

IMPACT OF THE ELECTRIC POWER FLOW AND POWER GRID CAPACITY ON THE VALUE OF TECHNICAL LOSSES

Miroslav Radosavljev, Elektrovojvodina, Novi Sad
Momčilo Šešlija, Elektrovojvodina, Novi Sad

SUMMARY

This report contains an outline of the impact of the electric power flow and power grid capacity on the value of technical losses for the purpose of conducting an adequate assessment of appropriateness of investments in particular parts of the power grid. The overall analysis has been conducted on the basis of the "Practical Method and Programme for Estimating Relative Technical Losses of Electric Power on the Consumer of the Power-SupplyCompany". This programme has been used in «Elektrovojvodina» for a long time.

Business Company «Elektrovojvodina» Ltd. consists of 10 local branches (of different size, power consumption pattern and physical capacity of the power grid). For the Business Company, local branch and sub-station district of the branch, a single calculation of technical losses has been completed for the period 2004 to 2005. During the analysis of technical losses, the following data have been used:

- data on procured (purchased) electric power for the analysed time period of one year.
- data on supplied (sold) electric power, as well as data on supplied high and low-voltage electric power for the analysed time period of one year.
- data on the total length of power lines (both overhead and cable) by all voltage levels.
- data on the total installed capacity of the power transformer MV/LV.

All obtained data have been systematically presented in the form of tables showing the impact of the electric power flow and the power grid capacity on the value of technical losses.

INTRODUCTION

The programme for «calculation» of the relative technical losses is based on a premise that every power-supply grid has at its disposal data pertaining to technical characteristics of the power –supply grid, as well as data on electric power trade. The data on electric power trade include data on procured (purchased) and supplied (sold) electric power for specific period of time and on specific territory. The analysed time period, for which this calculation has been completed, is one year and selected consumers include: the area of the whole Business Company, each of the 10 local branches of the Business

Company and sub-station districts within every local branch for which they have appropriate data on electric power sales.

Technical data contain data on the total length of power lines by voltage levels and types (overhead and cable), as well as data pertaining to the total installed capacity of individual transformers MV/LV.

From the above-mentioned data, which are available in every power-supply grid and by means of designing particular elements of power-supply grid and considering the realised sales of electric power, power consumption pattern and actual technical data of the grid, it is possible to conduct an adequate calculation of technical losses for the selected consumer and specific period of time.

In power utilities, electric power losses are calculated as a difference between procured (purchased) and supplied (sold) electric power. Losses calculated this way are substantially greater than technical losses, since they also consist of non-technical (commercial) losses. Commercial losses represent the result of the unregistered consumption (stealing of electric power by existing consumers and illegal connection to electricity supplies by new consumers), errors in measuring instruments (delays in the calibration of consumers' electricity meters, faulty operation of electricity meters and measuring transformers), personal consumption, as well as errors in readings and calculations of electric power. Commercial losses can be reduced significantly in a short space of time and even without greater capital investments.

Reduction of technical losses consists of operational measures (power grid reconfiguration, voltage regulation, compensation of reactive power) and investment measures (power grid reconstruction and development, extension of the conductor cross-section, switching from 10kV to 20kV voltage-level and similar things). Technical losses cannot be reduced significantly within the short space of time and without substantial capital investments [1].

This report has also been prepared in order to offer suggestions as to how to identify places with incurred greater losses, both technical and commercial and how to effect their reduction by means of concrete measures.

DESCRIPTION OF THE METHOD

The first phase of the loss analysis is the loss value estimate at the level of the Business Company as a whole and its local branches. From the obtained data for the period 2004-2005, presented in the Table 1, a conclusion can be drawn that total and commercial losses have been reduced at all levels, while technical losses range between 5.22% and 8.10% in 2004 and between 5.38% and 8.25% in 2005.

Table 1-Comparative outline of electric power losses in "Elektrovojvodina" for the period 2004-2005

	<i>technical losses [%]</i>		<i>commercial losses [%]</i>		<i>total losses [%]</i>	
	2004	2005	2004	2005	2004	2005
PSG "Novi Sad"	6.95	6.85	8.22	5.31	15.17	12.16
PSG "Subotica"	8.10	8.25	5.28	4.18	13.38	12.43
PSG "Pančevo"	6.66	7.03	7.03	5.61	13.69	12.64
PSG "Zrenjanin"	7.80	7.99	7.52	5.53	15.32	13.52
PSG "Sombor"	6.95	7.10	6.36	4.88	13.31	11.98
PSG "Ruma"	7.24	7.25	7.14	4.96	14.38	12.21
PSG "Kikinda"	5.22	5.38	2.55	1.09	7.77	6.47
PSG "S. Mitrovica"	8.07	8.15	7.23	5.18	15.30	13.33
PSG "Vrbas"	6.43	6.65	7.21	6.31	13.64	12.96
PSG "Senta"	6.27	6.30	4.05	2.39	10.32	8.69
Total power-supply grid (PSG)	6.98	7.07	6.96	5.06	13.94	12.13
Total Elektrovojvodina	6.74	6.82	6.53	4.70	13.27	11.52

