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COMPARISON OF NETWORK LOSSES AT 10 KV AND 20 KV OPERATING VOLTAGE OF THE DISTRIBUTION GRID

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Abstract

Within the perspective of the transition from 10 kV to 20 kV operating voltage of the distribution network, this paper discusses in detail and presents a comparision of losses in the network at 10 kV and 20 kV operating voltage. The energy balance is presented, including the annual electrical energy consumption, annual electrical energy losses and electrical energy consumption by months. The paper presents technical electrical energy losses obtained on the basis of an approximate method of calculating losses in the MV network, as well as the costs of electrical energy losses for a certain period.

Keywords: electrical energy; technical losses; distribution network; operating voltage; analysis.

1. Introduction

Network losses are defined as the difference between the energy delivered to the grid and the energy taken from the grid. The main division of losses is into technical and non-technical losses. Technical losses are of a physical nature, a consequence of the passage of electricity through the elements of the power system and the conversion of that energy into heat. In addition, they are divided into permanent and variable:

- Constant losses do not depend on the load current passing through the network elements and they include losses in transformer cores, losses due to corona, etc.
- Variable losses are proportional to the square of the load current, and occur in the conductors and windings of the transformer (heat dissipation).

The issue of calculating power and energy losses and the costs of power and energy losses in distribution networks is very complex, but important for the operation of the distribution system. The structure and magnitudes of losses differ depending on the voltage levels of power grids. To calculate the technical losses of electricity required is to know the technical parameters of all lines and transformers from high to low voltage, time and quantitative load distribution during the observed period for all elements.

Due to the common unavailability of many data, especially medium and low voltage load time diagrams, access to certain approximations is inevitable in order to realize the best possible calculation from the available data set. This paper presents the results of loss estimation by the approximate method for the appropriate distribution network and their reduction by moving to a higher voltage level, because the reduction of losses is important for the energy system in order to use as much energy as possible instead of irreversibly lost. [2]

2. Electrical energy losses

World benchmarks for losses in distribution networks target electricity losses of up to 8% of electricity taken over. According to the cause, electricity losses are divided into:

- technical losses,
- commercial losses.

Technical losses are a consequence of the distribution of electricity through the network elements to the metering point of the customer. Commercial losses are the result of unregistered consumption, non-simultaneous reading of electricity meters and subjective errors when reading electricity meters. [1]

2.1. Technical losses and costs of technical losses

Technical energy losses are a consequence of the distribution of electricity through the network elements to the metering point of the customer. In the entire distribution network, the sums of losses are equal in:

- LV network 0.4 kV,
- 10 (20) /0.4 kV transformation,
- MV network 10 kV,
- 35/10 (20) kV transformation,
- MV network 35 kV.

2.2. Approximate method of calculating losses in the MV network

The usable time of the peak load T_v is calculated as the ratio of the total annual energy taken up by W_{uk} and the realized peak load P_m:

$$T_v = \frac{W_{uk}}{P_m} \; [h] \tag{1}$$

The peak load factor arises from the duration of the peak load F_v:

$$F_v = \frac{T_v \; [h]}{24 \times 365 \; [h]} \tag{2}$$

The annual duration of peak losses of active power in the distribution network T_g with a loss factor of 0.17, it is calculated according to:

$$T_g = \left[0.17 \times \frac{T_v}{24 \cdot 365} + 0.83 \times \left(\frac{T_v}{24 \times 365}\right)^2\right] \times 24 \times 365 \; [h] \tag{3}$$

Energy loss costs C_{gE} refer to the costs of additional energy (fuel, water…) for the production of each kWh lost in the network. They are calculated according to:

$$W_{gE} = T_g \times P_{g,Cu} + T_n \times P_{g,Fe} \tag{4}$$

$$C_{gE} = W_{gE} \times k_E \tag{5}$$

Where are:
W_{gE} - total annual electricity losses [MWh],
T_g - annual duration of peak losses of active power [h],
T_n- nominal time 8760 [h / year],
$P_{g,Cu}$ - power losses in the MV network due to load [kW],
$P_{g,Fe}$ - idle power losses in MV network [kW],
C_{gE} - energy loss costs [KM],
k_E- price of energy losses [KM / kWh].

