# Specifics of the calculation of the regimes and parameters of system-building power lines of the unified power system

A.G. Rusina

***Abstract* - The article considers one task of the calculation of the regimes of power lines and general provisions on net modeling accounting the conditions of the power market**

***Index Terms* – power system, simulation, equivalenting**

## I. INTRODUCTION

The basis of the modeling has the conditions with the general features: system approach as the principal for defining of the structure of the system of the object, borders, nodes and connections under consideration; target principle of the calculation for the certain task; usage of the power balance which shows all the structure elements of the system; usage of the power losses for defining the parameters of the equivalent circuit of the system. This principle is not new but is rational for many tasks and is methodologically worked out for the specific tasks.

## II. STRUCTURE UNITS OF THE POWER SYSTEM

### *A. Structure units of the System Plants (SP)*

Structure units we will call the zones of power supply. It's borders depend on specific task. It can be the borders of business activity, e.g. in the tasks of settlements between SP on transport services. It can be defined by the units of current separation or flow distribution if we consider the power balance or calculate intrinsic losses in power system and so on.

### *B. Power system or zones of power supply*

that are defined by the points and area borders of the flow distribution are in the limits from maximum to minimum power flow for the power line on the sertain intervals of time.

Inside the system the structure units are the elements which sufficiently influence on flow distribution – power stations, large substations, net plants, nets of the wholesale market. It can be independent objects. Such system allows to analyze the state of power system and interaction of it's elements. Zones of power supply can vary in time.

### *C. System, representing the power balances of energy and power*

The connections between the tasks of calculation of the power circuit and power balances usually are not taken into account. These are two independent tasks, which are connected in general, but are solved without taking this connection into account. The connection is taken into account only for the task of the generator power  This statement has no ground. To connect these tasks we have to consider the whole system and it's stations and to equivalent the power circuit by the elements of the balance. Specially while considering the 10-20 year perspective when the general information for major technical decision taking are the power balances.

The components of the balance can be different and they define the internal structure of the circuit for the system. Expense side of the power balance can be represented by the tariff groups of consumers, by the types of consumption, by territory and so on.

### *D. The task of equivalenting of power circuit taking into account the commodity barter in the power market between the sellers (generating elements) and purchasers (consumers)*

The commodity flow of power and energy are taken into account. It lays under the equivalent power system. Commodity flow can be forced,

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optimal and occasional. The border points of the system in this case are defined by the principle of the commercial connections of the market objects. It characterizes by the production or consumption of the power, zero flow, power transit, and these requirements should be accounted while making the power circuit.

The system of the commercial connections between objects of the market can lead to the change of borders of business belonging of power line. The new parameter appears when making commercial equivalent – price. The nature of the price and power parameters do not coincide. Huge influence on borders is shown through network tariffs which are connected with expense on the power transportation. Besides, the price can be to basis for forced flow distribution. The price makes the value of the elements of flow distribution weaker or stronger. It can be constant or variable and influence on the parameters of the system equivalent circuit and it already requires major changes of the equivalemt curcuit.

The borders of the zones of power supply do not match by different reasons.

*E. Definition of the equivalent nods*

Equivalenting is almost always used for the circuit under consideration. For defining the equivalemt nods we need to apply the principle of concentration of generation, load, parameters of the equivalent circuit. To evaluate the picture of the balances of power energy when concentrating we need to take into account the dynamics of all the parameters of the regime that influence the power energy.

Necessity of the integral presentation of the power system regime for specific period T is connected with process forecasting for voltage variation, reacting power, change of the coefficients of transformation for transformer and autotransformets, power circuit/ This causes big difficulties, that rarely can be solved. Apart form that, the processes are interconnected and we need to take this correlation into account. Big problems appear because of the necessity to have the processes of the load variation in the concentrated system nods, which depend on many occasional and undefined factors. Finally, the shift from the power to energy production requires the usage of the special circuit and all the known circuits are approximate.

Forecasting methods are different for different factors. If to take the task of calculation of the normal regime of the system, then the main roles are given to the power in the nods of the generation and load. By the zone of power supply we need to have the loads in the nods for the period. The method for application of rang models for this task is given in [3, 4].

