

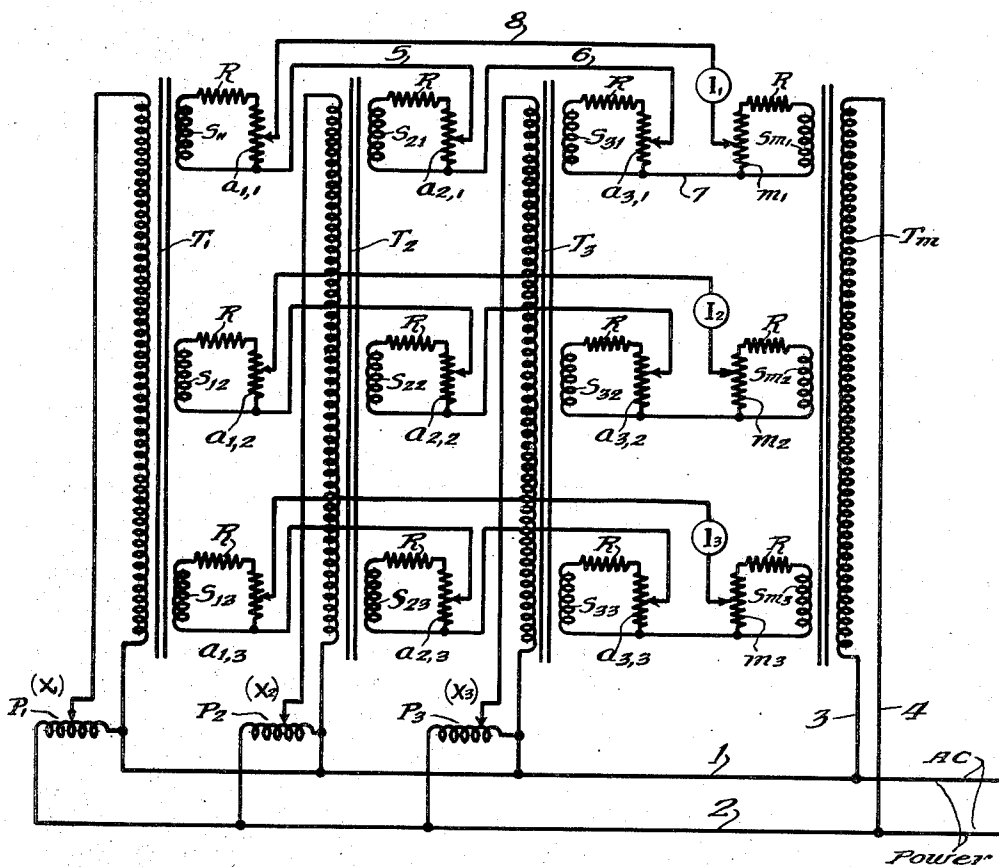
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ELECTRICAL COMPUTER

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ELECTRICAL COMPUTER

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This invention relates to an improved electrical computer for use in solving linear simultaneous equations. More specifically the invention is an electrical apparatus having a plurality of transformers in specially arranged circuits whereby a plurality of simultaneous equations, such as the type, $\sum_i A_{ij} X_j = M_i$ may be solved.

In connection with present day research on analysis work, it is frequently necessary to solve many simultaneous equations to determine the desired mathematical values. As a result, there are now available various electrical computers which save a considerable amount of time for their users.

Briefly, the improved electrical computer of this invention comprises in combination a plurality of $n+1$ identical transformers, where n is the number of unknowns which may be handled by the particular apparatus, with each transformer having a multiple number, n of identical secondaries, an alternating current voltage supply connecting to each primary of each of the plurality of transformers, means for dividing or controlling the voltage supply to all but one of the primaries of the series of identical transformers, additional voltage dividing means connecting to each of the identical secondaries providing thereby means to individually adjust the voltage output from each secondary, lines connecting a secondary and accompanying voltage dividing means from each of the transformers into a multiple number of n circuits, current or voltage indicating means, and means connecting the latter to each of the circuits between the secondary of the transformer normally having no voltage adjustment means connecting to its primary coil and the remaining serially connected secondaries of each of the identical transformers, whereby each circuit may be individually balanced upon adjusting the voltage dividers at each secondary to known values obtained from each linear equation, and the variable voltage dividing means connecting to each primary of each transformer is successively adjusted to provide a balancing of all circuits.

