SOME IMPACTS OF THE REGULATION OF ELECTRICITY SUPPLY CONTINUITY ON DECISION MAKING BY DISTRIBUTION NETWORK OPERATORS CONNECTED WITH THE TELEMECHANIZATION OF THE MV OVERHEAD DISTRIBUTION NETWORK

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ABSTRACT

The regulation of electricity supply continuity may have a substantial influence on decisions made by distribution network operators (DNOs) about investments in their networks. The evaluation of all impacts of this regulation is a very extensive and difficult task. It is important both for the energy regulatory office when preparing regulatory mechanisms and for distribution companies attempting to achieve the optimum operation and development of the system.

This paper summarizes some partial knowledge of the impact of the regulation on decisions made by DNOs about the optimum telemechanization of the MV overhead distribution network. Telecontrolled section switches and reclosers are considered here as possible telemechanization elements. The results follow from the simulation of the reliability of a selected part of the 22 kV distribution network. Comparison is made for the regulatory mechanism evaluating the reliability based on electric energy not supplied as well as for the regulatory mechanism comprising the composed customer's standard for electricity supply continuity which includes a limit of the annual number of supply interruptions and a limit of their total annual duration.

INTRODUCTION

In many countries, the business activities of distribution network operators (DNOs) are subjected to regulation by national energy regulatory offices. Some regulators apply the regulation even in the field of electricity supply continuity (in the field of long-duration supply interruptions, i.e. interruptions with duration of more than 3 minutes). Customer's or system standards [1] may be used as a tool for this regulation. In both cases, these standards result in financial losses for DNOs when the set limits of indicators of electricity supply continuity have not been met. The regulators expect that DNOs will react on this risk of financial losses by undertaking measures which will improve the electricity supply continuity (or will keep it on the present level at least – depending on the objective of the regulation). These measures may be of operational character (e.g. improved organization of failure services, more appropriate connection of the network) or of investment character (e.g. substitution of elements with low reliability by more reliable elements, cabelization of selected sections of the overhead line, higher extent of the telecontrol of the network).

The benchmarking reports of the Council of European Energy Regulators (CEER) [1, 2] bring forth information about positive results of the regulation of electricity supply continuity. These conclusions usually follow from comparison of aggregated indices *SAIFI* and *SAIDI* for large network complexes as observed during several last years. As it is stated in report [2], a more detailed technical information about the ways by which the presented improvements have been achieved is not presented.

A natural large information asymmetry exists between regulatory offices and DNOs which leads to a difficult position of the regulatory office when setting parameters of the regulation.

May the regulator be sure that the chosen regulatory mechanism will really lead to the aim set by him? From the opposite view: how should DNOs proceed in an optimum way when operating and developing their networks? It is difficult to give answer to both these question (although the question for DNOs is considerably easier when the strategy of the regulator is known). A certain guide for studying these questions may be provided by sensitivity analyses and by comparing different types of regulatory mechanisms. It may be based on the simulation of the reliability of real distribution networks. It is usually valid that the reliability of the MV level mostly contributes to indicators of the reliability of the distribution network. It is therefore possible, for simplification, to work only with this level. However, from the point of view of the credibility of results obtained it is important to work also with the topology of the real network given by local (national) factors – geography, demography, dislocation and type of industry.

EVALUATION OF THE CONTRIBUTION OF AN INVESTMENT IN THE NETWORK

The evaluation of the contribution of an investment in the network which should result in the improvement of electricity supply reliability has a predicative character, i.e. it consists in the estimation of the behaviour of the network (from the point of view of reliability) in future (after the investment will be realized). A suitable tool for estimating the reliability are Monte Carlo simulations. When compared with analytical methods they have the following advantages: easier implementation of the impact of the considered investment, possibility of taking account of the process of successive restoration of electricity supply to customers after failure, as well as possibility of evaluating annual indicators of electricity supply continuity for individual customers.

