INSTALLATION OF REMOTELY CONTROLLED ELEMENTS ON OVERHEAD HIGH VOLTAGE LINES IN THE NETWORKS OF EG.D. A.S.

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The paper deals with the installation of remotely controlled elements (RCE) in overhead high voltage lines in the networks of EG.D, a.s., and it primarily focuses on the installation of reclosers. The reclosers help reduce the impact of high voltage faults by contributing to shorter fault location times, and some customers are not affected by the fault at all. The methodology used to select the most suitable locations for installation is described, along with the development of the number of RCEs as well as the target number of the reclosers determined on the basis of an expert study. Furthermore, assumed and already visible impacts to SAIDI and SAIFI quality parameters are mentioned.

1. INTRODUCTION

In order to increase network reliability and to meet increasingly stringent SAIDI and SAIFI quality requirements, the distribution network operators have to continuously expand the number of remotely controlled elements in their networks. The HV voltage level is very important in this area, as it contributes the most to the overall SADI and SAIFI.

1.1. THE REMOTE CONTROLLED ELEMENTS IN OVERHEAD HIGH VOLTAGE NETWORKS

1.1.1. Remote controlled sectional disconnecting switches

A remote controlled sectional disconnecting switch (hereinafter referred to as a “switch” only) is a device that enables remote switching of a specific section of a high voltage line at rated load. The assembly as a whole consists of the disconnecting switch itself, a power supply transformer, a control arm, a drive and a control box. The switch permits manual local switching as well. The switches can also be fitted with P, Q, and U measurement.

Figure 1: On the left: switch, on the right: recloser

1.1.2. Reclosers

A recloser is a remotely controlled switch with a reclose function, located on an overhead high voltage line. Reclosers are equipped with measurement and monitoring functions. Contrary to the switches, they enable switching of short-circuit currents. This is what makes it very favourable. In the event of a fault on the feeder downstream of the recloser, the recloser's overcurrent protection will be activated and the entire feeder may not be disconnected. Hence, the high voltage fault will not affect such a large number of customers. Should there be a fault upstream of the recloser, the recloser still serves a purpose. A control room operator sees that the recloser has not tripped and therefore knows that the fault is located upstream of the recloser, which helps to locate the fault more quickly.

Figure 2: Detail view of the recloser

1.2. CURRENT SITUATION IN THE NETWORKS OF EG.D

EG.D, a.s. has been currently (2023) operating a total of 22,098 km of high voltage network lines. Of this, overhead networks account for 17,877 km, with the remaining 4,221 km consisting of cable networks. The number of cable lines increases every year, while the length of overhead cables slowly decreases.

In the first half of 2023, a total of 1,372 remotely controlled elements were installed in the overhead HV networks. There were 31,528 manually controlled elements in the network.

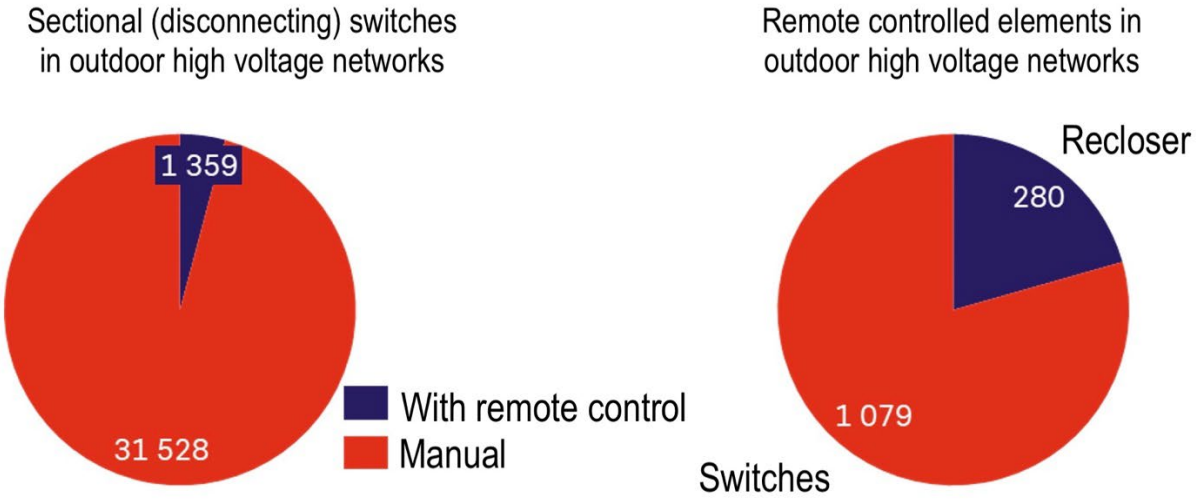


Figure 3: Number of sectional switches and reclosers in the high voltage networks in 2023

