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THE ECONOMIC USABILITY FACTOR ANALYSIS OF 110 kV LINES FROM ELECTRIC ENERGY REPARTITION SYSTEMS

BY

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Abstract. A rational and efficient operation for electric energy repartition and distribution systems from technical and economical point of view is conditioned by their ability to allow the increase of electric energy transit yield, active power and energy losses minimization, the improvement of power quality delivered to consumers, etc. Considering these issues, in the paper the economic usability factor (EUF) at most highly loaded working day of the cold winter state for the 110 kV lines located in the N-E area from our country is analysed. Based on the results supplied can be selected the power repartition system elements power lines and transformers that will be subjected to a more careful and detailed analysis in order to increase the available opportunities of the considered repartition system to achieve the pursued desiderata of each electric energy territorial repartition and distribution company.

Key words: repartition lines; economic usability factor.

1. Introduction

The power networks planning and the rational designing represent a highly current concept, both on the world and our country level. The continuous increase of the electric energy consumers installed capacity, of their number, as

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well as the increase of the consumption density in urban agglomerations have determined, the performance of even more elaborated studies and analyses in order to find new solutions for the consumer supply with high power quality, with power and active energy losses as small as possible, smaller current operation costs, etc.

Electric energy repartition public systems from our country are made up of overhead and cable lines with 110 kV nominal voltages, 110 kV/MV stations and 110 kV or MV switching substations intended for electricity territorial repartition, and for supply of consumers that have electric energy delimitation points with supplier at these voltages.

Taking into account the consumption current levels, the MVA/km^2 load density and the consumption forecast for a 15 to 20 years perspective, the voltage of repartition networks is currently 110 kV and will develop also at this voltage. Typically, the 110 kV repartition networks operate in looped or complex looped configuration; the electric energy supply being performed from the least two different injection points bars of the power system or local power plants (Georgescu, 2007; Ionescu *et al.*, 1998; PE132, 2003).

Regarding the policy on power quality supplied, power and energy losses minimization, power transmission yield and the related management methods; they represent priorities for each territorial electricity distribution and supply company. The aforementioned priorities must be harmonized with the general company development strategy, with *Quality – Environment – Health* and *Occupational Safety* integrated management system.

2. Electric Energy Repartition and Distribution System Monitoring

Both in the public electric energy repartition and distribution systems (ERDS) design and operation stage, it is necessary to know the consumption level and the load curves for all household and tertiary consumers supplied from these systems. In time, depending on the available equipment of the territorial electricity distribution companies, for the consumed electric loads and load curves monitoring, different methods are used, such as: remote control; local monitoring devices; active and reactive energy counters; electronic data acquisition systems, etc.

The electronic data acquisition systems from a certain process represent a measurement method that has strongly developed during the last decades especially due to significant and accelerated characteristics improvement of the used equipment. This has been possible as a result of the top technological achievements in the electronics area, such as data transmission through the intensive use of optic fibre circuits.

Presently, most of the public repartition systems from our country are automatically monitored or in process of being monitored up to the MV bars level at the step-down stations, either by using the SCADA systems or by using the Guardian systems that include electronic Alpha three-phase counters (Poeată *et al.*, 1981; Eremia *et al.*, 2006; Georgescu *et al.*, 2010).

At the same time, the spectacular evolution of the automatic computation systems, achieving remarkable performances, especially regarding the memory and data storage capacity, such an ever increasing computation speed directly influenced the mathematical models, methods and computation algorithms improvement by boosting, step by step, the implementation of real time complex processes management that occur in ERDS. In this way, a new approach conception related to analysis, development, reconstruction and optimal operation of electric energy repartition systems with the purpose of service quality improvement have outlined Georgescu, (2007); Georgescu *et al.*, (2011).

3. The Economic Utilization Factor of 110 kV Power Lines

A rational operating of an ERDS is conditioned, especially, by whole system capacity and its element (110 kV repartition lines, 110 kV/MV power transformers, MV feeders – 6 kV, 20 kV and LV feeders – 0.4 kV, MV/ 0.4 kV power transformers) allowing both power and energy losses minimization and the improvement of power quality delivered to consumers. These aims are tracked from the design phase, when each system element must be optimal dimensioned from technical and economical point of view.

The EUF (Electric Usability Factor) values, as instructed in our country (Buhuş *et al.,* 1991; 1993) represent the ratio of total transit load effective achieved in a given year and the transition that would be economic achieved through power transformer, power line or entire analysed system if was economical dimensioned in concrete conditions from the analysed year.

It must be noticed that during the years, the economic optimum point can be modified, when load curve indicators is modified (for example: maximum load duration) or may be significant changes in system prices both in our country and world market. Taking into account the EUF signification, these values should be determined in each year, in order to emphasize in this manner the operating installations where important deviations are recorded as compared to technical-economical optimum from that respective stage (Buhuş *et al.,* 1991; 1993). At the same time, the EUF periodical establishing must be interpreted as a necessary action in current operation that sets to systematically follow up the *economic health and the possibilities* that are still available to the public ERDS.

The 110 kV power lines of ERDS from our country are considered to have been designed from the technical and economical point of view corresponding to the maximum power duration, T_S, made in the previous operation year to the analysis.

Taking into account the present standards from our country, the circuits number and the phase conductors section that are ultimately adopted for 110 kV cable or overhead power lines must be the higher than the resulted values for the technical section (s_{tech}) and the economic section (s_{ec}), that is (Poeată *et al.*, 1981; Ionescu *et al.,* 1998; Georgescu, 2007; 2010):

$$s = \text{Max}\,(s_{\text{tech}},\, s_{\text{ec}}).$$

For EUF determination, that is *the annual economical usability of a power line,* the following notions and notations are used in the current practice (Buhuş *et al.,* 1991; 1993):

1° $I_{M_{\text{pec}}}(T)$ – *maximum load* taken into account when the transit capacity of a power line with the section *s* was designed, for a maximum load duration, *T*. This load is usually expressed through the relation

$$I_{M_{\text{pec}}}(T) = s j_{\text{ec}}(T). \tag{1}$$

When using the power line nominal voltage, apparent load value, $S_{M_{\text{pec}}}(T)$, can be estimated approximately with the following relation help

$$S_{M_{\text{pec}}}(T) = \sqrt{3} U_n s j_{\text{ec}}(T). \tag{2}$$

A maximum load domain corresponds to each conductor section and maximum load duration, which is economical to choose in the designing stage. Thereby, each of the $S_{M\text{pec}}$ loads is situated close to the middle of economical maximum load domains corresponding to the section *s*.

