Title: THE METHOD OF PARTIAL INVERSION IN RELAY CIRCUITS by

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The Method of Partial Inversion in Relay Circuits

[Note: Below is a translation of a Russian article which appeared in the Electrotechnical Section of Doklady Akademii Nauk SSSR, Vol LXXV No 5, pp 685-7 (11 Dec'50). The authors are V. A. Khvoshchuk and M. A. Gavrilov; Academician V. C. Kulebakin submitted the article 4 Oct'50.]

As is known, to any relay circuit, which contains the reacting organs of the executive elements and the contact circuits acting on them, there corresponds a so-called inverse circuit, which is identical in operation to the first circuit and is obtained from it by one's replacing in the first circuit all connections by their opposites (that is, all series connections are replaced by parallel connections and vice versa) and by one's substituting in place of each element of the original circuit the element's inverse. See M. A. Gavrilov's Teoriya Releyno-kontaktnykh Skhem (Theory of Relay-Contact Circuits) published 1950 by the Academy of Sciences of the USSR.

For example, the circuit in figure 1a has as is easily noted the same operation as the circuit in figure 1b, which is obtained from the first circuit by the above-indicated operations. In both of these schemes the circuits acting upon elements X_1 and X_2 have the following form:

$$F_{(X_1)} = a(b+c)d \quad \text{and} \quad F_{(X_2)} = \bar{a} \cdot ef.$$

The operation of complete inversion is applied, as is strictly shown, to all relay circuits without exception and is realized if the circuit is described analytically by one's taking the negative of the circuit's structural formula. For example, the structural formula for figure 1a is described in the following manner:

$$F = a(b+c)dX_1 + \bar{a} \cdot efX_2 \quad .$$

If one takes its inverse, one then obtains:

$$\bar{F} = (\bar{a} + \bar{b} \cdot \bar{c} + \bar{d} + \bar{X}_1)(a + \bar{e} + \bar{f} + \bar{X}_2) \quad .$$

This structural formula will correspond to the circuit in figure 1b.

If the circuit under consideration has bridge connections and, because of this, cannot be described with the aid of the signs for series and parallel connections, then the circuit's transformation to the inverse circuit is carried out graphically, as shown in Gavrilov's book mentioned above.

The inverse circuits possess the following defect: in the nonoperative state the reacting organs of the executive elements in them are shunted by contact circuits, thanks to which the input point of the circuit turns out to be short-circuited with the output point (see figure 1b). Such circuits, therefore, are connected with an additional resistance, which prevents the source from being short-circuited when the circuit is in the nonoperative state: otherwise in this case the current source must be disconnected from such circuits.

In actual practical relay devices one makes use of the so-called "polarized" circuit schemes, which according to the principle governing the connection of executive elements can belong to the inverse circuit schemes; these do not have the above-indicated defect. For example, the circuit in figure 1a will have the form shown in figure 1c when it employs a polarized connection of the executive elements X_1 and X_2. This circuit is identical in operation to the circuit in figure 1b; however when the circuit is in the nonoperative state its input and output points are not short-circuited.

Below we shall propose a general method for constructing polarized circuits. As is easily shown, these circuits are obtained for certain particular cases of relay circuits with the aid of partial inversion; that is, by using

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the above-indicated rules for not all of the elements but only a certain part of them. For example, if we designate the individual parts of the circuit shown in figure 1a as represented in figure 1d; that is, represent its structural formula in the following form:

$$F = F'_1 \cdot F'_1 + F'_2 \cdot F_2 \quad , \qquad (1)$$

then the circuit in figure 1b is described as follows:

$$F = (\bar{F}'_1 + \bar{F}_1)(\bar{F}'_2 + \bar{F}_2) \quad , \qquad (2)$$

while the structural formula for figure 1c is described in the following form:

$$F = (\bar{F}_1 + F_1)(\bar{F}_2 + F_2) \quad . \qquad (3)$$

These expressions indicate that complete inversion takes place in figure 1b, whereas in figure 1c inversion is effected only relative to parts, F_1 and F_2, of the circuit; within these parts the elements of the circuit are not inverted.

