SOFTWARE FOR NETWORK ELECTRICITY BALANCE

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Abstract: This paper present two software for electricity balance of complex network. The first software calculates successively permanent regimes and makes sum of input and output electricity for every load step. The second software uses statistical characteristics of nodes loads. Electricity is measured or estimated and energy losses are determined statistically. There are shown results obtained for a test network.

Keywords: energy losses, statistical characteristics, software.

1. INTRODUCTION

Knowledge of electrical energy flows in the network and of energy losses values in a period is a objective necessity for adequate administration of the transmission/distribution electricity.

Determination of energy losses is made by calculus. Romanian settlements permit determination of energy losses by measures [1], but only in restrictive conditions regarding to measure systems quality.

Determination of energy losses by calculus depends on information nature available. Energy losses can be determination by direct calculus of energy losses in networks elements for every load step and summarization them. In this case it must be known power flows in network lines in every regime or nodes loads on load step.

Another method determines energy losses based on mean regime and on statistical characteristic of network loads: mean, dispersion and covariance, [2], [3]. In this paper authors make new explanations regarding to partial differentials calculus of power losses in networks where nodal admittances matrix is non-symmetrical and present new methods for energy losses simulation using statistical characteristics

2. DETERMINATION OF BALANCE BY REGIMES CALCULUS ON LOAD STEP

It is calculated active and reactive power losses on every load step by working regime calculus. Active power losses, ΔW, and reactive power losses ΔW_r, result immediately:

$$\begin{aligned} \Delta W &= \sum_{i=1}^{p} \Delta P_i \cdot \Delta t_i \\ \Delta W_r &= \sum_{i=1}^{p} \Delta Q_i \cdot \Delta t_i \end{aligned} \tag{1}$$

where p is sub-period number that compose period T:

$$T = \sum_{i=1}^{p} \Delta t_i \tag{2}$$

ΔP_i, ΔQ_i – active and reactive power losses on step i.

For regimes calculus it must be known active and reactive power injected in nodes on every load step. It must be known voltage imposed in equilibration node and in generation nodes in these regimes, too.

3. DETERMINATION OF ENERGY LOSSES USING STATISTICAL CHARACTERISTICS

This method is based on the development in Taylor series of power losses, ΔP, around of mean values of characteristics that determine working regime: active and reactive power nodes and voltage of equilibration node.

Because mean regime is a fictitious regime, generation nodes type PU it will be change in the consumption nodes type PQ, [2]:

$$\begin{aligned}
\overline{\Delta P} \approx \Delta P\left(\left[\overline{P}\right],\left[\overline{Q}\right],\overline{Ue}\right) &+ \frac{1}{2}\cdot\sum_{i\in n\backslash e}\sum_{j\in n\backslash e}\left[\frac{\partial^2 \Delta P}{\partial P_i \cdot \partial P_j}\cdot \operatorname{cov}(P_i,P_j)\right]+ \\
&+\frac{1}{2}\cdot\sum_{i\in n\backslash e}\sum_{j\in n\backslash e}\left[\frac{\partial^2 \Delta P}{\partial Q_i \cdot \partial Q_j}\cdot \operatorname{cov}(Q_i,Q_j)\right]+ \\
&+\sum_{i\in n\backslash e}\sum_{j\in n\backslash e}\left[\frac{\partial^2 \Delta P}{\partial P_i \cdot \partial Q_j}\cdot \operatorname{cov}(P_i,Q_j)\right]+ \\
&+\sum_{i\in n\backslash e}\left[\frac{\partial^2 \Delta P}{\partial P_i \cdot \partial Ue}\cdot \operatorname{cov}(P_i,Ue)+\frac{\partial^2 \Delta P}{\partial Q_i \cdot \partial Ue}\cdot \operatorname{cov}(Q_i,Ue)\right]+ \\
&\frac{1}{2}\cdot\frac{\partial^2 \Delta P}{\partial U_e^2}\cdot\sigma_{Ue}^2
\end{aligned} \tag{3}$$

where:

$\left[\overline{P}\right],\left[\overline{Q}\right],\overline{Ue}$ - represent power column matrix of nodes (less equilibration node) and voltage mean value of equilibration node. Over-line shows mean value.

