Trends of changing the indicators on the continuity of electricity supply in Bulgaria

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***Abstract* - The results from analysis of the indicators of continuity of power supply in electricity distribution grids medium voltage are presented in the paper. Measures for improving of the indicators under consideration are proposed.**

Keywords – interruptions, electricity distribution grid, quality of power supply, consumers.

I. Introduction

In the world are used different methods for quality assessment of the of electricity supply to the consumers. For standardisation of the requirements to this service are created different instruments and requirements which to regulate the obligations of the companies serving different territories/countries.

Based on specified for a given period targets of these indicators, regulatory authorities in the different countries seek to optimize the process of improving the service quality by making it commensurate to the various subjects at similar methods of electricity supply to the consumers from the different suppliers (operators) [1]. In the different countries, the regulatory authority determines the quality indicators of power supply in high voltage (HV) and medium voltage (MV) grids or for low voltage (LV) grids. In Europe, the indicators are determined mainly for MV grid [2].

Determination of the indicators for continuity of electricity supply is carried out based on the actual number of affected consumers and the duration of interruptions and the number of consumers with a specific power depending on their location and the volume of purchased electric energy [3, 4, 5].

In some countries it is accepted to determine the real (actual) number of affected consumers per facilities - transformer stations (TS), sections, etc. This method is used also in Bulgaria. However, this is a complex calculation method, considering the dynamics of the changes of the number of consumers, their type and volume of the electricity used. For this reason according to the types of consumers, they are classified as: "large" and "small", "rural" and "urban", "household" and "industrial", etc. In other countries is used the method of determining the number of users based on the installed capacity of the transformers in TS. For example, N number of consumers per 1 MW of installed capacity.

A combined method is also used to define the number of the affected users and for rural and urban areas are used different values for the number of consumers per MW installed capacity in TS. In this method, when switching off a certain number of TSs, based on the total switched off installed transformers power in them, is determined the number of affected (interrupted) consumers. This method has some degree of inaccuracy because the actually affected consumers are not calculated but it is assumed that the number of consumers connected to one TS with certain installed capacity of the transformer is relatively constant.

Another way is through the introduction of coefficients to determine the number of the users without electrical supply (e.g., switching off a feeder in a substation). In this case, there is a large percentage deviations, due to the fact that in the different periods of the year and the day, the load of the transformers, at one and the same number of consumers is different.

The role of the regulatory authority is in a balanced manner to set the values of the goals of the electricity quality indicators and the trend of their fluctuation, in accordance with the investments in the grid and the best practices in the corresponding country.

In recent years, in practices a number of indicators have been implemented and used. In Bulgaria, by a decision of the Energy and Water Regulatory Commission (EWRC) for electricity quality indicators were accepted to be used System Average Interruption Duration Index (SAIDI) and System Average Interruption Frequency Index (SAIFI) [1, 6].

SAIDI is defined as ratio of the total duration of the interruptions to the total number of grid-connected consumers for the period. SAIFI is defined as ratio of the total number of the interruptions to the total number of grid-connected consumers for the period. To define them are used the following formulas [1, 3, 6]

$$SAIDI = \frac{\sum_{i=1}^{m} t_i \, n_i}{N} \text{, minutes} \qquad (1)$$

$$SAIFI = \frac{\sum_{i=1}^{m} n_i}{N} \text{, number/year} \qquad (2)$$

where: n_i is the number of consumers affected at the *i*-th interruption; N - the total number of grid connected consumers; m - number of interruptions; t_i - duration of the *i*-th interruption.

II. Achieved results in the European Union

Data concerning quality indicators of power supply (SAIDI and SAIFI) in Europe are given below. It is noticeable that the states with more developed economy have lower values. The reason for this are the yearlong policy of investments in the security of the grid, installing switching facilities on key places, work in parallel/ring of sensitive to the interruption objects and other technical and organizational measures which may lead to improvement of the results.

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From the report of the European regulatory commission are visible the trends in the change of the indicators in the different countries and achieved results [7, 8]. The graphs show clearly that the separation of interruptions in two types (those which are caused by "force majeure" and other) give a clearer idea of the events in the grid. The definition of the term "force majeure" is important for the accurate segmentation of the reasons for each interruption. It is an unpredictable event of extraordinary nature, which leads to a breach of the normal operation of the distribution grid and it is certified by the competent authorities. They may be caused by human factor, such as acts of war, terrorism, embargo, government prohibitions, strikes, riots, etc. The electrical grid may be affected also by natural disasters such as storms with wind over 60 km/h, heavy rains, floods, hails, lightning, snow accumulations, icing, earthquakes and landslides [1].