This transformer type of apparatus has an advantage over most of the present types of voltage dividing computers, in that it has a simpler construction and may be operated in an easy manner. Desirable control features may also be readily adapted to or incorporated with, this improved computer to provide an efficient and rapidly operated machine. For example, with the use of servo-motors in combination therewith, the apparatus may be made to readily handle slowly converging systems of equations which can not be easily solved on the usual manually operated computer. Also, with the servo-motor embodiment of the computer, it may be made to operate substantially automatically and thereby

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eliminate the otherwise necessary manual readjustment of the potentiometers to effect the balancing operation. Certain of these additional features will be more fully described and explained following the description of the construction and operation of the basic transformer type of simultaneous equation computer.

The accompanying drawing illustrates diagrammatically and in a simplified embodiment, the arrangement of the identical transformers and of the circuits which make up the computing apparatus. It should be understood that the apparatus is not to be limited in any way by the number of transformers indicated in the drawing, for the computer may well contain any number of transformers and circuits to permit its use in solving any number of unknowns.

Referring now to the drawing, there are indicated therein a plurality of identical transformers T_1, T_2, T_3 and T_m . Each of the transformers have identical primary coils and a multiple number n of identical secondaries. The secondaries of the first transformer T_1 are indicated by the symbol S_{11}, S_{12} , and S_{13} . The secondaries of the next transformer T_2 , are indicated by the symbols S_{21}, S_{22} , etc. and the secondaries of the remaining transformers are similarly designated by the mark S with suitable sub numbers, except for the last transformer of the series T_m , where the secondaries are indicated by the symbols S_{m1}, S_{m2} , and S_{m3} .

An alternating current is supplied to the primary of each of the transformers by way of lines 1 and 2, however, the voltage to each of the primary coils of each of the transformers is controlled by a variable voltage divider, such as, potentiometers P_1, P_2 and P_3 , auto-transformers, or the like, which connect between the supply lines 1 and 2 at each of the primary coils T_1, T_2 , and T_3 . The primary coil of the transformer T_m may operate on the full voltage and it is therefore unnecessary that a voltage dividing means be placed across the lines 3 and 4 which connect to this transformer.

In the embodiment illustrated, each of the secondaries from each of the transformers has a resistance R connected in series therewith, for the purposes of limiting the currents when the circuits are out of balance, without any appreciable loss in sensitivity of reaching a balance. However, it may be pointed out, that with the use of suitable current or voltage indicating means in the apparatus, that the R resistors may be unnecessary. Also, connecting across each secondary at each transformer T_1, T_2 and T_3 , are potentiometers or other voltage dividing means $a_1, 1, a_1, 2, a_1, 3, a_2, 1, a_2, 2$, etc., while across each of the secondary coils of the transformer T_m are the voltage dividers m_1, m_2 and m_3 .

One secondary coil, with its accompanying re-

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istance and potentiometer, from each of the plurality of transformers is connected into a balanceable circuit. There are thus formed a multiplicity of similar circuits, one for each of the secondary coils for each transformer. Upon referring to the drawing, it may be seen that each of the secondaries S_{11} , S_{21} , S_{31} and S_{m1} are formed into a circuit, the line 5 connecting one end of the secondary coil S_{11} with the center tap of the adjustable voltage divider $a_{2,1}$, the line 6 connecting coil S_{21} with the center tap of $a_{3,1}$, and line 7 connecting the secondary coil S_{31} with the secondary coil S_{m1} , while line 8 connects the center taps of $a_{1,1}$ and m_1 together to make a closed circuit. Connecting into line 8 is an indicating meter I , such that it may be observed when there is a current flow through the circuit, or more particularly, it may be observed when the circuit reaches a balance, with no current flow there-through.

In like manner, the secondaries S_{12} , S_{22} , S_{32} and S_{m2} are connected into an individual circuit, with a current indicator I_2 being connected thereto, to provide means for observing current flow within that circuit. The secondary coils S_{13} , S_{23} , S_{33} and S_{m3} are connected into still another balanceable circuit with indicator I_3 connecting thereto between the secondary coil S_{m3} and the other serially connected coils.

