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The calculation of the phase shift between current and voltage of the overhead lines by using the Telleggen's quasipower theorem

Section 6: POWER ENGINEERING

Analysis of various processes in three phase electric circuits is connected with control and measurement of a phase shift between a current and a voltage.

However, well-known procedures of phase shift measurements have number of drawbacks such as complexity of realization and also additional equipment must be in use, therefore, the application of Telleggen's quasipower theorem for calculation of a phase shift between two signals, which have an equal frequency are discussed in this report.

The Telleggen's quasipower theorem have been widely adopted both linear and nonlinear, active and passive electric circuits, which are submitted to the Kirchhoff's laws. It is important that the circuit's power supply can be non-sinusoidal [1]. Moreover, currents and voltages, which don't possibly exist in a circuit at the same time, can be accepted as input data for phase shift calculations. The equation (1) illustrates this statement:

$$\sum i'_p \cdot u''_p = \sum i'_a \cdot u''_a, \qquad (1)$$

where: currents i'_p and i'_a are submitted to the first Kirchhoff's law; voltages u''_p and u''_a are submitted to the second Kirchhoff's law.

The terms of an active $(\dot{P})$ and a reactive $(\dot{Q})$ quasipowers, which are calculated by means of data files of instantaneous values *a(t$_j$)* and *b(t$_j$)*, are given in [2, 3, 4]. It was suggested to separate active $(\dot{P})$ and reactive $(\dot{Q})$ quasipowers [2, 3] and further calculate them by means of formulas (1, 2):

$$\dot{P}_{a,b} = \frac{1}{N} \bullet \sum_{j=1}^{N} \left[a(t_j) \bullet b(t_j) \right]_{j=1}^{N}. \qquad (1) \qquad \dot{Q}_{a,b} = \frac{1}{4\pi} \sum_{j=1}^{N} \left[a(t_j) - a(t_{j+1}) \right] \bullet \left[b(t_j) + b(t_{j+1}) \right] \qquad (2)$$

where: *a(t$_j$)* and *b(t$_j$)* are data files of instantaneous values (3,4):

$$a(t_j)\Big|_{j=1}^{N} = a(t_1), a(t_2)...a(t_N); \; b(t_j)\Big|_{j=1}^{N} = b(t_1), b(t_2)...b(t_N). \quad (3) \qquad t_j = t_{j-1} + \Delta t; \; N = \frac{T}{\Delta t}, \quad (4)$$

here: T is a period of a signal, Δt is the step of discretization, N is number of fragmentations during the period of a signal.

In whole, quasipowers $\dot{P}$ and $\dot{Q}$ are different from usual active P and reactive Q powers, which are used in the general electric engineering. It is supposed that $\dot{P}$ and $\dot{Q}$ are vectors and the angle between them can be calculated by formulas (5,6,7)

$$sin\,\phi_{a,b} = \frac{\dot{P}_{a,b}}{A \cdot B}; \;\; (5) \qquad cos\,\phi_{a,b} = \frac{\dot{Q}_{a,b}}{A \cdot B}; \;\; (6) \qquad tg\,\phi_{a,b} = \frac{\dot{Q}_{a,b}}{\dot{P}_{a,b}}, \;\; (7)$$

where: A and B are active values of signals $a(t_j)$ and $b(t_j)$ (8):

$$A = \sqrt{\frac{1}{N}\sum_{j=1}^{N} a^2(t_j)} \qquad B = \sqrt{\frac{1}{N}\sum_{j=1}^{N} b^2(t_j)} \qquad (8)$$

Formulas (5), (6), (7) have been checked for analysis of processes in three-phase overhead lines. Moreover, data files of instantaneous values have been measured by means of digital recorder “Black Box“ (Russia).

The voltage and current oscillograms for one of the high-voltage overhead line under both the steady state and the emergency (short circuit of the phase B) regimes are given in figure 1. The phase shifts between voltages and also between voltages and currents are shown in figure 1. Results were obtained by formulas (5), (6), (7) and compared with oscillographic results. All results are shown in table 1. In addition, there are special rules for angle calculations (9):

$$\left.\begin{array}{l}
\varphi_{a,b} = |\phi_{a,b}|, \text{ if } P_{a,b} > 0 \text{ and } Q_{a,b} > 0. \text{ The angle lies in the I quadrant.} \\
\varphi_{a,b} = \pi - |\phi_{a,b}|, \text{ if } P_{a,b} < 0 \text{ and } Q_{a,b} > 0. \text{ The angle lies in the II quadrant.} \\
\varphi_{a,b} = \pi + |\phi_{a,b}|, \text{ if } P_{a,b} < 0 \text{ and } Q_{a,b} < 0. \text{ The angle lies in the III quadrant.} \\
\varphi_{a,b} = \pi + |\phi_{a,b}|, \text{ if } P_{a,b} > 0 \text{ and } Q_{a,b} < 0. \text{ The angle lies in the VI quadrant.}
\end{array}\right\} \qquad (9)$$

The phase shift test shows, that the phase shift between current and voltage of the damaged phase and neighbor phases changes in case of one - phase short circuit. Thererfore, this phenomena helped to develop a functional check system of a dead-grounded neutral radial overhead line.

