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MONITORING POSIBILITIES AND STEDY-STATE ANALISYS OF ELECTRIC ENERGY REPARTITION NETWORKS

BY

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Abstract. A technical and economical electric energy repartition and distribution systems (ERDS) efficient operation is conditioned by their ability to allow the active energy losses minimization, the improvement of power quality delivered to consumers, the rational loading of different elements, etc. In the paper, based on daily load curves monitored as 24 hourly levels, 48 levels at 30 min and 96 levels at 15 min, the steady-state of a real 110 kV network were analyzed in order to establish the load measurement duration influence on the parameters that characterizes these steady state *i.e.* voltage level on all network nodes, the loading and the active power/energy losses in 110 kV lines and power transformers etc. Based on the results, the paper end presents a series of conclusions, discussions and comments, drawn from the complex analysis.

Key words: load monitoring; daily load curve; repartition networks.

1. Introduction

Generally, the repartition and distribution systems contain a typically developed electricity network, made up of overhead or underground power lines with rated voltage of 110 kV, 20 kV, 10 kV, 6 kV and 0.4 kV, and power transformers that equips both step-down stations and substations. Through

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repartition systems are transferred small power (tens of MW) compared with the power that flow in electric energy transmission system. In fact, the repartition systems present a regional distribution character. In our country, the network with 110 kV rated voltage represent the power repartition network, which operate in mixed, meshed and radial configuration. The multiple voltage levels existence at the electric energy repartition and distribution networks is a development characteristic over time (Georgescu, 2007; Georgescu *et al*., 2014).

In essence, the balanced steady state computation of an electric energy repartition system consist in determining of all parameter values which define the state, starting from some material parameters that relates to active and passive elements and network configuration. This primary information allow the elaboration of a steady state mathematical model as an algebraic equations system, generally, nonlinear, that describe the operation of direct sequence single-line equivalent diagram of the analyzed system.

The sinusoidal and balanced steady-state analysis of electricity repartition systems is necessary for monitoring in a time as close as possible to the real one, in order to determine the all characteristic network parameters namely: the current and power flow on each node and feeder; the voltage drop on all electrical network elements; the voltage level in injection nodes of active/reactive power (220/110 kV or 400/110 kV station from transmission network) and on high voltage (HV) and medium voltage (MV) bars of the step-down (110 kV/MV) station from repartition network; active/reactive power losses for total or partial areas of the repartition system etc. At the same time, it is necessary to analyze certain contingencies, to reflect the elements disconnection effects both real operation and economic dispatching of the system (Aswani *et al*., 2014; Dugan *et al*., 2003).

As previously mentioned, actually, the steady-state paradigm is recognized by the majority of specialists from energetic domain as a fundamental problem in the electric energy systems operation analysis and, therefore, is widely used in the planning, development, design and operation of these (Georgescu *et al*., 2012; Ionescu *et al*., 1998).

Spectacular technological developments in recent decades, of the electronics and computer or distribution systems monitoring techniques, leading at outstanding performance, especially memory capacity and computing speed and some achievements becoming more efficient of data transmission by intense usage of optic circuit fibbers, have influenced directly the load monitoring possibilities and mathematical models, methods and computation algorithms. All of these have boosted the real-time management of the complex processes from our country electric energy repartition systems.

In the paper, taking the advantage of the possibilities offered by SCADA Systems (Supervisory Control and Data Acquisition) that equip the most 110 kV/MV step-down transformer stations of our country, was created the practical possibility for a steady-state analysis of a real repartition network from Iasi town over the day or days considered to be the most loaded of 2014. The analyzed steady-state use SCADA information provided by the integration of values at 15 min., 30 min. and 60 min. intervals.

2. Load Monitoring Possibilities in Electric Energy Repartition Networks

Both in the public 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. Over time, depending on the available equipment of the territorial electricity distribution companies, for consumption and load curves monitoring, different methods are used (Albert *et al*., 1997; Dickert *et al*., 2009; Eremia *et al*., 2006; Georgescu *et al*., 2012).

Today, the electronic data acquisition systems from a certain process represents a measurement method that has strongly developed in last decades especially due to significant and accelerated characteristics improvement of the used equipment. It 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 (Georgescu, 2007; Golovanov *et al*., 2001).

At present, most of the public repartition systems from our country are automatically monitored or in process of being monitored up to the medium voltage (MV) bars level at the step-down stations, by using both SCADA systems and the smart metering systems (Neagu *et al*., 2012).

