MV GRIDS DEVELOPMENT AND AUTOMATION

Daniel KOUBA
E.ON – Czech Republic
daniel.kouba@eon.cz

Libor KOLAR
E.ON – Czech Republic
libor.kolar@eon.cz

Jiri CELEDA
E.ON – Czech Republic
jiri.celeda@eon.cz

Michal JURIK
E.ON – Czech Republic
michal.jurik@eon.cz

ABSTRACT

The paper is focused on a development of current medium voltage distribution systems. There are increasingly stricter demands on these distribution grids, especially in area of grid reliability, connection of renewable energy sources or high industry parks, and targets of The Smart Grid Concept. The primary aim of this paper is to propose a gradual development of existing MV equipment with expectation of partially automated grid in the future.

INTRODUCTION

Smart Grid objects are usually focused on the low voltage grid. In our opinion, initial creation of Smart Grid at higher voltage level is more efficient, because there more customers can be influenced by smart technologies. Considering that the high voltage (HV) grid has already reached advanced requirements such as security, reliability, protection, remote control etc., we tend to improve the current medium voltage (MV) grid. It shows us the measurable impact of the new smart devices for the customers with the reasonable costs.

The MV grid has own specific deficiencies which are needed to be eliminated. We should achieve the HV grid properties as an ideal MV grid. We consider these main targets as the MV Smart Grid:

- Increase of reliability
- Operation cost reduction
- Ability to connect renewable energy sources
- Reduction of losses

Distribution automation is the system by means of which the fault location can be excluded, along with subsequent changes in network connection. Disconnection of the affected section and power supply restoration are reached without the necessity of manual switching.

In connection with the Smart Grid idea, the idea of so-called advanced distribution automation appeared in the past decade; this idea is to be ranked among key parts of Smart Grid networks.

The advanced distribution automation is to represent intelligent network control that will, in real time (or quasi-real time), respond to changes in load and production, as well as to occurrence of fault state, usually without the controller's intervention.

Distribution automation utilizes the following instruments:

- Short circuit indicators with local/remote signalling,
- Local automation (reclosers, automatic section switches, changeover switches),
- Remote-controlled switch-disconnectors (SCADA).

In this paper, pole-mounted reclosers are considered as automatic switching devices for overhead MV lines and smart MV switchgears are presumed for cable grid.

AUTOMATION OF OVERHEAD LINES

Recloser is a circuit-breaker with reclosing ability, located on the poles of overhead line. It is equipped with remote terminal unit as well as the elements with protective, monitoring and automatic functions.

Recloser complies with the function of feeder protection and thus it responds to faults before action of protection in the substation (see Fig. 4).

Due to the fact that the recloser can be mounted almost anywhere in the line (limitation is caused by breaking capacity of short-circuit current), it also clears the faults that would hardly be recorded by feeder protection in the substation due to a large distance of the point of fault (e.g. interrupted conductor).