Fig. 1 [7, 8] shows the impact of all unplanned interruptions on the average duration of interruptions per consumer (SAIDI) and the average number of interruptions per consumer (SAIFI).

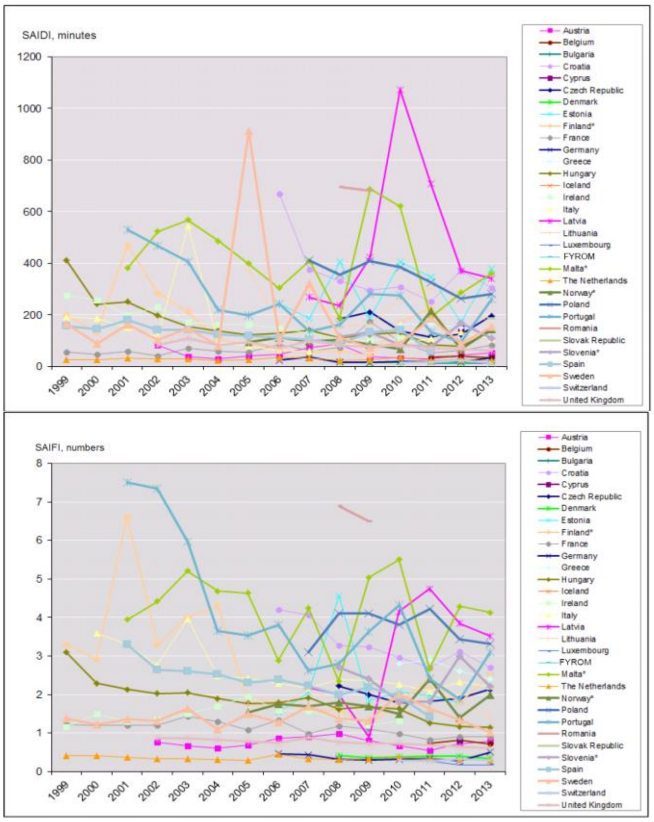

Fig. 1. SAIDI and SAIFI for unplanned interruptions, including exceptional events

Fig. 2 [7, 8] shows the variation of the values of SAIDI and SAIFI, as a result of unplanned interruptions, without those caused by "force majeure". In this way, the actual state of the electricity distribution grid (EDG) of each country is obtained. It is a fact, that the impact of the "force majeure" is bigger with SAIDI indicator, while with SAIFI indicator it is less. The reason for this is that when a "force majeure" is available, breakdowns are fixed for a longer period of time, due to the lack of access, adverse weather conditions, etc.

Planned power interruptions also affect the quality of the power supply to the consumers. When they are longer, customers are actually without power supply for a longer time. At the same time, they are necessary because the repair and preventive maintenance of the existing installations and the construction of new ones will ensure a higher quality in the future.

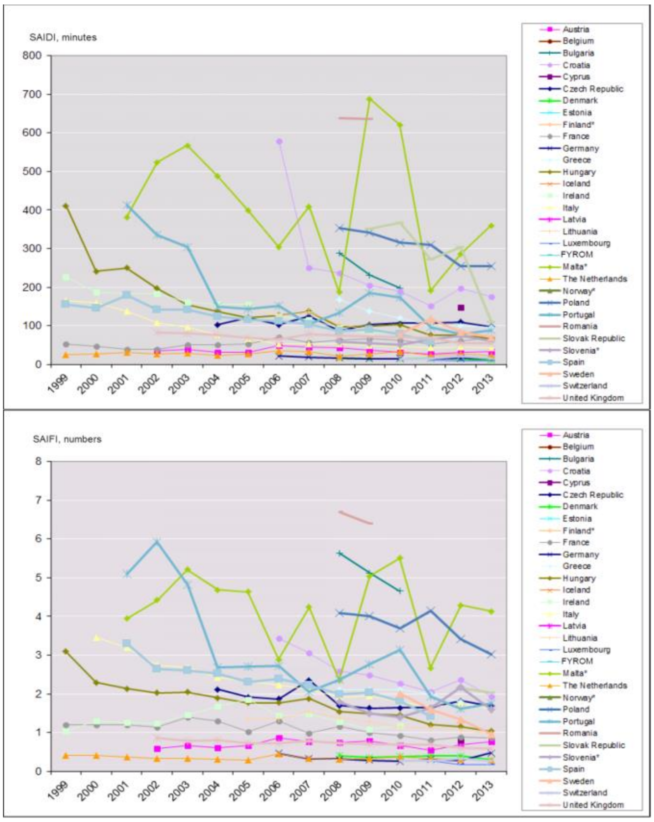

Fig. 2. SAIDI and SAIFI for unplanned interruptions, excluding exceptional events

