IMITATIAL MODELING OF CONDITION THE POWER BLOCK.

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ABSTRACT

The new method modeling of condition power block, based on joint application a method of modeling of casual events and method modeling of casual processes is developed.

The automated decision of some practical problems, as forecasting of the basic industrial parameters of power station as a whole and separate power units (PB) on various intervals of time (year, quarter, month), an estimation of probability of performance of a production schedule and necessary size of an operative reserve of power, the substantiation of requirements to deduced in cold reserve PB, provides an opportunity of adequate modeling conditions PB.

The basic method used at modeling of conditions энергооборудования, the method of statistical tests [1] is. Its essence consists that various conditions played by casual image on the basis functions of distribution. Modeling of conditions PB by analytical methods meets the serious difficulties caused by set of possible conditions and their complex interrelation. Statistical modeling can be organized both at a level of casual events, and at a level of casual processes. The initial information at modeling at a level of casual events (conditions PB) probabilities of display of these events, and result of calculation - casual sequence of events. The initial information at modeling at a level of casual processes functions of distribution of intervals between the same events and functions of distribution of duration of course of these events, and result of calculation - casual sequence of intervals between events. If modeled events are dependent, this dependence should reflect in modeling algorithm. The variety and interrelation of events, dynamics of change of the parameters describing events, in time not only create significant difficulties in algorithmization of real laws, but also cause, as a rule, private character of developed programs. Many noted difficulties it is possible to avoid if to use both of a method of modeling. At a level of casual events to model type of a condition, and at a level of casual processes - duration of a condition.

Statistical estimations of relative values of total duration of conditions and statistical functions of distribution of realizations of duration of conditions can calculated according to operating experience for a number of years of supervision. Their designations, accordingly, through $\delta\tau^*_{\Sigma,i}$ and $F^*(\tau_i)$ with i=$\overline{1,m_s}$, where m_s - number of conditions PB. As $\sum_{i=1}^{m_S}\delta\tau^*_{\Sigma,i}=1$, set $\delta\tau^*_{\Sigma,i}\geq 0$ with i=1, can be presented as a number of frequencies of conditions PB. For fixed though also any sequence of conditions (SC), we shall calculate an integrated number of distribution of total duration of conditions F($\delta\tau^*_{\Sigma,i}$).

Thus size $F_i(\delta\tau^*_{\Sigma,i})$ we shall define under the formula:

$$F_i(\delta\tau^*_{\Sigma}) = \sum_{j=1}^{i}\delta\tau^*_{\Sigma,j} \qquad (1)$$

$$F_1(\delta\tau^*_{\Sigma}) = \delta\tau^*_{\Sigma,1}$$

$$F_{m_S}(\delta\tau^*_{\Sigma}) = 1$$

As an example in table 1 estimations of relative duration of conditions PB 300MBт, working on gas-black oil fuel are resulted.

Table 1

Estimation of relative duration of conditions PB 300 MBт

N	Type conditions	Relative duration (%)	Number of distribution	Average duration conditions (h.)
1.	Working	73,9	0,739	543
2.	Emergency idle time	0,1	0,740	16
3.	Refusal at start-up	0,8	0,748	189
4.	Repeated refusal	0,5	0,753	48
5.	Sudden refusal	1,8	0,771	43
6.	Emergency application	4,9	0,820	103
7.	Cold reserve	9,3	0,913	185
8.	Average repair	2,7	0,940	2344
9.	Major overhaul	6,0	1,0	3362

Necessity of differentiation of emergency switching-off caused by their distinction and the requirement of adequacy of modeled process of change of conditions PB. The condition of emergency idle time (at system failures) characterizes switching-off PB basically influence of a power supply system, sudden refusal leads to necessity of use of a hot reserve, damages PB eliminated by switching-off PB under the emergency application, - to use of a cold reserve, refusals at start-up (from a condition of a cold reserve and emergency repair) - operative opportunities of translation PB from non-working conditions in working, repeated refusal (refusal on an interval less than 24 hour) - quality of the control of results after emergency repair.

On fig. 1 some histograms of duration of conditions are resulted. Character of distribution of duration of conditions, is defined numerous, but not always by equivalent factors.

The method of statistical tests with reference to modeling of conditions PB is realized in following sequence:

1. Random variable X with uniform distribution to interval [0,1] is modeled
2. We define an interval of some F($\delta\tau^*_\Sigma$) in which size X gets, by consecutive comparison of borders of intervals. If

$$F_{i-1}(\delta\tau^*_\Sigma) > x > F_i(\delta\tau^*_\Sigma) \tag{2}$$

That corresponds to size X i-th condition PB.

