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DEVELOPMENT PROJECTION OF DISTRIBUTION ELECTRIC POWER NETWORKS OF PE ELEKTROPRIVREDA BIH D.D. - SARAJEVO

PROJEKCIJA RAZVOJA DISTRIBUTIVNIH ELEKTROENERGETSKIH MREŽA JP ELEKTROPRIVREDE BIH D.D. - SARAJEVO

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Abstract: Distribution network planning is a regular business process for determining optimal construction and reinforcement in the distribution network of a particular area that all power distribution companies are concerned. It is conducted based on techno-economic analyses for purpose of achieving the required safety and quality of power with minimum investment costs. The development of the distribution system should include all the needs of customers and electricity producers for the observed planning period. In addition, the development plan needs to be coordinated with the strategic directions of the development of the electricity distribution network. Among other things, this involves transition to direct transformation and one medium voltage (MV) level. In order to reduce losses and repair voltage conditions, interpolations of secondary TS and shortening of low voltage (LV) networks are planning. The paper presents some of the results of the research carried out in the study "Development projection of distribution networks of PE Elektroprivreda BiH, d.d. Sarajevo for the period 2015 - 2025".

Keywords: development planning, distribution MV and LV networks, forecast of consumption/production

Sažetak: Planiranje distributivne mreže je redovni poslovni proces utvrđivanja optimalne izgradnje i pojačanja u distributivnoj mreži određenog područja, s kojim se susreću sve elektrodistributivne kompanije. Provođi se na osnovu tehnokonomskih analiza sa svrhom postizanja zahtijevane sigurnosti i kvaliteta napajanja uz minimalne troškove ulaganja. Razvojem distributivnog sistema treba obuhvatiti sve potrebe potrošača i proizvođača električne energije za posmatrani period planiranja. Pri tome, plan razvoja potrebno je uskladiti sa strateškim pravcima razvoja elektrodistributivne mreže. Pored ostalog, tu se podrazumijeva prelazak na direktnu transformaciju i jedan nivo srednjeg napona (SN). U cilju smanjenja gubitaka i popravke naponskih prilika, planiraju se interpolacije sekundarnih transformatorskih stanica (TS) i skraćenje niskonaponske (NN) mreže. U radu su prikazani neki od rezultata istraživanja iz studije „Projekcija razvoja distributivnih mreža JP EP BiH d.d. Sarajevo za period 2015 – 2025. godina“.

Ključne riječi: planiranje razvoja, distributivne SN i NN mreže, prognoza potrošnje/proizvodnje

INTRODUCTION

In order to ensure the delivery of electrical energy to consumption of the required quantity, continuity and quality, it is necessary to plan an adequate operation and development of the distribution system. Therefore, the planning of the development of electricity distribution networks is one of the key operating processes of the distribution system operator (DSO). In accordance with applicable law, DSO is responsible for developing a distribution network to ensure long-term capacity of the distribution network to satisfy electricity distribution requirements. In recent years, more and more distributed sources have been connected to the MV and LV distribution network, so the development plan should

include the needs of the electricity producers for the adequate distribution of generated electrical energy from distributed generators (DG). Sustainable energy future is also based on greater exploitation of renewable energy technologies and on the introduction of energy efficiency modules. The planning of the development of the distribution network and the organization of electrical energy distribution activities need to be harmonized with the current legislation in this field. For example, DSO is obliged to supply all customers with electrical energy in accordance with EN 50160, which is a significant challenge for the distributor. The development of the distribution network is therefore necessary to plan in order to satisfy the provisions of this standard, which specifically refers to the correction of voltage conditions in the LV network [1] - [3]. In the PE Elektroprivreda BiH (EP BiH), in the past several years, several systematic studies have been carried out aimed at researching and analysing further directions of development and distribution system

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operations. Thus, a research was undertaken in terms of transition to one level of medium voltage (20 kV) and direct transformation [4], [5]. The development of electricity distribution networks and the increased presence of 20 kV networks as well as cable networks are accompanied by analyses that consider the treatment of the neutral point at medium voltage. The analysis with this topic was carried out in the EP BiH, in the study "Neutral point treatment in distribution networks of PE Elektroprivreda BiH" [6]. Detailed analysis of the existing and expected conditions on the network, taking into account the requirements for new connections of consumers and producers, create the basis for the development of short-term and mid-term development plans in the distribution of electrical energy. In distribution activities yearly and three-year development plans are usually done. All planning documents must respect strategic directions regarding the development of power distribution networks and systems. Such a process implies a rather broad and complex examination of the issues, which ultimately results in investments in the electricity distribution system and adequate development. It often happened, as a result of various influences, the urgency of resolving consumer or producer demands, the organizational structure of distribution companies and human resources, the available financial resources and current problems, that the operational planning process in the electricity distribution business was not a consequence of detailed elaborations with a clear vision of the distribution system development. This was especially reflected in the non-systematic further development of the 35 kV network and the delay in the development of LV networks. Such omissions, due to accumulated problems, can often be present in short-term plans. Therefore, there was a need for conducting a professional research which, as its final result, should contain a list of systemic electricity facilities that will be the subject of construction in a longer period of time (here it is the period from 2015 to 2025). To make analyses of this type it is necessary to realize an increase in consumption/production for a certain period and make detailed forecasts [7]. This type of study should be the basis for future short-term and mid-term planning documents related to development of the electricity distribution system, with a clearly defined list of planned electricity facilities for construction, with a defined frame of time and cost estimate. In the paper, some of the research results from the study "Development projection of distribution networks of PE Elektroprivreda BiH d.d. - Sarajevo for the period 2015 – 2025" were briefly presented [8]. Here, the characteristics of global and spatial forecasts of peak power are elaborated according to long-term planning programs, and the proposed dynamics for the construction of new power facilities and the reconstruction of the existing ones. In accordance with the selected methodology of the study research, and in order to achieve as high quality projections of the development of the distribution networks of

