DESIGN PROCEDURE OF LOSSES OF ENERGY IN ELECTRICAL NETWORKS AT PROBABLE REPRESENTATION OF ELECTRIC LOADINGS DIAGRAMS

A. B. Balametov, H. T. Aliyev, S. Q. Mamedov

Azerbaijan Research Institute of Energetics and Energy Design.
Baku, Azerbaijan. Phone (99412 31-11-57, 32-80-76, Fax (99412 31-42-08

ABSTRACT

At account of losses of energy in distributive electrical networks characteristics of a production schedule are used. For definition of dispersion it is necessary to have a statistical lines of distribution of a random variable. However, reception under operating conditions statistical lines of distribution of loadings rather inconveniently. With the purpose of overcoming these lacks have received development methods of account of losses of the energy, based on probable representation of diagrams of electric loadings. In the given work the method of account of losses, which is based on representation of loading on duration as a continuous random variable, is considered.

Keywords: production schedules, losses of energy, probability theory, approximating dependences.

I. INTRODUCTION

Natural changes of loading are shown, on the one hand, at daily change of loadings, with another - at seasonal behaviors. Therefore daily diagrams are expedient for considering as realization of casual process, thus separate realization x (t), received as a result of registration of a production schedule, it may be considered as an element of set of probable realizations of casual process x (t) $\in$ M. For scope of influence of daily and seasonal factors on loading research of a production schedule as casual process follows. On no attended substations within one-year only two realizations - winter and summer daily the diagrams describing the maximal and minimal loadings, as a rule, are registered. Hence, the set of diagrams of loadings of the bottom level is in complete; the number of its known elements is not enough for account of statistical characteristics of a production schedule. In this case unknown elements of set with sufficient accuracy for practical accounts may be designed proceeding from features of investigated casual process.

The basic groups of consumers of the electric power in systems of electro supply of cities are: household; the industrial enterprises; the electrified transport. Daily diagrams of active load for the certain types of consumers or their groups are given in [1].

Production schedules of branch circuits 6 - 10 кV and above electric power systems are diagrams of the mixed loading and have the most various configurations. Production schedules in branch circuits are formed under influence of set of factors and are usual on duration look like smoothly decreasing functions, which are approximated by various analytical dependences [2,4-7]. The daily production schedules of the consumers which have been removed for minimal x_1 (t) and maximal x_n (t) of the modes of loading available in practice, it is possible to consider according to the bottom and top borders of set of realizations of casual process.

II. PRODUCTION SCHEDULES ON DURATION AS A RANDOM VARIABLE, SUBMITTING TO THE LAW OF IN β- DISTRIBUTION

The estimation of the characteristic of a production schedule is necessary for account of losses of energy as random variable. For this purpose the annual production schedule on duration is used. The characteristic of a production schedule on duration is duration of the greatest loading T_{max}. On meaning T_{max} character of a production schedule on duration may accept the various form. Accepting an assumption that change of loading occurs continuously, the production schedule on duration can be described continuous stochastic function. On meaning Tmax character of function varies between extreme meanings: from $g_1=I_{max}$ (t) up to $g_n=I_{min}$ (t).

By analogy between productions schedules on duration for various meanings T_{max} with representation of loading as the continuous random variable, submitting to the law in β - distributions for density of probabilities we have:

$$f(x,\gamma,\eta) = \left\{ \frac{\Gamma(\gamma+\eta)}{\Gamma(\gamma)\Gamma(\eta)} x^{\gamma-1}(1-x)^{\eta-1}, \right.$$
$$0 \le x \le 1,\ 0 \le \gamma,\ 0 \le \eta$$

Here Г - gamma-function.