3. Again realization of random variable X is modeled;
4. The interval of function $F^*(\tau_i)$ in which size X gets is defined, i.e. the interval for which is satisfied a condition

$$F_{j-1}(\tau_i) > x > F^*_j(\tau_i) \tag{3}$$

5. Under the formula

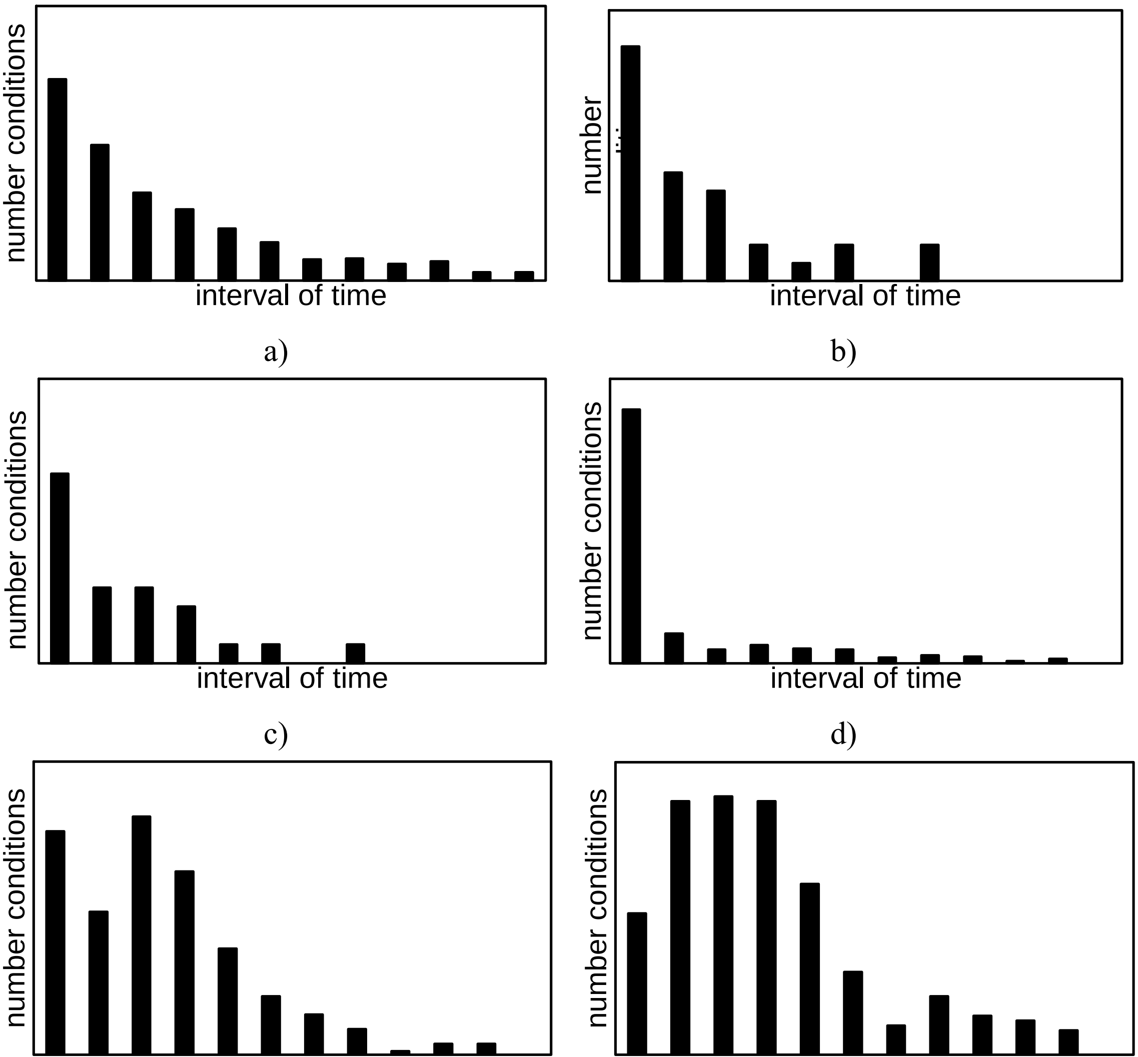
$$\tau_i = \tau_{i,j-1} + \frac{(\tau_{i,j} - \tau_{i,j-1})[X - F_{j-1}(\tau_i)]}{F_j(\tau_i) - F_{j-1}(\tau_i)} \tag{4}$$

realization of duration i-го conditions is calculated. Having repeated n.1-5 before performance of a condition

$$\sum_{i=1}^{m_S} \sum_{j=1}^{m_i} \tau_{i,j} \geq \Delta T$$

where m_s - number of conditions; m_i - number of realizations conditions i-го type; $\tau_{i,j}$ - j-th realization of duration i-го conditions; ΔT - an interval of time for which the sequence of conditions PB is modeled.