EP BiH for the period 2015-2025, the area under the competence of EP BiH is divided into several regional units. PowerCad and WinDis software packages were used for planning distribution networks. The systemic electricity facilities, proposed for construction, are classified into four different groups considering the reasons for their construction. Those are the construction of primary TS 110/x kV, the transition to unique MV voltage level (20 kV), the construction of new MV lines, the interpolation of TS MV/LV in the aim of reducing the length of existing LV networks and bringing the quality of electrical energy supply to the prescribed level.

1. ANALYSIS OF CURRENT SITUATION AND CHARACTERISTICS OF THE EXISTING NETWORK

The starting point in the planning of distribution networks is always the existing situation in the distribution network as well as the analysis of the possibilities of such a network in satisfying the needs of all consumers/producers in a given period. If the analysis determines that the network cannot satisfy the set of aims or satisfy the prescribed limitations, then the process of planning the development and construction of distribution networks is approached. Analysis of the current situation is also necessary because the equipment used has a relatively long life, so it is not only important for the object to be put into operation for a specified time. It's also important that the object fits into the existing system in a satisfactory manner over a longer period of time, as well as fits into the strategy of long-term development. The basis for the development of multi-annual development plans are the studies of the long-term development of the distribution network. The network development studies elaborate in detail the existing state of the observed area and on the basis of the prediction of the burden of growth and the forecast of distributed production, in accordance with the adopted criteria and approach to development planning, suggest the long-term development of the network. For example, the characteristic for the territory of EP BiH, is that the scope of the network at the voltage level of 20 kV is still not satisfactory, considering the time period in which the equipment adapted for 20 kV is being purchased and installed. Also, 35 kV networks and electric power facilities that include this voltage level are still significantly present. The total consumption at the 35 kV voltage level (industrial customers at 35 kV) in the last twenty years has seen a significant drop. Existing customers at 35 kV voltage should be solved in accordance with the transition to direct transformation of 110/20 kV, so that these customers, depending on the required maximum power, are customers at 110 kV or 20 kV voltage. The medium voltage network is mostly isolated, but with characteristics that earth currents have exceeded the recommended values for most distribution areas and operating conditions. Only a small part of the network of electricity distribution Sarajevo (ED Sarajevo) works with a neutral point grounded through a small resistor. The development of

the electricity distribution network is accompanied constantly by the increased presence of the underground cable network in relation to the overhead network. This leads to a constantly increase in earth fault currents so that the option of an isolated MV distribution network is no longer an acceptable solution. This means that the further development of the network should also consider the most favourable network operating conditions and the appropriate treatment of the neutral point. Also, in recent years, the installation of a multi-purpose self-supporting cable or universal cable (UKB) is present, mostly due to the inability to resolve property-legal relations for an adequate passage of lines. Considering the significantly higher value of the UKB's permissible capacity, this also leads to an increase in earth fault currents. This fact, as well as the high cost and lesser bandwidth of the UKB, have led to the justification of using UKB only in exceptional cases. The transition of the network to the voltage level of 20 kV significantly reduces the losses of electrical energy and increases the throughput of the existing feeders, but also leads to doubling the value of existing earth fault currents. In the part of the LV network, it has been shown that some TS 10(20)/0.4 kV often belongs to the excessive length of the LV network. On the long LV feeders, voltage conditions are often threatened, so requests for the implementation of interpolation of new TS in order to shorten the network and reduce losses are made. In the existing overhead network of low voltage there are also problems of worsening of a larger part of the network on wooden poles, a large proportion of conductors with a cross-section of Al/Fe 25 mm² and lesser and a larger voltage drop. Therefore, for the part of the existing network, reconstructions need to be planned.

1.1. Input data and model of the existing network

In order to make a development projection, first of all it is necessary to dispose of up-to-date models of distribution network and objects. It is also necessary to include distributed resources. On models of the network, it is necessary to set the profiles of existing customer loads and forecasted consumption/production. In the schemes prepared in this way, the calculation of the existing and perspective states is done. In EP BiH, the basic data about network construction are available in the database of distribution electrical energy objects (DEEO), which has been in operation for several years. This database includes MV and LV distribution networks, transformer stations as well as scheduling of connection points. For the modelled MV network, energy analyses were carried out in the PowerCad software tool. For the analysis of LV networks, the WinDis software tool was used. These software tools do not allow automated download of data from the DEEO database, so that only the updating of the basic network models is quite extensive work. Therefore, in EP BiH, the procurement of a software tool for network calculation is considered, which will be able to communicate with the database and automatically download changes on the network. For the purpose of balanced development of the

electricity distribution network, a study survey defined the list of criteria for determining investment priorities such as: ensuring the undisrupted connection of all new customers and producers, fulfilment of requirements regarding the quality of electrical energy in terms of voltage conditions, reliability and security of electricity delivery. When planning the projection of distribution network development, it is necessary to anticipate permanent modernization, i.e. gradual replacement of individual devices with new and modern ones, and installation of modern devices that contribute to a more reliable distribution network operation and a better supply of its users. Here, apart from technical criteria, the economic principles of distribution network planning should be taken into account through the valuation of profits and costs of installation or replacement of devices.