Financial equivalent of the reliability

Evaluation of the contribution of an investment based only on the change of reliability indicators would not be sufficient at present time. The managing staff of the distribution company evaluates the proposed investments according to economical criteria. In the case of investments which should lead to improvement of the reliability, a necessary part of the calculation of economical indicators is the financial equivalent of the reliability – costs of supply interruptions. The costs of supply interruptions may be based [3] on (i) functions of damages, (ii) evaluation of energy not supplied, (iii) costs of penalty payments as a consequence of not meeting the customer's standard for electricity supply continuity.

The functions of damages represent, in general, a precise expression of damages caused by the interruption of electricity supply to a concrete customer. However, their application in practice is limited only to some consumers with sensitive technologies. If they are used more widely, sectorial functions of damages, for example, arise which include certain simplifications.

Evaluation of energy not supplied is a relatively widespread method and it may be easily implemented. In the case of a one component evaluation (with the same price for all customers) the costs of energy not supplied are proportional to *SAIDI*.

As costs of penalty payments we consider in this paper the costs resulting from not meeting the customer's standard for electricity supply continuity. This standard may include one or more indicators being evaluated and various mechanisms of the calculation of the penalty which DNOs are obliged to pay to a concrete customer. It is essentially important that basic indicators of the electricity supply continuity are always evaluated for each individual customer (not system indices like *SAIFI*, *SAIDI*).

In the following parts of the paper we consider the costs of energy not supplied as the product of the unit price of energy not supplied c_{ned} and of energy not supplied given by the sum of annual durations of supply interruptions, of the maximum simultaneous consumption P_{max} and of time of using the maximum T_u (T_u = 2000 hours).

The costs of penalty payments are the sum of penalties paid to customers for whom the limit of the annual number of supply interruptions L_n or the limit of the total annual duration of supply interruptions L_t has been exceeded (logical "or" is valid between these limits, only interruptions with a long duration are taken into calculation). The magnitude of penalty payments c_p is the same for each customer – c_p = 500 CZK (it does not depend on the type of the customer or on the magnitude of his consumption). It is assumed that the penalty payment will be received by all customers entitled to receive it.

Evaluation of the contribution of an investment

Indicators like e.g. the net present value (*NPV*), internal rate of return, payback period or the index of profitability are used for the economical evaluation of the contribution of an investment. The net present value is equal to the discounted value of cash flow at the end of the chosen period. Investment and operational costs enter into the calculation of *NPV* with a negative value, "contributions" resulting from the realization of the investment enter into it with a positive value.

In the case of installing telecontrolled switching elements in the MV distribution network this contribution consists in decreasing the costs of supply interruptions manifesting itself in each year of the period being evaluated. The decrease of the costs of supply interruptions corresponds to the difference between the costs of supply interruptions for the existing state and the costs of supply interruptions after the feeder has been additionally equipped with telecontrolled section switches and reclosers. For both states, the costs of supply interruptions are obtained from the evaluation of the simulation as average annual values. Let us consider that the whole investment is realized at the beginning of the first year and that the annual operational costs are constant for the whole period of evaluation. The length of the period being evaluated has been chosen 20 years (with regard to the life time of reclosers). In general, the decrease of the costs of supply interruptions is different for each variant of additional equipping of the feeder and different values of *NPV* correspond to it. The variant with the highest *NPV* corresponds to the best solution (optimum solution from variants being evaluated).

ANALYSED PART OF THE DISTRIBUTION NETWORK

The below-given results have been obtained for a set of twenty 22 kV overhead feeders supplying 137 thousand customers approximately. The feeders were chosen from a real comprehensive distribution network based on the number of failures on the feeder during a ten-year period, on characteristic values of durations of supply interruptions and on the number of supplied customers. The set being analysed thus represents the choice of the most problematic feeders on which we may expect the greatest contribution from installing telecontrolled section switches and reclosers.

We consider that these feeders are now equipped only with locally controlled section switches (with the exception of section switches at the points of disconnection, some of which are telecontrolled). A limited number of existing switching points (not more than 9) was included into optimization for each feeder. The number of reclosers in these chosen switching points was not limited in the optimization.

The simulations of the reliability of these feeders were based on real failure rate data including the assignation of failures to individual sections. The simulations were performed by using the Monte Carlo method [4].