n – network nodes number
e – equilibration node
$\operatorname{cov}(X_i, X_j)$ is *covariance* of them:

$$\operatorname{cov}(X_i, X_j) = \overline{(X_i - \overline{X_i})\cdot(Y_i - \overline{Y_i})} \tag{4}$$

and

$$\sigma_{Ue}^2 = \overline{\left(Ue - \overline{Ue}\right)^2} \tag{5}$$

The active energy losses in period T it can be written as:

$$\Delta W = \overline{\Delta P} \cdot T \tag{6}$$

The same relation it can be written for mean reactive power loss and for reactive energy losses. The mean powers of nodes are determined with measured energies:

$$\overline{P}_i = \frac{W_i}{T} \tag{7}$$

4. SOFTWARE. NUMERICAL RESULTS

The tests were made for a real network 400/220 kV in area DET Bacau. Nodes loads were recorded by SCADA system. Calculus was made with computer program BIL V1.0 that uses up methodology. The partial differentials of power losses are calculated analytically or numerically.

Results are presented graphically and as tables of data base (figure 1). Balance was made for a 24 hours period, loads were reading for a 15 minutes period, resulting 96 regimes. It was realized a variant which calculates partial differential numerically with relations as (25)÷(38) for verification calculus of partial differential analytically with relations as (13)÷(24). Characteristics variation for numerical differential calculus was 0.05 (MW, Mvar, kV). Results are shown in the table 1.

