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GRID AUTOMATION PLANNING OF CROATIAN DISTRIBUTION NETWORK OF ELEKTROISTRA PULA

SUMMARY

The distribution system operator of Croatia (HEP ODS), Energetski institute Hrvoje Požar (EIHP) and Siemens AG conducted a grid automation planning study for the Elektroistra Pula region in order to increase the reliability by integrating automation functions into the medium voltage network.

Based on network planning variants for the years 2022 and 2032 different automation scenarios with a changing degree of substation automation were proposed and analyzed. For each planning year the position and quantity of the evaluated automation equipment is determined and is evaluated in a techno-economical assessment.

As a result, the technical and economic efficiency of the application of different standard and innovative solutions based on the synthetic network approach is compared and the optimal measures have been derived, in order to develop a methodology to transfer these results to additional networks.

It could be shown that with the cost-efficient integration of automation function with smart ring main units with remote control, the current SAIDI can be reduced significantly and the target value can be achieved.

Key words: network automation, reliability, SAIDI, synthetic network approach

RAZVOJ AUTOMATIZACIJE DISTRIBUCIJSKE MREŽE ELEKTROISTRE PULA

SAŽETAK

HEP Operator distribucijskog sustava (HEP ODS), Energetski institut Hrvoje Požar (EIHP) i Siemens AG izradili su studiju razvoja automatizacije distribucijske mreže za distribucijsko područje Elektroistra Pula kako bi povećali pouzdanost distribucijske mreže.

Na temelju prethodno definiranih ciljanih varijanti razvoja mreže za 2022. i 2032. godine predloženi su i analizirani različiti scenariji automatizacije s promjenjivim stupnjem automatizacije srednjenaponske 10(20) kV mreže Za svaku godinu razmatranog planskog razdoblja definirane su lokacije, položaj i količina opreme za automatizaciju uz tehno-ekonomsku analizu.

Rezultati studije su tehnička i ekonomska analiza učinkovitosti primjene različitih standardnih i inovativnih rješenja temeljenih na pristupu sintetske mreže, zatim dobivene optimalne mjere automatizacije te razvijena metodologija za primjenu u definiranju razvoja automatizacije na ostala distribucijska područja.

Ključne riječi: automatizacija distribucijske mreže, pouzdanost, SAIDI, pristup sintetske mreže

1. Introduction

HEP Operator distribucijskog sustava d.o.o. (HEP ODS), as the sole distribution system operator in Croatia, is responsible for the electricity distribution and supply for in total 21 distribution areas in Croatia. As most of European DSOs HEP ODS is facing diverse challenges regarding their electrical power supply, which result from different developments in this sector over the last decades, e.g. heterogeneous increasing demand for electric power, increasing expansion of decentral generation units and enhanced requirements regarding the economy of lifetime for assets and regulatory obligations. As a result, cost-effective investments and economic operation as well as long-term concepts are gaining more importance. On top of these challenges HEP ODS sets additional key business objectives which should be achieved in the future and strives towards increasing the quality of electricity supply, the general operating efficiency, enhancing energy efficiency in electricity distribution and the development of the distribution network into the distribution system with advanced solutions.

In order to face these challenges and to achieve the targeted objectives HEP ODS in particular wants to implement a smart grid concept with an emphasis on distribution automation (DA), smart network control and operation to benefit from these technologies in a long term and to increase the reliability of supply.

Primary objective of this study is the evaluation of the integration of network automation functions in the Elektroistra Pula in the north-west region of Croatia in order to improve reliability of electricity distribution by decreasing the unavailability of customer supply (SAIDI). To enable this, the localization and the amount of automation infrastructure will be determined based on a synthetic network approach. The automation concept should serve as a blueprint for other regions.

This paper summarizes the development of the automation concept for the Elektroistra Pula distribution network to answer the following questions:

- How to increase reliability and power security by increasing the level of network automation?
- Which automation concepts are suitable and how can the appropriate technology be selected?
- What are suitable locations for metering and remote-controlled points in the network?

2. Current Network and Future Expansion State

The medium voltage (MV) network of Elektroistra Pula Region comprises the voltage levels 35 kV, 20 kV and 10 kV with a maximum load of about 290 MVA. The total network length amounts to 3000 km with a relatively low cable density of 38 %.