1.2. Classification to regional units

In order to achieve a better quality of the development of the distribution networks of EP BiH, taking into account the specificities of certain areas, the research is based on the definition of regional units. Regional units have been selected in such a way that the application of appropriate criteria, for the projection of the development of the electricity distribution network, for the selected area, gives a clear and precise projection of the development of the observed area. For each regional entity, the existing situation is examined in detail regarding the structure of the network and facilities and the structure of consumption/generation of electrical energy. That is, when defining regional units, special attention is paid to the following specificities:

- 110 kV network topology and planned construction of new TS 110/x kV,
- representation, load and structure of existing supplied TS,
- topology and construction of MV network,
- preparedness of the existing 10 kV network for transition to the voltage level of 20 kV,
- preparedness of existing supplied TS for transition to direct transformation and voltage of 20 kV,
- treatment the neutral points of the MV network,
- consumption/production structure distributed according to download/injection sites in MV and LV networks,
- planned construction of new MV lines between significant power points or adjacent feeders,
- length of the LV network of individual TS 10 (20)/0.4 kV, that is, the length and structure of the LV feeder,
- load of existing TS 10(20)/0.4 kV,
- current organization of EP BiH by ED sections and distribution units,
- spatial and geographical specificity.

Implementation of the previous items, the area supplied by the electricity distribution network of EP BiH is divided into 21 regions, which is shown in Table I and Figure 1.

Table I: A tabular overview of the defined regional units in the EP BiH area

ED	Region	Municipalities
ED Bihać	Region I	Bihać without Kulen Vakuf and Martin Brod
	Region II	Cazin, Velika Kladuša, Bužim and Bosanska Krupa
	Region III	S. Most and Ključ
	Region IV	Bosanski Petrovac with Kulen Vakuf and Martin Brod
ED Mostar	Mostar	Mostar and Nevesinje (part)
	Jablanica	Jablanica and Prozor (part)
	Konjic	Konjic
ED Sarajevo	Region I	Centar, Stari Grad, Novi Grad, Novo Sarajevo and Ilidža
	Region II	Vogošća and Ilijaš
	Region III	Hadžići and Trnovo (PJD Hadžići)
	Region IV	Goražde, Foča-Ustikolina and Pale-Prača
ED Tuzla	Center	Tuzla and Lukavac
	North	Čelić, Doboj Istok, Gračanica, Gradačac and Srebrenik
	South	Banovići, Kladanj and Živinice
	East	Kalesija, Sapna and Teočak
ED Zenica	ZDK North	Tešanj, Doboj south, Maglaj and Zavidovići
	ZDK Center	Žepče, Zenica and Kakanj
	ZDK South	Visoko, Breza, Vareš and Olovo
	Basin of river Vrbas	Bugojno, Gornji Vakuf-Uskoplje and Donji Vakuf-Jajce
	Basin of river Lašva	Travnik, Vitez and Novi Travnik
Basin of river Bosna	Fojnica and Busovača-Kiseljak	

For each regional unit, the following analyses have been made:

- analysis of power flows and voltage conditions,
- analysis of trends in the increase in consumption in the previous period,
- urban, regulatory and other plans of the observed area,
- current requirements for connecting customers/producers,
- consumption/production forecast for the next ten-year period,
- analysis of the number and length of interruptions in electricity supply (SAIFI and SAIDI),
- analysis of LV networks based on available data from the database of technical data DEEO and all other available information (measurements, end-customer complaints, analysis of connection conditions in the process of electrical energy delivery, information from relevant organizational units, etc.).

Based on the analysis of the current state and characteristics of the existing network, as well as the forecasts of consumption and production of electrical energy, the projection of the electricity distribution network and facilities development for the selected regions with determined dynamics of investments in certain types of projects was made. In addition, for each regional unit, unique criteria and methodology of planning were applied.

2. METHODOLOGY USED FOR PLANNING

For purpose of making a development plan for the electricity distribution network and the construction of new objects, it is necessary to make appropriate power flow calculations and to observe the voltage values in the discontinuity points of the power distribution network. When planning, the criteria of voltage constraints and thermal constraints should be respected. In most cases, backup supplies should also be planned. Modern methods of planning the development of electricity networks include several interrelated analyses related to the safety and reliability of power supply, the “n-1” availability of the distribution network, the economic validity of investments in the distribution network. The purpose of the methodology and criteria for planning the development of the distribution network is the establishment of procedures and rules and defining guidelines that will ensure coordinated and efficient planning and construction in order to fulfill the long-term ability of the distribution network to fulfil the requirements for electricity distribution. Methodology and planning criteria apply equally to all distribution network users. Since the development of the electricity distribution network is a long-term process, with concrete specifics and working conditions have to be respected, the chosen methodology basically represents the application of general criteria and commitments, while adapting to specific conditions of design, construction, expansion, the current condition of equipment and operating modes in certain areas.