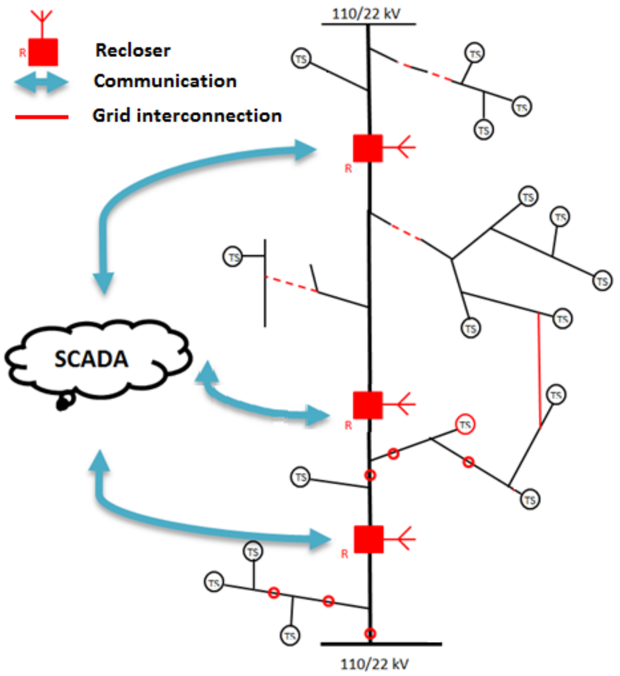


Figure 1: Installation of reclosers in overhead lines

However, the main benefit of the reclosers lies in their ability to execute a certain autonomous operations that in co-operation with other elements ensure automation of a part of distribution network line.

We propose three devices as an ideal number of the reclosers between two supply substations or busbars (in case of the same substation). The number is limited by the required selectivity of protection settings.

Firstly, we install one recloser in one line and then we will add recloser at the end of the line where the interconnection to other line is possible.

Finally, two feeders supplied by same busbar will be operated in parallel. This operation enables the highest contribution of new automatic devices in grid.

In case of two supply substations, feeders have to be operated in radial with a bit less contribution to system reliability caused by additional switching. However, the communication settings from SCADA to all three reclosers provide the similar function as parallel operation of the feeders. The advanced behaviour may be denoted as quasi-parallel operation.

Parallel network operation will assure that in case of fault, only the smallest possible number of customers will be disconnected from electric power – this is ensured by power supply from both sides and automatic functions of the recloser and its protections, enabling handling of only necessary number of customers. In case of radial network operation, the whole MV line affected by fault is switched off.

The recloser is also convenient to install to the radial branch, where the faults occur very often.

Methodology of installation

In this chapter, the described methodology is based on the discussed installation of reclosers but it is possible to use it for general placement of automatic devices.

The first step was to select feeders which have been most affected by faults over the last six years.

We also checked if the occurrence of the faults is repeated. Then we found the faulted part of each line and analysed the fault type, while focusing on short-circuit faults and earth faults (*F* coefficient).

Next criterion for each fault describes how many customers were without electricity (*C* coefficient). From this analysis, we got the list of the lines where we want to install reclosers.

The placement of automatic devices to each line is determined by using the two parameters: *FC* selects the line and *HO* finds the optimum position of device.

$$FC_i = \sum_{j=1}^{n} F_j \cdot C_j$$

Where index “*i*” selects the line and “*j*” means the number of faults. Feeders with the highest *FC* parameter are the most convenient for installation of an automatic device.

The *HO* parameter is formed by the product of two coefficients. Health coefficient *H* takes into account the number of faults which would be reduced in case of installation of automatic device.

Second coefficient *O* represents the sum of supply points which would be turned on during the fault owing to reaction of automatic device.

$$HO_m = \sum_{k=0} H_k \cdot \sum_{l=0} O_l$$

Where index “*m*” selects the position and “*k*” means the number of fault between the counted position and the end of line. The index “*l*” reflects the summarization of supply points in the whole feeder excluding the branch that begins with counted position.

The following figure shows a graphical representation of selecting the optimum position for installation. The red curve is given by the value of fault reduction in each node along the line. The blue curve involves the protected customers in each node of the line. We get the optimal location for installing of automatic device by finding the maximum of *HO* parameter which represents the green curve.

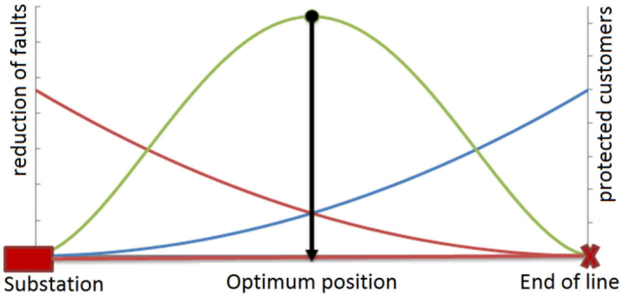


Figure 2: Settings of optimum position

It is important to note that, in fact the functions are not continuous but they are comprised of discreet nodes, referring to the poles where is convenient to install recloser, as well as poles with current switch-disconnectors.

