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USE OF THE SAMPLED ELECTRICAL ENGINEERING DEVICE AT DIAGNOSING ELEMENTS IN ELECTRIC SYSTEMS

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Stages of diagnosing procedures of the electric system elements have been introduced. The specialized mathematical device – sampled electrical engineering is developed for work with massifs of instant values of currents and voltages obtained by digital registrars of electric signals. The key rules and procedures of the sampled electrical engineering device are given.

Introduction

The transition from the system of planned-prophylactic repairs to the ones according to real operating conditions of the equipment is topical for Russian Federation power engineering. In order to make a proper decision at diagnosing electric equipment condition it is necessary to have rather complete and reliable information on the control objects – electric mode parameters (EMP) and equivalent circuit parameters (ECP). At present there are various electric signal monitors used only for recording emergency processes, «storing» one or another arrays of controlled quantity counts in power systems. In this connection, the attempts of wider application of information put in the arrays of instantaneous voltages and currents of EES various elements when solving the above listed problems are fully justified. The cogent advantage at analyzing electric processes in EES elements and power system in whole is the fact that in arrays of instantaneous currents and voltages the most complete and reliable information on physical processes in EES elements is given.

In practice, as a rule, the following parameters of electric mode: the effective values of currents and voltages, the generated and consumed electric energy are measured. The parameters of the equivalent circuits of EES system parameters are determined by reference or publishing data [1]. However, it is obvious that information on EMP on the controlled object is not sufficient for ascertaining real operating condition of equipment. It is known as well that ECP values at equipment operating process undergo significant changes and depends to a large extent on the majority of factors.

It is expected that the network of digital recorders of electric signals, synchronized accurately to each other in time through the channels of fiber-optics communication or the allocated high-frequency communication range, or the ideal synchronizing systems on the basis of GPS, allows obtaining information on object current state in real-time mode [1]. Such information is necessary for complexes of estimating the object state, diagnosis of electric equipment state, adaptive control of the controlled object. The object adaptive model should be taken as a principle of the adaptive control. It is constructed on the basis of current information on mode and circuit parameters – ECP determined on the basis of EMP values. The adaptive model of EES element implies obtaining of information valid to control object state. It is achieved by continuous calculation and storage of current EMP and ECP in data base.

In scientific literature, for example [2], the process of determining the operation condition of the object under diagnosis with the prescribed accuracy is understood under technical diagnosis. The tree-stage procedure of diagnosis is possible:

I. The equivalent circuit parameters of the known good object are determined on the basis of computing the arrays of instantaneous currents $i(t_j)$ and voltages $u(t_j)$ at «input» and «output» of object (Figure) in operating mode. As a result of identification the Γ-, Т- and П-type equivalent circuits with parameters (resistance and reactance) bearing information on good object under diagnosis («well») are obtained.

II. Similarly the parameters of the object equivalent circuit at the moment of its control are determined.

III. The diagnosis is carried out comparing and correlating the results obtained at the first and the second stages and diagnose is set in the form «in order» – «out of order».

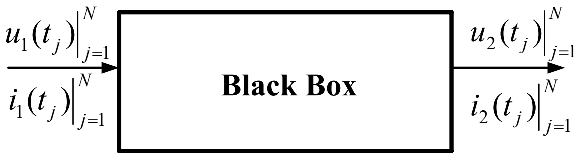

Figure. *Obtaining the measurements at «input» and «output» of the object*

In ELTI TPU at the departments «Electric power stations» and «Electric power systems and high-voltage equipment» the researches and design and development works directed to application of arrays of instantaneous currents and voltages obtained by digital recorders of electric signals at diagnosis are carried out [3–6]. In this article the question of development of «handy» mathematical apparatus called «the sampled electrical engineering» operating on the arrays of instantaneous currents and voltages is considered.

The main rules and procedures of the sampled electrical engineering

In most cases any measurements of electric quantities, in particular, current $i(t_j)$ and voltage $u(t_j)$ are carried out by digital method of measurements and meters and measuring systems implementing them. Therefore, in the general case let us proceed from the supposition that there are two arrays of the experimental data $a(t_j)$ and $b(t_j)$ obtained at the same instants of time $t_1,t_2,...,t_j,...t_N$, where $t_2=t_1+\Delta t;...t_j=t_{j-1}+\Delta t;$ ... $t_N=t_{N-1}+\Delta t$ with sampling increment Δt at general number of counts of the array N and array length T_M (one suppose that the array length equals or more than the period of signal T), i.e. $T_M \geq T$, $N=T/\Delta t$.

It is clear that T and Δt should be multiple to each other so that a number of counts N on signal period is integral.

