Nov. 30, 1937. H. WALTER 2,100,458

ELECTRICAL CIRCUIT WITH MODULATING OR RECTIFYING DEVICES

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Fig. 1

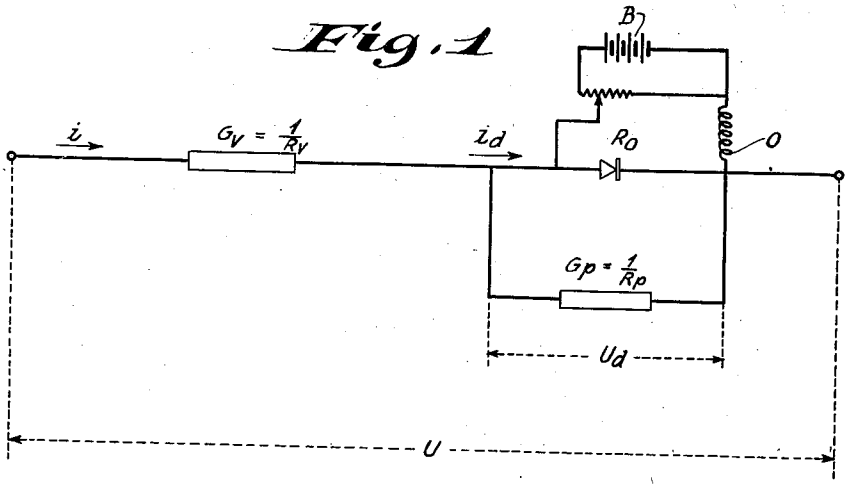
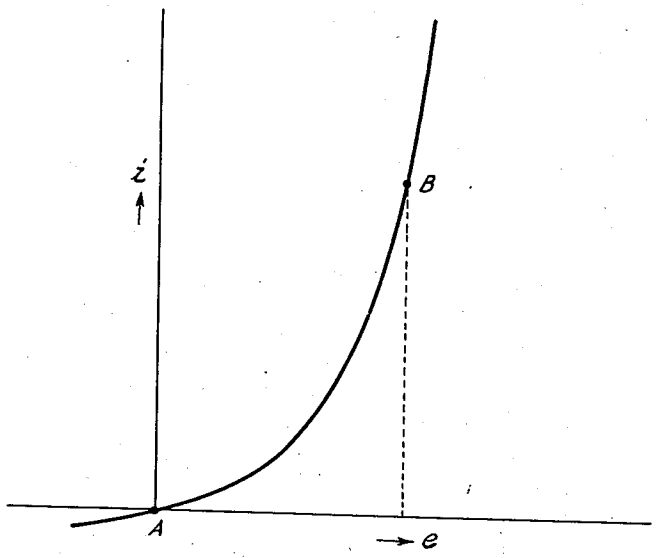


Fig. 2



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ELECTRICAL CIRCUIT WITH MODULATING OR RECTIFYING DEVICES

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5 Claims. (Cl. 250—21)

This invention relates to electrical circuits which include modulating or rectifying devices. It is apparent that distortionless modulation or rectification would result, if a rectilinear relation between input current and output voltage existed in the modulator or rectifier. Such an ideal condition has never been produced in known modulating or rectifying circuits. Moreover, departing from this relation in the operation of vacuum or gas filled tubes, as well as in rectifiers of the dry cell type, such as copper oxide rectifiers in circuits known heretofore produces distorting harmonics in the output of the rectifier or modulator.

One object of the invention is to increase the power output without increasing distortion. Another object is to decrease distortion without decreasing power output. Still another object is to approach an ideal modulating or rectifying device.

The present invention is based on the following knowledge: In modulating or rectifying circuits combined with resistances in parallel or series arrangement the coefficient of the third harmonic of the equation giving the relation between the instantaneous values of applied voltage and resulting current may be represented by an equation having positive and negative terms. In accordance with the present invention it is proposed to overcome the disadvantages of the known modulating or rectifying devices by such a dimensioning of the resistances combined with the modulator or rectifier, that the coefficient of the third or higher harmonics is zero.

The invention may now be more fully understood by reference to the following description, when read in connection with the accompanying drawing, Figure 1 of which illustrates an electrical rectifying circuit and Figure 2 of which shows a curve of a known rectifying device of the dry cell type such as copper oxide.