The distribution network is mainly ring structure or a simple radial scheme for suppling areas with low customer density, especially in the 20 kV network based on overhead lines. The MV network faces only a relative low share of critical line utilizations but shows a high voltage drop of about 12 % between the primary substations and last ring main units (RMU) in the feeders due to spacious network structure (see Figure 1). As no information on the LV-network is available, the voltage drop in the MV network to 92.4 % of nominal voltage might exceed the threshold value of +/-10 % according to the EN 50160 [1]. This behavior is to be corrected in target network planning.

The Elektroistra Pula network is operated by one local dispatching center. The current level of network automation allows the monitoring (one-way communication to distribution substation or control center) to control, monitoring, and automation (two-way communication to distribution substation or control center) by remotely controlled disconnectors and tap changers.

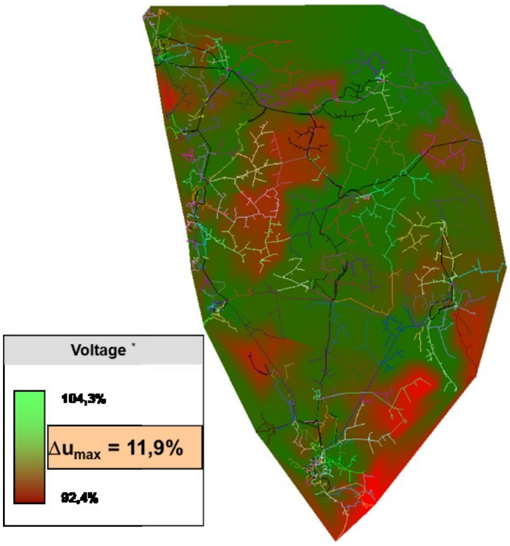

Figure 1. Overview of voltage range deviation in DA Elekroistra Pula.

But the remote control and automation does only exist in about 50 MV/LV transformation stations, affecting the quality of normal or maintenance regime management, leading to increased time for localization and liquidation of networks outages. The troubleshooting and clarification, especially for long 20 kV feeders, is done by "on-site" switching which resulting in a poor reliability of supply for the Elektroistra Pula region. The current network reliability was evaluated by the DISQUAL indexes SAIFI (System Average Interruption Frequency Index) and SAIDI (System Average Interruption Duration Index) [2]. The indexes are defined according to equation (1) and (2).

$$SAIFI = \frac{Total\ number\ of\ customer\ interruptions}{Total\ number\ of\ customers\ served} \tag{1}$$

$$SAIDI = \frac{\sum Customer\ interruption\ durations}{Total\ number\ of\ customers\ served} \tag{2}$$

In order to reproduce the HEP ODS statistical indexes, the German FNN failure statistic [3] was applied on the network and the reliability data was trimmed to achieve the average SAIFI value by adjusting the failure rate. Assuming that the cables don't need maintenance, the behavior has to be the same as in Germany and so the same failure rate. In this case the failure rate of the overhead line (OHL) was increased. The statistical reliability indexes and the calculated indexes with the adjusted failure rates for the present network are presented in Figure 2.

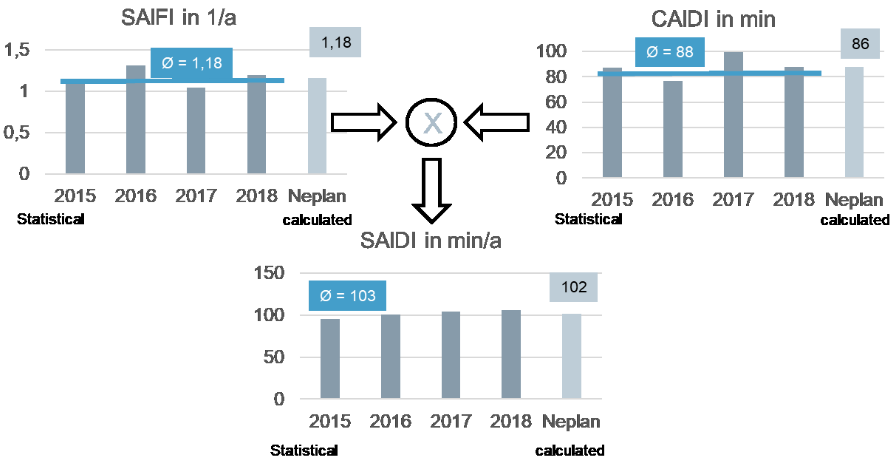

Figure 2. Elekroistra Pula statistical reliability indexes and the calculated indexes for the present network.