We shall receive realization of conditions PB. The information file of conditions includes date and time of the beginning and the end of a condition, duration of a condition, a kind of switching-off, type of a condition. This realization of conditions, reflecting the general laws of number and duration of conditions, nevertheless, can is essential differ from concrete laws of change of conditions in time. Difference reduced not only to a divergence of the moments of occurrence of conditions. It is natural, since it is necessary to operate with random variables, and is inevitable.



a) b)

c) d)

e) f)

Fig. 1. Histograms of duration conditions.
a - working condition; b - emergency idle time; c - refusal at start-up; d - sudden switching-off;
e - switching-off under the emergency application; f - cold reserve.

In modeled realizations are possible:

- same joint conditions. For example, consistently two working conditions.
- practically impossible conditions. For example, at finding PB in a condition of a cold reserve of occurrence of a condition of emergency idle time
- conditions which are impossible in the set interval of time. For example, capital and average repair during an autumn-winter maximum of loading are not spent.

Principal causes of inadequacy of modeled realizations of sequence of conditions PB of real sequence of conditions are initial preconditions (accident and independence of conditions) when are not considered:

- the determined character scheduled (average and capital) repairs;
- dependence of probability of conditions on parameters of individual reliability PB;
- interrelation of conditions PB;
- dependence of probability of conditions on a season.

Let us consider methods of the account of these features. At the automated forecasting basic industrial parameters PB, which scheduled repair, is not stipulated, a number of distribution of probabilities of conditions can be received by transition to conditional probabilities of conditions.

Conditional probability i-го conditions provided that the condition j is impossible, pays off under the formula:

$$\delta\tau^{**}_{\Sigma,i} = \frac{\delta\tau^{*}_{\Sigma,i}}{\sum\limits_{\substack{\nu=1 \\ \nu\neq j}}^{m_S} \tau^{*}_{\Sigma,\nu}} \tag{5}$$

$$\delta\tau^{**}_{\Sigma,j} = 0$$

And a number of distribution of conditional probabilities of conditions - under the formula (1)

If on considered PB carrying out of scheduled repair work modeling SC is spent on intervals of time before repair is provided. Otherwise (scheduled repair is not stipulated) - on all set interval of time. Objective character of realizations in this model entirely concerns only to full conformity to real statistical data. However, still, SC insufficiently full reflects distinction of parameters of reliability PB. Reflection of this distinction can be reached by transition from the average values of relative total duration of conditions of all PB $\delta\tau^{*}_{\Sigma,i}$, to relative total duration of conditions of everyone PB and from the average distributions of duration of conditions of all PB $F(\tau_i)$ to distributions of duration of conditions of everyone PB.

As an example confirming necessity of the account of individual reliability PB, in table 2 estimations of probability of finding PB in various conditions are resulted. Despite of casual character of emergency conditions, and conditions of a cold reserve concrete PB (the probability of finding PB in a condition of a cold reserve depends on its technical condition, the specific charge of fuel, an opportunity of decrease in number of start-up and so forth), probability of transition from a working condition in a condition of restoration at sudden refusals, or in a condition of a cold reserve are various. From a condition of a reserve transition in a condition of restoration is impossible at sudden refusals, and furthermore - again in a condition of a reserve. These and a number of other features real SC PB could not be considered in the algorithm considered above, assuming mutual independence of adjacent conditions PB. The interrelation conditions be considered by conditional probabilities of occurrence of conditions.