Within the analysis of technical losses, it should be taken into account that they are themselves a very complex category and their variations can occur as a result of various factors which are not interdependent. The analysis comprises the increase in the electric power flow through the grid, as well as the increase in physical capacity, that is the level of development of the power grid itself.

The analysis of the increase of the electric power flow- the analysis of the impact of the increase of the electric power flow on the value of technical losses has been conducted on the basis of the model of the integrative power grid readings from 2005 including electric power flows from 2004 and 2005 and the results have been systematized and presented in Table 2. During the period from 2004 to 2005, there was the increase of electric power flow by 3.17% registered at the level of all consumers. Naturally, this increase of the flow effected the increase of the values of technical losses by all local branches of the Business Company and by the whole category of consumers.

Table 2- Impact of the increase of electric power flow on the value of technical losses

<i>power grid 2005</i>	<i>technical losses [%]</i>		<i>difference of losses</i>
	<i>power flow 2004</i>	<i>power flow 2005</i>	<i>[%]</i>
PSG "Novi Sad"	6.76	6.85	0.09
PSG "Subotica"	7.99	8.25	0.26
PSG "Pančevo"	6.64	7.03	0.39
PSG "Zrenjanin"	7.72	7.99	0.27
PSG "Sombor"	6.88	7.10	0.22
PSG "Ruma"	7.08	7.25	0.17
PSG "Kikinda"	5.21	5.38	0.17
PSG "S. Mitrovica"	8.00	8.15	0.15
PSG "Vrbas"	6.33	6.65	0.32
PSG "Senta"	6.18	6.30	0.12
Total power-supply grid (PSG)	6.86	7.07	0.21
Total Elektrovojvodina	6.62	6.82	0.20

The analysis of the power grid capacity- The analysis of the impact of the power grid capacity has been conducted on the basis of the model of integrative power grid readings from 2004 and 2005 and fixed value of the electric power flow from 2005. From the results obtained and presented in Table 3. it is evident that the values of technical losses have dropped in all local branches of the Business Company, which represents a direct consequence of investing in the power grid.

Table 3-The impact of the power grid capacity on the value of technical losses

<i>power flow 2005</i>	<i>technical losses [%]</i>		<i>difference of losses</i>
	<i>power grid 2004</i>	<i>power grid 2005</i>	Δ <i>[%]</i>
PSG "Novi Sad"	7.04	6.85	-0.19
PSG "Subotica"	8.36	8.25	-0.11
PSG "Pančevo"	7.05	7.03	-0.02
PSG "Zrenjanin"	8.07	7.99	-0.08
PSG "Sombor"	7.17	7.10	-0.07
PSG "Ruma"	7.40	7.25	-0.15
PSG "Kikinda"	5.39	5.38	-0.01
PSG "S. Mitrovica"	8.22	8.15	-0.07
PSG "Vrbas"	6.75	6.65	-0.10
PSG "Senta"	6.39	6.30	-0.09
Total power-supply grid (PSG)	7.19	7.07	-0.12
Total Elektrovojvodina	6.93	6.82	-0.11

Positive effects of capital construction and investment in development of the power grid are particularly noticeable in local branches of PSGs "Novi Sad", "Subotica and "Ruma" which, in comparison with other branches, invested more in development and physical extension of the power grid elements for 2005 and all that is outlined in Table 4.

Table 4 - Physical extension of the power grid elements in 2005 [2]

	110/x [kV/kV]		20/0.4 [kV/kV]		35kV	20kV	0.4kV
	ET number	Sins [MVA]	TS number	Sins [MVA]	[km]	[km]	[km]
PSG "Novi Sad"	2	23.00	87	49.05	0.93	48.52	55.41
PSG "Subotica"			26	10.94		14.20	6.80
PSG "Pančevo"	2	63.00	11	4.93		8.10	6.70
PSG "Zrenjanin"			8	2.23		5.54	2.99
PSG "Sombor"			8	1.56		2.20	4.06
PSG "Ruma"	1	31.50	20	20.88		45.03	5.05
PSG "Kikinda"			2	1.26		2.50	0.60
PSG "S.Mitrovica"			7	2.96		11.04	3.65
PSG "Vrbas"			6	1.91		6.97	2.76
PSG "Senta"			5	1.36		3.90	0.97
Total power-supply grid (PSG)		117.50	180	97.08		148.00	88.99

