capacitance in a measuring circuit leads to an increased nonlinearity, which is partly eliminated by an additional resistor.

In order to eliminate the effect of supply voltage variations on the frequency meter readings the supply to the commutating transistor is stabilized by means of a semiconductor stabiltron type D813. A change in the ambient temperature produces not only changes in the capacitance but also in the voltage across the stabiltron. Temperature compensation is achieved by connecting in series with the reference stabiltron a thermistor type MMT-9 shunted by a resistor.

The measuring capacitors must have small leakage currents. A sample model arranged as shown in the attached circuit was tested in the range of 5-100 cps. The frequency meter nonlinearity in this range amounted to 0.52%, i.e., ±0.26% (Fig. 3).

In order to be able to use the instrument in other frequency ranges a switch with a set of capacitors is required.

CHECKING THREE-PHASE WATTMETERS

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Three-phase wattmeters intended for measuring active or reactive power in a three or four-conductor network are normally checked by comparing them with the readings of 2 or 3 single-phase wattmeters [1]. According to the standard specification [2] this checking should be carried out with the power factor (cos φ or sin φ) equal to its nominal value or half that value. The required phase shift is established by means of reference wattmeters whose readings are computed in advance.

In [1] formulas are given for computing the readings of reference wattmeters in terms of current and voltage according to the circuit they are used in. Experience has shown that computing wattmeter readings by means of these formulas is often difficult. This is due to the fixing by specification [2] of the top limits for measuring wattmeters at a value which is not equal to the power determined by the product of the nominal current, voltage and power factor, but corresponds to one of the integer values specified by the standard and nearest to the calculated power.

Normally the instrument is checked at the nominal voltage. In such a case for a nominal power factor (cos φn or sin φn) the current I corresponding to the full-scale deflection of the wattmeter will not be the same as the nominal current In. Hence, the calculation of the reference single-phase wattmeter readings cannot be made on the basis of nominal values of current and voltage, as recommended in [1], but on the basis of power Pn which corresponds to the full-scale reading of the wattmeter under test.

As an example let us examine the checking of a three-phase wattmeter designed for measuring active power in a three-conductor network with a nominal power factor differing from 1.

Let the instrument be used for measuring power at a line voltage V1, current In and a power factor cos φn. The calculated active power is:

\[ P_c = \sqrt{3} \ \sqrt{V_c I_n \cos \phi_n} \]

It has already been pointed out that power Pn which corresponds to the full-scale deflection of the instrument approaches the value of Pc, but is not equal to it.
For a most general case let us assume that the wattmeter under test is connected to the mains through instrument current and voltage transformers with a transformation ratio of $K_T = I_n/I_2n$ and $K_n = V_n/V_{2n}$ respectively, where $I_{2n}$ and $V_{2n}$ are the nominal values of the current and voltage in the secondary winding, for which the instrument in fact was designed (reference instruments are selected by these values). The power corresponding to the full-scale deflection of the wattmeter will then be equal to:

$$P_n = P_{n'}/K_TK_n.$$  

Let us note that it is sufficient to calculate for the maximum measured power $P_n$ of the instrument under test, since other test points can be obtained by calculating them in the required proportion.

In the case under consideration two reference single-phase wattmeters are used in an Aron-type connection, hence their nominal readings $\alpha_1$ and $\alpha_3$ must satisfy the condition:

$$\alpha_1C_{w1} + \alpha_3C_{w3} = P_n.$$  

In case of an even loading of the phases, when the condition $C_{w1} = C_{w3} = C_w$ must be met, we have:

$$(\alpha_1 + \alpha_3)C_w = P_n'.  

Here $C_{w1}$, $C_{w3}$ and $C_w$ are the wattmeter calibrations.

At the same time, for an even loading of phases the wattmeter readings in terms of $\cos \varphi$ will be determined by the expression:

$$\frac{\alpha_1}{\alpha_3} = \frac{\cos (\varphi + 30^\circ)}{\cos (\varphi - 30^\circ)}.$$  

From this equation a graph of $\alpha_1/\alpha_3 = f(\cos \varphi)$ is normally plotted to a scale convenient for calculations. The shape of this curve is shown in the figure attached.

From the above expression one determines:

$$\alpha_1 + \alpha_3 = \frac{P_n}{K_TK_nC_w}.$$  

and from the graph one finds $\alpha_1/\alpha_3$, which makes subsequent calculations quite easy.

Irrespective of the required test conditions, the phase shift which corresponds to a given $\cos \varphi$ is determined for a uniform phase load distribution. This operation, which only involves reference wattmeter readings, consists of the following.

The maximum readings of the reference wattmeters for certain constant values of voltage and current correspond to a phase shift of $-30^\circ$ for the first wattmeter ($\alpha_1$ max) and $+30^\circ$ for the second ($\alpha_3$ max), moreover for a normal voltage $V_{2n}$ and current $I_{2n}$ which correspond to $P_n'$ we have:

$$\alpha_1 \max = \alpha_3 \max = \frac{P_n}{2K_TK_n \cos \varphi_1 \cos 30^\circ C_w} = \frac{P_n}{1.73K_TK_n C_w \cos \varphi_1}.$$  

By adjusting the phase shift and current, maximum readings are obtained at the nominal voltage first on one $\alpha_1$ max and then on the other $\alpha_3$ max wattmeter. Next, without changing the current setting, readings $\alpha_1$