RECOMMENDATIONS FOR DISTRIBUTION NETWORK PLANNING BASED ON BENCHMARKING OF ENERGY LOSSES IN CROATIAN DSO NETWORK

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ABSTRACT

Technical energy losses are an important indicator of the status of the distribution network, which, in addition to the particular area distribution network characteristics, may help to determine the guidelines for planning the distribution network development in terms of energy efficiency or technical power losses. The paper presents a benchmark of technical energy losses by all network elements among 21 distribution areas within HEP DSO. The results point to the conclusion that, in terms of technical losses, a system with direct transformation 110/20 kV and one medium voltage level (20 kV) is preferred. Therefore, in order to optimize the investment, it is necessary to consider integrated development planning of the distribution network and the 110 kV voltage level transmission network.

INTRODUCTORY ON DETERMINATION OF TECHNICAL LOSSES

Based on the study of losses [1] in HEP DSO (Croatian distribution system operator), the paper presents a benchmark of technical energy losses by all network elements among 21 distribution areas. Considering the results of calculations of technical losses and structures of the distribution networks, two concepts of the distribution networks, a classical one with three voltage levels 110-35-10 kV and a newer one with two voltage levels 110-20 kV are compared concerning energy losses.

In order the comparison to be consistent, the analysis of technical losses includes primary distribution network (35 kV lines, 110/10(20) kV and 35/10(20) kV transformers), 10(20) kV lines and 110/35 kV transformers owned by transmission system operator.

The main variables that most significantly affect the accuracy of estimates of technical energy losses in the observed element of the distribution network are: distributed energy, peak load and shape of the load duration curve, load (non)coincidence, load phase disbalance, temperature dependence of the conductors' resistance and network model(s).

For a reliable analysis and calculation of technical energy losses, an accurate energy balance is necessary, which reflects the energy flows by voltage levels and the elements of the distribution network, including all inputs and deliveries of the electricity to / from the observed network or its part: input from the transmission network and other distribution networks, input from the power plants connected to the distribution network, delivery to the transmission network and other distribution networks, sale to end customers and electricity losses.

A detailed description of the impacts of energy balance components on the calculation and expression of losses and suggestions for improving the monitoring of the energy balance are given in [2].

For most of the primary network components (over 90%), technical losses were calculated using hourly load data from the HEP DSO SCADA system and HOPS (Croatian transmission system operator) SCADA / EMS system.

The calculated technical losses are expressed as relative values in relation to the total distributed energy.

The average technical losses at HEP DSO level are 4.27% and vary from 3.85% to 6.05% by 21 distribution areas. On average (at HEP DSO level), most (27%) of losses is in 10(20)/0.4 kV transformation, followed by 0.4 kV lines, connections and measuring equipment (34%). The share of technical losses in the primary distribution network is 21%, and the remaining 18% is in the 10(20) kV lines. The share of technical losses non-dependent on load is 40%, of which 57% is the contribution of the MV/LV transformers and 21% is the contribution of meters and measuring equipment.

ANALYSES OF LOSSES IN PRIMARY DISTRIBUTION NETWORK

The total technical energy losses in the primary distribution network are shown in Figure 1 relatively to the energy entering the distribution network, which corresponds to the distributed energy. The losses are lower in the distribution areas with the direct transformation of 110/10(20) kV (Elektra Zagreb, Elektra Sisak, Elektra Zadar), while they are high in distribution areas with extensive 35(30) kV network (Elektra Šibenik, Elektrolika Gospić, Elektrojug Dubrovnik, Elektra Križ, Elektra Požega). Technical losses by the elements of the primary distribution network are not easy to compare, due to the different shares of direct transformation of 110/10 (20) kV and 35(30) kV network and transformation of 35(30)/10(20) kV. Considering that in the distribution areas with 35(30) kV networks there are more transformer stations 110/MV owned by the transmission system operator, the difference between the two observed concepts of distribution network development in terms of technical losses in the primary network is even greater in favour of direct transformation, as shown in Figure 2.