Table 1Energy losses calculated

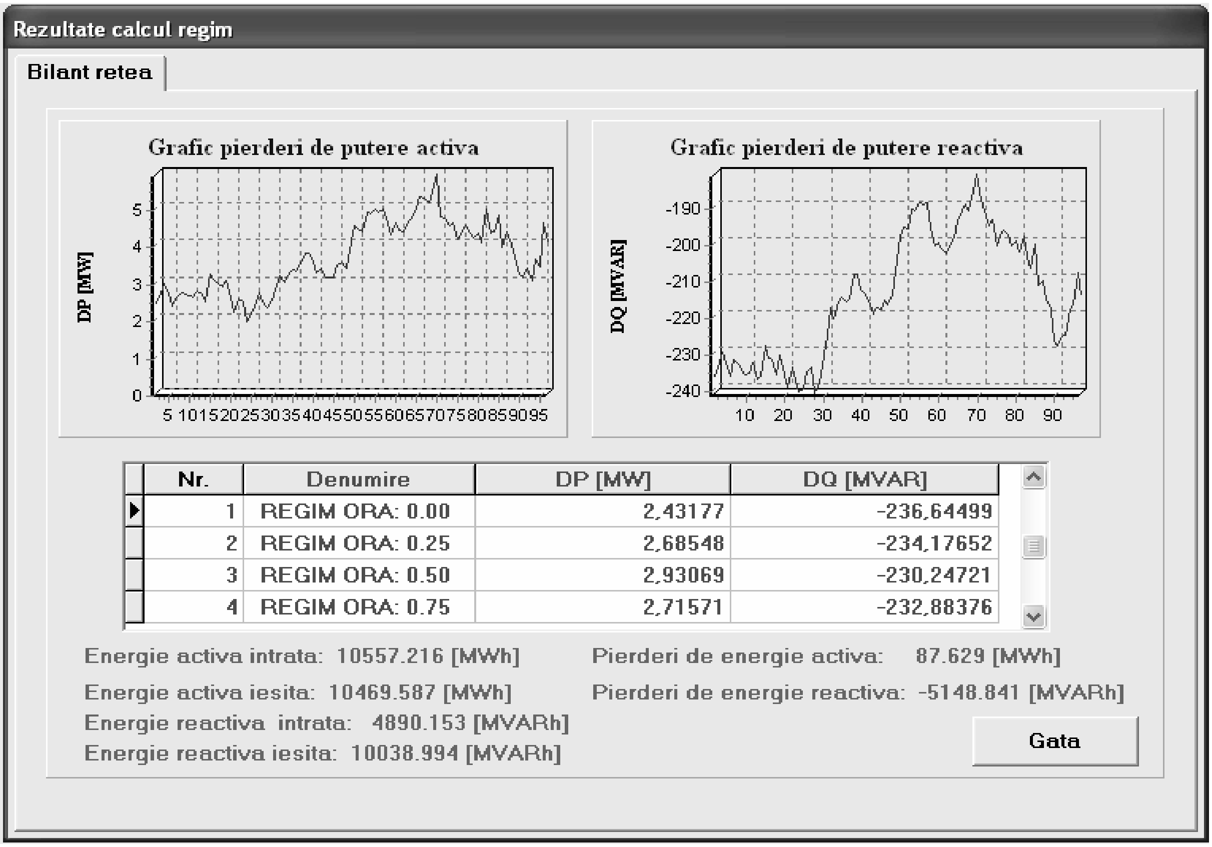

Figure 1Results obtained with software RP V3.1

Nr. Crt.	Name	Active energy/power [MWh], [MW]				Reactive energy/power [Mvarh], [Mvar]			
		Analytical partial differential		Numerical partial differential		Analytical partial differential		Numerical partial differential	
1	Energy losses	87.24595		87.66520		-5182.67682		-5148.57091	
2.	Mean power losses	[MW]	[%]	[MW]	[%]	[Mvar]	[%]	[Mvar]	[%]
		3.63525	100	3.65272	100	-215.9449	100.0	-214.5238	100.0
3.	Power losses in the mean regime	3.17600	87.37	3.17600	86.95	-219.9592	101.9	-219.9592	102.5
4.	Contribution of term COVPP	0.41109	11.31	0.41548	11.37	3.51283	-1.63	4.6646	-2.17
5.	Contribution of term COVQQ	0.05155	1.42	0.05528	1.51	0.53478	-0.25	0.7073	-0.33
6.	Contribution of term COVPQ	-0.00243	-0.07	-0.011	-0.30	-0.02739	0.01	-0.1352	0.06
7.	Contribution of term COVPUe	-0.00138	-0.04	0.01634	0.45	0.00399	0.00	0.20532	-0.10
8.	Contribution of term COVQUe	0.00025	0.01	-0.0007	-0.02	0.00008	0.00	-0.0095	0.00
9.	Contribution of term σ^2_{Ue}	0.00017	0.00	0.00125	0.03	-0.00998	0.00	0.00248	0.00

The errors obtained given the method from relation (1) are shown in the table 2.

Table 2. Comparative results

Nr. Crt.	Name	Regime calculus (rel. 1)	Statistical balance			
			Analytical differential		Numerical differential	
			Value	Error [%]	Value	Error [%]
1.	Mean active power loss [MW]	3.65120	3.65272	0.05	3.63525	-0.44
2.	Mean reactive power loss [MVAR]	-214.535	-214.523	0.01	-215.945	-0.66

Note that results obtained for all situations are good and very good. The statistical method that use numerical partial differential gives results without errors.

The statistical method that use analytical differential gives negative errors under to 0.7%.

Regarding to terms contribution in relation (4), it is note that prevalent value is given by terms that contain partial differential by order 2 reported to active powers (over to 11% from mean active power losses).

Terms that contain partial differential have a relevant value (1.5%), too. The same situation is for calculus of mean reactive power losses but its contributions are smaller (2%, respectively 0.3%).

The other terms from relation (4) have a negligible contribution by different signs. The statistical method based on analytical differential has drawback that in this case it must be calculated elements of nodal impedance matrix [$\underline{Z}_n$]. This matrix is much full than matrix [$\underline{Y}_n$].

Using special techniques for generating of reverse matrix, [5], this difficulty can be exceeding. Calculus size is smaller, significantly.

5. CONCLUSIONS

a) Using of statistical characteristics (mean and covariance) permits simplification of energy losses calculus. In this case, there are calculated power losses for the mean regime defined by the mean values of node loads. At this value there are added terms that depend on the partial differential of power losses and on the statistical characteristics of loads. Method gives the same results if the partial differentials are calculated numerically and error under 0.7% if these are calculated analytically.
b) Numerical determination of partial differentials necessities a bigger size calculus because there are calculated permanent regimes for every numerical differential
c) Among terms due to statistical characteristics, it must be taking account on the active and reactive loads covariance and the others are negligible.

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