2.3. *Costs of electricity losses in 2019*

Annual losses of electricity at medium voltage in the distribution network in the municipality of Citluk in the period from 2015 to 2019 average 12% of the taken over electricity. According to the calculations for 2019, the total technical losses of the active power of the 10 kV network, at the time of peak load, amount to 1012.8 kW. Of that, losses in iron (constant losses) of 10 kV network make $P_{g,Fe}$ = 110.5 kW, and losses in copper (variable load-dependent losses) of 10 kV network make $P_{g,Cu}$ = 902.3 kW.

The price of energy loss is determined on the basis of the valid prices of the public service provider for the provision of universal service, which includes tariff rates for distribution system users, according to the decisions of FERK (Energy Regulatory Commission in FBiH). Also, the price was determined according to the structure of the consumer category of the distribution network "Citluk". If we assume that:

cost of energy loss, $k_E = 0{,}09\ \left[\frac{KM}{kWh}\right]$,

and for the average value of the equivalent duration of the peak power (for 2019) is taken T_v, then the annual costs of energy losses C_{gE}, in the 10 kV network for 2019 are:

$$C_{gE} = W_{gE} \times k_E$$

$$C_{gE} = 3.149.387\ [kWh] \times 0{,}09\ \left[\frac{KM}{kWh}\right]$$

$$C_{ge} = 283{,}445\ [KM]$$

If the network is adjusted to operate at 20 kV voltage (using the Power Factory software tool) and the same peak load data for 2019 are used, the cost of energy losses is obtained:

$$C_{gE} = W_{gE} \times k_E$$

$$C_{gE} = 1.731.523\ [kWh] \times 0{,}09\ [KM]$$

$$C_{ge} = 155{,}837\ [KM]$$

From the above, it can be concluded that by switching the existing 10 kV network to 20 kV operating voltage, the savings would amount to 127,607 KM (2019), ie the losses would be 1.82 times lower. Since electricity consumption depends on many different factors, analogous analyzes were made for the period from 2019 to 2028 (ten-year period) assuming annual growth / decline rates for consumption scenarios +/- 0.3%, +/- 0.5% and +/- 0.8%, the results shown in Table 1.

Average consumption growth rate [%]	**Saving [kWh]**	**Saving [KM]**
+ 0.3	14,522,639	1,307,038
- 0.3	13,845.413	1,246,087
+ 0.5	14,758,104	1,328,229
- 0.5	13,629,022	1,226,612
+0.8	15,120,815	1,360,873
- 0.8	13,312,831	1,198,155

Table 1. Estimation of savings in case of 20 kV operation (2019 - 2028)

According to the presented results, it can be concluded that the estimated savings in the ten-year period, depending on the trend of consumption growth rate, taking the average purchase price to cover losses of 0.09 KM / kWh, ranges from 1.19 to 1.36 million KM. The cost of purchasing electricity to cover losses may fluctuate, so the expected financial savings may be more significant than reported in the previous analysis.

