SELF-OPTIMISATION OF MODES OF ELECTRO POWER SYSTEMS AS DISPLAY OF A PRINCIPLE OF THE LEAST ACTION

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Abstract. *In article the problem of creation of electric power systems (EPS) self-optimization conditions is investigated on the basis of a principle of the least action. Self-optimisation of systems is understood as their natural property automatically self- influenced in such method that at existing parameters and conditions they accept the most favourable statuses characterised by the minimum power consumption. As shown, regular acceptance of optimum decisions, according to this principle, forms in EPS the strategy of their development, reconstruction and operation, that on everyone optimizing step preconditions for the greatest possible decrease the losses of the electric power are pawned at its transportation.*

Keywords

electric power system, principle of the least action, non-homogeneity, self-optimization models.

Introduction

Normal statuses of an electro power system (EPS) differ among themselves in parameters of a mode and quantity of the electric power spent for its transfer from sources to consumers (electric power loss). Value of these losses except parameters of system, values of loadings and generation depends also on operating parameters - parameters of regulating devices (RD) (transformers, linear regulators, sources of jet capacity). At change of any parameters in EPS the new mode characterised in certain parameters of a mode and value of losses of the electric power is established. Not always presence of the existing mechanism of feedback thanks to which self-adjustability of system is carried out, can provide a mode, the optimal from the point of view of quality of the electric power and a minimum of its losses [1]. Thus, this property EPS as artificial system of cybernetic type [1] is necessary for improving.

As EPS by the nature are non-uniform this feature always leads to additional losses of the electric power at its transportation and distribution. To minimise these losses, that is to pass from natural status EPS to optimum, it is possible only compulsory by. There are two ways of the decision of this problem: reduction of heterogeneity EPS by purposeful change of its design data [2] and application of special technologies at operation EPS, streams of capacity allowing at the expense of redistribution in EPS to compensate negative influence of their heterogeneity [3, 4].

At realisation of noted approaches for a choice of the best variants with different degree of efficiency numerous methods of linear and non-linear programming are used. Their general lack is that they give private decisions. In given article possibility of formation of conditions of self-optimisation of normal modes EPS on the basis of a principle of the least action (PLA) during designing, reconstruction and operation EPS is investigated.

Principle of the least action as a method of optimisation of difficult systems

Self-optimisation of systems is understood as their natural property automatically self- influenced in such method that at existing parameters and conditions they accept the most favourable statuses characterised by the minimum power consumption. Transition of system from one status in another occurs according to a principle of the least action, which can be formulated as follows [5]. After a deviation from an optimum status of the functioning caused by external or internal indignations, in system there is a counter, opposite directed action, that is counteraction which tries to result system in an optimum status. Hence, for any system during any moment of its existence the qualitative optimum which depth is defined by degree of ideality of system is norm.

PLA predetermines an optimum of functioning of any system, and also a direction of development that conducts to increase of degree of its ideality. For natural systems display of the given phenomenon is obvious and unlimited. In artificial systems PLA it is shown it is mediated. Under the influence of an objective reality the person can accelerate or slow down only system development, but its direction is always directed to an optimum. Delay of development of artificial system, its maintenance in a static status causes in due course deterioration of its technical and economic indicators and, as a result, can end with impossibility of performance of the functions assigned to it. On the other hand, assistance to system development in a natural direction provides improvement of technical and economic indicators and approach to its ideal status [5].

For EPS a characteristic sign for an estimation of its affinity to an ideal status are losses of the electric power during its manufacture, transportation and distribution. At achievement of certain value operation EPS, and then technically impossible its functioning becomes by them in an increase direction at first economically unprofitable. For development EPS in a direction of reduction of losses of the electric power in it, it is necessary to spend a complex of the technical and organizational actions providing approach, technical restrictions, to economically ideal status how much allow.