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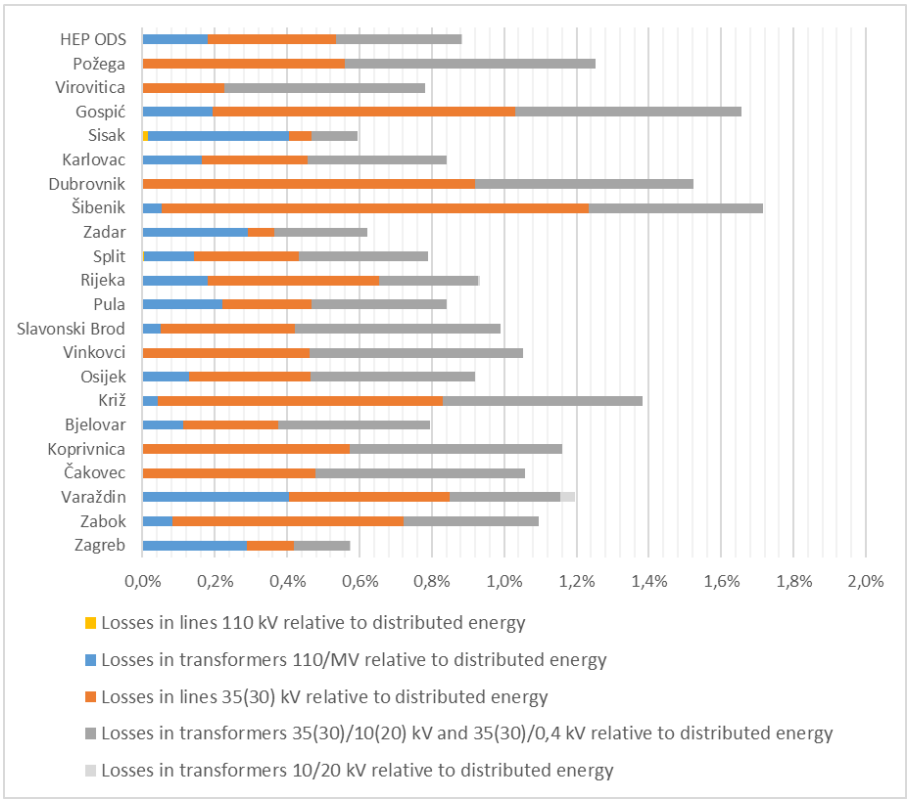


Figure 1. Technical losses in primary distribution network relative to distributed energy