3. Energy indicators

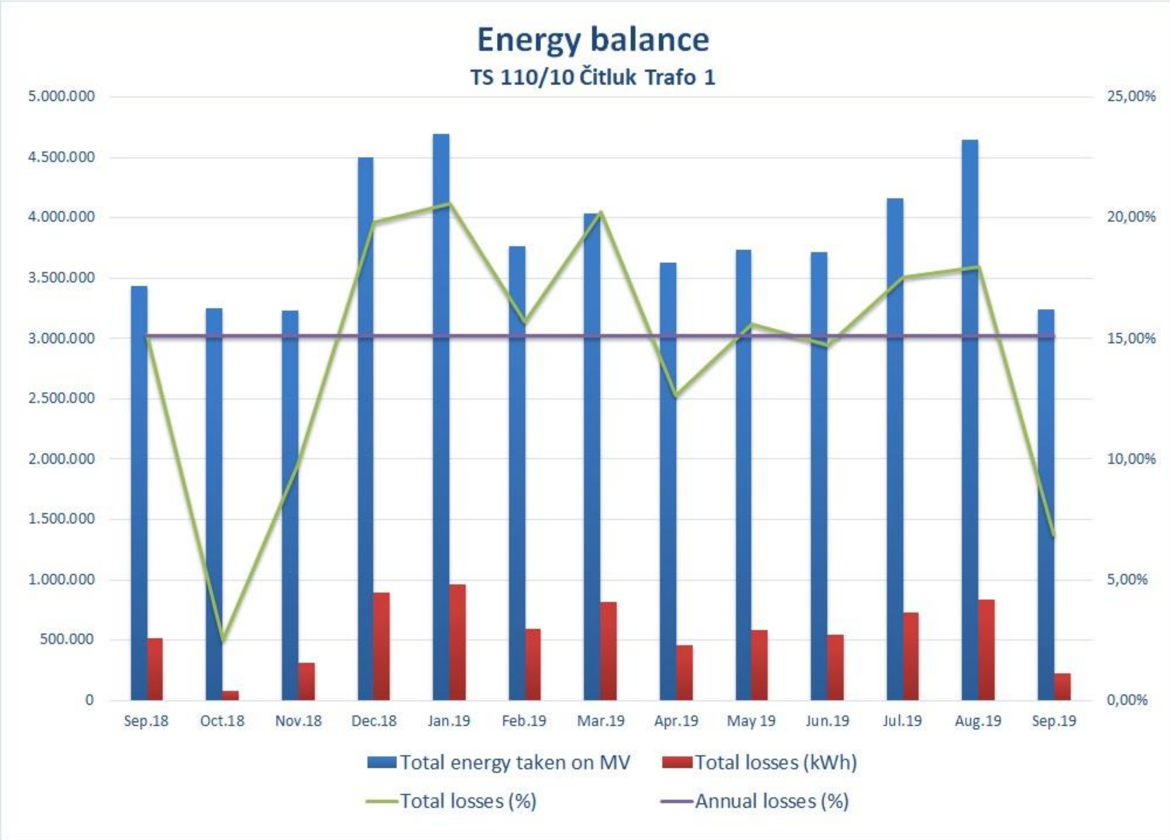

Fig. 1. Energy balance - TS 110/10 “Citluk Trafo 1”

