

Contemporary concepts of power system regime optimization

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Резюме - The theoretical foundations of optimization of regimes of electric power systems and advanced features of solving the basic problems of regime

Термины – optimization mode, the electricity market, the energy balance, optimization problem, the hierarchy of decision

I. INTRODUCTION

Tasks of optimization of the regimes of power systems was under consideration of many authors, scientific and engineering organizations of USSR. The scientific basis of it's solution, the production programs and big experience were obtained. These achievement were widely known in our country and abroad and were recognized as progressive development, it's role in power engineering is known. [1]. This article observes a number of issues that can be useful for the development of these tasks within contemporarily conditions of Russian energy production.

Only the tasks for regime optimization that influence on energy balance of power and power energy are considered. If to take a number of indexes that characterize the efficiency of the optimization in dynamics, then we will see unfortunate picture. For the period from 1990 all the indexes of efficiency got worse: averaged fuel expense on kW/h increased on 10 – 20%, losses in power networks increased in 1,5 -2 times, the efficiency of hydro resources decreased in times, the expenses on quality support on frequency and voltage, especially on conventional expenses – up to 100 %.

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A number of reasons lead to these results, the price-building laws («full expenses + profit»), aging of the equipment, but the optimization of the regime plays not the last role. This also shows that the market doesn't stimulate the optimization. The actuality of optimizing tasks is being defined by the state program of energy efficiency. If to increase the efficiency of optimization, then the degree of efficiency of energy objects will increase few percents and this is an enormous economy.

II. OBJECTIVES OPTIMIZATION ELECTRIC SYSTEM

A. Types tasks

This article discusses only the problem of optimization modes that affect the energy balance of power and electricity. Among them: the composition of operating units at the stations (CHP, CEC, GES), the number of operating units at the stations, the load distribution between the units, stations, systems, treatment and the scheme of the network, the uncertainty of flow and the management regime of the reservoir hydropower station (daily, annual and long-term regulation), the definition of power flows and power in the ECO and the EEC, the use of water resources, hydropower plants. These tasks are important for all stages of the management of energy enterprises - from operational to promising.

B. The effectiveness of solutions sensitive tasks

The reduction of the efficiency of optimization tasks is basically due to two factors: the non-optimal choice of solution and solutions without considering the nonlinearity of characteristics.

Consumables characteristics TPP B (P) have non-linearity without optimization of the regime and aggregates approximately 7 ... 10%, and optimization of 3 ... 5%. Characteristics of the costs of the system and (P) without optimization of the nonlinearity are - 10%, and

optimization - 5%. The performance efficiency of HPS have nonlinearity without optimizing the composition and mode of aggregates about 5%, and the optimization of 3%. The characteristics of power losses ΔP and electricity $\Delta \Theta$ in electrical networks for different purposes and voltage class are nonlinearity, respectively 7% and 3%. The characteristics of power losses $\Delta \Theta$ with suboptimal mode hydroelectric reservoir.

Accounting for nonlinear properties of the solution of these problems requires the use of methods of nonlinear and dynamic programming.

Maximum error of switching off non-linearity characteristics equal to the sum of limiting errors of arguments the total assessment regime, such as AND, and is in various problems of 10 - 30%. This corresponds to the data and reduce the effectiveness of which are at the beginning of the report. Zones are determined by the points and the territorial boundaries of the flow range from maximum to minimum power flows on transmission lines at certain intervals of time. Internally, the structural units are those elements that significantly affect the distribution of flows - power plants, major substations, network companies, network wholesale market. And they can be independent entities. This system allows you to analyze the state of power system and interaction of its elements. Zones of electricity may change over time.

C. Ways to improve the efficiency of solving optimization

The management of energy enterprises is constantly receiving enough attention, but significant improvements of technical - economic performance of energy companies that does not and what's more they continue to deteriorate. Without analyzing all the causes of this situation and not dwelling on the criticism made now management regimes, would like to speak on some of the principles of decision sensitive tasks, which may change this situation.

