

Transformation of the model of the design scheme of the power system in the problem of ensuring balance reliability

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Abstract. The paper deals with the issues reducing the number of territorial zones in the model calculation scheme UPS of Russia as applied to the problem of substantiating the required generating capacity (capacity reserve) under the conditions of ensuring normative indicators of balance reliability in accordance with the requirements of the new guidelines for design of power systems. On the example of the model UPS of Russia calculation scheme developed by SO UPS specialists, the possibilities of reducing the number of territorial zones to reasonable limits are shown.

1 Problems of forming a model calculation scheme UPS of Russia for the problem of balance reliability

The task justification of power reserves electric power systems when managing their development has always been given due attention. It is reflected in many monographic publications [1-5], reference books [6] and normative and technical documents [7-9]. Information both on forecasted parameters - load maximums, transmission capacity of links, cost characteristics of generating and grid equipment and many other things, and probabilistically determined - power equipment failure, power consumption forecasting errors, etc., had and has a certain error today. This is the basis for the application of various simplifications in the applied models calculation scheme, accounting of power consumption modes and other aspects, but, nevertheless, adequately reflecting the limitations of the real processes in the system. At the same time, it should be noted that in terms of the assumptions made, the studies conducted in our country differed little from those conducted abroad.

The model UPS design scheme under the above assumptions was considered in the form of aggregated territorial zones - united electric power systems (EPS) with unlimited possibilities of interconnection capacity within them. At the same time, it should be noted that the models calculation scheme UPS of Russia were also considered with the division of some EPS into two or more territorial zones, within which unlimited possibilities of interconnection capacity were also assumed. It should be noted that these simplifications

were quite justified, allowing to find an adequate solution to the problem justifying the means of redundancy that meets the interests of both generating companies and consumers.

In the current conditions of planning the development EPS of the country, specialists of SOs and servicing research institutes (STC UPS) have formed the opinion that availability of opportunities in obtaining information and, to some extent, market relations require greater detailing model calculation scheme UPS of Russia. It is quite likely that the models for solving operational problems played a certain role here. It is not a secret that today, when solving a number of tasks UPS of Russia regime planning for the conditions of current and operational regime management, information availability and market relations have led to the possibility of more detailed representation the power system calculation scheme in form of hundreds and thousands of nodes and links between them. This is quite understandable due to sufficiently reliable information both on power consumption and generation modes and the time factor of planning for a day ahead or in terms of hours current day.

When planning the development, the increase UPS model to solve, to a greater extent, the problems of estimating the balance reliability indicators (BRI) is reflected in open publications [4, 10], UPS reports and regulatory materials [7-9]. It should be noted that there was no scientific and practical justification of increasing the model UPS design scheme for the tasks justifying the means of ensuring the balance reliability (BR) - the reserve of generating capacity or, as it is

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customary today, the required generating capacity. It can be recognized that when solving the problem of identifying the most “bottlenecks” in the aspect of balance reliability of places for the reporting year and for one year in advance, the model UPS of Russia calculation scheme is quite appropriate to detail up to 50-150 territorial zones. At the same time, it is no secret that the scheme detailing is always associated with various simplifications [11, 12]. At the same time, the solution the problem of justifying means of ensuring balance reliability - the required generating capacities (capacity reserves), on the calculation schemes of large dimensions, causes significant difficulties, both from the standpoint of time costs and from the standpoint of analyzing the obtained results BRI.

2 Balance reliability indicators

According to the recommendations [1], the BRI suitable for the purposes of making managerial decisions - justification of capacity reserves - of the required generating capacity should have a simple physical meaning and be sensitive to perturbations. In domestic [1, 2, 4, etc.] and in foreign publications [3, etc.] probabilistic BRI satisfy the above recommendations most fully:

- integral probabilities of occurrence of power deficit (J_d) or its absence (p) in the territorial zones of EPS;
- average number of days of power deficit per year (Loss of Load Expectation - LOLE [3]);
- average number of hours of capacity deficit per year (Loss of Load Hours - LOLH [3]).