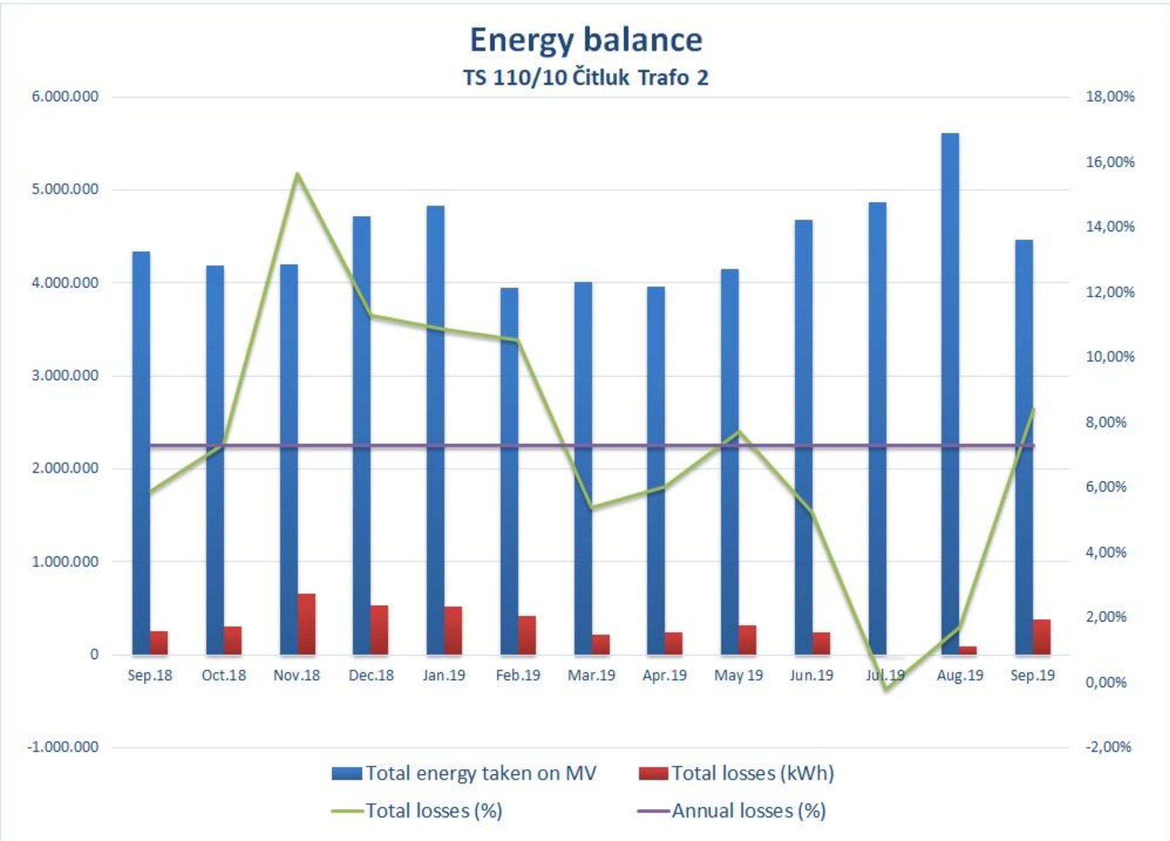

Fig. 2. Energy balance - TS 110/10 “Citluk Trafo 2”

Based on the energy balances and electricity losses in the past, the load development plan in the observed area and the analysis of power flows in the medium voltage network, it is possible to estimate the total energy balance and electricity losses for each year of the observed planning period. According to the official results, the energy indicators of distribution network “Citluk” for the period from September 2018 to September 2019 are shown in the pictures above.

In Figure 1., the following is visible:

- Annual energy losses amount to 15.10%
- The highest energy consumption is in January 2019 and in August 2019, more than 4.5 GWh per month
- The lowest energy consumption is in October and November 2018 and September 2019, approximately 3.2 GWh per month
- The largest energy losses are in January 2019, 20.59%
- The lowest energy losses are in October 2018, 2.53%

In Figure 2., the following is visible:

- Annual energy losses amount to 7,15%
- The highest energy consumption is in August 2019, approximately 5.6 GWh
- The lowest energy consumption is in February and April 2019, approximately 3.9 GWh per month
- The largest energy losses are in November 2018, 15.67%
- The lowest energy losses are in July 2019, approximately zero.

4. Conclusion

This paper presents the electricity losses of the distribution network “Citluk” and compares the technical losses of the 10 kV and 20 kV networks. The results were obtained using an approximate method of calculating losses in the MV network. The calculation of the cost of losses shows that there are significant savings when switching to a 20 kV network, ie the losses would be 1.82 times smaller than the losses in a 10 kV network. Theoretically, losses should be reduced 4 times by switching from 10 kV to 20 kV network, but in the presented network this is not the case due to the influence of the cable part of the network and incomplete load of the lines. By analyzing the estimate of savings for a ten-year period, we came to the conclusion that the savings in this period range from 1.19 to 1.36 million KM, depending on the price of electricity, which may vary.

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