In Figure 1 R_0 is a rectifier with the alternating current resistance R_0. The rectifier R_0 in series with a resistance of the conductance G_v is connected with a source of electromotive force, the voltage of which is u. A resistance of the conductance G_p is connected in parallel with the rectifier. The voltage across the parallel resistance is designated with u_d. The relation between the current i_d and the voltage u_d is determined by physical qualities of the rectifier and may be expressed by the equation

$$(1) \qquad i_d=\alpha_d.u_d+\beta_d.u_d^2+\gamma_d.u_d^3+ \ldots$$

(α_d, β_d, γ_d are coefficients, characterizing the qualtities of the rectifier.)

The corresponding relation between the resulting current i and the voltage u is given by the expression

$$(2) \qquad i=\alpha.u+\beta.u^2+\gamma.u^3+ \ldots$$

From Equations (1) and (2) and the well known laws of Kirchhoff the coefficients α, β, γ are seen to be

$$(3) \qquad \alpha=\frac{G_v}{G}(G_p+\alpha_d)$$

$$(4) \qquad \beta=\left(\frac{G_v}{G}\right)^3\beta_d$$

$$(5) \qquad \gamma=\left(\frac{G_v}{G}\right)^4\left(\gamma_d-\frac{2\beta^2_d}{G}\right)$$

$G=G_v+G_p+\alpha_d$ is the conductance between the rectifier terminals of the circuit.

In accordance with the idea of the invention the resulting conductance G is so dimensioned, that the Equation (2) contains no terms of third harmonics. Therefore it follows the expression:

$$(6) \qquad G=\frac{2.\beta_d^2}{\gamma_d}$$

It is to be seen, that by suitable dimensioning of the resistances combined with the rectifier the distortion occurring from the third harmonics may be decreased or fully eliminated. By corresponding dimensioning also the fourth harmonics can be eliminated instead of the third harmonics. This dimension is importane e. g. for detector measuring apparatus in which the third harmonics do not generate direct current and are therefore allowed.

The Equation (6) can also be satisfied without the presence of the parallel resistance G_p. It is possible to satisfy this equation only by suitable dimension of the resistance combined in series with the modulating or rectifying device. In omitting the resistance combined in parallel with the rectifier ($G_p=0$) it follows for the resulting conductance the expression

$$G=G_v+\alpha_d$$

Therefore from Equation (6) the relation for the dimension of the conductance of the series resistances is given by the equation

$$(7) \qquad G_v=\frac{2\beta^2_d}{\gamma_d}-\alpha_d$$

The characteristic of a rectifier device with dry cells (comprising e. g. a metallic member such as a copper or iron plate, having a coating of a compound such as an oxide of the metal formed

directly thereon) can be given approximately by the following exponential function:

$$(8)\quad i_d=\frac{1}{R_0.c_r}(e^{c_r.u_d}-1)=\frac{1}{R_0}u_d+\frac{c_r}{R_02}u_d^2+\frac{c_r^2}{R_03}u_d^3+\ \ldots$$

(c_r represents the rectifying constant of the rectifier, R_0 represents the algebraic sum of the resistances of the circuit (as to the undesired harmonic) when the desired relation is secured to reduce the coefficient of the higher harmonics to zero. The derivation of the equation referred above to is given in an article by Dr. Kaden in the journal "Hochfrequenztechnik und Elektroakustik" vol. 39, issue 1932, page 115.)

Substituting from Equation (8) in Equation (1) we have the following coefficients

$$(9)\qquad \alpha_d=\frac{1}{R_0},\ \beta_d=\frac{c_r}{2R_0},\ \alpha_d=\frac{c_r^2}{6R_0}$$

By inserting these three coefficients in Equation (7) we get the expression

$$(10)\qquad \frac{1}{G_v}=R_v=\frac{R_0}{2}$$

as the characteristic equation for the elimination of the third harmonics.

According to the invention the resistance combined in series with the modulating or rectifying devices is so chosen, that its value is the half of the alternating current resistance of the rectifier or modulator.

The resistance being so dimensioned the power output can be increased. The increasing of the power output is restricted by the generating of fourth harmonics of inadmissible value. Practically the invention permits increase of the power output while distortion is held within the same value as is usual in circuits not dimensioned according to the present invention. The invention permits the distortion to be diminished if the power output is maintained at the same value as in circuits not arranged in accordance with the present invention.

The derivation of the equations referred to above was made without considering the capacity of the modulating or rectifying device. Above a certain frequency this capacity varies the resulting equations.