INFLUENCE OF THE REGULATION AND OF THE FINANCIAL EQUIVALENT OF RELIABILITY ON THE OPTIMUM EQUIPPING OF A PART OF THE MV DISTRIBUTION NETWORK WITH TELECONTROLLED SWITCHES

The costs of energy not supplied represent a "traditional" criterion for optimization. However, it may be also imagined on the background of a system standard for electricity supply continuity which includes only the index *SAIDI* and has only a penalization component directly proportional to *SAIDI* (without a ceiling). As an alternative we will consider the costs of penalty payments which correspond to a customer's standard (described above).
The optimization of installing telecontrolled switches (telecontrolled section switches and reclosers) according to *NPV* leads to different optimum variants when the costs of energy not supplied or the costs of supply interruption enter into the calculation of *NPV* [5].
For the set of analysed feeders this fact is illustrated by Fig. 1 in which the values of *NPV*, of total investment costs N_i, *SAIDI* and *SAIFI* are shown. The optimization with using the costs of energy not supplied serves as the basic case (100% for each indicator). The optimization based on the costs of penalty payments was performed for three combinations of limits L_n and L_t which were selected from bands of their values expected for the given type of the network.
The optimization based on the costs of penalty payments leads to higher investment costs for some combinations of these limits. Index *SAIDI* is higher and its increase grows up with more free limits while *SAIFI* decreased. Its decrease is more considerable when the combinations of limits are more stringent.
NPV may be higher when applying optimization based on the costs of penalty payments compared with optimization based on the costs of energy not supplied. However, the comparison of *NPV* is not quite correct because they were obtained by using a different method for the evaluation of reliability.

SOME FEATURES OF VARIANTS OF EQUIPPING MV FEEDERS WITH TELECONTROLLED SWITCHES

Share of telecontrolled section switches and reclosers

The cause of the increase of *SAIDI* and the decrease of *SAIFI* in Fig. 1 can be made clear by having a look at the share of telecontrolled section switches (TC) and on the share of reclosers (REC) in the optimum equipping of the set of selected feeders with these elements.

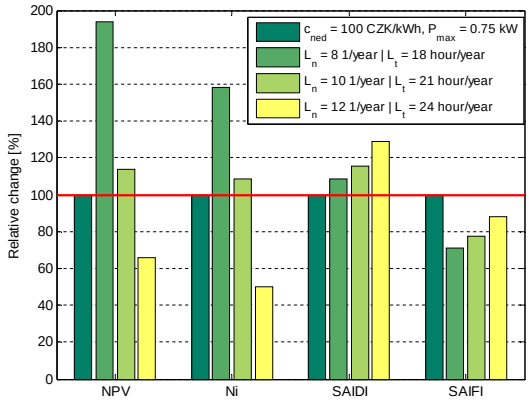

Fig. 1 Relative change of selected indicators for the optimum equipping of a set of 20 MV feeders with telecontrolled section switches and reclosers (basic case = optimization using the evaluation of energy not supplied)

For optimization operating with the costs of penalty payments, the relative share of reclosers in the total number of telecontrolled switches (TC + REC) for the given combination of limits is shown in Fig. 2. Relative shares are given for a wider spectrum of combinations of limits L_n and L_t. The values Inf (∞) correspond to the situation when the respective limit has not been included in the customer's standard.
An area of combinations of limits in which the installation of reclosers dominates is clearly formed in Fig. 2. Reclosers not only accelerate the process of localization of a failure (and/or the restoration of supply into sections not affected by the failure) but they contribute to decreasing the number of long-duration supply interruptions for some customers. This effect is given by the protecting function of the recloser.
The situation of optimization based on the costs of energy not supplied is illustrated by Fig. 3. The unit price of energy not supplied c_{ned} and the maximum simultaneous consumption by one customer P_{max} are parameters of the graph. Although the values c_{ned} =100 CZK/kWh and P_{max} about 0.75 kW would correspond to the network being analysed, the values of these parameters were chosen from wider intervals so as to obtain a better survey.
It may be seen from Fig. 3 that the share of reclosers in optimum solutions is small even at a very high valuation of energy not supplied and at a high consumption. Especially telecontrolled section switches would be effective on the feeders because they are less expensive when compared with reclosers (by a half approximately) and they contribute to the acceleration of the process of identifying the faulty section and to a successive restoration of supply. The annual number of long-duration interruptions registered by customers is not decisive when a one-component evaluation by means of energy not supplied is carried out.

