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Optimization of Power Reserves in Market Conditions

A. Mahnitko and J. Gerhards and T. Lomane and S. Ribakovs

***Abstract*-- The optimization problem of the power reserves in the electric power system (EPS) for the purpose of the operation reliability increase is considered. The analytical expression of the power reserve optimum price determination for the electric power concrete producer is given. The considered strategy of the power reserve formation for the EPS is realized on the base of Matlab program. The results of the total power reserve optimization for the EPS test diagram are presented.**

***Index Terms*-- electric power system, optimization, power reserve, equilibrium price**

I. Introduction

With the management of the large power systems the important place belongs to the providing the reliability of their functioning [1]-[9]. Under normal conditions the electric power system (EPS) regimes control is connected with the effective realization of the contract relationship for the electric power and system services wholesale market subjects [10]-[11]. For this it is expedient to use the potential possibilities of the competitive generation and the transmission electrical network capacity. This tendency enters into the specific contradiction with the need of the system reliability providing and the power system vitality, since the EPS regimes control without consideration of this need can lead to the severe consequences during the emergency appearance, sometimes it may be catastrophic nature, for the system and the users. Therefore, for the guaranteeing of the system reliability and the EPS vitality it is necessary to support the required generation reserves and the reserves of the intersystem connections capacity. This is possible with the refusal from the commercial expediency of the maximum use for the generation and the transmission electrical network. With the threat of the emergency appearance it should be completely reject from the market criteria for the EPS regimes control and must use the centralized principles of the dispatcher and automatic control.

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In the solution of the EPS control problems the significant role is devoted to the substantiation of the optimum values for the power operational reserves and the intersystem connections capacities. A constant attention of the specialists is paid to the solution of this problem [1], [2], [12], [13]. For the Latvian EPS and the other Baltic countries EPSs this problem becomes more actual. This urgency is explained by the tendency of the Baltic countries to accelerate the integration of its EPSs into the unified power system of the European Union with the saving the synchronous operation with the EPS of Russia, Belorussia and Ukraine.

On the importance of the problem of the power reserves formation repeatedly it was indicated in the working materials UCTE [14]-[20].

Under the market conditions the power reserves are the object of the trade. The refusal of the power reserve market creation, caused by the tendency of the obtaining the maximum benefit from the sale of the produced electric power, the policy and the strategy, oriented for the market, can be the reason for the system emergencies and in the final it leads to the disintegration of the power system. Thus the power reservation is the guarantee of the EPS successful operation. The power reserve use is one of the system services forms, represented by the system operator. The payment for this service depends on the value and effectiveness of the utilized reserve. An increase in the reserve leads to an increase in the reliability of the power supply for users, but it is connected with the additional capital investments.

The strategy of the EPS power reserve formation, considered below, is applicable for the case, not connected with the introduction of the new generating power and not consequently requiring the additional capital investments. The basis of this strategy is the calculation of the shared participation of the electric power producers (individual participants in the market) in the formation of the power reserve total for EPS. The optimum price of the power reserve for the electric power individual producers can be determined with that being steady the equilibrium price, which can be declared for the power reserve market.

The authors realize, that the complete solution of the problem for the power reserves market creation cannot be investigated within the framework one article. This is connected from the known with specific character of electric power branch, which distinguishes it from other branches of national economy. It is seemed to us that final solution of the problem of the power reserve market for the power system

UCTE, taking into account the possibility of the connection of the power systems of the Baltic countries, and in prospect and Russia, is far from its completion.

II. The Optimization Task of the Competitory Market

First of all, it is necessary to note, that in the process of the free trade between the electric power markets subjects (i.e. on the competitory double-sided markets), the electric power transmission line, that are located on the boundaries of different countries, will load differently. In this case the calculated regime of the system operation (the distribution of the generatable and usable powers, the power overflows along the lines and, correspondingly, the nodes prices) will coincide with the system regime, which can be obtained as a result of the centralized calculation of the optimum regime for the considered market as a whole.

