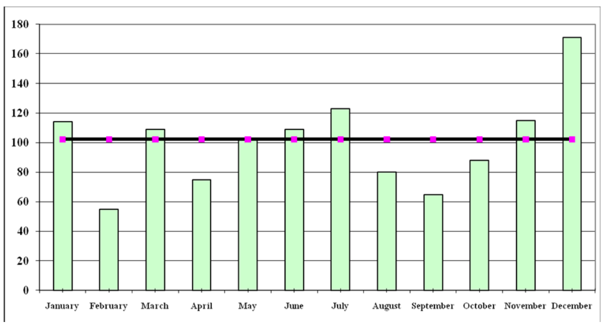

Fig. 3. Distribution of technological breakdowns within the months.

It is evident from fig. 3 that the distribution of the breakdowns during the months has three characteristic peaks:

1. The second decade of March - the period when the temperature changed from below “0^{0}” to above “0^{0}”, that adversely affected the line insulation.
2. The period from the middle of May to the end of July is the thunderstorm period, which adversely affects all equipment of electrical networks.
3. The second decade period of November to the second decade period of January is the frost-wind period, which is negatively affected wires and the lightning-protection the cables of overhead transmission lines.

To carry out the qualitative analysis [4] the whole electrical networks with a voltage 6-500 kV of Middle Volga region must be divided, in the first place, depending on the regime of operation of neutral grounded: with insulated neutral in 6-35 kV network and dead-end or effectively grounded neutral in 110 - 500 kV network.
Since 500 kV networks have the special system-forming value in the Middle Volga power system, operative and dispatching control of the Middle Volga and United electric power system of the Russian Federation as a whole, and also the fact that technological breakdowns in the 500 kV electrical network are the disturbance to the operating conditions of power system, he speaks, that it is necessary to isolate the 500 kV network of the Middle Volga into the separate group.
We thus, obtain three groups, which are subdivided according to the classes of the voltage:

1. 6-35 kV networks.
2. 110-220 kV network.
3. 500 kV networks.

Also this classification is entered in the contemporary criteria according to the carried out functions of the networks:

1. 6-35 kV networks - distributive, which ensure the distribution of the electrical energy between the points of consumption, by them the electric power is transferred to the small distances from the busbars of the lowest or medium voltage of district substations to different consumers .
2. 110 - 220 kV networks - feeding, intended for the electric transmission from the substations of the system- forming network and partially from the 110 - 220 kV electrical busbars of electrical stations to the supply centers of distribution networks - to district substations;
3. 500 kV networks - system-forming, which ensured ensure reliability and stability of electric power system as an integral object and perform the functions of forming electric power systems, uniting the power stations of large power.

IV. RESULTS. ANALYSIS OF CAUSES FOR THE TECHNOLOGICAL BREAKDOWNS

The distribution of more than 400 cases of technological breakdowns on the 6 - 500 kV on the 6 - 500 kV overhead transmission lines for three groups was analysed.
Technological breakdowns at the overhead transmission lines have dual nature. The overhead transmission lines are disconnected in the case of the appearance of breakdown both directly on route of overhead transmission line itself and during the breakdowns at the substations.

In connection with this let us introduce two concepts for the causes for breakdowns of overhead transmission lines:

1. The direct - cause, because of which technological breakdowns occurred directly on the route of the overhead transmission lines (for example, the break of wires, the overlap of insulators, the loss of supporting power of tower supports , etc);
2. The indirect - cause, because of which technological breakdowns occurred on the territory of a substation (for example, technological breakdowns in the circuit breakers, the malfunction of the devices of protective relaying and automation, etc).

One should not add the technological breakdowns, connected with the erroneous and non-effective actions of the personnel to these two groups and therefore they should be investigated separately.
In this paper only the technological breakdowns, which occurred directly in route of the overhead transmission lines itself have been examined (the direct cause). After the manifestation of disturbance in the normal operation of the overhead transmission lines of power transmission the structural element, on which occurred technological disturbance is established. The distribution of technological
disturbance is established. The distribution of technological

disturbances on the constructive elements is represented in Table 1.

Table 1
Damages in constructive elements of the overhead transmission lines of 6 - 500 kV (%)

Constructive element	Nominal class of voltage		
	6 - 35 kV	110 - 220 kV	500 kV
Line-wire	69	70	95
Overhead ground-wire cable	1	17	5
Insulator	12	7	-
Overhead line tower supports	12	2	-
Line accessories	6	4	-

The statistics specifies that to the most subject technological breakdowns by a constructive element the line-wire is.
A technological breakdown itself as physical phenomenon develops according to the following stages:
the first stage: the emergence of exposure and circumstances concomitant to this exposure on the object (overhead transmission lines) in this certain area – *exposure factors*;
the second stage: manifestation of factors of exposure – the emergence of the *cause for a technological breakdown*;
the third stage: development of the cause *for a* technological breakdown (the uncertain period);
the fourth stage: the final formation of *nature of a technological breakdown*.
After the detection of a constructive element on which a technological breakdown is revealed, a group of specialists is formed up. A group of specialists at first establishes nature of technological breakdown, then establishes the causes which led to a technological breakdown, and defines circumstances accompanying the emergence of a technological breakdown. On the basis of the obtained data
the group works out the plan of activities aimed at preventing and clearing of a technological breakdown, and also fixed periods of time for carrying out the activities and defines those who are to carry out the activities.
We will consider nature, the causes and concomitant circumstances of the emergence of a breakdown separately for each constructive element of the overhead transmission lines.