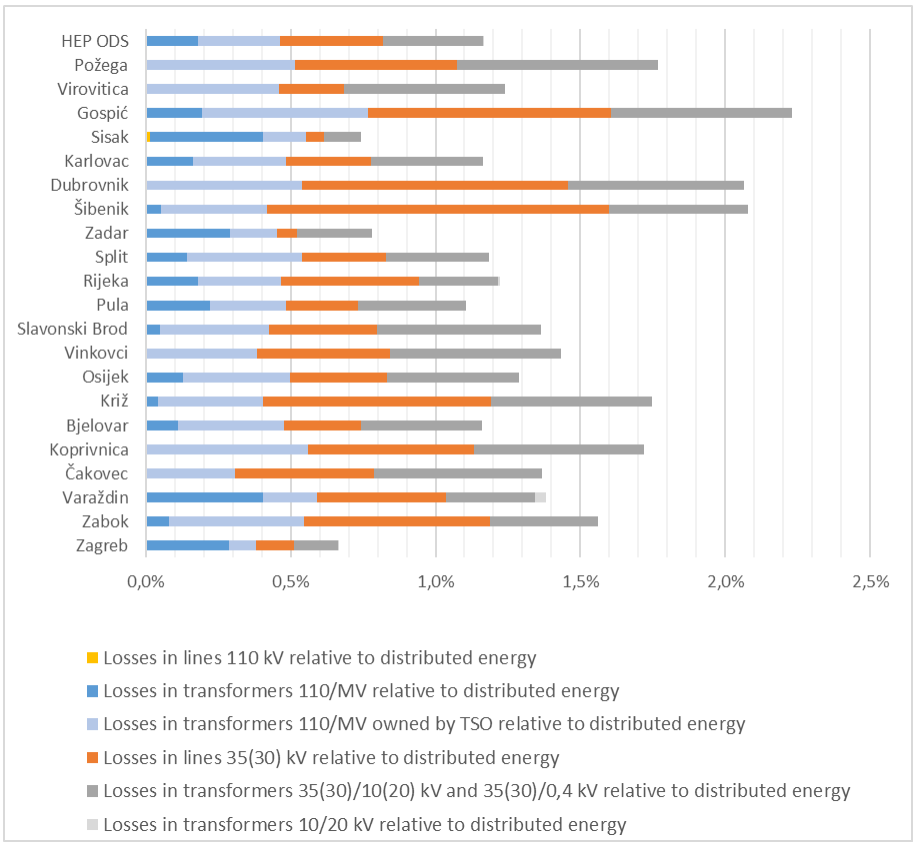
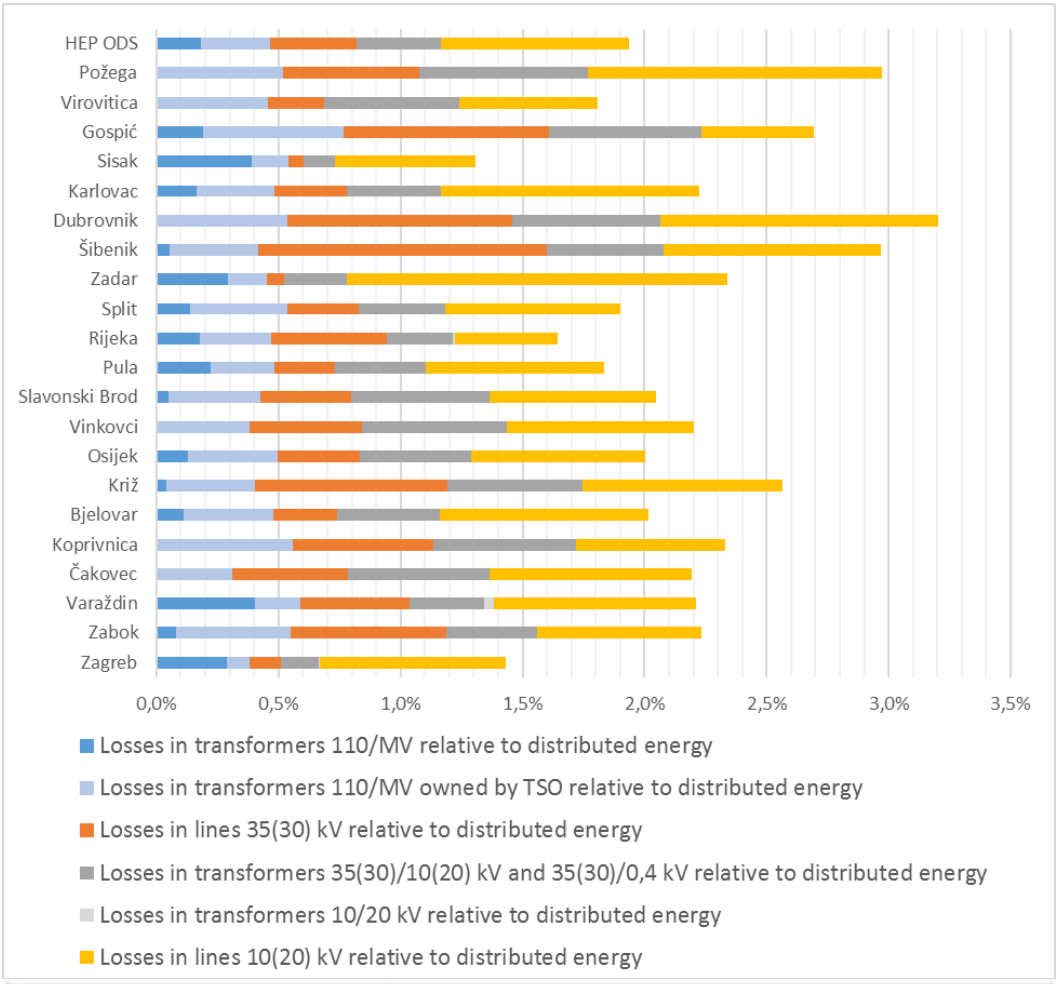


Figure 2. Technical losses in primary distribution network and transformation of 110/MV owned by transmission system operator relative to distributed energy