In each case, the adjustable potentiometers or dividers $a_{1,1}$, $a_{1,2}$, $a_{2,1}$, etc. may be calibrated to provide for the setting of numerical values thereto and to thus adjust the output from each secondary, or alternately, in a preferable embodiment of the computer, a comparison circuit may be provided with a calibrated and adjustable voltage divider, such as a decade, with suitable switching means and an indicator so that each of the aforementioned dividers may be adjusted to balance the setting on the decade or other calibrated divider of the comparison circuit.

The voltage to the primary of each transformer governs voltage output of each of the secondaries of the transformer. Thus, having given adjustments in the voltage output from the secondary coils in any one of the balanceable circuits, as determined by the set numerical values, the circuit can be balanced, to obtain no current flow, by adjusting any one of the voltage controllers P_1 , P_2 or P_3 . Each of these voltage controllers are normally operated in succession, to bring the entire computer into balance with the current indicators I_1 , I_2 , etc. providing means for telling whether or not a particular circuit is in balance.

To illustrate further the operation of the computer, let it be assumed the value of a series of unknowns x_1 , x_2 and x_3 are desired in the linear simultaneous equations of the type:

$$\begin{aligned} a_{1,1}x_1 + a_{2,1}x_2 + a_{3,1}x_3 &= m_1 \\ a_{1,2}x_1 + a_{2,2}x_2 + a_{3,2}x_3 &= m_2 \\ a_{1,3}x_1 + a_{2,3}x_2 + a_{3,3}x_3 &= m_3 \end{aligned}$$

wherein the a and m values are known. With individually calibrated potentiometers in the device, $a_{1,1}$, $a_{1,2}$ and $a_{1,3}$ potentiometers connecting to each of the secondary coils of T_1 are adjusted to the known values $a_{1,1}$, $a_{1,2}$, and $a_{1,3}$. In like manner the other " a " coefficients are set on to the voltage dividers $a_{2,1}$ and $a_{3,1}$, etc., of the secondary coils of the transformers T_2 and T_3 . The known m values are set into the adjustable voltage dividers m_1 , m_2 and m_3 which connect with the secondaries of the transformer T_m . The apparatus is thus made ready for balancing and

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the upper circuit may be balanced by adjusting the controller P_1 so that the indicator I_1 shows that there is no flow of current within the circuit. The controllers P_2 and P_3 are then adjusted in succession to balance the other circuits of the apparatus. Upon adjusting each succeeding controller, the preceding balanced circuit is thrown out of adjustment, since the voltage from each secondary of a transformer varies with the voltage supply to the primary. It is therefore necessary to repeat the adjustment of the controllers P_1 , P_2 and P_3 in a step-wise manner to effect the successive approximations and the final balancing of all circuits. Normally, only a few readjustments are necessary to effect a substantially accurate solution.

The desired x values x_1 , x_2 , and x_3 may be determined from the voltage across any one of the voltage dividers in the secondaries of each of the transformers T_1 , T_2 and T_3 , since each secondary is identical in each of the transformers. In an alternate and desirable construction of the unit, the variable controllers P_1 , P_2 , etc. may be selected in manner which would yield the voltage output from each of the secondary coils of the plurality of transformer T_1 , T_2 , etc. In other words, by proper calibration of the adjustment dial of each controller P_1 , P_2 , etc., the x_1 value may be read directly from the resulting setting of the controller P_1 , the resulting x_2 value may be determined from the resulting setting of the controller P_2 and the x_3 value may be determined directly from the resulting setting of the controller P_3 .

The accompanying drawing and the operation which has been described hereinabove is of course limited to solving 3 unknown values from 3 simultaneous equations, but as noted hereinabove, this transformer type of electrical computer need not be limited to any fixed number of transformers and to solving any set number of simultaneous equations.

In a preferred embodiment, suitable switching is connected to each of the secondaries of each of the transformers whereby the wires are reversed to accommodate negative values of a and m . Also, switching means may be connected with each of the voltage controllers, P_1 , P_2 , etc. so that the wires to them may be reversed and negative values of x may be read and determined from each of the latter.