The MV network shows high values and spread of interruption frequency, whereas the recovery time in some network parts with radial structure is very high, see Figure 3.

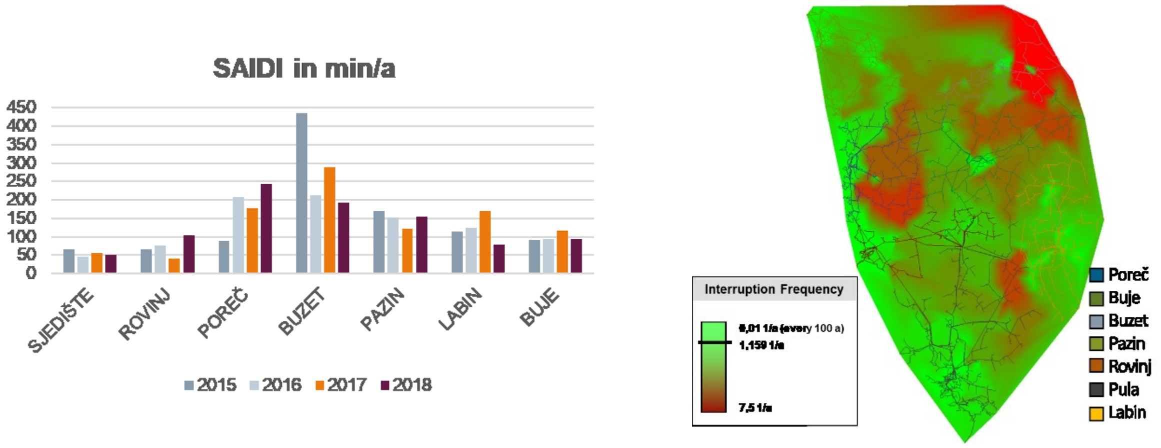

Figure 3. SAIDI values from statistic for each region in Elektroistra Pula and calculated SAIFI values.

SAIDI is a product of total number of customer interruptions and their interruption durations. To reduce SAIDI, the failure frequency (cable instead of overhead line) or the duration of resupply of the customers can be decreased. Due to change from overhead lines to cable the unavailability can be significantly reduced but the time period of over 60 years and the cost-benefit ratio due to the customer density have to be considered.

3. Methodology for Grid Automation Planning

After the analysis of the current network performance a methodology for grid automation planning for the Elektroistra Pula region is applied based on a synthetic network approach. Based on the current reliability level a target unavailability for the SAIDI value was defined, which was to halve the present value (SAIDI = 102 min/a) and that was used as a planning basis for subsequent steps. The followed approach to determine an optimal network automation to achieve the reliability targets is shown in Figure 4.

After a verification step and the comparison of calculated results with the provided statistical data, a reference network as a represented feeder for the present network is derived based on the network topology of the present grid (e.g. number of ring main units (RMU) per feeder, the distance between two RMU, cable density, number of short circuit breakers (CB), …).

This reference network was re-assessed with the results of the actual present network. Parallel to the automation planning for the present network the analysis were conducted for a target network for the year 2032 which was derived by EIHP within a network development considering conventional network expansion based on e.g. the load development.

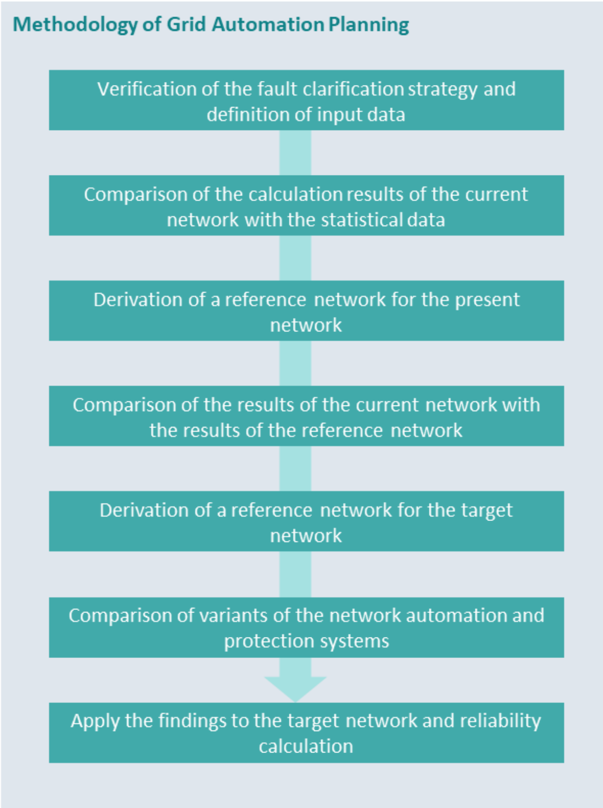

Figure 4. Methodology for the grid automation planning in Elektroistra Pula region based on a synthetic network approach.