2° According to the PE 135/2003 recommendations, the load domain, I_{Mc}, for the economical choice in designing stage of the maximum section used in practice, s_M, this is situated in the following currents domain, that is

$$0.9 k_j s_M j_{\text{ec}} \;...\; 1.4 k_j s_M j_{\text{ec}}, \tag{3}$$

where k_j represents the increase coefficient of the economical current density used in order to determine the economical number of conductors that equip a line phase or the number of different circuits. Thus, in real lines case with section s_M, upon establishing EUF, the middle of the economical usability domain mentioned above shall be considered as maximum load for economical designing. Therefore, for the power lines with the maximum section s_M, the economical designing loads shall be calculated with the following relations:

$$I_{M_{\text{pec}}} = m s_M j_{\text{ec}} \tag{4}$$

or

$$S_{M_{\text{pec}}}(T) = \sqrt{3} U_n I_{M_{\text{pec}}}(T). \tag{5}$$

Regarding the multiplier *m,* it shall be determined with the relation

$$m = \frac{0.9 + 1.4}{2} k_j. \tag{6}$$

For example, in present standards from our country, for 110 kV overhead lines with OL-Al conductors, for the maximum section s_M, the coefficient k_j and the multiplier m, respectively, the following values are recommended: $s_M = 300$ mm^2, $k_j = 1.35$ and $m = 1.40$.

3º *EUF – economic usability factor for transit capacity of a power line.* For this purpose, the power line is considered to be designed from economical point of view corresponding to the maximum load duration, T_s, made in the previous operation year and it is determined with the relation

$$\text{UDT} = \frac{I_M}{s j_{\text{ec}}(T_s) m}. \tag{7}$$

It must be mentioned that for all power lines with total phase sections smaller than s_M, $m = 1$ shall be considered.

4º CPW – *total cost of power and active energy losses* in the power line, obtained under the economical operating conditions with total minimum updated expenses, can be evaluated with the following expression:

$$\text{CPW} = ksL, \tag{8}$$

where k represents the increase of the power line cost with the phase conductors section s (for OL-Al 110 kV overhead lines $k = 120$ \$/km.mm^2).

5º CPW$_a$ – *total updated cost of the power and active energy losses* for the entire study duration, when the current power line operation was performed in analysed year and it is determined with the expression

$$\text{CPW}_a = \text{CPW}_{\text{ec},a}\text{GUT}^2. \tag{9}$$

4. The Necessary Data for EUF Computation 110 kV Power Lines

In the literature (Poeată *et al.*, 1981; Georgescu, 2007; Eremia *et al.*, 2006; Ionescu *et al.*, 1998), and actually standards, regulations and instructions from our country (Buhuş *et al.*, 1991; 1993; PE132, 2003), official data are published necessary for the EUF computation of the power lines from the electric energy repartition public systems. Further on, only for 110 kV overhead power lines, all of these strictly necessary data are specified in Table 1.

Table 1

Values of Economical Current Densities, j_{ec}, [A/mm^2], *for the Number of Circuits and Sections Dimensioning of 110 kV Overhead Lines*

Constructive type of the line				T_s, [h/year]							
				1,000	2,000	3,000	4,000	5,000	6,000	7,000	8,000
LEA	Al	110 kV	Al-Ol conductors	1.33	1.24	1.16	1.08	1.00	0.92	0.85	0.79
	Cu	110 kV	Uniinsulated conductors	1.71	1.61	1.50	1.39	1.29	1.19	1.10	1.02

The economical section of active conductors of the 110 kV overhead lines is determined with the relation

$$s_{\mathrm{ec}}^{c} = \frac{I_{\max}}{j_{\mathrm{ec}}}, \ \ [\mathrm{mm}^2], \tag{10}$$

where: $I_{\max}$ is the maximum load in steady state, [A]; j_{ec} – standardized value of the economical current density, [A/mm^2].

The economical current density, $j_{\mathrm{ec}N}$, standardized for determining the economical number of phase conductors or circuits, is always bigger that the economical current densities, j_{ec}, presented in Table 1, for the simple circuit 110 kV power lines, equipped with one conductor on each phase, that is

$$j_{\mathrm{ec}N} = K_{jnc} j_{\mathrm{ec}}. \tag{11}$$

In order to determine the values of the K_{jnc} coefficient from (11), the following relations can be used, in two different situations, respectively:

a) As regards the increase the phase conductors number of the analysed power line, without taking into account the costs of the additional connection equipment, the following relation can be used:

$$K_j = \sqrt{1 + \frac{A}{Ks_{\max}}}. \tag{12}$$

b) As concerns the increase the circuits number of the analysed power line, the following relation can be also used

$$K_{jnc} = \sqrt{1 + \frac{A + \frac{n}{L} C_{\mathrm{cel}}}{Ks_{\max}}}, \tag{13}$$

where n represents the number of cells with the cost C_{cel}, which intend to equip each circuit of the designed power line.

For determining the *conductors economical number*, *N*, that equip a line phase, the number of circuits of an electric energy repartition power line and the *normalized economical section*, *s*, of each one of these conductors, according to *NTE 401/03/00*, proceed as it follows:

1° The optimal calculus number of the conductors, N_c, that equip a phase of the power line circuits is determined with the relation

$$N_c = \frac{I_{\max}}{j_{\mathrm{ec}} K_{jnc} s_{\max}} = \frac{s_{\mathrm{ec}}^{c}}{k_{jnc} s_{\max}}. \tag{14}$$

The adopted constructive solution regarding the conductor economical number, N, of each analysed line phase or circuits, shall be established through rounding to the closest integer of N_c, resulted from (14). The following cases are excepted from this rule:

a) if $N_c \leq 1.41$, $N = 1$, in all the cases when economical section, s_{ec}^{c}, determined with (10), satisfies the inequality $s_{\text{ec}}^{c} \leq \sqrt{2}s_{\max}$ and $s_{\text{ec}}^{c} \leq s_{\max}$;

b) when N_c resulted from relation (14), satisfies the following inequality: $1.41 < N_c \leq 2.5$, $N = 2$ shall be chosen.

2º The total economical section for a power line phase shall be made with N identical conductors, with section s, thus $s_{\text{ec}} = Ns$ to be as close as possible to the value of the section s_{ec}^{c}, established with the relation (10). In most cases, if the number N is bigger than the unit, it results $s_{\text{ec}} = Ns_{\max}$.

Regarding the j_{ec} increase coefficients for conductor number determination that equip a k_j line phase, as the economical number of line circuits, when each circuit is provided with $n = 1$ cells (k_{j1c}) or $n = 2$ cells (k_{j2c}), depending on line type, the conductor material and the 110 kV repartition line length, their values are indicated in Table 2 (PE132, 2003).

Table 2

Increase Coefficients of j_{ec} for Economical Number of Conductors Determination that Equip a Line Phase (k_j), as the Economical Number of Line Circuits, each Circuit being Provided with $n = 1$ Cells (k_{j1c}) or $n = 2$ Cells (k_{j2c}), Depending on the Line Type, Conductor Material and the Line Length L, [km]

Power line type				$s_{\max}$ mm^2	K_j	No. of cells of each circuit	
						K_{1j}	K_{2j}
OPL	Al	110 kV	Conductors of OL-Al	300	1.32	$1.32(1+1.170/L)^{1/2}$	$1.28(1+2.340/L)^{1/2}$
	Cu	110 kV	Uninsulated conductors	300	1.18	$1.18(1+0.880/L)^{1/2}$	$1.18(1+1.760/L)^{1/2}$

3º The economical section of a new high voltage overhead line (110 kV), can be established through the annual maximum load ranges method, under the form of currents, $I_{\max}$, [A], or apparent powers $S_{\max}$, [MVA]. The respective ranges are determined on the economical current density basis, indicated in Table 1 and presented for an 110 kV overhead line in Table 3. When resort to this method, for a specified usage duration of the maximum load, T_s, [h/year], the corresponding table to the new power line constructive type, the load range that includes the maximum calculus load, $I_{\max}$ or $S_{\max}$, is chosen, and horizontally, on the first column of the selected table, there is the economical section necessary for the analysed line.