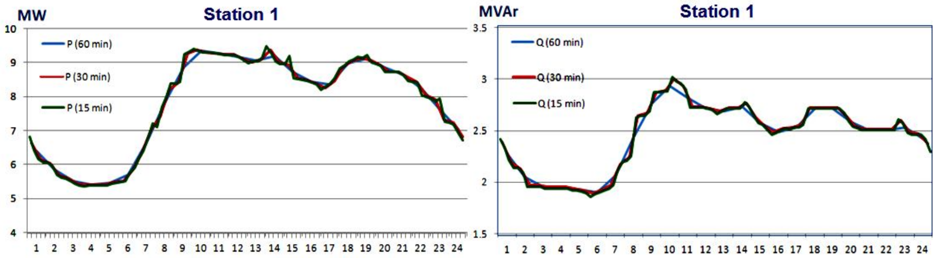

Fig. 1 – Active and reactive daily load curve recorded in 60 min., 30 min. and 15 min., for a step-down station (Station 1).

In the paper, the monitoring of active/reactive daily load curves on MV bars of the step-down station from proposed distribution system was carried out at intervals of 15 min., 30 min. and 60 min., through setting of the SCADA systems correspondingly. Thus, the daily load curves have been represented in: 24 hourly levels; 48 levels for 30 min.; 96 levels for 15 min.

For example, Fig. 1 presents the active and reactive load curves at one 110/20 kV station monitored in the three variants. By using the load curves as in Fig. 1 were prepared input data for the power flow (steady-state) analysis of the repartition network in order to establish the influence of the load measurement duration (time integration) on the indicators that characterizes these steady state analysis, such as: voltage level in all network nodes, loading and active power and energy losses on each network elements.

3. Case Example. Results and Discussion

A rational operating of an public 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, low voltage feeders – 0.4 kV and MV/0.4 kV power transformers) allowing both power and energy losses minimization and the improvement of power quality delivered to consumers. These desiderates are followed from the design phase, when each system element must be optimally dimensioned from technical and economical points of view (Albert *et al*., 1997; Eremia *et al*., 2006; Wane *et al*., 2013).

In order to establish the influence of load measurement duration from daily load curves on steady-state parameter, a real 110 kV electricity network from our country N-E area (Iaşi) was considered. The single line diagram of the 110 kV analyzed system is shown in Fig. 2. The proposed 110 kV network is supplied with electricity from two local power plants and national power system, and contains 39 single or double circuit overhead lines, and a total of 22 step-down stations (110 kV/MV) equipped with one or two power transformers.

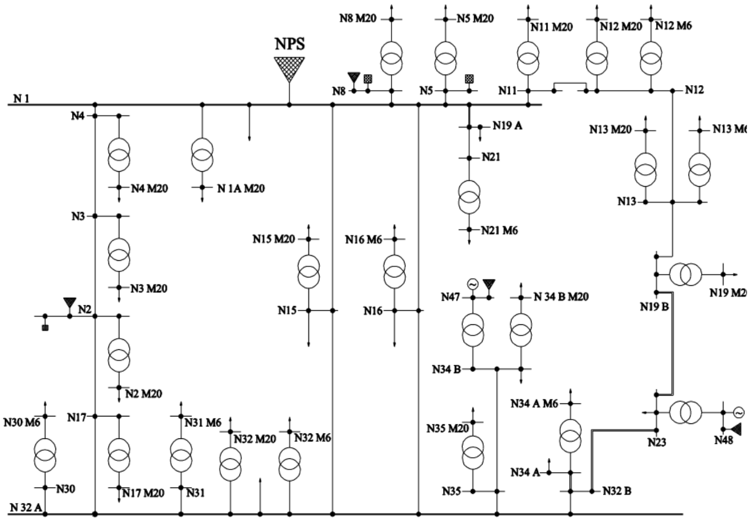

Fig. 2 – The single-line diagram of analysed test 110 kV system.

For the steady-state analyzes of proposed 110 kV network NEPLAN software was used. In addition of active and reactive daily load curves the input data necessary for power flows computation refers to topological and material characteristics of all components, *i.e.* power lines and power transformers.

To establishing the influence of measured load duration on active power losses and voltage level, using NEPLAN, the steady-state in three variants of active and reactive daily load curves recorded were computed, namely:

a) active and reactive daily load curves in 24 hourly levels, each level representing the 60 min. average load;

b) active and reactive daily load curves in 48 levels, each level representing the 30 min. average load;

c) active and reactive daily load curves in 96 levels, each level representing the 15 min. average load.

Regarding the required error for input data in steady-state analysis, it was 0.001% of nodal loads. Taking into account the proposed aim, for the public repartition network all daily steady-state in the most loaded day of cold winter season (Wednesday, January 22, 2014), considering the connection with NPS as the network slack node, and the daily load curves in three aforementioned variants (24, 48 and 96 levels) from all the other nodes (MV bars of the 110 kV/MV station and the two injection nodes), the time variations of steady-state electrical parameters was computed and analyzed.

Regarding the results of unknown parameters of studied ERDS for different steady-state from daily load curve level size, these are summarized as:

1° Basic unknown steady-state parameters:

a) active and reactive power injected in all repartition network nodes;

b) real nodal voltage (in absolute and relative values) and voltage arguments (in degrees), both for 110 kV and MV nodes.