The first way is to use appropriate mathematical optimization methods. This requires the

creation of mathematical models and algorithms [5]. The results of calculations of some problems. If the power plant to select the optimal number of operating units using appropriate optimization methods, the efficiency of the station will increase by 3 - 5% (proposed to use the direct search method options), if the optimization mode of use of water reservoirs during different water content - 5 - 10% (encouraged to use the gradient method and the method of Lagrange multipliers). If optimally distribute the load on the system, the burnout of fuel decreases by - 2 - 5% (proposed to use complex methods of nonlinear programming) [1]. Optimal electrical networks - leads to a reduction of electricity losses to 1 - 5%.

Optimality depends on many factors, but primarily on the number of possible options. For example, if EPS - deficient, it forced the regime and optimal yields nothing, if - the excess of electricity, there may be alternatives. If the station has great limitations on working capacity, it will be the same picture.

ECO Siberia actors of the electricity market are the 11 regional systems. Of these, 9 - deficient in energy and power, three Irkutsk, Krasnoyarsk and Khakassia (before the accident at Sayan - Shushenskaya GES) - redundant. These three EES - sellers. They determined the price for sale of electricity on the wholesale market area ECO Siberia and outflows of electricity to other ECO. What a we know, the optimization of the units at HPS is not made, optimizing usage of water resources is unclear on the criteria and schemes. Hence - the order for sale price significantly overstated, and buyers from this are commercial damage. This contributes to the principle of marginal pricing in the market ECO Siberia. Cost of hydroelectric power is about the same, and the costs of transport vary considerably.

Another example - the cost of transport of electricity on the grid ECO evaluated on network tariffs. Network rate is primarily dependent on the value of fixed assets and their condition. Distribution losses are small compared with the conventional - fixed costs,

and optimize networks to carry out the regime is not interesting.

Educated GC (generation companies) have a statutory power characteristics, but the optimum composition of the aggregates also did not choose.

If you do not change the attitude to "optimize", then to increase the efficiency of energy facilities can not.

III. PROCESS OPTIMIZATION IN POWER

A. *The real question*

How to build the optimization process? We can do it based on production opportunities or market view. The progressive equipment and efficient technology is used in power engineering. Massive intellectual and financial means are invested in it. But no investor will donate the money for production that he will not use efficiently later on. The program for the energy development is accepted and the issue of the investment efficiency is the major one in it's realization. Therefore, the only way is – from the efficient usage of the technical opportunities of the production to commercial results.

Nowadays the opposite principle is used in the power energy market – from the commercial results to production. This leads to constant reduction of the operational efficiency of power plants. The existing principle led to major reduction of the professional level of technical stuff, to technical illiteracy, to the absence of the mechanisms that will stimulate the efficiency of the technology usage, optimization principles and so on. The vivid example is technogenic catastrophe (and not the accident!) on Sayano-Shushenskaya HPP. And there are lots of examples like this in our power engineering.

B. *Критерий оптимизации*

Using the principle “from the efficient usage of the technical opportunities of the production to commercial results ”one of the basic issues is which index or indexes to use as a criteria of the evaluation? For the commercial entity for large scale goods and manufactures goods – that will be. For power energy profit can not be the criteria index. Power energy is a life

necessity for the society, it's role predetermines economy development, political position of the state, social position of people. Apart from that the power energy market in Russia is either monopoly (retail market on the regional level) or oligopoly (wholesale market). Oligopoly is a market with minimum features of competition, usually in collusion of large producers. In all the wholesale markets the quantity of sellers is less than 10 – this is heavy oligopoly. And even though we can not bring any examples, the collusion is a fact that doesn't require any. The characteristics of customer demand is not elastic. In these conditions even the market of pure competition (the more so oligopoly or monopoly) doesn't have regulation opportunities and everything is defined by the “game rules” which are established by the market organizers.