From a technological point of view the obtained electrical regimes must satisfy a whole series of the system limitations. These limitations have a form of the equalities and the inequalities. The limitations in the form of the equalities are assigned as the balance limitations according to the active and reactive power in the nodes:

$$\left.\begin{aligned} \sum_j P_{ij}(U_i,U_j,\delta_i,\delta_j) + \sum_{g\in G_i} P_g - \sum_{d\in D_i} P_d = 0,\ i\in N, \\ \sum_j Q_{ij}(U_i,U_j,\delta_i,\delta_j) + \sum_{g\in G_i} Q_g - \sum_{d\in D_i} Q_d = 0,\ i\in N, \end{aligned}\right\} \quad (1)$$

where P_{ij}, Q_{ij} are the active and reactive power flows via the *i*-*j*-th line from the *i*-th node to the *j*-th node;

P_g, P_d are the node capacities of the active power generation (sale) and demand (purchase);

Q_g, Q_d are the node capacities of the reactive power generation (sale) and demand (purchase);

U_j, δ_j is the modulus and phase of the voltage in the *j*-th node, respectively;

G_i, D_i are the sets of the node claims for the active power generation (sale) and demand (purchase) in the *i*-th node;

N is the set of the electrical network nodes.

The limitations in the form of the inequalities can be divided into the net (for lines), determined by the line's regime, and the nodes. In general form the net limitations are written as the inequalities:

$$X_\ell^{\min} \le X_\ell \le X_\ell^{\max} \quad (2)$$

and there are the ranges of a change for the currents or the active and reactive power flows in the lines (or sections).

The nodes limitations, given by the inequalities:

$$X_i^{\min} \le X_i \le X_i^{\max} \quad (3)$$

are the lower and upper limits on the active and reactive power generation, the nodes voltages, including the load nodes, and also the transformation ratios of transformers.

From the totality of the limitations (2), the limitations (3) assign the limits of the intersystem connections capacities, calculated from the condition of the overloads prevention and the stability preservation:

$$P_\ell \le P_\ell^{\max} \quad (4)$$

and the limitations, which determine the operating range of the active power aggregates:

$$P_g^{\min} \le P_g \le P_g^{\max} \quad (5)$$

Specifically, the limitations (4) and (5) influence on the price formation on the balancing market first of all.

With the going to the competitory relations in electric-power the optimization problem of the electrical regime is transformed unessentially. The changes concern only the objective function. The solution of the optimization problem for the competitory market, as in the case of the planned economy, is possible only with the using the technical and economic model, which describes the functional connections of the EPS economic characteristics and parameters. The limitations given above remain the same. Without taking into account of the system limitations and the technical losses, connected with the electric power transmission, the solution of the optimization problem consists in the maximization of the following objective function:

$$F = \sum_{j=1}^{D} c_{dj} \cdot W_{dj} - \sum_{i}^{G} c_{gi} \cdot W_{gi} \quad (6)$$

Where c_{dj}, c_{gi} are the price claims of users and generators;

W_{dj}, W_{gi} are the hourly volumes of the electric power consumption and generation, declared by the subjects;

G, *D* are the numbers of load and generator nodes.

It is known, that the function (6) is the welfare function of the market participants [21], [22]. It should be noted that during the trading the preference (in accordance with Eq. (6)) is given to the market participants, who indicated the smallest prices in the claims. This provides the minimization of the expenditures for the maintenance of a constant balance between the load and the generation.

Taking into account that the time interval Δt for the definition of the electric power volumes is identical both for the buyers and for the salesman, the objective function (6) is converted to the form:

$$F = \sum_{j=1}^{D} c_{dj} \cdot P_{dj} - \sum_{i}^{G} c_{gi} \cdot P_{gi}\,. \quad (7)$$

Thus the optimized task of the competitory market includes the previously known nodes parameters for the EPS electrical regime.

III. The Task of Power Reserve Creation

To provide reliable supply of the electric power and its high quality, the independent EPS, working in parallel, are forced to coordinate their operating conditions. The attraction of resources and controls one an EPS to render help to another is considered as technical service, which has certain limits and cost. The creation of a power reserve in a neighboring EPS is one of such paid services. The specific character of this service lies in the fact that it is closely connected both with the current operating condition and with possible situations in the future – for example, failure of the equipment at a power plant, belonging to the given EPS, the load increase and etc. Under the conditions of the territorial and economic disintegration the implementation of a market strategy - in particular, of the contractual deliveries with a penalty system for power undersupply and of "local selfishness" – is possible only if the necessary reserves of the generating power are available [1]-[13]. Otherwise a neighboring EPS cannot render help to each other. Therefore, the provision of the power reserve is a service in which the individual market participants and an EPS as a whole are interested. The creation of the necessary capacities for a rotating power reserve is an integral part of the "on one day forward" market.