2° Supplementary unknown steady-state parameters:

a) active and reactive power flows, both on the 110 kV power lines and power transformer that equip the step-sown station (110 kV/MV);

b) active and reactive power losses on each network elements (power lines and transformer), and on different areas or to entire ERDS;

c) reactive power generated (capacitive contribution) by power lines;

d) apparent power injected in the slack node from the transmission network (NPS).

By using the adequately results of studied ERDS steady-state, considering the daily load curves with different durations levels, was possible to analyze both time variations of electrical parameters that characterizes these steady-state and technical restrictions verification for a rational ERDS operation.

In the steady-state computation for examined ERDS the daily curve of active power variation injected by power plants was recorded also by SCADA systems being represented in Fig. 3 by curve 1. After steady-state computations results the daily variation of active power injected into slack node as shown by curve 2 from Fig. 3. Thus, the total active power injected from both local power plant and NPS into repartition system is described in Fig. 3 by curve 3.

Regarding the active/reactive power injected in the repartition system, it is found that at daily peak load, reactive power in slack node present different values depending on the load level duration, namely: 13.741 MVAr (60 min).; 14.223 MVAr (30 min.); 14.915 MVAr (15 min.).

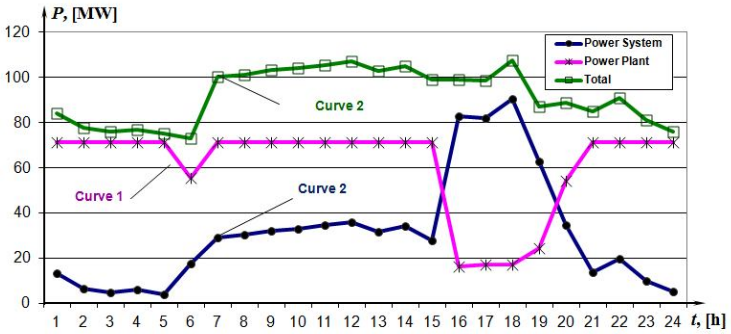

Fig. 3 – Daily variation of active power injected in analyzed repartition system from local power plants (curve 1), NPS (curve 2), and total active power (curve 3).

Also, for 110 kV lines and MV feeders, a number of characteristics parameters and technical or economical restrictions were checked, as follows: the transmission natural power of each 110 kV overhead lines single or double circuit, and MV overhead or underground lines; the offline computed transmission capacity of each repartition and distribution power line in predefined assumptions about the voltage limits and a stable operation; admissible loads from thermal point of view under constant load; economic usability factor (EUF) of 110 kV overhead lines single or double circuit (Georgescu *et al*., 2013; Georgescu *et al*., 2014).

Table 1

The Natural Powers of Repartition and Distribution Lines

Nominal voltage, [kV]		6	10	20	110
Three-phase natural power, [MW]	Overhead lines	0.10	0.25	1.00	30.0
	Underground lines	1.10	3.00	10.0	300

Natural power values of the overhead/underground lines ($P_{\text{nat}} \cong U_n^2 / Z_c$, where U_n is the nominal voltage and Z_c is characteristic impedance), are presented in Table 1. Based on steady-state results, for transmission capacity (active, reactive and apparent power) determination of overhead/underground lines, the following expressions are used:

$$\begin{aligned} P_{\text{transp}} &\cong \frac{U_i U_k}{B}\sin\delta \cong \frac{U_i U_k}{Z_c^{'}}\sin\delta, \\ Q_{\text{transp}} &\cong \frac{U_i^2}{B} - \frac{U_i U_k}{B}\cos\delta \cong \frac{U_i^2}{Z_c^{'}} - \frac{U_i U_k}{Z_c^{'}}\cos\delta, \qquad (1) \\ S_{\text{transp}} &\cong \sqrt{P_{\text{transp}}^2 + Q_{\text{transp}}^2}, \end{aligned}$$

where: U_i and U_k represents the nodal voltage effective values from input „*i*” and output „*k*” of power lines, and δ are angle of phase difference between nodal phasors $\underline{U}_i$ and $\underline{U}_k$.

The current admissible loads from thermal point of view under constant load for 110 kV overhead lines with different Al or OL-Al conductor sections used in examined repartition network are given in Table 2.

Table 2

Current Admissible Loads of Overhead Line Conductors in Operation

Nominal section, [mm^2]		120	150	185
Current admissible loads I_{adm}, [A]	Al	355	415	470
	Ol-Al	360	420	485

For thermally verification of the repartition overhead lines according with our country regulations, the next inequality must be fulfilled:

$$I_{\text{max.sarc}} \le K I_{\text{adm}}, \tag{2}$$

where: $I_{\text{max.sarc}}$ represent the maximum value of current from analysed day and K – the correction factor, depending on environmental temperature.