PLA has found the application for the description of processes of electrodynamics, electromagnetic, thermal character, etc. [5]. In the given work application PLA concerning development EPS for the purpose of maintenance of conditions for their self-organising, or self-optimisation of their functioning according to criterion of an optimality - losses of active capacity and the electric power (further, for reduction, loss) is considered.

Transferring of laws of any systems on an electro power system allows to assert, that at any moment functioning for current set of parameters of system and independent parameters of a mode it is in an optimum status from the point of view of electric power losses, but depth of the given optimum is predetermined by degree of ideality of the system. Thus, assistance to natural development EPS, that is to increase of degree of its ideality, allows, thanks to self-optimisation mechanisms, to provide relative decrease in losses of the electric power irrespective of its loading. It is essential advantage of the given approach compared with classical optimisation.

Increase of degree of ideality EPS is provided with its development in two directions: by change of design data and at the expense of system saturation by negative feedback. Both directions are associated for maintenance of the maximum system effect should be considered in a complex.

To reveal a physical essence of optimisation of design data EPS during their designing and reconstruction, and also to find out essence of realisation of feedback in EPS, it is necessary to establish original causes of a deviation of statuses of system from a global optimum by the set criterion of an optimality and to state them an estimation.

Conditions of optimum current distributing in EPS

Normal modes EPS are optimum under condition of achievement of a minimum of criterion function in which quality total losses of active capacity in them are accepted, that is

$$\Pi = f(x,\ u,\ t) \to \min\,, \qquad (1)$$

$$x \in D_x,\ u \in D_u\,,$$

where **x** - parameters of mode EPS; **u** - parameters of regulating devices; $\mathbf{D}_x$, $\mathbf{D}_u$ - admissible areas of change of parameters **x** and **u**.

To problem (1) there corresponds a definition problem current distributing, providing a minimum of losses of active capacity EPS during each moment of time t in the presence of restrictions on values of currents in branches and generating sites. In [6] it is shown, that optimum current distributing it is defined:

$$\begin{bmatrix} \ \\ \ \end{bmatrix} = \begin{bmatrix} \ & 0 \\ 0 & \ \end{bmatrix} \begin{bmatrix} \ \\ \ \end{bmatrix} \qquad (2)$$

$$\mathbf{I} \in \mathbf{D}_I\,, \qquad , \qquad (3)$$

where $\mathbf{I}_{ao}$, $\mathbf{I}_{po}$ - vectors of optimum active and jet making currents in branches; $\mathbf{J}_a$, $\mathbf{J}_p$ - vectors of active and jet making central currents;   - a matrix of factors т current distributing settlement scheme EPS in which resistance of branches are presented only by their active components (r-equivalent circuit EPS); **M** ' - the matrix of connections of branches in sites in which the lines corresponding to balancing sites are deleted.

In practice economically ideal status of the system calculated on (2), lays, as a rule, out of admissible area **D**. On fig. 1 the example of such case is resulted. Input in admissible area is carried out as a result of movement of system from a point $x_э$ [$x_{1э}$, $x_{2э}$] with is minimum possible in the set conditions value of losses of capacity in a point x_o [x_{1o}, x_{2o}] with great value of losses. We will notice, that at use gradient methods computing process is under construction on the contrary - lifting, and descent from level of the big losses (a point of initial approach $x^{(0)}[x_1^{(0)}, x_2^{(0)}]$) on level with smaller losses is carried out not.