Again, a reference network based on the target network for the year 2032 was derived analogue to the approach and basis of comparison to the present network.

Next the reference target network is analyzed with respect to the reliability index without any additional measures depending on the feeder length and the number of secondary substations on a feeder. It became apparent that the optimal protection/automation features are required to ensure, that the target SAIDI is met in all feeders (see Figure 5).

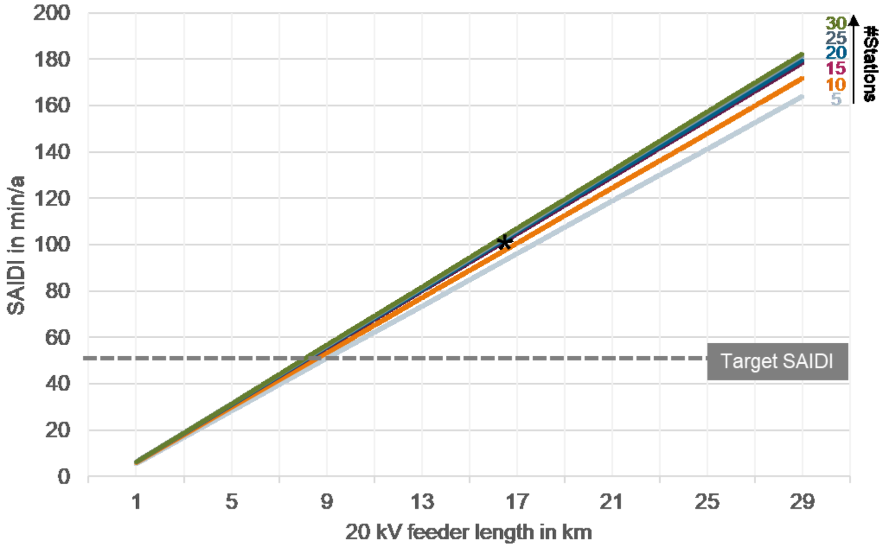

Figure 5. Reliability index without any additional measures depending on feeder length and amount of secondary substations of a feeder.

The target network based on conventional network expansion was complemented by an automation concept derived in this study by a methodology for grid automation planning with the objective to improve the reliability of supply. Therefore, different automation criteria to be implemented in the network were defined. As a result, three different variants were developed which differ with respect to their kind of automation (see Figure 6):

Variant 1: Variation of number of circuit breakers

Variant 2: Variation of number of smart RMU

Variant 3: Smart RMU with circuit breakers in feeder center and variation of smart RMU

