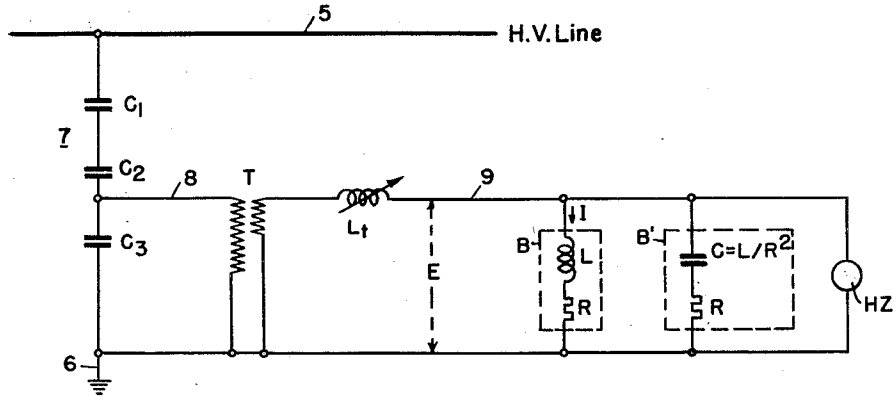
June 10, 1952 J. T. CARLETON 2,600,204

COMPENSATED POTENTIAL DEVICE CIRCUITS

Filed April 15, 1950



WITNESSES:

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Patented June 10, 1952

2,600,204

UNITED STATES PATENT OFFICE

2,600,204

COMPENSATED POTENTIAL DEVICE CIRCUITS

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Application April 15, 1950, Serial No. 156,106

4 Claims. (Cl. 175—294)

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My invention relates to potential-devices such as are shown in the Peters Patent 1,819,260, granted August 18, 1931. These potential-devices are adapted to be connected to either an intermediate-voltage tap of a string of coupling capacitors, or an intermediate tap of a bushing of a circuit breaker or transformer. In either event, the potential-device is adapted for use with a high-voltage alternating-current line; the tapped capacitor or the tapped bushing reduces the line-voltage to a relatively small value, such as 4,000 volts between the tapped point and ground, and the potential-device includes a step-down transformer and tuning means, for reducing this tapped voltage to a still lower value, such as 115 volts.

When the voltage-coil of a high-speed impedvance-relay is operated from such a potential-device, it has been found that faulty operations occur under certain conditions. It has been known that these faulty operations practically never occur within the rating of the potential-device, when the potential-device is operating on a resistive burden, or when the rest of the burden on the potential-device, other than the voltage-coil of the impedance-relay in question, draws a unitary-power-factor current from the output-terminals of the potential-device. It has long been known that the power factor of any burden could be corrected, and brought to unity, by the addition of suitable capacitive or inductive reactors, as the case might require, but these power-factor-correcting reactors are effective at only one frequency.

At times, an electrical system may operate, for very brief periods, at some frequency other than the normal or rated line-frequency; and it is a broad object of my invention, therefore, to devise some sort of compensating-circuit, to be added to the burden or load-circuit of a potential-device or other alternating-current voltage-source, so that the total current drawn by the burden and the compensating device, combined, shall always have a unitary power-factor, so that the entire combination behaves as a pure resistance, under all operating-frequencies of the source or potential-device.

Most burdens on a potential-device are coils, which have considerable inductance, as well as resistance, so that such burdens draw lagging current from the potential-device. I have found that it is possible to add a compensating device consisting of a capacitor and a resistance, which will bring the total burden to unity power-factor at all frequencies. It is a specific object of my

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invention, therefore, to provide a compensating device having a capacitor and a resistor of the proper specific values, for accomplishing this purpose, as will hereinafter be explained more in detail.

An exemplary form of embodiment of my invention is illustrated in the accompanying drawing, the single figure of which is a diagram of illustrative circuits and apparatus.

The drawing shows a conventional capacitor potential-device, connected between a high-voltage line 5 and the ground 6, and comprising a capacitance-divider 7 which may be either a coupling capacitor or a condenser-bushing, represented by three capacitors C_1, C_2 and C_3. The capacitance-divider 7 is shown as having a tapped point 8, which usually provides about 4,000 volts above ground.

