Errors for Calculus of the Energy Losses Using Statistical Characteristics of the Loads in the Busses

G. Hazi, A. Hazi and R. Grigore

Abstract--**This paper shows the possibilities for estimating the energy losses in the network using statistical characteristics – covariance of the loads and of the balancing bus voltage – calculated for the reference regime of the network. Input data for the network can be estimated energies in the busses for the respective period or a values interval where the loads in the busses will be randomly generated. The generation takes place in every time period related to the reference regime. Finally, we present the results obtained for two test networks.**

Index Terms--**Power system losses, statistics, power system simulation, estimation.**

I. INTRODUCTION

ESTIMATING the energy loses is a necessity due to variation of the loads in the busses and to extension of EMS SCADA in the network. Using statistical characteristics is a very good solution for estimating the energy losses. Calculation methodology presented in [2] was improved in [3] and [1] by using numerical partial derivatives and by considering asymmetry of nodal admittance matrix when transformers with quadrature voltage control are present. In this paper the authors show how statistical characteristics can be used for estimating the energy losses in a characteristic time period. Two variants for the input data are analyzed: estimated energies in the busses for the respective period; a values interval where the loads in the busses will be randomly generated in every time period related to the reference period. Based on data collected in a previous characteristic period, the authors determine the statistical characteristics of the powers in the busses (their covariance) and the voltage in the balancing bus.

II. FUNDAMENTAL PRINCIPLES FOR ESTIMATING THE ENERGY LOSSES

The fundamental relation for estimating the energy loses is:

$$\begin{aligned}\Delta W^{est} &= \Delta P\left(\left[\overline{P}^{est}\right],\left[\overline{Q}^{est}\right]\right)\cdot T + \\ &+CorP\left(\left[\overline{P}^{est}\right],\left[\overline{Q}^{est}\right],\mathrm{cov}(X,Y)^{calc}\right)\cdot T\end{aligned} \tag{1}$$

$$\begin{aligned}\Delta W_r^{est} &= \Delta Q\left(\left[\overline{P}^{est}\right],\left[\overline{Q}^{est}\right]\right)\cdot T + \\ &+CorQ\left(\left[\overline{P}^{est}\right],\left[\overline{Q}^{est}\right],\mathrm{cov}(X,Y)^{calc}\right)\cdot T\end{aligned} \tag{2}$$

where

$\Delta P\left(\left[\overline{P}^{est}\right],\left[\overline{Q}^{est}\right]\right)$ - the active power losses in the estimated mean regime; they are determined by calculating the regime in which the powers in the busses and the voltage in the balancing bus equal their mean value (calculated in relation 4).

$\Delta Q\left(\left[\overline{P}^{est}\right],\left[\overline{Q}^{est}\right]\right)$ - the reactive power loss in the estimated mean regime; it is determined by calculating the regime in which the powers in the busses and the voltage in the balancing bus equal their mean value (calculated in relation 4).

$CorP,Q\left(\left[\overline{P}^{est}\right],\left[\overline{Q}^{est}\right],\mathrm{cov}(X,Y)^{calc}\right)$ - correction term that depends on the estimated mean regime and on the statistical characteristic of loads in the reference regime. This term is determined in relation [3]:

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

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$\left[\overline{P}^{est}\right],\left[\overline{Q}^{est}\right]$ - estimated mean loads in the busses

$\mathrm{cov}(X,Y)^{calc}$ - covariance of loads and of voltage in the balancing bus calculated for the reference period

T – estimation period.

If there are estimated necessary energies in the busses, then:

$$\begin{aligned}\overline{P}_i^{est} &= \frac{W_i^{est}}{T}, \quad i \in n \setminus e \\ \overline{Q}_i^{est} &= \frac{W_{ri}^{est}}{T}, \quad i \in n \setminus e\end{aligned} \qquad (4)$$

where W_i^{est}, W_{ri}^{est} – estimated active and reactive energies injected in bus i in a T period .

n – network busses set

e – balancing bus

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

σ_{Ue}^2 represents the voltage dispersion in the balancing bus.