The urgency of the power reserve market creation is an additional argument for revision and reformulation of the problems of EPS regime calculation as well as of the mathematical models and methods to be used for this purpose. Formulations of the problems concerning the power reserves could be found in works [1], [2], [12], [13], among which the model proposed in [12] seems to be more advanced.

To participate in a power reserve market *i*-th node producer has a possibility to divide its production capacities into two parts. One of them (P_{gi}) could be claimed in the form of generation and sold at the price c_{gi} , whereas the second part could be left as underloaded generators (R_i) or reserve and sold at price c_{Ri} . The power reserve at *i*-th node can be determined from the expression:

$$P_{gi} + R_i = P_{gi}^{\max} . \qquad (8)$$

If power reserve R_i is not realized, the specific benefit B_i for the *i*-th node producer can be defined as

$$B_i = c_{gi} \cdot P_{gi} + c_{Ri} \cdot R_i - C_i(P_{gi}) \qquad (9)$$

with the costs of the generating sets starting and stopping not taken into account.

In Eq. (9), the $C_i(P_{gi})$ value is the cost of power production in I-th node per time unit. Such cost is determined by the fuel-cost function:

$$C_i(P_{gi}) = \alpha_i + \beta_i \cdot P_{gi} + \gamma_i \cdot P_{gi}^2 . \qquad (10)$$

The nodal power generation must satisfy the technological limitation given in (5).

For the *i*-th node the optimum electric energy price (from the viewpoint of the maximum profit for the producer) can be defined by solving the problem of unconstrained optimization of function (9) for the variable P_{gi} . Equating to zero the first derivative of function (9) with respect to variable P_{gi} and taking into account function (7), we obtain the following equation:

$$\frac{\partial B_i}{\partial P_{gi}} = c_{gi} - c_{Ri} - \frac{\partial C_i(P_{gi})}{\partial P_{gi}} = 0 . \qquad (11)$$

From equation (11) we can determine power P_{gi} that could be offered by *i*-th node producer for the power market. This power is presented as a dependence on the prices of generation (c_{gi}) and reserve (c_{Ri}) powers. For the problem under consideration this dependence is:

$$P_{gi}(c_{gi}, c_{Ri}) = \frac{c_{gi} - c_{Ri} - \beta_i}{2\gamma_i} . \qquad (12)$$

The verifying the behavior of the benefit function (9) extremum by taking the second derivative sign gives the following result:

$$\frac{\partial^2 B_i}{\partial P_{gi}^2} = -2\gamma_i \prec 0 . \qquad (13)$$

The negative sign of the resultant function evidences that there is reached maximum for function (9) with the generated power P_{gi} (equal to the power offered for market).

In the case when the commercial effect (benefit) is determined for an EPS as a whole, the optimum price of electric power for the node producer can be determined employing the Lagrange function:

$$L = \sum_i B_i + \sum_i \lambda_i \cdot (P_{gi} + R_i - P_{gi}^{\max}) . \qquad (14)$$

At a steady equilibrium price (EP) $c_* = c_{gi}$ in a power market, the optimum price c_{Ri} of the power reserve for *i*-th node producer can be determined. This optimum is reached (taking into account dependences (8) and (12)) as a result of solving the unconstrained optimization problem with respect to variable c_{Ri} :

$$B_i(c_{Ri}) \to \max \qquad (15)$$

The optimum price of power reserve for *i*-th node producer is thus determined by the expression:

$$c_{Ri} = c_* - \beta_i - 2\gamma_i \cdot P_i^{\max} . \qquad (16)$$

It should be noted that above-mentioned reasonings are valid for any time interval Δt, during which the value of the power reserve can be accepted constant. Any period of time T in question it is possible to present in the form the sequence of the indicated intervals. The joint solution of the problem of determining the optimum power reserves for entire period of time T will lead to an increase in the dimensionality of the decided task, but it will make it possible to consider the temporary factor.