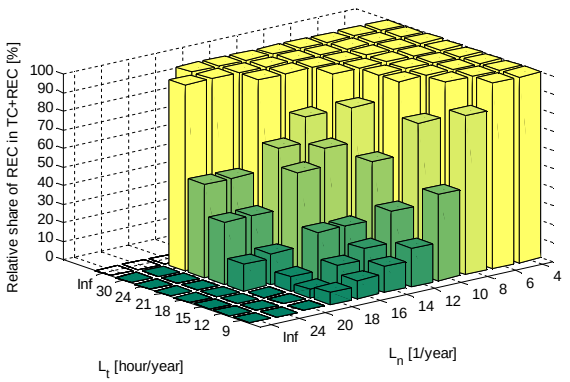

Fig. 2 Relative share of reclosers in the total number of telecontrolled switches (TC + REC) – optimization based on the costs of penalty payments (customer's standard with limits L_n and L_t)

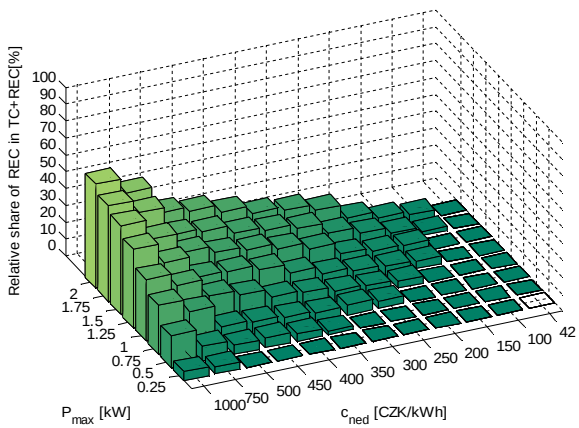

Fig. 3 Relative share of reclosers in the total number of telecontrolled switches (TC + REC) – optimization based on the costs of energy not supplied

Choice of the optimum variant

If we consider that the given switching point may be equipped with a locally controlled section switch, with a telecontrolled section switch or with a recloser, the number of possible combinations of equipping the feeder with these elements increases exponentially with the number of switching points included into optimization. The corresponding investment costs represent discrete values the number of which is relatively small. Consequently, a certain amount of money may be invested in the given feeder in more ways (by more variants). However, variants with the same investment costs may differ both in *NPV* and in *SAIDI* [4].

The performed analyses lead to the conclusion that, when installing the telecontrolled switches, more solutions can by found which have the same investment costs and similar values of *SAIDI* but result in a very different decrease of the costs of penalty payments (when using the composed customer's standard with limits L_n and L_t) which markedly manifests itself in the values of economical indicators.

CONCLUSION

The choice of the mechanism of regulation of the electricity supply continuity has a substantial influence from the perspective of DNOs. It has an influence on the set of investment and operational measures which, under condition of the regulation, DNOs will try to implement with the aim of maximizing their profit.

The customers perceive the electricity supply continuity mainly on two levels: through the frequency of supply interruptions and the durations of supply interruptions. The regulation of only one of these levels may lead DNOs to investments which will negatively influence the second (non-regulated) component. This is documented by the results of optimization of equipping the MV network with telecontrolled section switches and the reclosers. The regulation of only the component of durations (in the case of a one-component evaluation of energy not supplied and/or *SAIDI*) strongly suppresses the application of reclosers which have a favourable impacts both on the number of long-duration supply interruptions (>3 min) and on their duration (though for a higher price) when compared with telecontrolled section switches which do not change the number of long-duration supply interruptions.

On the other hand, regulators suffer from information disadvantage compared with DNOs and it makes their decisions about the appropriate form of the regulation of supply continuity more difficult. Regulatory offices must formulate objectives of the regulation and consider by which measures DNOs in the given country could fulfil their expectations. There is also another important question: will the chosen regulation be really functional, i.e. will it motivate DNOs to fulfil these objectives?

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