2. INSTALLATION OF THE RECLOSERS

2.1. A PILOT PROJECT

The first pilot project involving the installation of three reclosers took place in 2012 on the Malčice and Kasejovice lines. These reclosers were installed as part of the feeders powered from a single substation, and the possibility of parallel operation of the high voltage feeders was also tested here. This pilot project responded to changing laws, which introduced penalties for non-compliance with quality parameters. Insofar as the high voltage level has the greatest impact on SAIDI and SAFI parameters (roughly 80%), the decision was made to focus capital expenditures mainly on this level. One of the goals of the pilot project was to find suitable types of remote-controlled elements for high voltage levels.

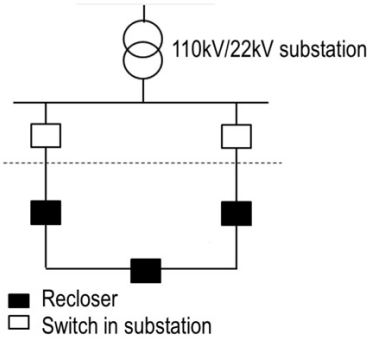


Figure 4: Location of the reclosers in the pilot project

The pilot project has demonstrated in practice that installing reclosers helps reduce SAIDI and SAIFI parameters more significantly than simply installing remote-controlled sectional disconnecting switches. After comparing the conclusions from the pilot project, considering all the technical advantages of the reclosers, and comparing the costs, which were about 20% higher for the reclosers, it was concluded that the technical benefits outweigh the increased capital expenditures. Therefore, the decision was made to install reclosers en masse, which were given priority over the remote controlled sectional disconnecting switches.

2.2. BLANKET INSTALLATION

For the first wave, it was decided to install 120 reclosers. The blanket installation began in the course of 2018. It was decided to increase the number of elements to 400 during the first wave of the installation.

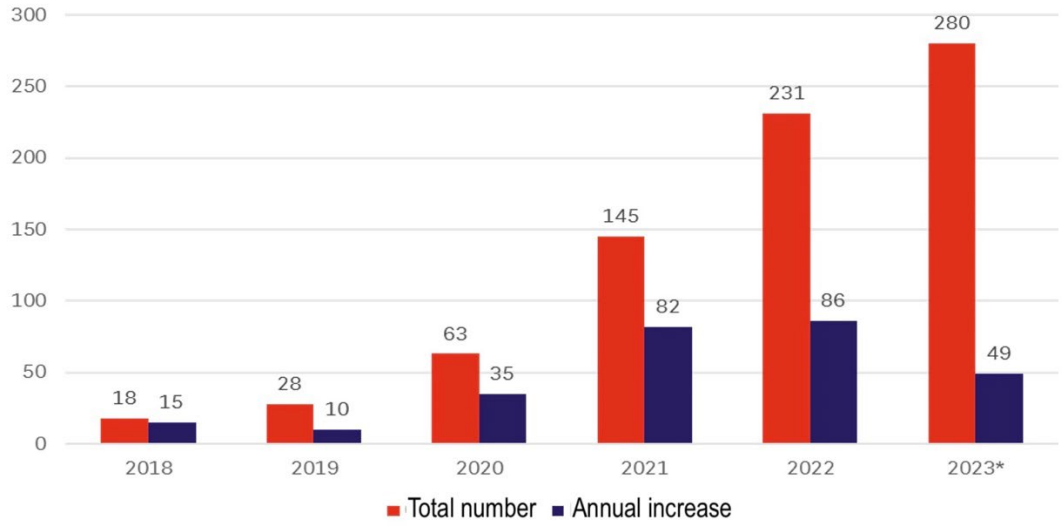


Figure 5: Development in number of the reclosers

2.2.1. Methodology for selecting installation sites

In order to determine the most suitable locations for installing the reclosers, an analysis of the fault rate of the high voltage lines and their share in the overall SAIDI and SAIFI was carried out. The "worst" 120 lines were selected for the installation of reclosers, with one recloser selected for each line.