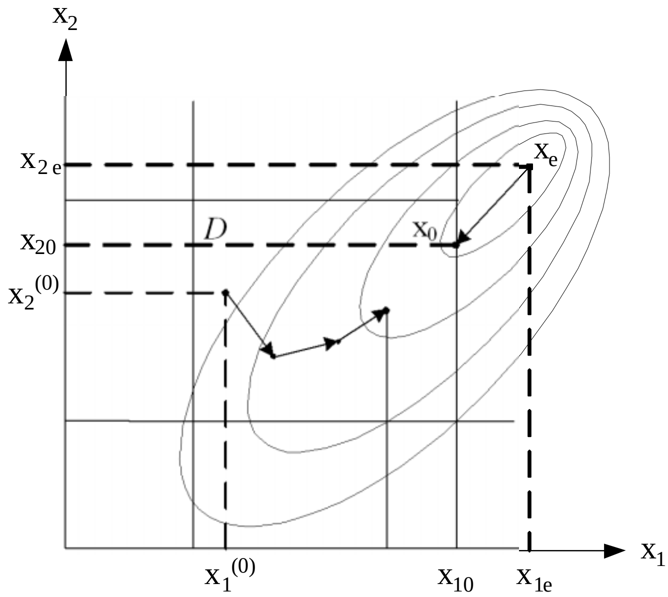

Fig. 1

Calculation current distributing and check of restrictions is thus spent as follows. Pays off current distributing on an r-equivalent circuit of a network without restrictions. Current **J**i received thus is compared with limiting $\underline{J}_i$ and $\overline{J}_i$. If it is broken i-e restriction the current in i-м the site is accepted equal limiting $\underline{J}_i$ or $\overline{J}_i$ and calculation repeats. Received thus not balance currents, for example $\Delta\mathbf{J}_i = \mathbf{J}_i - \overline{\mathbf{J}}_i$, it is carried between other generating sites under the r-scheme. Change of currents in branches unlike the previous causes increase in total losses of active capacity, but at such approach it is the least, that is responds PLA.

Thus, it is possible to draw conclusions, that for maintenance of a minimum of losses of active capacity in EPS active and jet currents in it should be distributed depending on active resistance of its elements. It responds a principle of the least action according to which transition of system from one status to another is carried out at the least power consumptions. Using PLA, it is possible to solve a number of problems of optimum control of modes EPS. We will show it on an example of problems of the most favourable distribution of loading between power stations and optimisation of streams of capacity and pressure in EPS.

Optimum distribution of loading between electric power sources.

Optimisation of modes EPS is spent by criterion of expenses for fuel (or the total expense of conditional fuel) at set for each moment of time to loading EPS

$$З_B = \int_0^T \sum_{i=1}^{s} B_i(P_i)ц_i dt \rightarrow \min, \qquad (4)$$

where $B_i(P_i)$ - expenses of conditional fuel on i-th power stations (account characteristics $B_i(P_i)$ are non-linear functions of active loadings of stations P_i); $ц_i$ - the price of ton of conditional fuel; s - quantity of optimised power stations in EPS.

By optimisation of active loadings of power plants restrictions on balance of active and jet loadings, loading of separate elements of system (transmission lines, transformers etc. are considered.), restrictions in the form of the equations of status EPS.

The fuel component of expenses electric power manufacture on i-th stations can be considered as cost of losses of the electric power in active resistance R_{ei} for the same time interval [7]. Then at the work of station with constant loading on an interval of time T it is possible to write down, that

$$З_{Ri} = П_i Tc = B_i(P_i)ц_i T\ , \tag{5}$$

where c - cost 1 kW/h electric power losses; $П_{Ri}$ - capacity losses on element R_{ei} from course P_i.

Considering, that

$$П_{Ri} = \frac{P_i^2}{U_i^2} \cdot R_{ei}\ , \tag{6}$$

we have

$$З_{Ri} = \frac{P_i^2}{U_i^2} \cdot R_{ei} Tc\ \ , \tag{7}$$

U_i - pressure on tyres i-th stations at loading P_i.

From (7) taking into account (5), we will receive values of such active resistance, cost of losses of the electric power on which is equivalent to expenses for electric power manufacture for each of stations:

$$R_{ei} = \frac{B_i\left(P_i\right)U_i^2 ц_i}{P_i^2 c}\ . \tag{8}$$

The economic characteristics of stations presented in such kind respond model of optimisation of mode EPS with use PLA. As follows from (8) resistance R_{ei} are non-linear functions of account characteristics and loadings of stations P_i.

