Change of power supply continuity indices due to force majeure circumstances

Georgi Dimov
Department of Electrical Supply, Electrical Equipment and Electrical Transport
Technical University - Sofia
Sofia, Bulgaria
g_dimow@abv.bg

Svetlana Tzvetkova
Department of Electrical Supply, Electrical Equipment and Electrical Transport
Technical University - Sofia
Sofia, Bulgaria
stzvet@tu-sofia.bg

Angel Petleshkov
Department of Electrical Supply, Electrical Equipment and Electrical Transport
Technical University - Sofia
Sofia, Bulgaria
apetl@tu-sofia.bg

Yavor Lozanov
Department of Electrical Supply, Electrical Equipment and Electrical Transport
Technical University - Sofia
Sofia, Bulgaria
ylozanov@tu-sofia.bg

***Abstract* — The results from an analysis of the influence of force majeure on the continuity of electricity supply in medium voltage electricity distribution networks in the European Union and Bulgaria are presented in the paper. For this purpose, the influence of force majeure circumstances on the quality indicators of the electric power supply SAIDI and SAIFI for two regions in Bulgaria - a region with a predominant cable network and a region with a predominant overhead network - is considered.**

Keywords — electric distribution network, quality indicators of electric power supply, continuity of electric supply, consumers, interruptions, force majeure

I. INTRODUCTION

Each electrical power supply network is designed, implemented, and operated in accordance with the requirements of state regulations and operating regulations [1, 2, 3, 4].

The network parameters are calculated so that all facilities in certain weather conditions operate without interruption. Often the facilities have to be operated under conditions that are not taken into account in the norm documents or the emergency plan of the power supply company or case of external interventions on them.

The methodology for the reporting and execusion of the target indicators and control of the indicators for quality of electric energy, and quality of service of the network operators, public suppliers and final suppliers from 2010 of the Commission for Energy and Water Regulation (EWRC) regulates the cases of force majeure [4, 5]. They are divided into two types:

- Third party intervention - these are:

- intentional or unintentional accidental actions of individuals and legal entities, other than the staff of network operators, public suppliers, final suppliers, leading to damage to network facilities;
- personnel of external organizations that caused accidents of design, construction (excavation, blasting), installation, repair, communication character or functional tests;
- thefts and fires caused not by own facilities and personnel, including interruptions in the electricity supply to consumers due to accidents in facilities owned by third parties.

- Force majeure - an unpredictable and insurmountable event of an extraordinary nature, which leads to a violation of the normal operation of the distribution network, certified by the competent authorities. Its caused by:

- human factor - military action, terrorism, embargo, government bans, strikes, riots;
- forces of natural character - storms (wind over 60 km h), torrential rains, floods, hail, lightning, snowfalls, icing, earthquakes, landslides.

If it is necessary to prove force majeure of a natural nature, the relevant information from the National Institute of Hydrology and Meteorology is required, and the reason is certified by an issued document.

In chapter seven of the Energy Act [6], "Restrictive regime, temporary interruption or restriction" cites the measures that need to be taken by institutions and companies when introducing a restrictive regime for consumption or production of electricity. According to Art. 72 A restrictive regime for the supply of electricity, heat or natural gas shall be introduced in cases when it is necessary to limit or interrupt the supply for a period longer than 48 hours on the territory of the whole country or part of it as a result of:

- force majeure;
- occurrence or prevention of accidents at facilities for production and transmission of electricity or heat and natural gas and for distribution of electricity and natural gas;
- congestion of electrical networks;
- long-term shortage of energy capacities or energy carriers;
- dispositional measures of state bodies for state of readiness or in case of military actions;

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- terrorist acts or encroachments on energy sites.

All these reasons lead to "stopping the clock", i.e. the duration of the interruption is not taken into account. This is done in the following cases:

- when, due to the fault of third parties, there is no access to facilities or infrastructure for power supply recovery. As soon as access is granted, "the clock is started";
- when a customer requests a delay in the recovery of the power supply for a certain period. In this case, the clock starts at a time agreed with the customer;
- where there is a delay in making the necessary switching due to emergency work by third parties, delayed actions by third party staff, imposed delays by internal instructions of third parties, actions by government authorities.