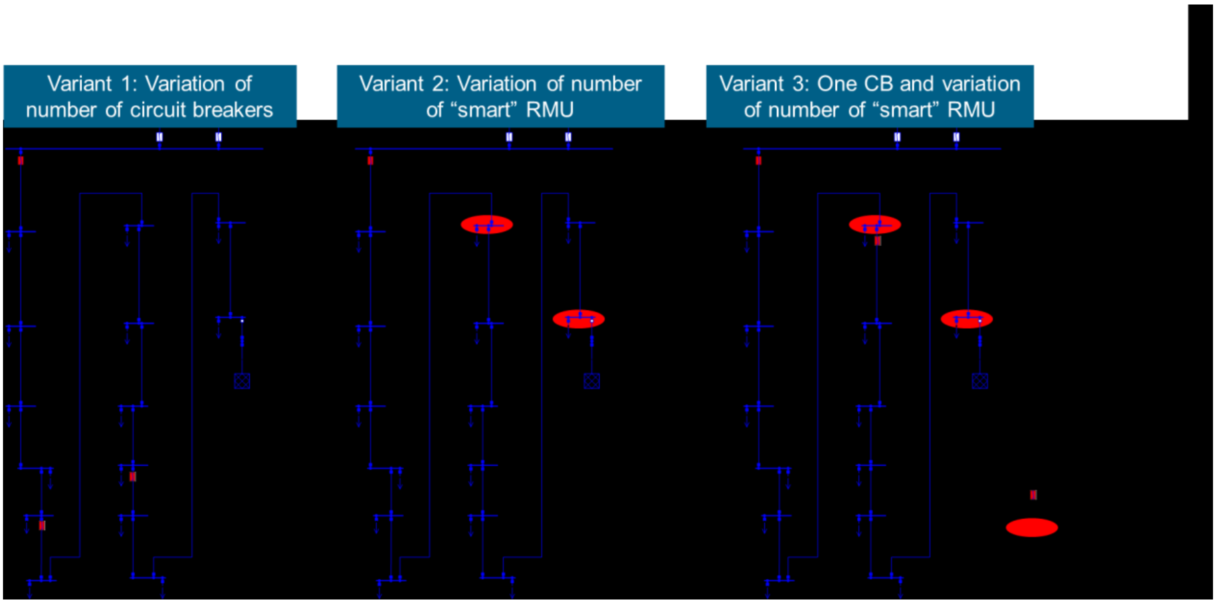

Figure 6. Automation variants for reference network.

The smart RMU in a feeder is equipped with remote controlled recloser and remote short circuit indicators. For each automation variant the length and number of RMU was varied. In case that the required unavailability was not achieved, appropriate automation was added to the feeder. For this, the optimum amount and position of the considered variables (CB and sRMU) are determined considering the time grading of protection systems and nodes with highest information gain or safety disconnection in order to comply with the target SAIDI value.

This approach is used to compare the quantity structures of the variants, from which the future automation concept can be derived. Since some feeders are already below this value without further measures, the SAIDI will also be below this value when applied to the target network. The basic statements made when comparing the quantity structures are, within certain limits, independent of the specified target SAIDI. An exemplary evaluation for the variation of number of smart RMU for variant 2 is shown in Figure 7. In the left diagram the feeders are represented by the length and number of RMUs. The right diagram represents the necessary number of smart RMU to achieve the target SAIDI depending on the length and number of RMUs per feeder. For this exemplary feeder (10 RMU, 15 km length) two sRMU are needed to achieve the target unavailability.

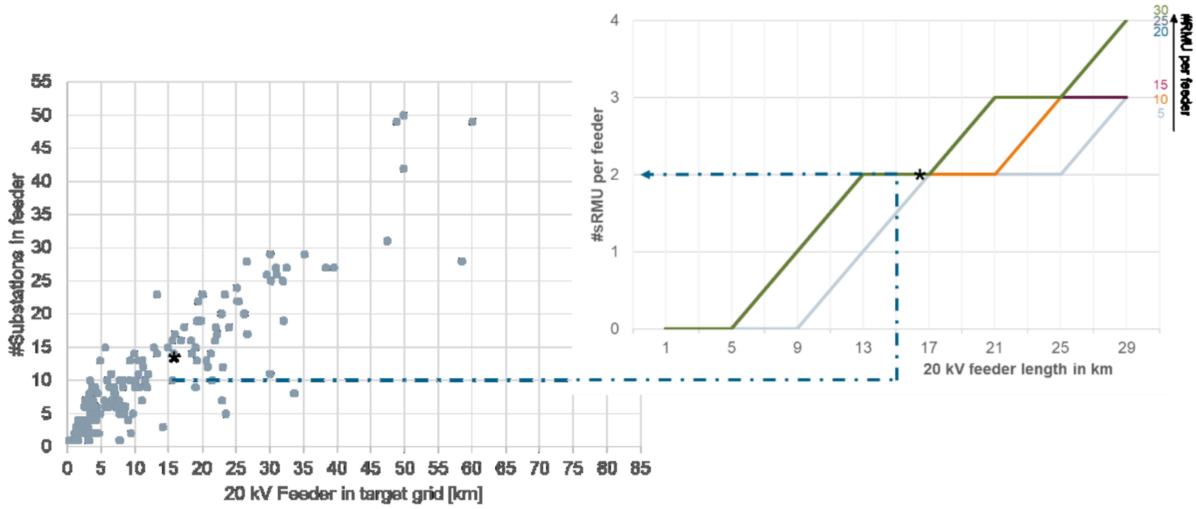

Figure 7. Necessary measures to achieve the target SAIDI for the variant 2.