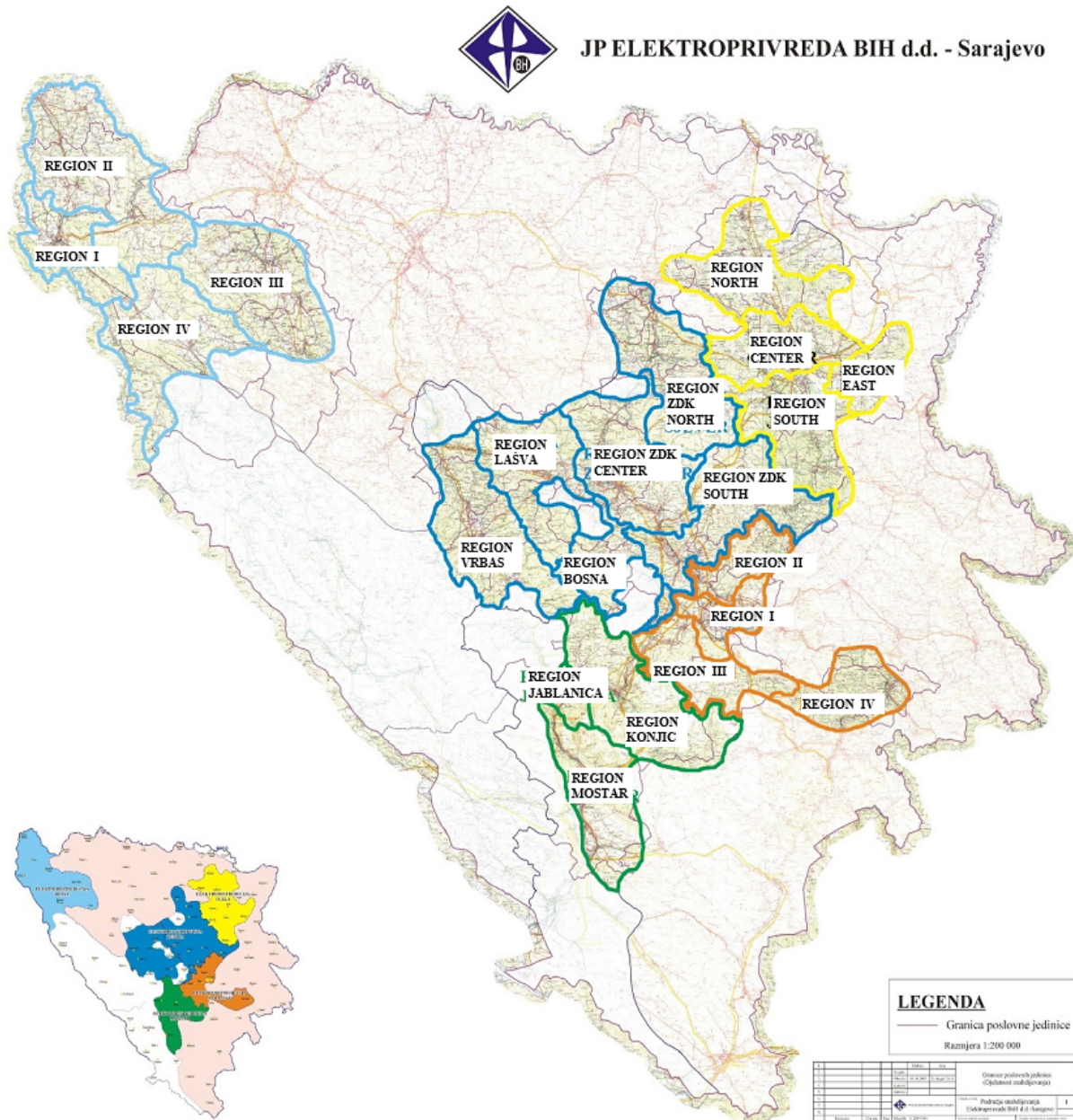


Figure 1: Geographical representation of defined regional units in the territory of EP BiH

2.1. Forecast consumption/production of electrical energy

Based on a trend analysis of the increase in consumption in the previous ten years, the electricity consumption forecast, for the projected period of 2015 – 2025, was made. When forecasting consumption, the impact of all customers and manufacturers who submitted the request for connection as well as those customers and manufacturers whose connections are expected based on regulatory, spatial and urban plans are taken into account. An aggravating circumstance in the development of a load forecast was that not all municipalities had proper and reliable regulatory plans. In the PowerCad software tool for analysis of distribution networks, models of the entire MV network of EP BiH for the existing and perspective state were made.

2.2. Strategic guidelines for planning the development of power distribution systems

For the development of the distribution network, the following key areas are identified as priority choices: transition to voltage level 20 kV, shortening of LV networks, introduction of intelligent measurement systems and automation with application of information and communication technologies (ICT). Long-term strategy and plans should be directed to the aforementioned areas, with recommendations to consistently and systematically implement the strategy of transition the network and objects to the direct transformation of 110/20 kV. Also, the calculations have shown that it is necessary to be installed in a larger volume of TS 10(20)/0.4 kV of low power in the existing network in order to shorten the low voltage lines.

2.2.1. Gradual replacement of the voltage level of 10 kV with 20 kV

The gradual replacement of the voltage level of 10 kV with a 20 kV voltage level is essentially a long-term process. In EP BiH, for more than twenty years, in the construction of new and reconstruction of existing objects, equipment adapted for the voltage of 20 kV is installed. Completion of this process and work with the voltage level of 20 kV should first be realized in overhead networks and later on in urban cable networks. The reason for this is that, in overhead networks, the application of 20 kV voltage leads to significantly less losses and better voltage conditions and for customers on remote parts of the feeder. In addition, economically observed, it is easier to implement adjustments to the voltage of 20 kV in overhead networks. Cable networks, even those with cables of older versions, have significantly better bandwidth than overhead networks, these networks are concentrated and in the event of an increase in load, the voltage conditions and increased losses in the MV network will not be affected. From the economic point of view, it is more demanding and expensive to adapt the underground cable network to operate at 20 kV voltage. Under practical conditions, there have been cases when we have a significant increase in load and demands for new connections at medium voltage and that the construction of supplied TS is delayed. Some of these cases can be solved by transition to 20 kV voltage level, which is the best techno-economic solution.