In Europe, and in particular in Bulgaria, the quality indicators of the electrical power supply are determined mainly for the medium voltage network by the regulatory body (EWRC). The indicators used are [5, 7]:

- System Average Interruption Duration Index (SAIDI) - ratio of the total duration of interruptions to the total number of connected users in the network for the period;
- System Average Interruption Frequency Index (SAIFI) - ratio of the total number of interruptions to the total number of connected users in the network for the period.

The results from an analysis of the influence of force majeure on the continuity of electricity supply in medium voltage electricity distribution networks in the European Union and Bulgaria are presented in the paper. For this purpose, the influence of force majeure circumstances on the quality indicators of the electric power supply SAIDI and SAIFI for two regions in Bulgaria - a region with a predominant cable network and a region with a predominant overhead network - is considered.

II. INFLUENCE OF FORCE MAJEURE ON POWER SUPPLY CONTINUITY IN THE EU

The influence of force majeure on electric power quality indicators (SAIDI and SAIFI) in Europe varies from country to country [8]. The values of both indicators are lower in countries with developed economic potential. The reason for this is the long-term policy for investments in the reliability of the electrical network, installation of means for switching of key facilities, supply of sensitive to interruption objects in parallel or in ring, and introduction of other organizational and technical measures leading to improved results.

In its report, the European Regulatory Commission shows the trend of changing indicators in different countries [8]. For this purpose, the exclusions are divided into two types: caused by "force majeure" and others. This gives a clearer idea of the impact of the former on network outages.

The analysis shows that the values of the SAIDI indicator for the electrical distribution network of each country under the influence of "force majeure" are significantly higher than the SAIFI indicator. In the presence of "force majeure" accidents in the network are localized and eliminated for a longer period of time due to lack of access, adverse weather conditions, etc.

The cable network is less vulnerable to the impact of external factors, such as the influence of third parties or "force majeure". However, it requires greater investment, both in its construction and in operation and maintenance.

In a number of European countries such as Sweden, Austria, Luxembourg, Spain, Germany, and the Netherlands the medium and low voltage cable network is between 50% and 90%, which is a prerequisite for better indicators of power supply continuity. In Bulgaria, the medium voltage cable network is about 22% and about 30% for low voltage [9]. Therefore, the results obtained for the indicators that are achieved in our country have their own logical explanation.

The influence of third parties or "force majeure" is significantly greater in overhead power lines. They have a higher number of shutdowns and with a longer duration, which leads to worse indicators SAIDI and SAIFI.

Considering the impact of force majeure on the SAIDI indicator for Sweden [8]. In 2005, this indicator exceeded 18 hours, i.e. over 1000 minutes. This is indicative in cases where there is a serious impact on the electric network and the possibility of its recovery in a short time is small. In such cases, a state of emergency is declared, restrictive regimes and the power structures of the state are involved to help energy companies.

The values of the SAIDI indicator for the period from 2005 to 2014 are shown in Fig. 1. In normal situations (2006, 2009, 2010, 2012 and 2014) the SAIDI values are less than 2 hours (120 minutes). In 2007, 2011 and 2013 higher values were observed between 3 and 6 hours (180 - 360 minutes), again under the influence of force majeure, but with less consequences, compared to 2005.

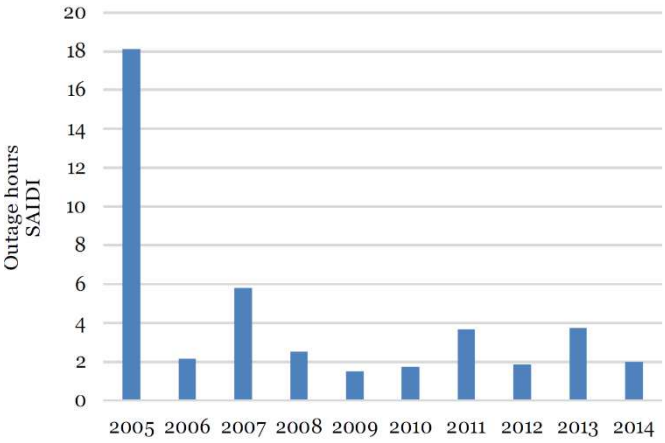


Fig. 1. Values of SAIDI for Sweden, for the period 2005-2014

The values of the SAIDI indicator for planned and unplanned outages for the same period are shown in Fig. 2. It's clear that planned shutdowns don't affect the duration of customer disruption significantly. The picture is similar in Bulgaria.

