MINIMUM SHORT CIRCUIT POWER IN THE LV DISTRIBUTION NETWORK TO MEET EN 50160 STANDARD REQUIREMENTS

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ABSTRACT

This paper describes the problem of power quality on a liberalised power energy market under the legislative conditions in the Czech Republic. It deals with an analysis of the voltage quality (VQ) parameters in the distribution network. It further elaborates on the technical economic variation assessment to meet the needs of low voltage (LV) distribution network in compliance with the minimum LV short circuit power. This value of the short circuit power ensures compliance with the EN 50160 standard requirements on the DNO´s part.

INTRODUCTION

The electricity market liberalisation brings considerable pressure to introduce penalties for insufficient voltage quality parameters. In case of poor voltage quality, these penalties should be of the electricity rebate payment nature. Another issue included in this paper is the responsibility for the poor voltage quality and the consequent damage. To avoid paying damages to customers, the number of complaints regarding voltage quality has been reduced. To ensure that DNO could be exempt from liability for the poor voltage quality and the damage resulting therefrom, minimum short circuit power needs to be secured in the LV distribution system. If so, the voltage quality problem is most likely not to occur.

VQ ANALYSIS

Voltage quality (VQ) analysis is based on the evaluation of several thousand measurements. These measurements were carried out in the E.ON Distribuce´s LV distribution network between 2002 and 2010. Every week the measurements were carried out at random across the distribution network which has been evaluated in compliance with the requirements of the EN 50160 [1] standard. A total of 3,000 measurements were carried out in the LV distribution network. Most customers are connected to the LV level. Figure 1 clearly shows that of all measurements 9.6 per cent failed to meet the EN 50160 requirements due to the voltage deviation excess, 14.1 per cent failed as a result of the harmonic voltage excess and 29.8 per cent of measurements failed since the continuous flicker parameter was exceeded. With respect to compliance with the EN 50160 [1] requirements, the flicker parameter is the most relevant from the LV distribution network perspective. Compliance with the required flicker parameter is discussed below.

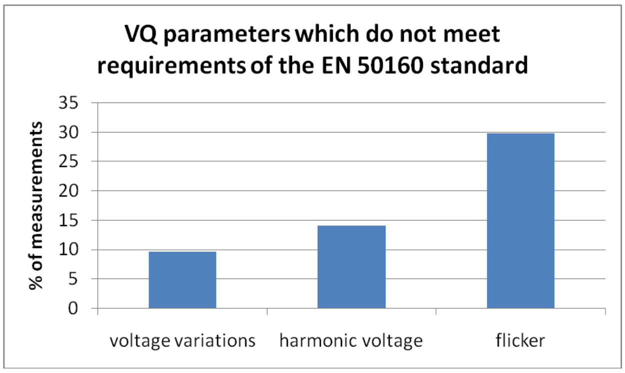

Fig. 1: VQ parameters in the LV distribution network which fail to meet EN 50160 requirements

VQ DEPENDENCY ON SHORT CIRCUIT POWER

Some hundreds of weekly VQ measurements in the LV distribution network with a known value of short circuit power parameter at the point of measurement were carried out between 2007 and 2010. This parameter was calculated on the measured network model basis. There is a parameter equivalent to the short circuit power, known as the short circuit impedance parameter. The flicker parameter dependency on the short circuit impedance is shown in Figure 2.

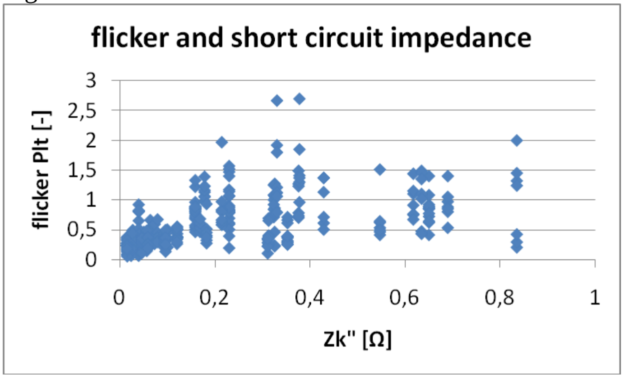

Fig. 2: Dependency of flicker parameter on the short circuit impedance parameter

Figure 2 clearly shows that the flicker parameter limit value of 1 according to EN 50 160 is exceeded when the three-phase short circuit impedance of approx. Zk“=0.18Ω is exceeded. The 3 phase short circuit power of Sk“=900kVA

corresponds to this value.
Those measurements where VQ failed to meet the EN 50 160 requirements were selected from the measurements with the known short circuit power parameter. The flicker parameter was exceeded in most cases. These unsatisfactory measurements were used to compose a function of number of networks which, depending on the short circuit power, meet the EN 50 160 requirements.