In the second step, the most suitable location within the line was sought based on the localization of the faults to specific sections. If the faults were distributed evenly along the entire line, this ideal position would be exactly in the middle of the line. The more the faults were concentrated towards the end of the line, the more the ideal position shifted away from the substation, and vice versa.

The final decision on the selection of the locations was always made by the control room operators, who could make minor adjustments to the position based on their operational experience. In this way, the first 120 locations for the recloser installation were selected.

In the second wave, when the decision was made to increase the total number to 400, a similar methodology was used. In cases where coverage installations were selected based on the need to reduce SAIDI/SAIFI, the installations were carried out taking into account the needs of direct control. For this reason, the rule of a maximum of one recloser per line has also been abandoned. However, the rule of a maximum of one recloser in a series downstream of the substation was still observed, as each additional recloser increases the tripping time of the feeder protections.

This condition was abandoned when it was decided to continue installations after 2024, when the target of 400 units should be reached. The condition was modified to allow a maximum of two reclosers in series in the power supply route. This will lead to longer tripping times on the feeder protection, but will still not compromise safe operation.

The following figure demonstrates the possibilities for installing the reclosers while complying with the rule of a maximum of two reclosers in series. Though the feeder from the substation B does contain a total of three reclosers, there are no more than two in series downstream of the substation.

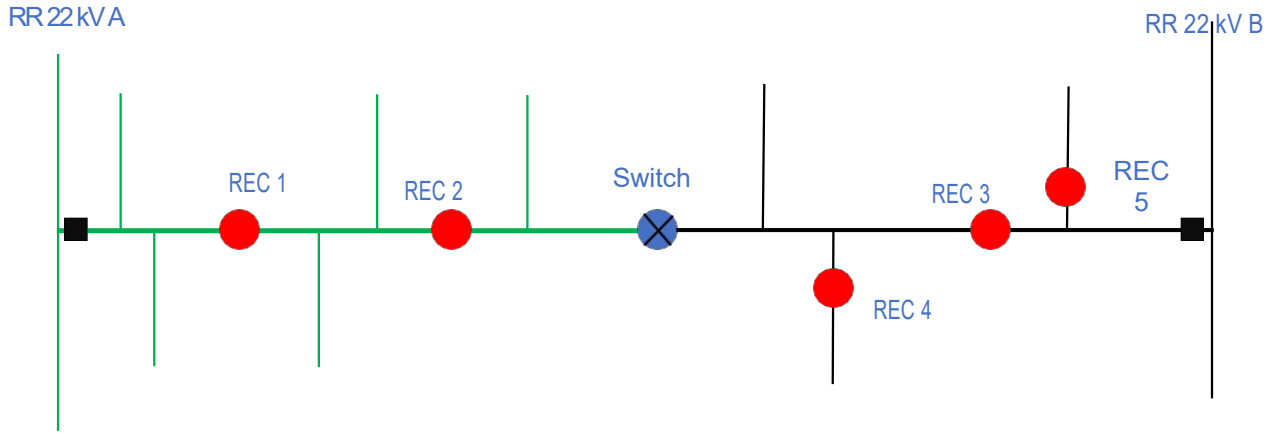


Figure 6: Exemplary layout of the reclosers respecting the rule of a maximum of two reclosers in series in the power supply route

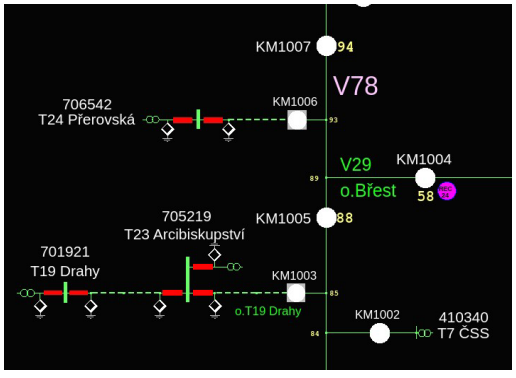


Figure 7: Mapping of the planned reclosers in the control system

For better understanding, all planned reclosers are also mapped in the control room system.

2.3. SETTING THE TARGET STATE

EGÚ Brno prepared a study to determine the target state [2]. Among other things, this study aimed to determine the maximum effective number of the reclosers for the EG.D network that would be reasonable from the economic point of view. First, the study was calculated for an option with a maximum of one recloser in series; then, after modifying the installation rules, for an option with a maximum of two reclosers in series from the power supply point.