IV. The Consideration of Intersystem Connections Capacities

The use of the power reserves is possible not only with the excess of itself generating power, but also with the presence of the capacity reserves for the EPS transmission network. Otherwise it is possible the situation, when the electrical network proves to be unable to transmit the required power on the condition of the balance reliability. As the result of this situation will be the nonfulfillment of the planned obligations for the market participants. Consequently, this fact is necessary to consider during the developing and the solving the problem of the power reserve creation on the energy-enterprises.

The presence of the intersystem connections capacity limitations in the electrical network or their totalities of form (2), the limitation (4) can lead to the rise in the price of the power created reserve. At the same time, from a computational point of view, it is not difficult the consideration of the minimum and maximum capacities for the electric power transmission lines. In this case the task of the determination for the producers maximum benefit from the power unrealizable reserve can be supplemented by the appropriate limitations according to the capacity of the concrete transmission lines or their groups.

With the use of linear models the connection between the nodes power and the power flows along the lines can be realized through the matrix of the current distribution coefficients. This matrix elements calculation with the assigned the balance node for the concrete EPS have not the fundamental difficulties. For the uniform networks ($R_\ell / X_\ell = idem$, for all lines ℓ) these coefficients are the integer numbers. The presence of the line ℓ capacity limitations can be shown as the inequality of form

$$P_\ell = \alpha_{\ell 1} P_1 + \alpha_{\ell 2} P_2 + \ldots + \alpha_{\ell N} P_N \qquad (17)$$

where - $\alpha_{\ell i}$ is the coefficient, which shows, what part of i node active power flows along the line ℓ_i.

V. Results of Study

It is considered the optimization problem of the power reserve determination for a concentrated EPS, which consist of three thermal power plants (PP1, PP2, PP3), operated on the common load, as it is shown on Fig.1.

The common load is presented as the sum of the nodes demand powers by following expression:

$$P_D = P_{d4} + P_{d5} = 500 + 300 = 800\ MW .$$

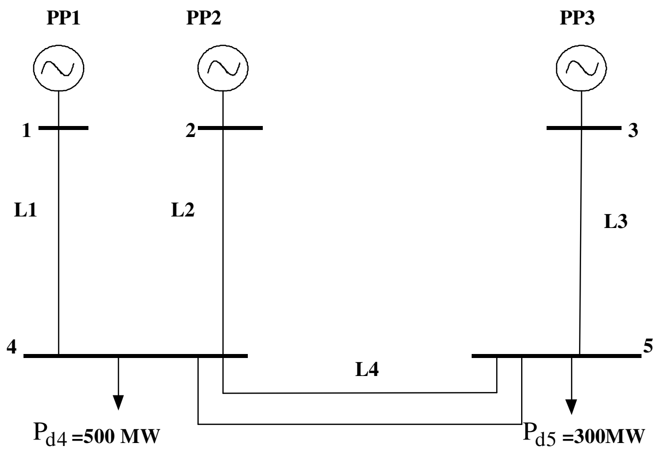


Fig. 1. Test diagram for the EPS Power Reserve Problem study

The input data are represented by the fuel-cost functions for these power plants (in €/h):

$$C_1 = 500 + 5.3 \cdot P_{g1} + 0.004 P_{g1}^2 ,$$

$$C_2 = 400 + 5.5 \cdot P_{g2} + 0.006 P_{g2}^2 ,$$

$$C_3 = 200 + 5.8 \cdot P_{g3} + 0.009 P_{g3}^2 ,$$

where P_{g1}, P_{g2} and P_{g3} are in MW.

The optimization problem must be solved with the following technological limits on the power generation

$$200 \le P_{g1} \le 450,$$

$$150 \le P_{g2} \le 350,$$

$$100 \le P_{g3} \le 225$$

and the following limits on the power reserve (in MW)

$$25 \le R_1 \le 150,$$

$$20 \le R_2 \le 120,$$

$$10 \le R_3 \le 60.$$

In this case, the necessary power reserve for the EPS as a whole is not to be less than 110 MW, i.e. $\sum R_i \ge 110\ MW$.