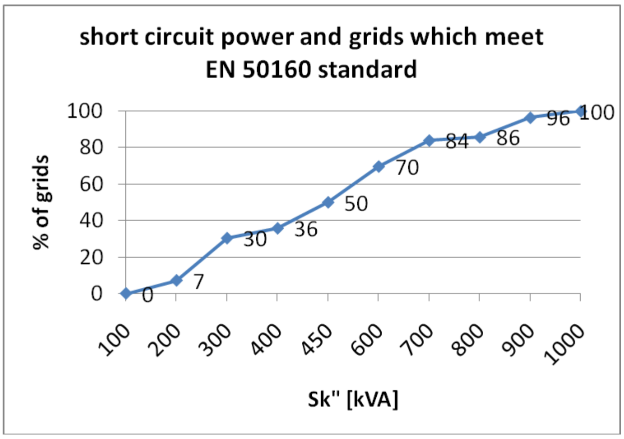

Fig.3: Cumulative dependency of the number of LV networks with unsatisfactory VQ on short circuit power (Sk“)

Figure 3 clearly shows that the short circuit power value was higher than 100kVA in all networks with unsuitable voltage quality. However, no problem with VQ was observed in any networks where the short circuit power is higher than 1000kVA. If the short circuit power was higher than 900kVA, the satisfactory voltage quality was recorded in 96 per cent of networks – normal LV networks without any noticeable contributing factors which would produce abnormal retroactive impacts. We can thus conclude that the short circuit power parameter of at least 900kVA will, with a sufficient degree of probability, ensure compliance with the EN 50 160 requirements for the LV distribution network.

REFERENCE SHORT CIRCUIT IMPEDANCE

IEC 725 [2] sets the reference impedance value, or more precisely, a relative short circuit power value for the LV distribution network and electric equipment of nominal current less than 16/75 A. It is assumed that if the required impedance (or more precisely, short circuit power) value is met at the point of network connection, an electric appliance will not produce any adverse retroactive impacts on the network, whereby no interference in the network will occur.

Electric equipment with nominal current	Reference short circuit impedance [Ω]	Reference short circuit power [kVA]
up to 16A	0,28	570
up to 75 A	0,21	760

Tab. 1: reference (relative) short circuit impedance and relative 3 phase short circuit power for electric equipment with nominal current up to 16A/75A connected to the LV distribution network

Table No. 1 clearly shows that the value of reference short circuit power parameter fails to provide a required voltage quality in the LV distribution network – see Fig. 3. From the DNO´s viewpoint, mere observance of a required reference impedance pursuant to IEC 725 [2] is insufficient with respect to the EN 50 160 requirements, and that is why harsher values of short circuit impedance/power of 0.18 Ω/900kVA need to be ensured in the distribution network. Although the reference short circuit power parameter is usually observed in the LV distribution network by DNO, the flicker parameter is yet exceeded. This means that the existing structure of electric appliances fails to meet emission limits, giving rise to the flicker parameter issue (see Figure 1). The question then arises of who is responsible for exceeding the flicker parameter and for failure to meet the EN 50 160 requirements.

STRUCTURE OF THE LV DISTRIBUTION NETWORK

The E.ON Distribuce´s distribution network supplies approximately 1.5 million customers with electricity in the Czech Republic. Most of these customers are connected from the low voltage network. This LV network accounts for up to 21 thousand km of underground cable, 17 thousand km of overhead lines and 18 thousand distribution substations 22/0.4kV. The network is managed by E.ON Czech Republic.

Item	Quantity
MV/LV distribution substation [piece]	18005
LV cable underground line [km]	21660
LV overhead line [km]	17151
Outlets from distribution substations	81261

Tab. 2: structure of the LV distribution network, region E.ON in the Czech Republic

Based on the knowledge of LV distribution network structure and the technical records of the company, an average length and cross-section of the cable and overhead LV outlet may be calculated.

Average value	S [mm^2]	Length [m]	Sk"[kVA]
Overhead line	45	1039	220
Underground cable	122	335	1750

Tab. 3: Average cross-section and length of the LV line, short circuit power (Sk") at the line end

The 45 mm^2 overhead line is mostly connected to the used type of AlFe42 line. The 122 mm^2 cable line is mostly connected to the used type AYKY120. As an average distribution transformer 22/0.4kV, an equipment of the 400kVA output is considered.

Line/value	Real length [m]	Maximal length [m]
Overhead line	1039	240
Underground cable	335	690

Tab. 4: Actual length and required maximum length of an average LV outlet to meet required voltage quality pursuant to EN 50 160

The required length of line corresponds to use of the short circuit power of 900 kVA. Table 4 shows that the existing cable network meets the requirements for the minimum value of short circuit power of 900kVA. An average outdoor outlet, however, does not meet this requirement, as the required maximum average length of outlet is, with respect to the short circuit power of 900kVA, considerably lower than actual average length.

TECHNICAL DESIGN

As to the required minimum short circuit power in the LV distribution network, only the overhead line network is not satisfactory.