Fig. 3 [7, 8] shows the values of SAIDI and SAIFI at planned power interruptions of the customers. It is noticeable that SAIDI and SAIFI values are times lower than the unplanned ones. Again the reason for this is the proper planning of the number and the time of the interruptions, for which have been informed the consumers in advance.

Fig. 4 [7, 8] shows the total value of SAIDI, taking into account all the planned and unplanned interruptions. As it can be seen, in some countries this indicator reaches up to 1300 minutes, mainly due to the influence of the “force majeure”.

Analysing the results achieved, dependence of SAIDI and SAIFI values on the ratio between overhead and cable grid in different countries is established. Cable grid is less vulnerable to the impact of external factors such as third parties influence or "force majeure". But for this it is necessary to make big investments. Fig. 5 and Fig. 6 show that "top performer" in this area is the Netherlands [7, 8]. This country has invested about 90% in cable grid medium voltage and has the lowest values of the indicators for continuity of electricity supply. Bulgaria has a small percentage of underground cable grid - about 22% for MV and 30% for LV. To some extent, this is an explanation of the results achieved.

The availability of underground cable grid directly influences the quality indicators of power supply. The presence of overhead power lines leads to a larger number of interruptions and hence - higher values of the SAIFI and SAIDI indicators. It is necessary to find the economic balance between security in the grid and the value of the investments made/price of the installations.