The tap 8 of the capacitance-divider 7 is used to energize the primary input-circuit of a step-down potential-transformer T. The step-down transformer T has a secondary output-circuit 9 which is connected to the burden B. The secondary output circuit 9 necessarily contains some sort of means for adjusting the equivalent leakage-reactance of the step-down transformer T, so as, in effect, to make this equivalent leakage-reactance substantially equal to the equivalent capacitive reactance of the source or divider. In the drawing, this leakage-reactance adjusting-means is shown as a variable or tunable inductance L_t, but it is to be understood that this representation is intended to indicate either a variable reactor, separate from the transformer T and serially connected within the secondary output-circuit 9 thereof, or the variable-reactance part of the leakage-reactance of a variable-leakage-reactance transformer T. In this way, the equivalent capacitive reactance X_c of the source is tuned out, so that the regulation of the secondary output-circuit 9 will be small, and the voltage of this circuit will be in phase with the voltage of the high-voltage line 5 during steady operating-conditions.

In the drawing, the voltage of the output-circuit 9 of the potential-device is indicated as E, and the burden B is represented as including a serially connected inductance L and resistance R, drawing a current I. Usually, the burden B on a potential-device will consist of a number of voltage-coils or load-circuits in parallel with each other, and the indicated burden, in the drawing, is intended to represent the equivalent of the total burden, with a sufficiently close approximation. Thus, if the total budren-current is a cur-

rent having a magnitude $\bar{I}$, at a power-factor cos θ, the total volt-ampere burden would obviously be $(E\bar{I})$, the equivalent resistance would be

$$R=\frac{E}{\bar{I}}\cos\theta=\frac{E^2\cos\theta}{(E\bar{I})} \quad (1)$$

and the total inductive reactance would be

$$X=2\pi fL=\frac{E}{\bar{I}}\sin\theta=\frac{E}{\bar{I}}\sqrt{1-\cos^2\theta}=\frac{E^2}{E\bar{I}}\sqrt{1-\cos^2\theta} \quad (2)$$

whence the equivalent inductance L, in henrys, would be

$$L=\frac{E^2}{2\pi f(E\bar{I})}\sqrt{1-\cos^2\theta} \quad (3)$$

In accordance with my invention, I apply a compensator-burden B', in parallel to the burden B, across the output-terminals 9 of the potential-device. This compensating burden B' consists of a capacitor C and a resistor R connected in series with each other. In order to achieve the objects of my invention, the resistance R must be the same in both the real burden B and the compensator-burden B', and the value of the capacitance C of the compensator-capacitor, in farads, should be related to the inductance L and the resistance R of the burden B by the relation,

$$C=L/R^2 \quad (4)$$

The effect of the above-described combination of a burden B and a compensating burden B' is to provide a combined impedance Z which acts as a pure resistance at all frequencies. Thus, the combined impedance Z of the two parallel-connected burdens B and B' is

$$Z=\frac{1}{\frac{1}{R+jwL}+\frac{1}{R-j/wC}}=\frac{(R+jwL)(R-j/wC)}{2R+j(wL-1/wC)}$$

$$=\frac{R^2+L/C+jR(wL-1/wC)}{2R+j(wL-1/wC)} \quad (5)$$

If the relation expressed in Equation 4 holds true, it will be found, by substitution in Equation 5, that the effective impedance of the two parallel-connected loads will be

$$Z=\frac{R^2+R^2+jR(wL-R^2/wL)}{2R+j(wL-R^2/wL)}=R \quad (6)$$

Equation 6 thus shows that the combined effect of my compensating burden B' and the regular burden B will be the same as if the total of the two burdens were simply the resistance R, regardless of the frequency f or the angular velocity $w=2\pi f$.

The value of the compensating capacitor C can be expressed in terms of the volt-ampere burden $(E\bar{I})$, the voltage E, the power-factor cos θ, and the frequency f at which said power-factor is measured, by combining Equations 1, 3 and 4. Thus,

$$C=\frac{L}{R^2}=\frac{(E\bar{I})^2}{E^4\cos^2\theta}\cdot\frac{E^2}{2\pi f(E\bar{I})}\sqrt{1-\cos^2\theta}$$

$$=\frac{(E\bar{I})}{2\pi fE^2}\cdot\frac{\sqrt{1-\cos^2\theta}}{\cos^2\theta} \quad (7)$$

With such a compensation, the potential device has a pure-resistance load, under all frequency-conditions, and hence no faulty relay-operations are obtained if the potential-coil HZ of a high-speed impedance-relay, or other critical device, is connnected, as an additional load, across the same potential-device, as shown in the drawing.