To form the electric power sale price for the *i*-th node producer (*i*=1, 3) the marginal approach is used. The relative increase of the fuel-cost functions for the *i*-th node is determined by the following expression:

$$\frac{\partial C_i}{\partial P_{gi}} = \beta_i + 2\gamma \cdot P_{gi} . \qquad (18)$$

We will assume, that the electric power sale price for the i-th node producer (with taking into account the expected benefit) is 10% greater than the marginal price. Thus, for the i-th node the price of the electric power for sale can be calculated according to the expression:

$$c_{gi} = 1.1(\beta_i + 2\gamma_i P_{gi}) . \qquad (19)$$

In this case the power reserve price of the EPS for the i-th node, taking into account function (12), will be defined as follow:

$$c_{Ri} = 0.1(\beta_i + 2\gamma_i P_{gi}) . \qquad (20)$$

The summary benefit function (B_Σ) for the power plants can be formed taking into consideration expression (9). For this task the MATLAB program was used. As a result the optimization problem calculation for the system mode without the consideration of the lines capacities limitations the following optimum variables of the generation and reserve power values were obtained:

$$P_{g1} = 382.5\,MW\ ;\quad P_{g2} = 250\,MW\ ;\quad P_{g3} = 167.5\,MW\ ;$$

$$R_1 = 67.5\,MW\ ;\quad R_2 = 100\,MW\ ;\quad R_3 = 57.5\,MW\ .$$

This mode of the power plants operation, with the total demand load $P_D = 800MW$ and with the power required reserve 110 MW, can provide the total benefit in size of 984.8 Arbitrary units

With the line $\ell 4$ capacity limitation by the value 120MW ($P_{\ell 4}^{\lim it} \le 120MW$) this regime cannot be realized because of the indicated line overload (the power flow along the line must be 135MW). In this case the system operator will have to make a decision about the need of this regime correction. In the calculated plan this correction consists of the using the additional inequality of type (4) to the decided task model.

For the considered EPS test diagram, with the balancing node number 1, the matrix of the current distribution coefficients α has form

$$\alpha = \begin{array}{c} \\ \ell 1 \\ \ell 2 \\ \ell 3 \\ \ell 4 \end{array} \begin{array}{c} \begin{array}{ccccc} n1 & n2 & n3 & n4 & n5 \end{array} \\ \begin{bmatrix} 0 & -1 & 1 & -1 & -1 \\ 0 & 1 & 0 & 0 & 0 \\ 0 & 0 & 1 & 0 & 0 \\ 0 & 0 & -1 & 0 & -1 \end{bmatrix} \end{array}$$

Thus, the presence of the line $\ell 4$ capacity limitation leads to the need of the additional inequality consideration for the optimization model calculation in the form:

$$P_{\ell 4} = (-P_{g3} + P_{d5}) \le P_{\ell 4}^{\lim it}$$

Fig. 2 shows the nature of the benefits change for the separate power plants in the dependence on the line capacity limitation value. The application of an expression (20) allows to determine the price of each power station reserve, which can be declared on the power reserves market.

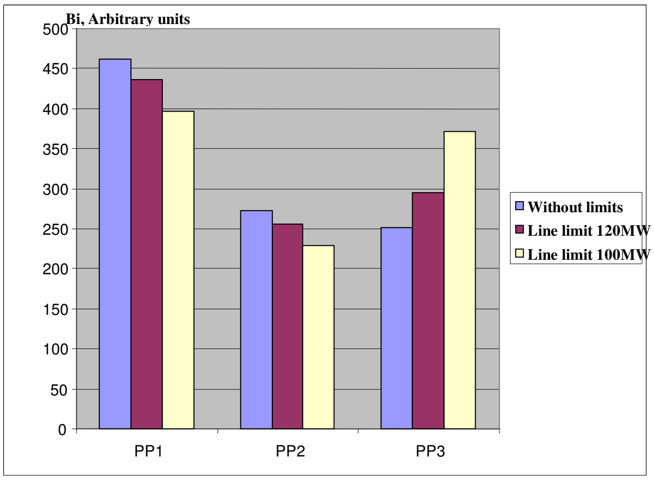


Fig. 2. Benefit B_i as a function of the connection line limits for three power plants: PP1, PP2, PP3.