By using the active/reactive power flow results regarding the 110 kV power lines EUF value were computed, using the following relations:

$$\text{EUF}_{\text{lin.el.}} = \frac{S_M}{S_{M\text{pec}}} = \frac{I_M}{I_{M\text{pec}}} = \frac{I_M}{s j_{\text{ec}} m}, \tag{3}$$

where: s is the section of phase conductors of a power line, [mm^2]; $S_M = \sqrt{P_M^2 + Q_M^2}$ – maximum apparent load, corresponding to the maximum active and reactive load from load curves, [kVA]; $S_{M\text{pec}} \cong \sqrt{3} U_n j_{\text{ec}}(T) s$ – maximum apparent load from design stage, for a power line with a section s and a maximum load duration T, over a year, (each of the $S_{M\text{pec}}$ loads are close to the middle of economical maximum load domains of the section s), [kVA]; I_M – the current corresponding to maximum apparent load of a year, i.e. the level with maximum apparent load to the maximum daily load curves from cold winter season, [A]; $I_{M\text{pec}}$ – the current corresponding to maximum apparent load with a operation time T, [A]; j_{ec} – standardized value of economical current density, [A/mm^2]; m – multiplier used in power lines with maximum section, $s_{\max}$ (for power lines with total phase sections smaller than $s_{\max}$, shall be considered $m = 1$).

Based on the active and reactive power flow results for all daily load curve level in the three studied variants, was found that none of the characteristic parameters of the 110 kV single and double circuit overhead lines (three-phase natural power, capacity transport linked to acceptable limits of the voltage level, stable operation) are not exceeded during the analyzed day.

Based on previously named parameter values (offline computed), is observed that in steady-state exist a reserve in 110 kV overhead lines, lower when considering the case of 15 min. load measurement duration and higher in the 30 and 60 min. case. It should be noted that the same conclusions are available in the case of MV feeders, which constitute the departures (exits) from 110 kV/MV station. For the EUF indicators of 110 kV overhead lines, offline computed in three load measurement variants (15, 30 and 60 min.) in the most loaded day of 2014 cold winter season, the following values were obtained:

a) for 60 min (hourly) levels: EUF < 30 % (8 overhead lines); 30% < < EUF ≤ 60 % (12 overhead lines); 60% < EUF ≤ 100 % (19 overhead lines);

b) for 30 min (half hour) levels: EUF < 30 % (6 overhead lines); 30% < < EUF ≤ 60 % (13 overhead lines); 60% < EUF ≤ 100 % (20 overhead lines);

c) for 15 min (quarter hour) levels: EUF < 30 % (2 overhead lines); 30% < EUF ≤ 60 % (15 overhead lines); 60% < EUF ≤ 100 % (22 overhead lines).

According to the regulations of our country, in order to supply with electricity the urban and rural areas from analyzed repartition system, the step-down stations (110kV/MV) can be equipped with one or two identical transformers.

If the station is equipped with one power transformer, the consumer reserve is carried out through the MV distribution network from 110 kV/MV neighbor's station and the maximum apparent power must verify the following relation (Georgescu, 2007; PE 132, 2003):

$$S_{\text{max.adm.}} = \frac{n}{n+1} K_S S_n , \tag{4}$$

where: n – 110 kV/MV station number, equipped with one transformer, which ensures the continuity of supply to consumers, in a short-circuit case from a station; K_S = 1.2 – coefficient for 20 % overload of the maxim load (*i.e.* peak load of the day).

If the case of station equipped with two identical power transformers, the consumer reserve is carried out only on the same transformer station bars, even if the station present mixed profile (when the consumer reserve is carried out through the MV distribution network from 110 kV/MV neighbor's station). If a transformer is unavailable, for the remaining transformer in operation, maximum apparent power flow cannot exceed 20% on daily peak load from cold winter state.

Regarding the power transformers from 110 kV/MV station, based on the steady-state NEPLAN results, a number of parameters and restrictions (from technical and economic point of view) were checked, namely:

a) The available power of all step-down station from analysed system.

b) The loading for one or two station transformer (the EUF indicators for power transformer).

c) For a failure state, overload possibilities over the allowable limit were checked, taking into account the consumer reservation cases.

Based on steady-state results, for each power transformers that equip the 110 kV/MV step-down station, the EUF value were computed, using the following relations:

$$\mathrm{EUF}_{\mathrm{transf}}=\frac{S_M}{S_{M\mathrm{pec}}}=\frac{I_M}{I_{M\mathrm{pec}}} \tag{5}$$

Taking into account the steady-state results for the analysed, considering the active/reactive daily load curves with different measurement durations, it was found that the available powers of all power transformers are appropriate, with a certain reserve installed both in power transformers and 110 kV/MV step-down stations, but will decrease with the reduction of the load measurement duration. The EUF indicators for power transformers, was also offline computed for the daily steady state, and the following values were obtained:

a) for 60 min (hourly) levels: EUF < 30% (3 station); 30% < EUF ≤ ≤ 60% (8 station); 60% < EUF ≤ 100% (10 station); EUF > 100% (1 station);

b) for 30 min (half hour) levels: EUF < 30% (1 station); 30% < EUF ≤ ≤ 60% (9 station); 60% < EUF ≤ 100% (11 station); EUF > 100 % (1 station);

c) for 15 min (quarter hour) levels: 30% < EUF ≤ 60 % (9 station); 60% < EUF ≤ 100 % (12 station); EUF > 100 % (1 station).