The following input data was used to determine the target number:

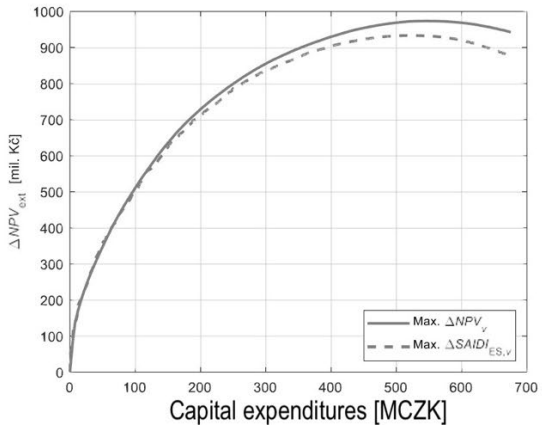
- fault rate from 2012 to 2021
- List of all high voltage feeders
- Topological data of selected 50 feeders
- Average consumption at feeders

Based on the data provided, 50 feeders were selected that best represented the EG.D network. Reliability calculations were performed on this sample of 50 feeders and the results were then extrapolated to the entire network.

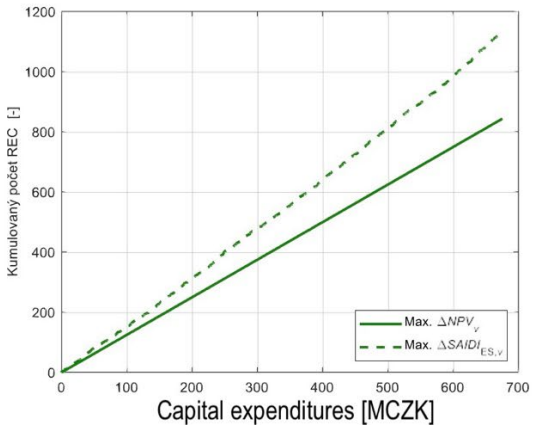
Type/state of the feeder	Number of feeders [-]			Rel. number of feeders [%] of all feeders			Rel. number of feeders for REC [%] of total number of the feeders for REC
	Total	For REC		Total	For REC		
		No	Yes		No	Yes	
Overhead	479	64	415	45.8	6.1	39.7	84.9
Mixed	148	75	73	14.1	7.2	7.0	14.9
Cable	338	337	1	32.3	32.2	0.1	0.2
Off	81	81	0	7.7	7.7	0.0	0.0
All	1046	557	489	100.0	53,3	46,7	100.0

Table 1: Conclusions of the study evaluating the possibilities of installing the reclosers

Forty seven per-cent of all feeders in the EG.D network are suitable for the installation of the reclosers. The study concludes that as the number of the reclosers increases, their contribution to the overall feeder voltage profile (NPV) begins to decline. The saturation of partial dependencies in the graphs can be observed roughly from capital expenditures of CZK 600 million.