For example, Siberian UPS doesn't have the competition. Only the power of HPP is being sold and the prices according to accepted principle for it's formation by the requests are hold up compared to primary costs of HPP. So HPP gets huge profit. Therefore sellers have no interest in optimizing the regimes for HPP hydro resources usage. There have been the case of escape due to wrong regime of water drawdown.

So the criteria can be only expenses on production of power and energy and the rules of the market should have only additional, correcting not the main role.

The market of power energy has it's criteria and there should be the hierarchy of the criteria in order to agree the technological and market efficiency. The following hierarchy of the optimization criteria can be used:

1. Higher level – optimization of internal expenses of the power entities– «optimization by the expenses». That is the minimization of the expenses for production taking the commercial range of goods into account (regime parameters by power and energy and services [my book]), that completely agrees with the typological strategy of business, competition and marketing.

2. Next level – optimal usage of power and energy of power plants on the power market («commercial optimization») by the

criteria of minimum of sale price of the goods and the sale price is based on optimal expenses of production.

3. Finally – optimization of the power plant regime on the market for the sake of society) – discounts/markup, bonuses, penalties.

The criteria discussed above have certain are of application, it's interconnected and interdependent. The connection is a hierarchy. Therefore, if to come from the principle “from effective usage of technical production to commercial results”, then the hierarchy has the following structure: minimizing of the expenses for production for the whole technological cycle, minimization of expenses for transport, minimizing the sale price, setting the rules for sale and purchase when developing the fiscal relationship.

C. A hierarchy of optimization in space and time

Main problems for optimization appear on first two levels. Creation of independent GC and Network companies (NC) breaks the connection between the production and transport of power energy and power, and it's not commercial but technological. There have been major changes of structure links in the system and we have to mind it. Local zones of power supply and the necessity to account lots of limitations on optimization have appeared. And the models of optimization have to account new structure properties of the system. But the same hierarchy of criteria has to be applied for local borders of structure or technological links.

Power energy us produced and consumed on electronic level and the interference in this connection by business borders breaks the fundamental laws of electrical engineering – laws of Ohm and Kirchhoff. This for sure reduces the social efficiency of optimization. In the operator control of “System Operator” the decisions are taken by the rules, which are defined by the operator control for power market and not the System Operator. It is supposed that this order infringes the purpose of power energy and it's social value. In our opinion System Operator has to provide the economy of production and transport of power

energy in the whole technological circle. We're not going to give the recommendations how to realize it. These are organizational decisions but there is no other way for rebirth of optimization. Mind that CDM of USSR UES was responsible for the economy of the [1] and it gave great results.

Specific problems of optimization are connected with the hierarchy of regime management. The changes happened in all the types of hierarchy. New space hierarchy brought to the breaking down of the system on local zones. It's known that the economy principle of synergy is broken – « $2+2=5$ ». That's why American practice has Pools. One may think that to make regional energy balances of power and energy while integrating it's operation is profitable. All the fundamental books on power engineering prove the profitability of unified systems.

Major changes happened in the hierarchy by the time management of regimes. What and how things are done for the period of month, year, few years is not clear. Long term agreements on power market do not exist, and on regional level with full or partial freedom they do – and they are done using different methodic. How do GC, NC, JSC Energo make their yearly plans? Sales company require data from customers on their purchases one year ahead, but without checking it and without any methodic. Of course there should be some hierarchy developed by the time for the technological objects and for market relationship. It will be different but it's disagreement leads to reduction of the efficiency of energy management.

The dispatching practice of many years showed that there are optimal terms that are defined by the content of the technological tasks. To assemble the equipment content – it's a week or a month, because the equipment load can be optimized and start expenses can be accounted. TO define the power regimes of HPP – that is a day or a month, which is connected with integral limits by outflow. For the load distribution – it's hour and a day. The increase of duration breaks the cycle of technological management, and decrease – it's efficiency. These obvious statements go against

commercial tasks, mainly by the evaluation of the profit. Different periods were taken on a free power market “one day ahead”- from few days to few hours and the efficiency of solving of technological management tasks was not analyzed. It's impossible to optimally manage the regimes of stations and systems if the management cycle does not account the process of technological management and its duration. On the level of optimization by the criteria of minimum expenses this issue should be solved with a basis, what have always been done in past.