Typically, for voltage quality assessing in the power networks current operation, two quality criteria are used, namely maximum allowable deviations criterion and statistical (integral) criteria.

In order to avoid as far as possible, the negative effects caused by slow voltage variations from the nominal voltage value, according to maximum allowable deviations criterion the voltage variation regulations on for different situations that may occur in power networks current operation were developed.

The maximum permissible deviations towards the nominal voltage are defined by the following relations:

$$\begin{aligned}\Delta U_{\mathrm{adm}}^{+}&=\frac{U_{\mathrm{max.adm}}-U_n}{U_n}\cdot 100,\ [\%],\\ \Delta U_{\mathrm{adm}}^{-}&=\frac{U_{\mathrm{min.adm}}-U_n}{U_n}\cdot 100,\ [\%],\end{aligned} \tag{6}$$

where: $U_{\mathrm{max.adm}}$ and $U_{\mathrm{min.adm}}$ represent the maximum and minimum value of the allowed voltage.

Admissible voltage variations present the following form:

$$\Delta U_{\mathrm{max.adm}}=\Delta U_{\mathrm{adm}}^{+}-\Delta U_{\mathrm{adm}}^{-}\ , \tag{7}$$

that, usually, $\Delta U_{\mathrm{adm}}^{+}>0$ and $\Delta U_{\mathrm{adm}}^{-}<0$.

The values of maximum allowable deviation according to the regulation of our country are ±7% for repartition networks and ±5% for distribution networks, and according to DISNORM 12/89 of UNIPEDE, the maximum allowable deviations are ± 10% for LV networks and ± 10% (or +5%, –10%) for MV distribution networks.

The experimental verifications have establish that the random variable – voltage deviation towards the nominal voltage $\Delta U(t)$ in any node of repartition and distribution networks follows a normal distribution law (Gauss), and according with the statistical criteria for voltage quality assessing in electrical networks, can be used the following statistical indexes:

1° The average value of the voltage deviation in the interval T:

$$\overline{\Delta U} = \frac{1}{T}\int_0^T \Delta U(t)\,\mathrm{d}t,\ [\%]. \tag{8}$$

2° The square mean deviation or the irregularity of voltage in the interval T:

$$I = \overline{\Delta U^2} = \frac{1}{T}\int_0^T \Delta U^2(t)\,\mathrm{d}t,\ [\%]^2. \tag{9}$$

3° The dispersion toward the average value of voltage deviation at interval T:

$$\sigma^2 = \frac{1}{T}\int_0^T \left(\Delta U(t) - \overline{\Delta U}\right)^2 \mathrm{d}t,\ [\%]^2, \tag{10}$$

where σ, [%], represent the *standard deviation* of the voltage.

From relations (8), (9) and (10) it is found that between the statistical indexes of voltage quality a dependency expressed by following relation exist:

$$I = \sigma^2 + \left(\overline{\Delta U}\right)^2 \tag{11}$$

Square mean deviation $\overline{\Delta U^2}$ or the irregularity I, in $[\%]^2$, is the best index that reflect the voltage quality and, moreover, can evaluate the damage caused to consumers by voltage poor quality. This statistical index allows an objective assessment of the voltage quality in power networks namely: very good, if $I \leq 10\ (\%)^2$; good, if $10\ (\%)^2 < I \leq 20\ (\%)^2$; mediocre, if $20\ (\%)^2 < I \leq 50\ (\%)^2$; inadequate, if $50\ (\%)^2 < I \leq 100\ (\%)^2$; very bad, if $I > 100\ (\%)^2$.

For studied repartition system, the most loaded day of the 2014 winter, considering active/reactive daily load curves with different measurement durations, the voltage variations was analyzed in 110 kV and MV nodes, using both voltage quality criteria aforementioned. To exemplify, for two station in Table 3 is presented the daily variation bands of the voltage on the 110 kV or

MV bars, and Table 4 present statistical index ($\overline{\Delta U}$, I, σ^2) for voltage quality analysis on analyzed day, in the three variants regarding the measurement load duration (60, 30 and 15 min).