Table 2

Probabilities of conditions PB

Number the block	Type of condition						
	Working	Emergency idle time	Sudden refusal	Emergency application	Cold reserve	Average repair	Major overhaul
1	0,748	0,001	0,043	0,046	0,06	0,088	0
2	0,752	0	0,016	0,057	0,095	0	0,073
3	0,662	0	0,005	0,054	0,121	0,037	0,070
4	0,642	0,001	0,026	0,063	0,102	0	0,145

5	0,631	0	0,028	0,068	0,172	0,065	0,025
6	0,83	0,002	0,011	0,040	0,055	0	0,062
7	0,783	0	0,009	0,033	0,092	0	0,081
8	0,86	0,001	0,012	0,040	0,047	0	0,03

The estimation of conditional probabilities spent on statistical data SC under enough simple formula which looking like:

$$Q^*_{i,j} = \frac{m_{i,j}}{m_i} \tag{6}$$

where m_i - number of conditions i - го type; $m_{i,j}$ - the number of conditions j-го type provided that preceded this condition a condition i-го type.

Considering bulkiness and labour input of the statistical analysis of initial data real SC manually, possible subjective mistakes, have been developed algorithm and the program of calculation of conditional probabilities of occurrence of conditions. The essence of algorithm reduced to consecutive comparison of adjacent conditions PB. Necessity of such comparison is caused by a significant share of non-working conditions (on the average 20 %) in which PB it is translated formally from a non-working condition. Such translations, reducing number of start-up PB, promote decrease in the charge of fuel. If the moments of end preceded and the beginnings of the subsequent of non-working conditions coincide, as the next condition the non-working condition is fixed. Otherwise - a working condition. Results of calculations are brought in a matrix of change of conditions which structure at m_s=5, is resulted in table 3.

It is necessary to have in view of, that a chance, when

$$\sum_{j=1}^{m_s} m_{i,j} \neq \sum_{j=1}^{m_s} m_{j,i} \tag{7}$$

and practically always:

$$m_{i,j} \neq m_{j,i} \tag{8}$$

Table 3

Structure of a matrix of change of conditions

Conditional number (i) a previous condition	Conditional number (j) the subsequent condition				
	1	2	3	4	5
1	$m_{1,1}$	$m_{1,2}$	$m_{1,3}$	$m_{1,4}$	$m_{1,5}$
2	$m_{2,1}$	$m_{2,2}$	$m_{2,3}$	$m_{2,4}$	$m_{2,5}$
3	$m_{3,1}$	$m_{3,2}$	$m_{3,3}$	$m_{3,4}$	$m_{3,5}$
4	$m_{4,1}$	$m_{4,2}$	$m_{4,3}$	$m_{4,4}$	$m_{4,5}$
5	$m_{5,1}$	$m_{5,2}$	$m_{5,3}$	$m_{5,4}$	$m_{5,5}$

The parity (7) speaks initial and final conditions SC PB for which the previous (subsequent) condition is not known. In the ratio (8) finds the reflection as interrelation of conditions PB, and formal character of change of some non-working conditions. Here $m_{i,j}$ - the number of preceded conditions of i-th type from which PB has been translated in a condition of j-th type; $m_{j,i}$ - number of the subsequent conditions of j-th type in which PB has been translated from a condition of i-th type; $m_{i,j}$ - the general number of conditions of i-th type.

It is obvious, that $m_{i,j}$ - number of switching-off (start-up) PB, and $m_{1,j}$ - number of switching-off PB in j-th condition. Alongside with $m_{i,j}$ where i=1, m_s and j=1, m_s were calculated also total duration of finding PB in i-th condition provided that a preceded condition was j-th. The estimation of probability of translation PB from i-th condition in j-th condition calculated under the formula (6), and a number of probabilities of conditions, under the formula:

$$F_i(Q^*_{i,j})_v = \sum_{\substack{j=1 \\ j\neq i}}^{v} Q^*_{i,j} \tag{9}$$

$$F_i(Q^*_{i,j})_{m_S} = 1$$

The algorithm modeling condition PB thus transformed (regarding modeling type of a condition) a little. From average of some distribution of probabilities of conditions PB, we pass to a number of distribution conditional probabilities of occurrence of the subsequent condition (if a previous condition was a condition of the set type). For example, if to accept for a previous condition - working to this condition (i=1) there corresponds distribution $F_1(Q_{1,j})$. As a result, of playing type of a condition on $F_1(Q_{1,j})$ the subsequent condition there can be a reserve condition (i=7). To this condition, there correspond a number of distribution $F_7(Q^*_{7,j})$. As a result, of the next playing it is established, that at start-up PB there was damage PB and it is deduced in emergency repair, etc. Some experimental estimation of conditional probabilities of occurrence of conditions $Q^*_{i,j}$ and numbers of distribution of these probabilities $F_i(Q^*_{i,j})$ are resulted in table 4.