Let us use the following kinds of writing down the main rules of the sampled electrical engineering:

$$a(t_j)\Big|_{j=1}^{N} = a(t_1), a(t_2),...a(t_j),...a(t_N);$$

$$b(t_j)\Big|_{j=1}^{N} = b(t_1), b(t_2),...b(t_j),...b(t_N);$$

$$[a(t_j)\cdot b(t_j)]\Big|_{j=1}^{N} =$$
$$= a(t_1)\cdot b(t_1), a(t_2)\cdot b(t_2),...a(t_j)\cdot b(t_j),...a(t_N)\cdot b(t_N);$$

$$a^2(t_j)\Big|_{j=1}^{N} =$$
$$= a(t_1)\cdot a(t_1), a(t_2)\cdot a(t_2),...a(t_j)\cdot a(t_j),...a(t_N)\cdot a(t_N);$$

$$[a(t_j)+b(t_j)]\Big|_{j=1}^{N} =$$
$$= a(t_1)+b(t_1), a(t_2)+b(t_2),...a(t_j)+b(t_j),...a(t_N)+b(t_N).$$

The base formulas of classical electrical engineering and formulas of the sampled electrical engineering similar to them are given in the table.

At known instantaneous values of signals $a(t_j)$ and $b(t_j)$ the instantaneous power $p_{ab}(t_j)$ is determined by their product.

Active power is the average value of instantaneous power over a period.

The product of two effective values of voltage and current is usually called the total power.

At «direct» use of the arrays of instantaneous voltages and currents for determining parameters of electric subcircuit by the Ohm's law as a quotient from division of $u(t_j)|_{j=1}^{N}$ by $i(t_j)|_{j=1}^{N}$, a case of division by zero at $i(t_j)=0$ may be met. Therefore, «new» formulas for determining R_K and X_K are proposed.

The sampled electric engineering differs fundamentally from the classical one in:

- transition to use of lattice functions corresponding in the best way possible to the up-to-date measuring systems and meters using digital methods of processing and presentation of information;
- introduction of electrotechnical calculation of digital procedures of computing the reactive power of shift Q_C on the basis of development of M.A. Maevskiy's ideas on using voltage-current characteristics for instantaneous currents and voltages into theory and practice;
- new interpretation of classical works of B.D.Kh. Tellegen on quasi-power and introduction of notions of active and reactive quasi-power that allowed obtaining a number of procedures of determining phase-shift angle between signals presented by digital counts of instantaneous values which were not known before;

Table. *Formulas of classical and sampled electrical engineering*

Denomination	Classical electrical engineering	Sampled electrical engineering
Active, effective value of a signal	$A=\left[\frac{1}{T}\int_0^T a^2(t)dt\right]^{0,5}$	$A=\left[\frac{1}{N}\sum_{j=1}^{N} a^2(t_j)\Big\|_{j=1}^{N}\right]^{0,5}$
Average value of a signal	$A_{cp}=\frac{1}{T}\int_0^T \|a(t)\|dt$	$A_{cp}=\frac{1}{N_M}\sum_{j=1}^{N}\|a(t_j)\|\Big\|_{j=1}^{N}$
Constant component of a signal	$A_0=\frac{1}{T}\int_{-T/2}^{T/2} a(t)dt$	$A_0=A_{cp}$, at $T_M=T;\ N_M=N=\frac{T}{\Delta t}$
Instantaneous power of signals $a(t_j)$ and $b(t_j)$	$p_{ab}=a(t)\cdot b(t)$	$p_{ab}(t_j)\Big\|_{j=1}^{N}=a(t_j)\Big\|_{j=1}^{N}\cdot b(t_j)\Big\|_{j=1}^{N}$
Active power of signals $a(t_j)$ and $b(t_j)$ at known phase-shift angle φ_{ab} between them	$P_{ab}=A\cdot B\cdot\cos\varphi_{ab}$	$P_{ab}=\frac{1}{N}\sum_{j=1}^{N} p_{ab}(t_j)\Big\|_{j=1}^{N}$
Total power of signals $a(t_j)$ and $b(t_j)$	$S_{ab}=A\cdot B$	$S_{ab}=U_a\cdot I_b=\left[\frac{1}{N}\sum_{j=1}^{N}a^2(t_j)\Big\|_{j=1}^{N}\right]^{0,5}\cdot\left[\frac{1}{N}\sum_{j=1}^{N}b^2(t_j)\Big\|_{j=1}^{N}\right]^{0,5}$
Kirchhoff's first law for instantaneous currents in node of electric circuit with c q branches	$\sum_{k=1}^{q} i_k(t)=0$	$\sum_{k=1}^{q} i_k(t_j)\Big\|_{j=1}^{N}=0$
Kirchhoff's second law for instantaneous voltages in circuit with l branches	$\sum_{k=1}^{l} u_k(t)=0$	$\sum_{k=1}^{l} u_k(t_j)\Big\|_{j=1}^{N}=0$
Ohm's law for k subcircuit	$Z_k=\frac{U_k}{I_k}$	$R_k=\frac{P_k}{I_k^2};\ X_k=\frac{Q_k}{I_k^2}$