Table 3

The Extreme Values of Voltage Variation Bands in Two Power Stations from Repartition System, in Analyzed Day

Measurement duration	Voltage band	Power station I		Power station II		
		110 kV	20 kV	110 kV	20 kV	6 kV
60 min	Val. min [kV]	117.702	21.197	117.506	20.930	6.087
	Val. max [kV]	118.044	21.256	117.859	21.040	6.178
30 min	Val. min [kV]	117.699	21.194	117.503	20.929	6.087
	Val. max [kV]	118.059	21.262	117.873	21.044	6.179
15 min	Val. min [kV]	117.692	21.010	117.499	20.928	6.086
	Val. max [kV]	118.061	21.263	117.875	21.054	6.227

Table 4

The Statistical Index Values of Voltage in Two Power Stations from Repartition System, in Analyzed Day

Duration level	Statistical indicator	Power station I		Power station II		
		110 kV	20 kV	110 kV	20 kV	6 kV
60 min	$\overline{\Delta U}$ (%)	7.128	6.097	6.943	4.962	2.049
	I (%)^2	50.869	37.205	48.236	24.646	4.396
	σ^2 (%)^2	0.061	0.031	0.029	0.024	0.197
30 min	$\overline{\Delta U}$ (%)	7.137	6.106	6.948	4.968	2.059
	I (%)^2	50.987	37.257	48.249	24.664	4.415
	σ^2 (%)^2	0.048	0.026	0.025	0.017	0.175
15 min	$\overline{\Delta U}$ (%)	7.148	6.122	6.956	4.975	2.067
	I (%)^2	51.065	37.493	48.408	24.761	4.432
	σ^2 (%)^2	0.029	0.014	0.022	0.011	0.159

According to the obtained results for steady-state computation regarding nodal voltage values, the following observations can be drawn:

1° Considering the maximum deviation criterion, it is found that if the load measurement duration is reduced, the voltage variation bands in all independent nodes (110 kV and MV respectively), are increasingly greater.

2° These observation are valid also in the statistical criteria case, which indicate that the index ($\overline{\Delta U}$, I, σ^2) values of the analyzed day are increasingly smaller, as the reduction of the measurement load duration.

After analyzing results regarding the steady state of the studied repartition network (for the loaded day from January 2014), considering the active and reactive daily load curves in 24 hourly level at one hour, 48 levels at 30 min. and 96 levels at 15 min., in Figs. 4,...,6 are graphically represented the active power losses (MW) and reactive power losses (MVAr) both in 110 kV power line and power transformers from 110 kV/MV stations.

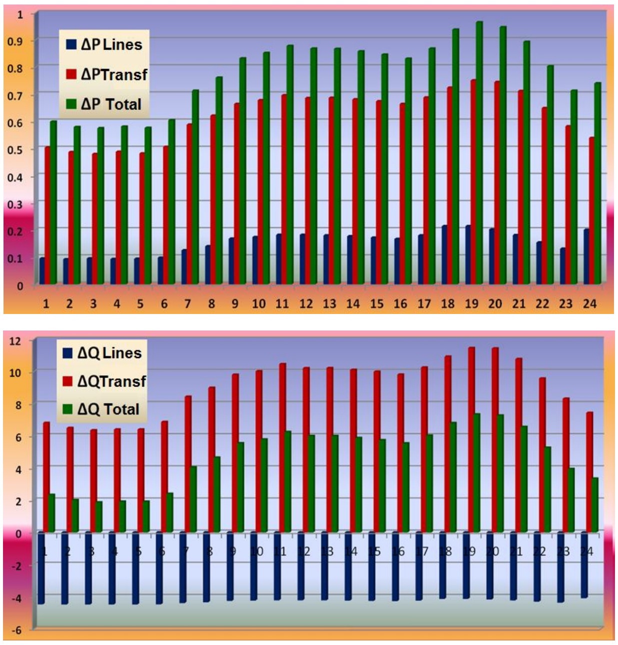

Fig. 4 – Active and reactive power losses variations in analyzed day for 24 hourly steady state computation.

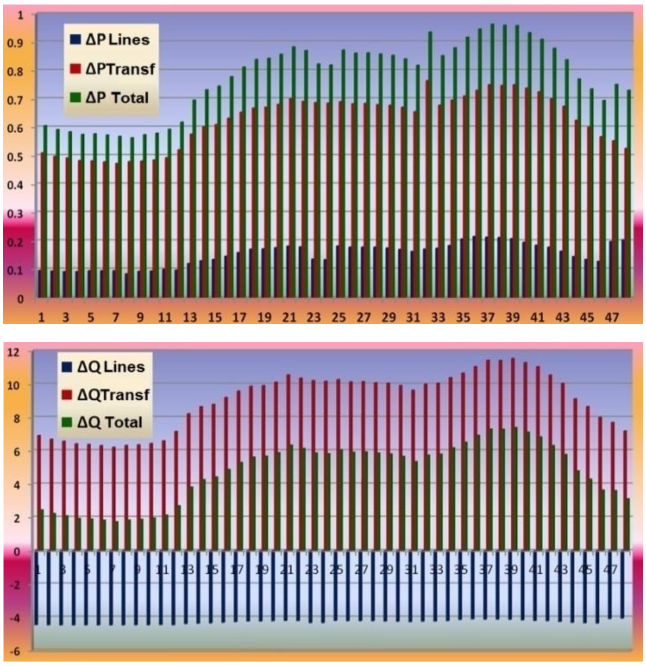

Fig. 5 – Active and reactive power losses variations in analyzed day for 48 steady state computation at 30 min load measurement duration.