2.2.2. Introduction of direct transformation and concept of new TS 110/x kV planning

In the construction of new supply transformer stations, the transition to transformation 110/10(20) kV is preferred. In the first periods of the introduction of direct transformation in urban areas, the transformation of 110/10 kV will be more presented, while transformation of 110/20 kV will be more presented in rural networks. Recommendation, based on analyses of electro-distribution areas, in the first periods of direct transformation, is that simplified TS 110/10(20) kV with low-power transformers (8 or 10 MVA) should be installed. It goes on gradually suppression of the voltage level of 35 kV and TS 35/10 kV. In case of the need for reconstruction of the existing TS 35/10 kV (although this situation should be avoided), the equipment for 20 kV is installed and plans for the subsequent upgrading of the 110 kV plant, that is, only a temporary 35 kV plant is planned. Transformation stations 110/10(20) kV have the purpose of distribution or supply of end customers, while the previous TS 110/35 kV were in the function of transmission of electrical energy. Changing the basic role of the TS determines a significantly different approach to the location selection. Also, the concept of direct transformation should lead to lesser technical losses of electrical energy. Figure 2 shows the concept of the distribution network with direct transformation and the concept with the 35 kV network.

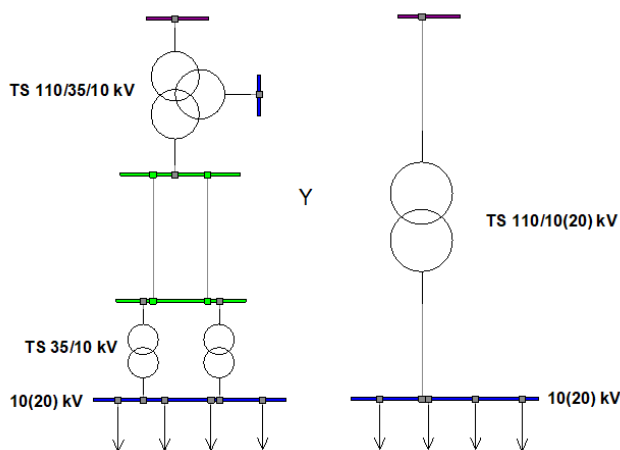


Figure 2: Comparison of the distribution network concept with voltage of 35 kV and concept with direct transformation 110/10(20) kV

2.2.3. Connection network 10(20) kV

The advantage of the 20 kV network in relation to 10 kV is the possibility of better connection and the provision of alternative power from the neighbouring supply TS. This is possible on overhead networks where transition to the voltage level of 20 kV provides better voltage conditions and the possibility, within the allowed voltage drops, to connect to the neighbouring source point. This will significantly affect the security of the power supply and the better value of the reliability indicators. When planning the development of a distribution system, the criterion of permitted current load is the basic technical criterion for the operation of the network. The selection of cable and overhead MV lines in EP BiH is standardized and implemented in accordance with technical recommendations. The medium voltage network should also be equipped with sufficient number of power line disconnectors connected to the remote control and management system. It is planned to replace the existing voltage levels of 35 kV and 10 kV with one voltage level of 20 kV.

2.3. The concept of LV network development

The existing low voltage network, especially in rural areas, is not optimally built. In EP BiH, the TS 10(20)/0.4 kV is on average connected to excessive length of the LV network, often a small cross section of the conductors. On the TS 10(20)/0.4 kV, 3.37 km of LV network is connected on average. The development of the low voltage network should be directed so they have short low voltage feeders and simplified TS 10(20)/0.4 kV with transformers of relatively low nominal power. Short low voltage feeders are achieved by interpolating new secondary TS. Due to reduction of losses, repair of voltage conditions and increased reliability, a small section of conductors needs to be changed. Where possible, it is recommended to use self-supporting cable bundles in overhead networks. In the next ten-year period, it is necessary to shorten the LV network to approximately 2.5 km of LV network by TS. In the forthcoming period, a correction of the LV network is foreseen in order to meet technical limitations for the realization of remote measurement systems.

3. RESULTS OF THE IMPLEMENTED ANALYSIS

The study “Development projection of the distribution networks of EP BiH” provides a comprehensive projection of the development of the distribution networks of EP BiH for the period 2015-2025 [8]. For the illustration, several graphically unified research results are presented here. The conducted analysis showed that in the next ten years it is necessary to realize 1762 projects divided into four basic categories: primary electrical energy objects (EEO), MV lines, transition to 20 kV and secondary TS. There are many different needs of individual regions and ED parts depending on the investment structure and the amount of investment. As an example, Figure 3 gives a graphical presentation of the required investments by 2025 for the Electrical Distribution System of ED Sarajevo and the respective regions. For example, it can be seen that region I needs the highest investment in supplied TS, while the needs of other regions for this type of projects are far less-

er. Figure 4 shows a graphical presentation of the required investments by 2025 for the regions of ED Tuzla. It seems that the largest investments in the new TS 110/x kV are needed for the area of the Centre region. The area of this region had a rather developed 35 kV network and here it should be gradually transit to direct transformation. For example, the area of the North region has a partially represented direct transformation and here more investment is needed in building a MV network and transition to a voltage level of 20 kV. Figure 5 gives a graphical representation of the investment to the type of project for the entire area of EP BiH. For example, the required investments in interpolation of secondary TS are approximately the same for the areas of ED Tuzla and ED Zenica. In ED Bihac, for the area of region II, the most necessary interpolations of secondary TS are recorded. For all types of projects, an appropriate year is also planned. For illustration, Figure 6 shows the required dynamics of investment in the electrical distribution network in the ED parts.