- wide use of computation procedures for parameters of single branches of the equivalent circuit or by power and square of branch current or on the basis of solving the difference equation for the circuit *RL* or *RC*, along with the computation procedures on the basis of the Ohm's law.

The possibilities of the sampled electric engineering device allow determining parameters and characteristics of the controlled circuits of the known configuration [6].

Conclusion

1. To work with the arrays of instantaneous currents and voltages, obtained by the digital recorders of electric signals, the specialized mathematical apparatus – the sampled electrical engineering was developed. It allows determining in operating mode determining the parameters of electric modes and elements of electric systems.
2. The three-stage procedure of diagnosing operating condition of the RF power engineering proposed by the authors was described. It allows passing from the system of planned-prophylactic repairs to the ones according to real operating conditions of electric equipment.
3. Working capacity of the formulas and procedures of the sampled electric engineering at determination of parameters of electric modes and equivalent circuits of electric system elements was shown.

REFERENCES

1. Berdin A.S., Kryuchkov P.A., Suvorov A.A., Shelyug S.N. Methods of determining the equivalent circuit parameters for the tasks of controlling electric modes // Problems of developing and functioning of electric systems: Collected papers / Ed. by P.I. Bartolomey. – Yekaterinburg: USTU, 2000. – P. 25–31.
2. Kinsht N.V., Gerasimova G.N., Kats M.A. Electric circuits diagnostics. – Moscow: Energoatomizdat, 1983. – 192 p.: ill.
3. Djumic D.V., Goldshtein E.I., Khrushchev Yu.V. Using the arrays of instantaneous currents and voltages in problems of forming the adaptive models of electric systems // The Bulletin of UGTU-UPI. Problems of controlling electric engineering in competitive market conditions: Collected papers / Ed. by P.I. Bartolomey. – Yekaterinburg: USTU, 2005. – № 12 (64). – P. 316–321.
4. Goldshtein E.I. Issues of discrete electrical engineering in the course of «Engineering management technology» // The Bulletin of UGTU-UPI. Power system: control, quality, competition: Collection of the reports of the II All-Russian scientific and technical conference. – Yekaterinburg: UGTU-UPI, 2004. – № 12 (42). – P. 473–477.
5. Avramchuk V.S., Batseva N.L., Goldshtein E.I., Isachenko I.N., Li D.V., Suleimanov A.O., Tsapko I.V. Functional check and diagnostics of electrotechnical and electromechanical systems and devices by digital counts of instantaneous currents and voltages / Ed. by E.I. Goldshtein. – Tomsk: Printing manufactory, 2003. – 240 p.
6. Goldshtein E.I., Batseva N.L., Dzhumik D.V., Usov Yu.P. Diagnosis of electrical circuits. – Tomsk: TPU Press, 2006. – 152 p.

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DETERMINING THE EQUIVALENT CIRCUIT PARAMETERS OF TRANSMISSION LINES, REACTORS, POWER RESISTORS AND CAPACITOR BANKS BY THE ARRAYS OF INSTANTANEOUS CURRENTS AND VOLTAGES

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The possibility of defining parameter of electric system static elements by the arrays of instantaneous currents and voltages for various problems of electric power engineering has been shown. The procedures of determining the parameter of the reverse Г-type equivalent circuit of a line are considered. The procedures of determining the equivalent circuit parameter of linear current-limiting reactor/resistor and computation results are introduced.

Definition of the equivalent circuit parameters of the electric system elements is the important and topical aim for power engineering of Russian Federation. It is obvious, that at management of a controlled object and diagnosis of its operating conditions, it is necessary to have rather complete and reliable information on the equivalent circuit (EC) parameters. However, in practice, the equivalent circuit parameters of the electric system elements are determined, as a rule, from the reference or published data. It is known that the values of the EC parameters undergo significant changes and depend considerably on a majority of factors at electrical equipment operation.

In connection with the ubiquitous introduction of the up-to-date measuring systems and meters using digital techniques of processing and providing information, the apparatus of the sampled electrical engineering [1], allows, comparatively simply, in the best way possible, solving a number of problems of determining the equivalent circuit parameters of electrical power engi-