The main task of this system is emergency detection, for instance, one phase and two phase short circuits or broken wire.

The phase shift between current and voltage can be evaluated by means of statistical information concerning equivalent circuit parameters under different regimes.

Results of the accuracy calculation were obtained by formula (10):

$$\delta = \left|\phi_p - \phi_0\right|; \qquad \delta_{\%} = \frac{\delta}{\phi_0}. \qquad (10)$$

Where: $\delta_{\%}$ is fractional accuracy; δ is absolute accuracy; ϕ_p is the phase shift, which was obtained by formulas (5), (6), (7); ϕ_0 is the phase shift, which was measured by digital recorder "Black Box". Results are shown in table 2.

The values of inaccuracy can be explained by small data precision which were given by means of the graphical method of phase shift measurements.

Results of this researches demonstrate that formulas (3), (4), (5) can be adopted both single-phase and three-phase circuits. This method of phase shift calculations between two signals can be realized by using a computer and a digital recorder. Results of these researchers can be used for the functional monitoring and protection systems of overhead lines, for creation of directional power relay and reactive power compensators.

Table 1

Angle, degree	**Calculated by formula**			**Oscillogram dates**	$\dot{P}$	$\dot{Q}$	**Regime**
	(6)	**(7)**	**(8)**		$\mathbf{10^6}$	$\mathbf{10^6}$	
ϕ(Ua,Ub)	119,528	118,563	118,789	115	-8473	15420	Steady state
ϕ(Ua,Uc)	237,824	238,571	238,365	230	-9191	14920	
ϕ(Ua,Ia)	-54,315	-55,804	-54,804	-56	10,97	-15,9	
ϕ(Ua,Ib)	67,862	68,731	68,613	67	7,1	18,3	
ϕ(Ua,Ic)	186,847	187,314	186,851	185	-19,6	-2,36	
ϕ(Ub,Ib)	-48,987	-49,889	-49,508	-48	12,96	-15,2	
ϕ(Uc,Ic)	-50,895	-51,773	-51,431	-48	12,41	-15,6	
ϕ(Ua,Ub)	134,746	133,778	134,249	124	-6133	6296	Short circuit of the phase B
ϕ(Ua,Uc)	240,835	241,988	241,727	230	-8201	-15250	
ϕ(Ua,Ia)	-15,578	-16,533	-15,649	-18	30,01	-8,4	
ϕ(Ua,Ib)	179,222	177,558	179,221	163	-2613	-6,13	
ϕ(Ua,Ic)	219,774	220,92	220,254	236	-7,46	-6,13	
ϕ(Ub,Ib)	41,754	45,461	45,109	48	97,25	97,62	
ϕ(Uc,Ic)	-21,091	-22,825	-21,326	-20	9,5	-3,7	