Table 3
Annual Maximum Load Ranges Defined in A *or* MVA *and the Economical Sections, in the Case of Some New* 110 kV *Overhead Power Lines with OL-Al Conductors and* s_{max} = 300 mm^2

Ranges defined in amperes						
s mm^2	T_s , [h/year]					
	2,000	3,000	4,000	5,000	6,000	7,000
150	0...208	0...194	0...180	0...168	0...154	0...148
185	208...264	194...246	180...230	168...212	154...196	148...180
240	264...336	246...313	230...292	212...270	196...248	180...230
300	336...736	313...689	292...612	270...594	248...547	230...505
2 × 300*	736...1,300	689...1,200	612...1,130	594...1,050	547...960	505...900
Ranges defined in MVA						
150	0...40	0...37	0...34	0...32	0....29	0...27
185	40...50	37...47	34...44	32...40	29...37	27...34
240	50...64	47...60	44...55	40...52	37...47	34...44
300	64...140	60...131	55...122	52...113	47...104	44...96
2 × 300*	140...248	131...228	122...215	113...200	104...183	96...172

*Two circuits of 20 km, each with two cells with switch; K_{2j} = 1.40.

It should be noted that exist concrete situations in electric energy repartition public systems where the technical restrictions are stricter than those imposed by the economic criteria. Among these cases, the followings can be mentioned: the electric energy supply continuity provided through additional investments, in order to create some new reserve paths; thermal stability in the short-term case states (short-circuits), that can occur in 20 kV network, where feeder minimum section (medium voltage distributors) from the 110/20 kV step-down stations, must be at least 150 mm^2, even if, in such cases, an EUF indicator of low value would be recorded, only a few percent; the minimum admissible voltage level for different consumer categories supplied with electric energy from the repartition public systems.

5. Case Example

If the meaning of the *economical usability factor* (EFY) is taken into account, its values should be determined each year in order to emphasize the operating electrical installations where important deviations are recorded as compared to the technical-economical optimum from that respective stage. At the same time, must be mentioned that during the years, the *reference economic optimum can undergo changes* if type and load curves indicators are modified, as for example the maximum load duration or significant changes can occur within the pricing system both in our country and in the world market.

For EUF determination of the 110 kV power lines, a public repartition system (110 kV repartition network and 110 kV/MT stations) was considered. This system belongs to the distribution operator from our eastern country area, namely Suceava, Neamț, Botoşani. The single line diagram of public repartition system is shown in Figs. 1 *a*, 1 *b* and 1 *c*.

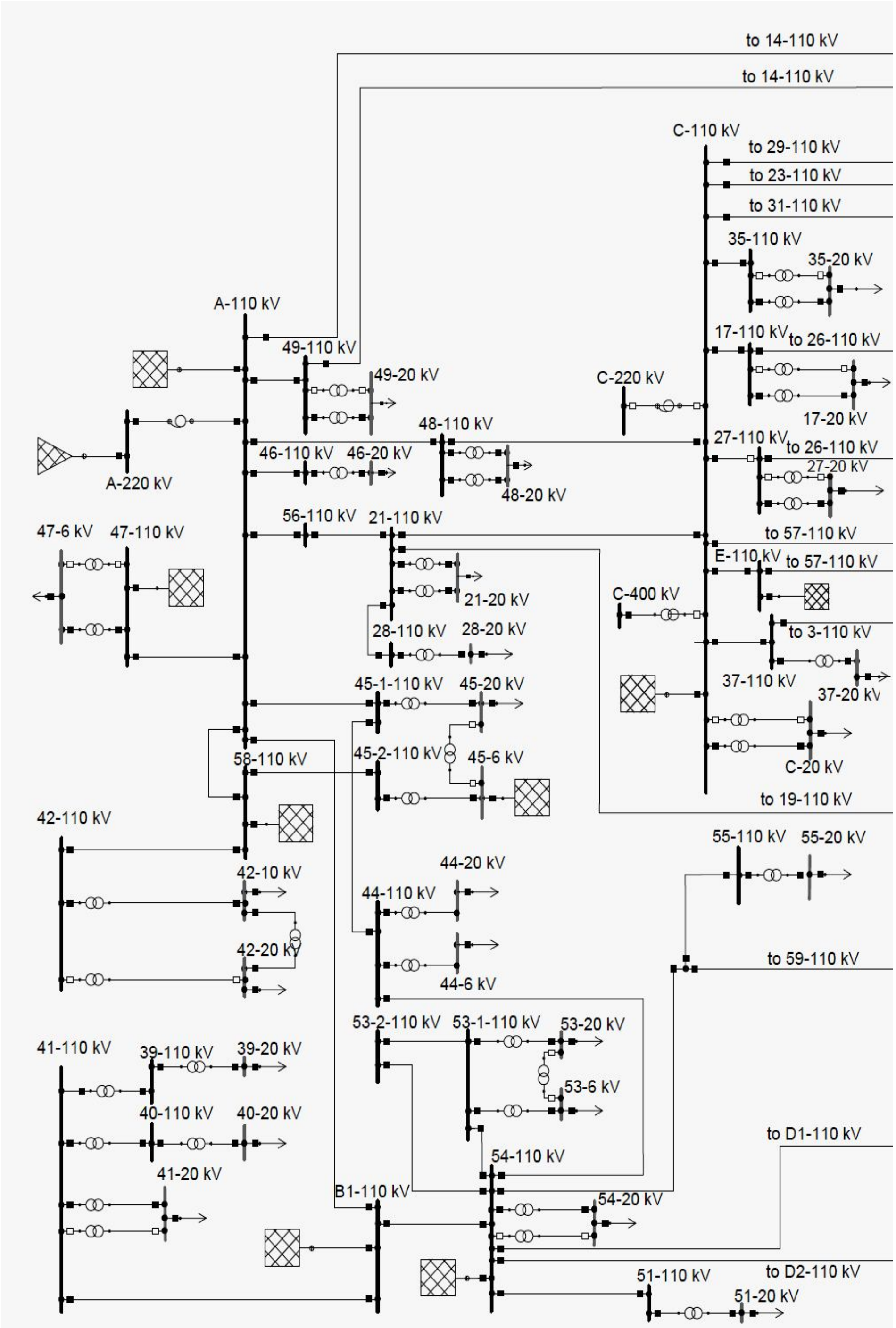

Fig. 1 *a* – Single line diagram of the analysed repartition system.

