REDUCTION OF ELECTRICAL ENERGY TECHNICAL LOSSES BY SWITCHING FROM 10 kV TO 20 kV OPERATING VOLTAGE IN DISTRIBUTION NETWORKS

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Abstract

Losses are always one of the key items in whatever process and form they occur. This paper will present the technical losses of electrical energy in a distribution network at two different operating voltages. Calculations and comparison of losses will be presented on the model of distribution network Elektro Zepce. The network model and calculations are made using the software tool DIgSILENT PowerFactory.

Keywords: Losses; electrical energy; distribution network; DIgSILENT PowerFactory; operating voltage

1. Introduction

The paper presents technical electrical energy losses in the distribution network at 10 kV operating voltage and at 20 kV operating voltage. The technical losses are due to energy dissipated in the conductors, equipment used for transmission line, transformer, subtransmission line and distribution line and magnetic losses in transformers. The distribution network model of the Elektro Zepce branch was chosen due to the availability of the necessary input data. The DIgSILENT PowerFactory software tool was used for modeling and necessary simulations. The need for the transition of the distribution network from 10 to 20 kV operating voltage is conditioned by the loads of MV lines, voltage conditions in the distribution networks and earth fault current in the MV network.

According to the theory [4], the advantages of the transition from the 10 kV to 20 kV voltage level are:

- reduction of relative voltage drop: 4 times smaller relative voltage drop along transmission lines,
- reduction of current load of transmission lines: 2 times lower current load of MV transmission lines,
- reduction of electricity losses in conductors: 4 times less electricity losses.

Due to the mentioned advantages, the transition to the operating voltage of 20 kV is unquestionable as a basic guideline for the development of distribution networks.

The transition to a 20 kV voltage level is a time-consuming process and usually consists of three phases:

- first phase - installation of components of the voltage level of 20 kV through regular maintenance of the network in operation at 10 kV (several decades)
- second phase - accelerated replacement of the remaining components of the 10 kV voltage level for the transition to 20 kV (several years),
- third phase - final transition of the network to 20 kV operation (several days)

2. Previous research

In the distribution networks of JP Elektroprivreda HZ HB d.d. Mostar, with a long-term perspective of the transition from 10 kV to 20 kV operating voltage, in the last 20 and more year's equipment with a nominal insulation level of 24 kV has been installed. In accordance with that, a study "Perspective and techno-economic conditions for the transition of the distribution network to 20 kV operating voltage" was prepared in 2014, the author is the Hrvoje Pozar Energy Institute.

The study considered the perspective of the transition from 10 kV to 20 kV operating voltage at all branches within the distribution areas of JP Elektroprivreda HZ HB and the result of the study is the ranking of branches for the transition to 20 kV operating voltage with an approximate cost estimate. The Elektro Zepce branch has been singled out as one of the most promising branches for a possible transition [4].

3. Electricity distribution network Zepce

The Elektro Zepce branch currently supplies 6,974 consumers via the 35/10 kV substation. In the near future, it is planned to put into operation a new 110/20(10)/10 kV substation. After the commissioning of the 110/20(10)/10 kV substation, the existing one will be dismantled.

The distribution network infrastructure is dominated by overhead lines with 79.16% and pole transformer stations with 59%. There is one distributed electricity producer in the distribution network of the Elektro Zepce branch, FNE Praha with an installed capacity of 150 kVA.

3.1 Overhead lines and cables

In the distribution network of Zepce there are four feeders with most overhead lines and three feeders with most underground cables. Table 1 shows the MV transmission line lengths.