Based on this reference network the required measures are derived for each variant in order to meet the target SAIDI value. The findings are then applied to the actual target network by adding the automation equipment into the network model. For this, length and number of substations per feeder with results of the synthetic network evaluation are compared.

Subsequent to the technical evaluation and the compilation of a bill of quantity for each variant an economical evaluation based on investment costs is conducted to derive an optimal techno-economical solution. Under these conditions variant 2 was chosen.

After the implementation of the automation into each dedicated feeder the target SAIDI of 51 min/a can be fulfilled. Figure 8 shows the results for interruption duration index by zones with their minimum, average and maximum values. Compared to the 20-kV network all 10-kV zones are clearly under the target value. The zones with larger mean values have long radial feeders without a possibility for changing the normal open point and resupplying the customers from neighbor feeders which are not affected by network failure.

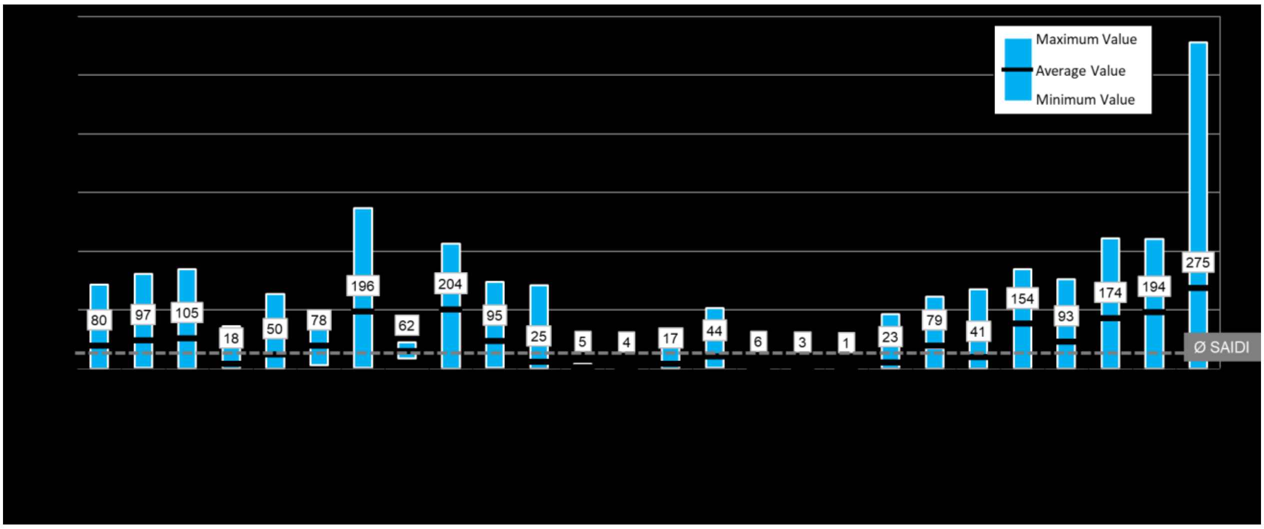

Figure 8. Interruption Duration Index by zones for the variant 2.

4. Conclusion

The objective of the study was to assess how to reduce the present unavailability in terms of the SAIDI value for the Elektroistra Pula region by half. It could be shown that the developed variants have a huge potential for the reduction of unavailability by using automation infrastructure compared to the current state. In addition, by increasing the share of cables in the MV-network the unavailability can be significantly reduce as well by decreasing the frequency of interruptions. However, this approach needs to be seen against the background of the long-life cycle of the components and also against the cost-benefit ratio due to the customer density. Nevertheless, target unavailability is not reachable without additional automation function in the present network.

In a comprehensive comparison of the variants it could be shown that the integration of a defined number of smart RMU (variant 2) represents the optimal techno-economical solution. With this variant the targeted SAIDI of 51 min/a can be achieve.

Moreover, the proposed approach for the grid automation planning for the Elektroistra Pula region based on a synthetic network can be transferred to the basic network structure and therefore be applied in other regions to reduce the unavailability by half.

5. Literature

[1] EN 50160 : Voltage characteristics of electricity supplied by public distribution system

[2] DISQUAL: Distribution Study Committee, UNIPEDE Group of Experts, 50.05.DISQUAL, Availability of Supply Indices UNIPEDE, Ref. 05005Ren9733, Paris, 1997

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[4] GAP – Grid automation planning – Elektroistra study, Siemens AG, EIHP, HEP ODS, 2020