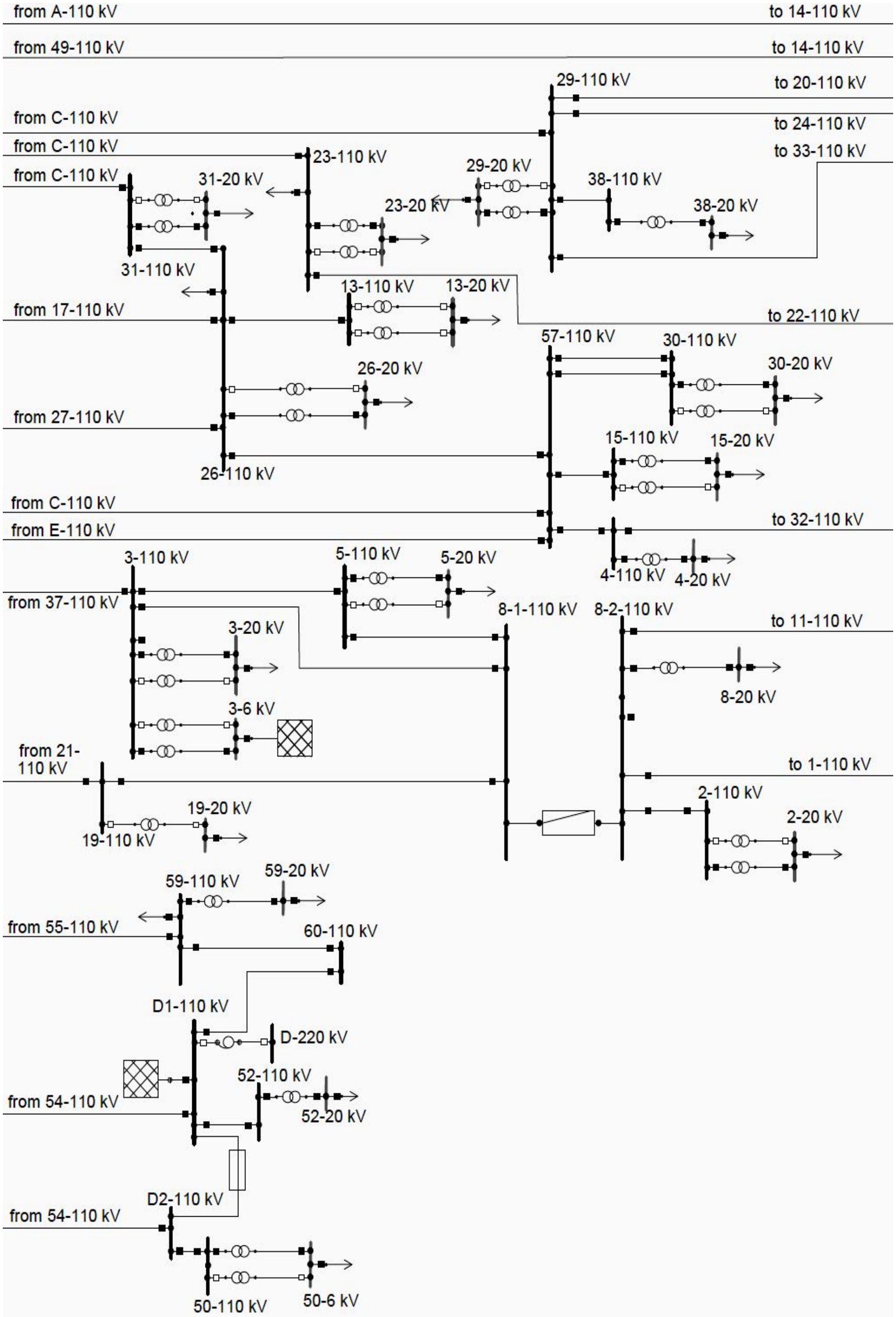

Fig. 1 *b* – Single line diagram of the analysed repartition system.

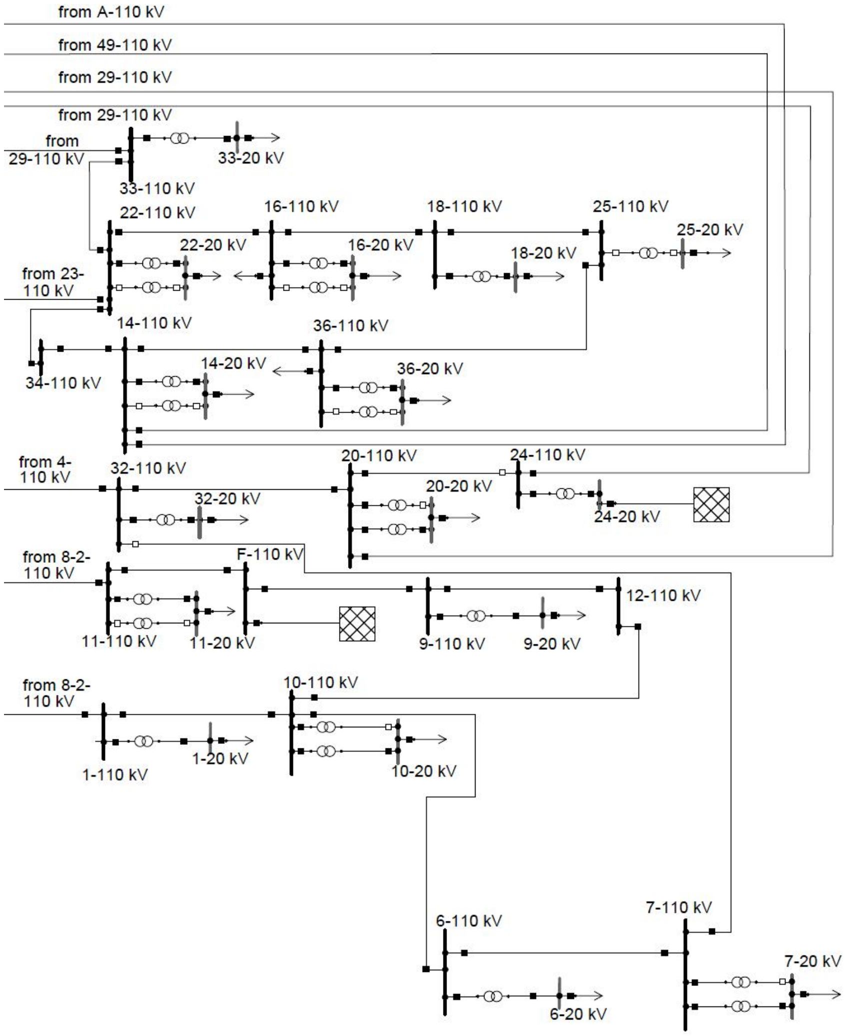

Fig. 1 *c* – Single line diagram of the analysed repartition system.

From the single line diagram analysis of the considered system, it results that the 110 kV repartition network works in complex looped configuration at winter steady state. Also, the repartition network comprises 168 lines (110 kV) with one or two circuits, and 35 step-down stations (110 kV/MT). These networks supply medium voltage distribution networks (6 kV and 20 kV networks). In the analysed public repartition system the electric energy is injected both power system and four local power plants.

For the EUF determination corresponding to a network element (line or power transformer) is necessary to know the real active/reactive loads that transit the element and them variation for different steady state of a year.