The reasons for the interruptions of the power supply are shown in Fig. 3, namely:

- Thunderstorm activity ~ 8%;
- Other severe meteorological conditions ~ 40%;
- Vandalism ~ 7%;
- Material ~ 15%;

- Staff errors ~ 1%;
- Overload ~ 3%;
- Automatic reclosing ~ 0%;
- Fuse failure ~ 7%;
- Unknown ~ 17%.

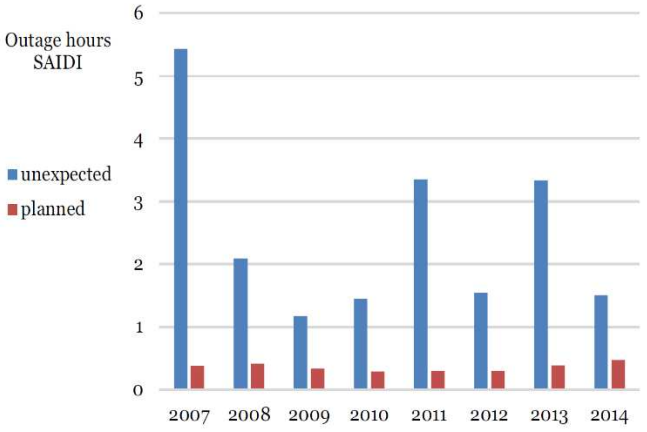


Fig. 2. Values in SAIDI hours for planned and unplanned interruptions for Sweden, for the period 2005-2014.

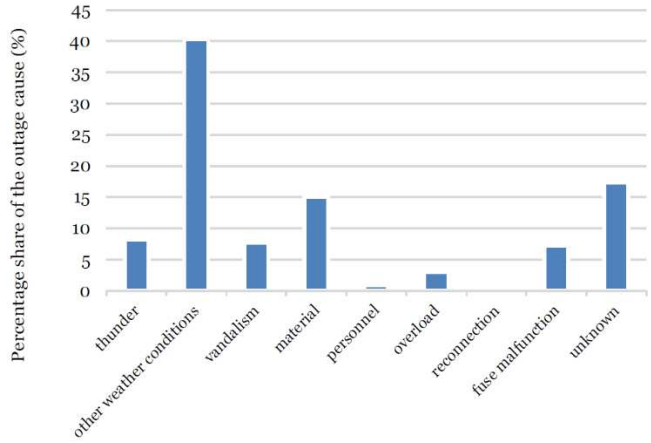


Fig. 3. Distribution of the reasons for force majeure interruptions (unplanned exclusions) for Sweden for the period 2005-2014

From Fig.3 it's clear that the weather conditions, which are the cause of half of the interruptions, are a major factor reducing the reliability of the power supply.

III. Analysis of the Power Supply Continuity Indicators in Cable and Overhead Network Under the Influence of Force Majeure in Bulgaria

The aim of the study is to assess the affect of force majeure circumstances on the quality indicators of electric power supply, calculated according to the EWRC methodology [5, 7] for two distinct regions:

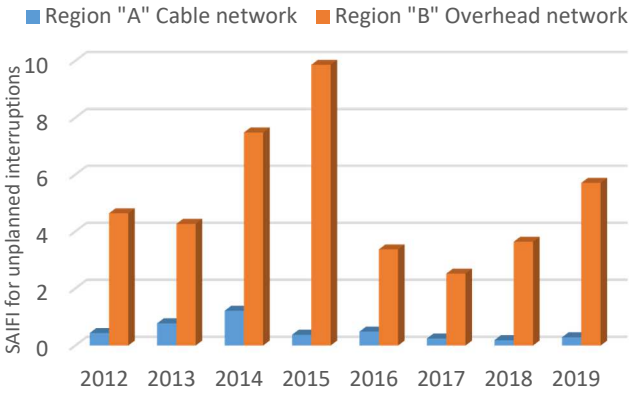
- Region "A" with a predominant cable network;
- Region "B" with a predominant overhead network.