If simulation is made by randomly generated loads in the busses in a values interval related to the reference regime, then the active power in the bus is (in i bus and j step):

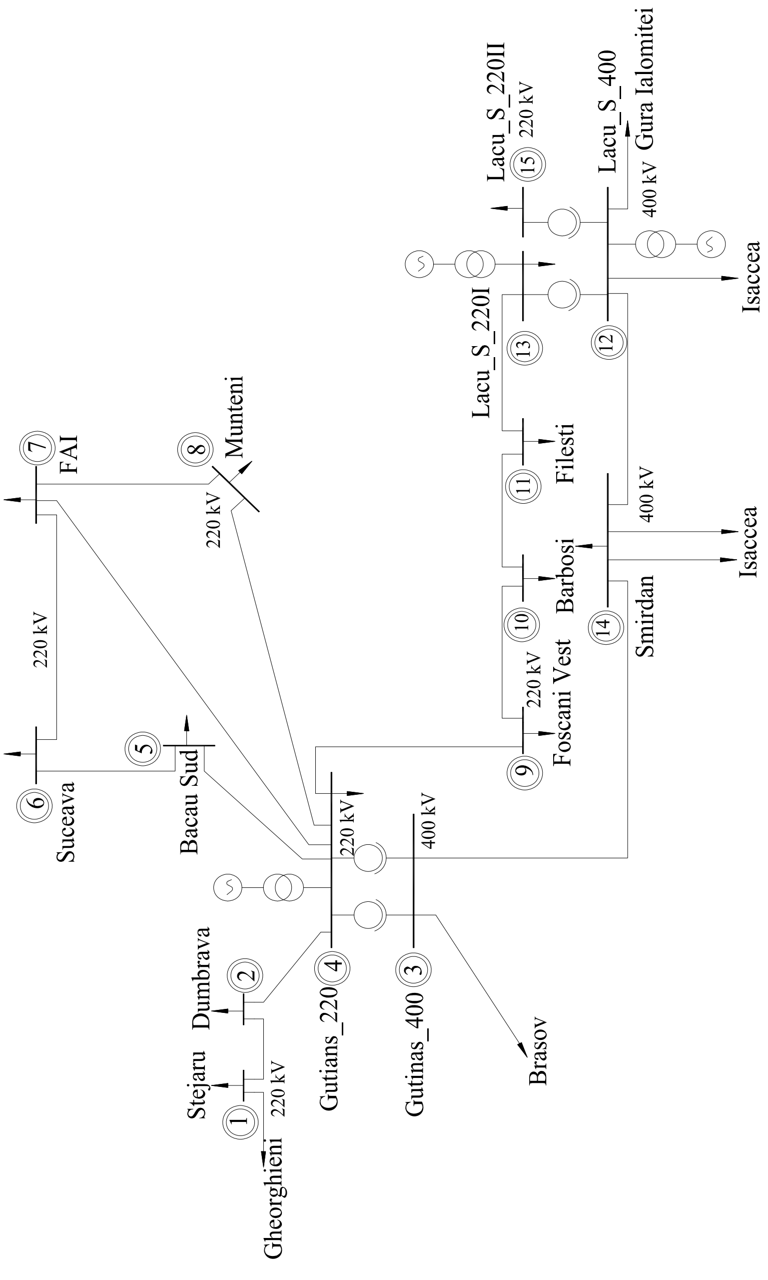

Fig. 1
Test network 1

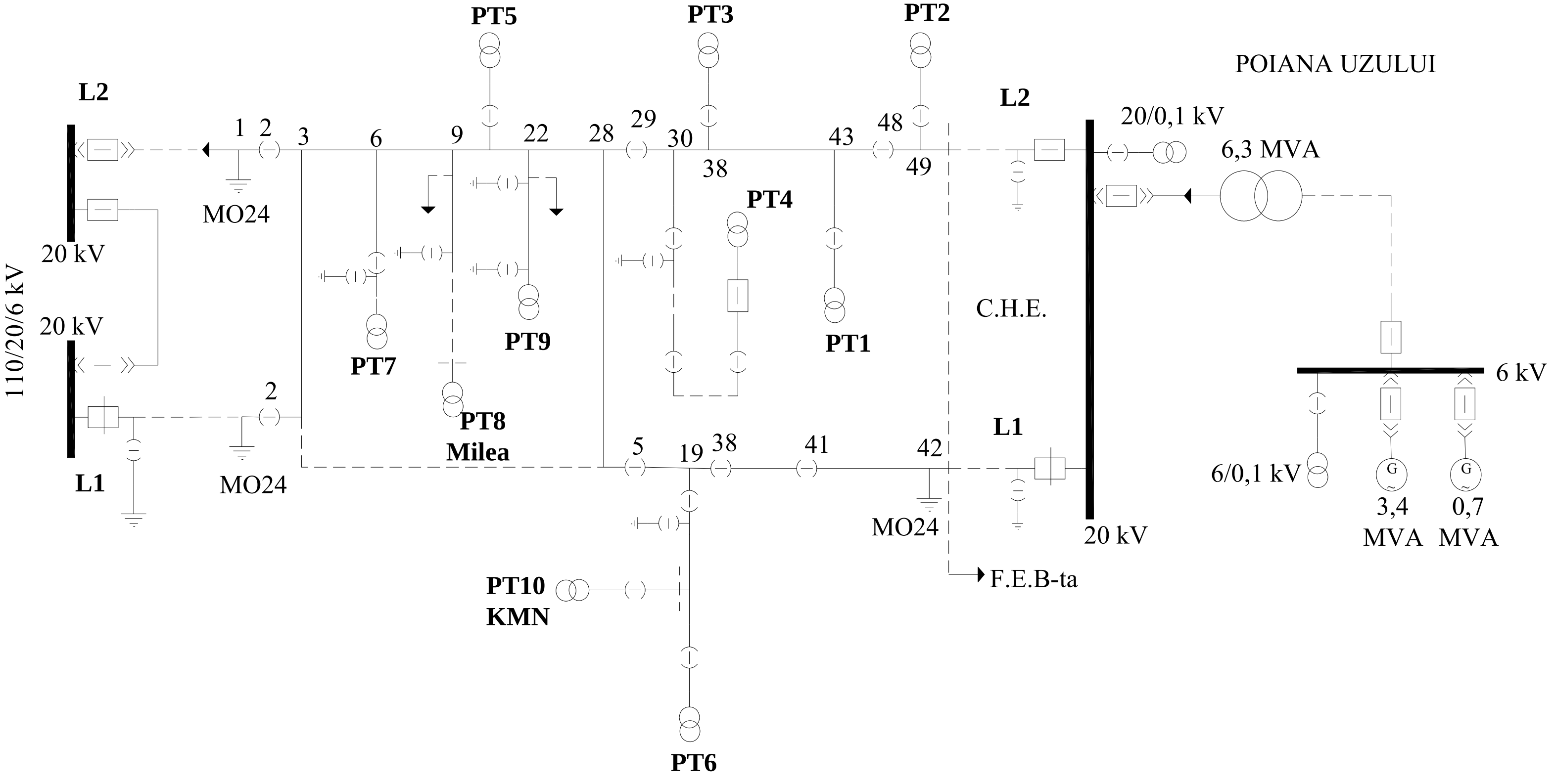

Fig. 2
Test network 2 diagram

$$P_{i\,j}^{est} = P_{i\,j}^{ref} \cdot \left(1 \pm \frac{p}{100} \cdot rnd(1)\right) \tag{6}$$

if the load in the bus varies in an interval ± p [%] related to the reference regime or

$$P_{i\,j}^{est} = P_{i\,j}^{ref} \cdot \left(1 + \frac{p_{\min}}{100} + \frac{p_{\max} - p_{\min}}{100} \cdot rnd(1)\right) \tag{7}$$

if loads are estimated in an interval ($p_{max} \div p_{min}$) [%]related to the reference regime .

Rnd(1) – is a function that generates random values in the interval (0,1).

The same mean is made for the reactive power.

III. NUMERICAL RESULTS

The tests were made on two networks: a 400/220 kV network in the Moldova area (figure 1) and a 20 kV network between 110/20/6 kV Dărmăneşti substation and Poiana Uzului CHE (figure 2). Table 1 shows the results for test network 1 and table 2 shows results for test network 2.