Pilot project of three reclosers

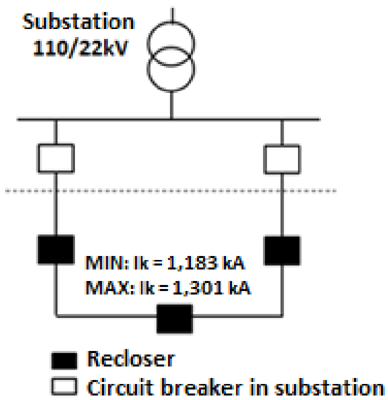


Figure 3: The grid topology of the pilot project

Regarding the pilot project objectives, it has to fulfill these expectations:

- Testing of a new technology for possible extension of automatic elements in distribution system;
- Verification of operating parameters of the equipment;

- Verification of assumption that in this way, it is possible to reduce index of reliability SAIDI and SAIFI;
- Verification of the methodology of optimum location and number of automatic devices;

Next figure shows the description of the real fault recording with the switching steps and their timing. Whole process takes 1.4 seconds including the automatic reclosing by the circuit-breaker in substation.

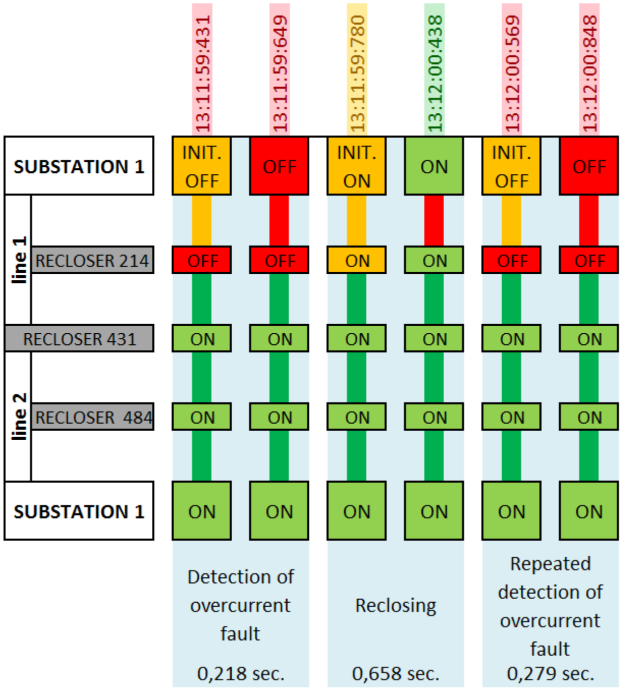


Figure 4: Graphical interpretation of switching

Based on the conclusion of the pilot project, there is assumed a decrease of fault interruption of SAIDI index by 27% and SAIFI by 45%.

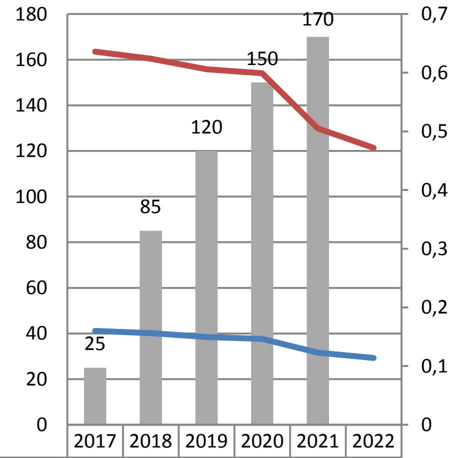
These high values apply to each MV feeder and correspond to the optimum placement of all three reclosers. Nevertheless, the optimum positions do not have to be achieved in a further rollout to the whole distribution grid.