In Region A, the network is constructed mainly as medium voltage cable lines, which are more than 90% of the total length. It is located in a big city and is characterized by a large number of facilities located close to each other, many customers and high power consumption. The laying of the cable power lines is carried out in collectors and pipe channels, which provides protection against damages in case of uncoordinated construction activity. Checks and tests of the condition of the cables in the collectors and the routes along which they pass is performed periodicaly in time. Visual checks on the condition of the cable fittings are performed and the transformer-stations connected in this network are inspected. To prevent accidents, planned preventive maintenance is carried out. The physical condition of the cable network is checked, according to a methodology determined by the network owner. The cables and cable fittings are replaced in accordance with the factory operating instructions. A sufficient amount of circuit breakers and power disconnectors have been installed in the region to ensure switching without disrupting customers' electricity supply.

In Region B, the network is mainly constructed with medium voltage overhead power lines that cover more than 90% of its total length. This region is located in mountainous terrain, with small settlements located at a great distance, with a small number of consumers and low electricity consumption. In most of the settlements during the autumn-winter period, the number of consumers using electricity is very small. Overhead power lines pass mainly through woods terrain with tall trees. Periodically, the condition of the clearings is inspected, which must comply with the regulations. In regions where trees are tall (times higher than medium voltage poles) this is not always enough. In these places, under the simultaneous influence of bad weather conditions and the peculiarities of the terrain, it often happens that trees outside the clearing fall on the overhead power line and this leads to a power supply interruptions. An inspection of the substations connected to this network is also performed and the condition of the facilities is checked. The installation of sectioning disconnectors is used to divide large sections for faster localization of the accident.

The indicators for the quality of the electric power supply for the period from 2012 to 2019 for the two regions are considered.

The change of the SAIFI indicator for unplanned interruptions caused by force majeure circumstances is shown in Fig. 4, for both regions, for the considered period.

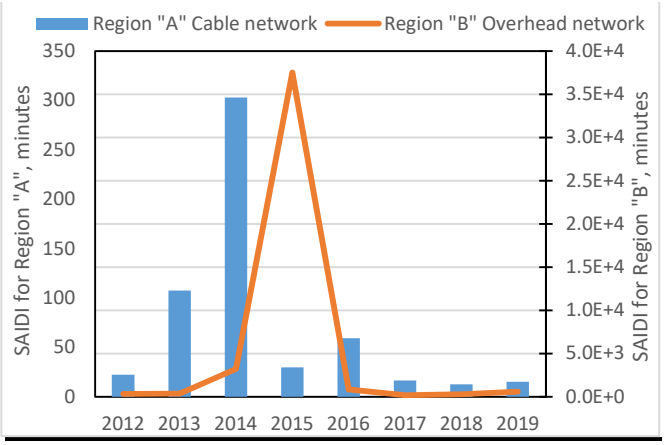


	2012	2013	2014	2015	2016	2017	2018	2019
SAIFI for Region „A“, number	0,44	0,78	1,22	0,38	0,49	0,25	0,19	0,29
SAIFI for Region „B“, number	4,64	4,27	7,48	9,86	3,37	2,52	3,64	5,71

Fig. 4. SAIFI values for unplanned shutdowns caused by force majeure

It can be seen that the value of the SAIFI indicator for Region "B" is many times (somewhere in the order of magnitude) higher than for Region "A". This is due to the type of distribution network and the possibilities for its operation in case of force majeure. For the cable network, the maximum value of the SAIFI indicator is 1.22 units for 2014, and for the overhead network - the maximum value is 9.86 for 2015. For the period under review (2012 - 2019) the average value of SAIFI for cable networks is 0.51 units, and for overhead networks - 5.18 units. Therefore, the number of outages in the cable network is 10 times smaller than in the overhead network.