10 kV Feeder	Overhead lines [m]	Cables [m]	Total [m]	Overhead lines [%]	Cables [%]
DV Begov Han	3,985	2,313	6,298	63.27	36.73
DV Ozimica	31,795	2,225	34,020	93.46	6.54
DV Viniste	22,784	1,351	24,135	94.40	5.60
DV TK Zepce	13,777	290	14,067	97.94	2.06
KO Obdaniste	250	3,261	3,511	7.12	92.88
KO Nova trgovina i Petlja	0	5,726	5,726	0.00	100
KO Zepcanka	100	3,969	4,069	2.46	97.54
Total [m]	72,691	19,135	91,826	79.16	20.84

Table 1. Distribution network transmission line lengths by type

The table shows:

- The total length of MV 10(20) kV transmission lines is 91,826 m.
- Overhead lines in the MV 10(20) kV network are dominant with 79.16%.
- There are 4 MV 10(20) kV feeder with dominant overhead lines, marked as DV (transmission line).
- There are 3 MV 10(20) kV feeder with dominant underground cable lines, marked as KO (cable line).
- The longest transmission line is DV Ozimica, with a total length of 34,020 m.
- The shortest transmission line is KO Zepcanka, with a total length of 3,511 m.

3.2 Transformer 10(20)/0,4 kV

Table 2 and Table 3 show 10/0.4 kV and 10(20)/0.4 kV transformer in the distribution network of Zepce.

10 kV Feeder	Number of transformers	Transformer 10/0,4 kV	Transformer 10(20)/0,4 kV	Installed power (kVA)
DV Begov Han	3	0	3	360
DV Ozimica	34	10	24	5,500
DV Viniste	25	4	21	4,260
DV TK Zepce	13	0	13	1,990
KO Obdaniste	7	2	5	3,330
KO Nova trgovina i Petlja	13	0	13	5,170
KO Zepcanka	3	0	3	1,660
Total	98	16	82	22,270

Table 2. Transformer 10/0.4 kV and 10(20)/0.4 kV

10 kV Feeder	CSTS	BSTS	CSTS	DSTS	TTS	BTS	ZTS	MBTS	KTS	OTS	Total
DV Begov Han	2								1		3
DV Ozimica	18	1	6	2		2		2	3		34
DV Viniste	16		2			1	1	2	3		25
DV TK Zepce	9			1			1		2		13
KO Obdaniste						1	3	1	1	1	7
KO Nova trgovina i Petlja	1						2	8	2		13
KO Zepcanka							1	2			3
Total	46	1	8	3	0	4	8	15	12	1	98
(%)	4	1	8	3	0	4	8	15	12	1	100

Table 3. Substations 10/0.4 kV and 10(20)/0.4 kV by type

The tables show:

- A total of 98 substations.
- The total installed power of all substations is 22,270 kVA.
- 16 substations are 10/0.4 kV while 82 substations are 10(20)/0.4 kV.
- The maximum installed power is 800 kVA, it is a private MBTS Duzel group on DV Ozimica.
- DV Ozimica has the most substations, 34, while DV Begov Han and KO Zepcanka have the least substations, 3 each.
- The most common types of substations are CSTS (substation on a steal-lattice pole) with 46%.

4. Energy indicators

According to official data, the energy indicators of the Elektro Zepce branch for the year 2019 are shown in Figure 1.

Fig. 1. Elektro Zepce branch - Energy indicators 2019

The figure shows:

- Annual taken energy is 36,459,127 kWh or approximately 36.5 GWh.
- Annual energy losses amount to 9.62%.
- The highest energy consumption is in January and December.
- The lowest energy consumption is in February, April, May and June.
- The largest energy losses were in March, 18.18%.
- The lowest energy losses were in July, 7.35%.

Figure 2 shows the taken energy of the branch and the losses of the branch in the years 2010 - 2019.

Fig. 2. Elektro Zepce – Electrical energy and losses 2010-2019

The taken energy since 2010 is on rise - from 29 GWh to 36.5 GWh, while branch losses are declining - from 11.9% (2010) to 9.5% (2019).