The further results show that one recloser installed in MV lines will reduce SAIDI by 14% and SAIFI by 30% in relation to fault interruption. [1]

Rollout and expectation

After reviewing state of all MV overhead lines in the distribution grid, we assessed the total need for reclosers and calculated their respective contribution towards SAIDI and SAIFI mitigation.

The results can be seen on the chart in Figure 5, which presents a significant reliability boost after automated parallel (or quasi-parallel) operation comes into practice. This is expected by the end of 2020, when the final reclosers in the line interconnection will have been installed.



	2017	2018	2019	2020	2021	2022
REC [pc]	25	85	120	150	170	
SAIDI MV [min. /cust./year]	41,15	40,18	38,49	37,65	31,57	29,32
SAIFI MV [- /cust./year]	0,636	0,624	0,606	0,599	0,505	0,472

Figure 5: Assumed decreasing of SAIDI, SAIFI

AUTOMATION OF EXISTING CABLE LINES

The aforementioned process of installation of automated grid elements can be also utilized in MV cable networks. Optimal installation points lie in MV switchgears in MV/LV substations, especially in those with larger number of MV cable feeders.

Smart MV Switchgear has to comply with all relevant requirements for compact switchgear construction (such as for the SF6 switchgears already in operation), communication with SCADA system, remote control of the switching element, protection or fault location device, and potential for automatic functions.

We identify two basic types of MV/LV substation with such Smart MV switchgear: A separation point and a manipulation point. The main difference is that MV switchgears in a separation point have remote-controlled circuit breaker with protection, whereas MV switchgears in a manipulation point have remotely controlled switch and a fault current detector.

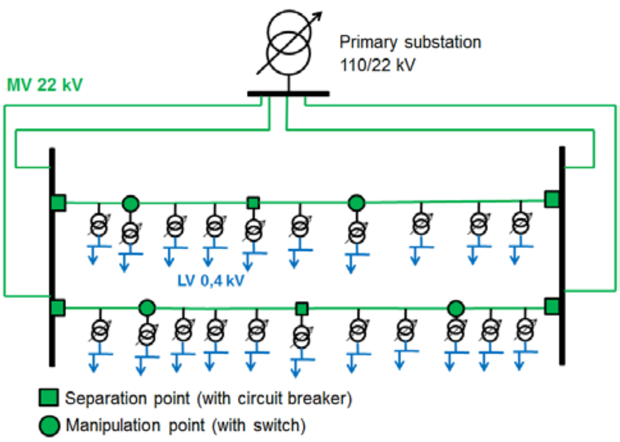


Figure 6: Installation of Smart MV Switchgear

Figure 6 illustrates an example of a cable network with partially automated MV/LV substations.
Separation points can be seen as equivalents to reclosers in that they also automatically decrease number of affected consumers in case of a fault. The lowest possible number of such devices in a line between two feeders is two, but we assume the same principle as with reclosers will be used and there will be three such installations per line. This is also highest acceptable number for which a satisfactory selectivity of protection can be achieved.
Degree of grid automation in MV cable lines can be increased further by installing manipulation points; especially in case of long lines, lines with higher number of consumers, or lines with high reliability requirements. Dispatcher can use these points for faster grid reconfiguration, according to the priority of power supply for segments in large urban grids. The SAIDI and SAIFI mitigation is not a crucial priority in cable networks due to relatively low number of reoccurring faults (on average, there are 5 faults per 1000 km of cable lines per year in E.ON Czech), and convenience of remote grid reconfiguration is the main driver here.
In the last type of MV line – one with both cable and overhead part, Smart MV switchgear has to communicate reliably with a recloser. However, such lines are fairly infrequent in E.ON Czech and their development is not encouraged.