Greater advantage of application of distributions $F_i(Q^*_{i,j})$ is increase of objective character of realization SC. In particular, at modeling SC adjacent same and practically impossible conditions are excluded, and probabilities of transitions from one condition in another are adequate observable on practice. One of the most important and difficult questions at modeling SC is the account of dynamics of change of probability of conditions in time. Earlier the accepted assumption of uniform distribution of conditions on the set interval of time not always corresponds to practice.

Table 4

Estimations of conditional probabilities of conditions

The subsequent condition (j)	Previous conditions (i)							
	Working		Sudden refusal		Emergency application		Cold reserve	
	$Q^*_{i,j}$	$F_i(Q^*_{i,j})$	$Q^*_{i,j}$	$F_i(Q^*_{i,j})$	$Q^*_{i,j}$	$F_i(Q^*_{i,j})$	$Q^*_{i,j}$	$F_i(Q^*_{i,j})$
Working	-	0	0.86	0.86	0.81	0.81	0.96	0.96
Emergency idle time	0.04	0.04	0	0.86	0	0.81	0	0.96
Sudden refusal	0.33	0.37	-	0.86	0	0.81	0	0.96
Emergency application	0.35	0.72	0	0.86	-	0.81	0	0.96
Refusal at start-up	0	0.72	0.02	0.88	0.01	0.82	0.04	1.0
Repeated refusal	0	0.72	0.09	0.97	0.05	0.87	0	1.0
Cold reserve	0.28	1.0	0.03	1.0	0.13	1.0	-	1.0

As an example on fig. 2 realizations of law of change of factor of technical use (K_{tu}) PB a state district power station within a year are resulted. As relative duration of a finding in working order PB during the winter period approximately twice less, than during the years period follows from fig.2.

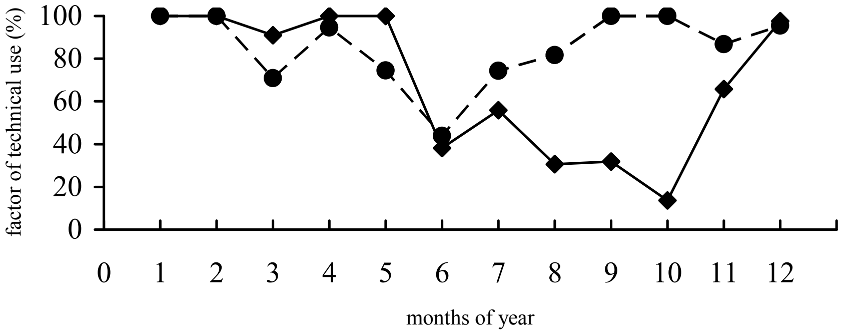


Fig.2. Laws of change of factor of technical use separate PB on months of year.

To consider non-uniformity of occurrence of conditions PB in current of year, numbers of distribution of probabilities of conditions in each month, which used at modeling type of a condition, are made. However, thus the discrepancies connected with an opportunity of modeling of adjacent same and practically impossible conditions kept.

To calculate matrixes of estimations of conditional probabilities of occurrence of conditions PB for each month, in view of sharp decrease in number of conditions PB, is connected with the big uncertainty of estimations. To exclude the specified discrepancies of modeling, we shall take advantage of that part of the information of a matrix of change of conditions which does not depend on number of conditions. Namely - the instruction on possible adjacent conditions. If adjacent conditions are possible, in a cell of a matrix we shall put down 1, otherwise - 0. We shall name this matrix - a matrix of transitions (MT). For the conditions entered into consideration (see table 1) (MT) shown in table 5.

The further increase of adequacy modeled SC is reached by use of the mechanism of specification of probabilities of occurrence of conditions after each playing type of a condition. An essence of the mechanism of specification we shall consider on a following example.

Table 5

Matrix of transitions

Conditional number of a previous condition	Conditional number of the subsequent condition								
	1	2	3	4	5	6	7	8	9
1	0	1	0	1	1	1	1	1	1
2	1	0	1	0	0	1	1	1	1
3	1	0	0	0	0	1	1	1	1
4	1	0	1	1	0	1	1	1	1
5	1	0	1	0	0	1	1	1	1
6	1	0	1	0	0	0	1	1	1
7	1	0	1	0	0	1	0	1	1
8	1	0	0	0	0	0	1	0	0
9	1	0	0	0	0	0	1	0	0

Let's assume, that relative duration of a working condition is equal $\delta\tau^*_{\Sigma wor} = 0{,}6$ considered month of year, conditions of a cold reserve- $\delta\tau^*_{\Sigma res} = 0{,}3$, conditions of emergency repair $\delta\tau^*_{\Sigma em} = 0{,}1$. At playing type and duration of a condition it has appeared, that PB is in working order, with relative duration $\delta\tau^*_{\Sigma wor} = 0{,}40$. From this condition according to conditions of example PB can pass both in a condition of a cold reserve, and in a condition of emergency repair.