5. Load flow analysis for distribution network Zepce

The load flow analysis was made on the network model of the Elektro Zepce using the software tool DIGSILENT. The peak load of the Zepce electricity distribution network in 2019 was used for the load flow analysis. An overview of power and electricity losses of the MV network is given. The situation at 10 kV and 20 kV operating voltage was analyzed and a comparison was made. With the knowledge of the annual electricity taken over and the peak load, the annual electricity losses were calculated with approximate formulas [3]. The required parameters for the calculation are listed below:

$W_{uk}=36,459,127$ kWh - Total annual taken electricity in 2019

$P_{vr}=6,611.59$ kW - peak load in 2019

Peak load duration:

$$T_v = \frac{W_{uk}}{P_{vr}} = 5,514.42h \quad (1)$$

Peak load factor:

$$F_v = \frac{T_v}{24 * 365} = 0.629 \quad (2)$$

Annual duration of peak power losses:

$$T_g = 8760 * \left[0.17 * \frac{T_v}{8760} + 0.83 * \left(\frac{T_v}{8760} \right)^2 \right] = 3,810.6h \quad (3)$$

5.1 Load flow analysis by 10 kV operating voltage

Based on the calculation of load flow at 10 kV operating voltage in the software tool, the following data of the distribution network Zepce are obtained:

$P_{g,cu}=268.9$ kW - power losses in cooper

$P_{g,Fe}=54.43$ kW - power losses in iron

$P_{g,s}=323.32$ kW - total power losses

Annual electricity losses:

$$W_{g,E} = P_{g,Cu} * T_g + P_{g,Fe} * T_{god} = 1,501,477.14 kWh \quad (4)$$

5.2 Load flow analysis by 20 kV operating voltage

Based on the calculation of power flow at 20 kV operating voltage in the software tool, the following data of the distribution network Zepce are obtained:

$P_{g,cu}=91.95$ kW - power losses in copper

$P_{g,Fe}=58.38$ kW - power losses in iron

$P_{g,s}=150.32$ kW - total power losses

Annual electricity losses:

$$W_{g,E} = P_{g,Cu} * T_g + P_{g,Fe} * T_{god} = 861,738.3 kWh \quad (5)$$

5.3 Comparison of technical losses by 10 kV and 20 kV operating voltage

The achievement by switching to 20 kV operating voltage in terms of reducing annual electricity losses is shown in Table 4.

Losses	10 kV operating voltage	20 kV operating voltage	Losses reduction
$W_{g,E}$ (annual electricity losses) [kWh]	1,501,477.14	861,738.3	639,738.84
$P_{g,s}$ (total power losses) [kW]	323.32	150.32	173

Table 1. Electricity losses at 10 kV and 20 kV operating voltage

Table 4 shows that by switching to 20 kV operating voltage, electricity losses would be reduced by 639,738.84 kWh, that means they would be 1.75 times smaller than at 10 kV operating voltage. The total power losses would be reduced by 173 kW, that means they would be 2.15 times smaller than at 10 kV operating voltage.

6. Conclusion

The aim of this paper was to show the reduction of technical losses of electricity in distribution networks by switching from 10 kV to 20 kV operating voltage. The program simulation and approximate method of calculating electricity losses confirmed the theoretical expectations of reducing losses by switching from 10 kV to 20 kV operating voltage. By simulating the distribution network at 20 kV operating voltage, we get better voltage conditions and less current were obtained, and thus lower loads on the network elements, less heating and smaller losses. The results show that by switching to 20 kV operating voltage, the expected energy losses in the distribution network Zepce would be 1.75 times smaller.

The total losses of active power would be 2.15 times smaller, the losses on the conductors 4.64 times smaller, and the losses on substations would be approximately the same. It is concluded that the direction of development and investment towards 20 kV operating voltage is justified and that the transition is unquestionably necessary. Operation at 20 kV voltage, in addition to reducing losses, also enables a better supply, which is the most important criteria for electricity consumers. The next step is to make a detailed analysis of the distribution network and make a cost estimate that will show the necessary investments for the transition to 20 kV operating voltage. Then, based on the cost-benefit analysis, it will be possible to determine the next steps.

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