In β - distribution γ и η are parameters of the form of distribution functions. Conformity of distribution of probabilities of loading under the law in β - distributions is established by account of distribution function in characteristic points of parameters of the form [3]. At $\gamma = 1$ and $\eta < 1$ density of distribution $\lim f(x, \gamma, \eta) = \infty$; at $\gamma = \eta = 1$ $f(x, 1, 1) = 1$; at $\gamma < 1$and $\eta = 1$ $\lim f(x, \gamma, \eta) = \infty$. As in process of increase of meaning T_{max} character of function of loading on duration smoothly changes from $g_n=I_{min}$ (t) up to $g_1=I_{max}$ (t) to meaning of function g1 which is expressed a straight line equal on ordinate Imax, will correspond) $\lim_{x \to 1} f(x, \gamma, \eta) = \infty$. To other limiting function g_n, the expressed straight line equal on ordinate I_{min}, answers $\lim_{x \to 1} f(x, \gamma, \eta) = \infty$. Meaning of distribution function f (x, 1, 1) =1 corresponds to linear function g. All other functions g=I (t) will be displayed through distribution functions of probabilities in limits from $\gamma = 0$; $\eta < 1$ up to $\gamma < 1$; $\eta = 1$.

Losses of energy with the account in - find load sharing& according to the formula

$$\Delta W = R\int_0^T I^2 dt = RT\left[I_{min}^2 + (I_{max}^2 - I_{min}^2)\delta(\gamma, \eta)\right]$$

Where $\delta(\gamma, \eta)$ - the factor of the form of the diagram, is defined as the sum of products of sizes of loading on probability of their occurrence:

$$\delta(\gamma, \eta) = \sum_{i=1}^{n} x_i p_i \ .$$

Generally $\delta(\gamma, \eta)$, dependent on parameters of the form of diagrams γ and η, it is necessary to define meaning of factor through meanings of density of in β - distribution. In turn parameters of the form of the diagram γ and η depend on average meaning $\bar{x}$ And dispersions D [x] loadings as random variable. Thus, the factor $\delta(\gamma, \eta)$ is defined by meanings $\bar{x}$ And D [x].

As account D [x] for electric loading represents significant difficulties it is offered to settle an invoice д approximately on meaning of average loading x.

Average meaning of a load current undertakes in relative units and is calculated according to the following formula:

$$x = \frac{\bar{I} - I_{min}}{I_{max} - I_{min}} \ .$$

Use of in - distribution at construction of model of a production schedule on duration has the positive parties. The basic from them is an opportunity of change of the form of curve density of in β - distribution due to change of parameters of distribution γ and η.

Questions of a choice of parameters of in - distribution in known works [2,4,6] are insufficiently full considered. Therefore the problem of construction of model of a production schedule as the random variable, having in - distribution, is not solved up to the end, and its decision requires the further researches.

III. APPROXIMATING DEPENDENCES OF PRODUCTION SCHEDULES

In [2] it is shown, that the annual production schedule on duration may be expressed by four kinds functions: parabolic at $T_{max} > 5840$; linear at T_{max} =4300-5840; exponential at T_{max} =2100 - 4300; hyperbolic linear at T_{max} = 0-2000.

In [6] production schedule on duration it is represented as smoothly decreasing function. Approximation of production schedules on durations will be carried out by the following analytical dependences of a current in time:

$$I = I_{max} - (I_{max} - I_{min})\left(\frac{t}{T}\right)^{\lambda} \qquad (1)$$

или

$$I = I_{min} + (I_{max} - I_{min})\left(1 - \frac{t}{T}\right)^{\frac{1}{\lambda}} \qquad (2)$$

Where - I_{max}, I_{min} meanings maximal and minimum currents for the rated period of time T.

The auxiliary factor λ is defined under the following formula:

$$\lambda = \frac{I_{cp} - I_{min}}{I_{max} - I_{cp}}$$

Approximation of production schedules by analytical dependences of a kind (1) and (2) results in there difference from real production schedules, and do not satisfy to characteristics of real diagrams. Though on demand factor of dependence of a kind (1) both (2) and real diagrams are equivalent. However approximating dependences of a kind (1) and (2) on a dispersion are not equivalent, and have significant regular errors. Dependence of a kind (1) has a divergence from practical in the field of the minimal loadings; dependence of a kind (2) has a divergence in the field of maximum demands. The divergence of the form of dependences of a kind (1) and (2) from real production schedules is possible for removing representation of dependence exponential function and a combination of different functions.