TABLE I

NUMERICAL RESULTS FOR TEST NETWORK 1

Load modification [%]	Generation type	Active energy losses			Reactive energy losses		
		Mean error [%]	Minimum error [%]	Maximum error [%]	Mean error [%]	Minimum error [%]	Maximum error [%]
-5	Random	0.0035	0.0069	0.0409	0.0006	0.0007	0.0083
+5	Random	0.0341	0.0043	0.0801	0.0072	0.0033	0.0135
±5	Random	0.0783	0.0087	0.1792	0.0197	0.0025	0.0368
-10	Random	0.1373	0.0412	0.2277	0.0253	0.0008	0.0422
+10	Random	0.1065	0.0635	0.2339	0.0265	0.0174	0.0499
±10	Random	0.4545	0.2382	0.7839	0.0981	0.0529	0.1583
-20	Random	0.4612	0.3224	0.6552	0.0857	0.0752	0.1035
+20	Random	0.4582	0.3106	0.6352	0.1202	0.0950	0.1521
±20	Random	1.7995	1.3912	2.5604	0.4080	0.3355	0.5862
-5	Fixed	0.0001	0.0001	0.0001	0.0000	0.0000	0.0000
+5	Fixed	0.0001	0.0001	0.0001	0.0000	0.0000	0.0000
-10	Fixed	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
+10	Fixed	0.0001	0.0001	0.0001	0.0000	0.0000	0.0000