The change over the years of the SAIDI indicator for unplanned shutdowns caused by force majeure is shown in Fig. 5. Here again, there are very high values of the duration during which customers are left without power in the region with a predominant overhead network. The reason for this is the strong impact of atmospheric conditions on the network. As a result of these impacts, there are problems not only in the medium voltage distribution network of the electricity distribution company but also in the electricity transmission network of the Transmission System Operator (TSO). As a result of severe weather conditions, some or all infrastructure services are often terminated.



	2012	2013	2014	2015	2016	2017	2018	2019
SAIDI for Region „A“, min	22,2	107,4	302,8	29,8	59,2	16,3	12,5	15,1
SAIDI for Region „B“, min	325,8	355,5	3203,3	37500,4	859,7	160,5	293,4	569,4

Fig. 5. SAIDI values for unplanned shutdowns caused by force majeure

In 2015, in the region with a predominant overhead network, the SAIDI indicator reached values over 36,000 minutes (over 600 hours). For this year, catastrophic consequences have been observed for all elements of the electric power system in this area. Initially, we have an emergency power outage in a high voltage network. All 110 kV power lines are left without power supply, and from there all substations in this region, and accordingly the entire distribution network of medium and low voltage is unsupplied. At the first stage, the voltage is restored in the high voltage (HV) power transmission network and the HV/MV transformers in the substations are supplied. The second stage is assessment and analysis of the damages to the electricity distribution network in the region and drawing up an action plan for providing power to the customers. At this stage, the electricity distribution company has a Crisis Staff, which manages the actions of all specialists and manages the resources that are used (materials, ordinary and specialized equipment, generators, etc.). Priorities for the elimination of accidents are being prepared and worked out. In settlements with passable roads, where the elimination of accidents will continue for a long time, generators are installed to supply consumers. Specialists, equipment, and materials from other regions are redirected. Communication with institutions and media for transparency in the coverage of the situation and the measures taken. A restrictive regime for the consumption of electricity in the region was announced, initially by the electricity distribution company, and after 48 hours by the Ministry of Energy.

A force majeure in the sense of the methodology for the electricity distribution company is also the emergency/unplanned interruption of the power supply by TSO to substations and the transformers in them. In these cases, a large number of customers remain without power supply - from several thousand to several tens of thousands. This significantly affects the quality of customer power.

In cases where the accident continues for a longer period of time, an alternative power supply is made to the customers through the medium voltage network, for the places where this possible. In cases when the voltage quality will be outside the standard BDS EN 50160 [4] this action isn't performed.

Another significant impact on the medium voltage network is uncoordinated construction activity. Very often excavators work in the cable route and sometimes interact with the cables and cause accidents.

The situation is similar when loading and unloading activities are performed with large machines or large materials. Then there is an involuntary reduction of the distance to the overhead power line and subsequent shutdown. Sometimes this is associated with damage to the facility, unfortunately and to accidents.

In the current 2020, it will probably be possible to verify the impact of the government's quarantine measures related to COVID-19 and whether they will directly affect the quality indicators of the electric power supply.

IV. Conclusions

The analysis of the achieved values of the indicators for continuity of power supply SAIDI and SAIFI in the electric distribution network of the two regions "A" and "B" shows that the influence of force majeure is different on the two types of network, depending on the factors causing the disturbances.

Unfortunately, the impact of force majeure on the electric distribution network can always be expected. These are factors that in most cases do not depend on the capabilities of the operators. However, it is necessary for the electric distribution company not to be inactive in anticipation of such events, but to take preventive measures and precautionary actions in order to reduce the negative impact of force majeure factors. Such measures are:

- Network development;
- Network element redundancy;
- High operability;

- Use of highly qualified staff;
- Use of state-of-the-art technologies;
- Implementation of SCADA with telemechanics and remote control;
- Replacement of the overhead network with a cable network.

Based on the balance between security, quality and price at the expense of new investments, it is necessary to take measures to improve the quality of electricity supply.

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