Through the rational application of all monitoring methods of the loads

(Alpha counters, automated metering for electric energy consumption – Guardian monitoring system, supervisory control and data acquisition – SCADA) all active and reactive load curves at MV bars of 110 kV/MV step-down stations during 2013 year were recorded and stored. From daily load curves analysis of cold winter state revealed that the most loaded working day was Wednesday, January 16, 2013.

In order to perform this study, the daily load curves and, particularly, the load curve of most loaded working day were processed as 24 hourly levels; each level represents the average load of one hour. Knowing the topology and material network characteristics and hourly loads to the MV station bars, and by using NEPLAN application, 24 steady state of repartition system for Wednesday January 16, 2013, were calculated.

Based on the results given by NEPLAN application, the state quantities for the 24 hourly states of the analysed repartition system, and by using the presented methodology in the previous sections of this paper the EUF values in the most loaded working day of cold winter state have been established. Thus, the results regarding the 110 kV power lines are detailed in Table 4, which comprises the following information: name of the branch point; element name (overhead power line – OPL); section; daily active, reactive and apparent energy; maximum apparent load duration per day, and per year, respectively; maximum apparent load that flows from the repartition power line; power line EUF.

Table 4

The EUF of 110 kV *Repartition Power Lines from the Analysed System*

Branch point 110 kV	Element name	s mm^2	W_P MWh	W_Q MVArh	S_{max} MVA	W MVAh	T_S day h/day	T_S year h/year	I_{max} A	J_{ec} A/mm^2	UDT %
A	OPL110 A-48	185	317.530	81.374	26.214	327.791	12.880	4701.118	137.586	1.020	72.912
	OPL110 A-B	150	153.273	93.167	11.522	179.368	16.035	5852.801	60.472	0.930	43.349
	OPL110 A45-1	185	153.359	43.247	12.732	159.340	12.890	4704.929	66.827	1.020	35.414
	OPL110 A-46	185	130.913	26.344	6.867	133.537	20.030	7310.898	36.042	0.830	23.472
	OPL110 A-58	185	267.169	105.780	19.876	287.348	14.891	5435.104	104.322	0.960	58.740
	OPL110A-14	185	253.736	11.865	17.960	254.013	14.567	5317.024	94.268	0.970	52.532
	OPL110 A-47	185	95.231	123.089	7.319	155.627	21.900	7993.629	38.417	0.790	26.286
	OPL110 A-49	185	310.874	31.284	20.918	312.444	15.385	5615.385	109.792	0.950	62.470
	OPL110 A-56	185	172.104	40.095	18.682	176.713	9.743	3556.138	98.054	1.120	47.323
B1	OPL110 B-54	150	304.285	91.987	18.126	317.885	18.063	6593.123	95.138	0.880	72.075
	OPL110 A-B	150	154.063	124.437	12.013	198.040	16.980	6197.748	63.052	0.900	46.705
	OPL110 41-B	185	478.221	43.787	26.438	480.221	18.709	6828.659	138.766	0.860	87.219
C-110kV	OPL110 C-57	185	46.577	11.362	6.107	47.943	8.086	2951.288	32.054	1.160	14.937
	OPL110 C-37	185	205.318	24.302	11.740	206.751	18.138	6620.524	61.622	0.880	37.851
	OPL110 C-27	185	0.000	6.450	0.272	6.450	24.425	8914.991	1.428	0.790	0.977
	OPL110 C-29	185	531.554	86.394	26.769	538.529	20.721	7563.164	140.502	0.820	92.618
	OPL110 48-C	150	92.200	87.411	9.056	127.049	14.451	5274.546	47.530	0.980	32.333
	OPL110 C	185	232.493	51.430	13.455	238.114	18.228	6653.278	70.620	0.870	43.877
	OPL110 C-23	185	506.538	37.249	25.266	507.906	20.706	7557.589	132.610	0.820	87.416
	OPL110 C-31	185	101.428	20.399	5.687	103.459	18.739	6839.685	29.848	0.860	18.760
	OPL110 21-C	185	207.998	69.842	14.395	219.411	15.699	5730.285	75.554	0.940	43.447
	OPL110 C-17	185	132.436	32.739	7.545	136.423	18.623	6797.473	39.602	0.860	24.891
	OPL110 C	185	135.650	36.760	8.436	140.543	17.160	6263.554	44.276	0.900	26.592
D1-110kV	OPL110 D-52	185	73.923	4.821	4.650	74.080	16.409	5989.189	24.407	0.920	14.340
	OPL110 54-D	150	679.291	71.922	32.111	683.088	21.911	7997.403	168.541	0.790	142.228
	OPL110 D-60	185	365.158	64.845	20.515	370.871	18.620	6796.350	107.677	0.860	67.679

Table 4 (Continuation)