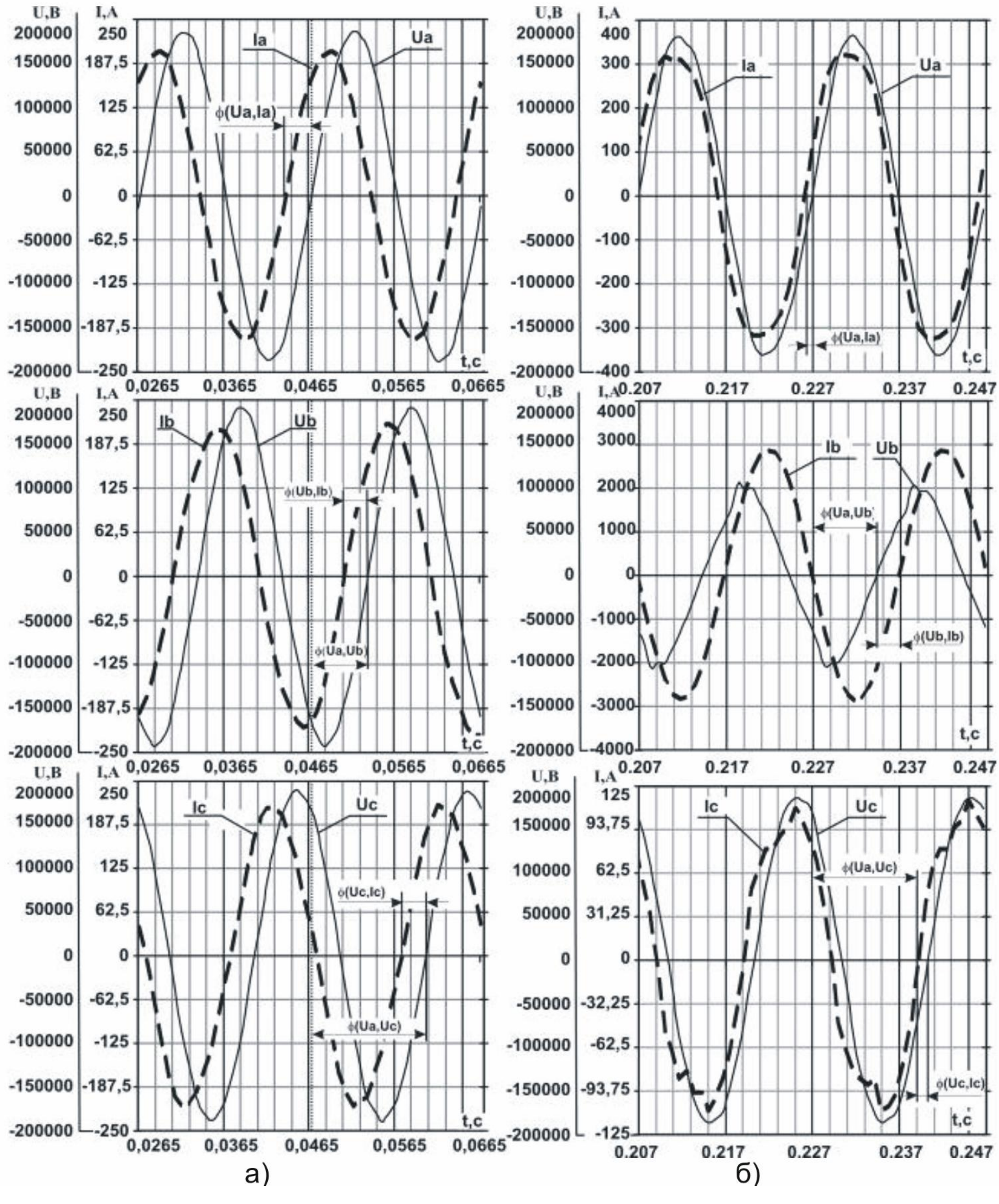

Fig.1. – The voltage and current oscillograms of the overhead line under the steady state (a) and the emergency (short circuit of the phase B) (b) regimes

Table 2

Angle, degree	Absolute accuracy of the phase shift calculation by formula:			Fractional accuracy of the phase shift calculation by formula:			Regime
	(6)	(7)	(8)	(6)	(7)	(8)	
ϕ(Ua,Ub)	4,528	3,563	3,789	3,94	3,098	3,295	Steady state
ϕ(Ua,Uc)	7,824	8,571	8,365	3,4	3,726	3,637	
ϕ(Ua,Ia)	1,685	0,196	1,196	3	0,35	2,136	
ϕ(Ua,Ib)	0,862	1,731	1,613	1,287	2,584	2,407	
ϕ(Ua,Ic)	1,847	2,314	1,851	0,998	1,251	1	
ϕ(Ub,Ib)	0,987	1,889	1,508	2,056	3,935	3,142	
ϕ(Uc,Ic)	2,895	3,773	3,431	6,031	7,86	7,148	
ϕ(Ua,Ub)	10,746	9,778	10,249	8,666129	7,885	8,265	Short circuit of the phase B
ϕ(Ua,Uc)	10,835	11,988	11,727	4,71087	5,212	5,099	
ϕ(Ua,Ia)	2,422	1,467	2,351	13,45556	8,15	13,061	
ϕ(Ua,Ib)	16,222	14,558	16,221	9,952147	8,933	9,952	
ϕ(Ua,Ic)	16,226	15,08	15,746	6,875424	6,389	6,672	
ϕ(Ub,Ib)	6,246	2,539	2,891	13,0125	5,289	6,023	
ϕ(Uc,Ic)	1,091	2,825	1,326	5,455	14,125	6,63	

References:

[1] P. Penfield, R.Spens, S.Duinkers/. Energetical theory of the electric circuits/ Moscow:"Energy", 1974.
[2] "Functional check and diagnostics of electrical engineering and electromechanical devices and systems, using array of instantaneous values"//Under edition E.I. Goldstein. Tomsk, 2003.
[3] N.L. Baceva. Dissertation for PhD Degree. Determination of the equvalent curcit parametrs of the low-power single-phase transformers in operating mode. – Tomsk: TPU, 2005.
[2] Patent 2264630 RU, G01R25/00. The method of the calculation of the phase shift between two sinusoidal signals/N.L./Batseva, E.I. Goldstein, A.O. Sulaimanov, A.V. Pankratov/ Published 20.11.2005, Bulletin N^{o}. 32.
[3] Patent 2264631 RU, G01R25/00. The method of the calculation of the phase shift between two sinusoidal signals/ N.L./Batseva, E.I. Goldstein, A.O. Sulaimanov, A.V. Pankratov / Published 20.11.2005, Bulletin N^{o}. 32.
[4] Patent 2242014 RU, G01R25/00. The method of the calculation of the phase shift between two sinusoidal signals/ N.L.Batseva, E.I. Goldstein./ Published 10.12.2004, Bulletin N^{o}.28.

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