Line-wires and overhead ground-wire cable

Table 2
The nature of technological breakdowns on line-wires and the overhead ground-wire cable of the overhead transmission lines of 6 - 500 kV (%)

The nature	6 - 35 kV	110 - 220 kV	500 kV
Overlapping	33	56	90
Abruption, breaking, interruption	23	34	5
Theft	38	2	-
Overheat of short-circuit current	5	6	-
Submelting, melting	1	2	5

Overlappings include: overlappings between phase line-wires; overlapping between a phase line-wire and a support body; overlapping between a phase line-wire and the overhead ground-wire cable; overlapping on a trees and bushes; overlapping on transport, mechanical devices and other overlappings by foreign subjects [of 8].
The causes for damages which were found out by the group investigating into the cases of technological breakdowns are given below.

Table 3
The causes of technological breakdowns on line-wires and the overhead ground-wire cable of the overhead transmission lines of 6 - 500 kV (%)

The causes	6 - 35 kV	110 - 220 kV	500 kV
Mechanical damages	45	17	-
Line-wire dancing (overhead line galloping)	23	23	-
Line-wire vibration	17	9	5
Intrusion of foreign objects	6	-	32
Violation of the requirements for fire safety	4	8	41
Short-circuit overcurrent	2	11	-
Overlapping by birds	2	13	-
Lightning overvoltage	0,5	5	11
Operating deficiency	0,5	3	11
Defects of repair work	-	5	-
Defects of installation and building	-	6	-

Distribution of the causes for technological breakdowns on line-wires and overhead ground-wire cables depending on a type of exposures on them for three groups: exposures to the natural atmospheric phenomena (47%), exposures to activities done by unauthorized people and organizations (45%), exposures to birds and animals (4%) and other defects (4%).

Insulation

The analysis of damages on the overhead transmission lines of the Middle Volga region shows that the number of the technological breakdowns connected with the damage of insulation of the overhead transmission lines, is rather great (up to 12 and 7% for grids 6 – 35 and 110 – 220 kV respectively). For the Middle Volga region the following nature (tab. 4) and the causes (tab. 5) of damages of insulation are typical.

Table 4
The nature of technological breakdowns on insulation of the overhead transmission lines of 6 - 220 kV (%)

Rupture of insulation	31
Disruption	31
Violation of bracing	25
Crack, fistula, chip	13

Table 5
The causes of technological breakdowns on insulation of the overhead transmission lines of 6 - 220 kV (%)

Mechanical damages	34
Line-wire dancing (overhead line galloping)	29
Contamination	10
Defects of installation	7
Line-wire vibration	7
Overlapping by birds	7
Lightning overvoltage	6

The insulation are mostly subject to technological breakdowns during the periods when temperatures either change from above zero to below zero or vice versa (62%), and, besides, we should point out to number of cases of vandalism (26%), when insulators are broken into pieces (tab. 6).

Table 6
The influences made on insulation
of the overhead transmission lines of 6 - 220 kV (%)

Atmospherics	62
Exposures to activities done by unauthorized people and organizations	26
Exposures to birds	5
Defects of a design and manufacture	5
Operation deficiency	2

Overhead line tower supports

When in operation supports are affected by a number of external loads. Continuous loads affecting the tower supports include those generated by the weight of elements of the support, line-wires, overhead ground-wire cables, insulators and line fittings, and also load caused by sleet, wind pressure on wires and the tower supports and unbalanced pull force when pulling wires which affects angular, terminal and some anchor tower supports.

Table 7
The nature of technological breakdowns
of overhead line support of 6 - 500 kV (%)

Disruption, loss of bearing ability	79
Crack, chip	9
Extraction from soil	6
Deformation	3
Splitting by a thunder-storm	3

During repair and assembly operations and in case of a line-wire break tower supports are additionally affected by instantaneous loads caused by a pulling a broken line-wire and forces in rigging.

Table 8
The causes of technological breakdowns
on the OTL support of 6 - 500 kV (%)

Mechanical damages	89
Line-wire dancing (overhead line galloping)	5
Lightning overvoltage	3
Line-wire vibration	2
Flood, drifting of ice	1

Line accessories

The analysis of breakdowns and cases of faulty production on overhead transmission lines shows that the amount of cut-offs on lines caused by damages on line accessories, makes a rather small percentage (4 – 6%) in comparison with damages on line-wires and insulators. However, incorrect operation and damages of line accessories led to serious breakdowns because of sleet and line-wire dancing, wind and vibration. So, one cannot underestimate the factor determined by damages on line accessories .