Conditional probabilities of these conditions (a preceded condition the working condition is) will be equal:

$$\delta\tau^{**}_{\Sigma res} = \frac{\delta\tau^{*}_{\Sigma,res}}{\delta\tau^{*}_{\Sigma,res} + \delta\tau^{*}_{\Sigma,em}} = 0{,}75$$

$$\delta\tau^{**}_{\Sigma,em} = \frac{\delta\tau^{*}_{\Sigma,em}}{\delta\tau^{*}_{\Sigma,res} + \delta\tau^{*}_{\Sigma,em}} = 0{,}25$$

Further, if as a result of playing the next type of a condition and its duration, it is established, that next condition PB is emergency repair with relative duration $\delta\tau_{em} = 0{,}15$ it has appeared, that $\delta\tau^{*}_{em} > \delta\tau^{*}_{\Sigma em}$. In it finds the reflection a natural parity of average sizes and separate realizations. As the sum relative длительностей arisen conditions PB does not exceed unit $((\delta\tau^{*}_{wor} + \delta\tau^{*}_{em} = 0{,}55 < 1)$ process of modeling proceeds. During the considered moment of time, (emergency repair is completed) PB can pass both in a working condition, and in a condition of a cold reserve. However, conditional probabilities of transition in these conditions will not be equal any more

$$\delta\tau^{**}_{\Sigma,wor} = \frac{\delta\tau^{*}_{\Sigma wor}}{1 - \delta\tau^{*}_{\Sigma em}} = 0{,}67$$

$$\delta\tau^{**}_{\Sigma,res} = \frac{\delta\tau^{*}_{\Sigma res}}{1 - \delta\tau^{*}_{\Sigma em}} = 0{,}33$$

As $\delta\tau_{\Sigma wor}$ is partially spent. We shall lead current correction of conditional probabilities under the formula

$$\delta\tau^{**}_{\Sigma,wor} = \frac{\delta\tau^{*}_{\Sigma wor} - \delta\tau^{*}_{wor}}{\delta\tau^{*}_{\Sigma wor} + \delta\tau^{*}_{\Sigma res} - \delta\tau^{*}_{wor}} = 0{,}4$$

$$\delta\tau^{**}_{\Sigma,res} = \frac{\delta\tau^{*}_{\Sigma res}}{\delta\tau^{*}_{\Sigma wor} - \delta\tau^{*}_{wor} + \delta\tau^{*}_{\Sigma res}} = 0{,}6$$

Comparison of results of calculation testifies to essential change of sizes $\delta\tau_{\Sigma wor}$ and $\delta\tau^{**}_{\Sigma wor}$. If as a result of playing type and duration of a condition it has appeared, that the next condition is working, and realization of duration of a working condition exceeds $\delta\tau^{**}_{\Sigma wor} = 0.2$, in the remained interval of time of the considered period probably only reserve condition and consequently process of modeling of conditions comes to the end

CONCLUSION

1. Process of change of conditions of power units characterized by an opportunity of formal transition from one non-working condition in another that promotes decrease in number of switching-off (start-up). The number of such changes of conditions, on the average, makes about 20 % from number of non-working conditions. Application of known methods of modeling of conditions does not allow consider these features.
2. The new method of modeling of a condition of the power units, based on joint application of a method of modeling of casual events and a method of modeling of casual processes is developed. The method allows:
- exclude modeling adjacent same conditions and impossible combinations of adjacent conditions;
- consider statistical interrelation of conditions;
- consider laws of change of conditions in a season.
1. Modeling of inadmissible combinations of adjacent conditions is prevented on the basis of a matrix of transitions

2. The interrelation of conditions displayed by transition to conditional probabilities of conditions and correction of relative duration of conditions on a residual interval of modeling.
3. Dependence probability occurrence of conditions time is considered by consecutive modeling conditions on intervals for which this dependence can be neglected
4. On the basis algorithm, modeling conditions power units as a whole, and the algorithm and the program of forecasting of the guaranteed estimations of the basic industrial parameters both for a state district power station developed for separate power units.

REFERENCES

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