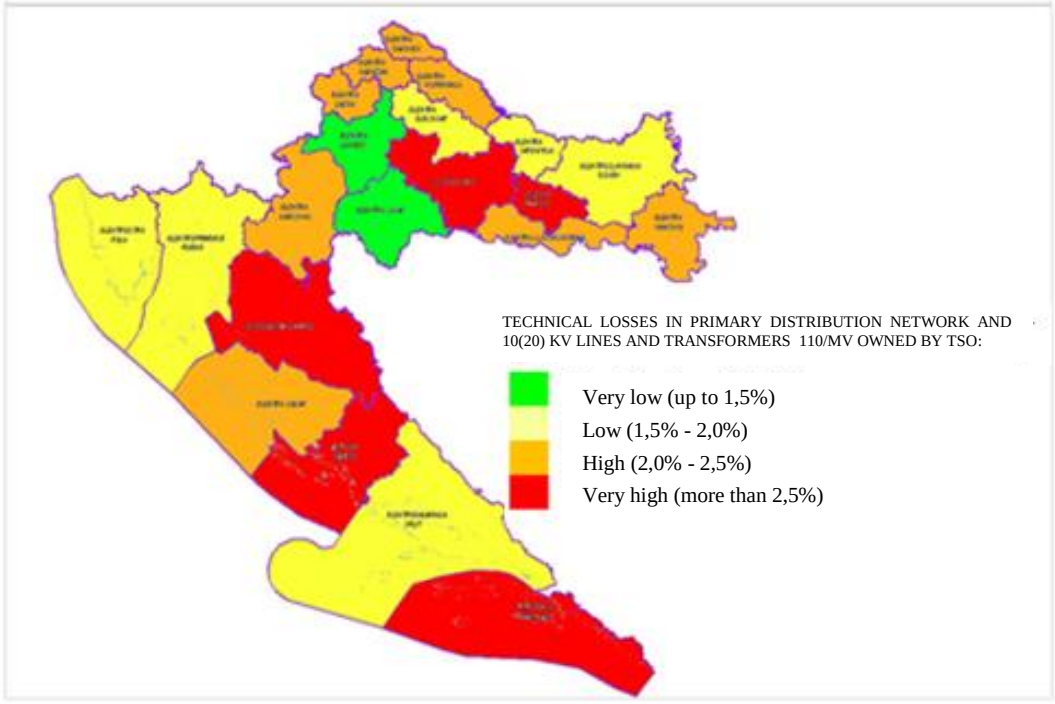


Figure 3. Technical losses in the primary distribution network and 110/MV transformation owned by transmission system operator and 10(20) kV network relative to distributed energy

For a comprehensive comparison of two concepts of distribution network development in terms of energy efficiency (regardless of the separation of ownership over transformers 110/MV between the transmission and the distribution system operator), the analysis also has to include the technical losses in the 10 kV or 20 kV lines. For the networks with direct transformation longer feeders and therefore higher losses are characteristic.

The results of conducted analyses of technical losses in the observed network components (primary distribution network, 110/MV transformation owned by the transmission network operator and 10 kV or 20 kV lines) diven in Figure 3 show that the average level in Croatia is 1,94% of the distributed energy. Lower technical losses are observed only in Elektra Sisak (1,32%) and Elektra Zagreb (1,43%), because of the direct transformation of 110/10(20) kV and a significant share of 20 kV network. Oppositely, high technical losses are observed in the distribution areas with 35(30) kV network and a negligible share of 20 kV networks (Elektrojug Dubrovnik 3.20%, Elektra Požega 2.97%, Elektra Šibenik 2.96%, Elektrolika Gospić 2, 70%, Elektra Križ 2.56%).

Detailed overview of observed technical losses and distribution network characteristics by distribution areas is given in Table 1, where the total share of direct transformation and 20 kV network is determined as an average of the contributions by each category. As shown in Figure 4, the correlation between technical losses in primary distribution network, 10(20) kV lines and transformers 110/MV owned by TSO and the share of direct transformation and 20 kV network can be determined.