Since the burden of the impedance-relay voltage-coil HZ is usually quite small, as compared to the total burden on the potential-device, this coil HZ may be added after the rest of the burden has been compensated, as above described, or the burden of the voltage-coil HZ could be included in the equivalent-circuit burden B which is represented by a single equivalent inductance L and a single equivalent inductance R, representing all of the burdens combined, except for the compensating burden B' which is added in accordance with my invention.

Equation 4 states that the compensator-capacitance C, in farads, is equal to L/R^2, where L is the inductance, in henrys, and R is the resistance, in ohms, of the equivalent combined impedance of all of the parallel-connected burdens which are being compensated. It is not necessary for each of these parallel-connected burdens to have precisely the same ratio of inductance to resistance. The necessary value of the compensating reactance C depends only on the impedance of the total burden, as stated. Sometimes, acceptable results are obtained when the value of the compensating impedance $(R-j/wC)$ only approximately satisfies the required conditions, which are: (*a*) that the compensator-resistance shall be equal to the total or equivalent burden-resistance, and (*b*) that the compensator-capacitance shall be equal to the equivalent burden-inductance divided by the square of the equivalent burden-resistance.

While I have described my invention in accordance with a single illustrative form of embodiment, and in connection with a particular relaying-problem involving high-speed impedance-relays, I wish it to be understood that my invention is not altogether limited in these particulars. I desire, therefore, that the appended claims shall be accorded the broadest construction consistent with their language.

I claim as my invention:

1. The combination of an alternating-current input-circuit, a burden connected thereto and having any equivalent burden-inductance and any equivalent serially connected burden-resistance, and a capacitive-impedance compensator-device connected in shunt to said burden and having a compensator-resistance which is substantially equal to the equivalent burden-resistance, and a serially connected compensator-capacitance (in farads) which is substantially equal to the equivalent burden-inductance (in henrys) divided by the square of the equivalent burden-resistance (in ohms), whereby the combined load on said input-circuit is substantially a pure resistance over a range of frequencies of the input circuit.

2. The combination with an alternating-current power-line, of a potential-device including a tapped capacitance-divider for supplying a reduced line-voltage, a burden connected thereto and having any equivalent serially connected burden-inductance and any equivalent burden-resistance, and a capacitive impedance compensator-device connected in shunt to said burden and having a compensator-resistance which is substantially equal to the equivalent burden-resistance, and a serially connected compensator-capacitance (in farads) which is substantially equal to the equivalent burden-inductance (in henrys) divided by the square of the equivalent burden-resistance (in ohms), whereby the combined load on said capacitance-divider is sub-

stantially a pure resistance over a range of frequencies of the power-line.

3. The combination with an alternating-current power-line, of a potential-device for deriving a reduced line-voltage, a burden connected thereto, including the voltage-coil of a high-speed impedance-relay connected in shunt across the output-circuit of said potential-device, said burden having any equivalent burden-inductance and any equivalent serially connected burden-resistance, and a capacitive-impedance compensator-device connected in shunt to said burden and having a compensator-resistance which is substantially equal to the equivalent burden-resistance, and a serially connected compensator-capacitance (in farads) which is substantially equal to the equivalent burden-inductance (in henrys) divided by the square of the equivalent burden-resistance (in ohms), whereby the combined load on said potential-device is substantially a pure resistance over a range of frequencies of the power-line.

4. The combination with an alternating-current power-line, of a potential-device including a tapped capacitance-divider for deriving a reduced line voltage, a burden connected thereto, including the voltage-coil of a high-speed impedance-relay connected in shunt across the output circuit of said potential-device, said burden having any equivalent burden-inductance and any equivalent serially connected burden-resistance,

and a capacitive-impedance compensator-device connected in shunt to said burden and having a compensator-resistance which is substantially equal to the equivalent burden-resistance, and a serially connected compensator-capacitance (in farads) which is substantially equal to the equivalent burden-inductance (in henrys) divided by the square of the equivalent burden-resistance (in ohms), whereby the combined load on said potential-device is substantially a pure resistance over a range of frequencies of the power-line, and whereby said impedance-relay is substantially free of faulty operations within the rating of the potential device, notwithstanding deviations in the line-frequency.

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