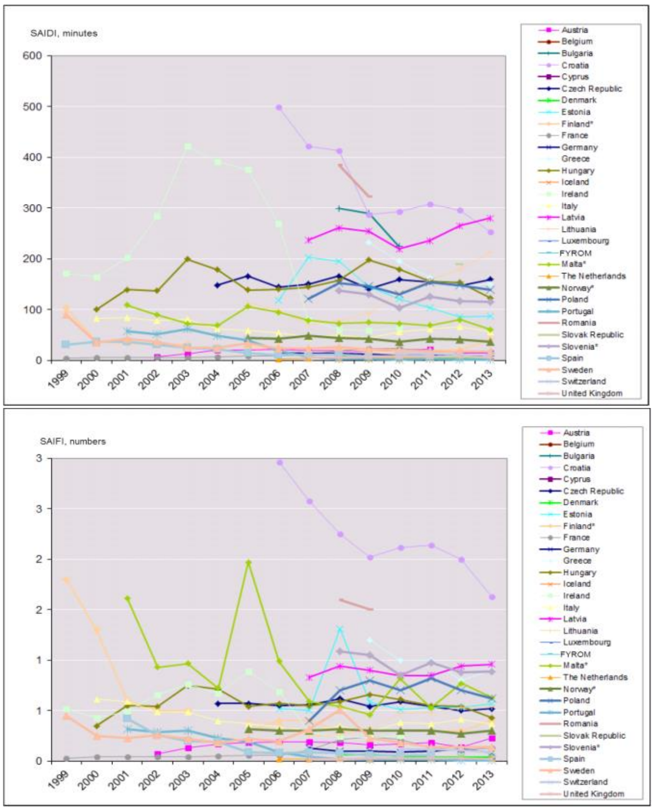

Fig. 3. SAIDI and SAIFI for planned interruptions

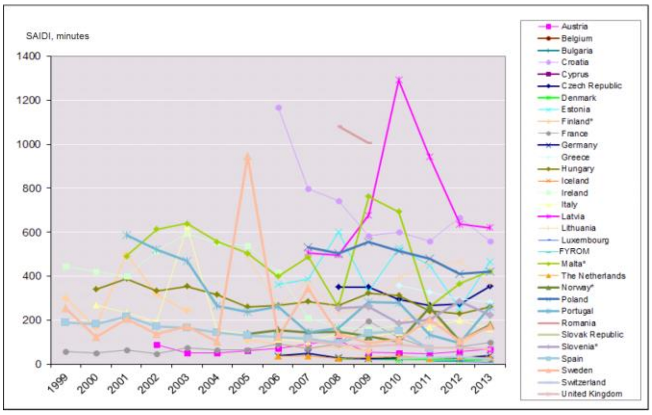

Fig. 4. Total SAIDI (planned and unplanned), including exceptional events

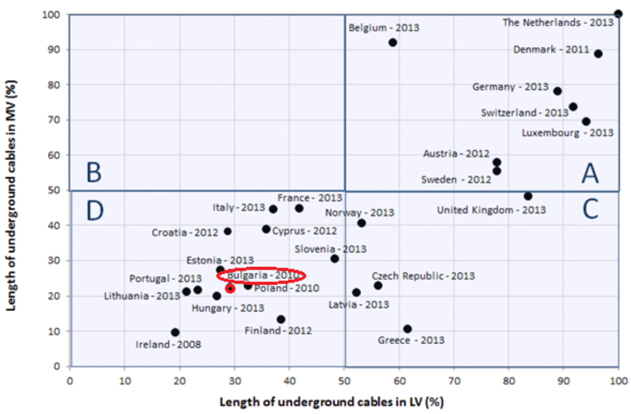

Fig. 5. Clustering European countries according to the technical network characteristics

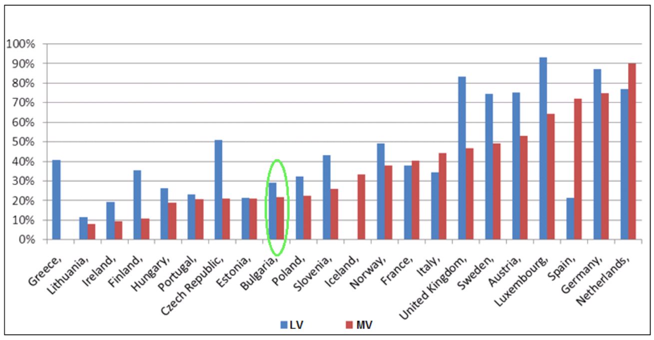

Fig. 6. Proportion of cable lines at the LV and MV levels in EU

III. Analysis of the Quality Indicators of Electricity Supply in Bulgaria

Quality indicators of the power supply for the period 2006 to 2018 in the electricity distribution company (EDC) are considered. The changes over the years of the indicators SAIDI and SAIFI are shown respectively in fig. 7 for planned power interruptions and in fig. 8 for unplanned power interruptions. It is observed a reduction of their values over the years. Three time periods are clearly distinguished.

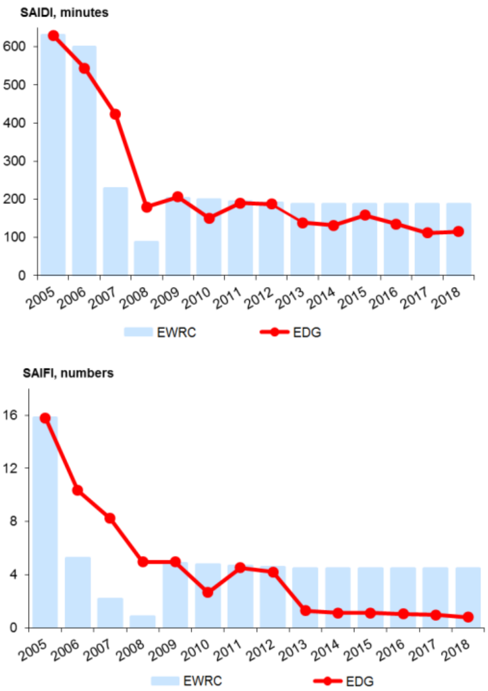

Fig. 7. SAIDI and SAIFI for planned interruptions of EDC in Bulgaria

In the first period from 2006 to 2008, it is observed a sharp reduction in the values. This is due to organizational and technical measures, which are taken from the EDC. EWRC recognizes the investments made in the grid, as costs and this leads to these results.

The second period from 2008 to 2017 is characterized with smooth reduction of the two indicators until reaching the point of saturation. This is may be due to the fact that the grid investments are reduced and technical solutions are sought with small investments and higher effect. Also a number of organizational measures apply, which also lead to this reduction.

The period 2017 – 2018 looks different. Here the curve of variation for the indicators starts to move upwards. This may be due to the reduction of the investments in the grid and the exhaustion of the effects of the organizational measures.