If the balance of power energy is the base for defining the parameters of the equivalent circuit, then the usage of the specific method of transition from the balance of the power to the balance of the energy is required.

*F. Finding the parameters of the equivalent curcuit*

The methods of equivalenting of power systems by all the network parameters are well developed in power engineering. If power equivalenting is based on momentary parameters and reflects the static state of the system, then while taking long periods into consideration, there is a need to account to dynamic properties of the system and, therefore it's necessary to have the characteristics of the processes of the alteration of the parameters of the regime in time and the evaluation of it's conjoint influence on the decisions being taken. In this case it's efficient to use the losses of power or energy as the indicator of the dynamics internal processes because they functionally depend on the total of the processes of current, power, energy and other parameters variation, for the certain time period.

## III. THE TASK OF PERSPECTIVE DEVELOPMENT OF POWER PRODUCTION

*A. Data acquisition problems*

The methods of power systems parameters and operating conditions calculation for various

purposes are well developed and described in literature. They present the basis for solving problems of prospective power engineering development under electric power market conditions. At the same time they are not completely applicable. Several proposals for their development are presented in the paper.

Changes in data acquisition technologies are the feature of new conditions which affects power systems models and their calculation methods, namely:

- Alternative variants of projects consideration. Alternative variants consideration is one of the conventional principles of taking future uncertainty into account. The number of the variants and their calculation method depends on data exhaustiveness and reliability;
- Various power grid parameters designing, as they use various data, and its reliability affects parameters choice;
- Mathematical models, as they are affected by the data errors;
- Adaptive calculations, etc.

A number of proposals for taking data into account using the example of Siberian Interconnected Power System will be reviewed further.

Local power companies are the main participants of electric power wholesale market. They provide data for power systems operating conditions and parameters calculation. At present, there are no common rules for its formation and each market participant provides data depending on its interests and using its own methods. This leads to low data reliability and accuracy. Especially many difficulties arise at solving prospective development problems. The calculations made for Siberian IPS backbone power grids development analysis show that even for one-year perspective the initial data models errors amount approximately 10% and forecast errors amounts 30-200% [1]. Low data reliability is resulted from industrial objects commissioning schedule violations, wrong regional electrical power consumption growth estimation and urge towards getting financial support from the federal budget. Such situation is very typical and it is caused by economical instability in the state [in Russia]. It is impossible to make justified engineering solutions based on such initial data of highly concentrated regional power systems' nodes.

Data errors can be classified by the following types: marginal, probabilistic, root-mean-square and mean modulus. For five-year forecasts they can be calculated using inverse verification method based on the statistical yearbooks. The main decisions on technical problems are done during the five-year period.

For making engineering solutions different operating condition parameters and types of errors are used. For power grid parameters choice (scheme, power line wires cross section and voltage choice) maximal, minimal and average load forecasts are used. Main attention is usually focused on maximal errors of these values. A number of alternative variants of the calculations are produced. The choice of variants number and their evaluation is made using expert methods as it adopted in common practice. If probabilistic or root-mean-square errors are used, mathematical expectations of load can be founded and one can make probabilistic, not deterministic power flow distribution calculations.

When making perspective calculations it is necessary to refine solutions adaptively. In strategic management the following periodicity of refinement is recommended: five-year plans are refined annually, ten-year plans are refined at least once in three years, twenty-year plans are refined every five years. Use of probabilistic errors' marginal meanings is appropriate in this case.

For electrical energy and power purchasing/selling prices calculation use of average power forecasts and their root-mean-square or marginal probabilistic errors and load mathematical expectations is appropriate. In some papers use of load curves forecasts (LC) it is proposed [Voropay], but our calculations show that LC forecast errors amount over 30% even with one-year feed forward. In our opinion such information cannot be used for commercial calculations.

Calculation informational model which takes into account data exhaustiveness and reliability include following blocks: - development of initial data forecast models and methods of data reduction to the present task calculation scheme;- choice of required data for using it for specified purposes;- determination of necessary data for alternative project variants calculation. This model complicates all the calculation and its realization is possible in CAD systems (computer-aided design systems). There is no suitable CAD software for modern designing conditions. These CADs strongly differ from the CADs which were used for designing in USSR. Using designing methods on the basis of initial data defined in grid nodes which are recommended now will certainly lead to wrong results.