We shall assume that in such cases circuits of the type in figure 1a are transformable in circuits of the type in figure 1d.

Let us be interested in the operation of a certain element X, which is located within the part of the circuit designated in figure 1d by the symbol F_1. In the most general case, F_1 in the circuit can be circuits that are connected both in series and in parallel with the element X. Let us designate the first circuits by f'_1 and the second ones by f_1. Then the circuit in figure 1d takes the form represented in figure 2a. This circuit will represent in the general form the entire class of circuits under study.

For complete inversion the circuit in figure 2a is converted into the circuit in figure 2b, and for partial inversion, corresponding to figure 1f, it takes the form represented in figure 2c. Transformation of the circuit in figure 2a into the circuit in figure 2c will obviously be permissible only if the contact circuits acting on this element have one and the same form.

The structural formula of the circuit in figure 2a is as follows:

$$F = F'_1\,(f'_1 X + f_1) + F'_2 F_2 = F'_1 f'_1 X + F'_1 f_1 + F'_2 F_2 \quad . \qquad (4)$$

The circuit of element X will be closed when the contact circuits connected in series with X are closed and the circuits connected in parallel with X are disconnected. Therefore we have:

$$F(x) = F'_1\, f'_1\,\overline{(F'_1 f_1 + F'_2 F_2)} = F'_1 f'_1 (\bar{F}'_1 + \bar{f}_1)(\bar{F}'_2 + \bar{F}_2)$$
$$= F'_1 f'_1 \bar{f}_1\,(\bar{F}'_2 + \bar{F}_2) \quad . \qquad (5)$$

The structural formula of the circuit in figure 2c is:

$$F' = (\bar{F}'_1 + f'_1 X + f_1)(\bar{F}'_2 + F_2) = f'_1 X(\bar{F}'_2 + F_2) + (\bar{F}'_1 + f_1)(\bar{F}'_2 + F_2) \quad . \qquad (6)$$

The circuits acting upon the element X in this circuit are:

$$F'(x) = f'_1(\bar{F}'_2 + F_2)\,\overline{(\bar{F}'_1 + f_1)(\bar{F}'_2 + F_2)}$$
$$= f'_1(\bar{F}'_2 + F_2)\,(F'_1 \bar{f}_1 + F'_2 \bar{F}_2) = F'_1 f'_1 \bar{f}_1 (\bar{F}'_2 + F_2) \quad . \qquad (7)$$

Expressions (5) and (7) will be equal with each other only if the parentheses in both expressions are equal to unity. This will occur for the following conditions:

$$\text{(a)}\ \ \bar{F}'_2 = F'_1 \ , \quad \text{(b)}\ \ \bar{F}'_2 = f'_1 \ , \quad \text{(c)}\ \ \bar{F}'_2 = \bar{f}_1$$

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If a reacting organ of an executive element is contained in the circuit of F_2 also, then these conditions must be maintained also relative to the circuits F'_1 , f_2 , and f'_2 .

The relations obtained above are the bases for the method of constructing polarized circuits and determine the limits of applicability of the method.

-- end --

Figure 1

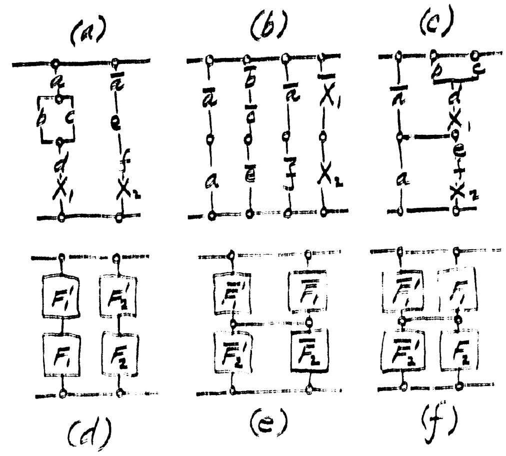

Figure 2