In the Middle Volga region the nature (tab. 9) and the causes (tab. 10) of damage of line accessories looks as follows:

Table 9
The nature of technological breakdowns
on line accessories of 6 - 500 kV (%)

Abruption, breaking, interruption	71
Disruption, loss of bearing ability	22
other causes	7

Table 10
The causes of technological breakdowns
on line accessories of 6 - 500 kV (%)

Line-wire vibration	46
Defects of installation	27
Line-wire dancing (overhead line galloping)	18
Corrosion	9

When doing overhead inspections one should examine elements of line accessories carefully and take measures to replace defective elements. There are cases of low-quality manufacture of line fittings found out during overhead inspections [of 9-10].

conclusions

More than 1000 cases of technological breakdowns on power facilities of the electrical networks of the Middle Volga region have been analyzed. The majority of those cases are made up of technological breakdowns directly on overhead transmission lines (67%). It was been found that intensity of breakdowns in electrical networks has a seasonal nature. There has been given the classification of electrical networks according to nominal classes of voltage. The analysis of technological breakdowns involving constructive elements, the nature and causes, circumstances accompanying them has been done.

Thus, the analysis of overhead transmission lines condition shows that technological breakdowns are caused by two main groups of factors:

1. natural factors - the atmospheric phenomena, impact made by birds and animals (on line-wires and the overhead ground-wire cables it makes about 51% and line insulation - up to 67% of the technological breakdowns);
2. exposure factors - exposure to man's activities and involving both activities of repair and assembly personnel, manufacturer's personnel (cases of faulty production), and activities of non- authorized people (for line-wires and the overhead ground-wire cables - 45% of all bases and line insulation – about 33%).

The given analysis gives an opportunity to work certain measures preventive actions aimed at clearing and prevention of technological breakdowns causes of various nature to increase reliability of overhead transmission lines operation and to decrease a total number of breakdowns in electrical networks.

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REFERENCES

[1] Surba, A. S. Investigation and Analysis of Technological Breakdowns in the Operation of Power Systems [in Russian], JSC "RAO EÉS Rossii," Moscow (2005) [in Russian].

[2] RD 153-34.0-20.801–00. Instructions on Investigating and Analyzing Technological Breakdowns in the Operation of Power Systems, Power Stations and Boiler, Electrical and Thermal Networks [in Russian], JSC "Énergoservis," Moscow (2001).

[3] Khrennikov, Alexander Yu. "Diagnostics of electrical equipment's faults, defects and weaknesses." Reports of Conference on Condition Monitoring and Diagnosis (CMD 2006), Korea, April 2006.

[4] Khrennikov, A. Yu. and Gol'dshtein, V. G. "Technical Diagnostics, Damageability and Life of High-Power and Measuring Transformers and Reactors [in Russian], Énergoatomizdat, Moscow (2007).

[5] Khrennikov, Alexander Yu. "Fault Detection of Electrical Equipment. Diagnostic Methods." International Journal of Automation and Control Engineering (IJACE), 2013 Vol.2 No.1, pp.19-27.
http://www.seipub.org/ijace/Archive.aspx

[6] Gol'dshtein, V.G., Gordienko, A.N., Pukhal'skii, A.A., and Khalilov, F.Kh. "Increasing the Operating Reliability of Electrical Equipment and the 0.4 – 110 kV Petroleum Industry Lines to the Action of Surges [in Russian], Énergoatomizdat, Moscow (2006) [in Russian].

[7] Khrennikov, A. Yu., Gol'dshtein, V. G., Skladchikov, A. A. "An analysis of the condition of the 6–500 kV overhead power lines of the Samara region." Power Technology and Engineering: Volume 44, Issue 4 (2010), Page 322.
http://www.springerlink.com/openurl.asp?genre=article&id=doi:10.1007/s10749-010-0184-2

[8] Khrennikov, Alexander Yu. "New "intellectual networks" (Smart Grid) for detecting electrical equipment faults, defects and weaknesses." Smart Grid and Renewable Energy, Volume 3, No 3, August 2012.
http://www.scirp.org/journal/sgre

[9] Khrennikov, Alexander Yu. "Smart Grid technologies for Detecting Electrical Equipment Faults, Defects and Weaknesses." Workshop on Mathematical Modelling of Wave Phenomena with applications in the power industry, Linnaeus University, Växjö, 23-24 April 2013.
http://www.lnu.se/mmwp

[10] Khrennikov, Alexander Yu. "Transformer Testing Experience by LVI/FRA Methods. Short-Circuit Performance of Power Transformers." Current Advance in Energy Research (CAIER) Volume 1, Issue 1 Jun. 2014 PP. 8-14.
www.vkingpub.com/VkUpload/20140613110141888l.pdf

[11] Khrennikov A.Yu., Shakaryan, Yury G., Dementyev Yury A. Shortcurrent Testing Laboratories. Short-Circuit Performance of Power Transformers, Transformer Testing Experience. International Journal of Automation and Control Engineering (IJACE), 2013 Volume 2, Issue 3 pp. 120-127.
http://www.seipub.org/ijace/AllIssues.aspx

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