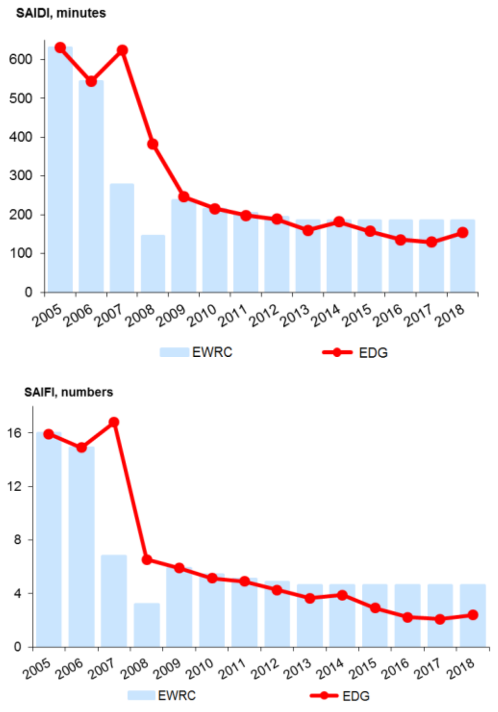

Fig. 8. SAIDI and SAIFI for unplanned interruptions of EDC in Bulgaria

So that the Commission can obtain access to information for a certain period or event in the EDG of each EDC, at any time the Commission defines requirements for gathering, storage, provision of information, monitoring and control.

The method for calculating of SAIDI and SAIFI from energy companies is the same and is approved by EWRC. The indicators SAIDI and SAIFI are calculated by the number and duration of interruptions per customer for each section with a corresponding number of substations/transformer stations and customers connected to them. The sum of the indicators by sections, that are part of an event, form the total value of SAIDI and SAIFI for this event.

Each energy company carries out continuous monitoring and internal control of the indicators and collects all the information for the quality indicators of power supply and the quality of service by providing them in the form of samples approved by the Commission - Appendix 1 and Appendix 2 of the methodology [1].

If available any grounds for suspicion on the part of the grid operator for any available influence on the part of the consumer on the characteristics of the voltage of other consumers, an independent scrutiny of the voltage parameters can be done by an accredited controlling body. Public providers and consumers are obliged to assist and provide immediate access and conditions for the pursuit of independent scrutiny. Any deviations found in the voltage characteristics, with observed contractual obligations on the part of the grid operator, shall be grounds for imposing sanctions to the consumer for the scrutiny period and claim damages according to the relevant procedure as approved by the Commission.

Each energy enterprise must develop an internal procedure approved by the Commission for data registration in accordance with item 1 and 3 [1]. The internal procedure corresponds to the format and is considered to be an element of the Quality Management System (QMS) implemented in the energy enterprise. The technical means by which is secured the procedure must be traceable, metrologically calibrated and to comply with the requirements of the standards BDS EN/IEC 61000-4-1: BDS EN/IEC 61000-4-7, BDS EN/IEC 61000-4-15/A1 and BDS EN/IEC 61000-4-30 [3, 9].

Each energy enterprise is obliged to store data in the time limits as defined in the existing legislation. Each energy enterprise shall collect the data in electronic form and in a format as approved by the Commission and shall provide them in the time limits defined by the Commission. The Commission is entitled by random selection to carry out monitoring and control of the process of collection, storage and reliability of the information provided. In case of any doubt for deviations found of the data provided by more than 5% compared to the result from the sample shall be carried out regulatory audit of all the information [1].

IV. Measures to Improve the Quality Indicators of the Power Supply

The purpose of the measures applied is to increase the reliability of the EDG and improvement of the quality indicators of the power supply. Depending on the need of changes in the work technology or the application of new technical solutions, measures can be: organizational and technical [10].

Organizational measures are related to a change in work organization of the teams and the available resources.

The main task at the design stage of the EDG is minimising the losses and ensuring maximum continuity of power supply. Any change in the normal condition of the grid leads to reduction reliability and increasing the losses. Therefore, the main purpose of operational staff is keeping the EDG maximum close to its normal condition. It is necessary to know well the resources of the grid in order to make a correct assessment of its potential for the transfer of loads in the event of operational necessity. Erroneous decisions would lead to disturbances and sometimes to lasting and continuous breakdowns. Therefore, each disconnection must be carefully planned taking into account all the known circumstances that would affect the manipulations.