Having placed sources of electric energy behind the resistance calculated on (8) (see fig. 2), it is possible to replace definition of total expenses on manufacture of the electric power by calculation current distributing in an equivalent circuit made only from active resistance of elements EPS and economic resistance of power plants. Calculation such current distributing does not cause complexities and can be executed any known method.

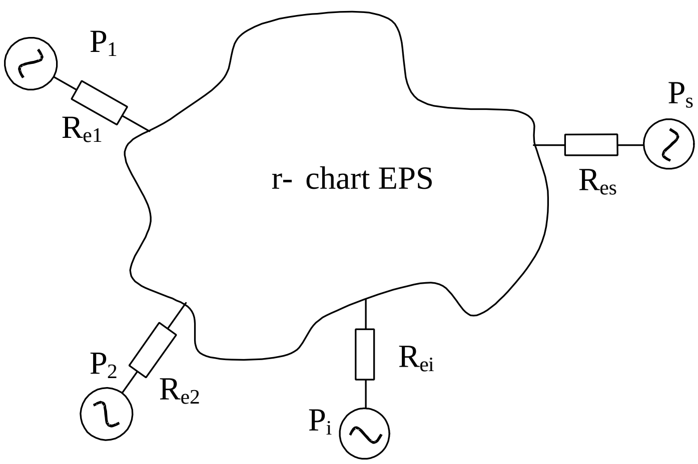

Fig. 2

Let’s show, that optimum mode EPS when as criterion of optimality total expenses for generating and transfer of active capacity in EPS are accepted in this case is provided. An optimisation problem we will formulate as follows:

$$П = \sum_{i=1}^{s} 3R_{ei} I_i^2 \rightarrow \min \tag{9}$$

Under conditions of balance of capacity in EPS

$$P_1 + P_2 + ... + P_s - P_{нс} - П_c = 0$$

and $P_{i\,min} \le P_i \le P_{i\,max}$, $i = \overline{1,s}$,

where $P_{нс}$ - total loading EPS; $П_c$ - total losses of active capacity in system.

Let's write down function Lagrange for (9):

$$L = \sum_{i=1}^{s} 3R_{эi}I_i^2 + \lambda\left(\sum_{i=1}^{s} P_i - P_{нс} - П_c\right).$$

After substitution of values of economic resistance from (8)

$$L = \sum_{i=1}^{s} B_i(P_i)\frac{ц_i}{c} + \lambda\left(\sum_{i=1}^{s} P_i - P_{нс} - П_c\right).$$

From conditions $\partial L / \partial P_i = 0,\ i = \overline{1,s}$ we will receive criterion of the optimal distribution of loading between power plants:

$$\frac{ц_i b_i}{1-\sigma_i} = idem,\ i = \overline{1,s}, \tag{10}$$

where $b_i = \partial B_i / \partial P_i$ - relative increases fuel expenses at stations; $\sigma_i = \partial П_c / \partial P_i$ - relative increases losses of active capacity in EPS.

That is, we come to known [8] conditions of optimum distribution of loading EPS between stations. Hence, calculation of established mode EPS where stations are presented by economic resistance R_{ei}, minimisation (4) method Lagrange or, for example, by a gradient method results besides to result, as.

Conclusions

1. Electro power systems as artificial systems are not optimum from the point of view of losses of the electric power during its manufacture, transportation and distribution. Their perfection is carried out in decision-making process on their development and reconstruction, and also during operation by optimum control of modes of their work. For working out of strategy of development, reconstruction and operation EPS on uniform methodological principles there can be used principle of the least action.

2. Process of optimum distribution of loading between energy sources in a power supply system probably to model with use of a principle of the least action. Thus the energy source in model is represented active resistance, cost of losses of the electric power in which is equalled to expenses on manufacture of the same quantity of the electric power. Definition of optimum loading of stations is reduced to calculation of established mode EPS on its r-equivalent circuit.

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