*B. Power systems equivalenting peculiarities*

Power network calculation block is the most difficult part of power system calculation algorithms due to high network dimensionality, data acquisition problems and power systems operation optimization methods. Power systems calculations can be simplified by equivalenting network nodes and branches. Structural zones may present themselves concentrated nodes. Structural zones can be obtained: based on the system units, economic boundaries; based on IPS wholesale market price flows ; based on the IPS electrical energy balances. They are characterized by their operating condition parameters (power flow distribution, energy balances, currents and voltages). When making power system equivalent circuit with concentrated nodes and its reduction internal operating properties of the nodes must be taken into account.

Load active power losses can be quite easily transformed into resistance and reactance of the grid. Knowing $P,Q,U,\Delta P$ values one can approximately calculate impedances and relationship between resistances and power R(P). We have t o underline that these are not losses defined by the Joul- Lents, but the regime losses of electric zone. The characteristics $\Delta P(P)$ can be built after making the calculation experiment when varying the regime values that influence on losses [2, 4]. Often by the results of the calculation we can get the regressive dependency $\Delta P = a + bP^n$ and get the forecast of the losses using it. The data for real objects shows that the maximum error doesn't exceed 10%. Therefore, same errer will be for the resistance of the net.

Using the perspective energy balances for unified power system $Э$ and the losses of energy through the net $\Delta Э$ we can define the equivalent active resistance

$$R_{экв} = \frac{\Delta Э}{Э^2} * const, \qquad (1)$$

where $const = U^2 * t * \cos^2 \varphi$.

The method of equivalenting by the losses is perspective for solving lots of tasks. The important thing is that this approach doesn't need the dynamic characteristics for the loads in the nods of the network and the usage of some averaged circuit is an important factor.

The calculations on existing examples were done for all the tasks above/ Below we have an example of the equivalent circuit of calculation for the Unified Power System (pic. 1)

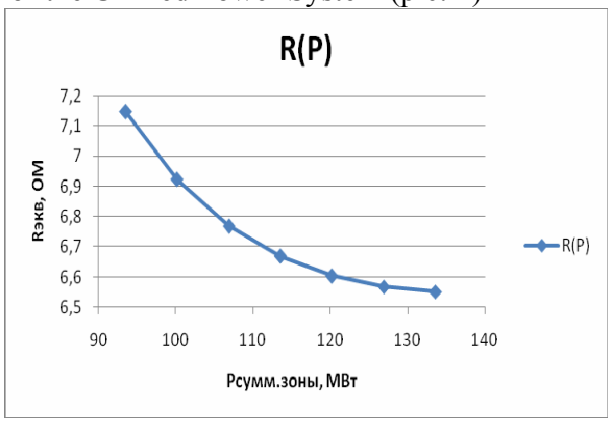
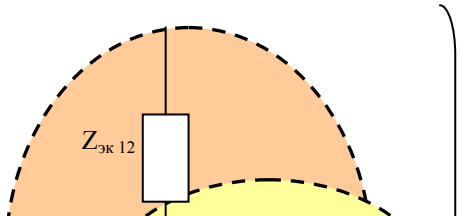



Fig.1. Example of the *characteristics of active resistivity* and power of the load for Tyvyn power system

The borders of the system – is the territorial borders of UPS and it's grid. Internal structure of the wholesale market of UPS is represented by the regional systems, major consumers, backbone power system. The equivalenting of the structure units was given in the example on losses for the averaged monthly power in the limits of it's variation and by the losses of the



power for the maximum regime. The electrical equivalenting was done for the connection lines between the structure units. For the power lines of any purpose the equivalenting of the system should be targeted. The classical rules of equivalenting with the usage of the electronic laws will have additional conditions. Without proved and correct equivalenting no technical task can be solved. But more error will be when solving economical or commercial task. For the wholesale market the usage of well known principles of electric equivalenting is not the only way.