Technical design to bring the LV level in the position corresponding to EN 50 160 is as follows:

a) To increase the cross-section of existing LV overhead lines
b) To build new MV/LV substations

The highest, technically available, cross-section for the overhead lines used by E.ON Czech Republic is the AES120 conductor. Using 710 m long conductor, a short circuit power of 900 kVA can be achieved. An average outlet length for the overhead line is, however, higher – 1039 m (see Table 4). The highest available cross-section for cable lines is NAYY150. If the 830 m long cable is used, the value of Sk"=900kVA can be achieved. Even with the highest cross-section of a cable conductor available, we could not achieve the required short circuit power of 900kVA at the end of the 1039m long line.

Line / Value	Maximal S [mm^2]	Maximal length [m]	Required length
AES	120	710	1039
NAYY	150	830	1039

Tab. 5: Maximum allowable length and required length of lines

As the only technically feasible solution to ensure the required short circuit power value in the LV voltage distribution in compliance with the EN 50 160 requirements, it is recommended to make the existing distribution network denser with new substations, while keeping the existing overhead line. A number of new substations can be calculated from the ratio of the actual average length to a maximum length of overhead line of average cross-section. It is also necessary to consider the fact that a maximum distance between two substations may be 2x240=480m to ensure a maximum length of outlet according to Table 4, or more precisely, to ensure the short circuit power of 900kVA at the end of the line using the existing cross-sections. The overhead distribution network must be thus extended with $\left(1-\frac{2\cdot 240}{1039}\right)\cdot 100\% = 54\%$ new substations. This accounts for a construction of 9723 new substations, including transformers, with approximate total investment cost of EUR 175 million.

Item	Items/km	Price/Item/km	Total price
HV/LV substation	9723	12	116 676
Transformer	9723	6	58 338
HV line	8750	12	105 000

Tab. 6: Cost of investments in equipment [thousand EUR]

Under the present conditions, providing full voltage quality in compliance with EN 50 160 in the LV distribution network at the E.ON´s supply territory in the Czech Republic (approx. 1.5 million customers) would account for approx. EUR 280 million investments.

CONCLUSION

The flicker parameter under EN 50 160 was exceeded in approximately 30 per cent of low voltage distribution networks. A criterion to ensure a required voltage quality was suggested as the prerequisite of 900kVA short circuit power. With respect to a present structure of the LV distribution networks in the Czech Republic, this criterion cannot be achieved by increasing the existing cross-sections of LV lines even to a technically highest possible limit, neither by construction itself nor by using cable lines. This parameter can only be met by making the distribution network denser with new substations and new HV lines. In the region of E.ON, which supplies approx. 1.5 million customers with electricity, this represents cost of investments amounting to approx. EUR 280 million. Any introduction of sanctions for failure to meet the voltage quality by a distributor or tightening of limits for voltage quality parameter evaluation will result in an increasing number of networks which will not be in compliance with the EN 50 160 requirements. A higher number of non-compliant networks would then account for a higher volume of necessary investments to transform these networks in a way so that they meet the EN 50 160 requirements. These investments will be then partially reflected in the price for electricity distribution by DNO and, as a result, will lead to another price increase.

Finally, it is necessary to note that also a dispersed generation (renewable energy sources) has an adverse impact on the voltage quality in the distribution network. The impact of the power generating plant operation on the flicker parameter in the MV distribution network is illustrated in Figure 4. Flicker in the MV distribution network is, of course, spread and transferred into the LV distribution network. A majority of all customers are connected from this LV network. It will be interesting to monitor a development of voltage quality parameters in the distribution network as more and more new renewable energy sources will be connected.

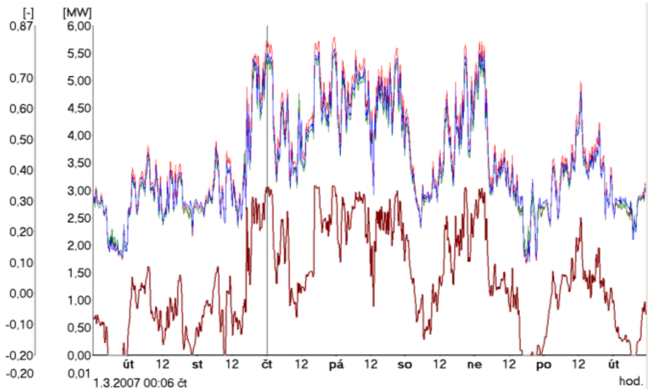

Fig. 4: Behaviour of the Flicker Pst parameter (upper curve), MV, in dependence on the supplied active power (lower curve in brown colour), wind power plant with 2x1.5MW power capacity

Acknowledgments

The authors would like to thank all of their colleagues from E.ON who are involved in providing the required voltage quality in the distribution network pursuant to EN 50 160.

REFERENCES

[1] EN 50160 Ed.3 Voltage characteristics of electricity supplied by public distribution systems. Brussels: European Committee for Electrotechnical Standardization, 2010

[2] IEC 725:1981 Considerations on reference impedances for use in determining the disturbance characteristics of household appliances and similar electrical equipment, International Electrotechnical Commission, Geneva, 1981