D2-110kV	OPL110 D-50	185	29.745	3.742	1.625	29.979	19.004	6936.413	8.528	0.850	5.423
	OPL110 54-D	185	583.886	72.167	27.764	588.329	21.826	7966.645	145.721	0.790	99.706
E-110kV	OPL110 E-57	185	604.913	115.698	28.452	615.878	22.296	8137.964	149.333	0.790	102.178
	OPL110 C-E	185	135.687	27.588	8.319	138.463	17.143	6257.154	43.665	0.900	26.225
3-110kV	OPL110 37-3	185	118.157	25.372	8.168	120.850	15.240	5562.603	42.869	0.950	24.392
	OPL110 3-8	185	18.961	28.312	2.245	34.075	15.636	5707.181	11.781	0.940	6.775
	OPL110 3-5	185	56.832	6.140	3.082	57.163	19.105	6973.464	16.175	0.850	10.286
4-110kV	OPL110 57-4	185	383.693	85.133	19.316	393.024	20.957	7649.368	101.384	0.810	67.657
	OPL110 4-32	185	288.234	49.538	13.737	292.460	21.929	8003.948	72.101	0.790	49.333
5-110kV	OPL110 3-5	185	56.832	5.268	3.081	57.076	19.081	6964.469	16.171	0.850	10.284
	OPL110 5-8	240	27.807	28.701	2.240	39.962	18.377	6707.650	11.756	0.870	5.630
8-1 - 110kV	OPL110 3-8	185	18.959	24.427	2.153	30.921	14.795	5400.258	11.298	0.970	6.296
	OPL110 5-8	240	27.812	25.001	2.137	37.397	18.026	6579.431	11.216	0.880	5.310
	OPL110 19-8	185	23.757	49.429	2.903	54.842	19.456	7101.340	15.239	0.840	9.806
14-110kV	OPL110 A-14	185	250.758	79.595	17.775	263.087	15.245	5564.525	93.293	0.950	53.083
	OPL110 14-49	185	221.682	69.016	16.176	232.177	14.784	5396.240	84.899	0.970	47.311
	OPL110 14-36	185	299.754	47.663	18.208	303.520	17.170	6266.989	95.566	0.900	57.397
	OPL110 34-14	185	128.629	86.553	13.041	155.038	12.245	4469.534	68.447	1.040	35.575
15.110kV	OPL110 57-15	185	79.737	24.374	4.469	83.379	19.217	7014.171	23.456	0.850	14.917
16-110kV	OPL110 22-16	185	204.956	14.090	11.102	205.440	19.060	6956.856	58.270	0.850	37.056
	OPL110 16-18	185	26.926	52.083	3.356	58.631	17.997	6568.881	17.612	0.880	10.818
17-110kV	OPL110 C-17	185	132.365	39.431	7.606	138.113	18.703	6826.501	39.922	0.860	25.093
	OPL110 17-26	185	48.464	9.695	3.238	49.424	15.721	5738.112	16.996	0.940	9.773
18-110kV	OPL110 16-18	185	26.943	35.496	3.239	44.563	14.171	5172.289	17.001	0.990	9.282
	OPL110 18-25	185	45.213	44.387	4.511	63.359	14.468	5280.787	23.675	0.980	13.058
19-110kV	OPL110 19-21	185	23.767	16.610	1.923	28.996	15.533	5669.493	10.092	0.950	5.742
	OPL110 19-8	185	23.767	16.610	1.923	28.996	15.533	5669.493	10.092	0.950	5.742
20-110kV	OPL110 32-20	185	187.335	90.275	9.768	207.952	21.927	8003.397	51.270	0.790	35.081
	OPL110 20-24	185	0.000	3.215	0.136	3.215	24.349	8887.347	0.714	0.790	0.488
	OPL11020-29	185	410.215	223.531	21.333	467.164	22.555	8232.631	111.972	0.790	76.614
21-110kV	OPL110 21-56	150	170.245	109.086	18.426	202.196	11.303	4125.513	96.710	1.070	60.255
	OPL110 21-C	185	207.446	52.904	14.219	214.086	15.508	5660.473	74.630	0.950	42.464
	OPL110 21-28	240	119.475	25.269	7.140	122.118	17.616	6429.737	37.477	0.890	17.545
	OPL110 19-21	185	23.771	8.696	2.055	25.312	12.689	4631.327	10.784	1.030	5.660
22-110kV	OPL110 22-16	185	205.550	27.831	11.184	207.426	19.103	6972.702	58.700	0.850	37.329
	OPL11033-22	185	97.511	92.858	8.499	134.651	16.318	5956.052	44.610	0.920	26.210
	OPL110 22-34	185	120.183	120.652	13.150	170.296	13.338	4868.526	69.022	1.010	36.940
	OPL110 23-22	185	312.078	31.624	17.131	313.676	18.860	6883.854	89.914	0.850	57.179
23-110kV	OPL110 23-22	185	312.427	34.625	17.150	314.340	18.879	6890.804	90.013	0.850	57.242
	OPL110 C-23	185	502.841	38.044	25.030	504.278	20.751	7574.209	131.374	0.820	86.601
24.110kV	OPL110 29-24	185	44.422	10.477	4.374	45.641	10.746	3922.441	22.960	1.080	11.492
25-110kV	OPL110 18-25	185	45.242	30.830	4.453	54.748	12.663	4622.104	23.372	1.030	12.266
	OPL110 36-25	185	45.242	30.830	4.453	54.748	12.663	4622.104	23.372	1.030	12.266
26-110kV	OPL110 26-57	185	182.256	59.577	9.516	191.746	20.755	7575.609	49.944	0.820	32.923
	OPL110 27-26	185	145.694	23.695	7.750	147.608	19.618	7160.603	40.676	0.840	26.175
	OPL110 31-26	185	101.366	30.955	5.776	105.987	18.899	6898.116	30.318	0.860	19.056
	OPL110 26-13	240	0.000	1.879	0.079	1.879	24.498	8941.899	0.415	0.790	0.219
	OPL110 17-26	185	48.461	11.406	3.267	49.785	15.695	5728.706	17.148	0.940	9.861
27.110kV	OPL110 27-26	185	145.629	28.752	7.788	148.440	19.633	7165.987	40.874	0.840	26.303
28.110kV	OPL110 21-28	240	119.464	27.024	7.155	122.482	17.632	6435.734	37.554	0.890	17.581
29-110kV	OPL110 C-29	185	526.325	106.846	26.608	537.061	20.790	7588.222	139.656	0.810	93.197
	OPL110 29-38	185	48.292	9.321	2.995	49.183	16.914	6173.711	15.720	0.910	9.338
	OPL110 29-33	185	38.359	104.555	5.783	111.369	19.836	7240.263	30.352	0.840	19.532
	OPL110 29-24	185	44.425	17.448	4.375	47.729	11.237	4101.685	22.961	1.070	11.599
	OPL11020-29	185	411.469	216.342	21.256	464.877	22.526	8222.127	111.566	0.790	76.336
31-110kV	OPL110 C-31	185	101.399	25.178	5.723	104.478	18.803	6863.105	30.039	0.860	18.880
	OPL110 31-26	185	101.399	25.178	5.723	104.478	18.803	6863.105	30.039	0.860	18.880
32-110kV	OPL110 4-32	185	286.199	87.468	14.017	299.267	21.991	8026.786	73.569	0.790	50.338
	OPL110 32-20	185	187.698	75.551	9.566	202.333	21.785	7951.612	50.210	0.790	34.355
33-110kV	OPL110 29-33	185	38.409	87.811	5.304	95.844	18.611	6793.141	27.840	0.860	17.498
	OPL110 33-22	185	97.311	109.918	8.712	146.804	17.356	6334.835	45.728	0.900	27.464
34-110kV	OPL110 34-14	185	120.537	99.612	13.065	156.370	12.328	4499.746	68.571	1.040	35.640
	OPL110 22-34	185	120.537	99.612	13.065	156.370	12.328	4499.746	68.571	1.040	35.640
35.110kV	OPL110 C-35	185	232.429	59.536	13.530	239.933	18.265	6666.803	71.015	0.870	44.122

Table 4 (Continuation)