D. Background information in the optimization mode

Initial information for the tasks solution is the forecast of load and consumption graphs, characteristics of objects, that connect the criteria and independent variables, the properties of the system structure that influence on math model, limits (technical, business, commercial). The task solution end by getting the discreet price characteristic of production by the whole nomenclature of goods and services. Now a major attention is drawn to the power and energy forecasts. Commercial principles are based on full exact requests on purchases for unfortunately we can not store the energy. But in reality the consumption is not defined exactly. And asking the exact forecast is absurd. But the rules of market are so that for each error in forecast the customer pays the penalty.

There are some unavoidable errors. Our research on Western Siberian railway show that occasional strand of load in winter time is 10 - 15 % out of the whole. In the technological management cycle it gets neglected with the usage of automatic and dispatch means of management. In commercial cycle there is a penalty system, but it can not neglect the inenarrable. Therefore, we need to develop special mathematical forecast methods, special models for calculation and for taking decisions. The existing order on the level of System operator lead to unproved tariff overcharge for the customers.

IV. FEATURES SOLUTIONS REGIME TASKS FOR LOOKING CALCULATIONS OF ENERGY

DEVELOPMENT

A. Forecast charts load

Separately there are the regime optimization tasks for perspective calculations for energy development. There was no need in load forecast (LF) for long term tasks of development of power system in USSR. This task appeared due to market relations in power energy and the necessity of solving investment, technical and commercial tasks all together. For that we need the energy balances, in which the regimes and expenses of generating and network companies will be reflected. Without the load graphics we can not do it.

The reliability of LF and energy balances have great importance for optimization. Forecast error can be obtained only by the model errors and additional expert remarks. These evaluations are very relative – this is taking the decision in the indefinite situation. We can only set the zone for forecast parameters change and get the alternative options for solutions in it..

Quantity evaluations of forecast error are obtained for all the power systems of Siberian UPS [3]. Lets see the results for Novosibirsk power system for different time periods and for LG and specific load parameters (maximum, minimum, middle).

All calculations allow to make conclusion that we can develop formal math models to forecast max, min and middle load based on statistical information and to use it with extrapolation on five year period, but LG have the error from 30 to 100% and more by retrospective data for 5 years. Forecast error will be certainly big. Even for five years, limited error is 10 - 25%. More exact is the forecast for power energy production – middle power, its error is round 10%.

B. Some features of the solution long-term problems of energy

Occasional factors influence extreme values of LG less then other hour values. Many occasional factors influence the process of load change (LG configuration) , that's why its variability is much higher then extreme values. The errors of specific load for 5 years do not exceed 20%, and hourly load up tp 30 -50%. The model for the process of LG depends on

the structure of power consumption structure. The structure is typical in the given example: the production is round 60%, and public living needs and railway transport is approximately 40% [3]. We have not managed to model the good process of load change in time. Approximately same results we have for other regional systems.

The commercial and economy indexes can be calculated for 5 years and more not as a forecast values, but approximate assumptions. This requires special "optimization". For perspective calculations it's using the energy balances, by it's average power and unit costs forecast using the special model of EES. This method is developed and the calculations for Siberian UPS are done with it's help [4].

V. CONCLUSION

The problem of optimizing the regimes EES relevant. It would be useful to consider it as a real way of energy saving. Leading institution developing this problem could be Energy Systems Institute. L.A. Melentiev SB RAS, which has enormous scientific potential in this regard.

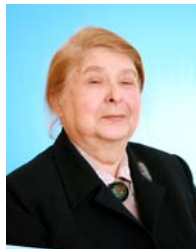
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VI. BIOGRAPHY



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