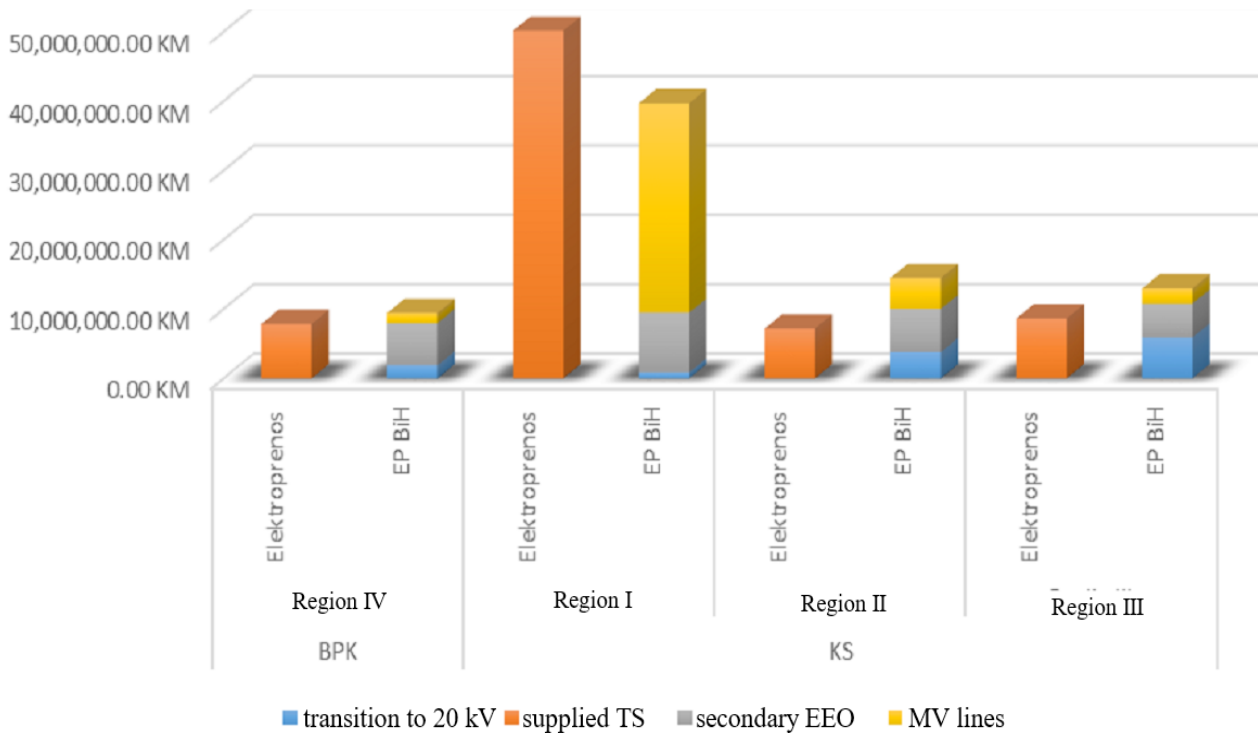


Figure 3: Overview of investment in EES by type of project for ED Sarajevo

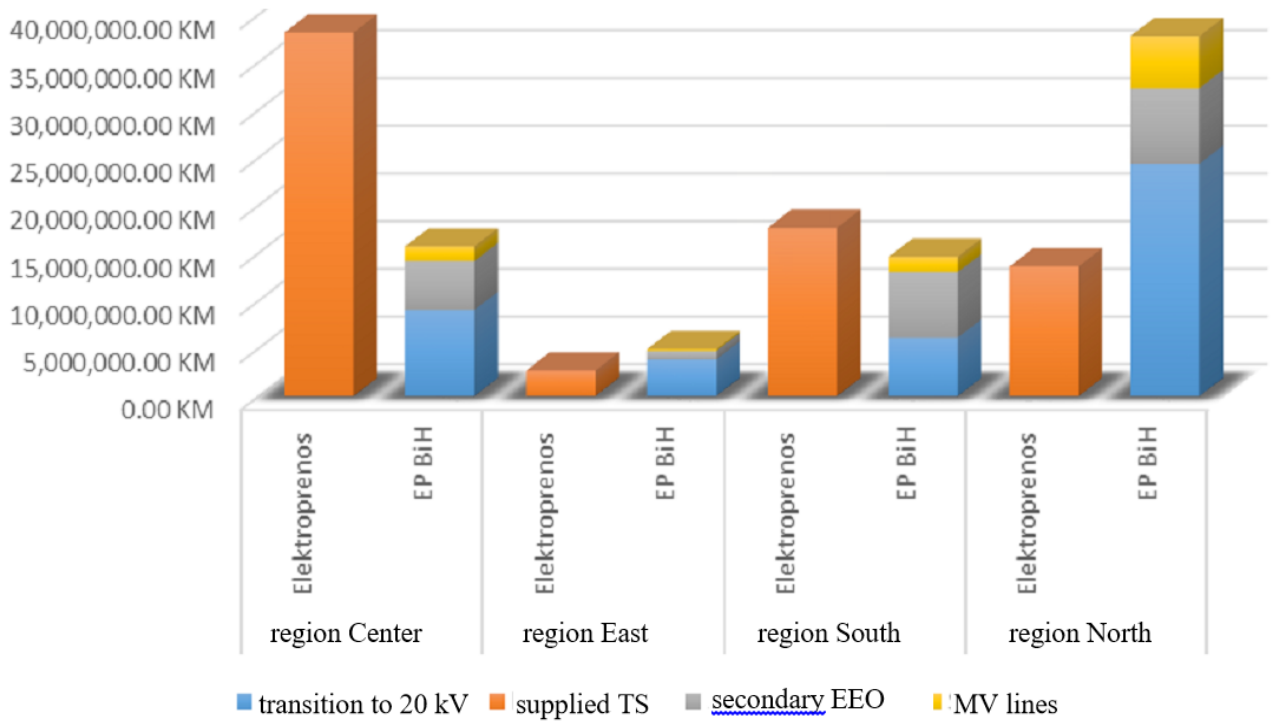


Figure 4: Overview of the investment in the EES by type of project for ED Tuzla

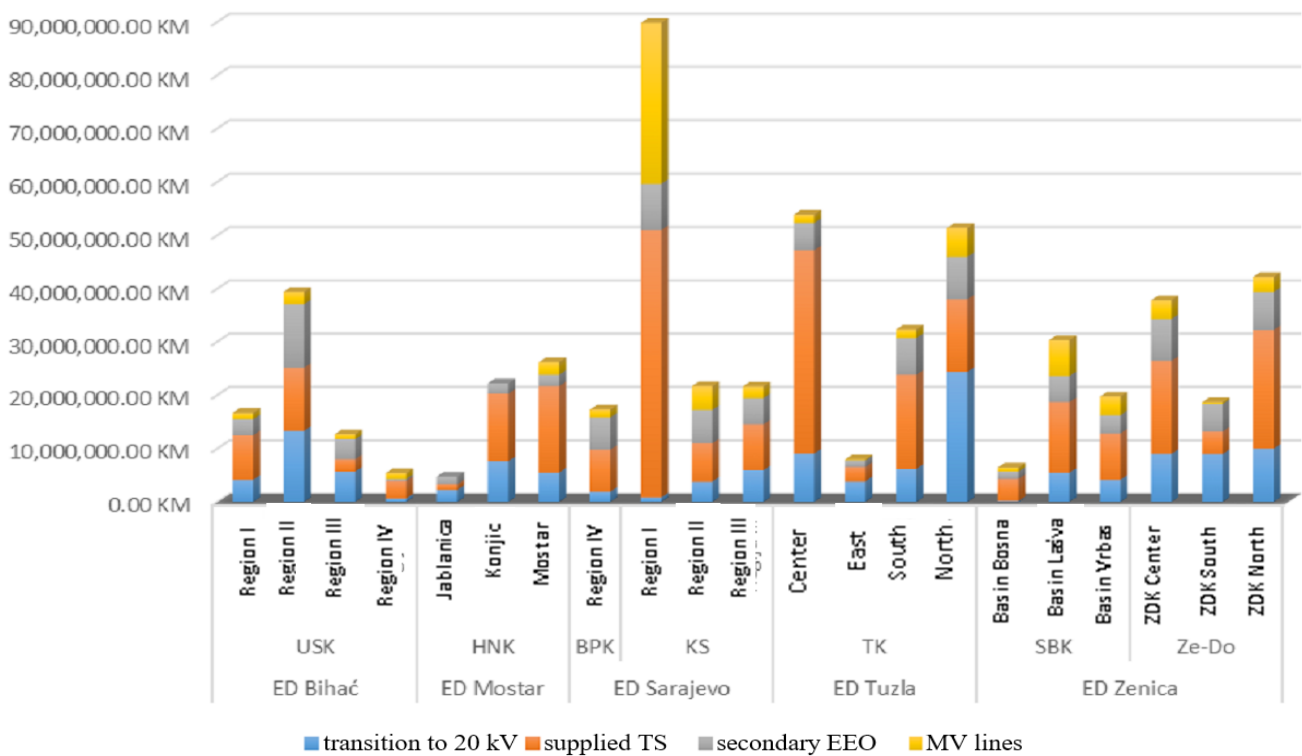


Figure 5: Comparison of investment in EES by type of project and regions

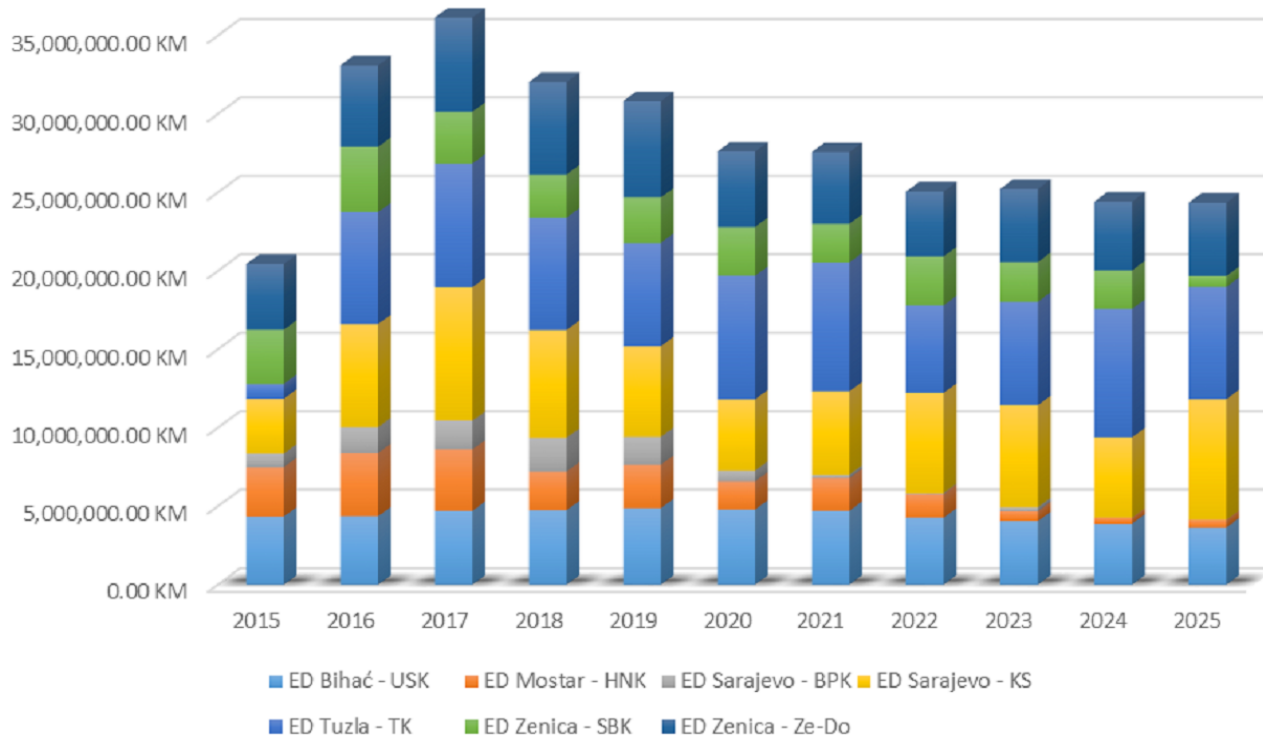


Figure 6: Dynamics of investment in the electricity distribution network by ED parts

4. CONCLUSION

Research on this topic has shown that it is extremely difficult to define a long-term projection of the development of the electricity distribution system in the current circumstances. First of all the reason is the absence of adequate official documents of social and economic development at all levels. Also, the development of the primary electricity transmission network was completely stopped, for a time, by various blockades. This significantly influenced the existing practice of expanding the electricity distribution system to connect new consumers/producers as well as to reflect on the projections of the future development of the electricity distribution system. The problem with long-term planning may also be the incomplete database, especially for the LV network. The dynamics of realization of projects for transition the MV network to 20 kV will largely depend on the dynamics of realization of investment projects in the primary TS. Therefore, in the initial years