a) Cumulative NPV



b) Cumulative number of REC

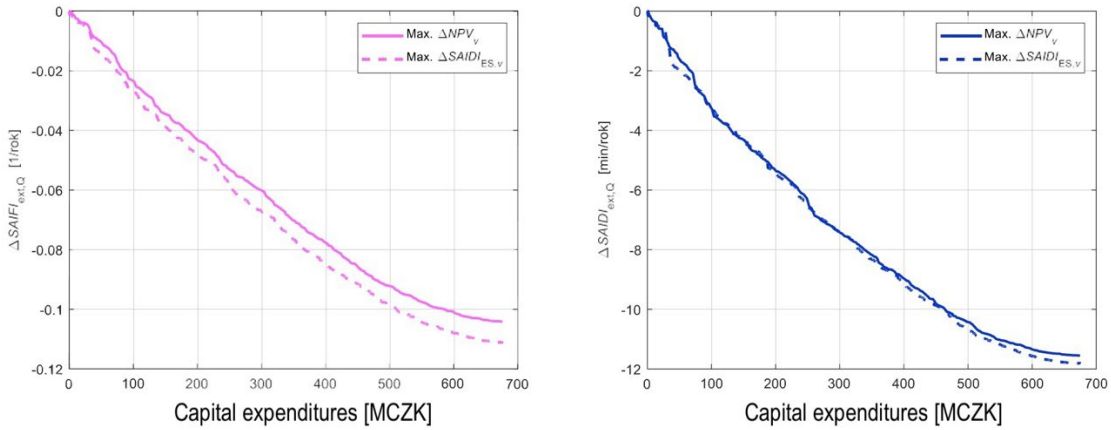


Figure 8: Dependence of capital expenditures on SAIDI/SAIFI parameters

	Total estimated number of REC in the network (excluding disconnection points) at max 2 REC in series on the feeder	
	Lower estimate	Upper estimate
Number of REC [-]	683	856
Capital expenditures N_i [CZK mil.]	546.4	684.8
Change to ΔNPV_{ext} [CZK mil.]	973.3	933.3

Table 2: Effective number of reclosers in the EG.D network

The main conclusion of the study was that the total estimated effective number of the reclosers in the network ranges between 680 and 850, wherein the lower limit is an extrapolation of the results for the most economically beneficial solution from a sample of 50 feeders, and the upper limit is an extrapolation that gives preference to a greater reduction in the SAIDI indicator.

2.4. PLANS FOR THE FUTURE

Based on a study [2], a target number of 800 reclosers was set for 2030. The specific locations will continue to be selected based on requirements from the control room operators and data on the fault rates of individual lines. Currently, the specific locations for the installation of reclosers have been selected until 2026.

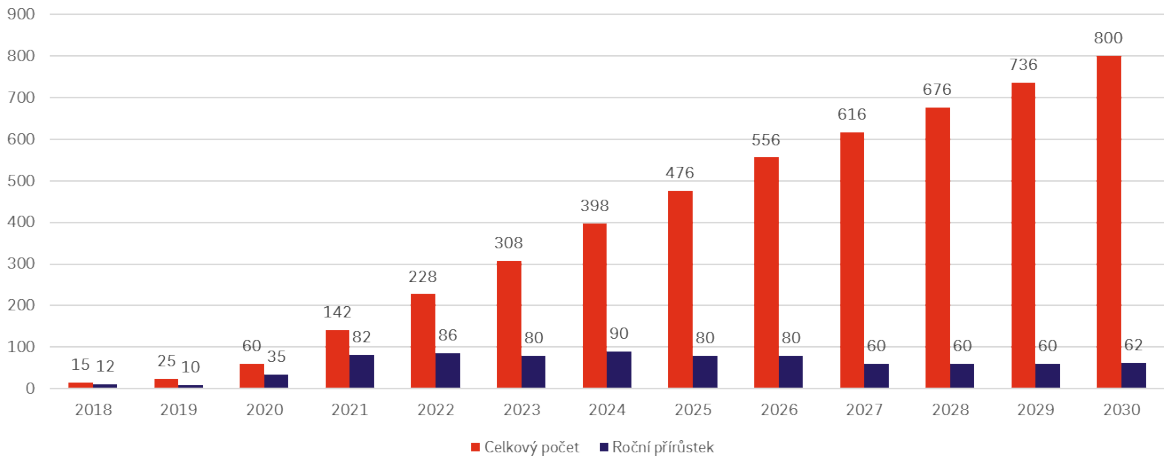


Figure 9: Current development and future plans regarding the number of the reclosers

3. IMPACT ON QUALITY PARAMETERS

The SAIDI and SAFI parameters are used to monitor continuity of the supply. The SAIDI parameter determines the average length of a single interruption, while the SAIFI parameter determines the average number of outages per connection point per year.

For the purposes of monitoring the benefits of the reclosers, it is advisable to consider these parameters only beyond the high voltage level and to monitor the so-called system parameters, i.e., all faults that have occurred in the network (for the purposes of evaluating the ERÚ's Q component, certain types of faults are not included in the calculation, e.g., faults during disasters or third-party interventions, or faults lasting less than 3 minutes; however, the reclosers frequently help with this type of fault as well). Unlike the Q components, we are only interested in faults, as the reclosers do not offer any benefits during planned outages.

The following figures illustrate the development of the number of faults at the high voltage level and the development of the SAIDI and SAIFI parameters under the above conditions (only high voltage level, system values, only faults, outages are not considered).