Approximating dependences of production schedules exponential function. Approximation of production schedules exponential dependences of a kind

$$I = I_{min} + (I_{max} - I_{min}) \cdot \ell^{-\alpha t^{\rho}} \qquad (3)$$

Is more adequate.

Here - and about auxiliary factors determined as a result of approximation.

Approximation of production schedules by

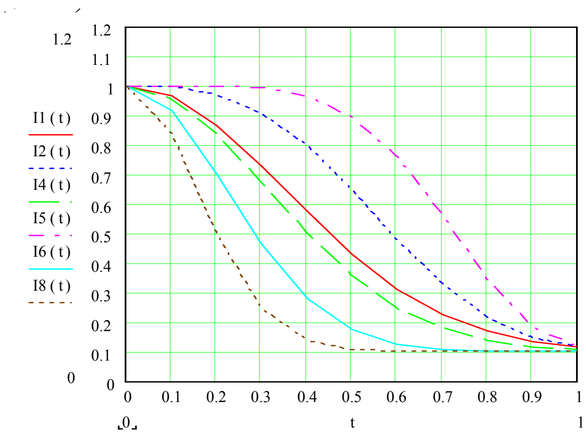

Fig. 1. Family of diagrams of the loadings described α and ρ.

Function of a kind (3) at different meanings of factors dependences (1) and (2) do not satisfy to characteristics of real diagrams for the following reasons. At $\lambda < 1$ on dependences (2) for curves II (t) and I4 (t) on fig. 1. Duration of maximum demand is equal to zero. At $\lambda > 1$ on dependences (1) for curve I6 (t) duration of the minimal loading is equal to zero. Thus, at a constant κ_3 approximation of production schedules by dependences (1) and (2) results in reduction of a dispersion and distortion of characteristics and by that to their difference from real diagrams.

IV. COMPARISON OF APPROXIMATING DEPENDENCES OF PRODUCTION SCHEDULES

For a numerical estimation of errors, were made approximation of characteristics of typical production schedules by functions of a kind (3) least-squares method. In connection with difficulties of approximation by function of a kind (3) selection of factors of approximation is carried out by realization of multiple accounts at the task with ρ a choice optimum α for each variant. For example, results of approximation for two real production schedules with k_z 0.5 and 0.4 exponential a kind (3) for different with ρ and with α appropriate root-mean-square value mistakes satisfy for a production schedule with $k_z = 0.5$ with $\rho = 3.2$ and $\alpha = 11.52$ and for a production schedule with $k_z = 0.4$ with $\rho = 2.2$ and $\alpha = 10.2$.

For comparison of characteristics of approximating dependences of production schedules of a kind (1), (2) and (3) on fig. 2. it is resulted results of approximation for production schedules with $k_z = 0.4$, $I_{min}=0.1$, $I_{max}=1$, $T=1$ and $\lambda=0.5$ sedate function of a kind (1), (2) and exponential a kind (3) for different with and providing $k_z = 0.4$.

For maintenance $k_z = 0.4$ factors of approximation with and exponential a kind (3) would be selected from a condition

$$k_3 = \int_0^1 i(t)dt = \int_0^1 \left(I_{min} + (I_{max} - I_{min}) \cdot \ell^{-\alpha t^{\rho}} \right) dt \quad (4)$$

For a production schedule of a kind (3) it is received

$$i(t) = 0.1 + 0.9 \cdot \ell^{-10.2 t^{2.2}} \quad (5)$$

For a production schedule of a kind (1) we have

$$i(t) = 0.1 + (1 - 0.1) \cdot \left(1 - \frac{t}{T}\right)^{\frac{1}{0.5}} = $$
$$= 0.1 + 0.9 \cdot \left(1 - \frac{t}{T}\right)^2 \quad (6)$$