Table I shows the values of the optimum parameters of powers and the EPS common benefit under varied conditions for the power transmission line $\ell 4$ by the capacity limitation.

TABLE I
THE VALUES OF THE PP OPTIMUM POWERS AND EPS COMMON BENEFIT UNDER VARIED CONDITIONS FOR THE POWER TRANSMISSION LINE $\ell 4$

Regime parameters	Without limits	Line limit 120MW	Line limit 100MW
Pg1, MW	382.5	375	363
Pg2, MW	250	245	237
Pg3, MW	167.5	180	200
R1, MW	67.5	75	87
R2, MW	100	105	113
R3, MW	57.5	45	25
Bsum, Arbitr.units	984.8	986.6	996.8

VI. CONCLUSION

1. The proposed principle of the power reserves formation by the maximum benefit of the separate sources can be used as one of the versions for the EPS power general reserve creation.

2. In the shown presentation the considered task of the EPS power reserve formation is the typical task of square programming, whose solution can be fulfilled with the aid of the existing office software of contemporary computers without the creation of the special program.

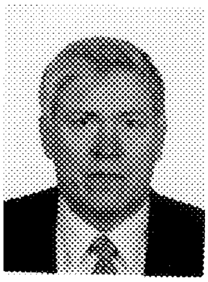
3. The assumed further geographical expansion of system UCTE will require the development of the acceptable methodology of the temporary factor calculation, which determines the domestic market of Western Europe and the markets for the territories, which are approached it to be

joined. The considered principle of the power reserve formation for each concrete time interval can be one of the component elements of this methodology.