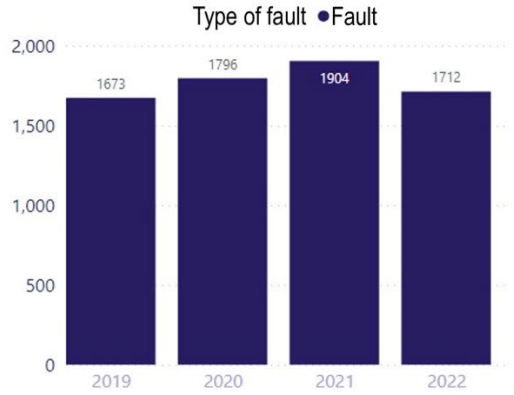


Figure 10: Development of the number of the faults at the high voltage level

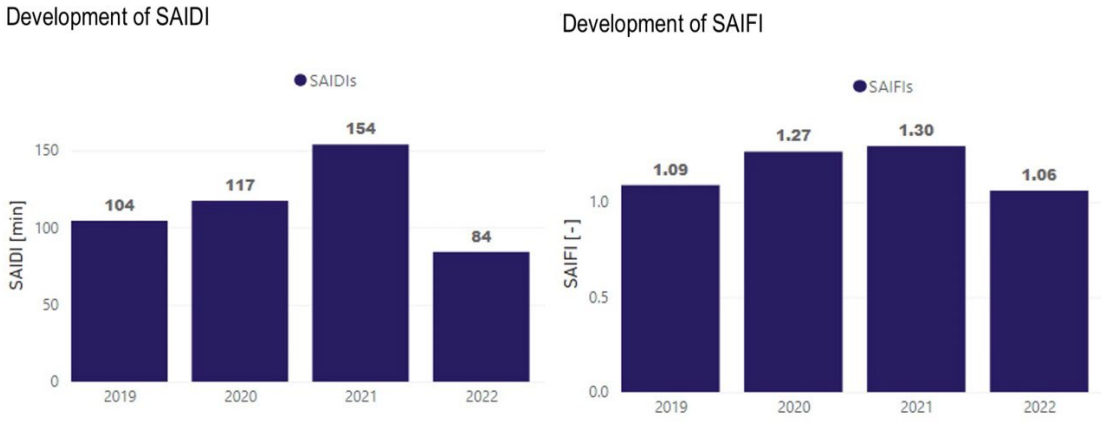


Figure 11: Development of the SAIDI and SAIFI parameters at the high voltage level

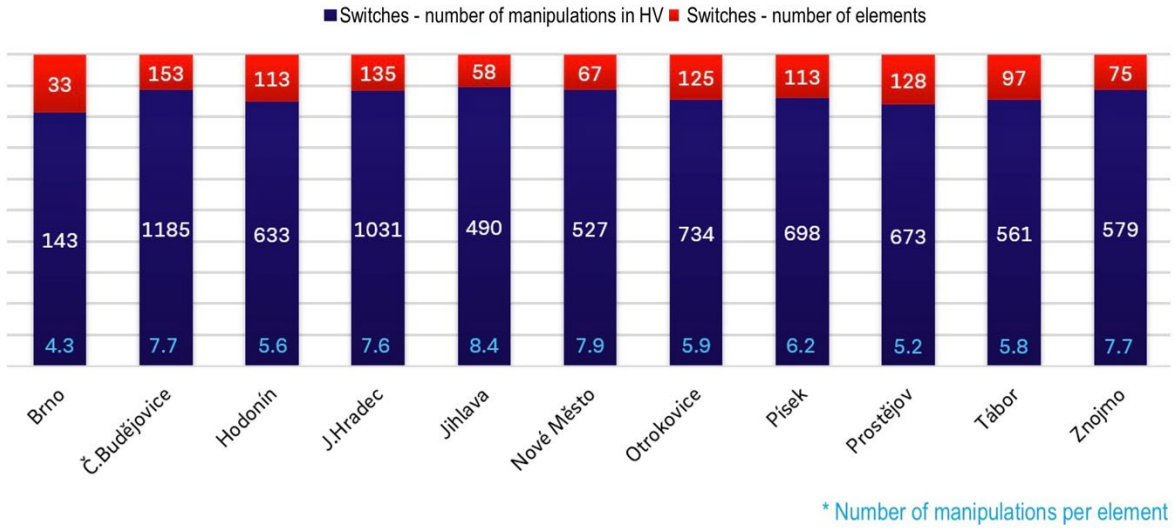
It may seem at first glance that there is no noticeable decline in the SAIDI/SAIFI parameters in the graphs; in fact, there is a significant increase in 2021. However, this was caused by a tornado that struck the South Moravia region in June. However, when comparing the number of the faults in 2019 (1,673) and 2022 (1,712) and the SAIDI and SAIFI parameters, it can be seen that even with a higher number of faults, there was a decrease in both parameters. It is therefore obvious that the impact of the individual faults is lower, both in terms of the total number of customers affected and the duration of the fault. This fact can clearly be attributed to the growing number of the reclosers in the network.