Were simulated family of production schedules with $k_z = 0.4$, $I_{min}=0.1$, $I_{max}=1$, $T=1$ and $\lambda=0.5$ sedate function of a kind (2) and exponential a kind (3) for different with and providing $k_z = 0.4$ (fig. 2).

$$\text{at} \int_0^1 i(t)dt = \int_0^1 \left(0.1 + (1 - 0.1) \cdot \left(1 - \frac{t}{T}\right)^{\frac{1}{0.5}} \right) dt = 0.4,$$

Expression gives $\int_0^1 (i(t))^2 dt = 0.232$ and $k^2_{ф} = 1.45$.

Depending on factors of approximation and from production schedules, meaning $k^2_{ф}$ varies within the limits of 1.6 - 2. Thus, approximation of production schedules by dependences of a kind (3) allows receiving possible limits of distribution $k_{ф}$ relatives to real.

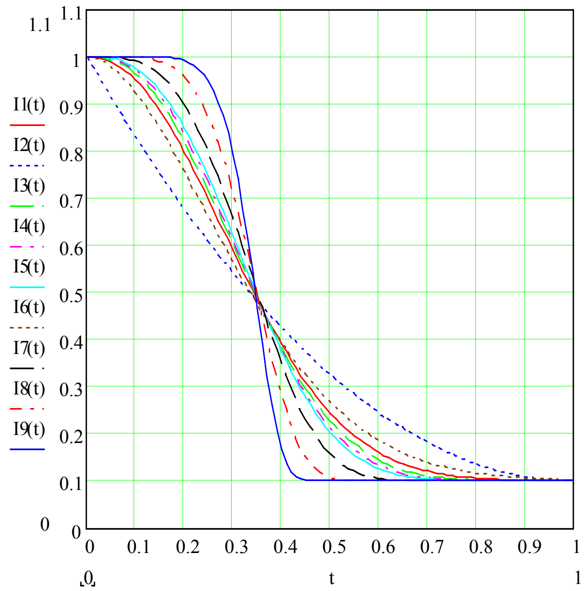

Fig. 2. Family of production schedules with $k_z = 0.4$, $I_{min}=0.1$, $I_{max}=1$, Ò=1 and l=0.5 sedate function of a kind (2) and exponential a kind (3) for different with and providing $k_z = 0.4$.

V. IMITATING MODELING CHARACTERISTICS OF PRODUCTION SCHEDULES

For an estimation of limits of change $k^2_{ф}$ in practice techniques based on comparison of all possible configurations of a production schedule on duration, by modeling of parameters of diagrams and a choice among them the most suitable to given k_z to the objective characteristic parameters k_{min} are used. There is no necessity to analyze all variants of production schedules at given P_{av}, P_{min}. For reception of formulas, approximation alternative account $k^2_{ф}$ for diagrams of various configurations or for typical diagrams to analyze all variants of production schedules estimated tens thousand. Sample of diagrams with limiting characteristic parameters considerably allows simplifying reception of formulas $k^2_{ф}$. To sample of characteristic diagrams it is possible to relate variants of diagrams having maximal, minimal meanings of a deviation of parameter from average.

As criterion of a choice of characteristic diagrams it is possible to accept variants of diagrams having maximal and minimal meanings $k^2_{ф}$ by criteria:

For a given value of demand factor of a production schedule $k_z \rightarrow$ **const,**

It is prospected from the diagram:

Maximal $k^2_\phi = f(k_{min}, t^*_{min}, t^*_{max}) \rightarrow$ мах,

And minimal $k^2_\phi = f(k_{min}, t^*_{min}, t^*_{max}) \rightarrow$ мин,

meanings of factor of the form.

The ordinate of one limiting diagram usually corresponds with $I=I_{max}$, and has the greatest duration of a maximum, and in other part an estimated time loading keeps the minimal constant meaning, and the diagram is characterized by the greatest meaning k^2_ϕ.