Determination of probabilistic BRI in the models developed in our country or abroad is carried out by modeling of random states generating capacity caused by withdrawal of generating equipment for emergency repair at a certain time interval of load change. In our country, until recently, modeling was carried out for 24 steps of the daily schedule December day, with its extension to all working days of the year (250) [2, 6, 7]. In North America, to obtain the BR LOLE index, modeling is performed for 365 values of load maxima, without taking into account their daily decreases. At present, when determining the J_d indicator, as well as when determining the European LOLH indicator, modeling is performed for all 8760 intervals of hourly load changes [8, 9]. At the same time, it should be noted that the normative value of LOLH indicators, when changing the modeling principles, remained at the same level ($p = 0.996$, $J_d = 0.004$), which is not quite correct, but this is not the issue of this article. For information, in European countries $LOLH = 3 - 8$

hours, which corresponds to $p = 0.99909 - 0.99966$ or $J_d = 0.00034 - 0.00091$.

3 Model design scheme, its influence on the BRI from the point of view justification of the required generating capacity

At all times, sufficient attention has been paid to the formation of models design scheme UPS of Russia for BR tasks. It should be noted that for the first time the approach of formation of the calculation scheme for the BR task based on the use of controlled sections of the real scheme electrical connections UPS of Russia was applied by the specialists of INEI RAS and Institute “Energosetproekt”. The problematic point in this approach was and remains the issues of determining the capacity links included in a particular controlled section [11, 12]. At the same time, we leave behind brackets the influence of such important in the aspect of BR issues of their adequate application for conditions constantly changing composition of generating equipment under random modeling in the task of estimation of BRI.

It is quite obvious that the model calculation scheme UPS of Russia for BR tasks should be represented in the form of a graph, the vertices of which are zones of equal reliability, and the edges - intersystem links. Zones of equal reliability (territorial zones) are understood as a set of nodes included in it, network constraints between which, as in a concentrated system, do not affect the BRI in it. Taking this into account and analyzing the controlled cross-sections, schemes with 50 territorial zones were first proposed (2012, INEI RAS), then with 56 (taking into account Ukraine, Belarus and the Baltic states in 2014, STC UPS), but without taking into account the East UPS. In the last paper Scheme and Program of UPS Development for 2024-2029 (hereinafter referred to as UPS SPD without specifying the years). SO UPS and STC UPS propose a calculation scheme with 100 and 110 territorial zones with the East UPS.

The use of UPS calculation schemes with a large number of territorial zones in the task of estimating the BRI can be somehow explained by the possibility of identifying “bottlenecks”. The BRI for territorial zones and the links connecting them will be low in such places UPS of Russia calculation scheme. The solution to the problem of justifying the capacity reserve, or, in today's interpretation the required generating capacity, is to bring these BRI up to the normative value. This is also stated in the new methodological guidelines for the design of power systems (hereinafter referred to as the new MI) [8]. Fig. 1, a shows the design scheme of UPS. It is based on the materials of Appendix 5 of the

UPS SPD work. Small circles indicate territorial zones allocated in each of the 7 UPS. The territorial zones included in the UPS Center, Volga and North-West have a high level of BRI $\rho > 0.9999$ (white circles). A small number of territorial zones of the Ural UPS (1), South (6), Siberia (6) and practically all UPS of the East (9) have BRI below the normative value (shaded

circles on the scheme). Many connections between territorial zones within the UPS are not shown in the figure. At the same time, the links limiting the redistribution of capacity between deficit and surplus parts UPS are highlighted in bolder colors.