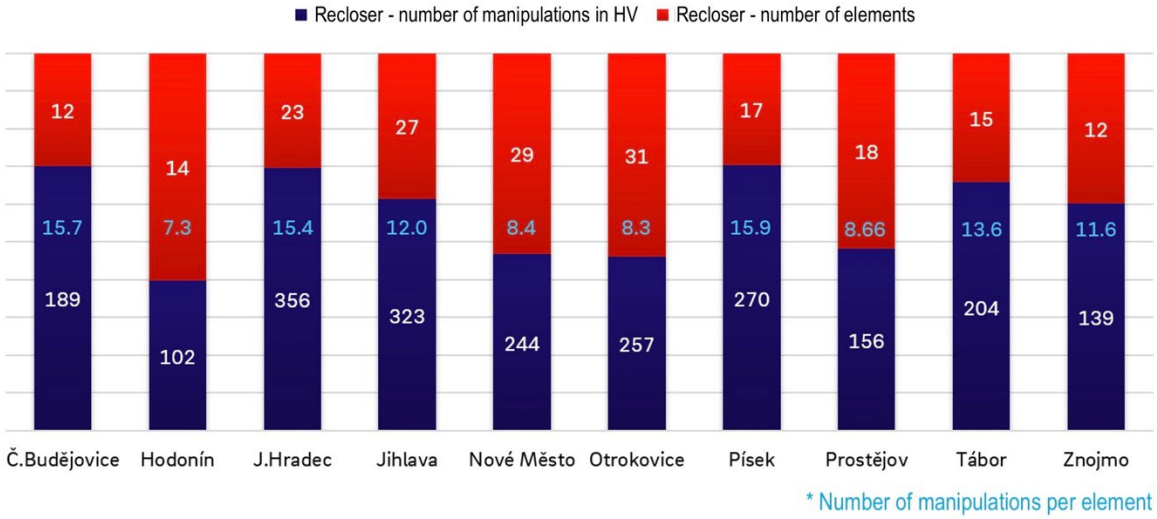
Disconnecting only a part of the affected feeder results in fewer affected customers (this is reflected in the SAIFI parameter). Faster troubleshooting and fault detection reduce downtime (reflected in the SAIDI parameter). To identify trends, it would be more appropriate to monitor a longer period than four years; however, the graphs begin in 2019, when the reclosers began to spread more widely.

However, the goal is not only to reduce the impact of the faults, but also to reduce the total number of the faults. That is why EG.D, a.s. places great emphasis on cabling at the high voltage level.

4. NUMBER OF HANDLINGS

The results also provide a comparison of the number of the switch and recloser manipulations. Insofar as the reclosers enable automatic disconnection of short circuits, their usability is higher than that of conventional remote-controlled sectional disconnecting switches. The graphs below show the number of the elements in each region and the number of the manipulations in 2022. The ratio of these two values can then be used to determine the average number of the manipulations per element in each region. While for the remote controlled sectional disconnecting switches this number ranges from 4 to 8 manipulations, for reclosers it is 11 to 16 manipulations per year.





5. CONCLUSION

In the long term, the reclosers are one of the measures that help to improve the quality of electricity supply. However, they are not the only measure; other measures include cabling at high voltage and low voltage levels, or a greater number of operations performed under voltage. This set of measures has helped to reduce the SAIDI and SAIFI parameters over the long term.

Based on the study, the target number of the reclosers for the EG.D network was set at 800 by 2030. Any higher number would no longer be economically reasonable. The installation of the remote controlled sectional disconnecting switches will continue in places where measurement is not required and protective functions are not necessary, such as the connection point between two feeders, which is normally switched off.

In the future, more advanced automation features called "self-healing" will also be tested. This functionality consists of automatic switching to a new configuration in the event of a fault, based on communication between individual elements, in order to ensure backup power supply.

6. BIBLIOGRAPHY

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[2] Skala P., Krčál V, EGÚ Brno, *Cílená integrace recloserů do venkovních sítí VN*, 2022

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