According to the Table 1 and in compliance with the previously drawn conclusions, it is evident that decrease of technical losses has been achieved in the PSG "Novi Sad" which only substantiates the fact that the effect of the power grid development has had greater impact on decrease, than the impact of the effect of consumption increase on the increase of the values of technical losses. As far as PSG "Ruma" is concerned, the effect of development has been in proportion to the consumption increase, while in other local branches of the Business Company, the power grid capital development has not followed the electric power flow increase in an appropriate manner, thereby failing to compensate for the electric power flow effect and leading to the registered increase of the values of technical losses in 2005, in comparison with 2004.

The next step in this analysis would be to divide, if possible, every local branch of the Business Company into several sub-station districts which are not interdependent. This method was used for processing of data for 2004 and 2005 and the analysis was published on these data for seven local branches of the Business Company at the level of the SS 110/x sub-station district:

PSG "Novi Sad"	(5 sub-station districts)
PSG "Subotica"	(3 sub-station districts)
PSG "Pančevo"	(5 sub-station districts)
PSG "Zrenjanin"	(4 sub-station districts)
PSG "Sombor"	(4 sub-station districts)
PSG "Ruma"	(4 sub-station districts)
PSG "S.Mitrovica"	(2 sub-station districts)

where the results were determined for technical, commercial and total losses and at the same it was evident that total losses of selected sub-station districts range widely between 8.95% and 21.94% for 2004 and between 7.09% and 20.33% for 2005, which should direct further analysis towards more detailed analysis of the commercial losses category, since such significant deviations from regular and projected values cannot be justified by technical losses. In 2004 technical losses of all selected sub-station districts range between 5.36% and 10.05% and between 5.75% and 10.28% for 2005. A specific value of the selected sub-station districts is particularly reflected in deviations in differences of total and technical losses, i.e. commercial losses which should be given more attention in further analysis. Taking into account 2004 data, a special attention is paid to sub-station districts in which commercial losses are outside the average range. According to the data obtained in the sub-stations such as: "Futog" (12.25%), "Temerin-Žabalj" (8.96%), "Srbobran-Bečej" (8.80%), "Vršac" (8.75%), "Bela Crkva" (15.00%), "Nova Crnja" (9.76%), "Crvenka" (13.90%), "Inđija" (10.61%), "Šid" (9.96%), particular activities have been conducted aimed at forming teams for the specific purpose of intensification of control of measuring locations [3]. Due to the different nature and on-site conditions, activities are conducted at a different pace, with different intensity and success, while the results of those activities can be seen in the reduced percentage points of commercial losses within the selected sub-station districts. During 2005, according to the commenced activities in relation to control of measuring locations, significant drop of commercial

losses was registered in the following sub-station districts: "Temerin-Žabalj" (3.04%), "Srbobran-Bečej" (3.55%), "Bela Crkva" (8.49%), "Apatin" (0.36%), "Šid" (4.14%).

The analysis' results by sub-station districts are presented in Table 5.

Table 5- Comparative outline of losses by sub-station districts for 2004 and 2005