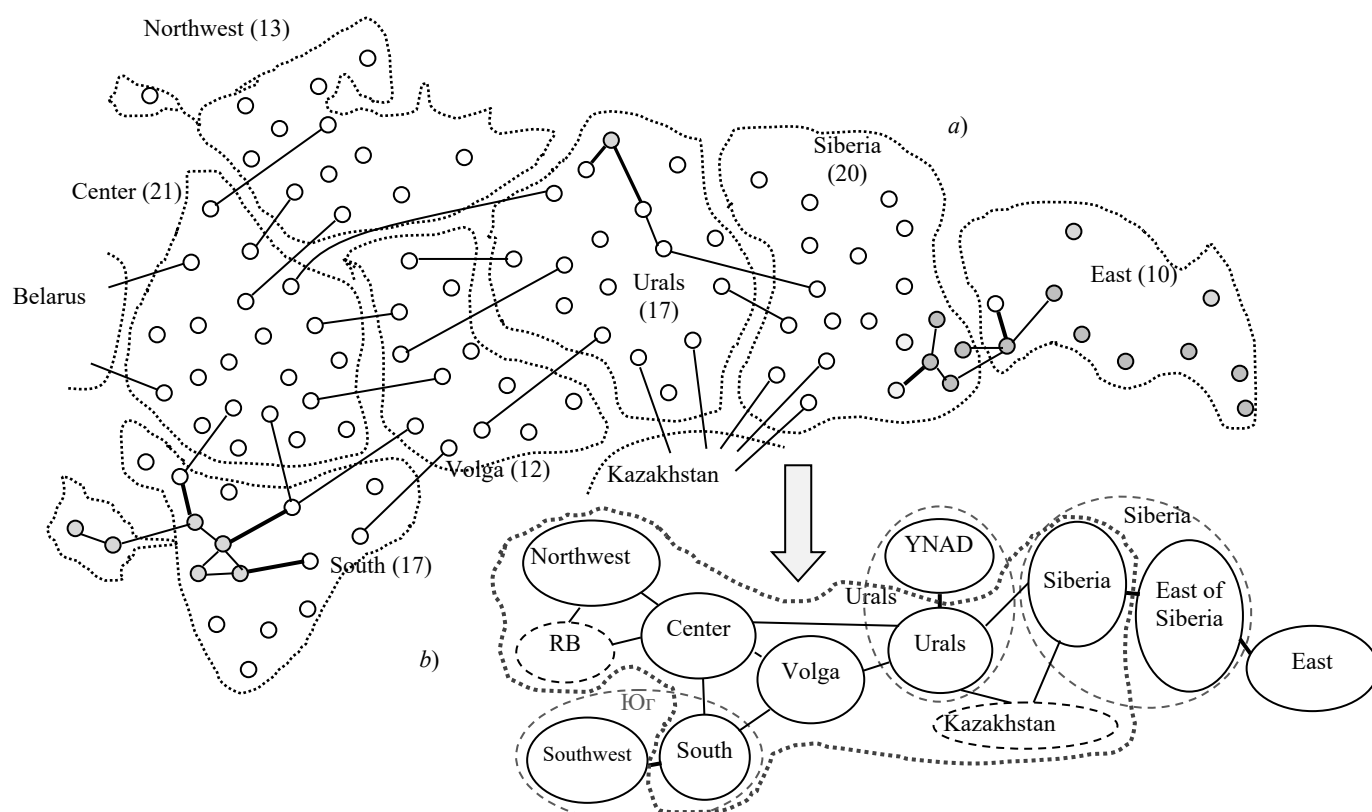


Fig. 1. Model of the calculation scheme of UES of Russia (a) and its equivalent for the problem of justification of redundancy means (b).

According to the values of probabilistic indicators of BR, in accordance with the theory of their obtaining, it is possible to distinguish territorial zones of practically the same reliability and thus to unite them into one zone. The capacity of the links within them practically does not affect the redistribution of capacity deficits. Such territorial zones, in accordance with the results of Appendix 5 of the UPS SPD work are shown in Fig. 1, b). In this case, the calculation scheme of 110 territorial zones is reduced to 10, not counting the energy systems of Belarus and Kazakhstan. In fact, according to the BRI it is still possible to combine the territorial zones UPS of the North-West, Center, Volga and part UPS of the South, Urals and Siberia into one zone, highlighted in Fig. 1, b) by a small dotted line. Then the scheme will be reduced to 5 territorial zones. The latter is not quite correct due to the fact that the reporting materials of SOs and FGCs, especially those typical for the BR tasks, are prepared in the context of UPS.

As a matter of fact, this is the essence of the proposed hierarchical approach of transforming the model UPS of Russia calculation scheme for solving the problem of substantiating the required generating capacity. The scheme model used for solving the assessment of BRI on the basis analysis of the obtained results can be transformed into a simpler model for solving the problem of substantiating the requirements for the required generating capacity of power plants under the conditions of balance reliability. Based on Fig. 1, it is clear that in order to substantiate the required generating capacity in the problematic territorial zones UPS of the East, Siberia and the South, it is enough to identify these reliability zones and for them to carry out more detailed calculations to justify the required generating capacity from the standpoint of ensuring the normative indicator of BR.

4 Conclusion

The task of justification of the required generating capacity (capacity reserve) involves multiple estimation of the BRI under different variants of the generating capacity composition. For the model calculation scheme UPS of Russia (110 territorial zones) developed by SO UPS the solution of the problem is associated with significant difficulties, both of informational and computational nature, and of methodological nature related to the management decision-making process. As applied to the solution of the problem justification of the required capacity on the basis analysis BRI of the initial version the calculation model scheme, the possibilities of reducing the number of territorial zones UPS calculation model to reasonable limits are shown, which will lead to a significant reduction in the time of obtaining the result.

The article was prepared within the framework of the R&D "Scientific bases of energy transition research at the regional level" (№124013000621-4).

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