In some cases, it is necessary to use more personnel to carry out the manipulations. It is then possible with the positioning of teams at key places to be performed a sequence of manipulations in which to be affected a minimum number of consumers with a minimum duration of interruptions. This method is effective when there are switches in which a large number of facilities or consumers will be deprived of electricity supply. Unfortunately, it is related to costs for staff working time, transport equipment, etc.

A similar effect for minimising the number of affected consumers and the duration of the interruption has the use of RTU (if any) by the operational staff for switches in the EDG.

In addition to the use of measures relating to the technology of the working process, it is necessary to be made technological changes in the EDG. This sometimes is related to preliminary preparation of the elements in the grid for making switches. This happens when the whole grid, if possible, is phased-in.

Then by placing switching equipment at key places, with the aid of operational staff or available RTU, manipulations do not disturb the consumers. Practically their power supply lacks dead time. This is when two or more feeders have the opportunity to function in parallel.

In some cases, it is justifiable to install reclosers with protection on electric lines [11]. Most often, this is used in the overhead power lines. Installation is carried out in points where the route of the overhead power lines passes from flat country to mountainous.

In recent years in Bulgaria started commissioning of differential protection of feeders medium voltage, which in disturbances or feeder disabling shows the approximate location of the breakdown. In this way is reduced several times the duration for its location.

When properly calculated the settings of Relay Protection and Automation (RPA) of RES power plants is achieved effect of non-admission of disturbances transfer to the EDG.

In some substations are used different ways of grounding of the neutral point of the transformers. The use of Petersen coil reduces the current to the ground and hence the disconnections caused by ground short-circuit. In the cases when we have ground short-circuit on the electric line, the feeder switches off and the current of the short circuit is limited.

In recent years is used Petersen coil with increase of the active component of the current of ground short-circuit. Most of them have installed devices for automatic setting of the compensation. When there is available ground short-circuit on the electric line, it does not switch off automatically but remains alive. The operational staff begins localising the alive breakdown while observing the necessary safety requirements. The positive thing here is that consumers in this entire process have power supply.

In some cases, in facilities with sensitive to disturbances consumers, power supply back-up from several sources and automatic transfer switch are installed. This method is reliable, but it is connected with expensive investments, which are not always cost-effective.

The replacement of overhead line with underground cable grid also leads to improvement of the quality indicators of the power supply. Although this investment is bigger than for the construction of overhead power lines, sometimes in places with frequent breakdowns it is cost-effective the grid of certain section to be underground. The costs of the multiple recovery of breakdowns and the costs for the work of employees and equipment exceed in times the costs of laying a cable.

Not in the last is the use of SCADA (systems for Supervisory Control and Data Acquisition of the EDG). In recent years, the use of these systems became cost effective, considering the reduced costs for purchase and maintenance of SCADA rather than the maintenance of operational staff in the sites. Realization leads to high operability of the grid, as the time for manipulations is dramatically reduced. The construction of remotely controlled sites leads to high quality of power supply. Dispatchers in the EDC have the real picture of developments in ERM and hence the opportunity for rapid and adequate response. The operation of the RTU is not influenced by the weather conditions or the time in the day. By good connection with the facilities, SCADA considerably improves the operation of the EDG and hence improving the quality of the power supply and consumer service.

To obtain a better control of the achieved results is required monthly/quarterly monitoring and analysis of the implementation of the indicators SAIDI and SAIFI for the quality of the power supply of the consumers connected to the EDG. On the basis of the results obtained it is possible to take quick and adequate measures that will lead to real results.

V. CONCLUSION

The analysis of the achieved values of the indicators for the continuity of electricity supply SAIFI and SAIDI in Bulgaria shows that when using the organizational and technical measures can be achieved significant improvements. Considering the last period 2017 - 2018 it can be concluded that at the moment the curve of their change is in the minimum and starts to increase. It is necessary to take new measures to improve the quality at the expense of a new type of investments on the basis of balance between security, quality and price.

In recent years, attempts are made to switching to decentralized RES energy generation. In Bulgaria, this will lead to a reduction of grid security and increase of the costs of providing quality service. For example creating node security. With the introduction of monitoring, control and management of a new more high tech level (smart grids) will be optimized the number of affected users in each disconnection. For the time being, this is expensive investment that still does not allow to be introduced in Bulgaria.

The role of EWRC is through good business case of investments, which EDC must make in their EDGs, to lead to keeping the same or improving the quality indicators of the power supply.

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