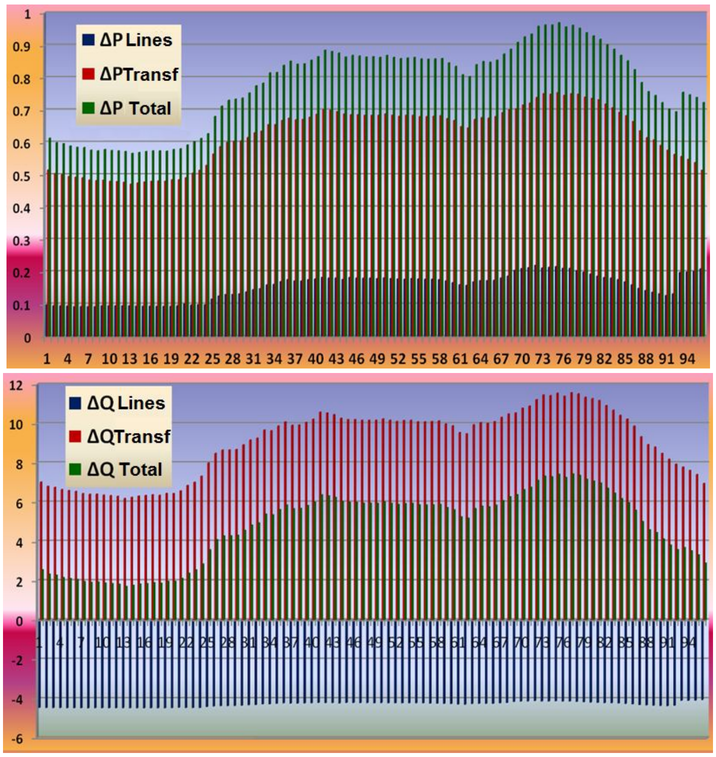

Fig. 6 – Active and reactive power losses variations in analyzed day for 96 steady state computation at 15 min load measurement duration.

For the active and reactive daily losses computation in analyzed day, active and reactive power losses to each considered load level form daily load curves was used through the following expressions:

a) for active and reactive daily load curves registered as 60 min. (one hour), 24 hourly steady-state were computed:

$$\Delta W_a = \sum_{k=1}^{24} \Delta P(k),\ [\mathrm{MWh}];\quad \Delta W_r = \sum_{k=1}^{24} \Delta Q(k),\ [\mathrm{MVArh}], \tag{12}$$

b) for active and reactive daily load curves registered as 30 min. (half hour), 48 steady-state were computed:

$$\Delta W_a = \frac{1}{2}\sum_{k=1}^{48} \Delta P(k),\ [\mathrm{MWh}];\quad \Delta W_r = \frac{1}{2}\sum_{k=1}^{48} \Delta Q(k),\ [\mathrm{MVArh}], \tag{13}$$

c) for active and reactive daily load curves registered as 15 min (quarter hour), 96 steady-state were computed:

$$\Delta W_a = \frac{1}{4}\sum_{k=1}^{96} \Delta P(k),\ [\mathrm{MWh}];\quad \Delta W_r = \frac{1}{4}\sum_{k=1}^{96} \Delta Q(k),\ [\mathrm{MVArh}]. \tag{14}$$

Regarding the active power losses in the 110 kV repartition system in the three considered variants both in absolute and percentage value of total active energy that flow from the system, they are presented in Table 5, for power lines, power transformers and for the whole system. According to Table 5, in Figs. 7 the active energy losses in MWh and % for repartition network are graphically represented.

Table 5
Daily Active Energy Losses In Analysed Repartition System in the Three Considered Variants

Load measurement duration	110 kV power lines		Power transformator		The entire network	
	[MWh]	[%]	[MWh]	[%]	[MWh]	[%]
15 min	3,786	0.148	15,887	0.620	19,673	0.767155
30 min	3,739	0.146	15,281	0.596	19,020	0.741691
60 min	3,654	0.142	14,976	0.584	18,630	0.726483