The capacitance of the rectifier ought to be considered, if it cannot be neglected compared with the alternating current resistance R_0. According to another idea of the present invention the influence of the rectifier capacity is decreased to such a small degree that it may be neglected. For this purpose the alternating current resistance R_0 of the modulating or rectifying device is decreased by a suitable biasing potential from a source B connected as shown. The usual choke coil D may be included in the biasing circuit to prevent the alternating current from reaching the biasing source. This automatically causes the upper cut-off frequency of the rectifier to increase. Figure 2 shows the relation between the current i and the voltage e of a copper oxide rectifier of normal construction. The slope of this curve for a certain voltage is proportional to the reciprocal of the resistance R_0 for this voltage. It is apparent that at the point B of the curve the current varies in a greater degree when voltage varies than at the point A. It will be seen, that the alternating current resistance R_0 of the modulating or rectifying devices decreases substantially by increasing of the biasing potential.

By moving the point on the resistance in series with B and changing the biasing potential of the rectifier the upper cut-off frequency of the circuit can be adjusted to the value required.

Another object of the present invention is to compensate for the dependence on temperature of the alternating current resistance. It is known, that for copper oxide rectifiers this dependance has a large value. The alternating current resistance change amounts to 40 per cent (when temperature increases 10%). According to the invention the biasing potential is always so regulated that the alternating current of the rectifier always has the same suitable value.

The regulating of the rectifier or modulator resistance in accordance with the invention is not restricted to the compensation for undesired harmonics referred above to. The invention is also applicable for all other circuits with rectifying or modulating devices e. g. for electrical measuring apparatus. By suitable regulating of the biasing potential the alternating current resistance of the rectifier may be kept constant or may be essentially decreased. The decreasing of the alternating current resistance of the rectifier not only increases the upper cut-off frequency but also the power output. The known method of decreasing the rectifier resistance was to combine a suitable number of rectifiers in parallel. Compared with this method the present invention causes a substantial reducing of means. In the scope of the invention it is possible, to regulate automaticaly the biasing potential with means well known to those skilled in the art.

It will be obvious that the general principles herein disclosed may be embodied in many other forms different from those illustrated, without departing from the spirit of the invention as defined in the following claims.

What is claimed is:

1. In an electrical circuit, a rectifying device, a resistance in series with said device, means for applying alternating current wave energy to said device and resistance, and a second resistance in parallel with said device, said resistances being so dimensioned that the conductance of the resistance in parallel with said rectifying device is practically null with respect to the applied alternating current and the conductance G_v of the resistance connected in series with said rectifying device with respect to said applied alternating current is determined by the expression

$$\frac{2\beta^2_d}{\gamma_d}-\alpha_d$$

wherein α_d, β_d, γ_d, denote the coefficients of the current-voltage i_d, u_d characteristic

$$i_d=\alpha_d.u_d+\beta_d.u_d^2+\gamma_d.u_d^3+\ \ldots$$

of the rectifying device.

2. In an electrical circuit, a translating device having a substantially exponential voltage ampere characteristic, means for applying alternating current wave energy thereto, a resistance in series with said device, said resistance having a conductance

$$G_v=\frac{2\beta^2_d}{\gamma_d}-\alpha_d$$

wherein α_d, β_d, γ_d denote the coefficient of the current-voltage i_d, u_d characteristic

$$i_d=\alpha_d.u_d+\beta_d.u_d^2+\gamma_d.u_d^3+\ \ldots$$

of the translating device.

3. An electrical circuit as recited in claim 2 in

which said translating device is a rectifier of the copper oxide type.

4. An electrical circuit as recited in claim 2 in which an adjustable source of potential is connected in shunt with said translating device, whereby the ratio between the resistance of the translating device and the capacity of the translating device may be adjusted when the frequency of the applied alternating current is changed.

5. In an electrical circuit, a rectifying device, a resistance

$$\frac{1}{G_v}$$

in series with said device, means for applying alternating current wave energy to said rectifying device and resistance, and a second resistance

$$\frac{1}{G_p}$$

in parallel with said device, said second resistance having a value such that

$$G_p + G_v = \frac{2\beta^2_d}{\gamma_d} - \alpha_d$$

wherein α_d, β_d, γ_d, denote the coefficients of the current voltage i_d, u_d characteristic . . .

$$i_d = \alpha_d . u_d + \beta_d . u_d^2 + \gamma_d . u_d^3 + \ldots$$

of the rectifying device.

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