The task under consideration are illustrated in the pic. 2. All the conditions on definition of the zone borders of power supply and definition of the principles for equivalenting of it's borders are different. On pic 1 you can see in the schematics for the nod (i) the three options of the zone borders (j).Equivalent nods of type (i) are connected by the power network. All the total is the equivalent network circuit.

Fig. 2. The variation of the borders of power supply zones.

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## IV. MODELING OF THE CALCULATION TASKS FOR THE REGIMES OF POWER SYSTEM FOR PERSPECTIVE SOLUTIONS

For the future perspective of more then 5 years we usually can not apply the exact methods of regime calculations because of the absence of the necessary information, therefore different simplified methods are used. It allows to get preliminary solutions for the tasks for the development of the system on early stages prior to the technical projecting without having full information. Different ways of simplified calculations can be used. Four simplified models are described below.

*Model first (M1).* Major part of perspective calculations is connected with the energetic balances of power and energy, and it allows to develop the simplified model that includes all the structure elements of power system. The circuit of power system is represented as hypothetic electric circuit allowing to interconnect the energy balances and power flow in the network. Energy balances compile in all the levels of the hierarchy by the time and

it's important to know how it influence on production capability of the UPS. The model includes the equals of steady conditions and usual circuit for calculations. (M0), which are used for projecting**.** This is how the logics of UPS circuit building is used. This model allows to receive quality evaluations and to answer the issue on the necessity of the development of the system.

For long-term perspective the energy balances of power and energy have few modifications. For each modification we can give the hypothetical network where it's parameters will be connected with the loss of power.

*Model two (M2)* – is equivalenting the system with the account of the variability of it's regime parameters by the nods and branches.. Equivalenting - is one of the methods of simplification of the calculations. Model M2 is developed based on the separation of the circuit on the developing and non-developing parts. Last is equivalended by the loss of the power energy.

*The model of business-production type (M3)*, in which the system is represented by the equivalent circuit in the borders of the business objects and it's commercial relations. For this model it's important to have another one – the model of the commercial relations on the power energy market. The equivalent circuit can be drawn up by the losses of power and energy.

*Geometrical parameters Model (M4).* For this type the parameters of the equivalent circuit can be defined by the length of power line and specific active and reactive resistivity.

All the models should give address calculations of the power flow. Without it it's impossible to solve investment and commercial issues.

*Circuit of Siberian UPS with zone equivalenting the losses of power.*

Losses of power was defined for the structure units of Siberian UPS with the account of regime parameters. The circuit used for balance calculation has more then 1000 nods and in regional energy balances up to 100. The equivalent circuit has by an order less nods. It has all the parts (nods) defined, which are accounted in the energy balances.

The characteristics of the power losses are obtained with the account of the changed of the summary power of the load of UPS and separate regional systems, regimes of the electric interconnections between zones. The electric equivalenting was used in separate parts of the circuit, the class of the power was accounted , and separately were accounted the losses for power line, that connects the zones. The program of calculation of the flows and losses was used for ring connections. The circuit obtained is shown on the pic. 3. It can be used as the initial option for the construction of the hypothetic circuit.

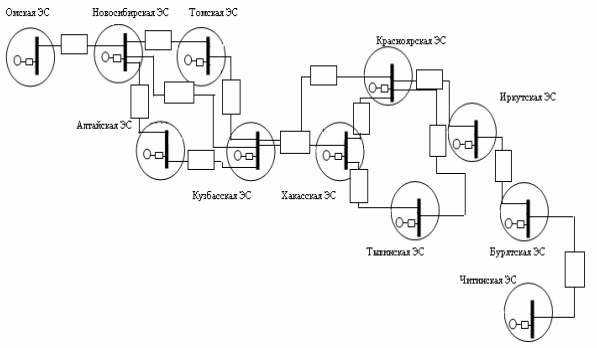


Fig. 3. Equivalent circuit of the Siberian UPS.

## V. CONCLUSIONS

The method of perspective calculations of the power lines development is not completely defined yet. But existing methods already have many disadvantages. The suggestions of this article can be useful for it's development.

The correction of the offered suggestions is proves by the calculations on real data of Siberian UPS.

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## VI. BIOGRAPHIES

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