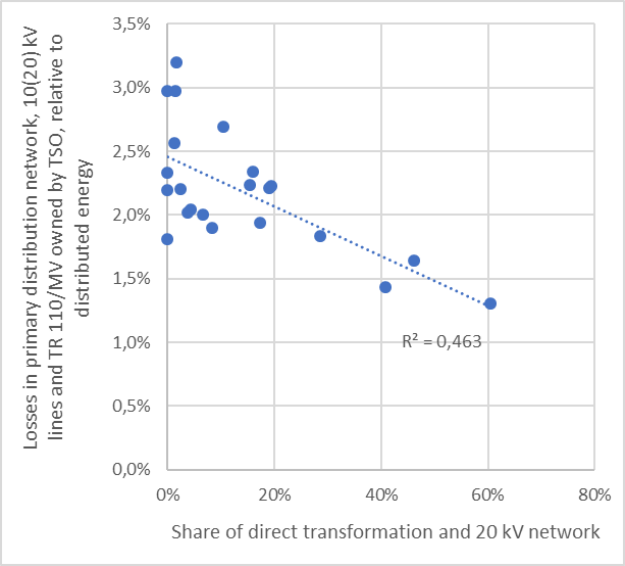


Figure 4. Technical losses in primary distribution network and transformation of 110/MV owned by transmission system operator relative to distributed energy

Table 1. Overview of losses and network characteristics by distribution areas

Distribution area	Share of 20 kV network	Share of direct transformation	Share of direct transformation and 20 kV network	Technical losses in primary distribution network, 10(20) kV lines and TR 110/MV owned by TSO, relative to distributed energy
Zagreb	39%	42%	41%	1,43%
Zabok	21%	10%	15%	2,23%
Varaždin	11%	27%	19%	2,21%
Čakovec	0%	0%	0%	2,20%
Koprivnica	0%	0%	0%	2,33%
Bjelovar	0%	7%	4%	2,02%
Križ	0%	3%	1%	2,56%
Osijek	3%	10%	7%	2,00%
Vinkovci	5%	0%	2%	2,20%
Slavonski Brod	3%	6%	4%	2,05%
Pula	40%	17%	29%	1,84%
Rijeka	64%	29%	46%	1,64%
Split	0%	17%	8%	1,90%
Zadar	1%	31%	16%	2,34%
Šibenik	0%	3%	1%	2,97%
Dubrovnik	0%	3%	2%	3,20%
Karlovac	16%	23%	19%	2,23%
Sisak	71%	50%	60%	1,31%
Gospić	14%	7%	11%	2,69%
Virovitica	0%	0%	0%	1,81%
Požega	0%	0%	0%	2,97%
HEP DSO	19%	15%	17%	1,94%

RECOMMENDATIONS FOR DISTRIBUTION NETWORK PLANNING CONSIDERING ENERGY EFFICIENCY (TECHNICAL LOSSES)

Technical energy losses are an important indicator of the state of the distribution network, which, in addition to the distribution network characteristics per distribution area, may help to determine the guidelines for planning the distribution network development in terms of energy efficiency or technical energy losses.

Detailed analysis of technical losses in the primary distribution network and 10(20) kV lines, including transformers 110/MV, regardless of the separation of ownership between the transmission and the distribution system operator, suggests that, with respect to technical losses, the development of the distribution network needs to be gradually steered from the classical system with three voltage levels 110-35-10 kV to a newer system with direct transformation of 110/20 kV and one medium voltage level (20 kV). The networks featuring the combination of a significant share of the direct transformation of 110/10(20) kV and significant share of 20 kV operating voltage have the losses lower than average, contrary to distribution networks with extensive 35(30) kV network and negligible shares of 20 kV operating voltage.

Therefore, in order to optimize the investment, it is necessary to consider integrated development planning of the distribution network and the 110 kV voltage level transmission network and include coordination of both transmission and distribution system operators.

A methodology should be developed for the analysis of the technical and economic justification of the investments in the facilities commonly owned by the transmission and the distribution network operator including the evaluation of all relevant alternative solutions.

REFERENCES

[1] T. Baricevic and other, 2016, *Expert and Scientific Support in Development of Methodology for Planning of Power Losses and Methodology for Calculation of Realisation of Power Losses and Estimation of Technical Losses and Unauthorised Use of Electrical Energy*, EIHP, Zagreb, Croatia

[2] T. Baricevic, M. Skok, 2018, " Recommendations for Improvement of Methodology for Determination of Energy Losses and Overview of Technical and Non-technical Losses in HEP DSO Distribution Network", *Proceedings, Croatian CIRED conference*