TABLE II

NUMERICAL RESULTS FOR TEST NETWORK 2

Load modification [%]	Generation type	Active energy losses			Reactive energy losses		
		Mean error [%]	Minimum error [%]	Maximum error [%]	Mean error [%]	Minimum error [%]	Maximum error [%]
-5	Random	0.10222	0.00147	0.19801	0.03685	0.00263	0.07287
+5	Random	0.09421	0.00597	0.19593	0.03616	0.00748	0.07281
±5	Random	0.12538	0.01692	0.40609	0.04718	0.00307	0.15453
-10	Random	0.25581	0.06774	0.39028	0.09043	0.02522	0.13726
+10	Random	0.19085	0.04370	0.34028	0.07462	0.01509	0.13148
±10	Random	0.51168	0.08743	1.05522	0.19338	0.02550	0.40693
-20	Random	0.59869	0.03447	1.17513	0.20544	0.00828	0.41772
+20	Random	0.39362	0.08043	0.87996	0.16237	0.04329	0.36403
±20	Random	0.73884	0.06969	1.46226	0.29553	0.04448	0.57802
-5	Fixed	0.00548	0.00548	0.00548	0.00420	0.00420	0.00420
+5	Fixed	0.00589	0.00589	0.00589	0.00488	0.00488	0.00488
-10	Fixed	0.00525	0.00525	0.00525	0.00386	0.00386	0.00386
+10	Fixed	0.00608	0.00608	0.00608	0.00522	0.00522	0.00522

IV. THE EFFECTS OF MODIFYING THE NETWORK CONFIGURATION

The networks operating scheme is established based on their normal scheme. It is usually established for two yearly intervals: the winter period and the summer period. A change the network structure occurs in the following situations:

- At the same time as a change in the normal scheme - once every 6 months
- For planned preventive maintenance works, usually 8-10 hours / day, with the daily return to the normal scheme and with an immediate restoration of power in case of need
- For corrective maintenance works – they occur very rarely and only in case of special natural phenomena (frost above normal values, strong wind)
- After performing upgrades.
- A disconnection of a number of transport lines due to the high voltage level in the network.

In all the above situations, the aim is to supply other routes for consumers.

Relations (1) and (2) show that modifying the network configuration affects the power loss in the medium regime, $\Delta P\left(\left[\overline{P}^{est}\right],\left[\overline{Q}^{est}\right],\left[\overline{Ue}^{est}\right]\right)$, $\Delta Q\left(\left[\overline{P}^{est}\right],\left[\overline{Q}^{est}\right],\left[\overline{Ue}^{est}\right]\right)$, but does not affect the statistical loads. It may also affect the partial derivatives of the power losses depending on the bus loads given in [2].

The periods of disconnection due to accidental interference are insignificant. In order to consider changing the structure of the network for preventive maintenance works or for upgrades, the respective terms will be calculated separately and will be multiplied by the estimated period of operation in those variations. This period will be decreased from the T estimation period.

The precise knowledge of the network allows the estimation, based on the above method, of the energy losses on short intervals of time - on the order of hours and up to one day – with good results.

V. CONCLUSIONS

Using the statistical characteristic for estimating the active and reactive energy losses on the network offers good and very good results:

- In case of a random ±20% variation of the loads related to the reference regime, errors are up to:
  - 2.6 % in the case of a high voltage network
  - 1.5 % in the case of a medium voltage network
- In case of a random ±10% variation of loads related to reference regime, errors are up to:
  - 0.8 % in the case of a high voltage network
  - 1 % in the case of a medium voltage network
- If loads vary in the same direction then errors are smaller, up to 0.35 %
- If loads vary proportionally to the reference regime then errors are approximately zero.
- The modifications in the network structure may be considered by calculating the energy losses on each time interval in which the network structure is constant.
- In order to estimate the short term energy losses (hours up to 1 day), calculations have to be precisely performed for the existent structure.

VI. REFERENCES

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