36-110kV	OPL110 36-25	185	45.268	19.310	4.462	49.215	11.361	4146.773	23.419	1.070	11.831
	OPL110 14-36	185	306.401	65.981	18.203	313.425	17.735	6473.262	95.540	0.880	58.686
37-110kV	OPL110 C-37	185	209.186	26.698	11.714	210.883	18.543	6768.089	61.483	0.860	38.644
	OPL110 37-3	185	118.353	23.979	8.192	120.758	15.184	5542.118	42.995	0.960	24.209
38.110kV	OPL110 29-38	185	48.263	10.598	3.053	49.413	16.671	6084.801	16.024	0.920	9.415
39-110kV	OPL110 41-39	185	85.718	4.460	4.723	85.834	18.718	6831.924	24.791	0.860	15.582
40-110kV	OPL110 41-40	185	96.911	31.995	5.217	102.056	20.148	7353.911	27.384	0.830	17.834
41-110kV	OPL110 42-41	185	141.351	111.071	13.567	179.769	13.648	4981.394	71.210	1.000	38.492
	OPL110 41-39	185	85.743	7.048	4.719	86.032	18.778	6853.986	24.768	0.860	15.568
	OPL110 41-40	185	96.931	28.496	5.159	101.033	20.170	7361.928	27.080	0.830	17.636
	OPL110 41-B	185	477.538	42.580	26.397	479.433	18.707	6828.222	138.547	0.860	87.082
42-110kV	OPL110 58-42	185	82.690	167.797	11.219	187.065	17.174	6268.609	58.884	0.900	35.366
	OPL110 42-41	185	141.203	103.153	13.458	174.868	13.384	4885.070	70.634	1.010	37.803
44-110kV	OPL110 45-44	150	285.119	42.302	17.481	288.240	16.984	6198.989	91.751	0.910	67.217
	OPL110 44-54	150	406.965	50.120	21.623	410.040	19.532	7129.040	113.494	0.840	90.074
45-1-110kV	OPL110 45-44	150	284.899	42.439	17.457	288.043	16.996	6203.378	91.623	0.910	67.123
	OPL110 A45-1	185	153.672	51.475	12.866	162.064	12.974	4735.507	67.530	1.020	35.787
45-2 110kV	OPL110 451-58	185	44.765	11.925	3.570	46.326	13.367	4878.799	18.737	1.010	10.028
46-110kV	OPL110 A-46	185	130.812	37.197	6.986	135.998	20.050	7318.417	36.668	0.830	23.880
47-110kV	OPL110 A-47	185	95.568	91.528	6.301	132.328	21.633	7895.929	33.069	0.790	22.627
48-110kV	OPL110 A-48	185	315.094	112.879	25.963	334.703	13.278	4846.547	136.271	1.010	72.931
	OPL110 48-C	150	91.831	47.434	8.193	103.358	12.994	4742.708	43.003	1.020	28.106
49-110kV	OPL110 14-49	185	223.314	18.677	16.272	224.094	14.185	5177.391	85.407	0.990	46.632
	OPL110 A-49	185	309.494	53.186	20.828	314.031	15.529	5668.206	109.321	0.950	62.203
50-110kV	OPL110 D-50	185	29.743	4.967	1.635	30.155	18.995	6933.291	8.582	0.850	5.458
51-110kV	OPL110 54-51	185	64.347	9.559	3.457	65.053	19.382	7074.382	18.145	0.850	11.539
52-110kV	OPL110 D-52	185	73.911	8.718	4.667	74.423	16.425	5995.229	24.495	0.920	14.392
531110kV	OPL110 54-53	185	40.733	6.400	2.034	41.233	20.882	7621.919	10.675	0.810	7.124
532 110kV	OPL110 54-53	185	108.016	17.466	7.904	109.419	14.260	5204.735	41.483	0.990	22.650
54-110kV	OPL110 B-54	150	307.115	59.719	18.151	312.867	17.754	6480.160	95.269	0.880	72.173
	OPL110 54-51	185	64.360	4.309	3.433	64.504	19.353	7064.019	18.018	0.850	11.458
	OPL110 44-54	150	410.747	47.228	21.909	413.453	19.437	7094.554	114.995	0.850	90.192
	OPL110 54-D1	150	678.001	71.843	32.042	681.797	21.916	7999.449	168.179	0.790	141.923
	OPL110 54-D2	185	582.947	73.763	27.719	587.595	21.834	7969.565	145.486	0.790	99.545
	OPL110 54-52	185	108.036	14.037	7.889	108.944	14.224	5191.751	41.406	0.990	22.608
	OPL110 54-53	185	40.739	2.924	2.022	40.844	20.806	7594.303	10.612	0.810	7.082
	OPL110 54-59	150	399.560	96.422	23.524	411.030	17.997	6568.953	123.468	0.880	93.536
55-110kV	OPL110 rack 55	150	34.771	6.530	2.039	35.379	17.874	6523.942	10.701	0.880	8.107
56-110kV	OPL110 A-56	185	170.985	84.037	18.490	190.521	10.613	3873.859	97.045	1.120	46.837
	OPL110 21-56	150	170.985	84.037	18.490	190.521	10.613	3873.859	97.045	1.120	57.765
57-110kV	OPL110 26-57	185	182.327	44.602	9.345	187.703	20.688	7551.149	49.050	0.810	32.732
	OPL110 C-57	185	42.423	14.164	2.989	44.725	15.412	5625.419	15.688	0.950	8.926
	OPL110 E-57	185	604.661	120.124	28.477	616.478	22.298	8138.677	149.465	0.790	102.268
	OPL110 57-30	185	0.000	3.293	0.139	3.293	24.401	8906.499	0.730	0.790	0.499
	OPL110 57-30	185	0.000	3.293	0.139	3.293	24.401	8906.499	0.730	0.790	0.499
	OPL110 57-15	185	79.738	23.261	4.459	83.062	19.187	7003.280	23.403	0.850	14.883
	OPL110 57-4	185	385.024	72.197	19.275	391.734	20.934	7640.766	101.165	0.810	67.511
58-110kV	OPL110 A-58	185	267.540	112.917	19.949	290.393	14.993	5472.492	104.707	0.960	58.957
	OPL110 58-42	185	82.770	157.814	10.907	178.203	16.829	6142.527	57.246	0.910	34.004
	OPL110 45-1	185	44.771	10.799	3.551	46.055	13.359	4875.944	18.638	1.010	9.975
59-110kV	OPL110 54-59	185	361.476	72.046	21.574	368.586	17.597	6422.956	113.235	0.890	68.773
	OPL110 59-60	185	361.848	24.207	20.201	362.657	18.491	6749.185	106.028	0.860	66.642
60-110kV	OPL110 D-60	185	363.646	46.393	20.360	366.593	18.546	6769.242	106.862	0.860	67.166
	OPL110 59-60	185	363.646	46.393	20.360	366.593	18.546	6769.242	106.862	0.860	67.166
st120	OPL110 rack 55	150	34.771	4.617	2.029	35.076	17.809	6500.363	10.648	0.890	7.976
	OPL110 54-59	185	362.662	85.681	21.727	372.646	17.666	6447.956	114.038	0.890	69.261
	OPL110 54-55	150	397.435	81.065	23.299	405.618	17.932	6545.061	122.287	0.890	91.601
F-110kV	OPL110 11-F	185	478.367	44.839	26.335	480.464	18.791	6858.850	138.225	0.860	86.879
	OPL110 F-9	185	567.246	37.911	31.261	568.511	18.731	6836.961	164.079	0.860	103.129
1-110kV	OPL110 8-1	185	17.414	40.177	2.176	43.789	20.732	7567.072	11.419	0.820	7.527
	OPL110 1-10	185	112.281	70.028	6.753	132.329	20.183	7366.892	35.444	0.830	23.083
2-110kV	OPL1100 8-2	185	185.615	28.735	9.885	187.826	19.571	7143.559	51.882	0.840	33.386

Table 4 (Continuation)