Installation of smart MV switchgears

Similarly to the deployment of reclosers, the technology of Smart MV switchgears has to be tested in real operation, in limited circumstances of a pilot project, in order to specify its roll-out potential. Since three major suppliers provided us with a technical solution that fulfilled requirements of E.ON Czech, all of them will be assessed. The plan is to install a separation point and a couple of manipulation points into a MV line, per supplier, in the same location of Brno-Bohunice, to ensure all have the same environment (cable network of the same age and technology, MV line connecting two different 22 kV stations). In case of successful pilot project operation, it is estimated that hundreds of separation and manipulation points will be deployed in urban networks throughout E.ON Czech.

INTERCONNECTIONS OF LONG RADIAL FEEDERS

Building new interconnections of long radial feeders is also included in the concept of Smart Grids and automation of DSO on MV level. These new interconnections will be primarily used while the alternative configuration of network is being operated.
Realization of new interconnections is described in following methodology which has three main points of view.
First point of view is a fault rate on both feeders. The final value consists of two parameters: total length and average age of lines. The total length of feeders means higher probability of fault. The average age of feeders shows us the future inevitability of supply interruption, based on technical service life.
Second aspect of view solves the reliability on both feeders. This parameter involves total sum of customers and total power consumption. First parameter describes the number of customers which are connected to both branches. This parameter is also used to determine SAIDI and SAIFI. Second parameter represents type of customers and therefore the importance of the branch.
Last point of view is usability of interconnections. This view is focused on requirements from control centre and department of grid development reflecting the requirements of the new connection of customers or switching abilities.

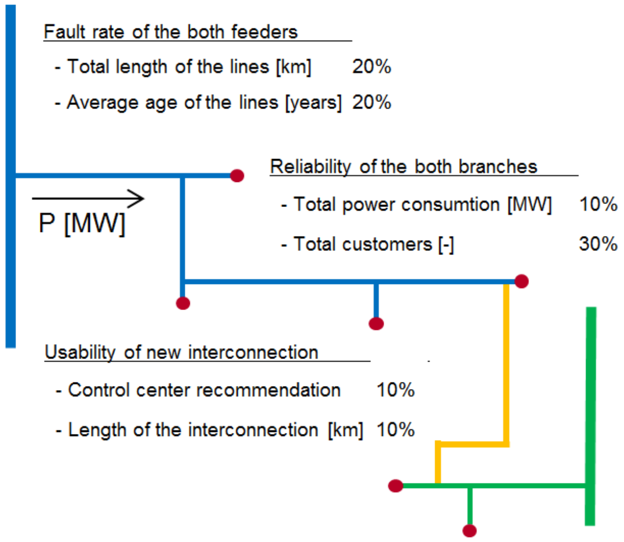


Figure 7: Aspects of building new interconnections

Final result is defined by percentage of the individual points of view. Failure rate is represented by 40 % of total. Reliability consists of 40 % of total, as well. And last point of view, usability, is represented by 20 % of final result.
Interconnections with the greatest potential (final result) will be chosen for implementation. This network development brings us more possibilities for installation of reclosers according to described methodology because the new circuits are created. Additional reclosers in grid will offer a challenge to the protection settings.
It is worth mentioning that it is often necessary to use cables for the interconnections especially in forest corridors.
The important information to determine the potential for installation of cables in forest corridors is based on the comparison of maintenance costs for overhead and cable lines in forest corridors, including their lifetime investment costs. The outcome of technical and economic comparison is that cables should be installed in a forest corridor with minimum length of 800m. [1]

CONCLUSION

The contributions of our work are, above all, a proposal of a placement methodology of the new automatic switching devices and experiences from pilot project. Emphasis is placed on meeting the requirements for Smart Grid given by the distribution system operator, E.ON Czech.

The mere installation of smart devices is not enough; therefore, interconnections of long radial feeders are included in the proposal for future grid automation. Since the construction of new distribution lines in new routes is very expensive, the benefits of these interconnections have to be carefully evaluated by same methodology as we have described.

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