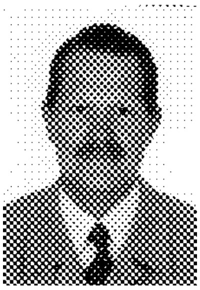
VII. References

[1] S.N. Siddiqi, M.L. Baugman, "Reliability differentiated pricing of spinning reserve" ,IEEE Transactions on Power Systems, Vol. 10, Issue 3,Aug 1995, pp.1211-1218.
[2] R. Billinton, and R.N. Allan, Reliability Evaluation of Power Systems. – New York: Plenum, 1996.
[3] S. Stoft, Power System Economics: Designing Markets for Electricity (J. Wiley and Sons, 2002). – 468 p
[4] V.P. Oboskalov, The reliability of the power balance providing for the electric power systems. – Ekaterinburg, GOU VPO UGTU-UPI, 2002. - 210 p
[5] G. Samorodov, T. Krasilnikova, R. Yatsenko and S. Zilberman, An Analytical Method for Reliability Evaluation of Two Interconnected Power Systems. – In Proc. 9th International Conf. on Probalistic Methods Applied to Power Systems. Stockholm, Sweden: Royal Institute of Technology, 2006.
[6] S.M. Zilberman, T.G. Krasilnikova, G.I. Samorodov, "Analytical method of the balance reliability optimization during the association of two power systems" // Elektrichestvo, 2008, №2, pp. 2–9.
[7] Power engineering of the XXI century: Power Systems and Control of them / S.V. Podkovalnikov, S.M. Senderev, V.A.Stennikov; With editor N.I. Voropaj. –Novosibirsk, Nauka,2004. 364 p.
[8] N.I. Voropaj, Problems and trends of control systems development for electric power systems //Proceedings of III international practical-scientific conferences "The power system: control, competition, development", October 13-16, 2008. Vol.1.–Ekaterinburg, UGTU-UPI, 2008, pp 24–28.
[9] Y.J. Chukreev and others. Contemporary state of the methodical and model-program developments for the reliability providing tasks during the EPS evaluation control // Proceedings of III international practical-scientific conferences "The power system: control, competition, development", October 13-16, 2008. Vol. 2. – Ekaterinburg, UGTU-UPI, 2008, pp. 152– 157.
[10] A.Z. Gamm, Simulation of the technical services market for the electric power systems // Izv. RAN. Energetika, 1997, № 1, pp. 116 – 122.
[11] Grzegorz Blajszczak, The system services under the market conditions // Elektrichestvo, 2001, № 10, c. 7 – 10.
[12] A.Z. Gamm, Market of capacity rezerves in terms of maneuverability and network constraints // Proceedings of the Russian national symposium on power engineering, vol. II. – Kazan, Russia, 2001, p. 281 – 284.
[13] G. Verbic, F. Gubina, "Cost-based models for the power-reserve pricing of frequency control" ,IEEE Transactions on Power Systems, Vol. 10, Issue 4, Nov 2004,pp.1853-1858.
[14] Final Report System Disturbance on 4 November 2006. UCTE Report – February 2007.
[15] 2005-08-29 UCTE Ad hoc Group "Geographical Distribution of Reserves", Final Report 1 - Basic Framework and Current State, Version1.0. July 2005. 27 p.
[16] 2005-08-29 UCTE Ad hoc Group "Geographical Distribution of Reserves", Final Report 2 - Use of Transmission Capacity, Version 1.0. July 2005. 7 p.
[17] 2005-08-29 UCTE Ad hoc Group "Geographical Distribution of Reserves", Final Report 3 - Border – Crossing Exchange of Primary Control Reserve. Limits and Constraints. Version 1.0. July 2005. 19 p.
[18] 2005-08-29 UCTE Ad hoc Group "Geographical Distribution of Reserves", Final Report 4 - Border – Crossing Exchange of Secondary Control Reserve. Limits and Constraints. Version 1.0. July 2005. 14 p.
[19] 2005-08-29 UCTE Ad hoc Group "Geographical Distribution of Reserves", Final Report 5 - Border – Crossing Exchange of Directly activated Tertiary Control Reserve. Limits and Constraints. Version 1.0. July 2005. 16 p.
[20] 2005-08-29 UCTE Ad hoc Group "Geographical Distribution of Reserves", Final Report 6 -Border – Crossing Exchange of Schedule activated Tertiary Control Reserve. Limits and Constraints. Version 1.0. July 2005. 15 p.
[21] R.Green and D.M.Newbery. Competition in the British electricity spot market //J.Political Econ.,vol. 100, No.5.Oct.1992, pp.929 – 953.
[22] H. Singh, S. Hao, A. Papalexopoulos, Transmission congestion management in competetive electricity market //IEEE Trans. on Power Systems, 1998. –Vol. 13, No. 2. –pp. 672-680.

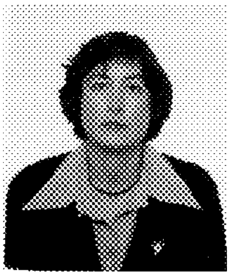
VIII. Biographies



Anatoly Mahnitko was born in Dnepropetrovsk, Ukraine in 1942. He graduated from Mechanics and Mathematics Faculty of Kiev State University (Ukrane). In 1972 recieved Ph.D. in the speciality of Electrical Engineering from Riga Technical University (RTU). He has been working in RTU from 1972 as a senior lecturer, Assistent, Associate Professor and Professor of the Institute of Power Engineering. His research interests include Electric Power System Mathematical Simulation and Optimization, the electric power market problems.



Janis Gerhards was born in Jelgava, Latvia in 1942. He graduated from the Riga Polytechnical Institute in 1966 and received Ph.D. in Power Engineering from Byelorussian Polytechnical Institute in 1981. From 1973 he is working in Riga Technical University (RTU) as assistant, associate professor, professor, vice-president. Currently he is a professor, Dean of Power and Electrical Engineering Faculty. In 1994-97 he was a chairman of Broad of Advisors of the Latvia State Power Company "Latvenergo". His special field of interest include Power System Optimization, Reliability and Planning.



Tatjana Lomane was born in Riga, Latvia in 1946. She graduated from Riga Polytechnical Institute in 1970. She received Ph.D. in Power Engineering from Leningrad Polytechnical Institute (Russia) in 1985. From 1975 she was working as a senior lecturer of Kishinev Polytechnical Institute (Moldova). From 1994 she is working as Assistant Professor, Associate Professor of Riga Technical University. Her research interests include EPS Protective Relay, EPS modes Control and Optimisation.

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