of the period from 2015 to 2025, it foresees the realization of projects for which there are already existent ones, or, in smaller reconstructions, preconditions in the primary TS can be created, while in the second period it is envisaged to realize projects whose realization depends on timely investment in the primary TS. By transition to the unique MV voltage level of 20 kV, in addition to the multiple savings and simplifications of the electricity distribution system, its capacity and accessibility to new consumers/producers is doubled. In the construction of new MV lines and secondary TS, the realization of the connection of new consumers and producers is a priority given

the basic role of DSO, and in the following phases the construction of MV lines is considered for the purpose of achieving the “n-1” criteria or improving the technical characteristics of the network. It turned out that it is necessary to intensify the total necessary investments in the development of the electricity distribution system in the system areas, in relation to the previous period, if the DSO wants to fulfill all the goals and objectives defined by the laws and norms.

REFERENCES

- [1] „Opšti uslovi za isporuku električne energije“, Regulatorna komisija za energiju u Federaciji BiH – Regulatory Commission for Energy in the Federation of BiH – FERK, Mostar, 2014
- [2] „Mrežna pravila distribucije JP EP BiH“, FERK, Mostar, November 2008
- [3] „EN 50160 – Voltage characteristics of electricity supplied by public distribution systems“, CENELEC, April 2011
- [4] S. Spahić, E. Bećirović, M. Salihović, E. Nukić, Dž. Mahmutović, H. Krvavac, Š. Gruhonjić Ferhatbegović, F. Hidić, N. Hasanspahić: Analiza razvoja srednjenaponskih distributivnih mreža u JP Elektroprivreda BiH d.d. Sarajevo sa aspekta prelaska na 20 kV naponski nivo, PE Elektroprivreda BiH d.d – Sarajevo 2013
- [5] S. Avdaković, S. Spahić, M. Salihović, Š. Gruhonjić Ferhatbegović, K. Serdarević, S. Delić, A. Selimić, R. Muminović, I. Penava, N. Hasanspahić: Perspektiva 35 kV naponskog nivoa u JP Elektroprivreda BiH d.d. – Sarajevo, PE Elektroprivreda BiH d.d – Sarajevo 2014

- [6] S. Avdaković, Z. Bajramović, Š. Gruhonjić Ferhatbegović, M. Salihović, S. Dupanović, E. Nukić, M. Šarić, A. Ibreljić, H. Semić, A. Jusić, J. Agačević: *Tretman neutralne tačke u distributivnim mrežama JP Elektroprivreda BiH, PE Elektroprivreda BiH d.d – Sarajevo* 2016
- [7] „Prognoza potrošnje električne energije do 2030. godine po elektrodistributivnim podružnicama JP Elektroprivreda BiH d.d. Sarajevo“, PE Elektroprivreda BiH d.d. – Sarajevo, Oktober 2011
- [8] S. Spahić, M. Mehović, A. Balić, Š. Gruhonjić Ferhatbegović, F. Hidić, B. Kurić, E. Nukić, I. Penava, N. Hasanspahić, M. Salihović, A. Bosović: *Projekcija razvoja distributivnih mreža JP Elektroprivreda BiH d.d. – Sarajevo za period 2015. – 2025. godina, PE Elektroprivreda BiH d.d – Sarajevo* 2015

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