The ordinate of other limiting diagram has a short-term maximum, and the rest a part an estimated time loading keeps constant meaning. The diagram is characterized by the least meaning k^2_ϕ. Use of diagrams reduces to a minimum of an expenditure of lab our by definition of a dispersion on fig. 3. Dependences k^2_ϕ for limiting production schedules from k_z are given.

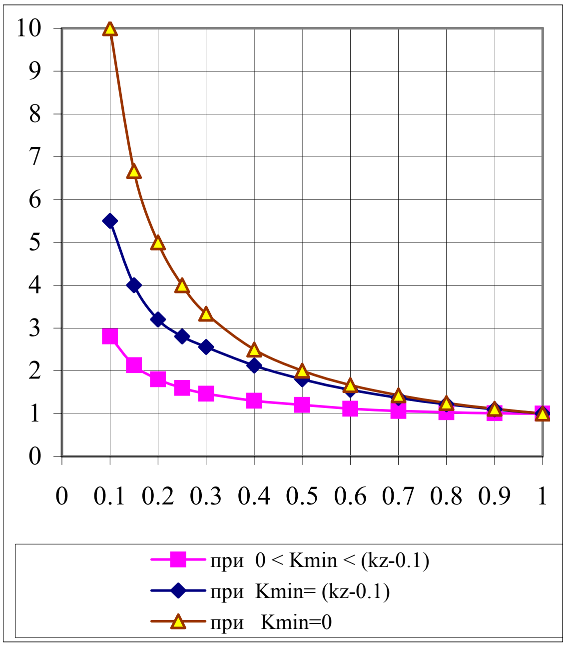

Fig. 3. Dependences k^2_ϕ for limiting production schedules from k_z

For meaning k_z equal 0.3 meaning k^2_ϕ has limiting meanings 1.47-3.3, and for $k_z = 0.2$ k^2_ϕ has limiting meanings 1.8-5.

Thus, the offered statement for account of limiting meanings of loading losses differ from known themes, that they are based on use most close approximating dependences of a production schedule and require the least expenses, providing thus necessary accuracy of modeling.

The Task such as the diagram already assumes presence of the data on its configuration, and in this case it is expedient to use directly the formula (1). At absence of such data the task such as the diagram may be carried out only subjectively. In practical accounts it is expedient to use approximating dependences for a production schedule close to real characteristics.

VI. CONCLUSIONS

1. Expressions for definition of the variable distribution losses, based on use of numerical probable characteristics of loadings are offered.
2. The technique recommended for practical use to the organizations, engaged is developed by operation of distributive electrical networks.
3. It is established dependences of a range of possible disorder of meanings k^2_ϕ from demand factor of a production schedule allowing an estimation of intervals of change of losses of energy.

REFERENCES

1. Electrotechnical directory: In 3 v, V3. 2 b. B 1. Manufacture and a distribution of electricity. - M.: Energoatomizdat Publishers, 1988. - 880 p.(in Russian)
2. *Klebanov L.D.* Questions of a technique of definition and decrease of losses of electric energy in networks. L: LGU Publishers, 1973, - 72 p. (in Russian)
3. *Khan G., Shapiro S.* Statistical models in engineering problems. M: Mir Publishers, 1969, 395 p. (in Russian)
4. *L.P.Anisimov, L.S.Levin, V.G.Pekelis.* Design procedure of losses of energy in working branch circuits. An electricity 1975, _4, p 27-30. (in Russian)
5. *G.E.Pospelov, H.M. Sich* Losses of capacity and energy in electrical networks. M.: Energoatomizdat Publishers, 1981. - 216 p. (in Russian)
6. Losses of the electric power in electrical networks of electric power systems. V.E.Vorotnitsky, J.S.Zhelezko, V.N.Kazantsev M.: Energoatomizdat Publishers, 1983. - 368 p. (in Russian)
7. *Balametov A.B., Mamedov S.Q.* About definition of factor of the form at accounts of losses of the electric power in view of restrictions in electro supply. Power (Proceedings of the Academy of Sciences.).- 2002.-_2, p. 21-29. (in Russian)