6-110kV	OPL110 10-6	185	283.844	18.408	16.065	284.440	18.237	6656.560	84.318	0.870	52.387
	OPL110 7-6	185	194.740	34.005	10.694	197.687	19.040	6949.568	56.130	0.850	35.695
7-110kV	OPL110 7-6	185	193.970	13.461	10.656	194.437	18.795	6860.068	55.928	0.860	35.152
	OPL110 32-7	185	0.000	30.960	1.330	30.960	23.977	8751.438	6.981	0.790	4.776
8-2-110kV	OPL110 8-11	185	384.314	43.659	21.136	386.786	18.849	6879.936	110.934	0.860	69.726
	OPL110 8-2	185	185.645	23.531	9.855	187.130	19.558	7138.606	51.726	0.840	33.286
	OPL110 8-1	185	17.399	49.624	2.550	52.586	21.240	7752.653	13.384	0.800	9.043
9-110kV	OPL110 F-9	185	564.306	36.830	31.066	565.507	18.749	6843.512	163.055	0.860	102.486
	OPL110 9-12	185	502.905	38.978	27.702	504.413	18.755	6845.461	145.399	0.860	91.388
10-110kV	OPL110 10-6	185	285.380	35.915	16.151	287.631	18.343	6695.173	84.772	0.870	52.670
	OPL110 10-12	185	497.597	42.510	27.393	499.410	18.778	6853.959	143.778	0.860	90.370
	OPL110 1-10	185	112.534	42.820	6.326	120.405	19.604	7155.526	33.203	0.840	21.366
11-110kV	OPL110 8-11	185	389.164	34.356	21.410	390.678	18.795	6860.238	112.371	0.860	70.629
	OPL110 11-F	185	475.808	49.495	26.216	478.375	18.795	6860.200	137.597	0.860	86.485
12-110kV	OPL110 9-12	185	500.096	40.152	27.538	501.705	18.766	6849.408	144.535	0.860	90.845
	OPL110 10-12	185	500.096	40.152	27.538	501.705	18.766	6849.408	144.535	0.860	90.845

It must be mentioned that the analysis, respectively the EUF computation values corresponding to the power transformers that equip the 110 kV/MT step-down stations for the electric energy repartition system from the N-E area of our country, on the most loaded working day from the cold winter regime of the year 2013 (Wednesday, January 16th), were presented in detail in a scientific paper published in the previous issue of this Bulletin (Georgescu *et al.*, 2013).

6. Conclusions

A rational operating of an electric energy repartition and distribution public system is conditioned especially, by whole system capacity and its element from all voltage levels (110 kV, 20 kV and 0.4 kV), to allow both power and energy losses minimization and the improvement of power quality delivered to consumers in order to minimize the damages caused to them by the inadequate quality of electric energy.

Regarding the policy concerning the power quality supplied, power and energy losses minimization, power transmission yield and the related management methods; they represent priorities for each territorial electric energy distribution and supply company. The above-mentioned priorities must be harmonized with the general company development strategy, with *Quality – Environment – Health* and *Occupational Safety* integrated management system.

Following the performed study within the paper, according to the present specifications from our country, for an extended repartition public system, consisting of the electric energy reparation network with nominal voltage of 110 kV (168 repartition power lines) and the step-down stations of 110 kV/MV (35 substations equipped with a total number of 52 power transformers), belonging to the distribution operator from the N-E area of our country, the EUF values are determined for each network power line and are synthetically presented in Fig. 2, in graphical form. The EUF values for the 110 kV repartition power lines correspond to the most loaded day (Wednesday, January 16th, 2013), from the cold winter season.

Based on detailed results regarding the EUF values of 110 kV power lines from analysed repartition system, summarized in Table 4 and Fig. 2, the following conclusions can be drawn:

1º An EUF value equal to 100% shows that the considered load transited through the power line is approximately equal with the economical load, $I_{M\mathrm{pec}}$, respectively, $S_{M\mathrm{pec}}$. In this case, EUF ≈ 100 % indicates the fact that under actual steady state the operation of respective power line leads to a minimum of the power and active energy losses, minimum total updated expenses (costs), as well as reduced specific operation expenses, etc.

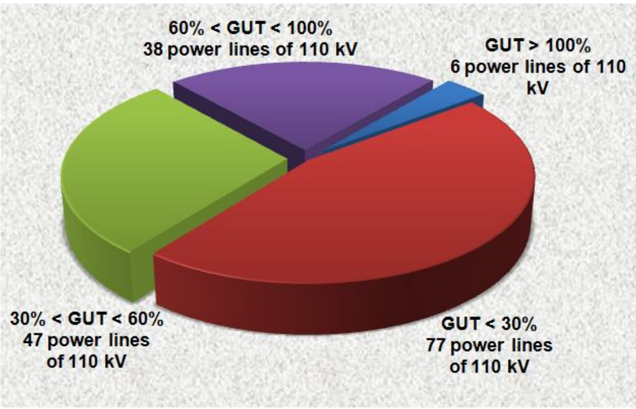

Fig. 2 – The EUF values at various loading levels of the 110 kV repartition power lines.

2º Regarding the cases when EUF >100 %, they indicate that a bigger load than the economical load, $I_{M\mathrm{pec}}$, respectively $S_{M\mathrm{pec}}$ through the power line is transited. In these cases, both the cost of the power and active energy losses and the total updated expenses, under actual operation conditions, have bigger values than their economic value corresponding to an EUF = 100%. Taking into account that the economic limits and, in addition, the thermal restrictions in long and short term duration, all of them can lead to less extended areas. Also, the previously mentioned aspects must be checked carefully, in the situation of the *intensive use of the 110 kV repartition power lines*.

3º For the 110 kV power lines with EUF smaller than 100%, it results a smaller load than the economical load of the respective line was sized, that is the economical load corresponding to the indicator EUF = 100%. Therefore, both the cost of longitudinal losses through thermal effect and the total updated expenses are smaller than their economic value, about 1.5 times, in the case of an indicator EUF of 60% and an increase of more than three times if the EUF value is under 30%, respectively.

In the case of the 110 kV power lines with EUF < 60%, the practical variants or methods for increasing this indicator in current operation must be determined. For example, the EUF value can be increased through the redistribution of the consumers supplied with electric energy through these power lines, the finding of other sections points, etc., in order to attain the proposed aim.

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ANALIZA GRADULUI DE UTILIZARE ECONOMICĂ A LINIILOR ELECTRICE DE 110 kV DIN SISTEMELE DE REPARTIŢIE A ENERGIEI ELECTRICE

(Rezumat)

O funcţionare raţională şi, în acelaşi timp, eficientă din punct de vedere tehnico-economic a unor sisteme de repartiţie şi distribuţie a energiei electrice este condiţionată de capacitatea acestora de a permite creşterea randamentului de tranzit al energiei electrice, minimizarea pierderilor de putere şi a celor de energie activă, îmbunătăţirea calităţii energiei electrice livrate consumatorilor, reducerea daunelor datorate calităţii necorespunzătoare a energiei electrice etc. Având în vedere aceste

aspecte, în cadrul lucrării s-a analizat gradul de utilizare economică (GUT) a liniilor electrice de 110 kV din zona de N-E a țării noastre, la nivelul celei mai încărcate zile lucrătoare din regimul rece de iarnă. Pe baza rezultatelor furnizate de o astfel de analiză, pot fi selectate elementele sistemului de repartiție a energiei electrice, respectiv liniile electrice de repartiție de 110 kV, ce urmează a fi supuse unor analize mai atente şi mai aprofundate, în vederea creşterii posibilităților de care dispune sistemul de repartiție considerat, pentru atingerea dezideratelor din punct de vedere tehnico-economic, deziderate urmărite de fiecare societate teritorială de repartiție şi distribuție a energiei electrice.