<i>sub-station districts</i>	<i>technical [%]</i>		<i>commercial [%]</i>		<i>total [%]</i>	
	<i>2004</i>	<i>2005</i>	<i>2004</i>	<i>2005</i>	<i>2004</i>	<i>2005</i>
"Novi Sad"	6.02	5.85	7.44	4.75	13.46	10.60
"Futog"	8.37	8.28	12.25	11.38	20.62	19.66
"Temerin-Žabalj"	9.64	9.36	8.96	3.04	18.60	12.40
"Bačka Palanka"	7.37	7.51	7.80	7.24	15.17	14.75
"Srbobran-Bečej"	7.50	8.17	8.80	3.55	16.30	11.72
PSG "Novi Sad"	6.95	6.85	8.22	5.31	15.17	12.16
"Subotica-Palić"	8.16	8.12	5.77	5.95	13.93	14.07
"Bačka Topola-Bajmok"	10.05	9.59	2.67	2.54	12.72	12.13
"Kanjiža"	6.13	6.38	3.03	0.71	9.16	7.09
PSG "Subotica"	8.10	8.25	5.28	4.18	13.38	12.43
"Pančevo-Debeljača"	5.36	5.75	3.59	3.67	8.95	9.42
"Kovin"	8.25	8.30	7.61	6.10	15.86	14.40
"Alibunar"	9.51	10.28	1.26	0.78	10.77	11.06
"Vršac"	7.72	7.88	8.75	6.05	16.47	13.93
"Bela Crkva"	6.94	7.07	15.00	8.49	21.94	15.56
PSG "Pančevo"	6.66	7.03	7.03	5.61	13.69	12.64
"Zrenjanin"	7.49	7.82	7.56	5.46	15.05	13.28
"Begejci"	5.74	7.46	8.46	6.69	14.20	14.15
"Novi Bečej"	8.72	8.97	5.85	3.05	14.57	12.02
"Nova Crnja"	7.38	7.24	9.76	9.77	17.14	17.01
PSG "Zrenjanin"	7.80	7.99	7.52	5.53	15.32	13.52
"Sombor"	6.97	7.06	6.91	6.57	13.88	13.63
"Crvenka"	6.78	6.84	13.90	13.49	20.68	20.33
"Apatin"	6.29	6.88	5.28	0.36	11.57	7.24
"Odžaci"	6.85	7.12	3.15	1.12	10.00	8.24
PSG "Sombor"	6.95	7.10	6.36	4.88	13.31	11.98
"Ruma"	6.87	7.00	2.99	0.85	9.86	7.85
"Inđija"	6.70	6.68	10.61	8.12	17.31	14.80
"Stara-Nova Pazova"	6.59	6.35	7.48	7.11	14.07	13.46
"Pećinci"	7.85	7.54	5.18	4.02	13.03	11.56
PSG "Ruma"	7.24	7.25	7.14	4.96	14.38	12.21
PSG "Kikinda"	5.22	5.38	2.55	1.09	7.77	6.47
"Sremska Mitrovica"	7.88	7.79	6.10	5.71	13.98	13.50
"Šid"	8.22	8.78	9.96	4.14	18.18	12.92
PSG "Sremska Mitrovica"	8.07	8.15	7.23	5.18	15.30	13.33
PSG "Vrbas"	6.43	6.65	7.21	6.31	13.64	12.96
PSG "Senta"	6.27	6.30	4.05	2.39	10.32	8.69

By means of directing the analysis towards the realised levels of average technical losses at the level of power utilities for the analysed sub-station districts, it can be concluded that the values of this measures are in the expected range, while deviations from the regular operations of these seven power utilities are considered to be a consequence of existing differences in types and configurations of the existing grid.

CONSLUSION

The most precise results are evident at the level of the Company and the results become less precise as the level becomes lower (sub-station district) since that mostly depends on the precision of the data on division into sub-station districts. Apart from all the above-mentioned facts, by means of monitoring the results for several years we can determine movements in the values of losses at all levels which, for the most part, effect the direction of activities aimed at reducing the losses.

On the basis of the obtained results, concrete measures are undertaken for the reduction of losses, both technical and commercial.

The value of technical losses, at the level of the Business Company for 2004 amounted to 6.74% and 6.82% for 2005. Within the local branches, the value of technical losses ranges between 5.22% (PSG "Kikinda") and 8.10% (PSG "Subotica") for 2004 and between 5.38% (PSG "Kikinda") and 8.25% (PSG "Subotica") for 2005. By means of the analysis of technical losses within sub-station districts, it can be concluded that technical losses for 2004 range between 5.36% and 10.05%. In 2005 limits were pushed higher and ranged between 5.75% and 10.28%. In accordance with measures for the reduction of technical losses (capital investments, optimal integrative readings), a special attention should be paid to sub-station districts where technical losses are greater than average (>8%), such as: "Futog", "Temerin-Žabalj", "Srbobran-Bečej", "Subotica-Palić", "Bačka Topola-Bajmok", "Kovin", "Alibunar", "Novi Bečej" and "Šid".

At the level of the whole Business Company, local branches and sub-station districts, measures are undertaken for identifying locations with increased commercial losses, not only activities which are regularly undertaken at all levels, but also additional "targeted" activities within sub-station districts with registered increase of commercial losses. These activities at the level of Business Company, local branches and sub-station districts effect the gradual reduction of commercial losses. The best examples of the way in which this activity has been conducted are the sub-station districts: "Temerin- Žabalj" (3.04%), "Srbobran-Bečej" (3.55%), "Bela Crkva" (8.49%), "Apatin" (0.36%) and "Šid" (4.14%) within which commercial losses have been reduced by over 50%, in comparison with 2004. In the forthcoming period, a special attention should be paid to additional activities in relation to monitoring measuring locations in the following sub-station districts: "Futog", "Bela Crkva", "Nova Crnja" and "Crvenka".

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