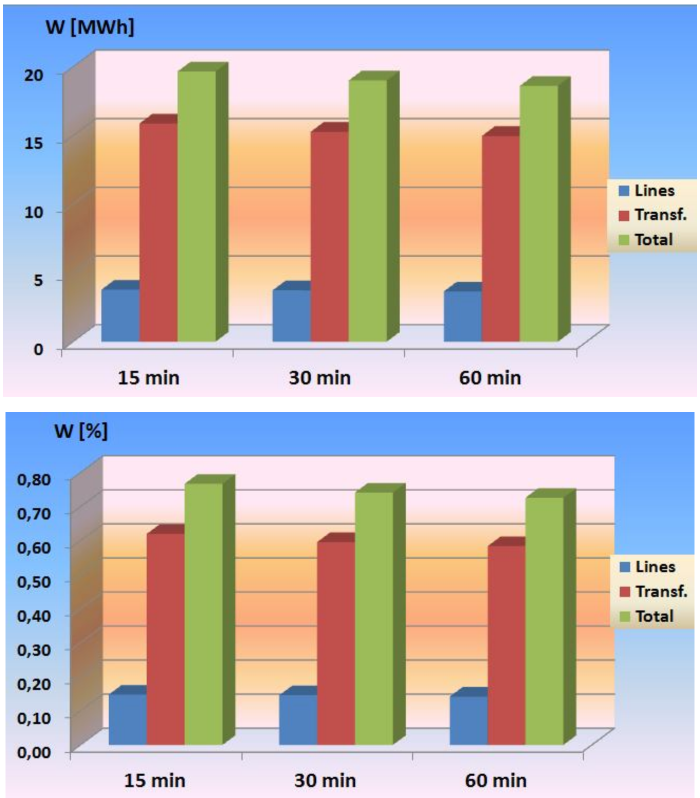

Fig. 7 – Daily active energy losses in analysed repartition system in the three considered variants in absolute and percentage values.

4. Conclusions

Actually, the steady-state paradigm is recognized by the majority of specialists from energetic domain as a fundamental problem in the analysis both operation and contingency of electric energy systems, being widely used for adopting the rational decisions from technical and economical point of view, regarding at the planning, development, reconstruction, design and operation of power system generally, or repartition and distribution networks in particular.

Taking into account that, currently, the most public electric energy repartition systems from our country are monitored up to the MV bars of the step-down station, monitoring process that will expand up to the substation bars from MV distributors in a short term perspective, using SCADA or other smart metering systems, corroborated with the increased performance of computer regarding the memory capacity and computing speed and the improvement of mathematical models, methods and algorithms for electrical networks steady state computing, have stimulated the driving in a time as close to the real time of complex processes that occur electricity repartition systems.

For a complex analysis, in the paper the active and reactive daily load curves with different measurement levels are used, provided by electronic acquisitions systems from repartition system nodes; the average load was obtained by integrating both active and reactive loads at 60, 30 and 15 min.

Following the obtained results on steady state of the repartition system by considering the active/reactive load curves with different measurement durations, it was found that the available powers are appropriate to all power transformers, or 110 kV/MV station respectively, with a certain reserve in power transformers that equip these station, but this reserve is increasingly low, while the load measurement duration is reduced. Regarding the EUF indicators (offline computed) for power transformers, these vary depending on the load measurement duration *i.e.* 60, 30 and 15 min., respectively. Similar observations are valid as regard the EUF indicators for the 110 kV power lines from the analyzed system taking into account the detailed results from the paper.

According to the obtained results voltage variations in independent nodes in the repartition system, in the three analyzed variants, the following observations can be drawn:

1° In accordance with the maximum permissible deviation criterion it is found that if the load measurement duration is reduced, the voltage variation bands in all 110 kV and MV nodes are increasingly greater.

2° Also, the previous observation are valid also in the statistical criteria case, which indicate that $\overline{\Delta U}$, I, σ^2 values for the analyzed day are increasingly low, if the measurement load duration is reduced.

At peak load the reactive power injected from slack node in the repartition network present different values, being of higher value if the load measurement duration is reduced.

Regarding the active power and energy losses of analyzed repartition system these result with different values in the three considered variants, for both power lines and power transformers and also on entire repartition network. These power losses values increase if the load measurement duration is reduced.

Given the actually load monitoring possibilities, based on complex analysis carried out in the paper, results, obviously, that for a online management close to the real of a electricity repartition systems process in order to increase the accuracy of state values that characterize steady state, is necessary to consider the active and reactive daily load curves with 15 min measurement duration, leading to the adoption of rational decisions at power networks level.

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POSIBILITĂŢI DE MONITORIZARE ŞI ANALIZĂ A REGIMURILOR PERMANENTE DE FUNCŢIONARE ALE REŢELELOR 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 minimizarea pierderilor de putere şi a celor de energie activă tranzitată, îmbunătăţirea calităţii energiei electrice livrate consumatorilor, încărcarea raţională a diferitelor elemente componente etc. În lucrare, pe baza curbelor zilnice de sarcină activă şi reactivă monitorizate în nodurile sistemelor de repartiţie, sub forma a 24 paliere orare, 48 paliere de 30 min şi 96 paliere de 15 min, au fost analizate regimurile permanente de funcţionare ale unui sistem/reţea reală de repartiţie în vederea stabilirii influenţei duratei palierului de sarcină măsurat asupra mărimilor de stare care caracterizează aceste regimuri, respectiv nivelul de tensiune în toate nodurile reţelei, încărcările diferitelor elemente componente, pierderile de putere şi energie activă în liniile electrice şi transformatoarele de putere etc. Pe baza rezultatelor obţinute, în finalul lucrării, sunt prezentate o serie de concluzii, discuţii şi comentarii, desprinse din analiza complexă efectuată.