A preferred embodiment of the apparatus should have still another variation from the diagrammatic construction and arrangement indicated in the accompanying drawing, in that, by the use of suitable switching connecting to each circuit, a comparison circuit with a single indicator, "electric-eye," or other such device, may be connected successively with each of the circuits, with the result that it is unnecessary to have the plurality of current indicators I_1 , I_2 , I_3 , that are shown in the basic diagram.

A still further desirable feature of this type of electrical computer embodies the use of amplification means and servo-motors in place of each of the current indicators I_1 , I_2 , etc., so that the apparatus may operate automatically to effect a balanced solution in a very rapid manner and eliminate the otherwise necessary manual readjustment of the potentiometers, variable auto-transformers or other variable voltage dividing means to effect the successive balancing operation. The proper controls which will provide balanced circuits may be adjusted to a zero or null value so that each servo-motor, in each

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of the plurality of circuits controls its respective transformer primary coil to keep the particular circuit in balance. Thus, it may be seen in this automatic type of computer, that each unbalanced circuit would have a servo-motor to mechanically operate an adjustable voltage controller connecting to each transformer and all motors would operate to effect a simultaneous balancing of all circuits and provide a rapid solution of the simultaneous equations. A principal advantage of the servo-motor operated embodiment of this invention, lies not only in the entire mechanical operation, but in the rapid solution of slowly converging systems of equations, not usually considered feasible with manually adjusted computers which work on only one equation at one time.

We claim as our invention:

1. An electrical computer for solving linear simultaneous equations which comprises in combination, a plurality of identical transformers, each transformer having a primary coil and a multiple number of identical secondaries, and an alternating current supply connecting to the primary coil of each transformer, adjustable voltage control means connecting across said supply to each of said primaries but one, adjustable voltage dividing means across the output from each of said secondary coils in each of said transformers, means connecting one secondary coil and its accompanying voltage regulating means from each of said transformers into series with one another and forming thereby a plurality of balanceable circuits, current indicating means and means connecting the latter with each of said balanceable circuits whereby each circuit may be adjusted to a balance and have no current flowing from one portion to another and calibrated means connective to first said adjustable voltage control means providing a measure of their resulting adjustment and a solution of said equations.

2. An electrical computer for solving for n unknown values and n linear simultaneous equations, which comprises in combination, a plurality of $n+1$ identical transformers each having a plurality of n identical secondaries, an alternating current power supply connecting to the primary coil of each of said transformers, an adjustable voltage divider connecting across said supply to each of said primaries but one, an adjustable voltage dividing means connecting across each of said secondaries from each of said transformers, means serially connecting one secondary with its accompanying voltage dividing means from each of said plurality of transformers into a plurality of n balanceable circuits, current flow indicating means connecting to each of said circuits between the secondary of the transformer having no voltage control means across its primary and the remainder of said serially connected secondaries whereby each of said circuits may be individually balanced to have no current flow therethrough upon the adjustment of one of said adjustable voltage dividers connecting to a primary coil and all of said plurality of circuits brought into balance with one another by the successive adjustment of each of said primary coil adjustable voltage dividers, and calibrated means connective to first said adjustable voltage control means providing a measure of their resulting adjustment and a solution of said equations.

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3. The electrical computing apparatus of claim 2, further characterized in that a comparison circuit having an adjustable and calibrated voltage dividing means and a single current flow indicating device is provided in combination therewith, suitable switching means connects with said circuits of said computer to selectively place said comparison circuit into operation with any one of said adjustable voltage dividing means, whereby said adjustable voltage dividers connecting with said secondaries may be set to conform with known coefficients within said simultaneous equations and each of said adjustable voltage dividers connecting with said primaries may be adjusted to balance said circuits and said equations to provide thereby resulting unknown values.

4. The electrical computing apparatus of claim 3 further characterized in that additional switching means connects to each of said circuits and is operative to selectively reverse leads at any one of said adjustable voltage dividers whereby negative coefficients in said equations may be accommodated.

5. An electrical computer for n unknown values and n simultaneous equations, which comprises in combination, a plurality of $n+1$ identical transformers each having one primary coil and a plurality of n identical secondary coils, an alternating current power supply connecting to the primary coil of each of said transformers, an adjustable and calibrated voltage divider connecting across said supply to each of said primaries but one, a current limiting resistance and an adjustable and calibrated voltage divider connecting across each of said secondaries from each of said transformers, means serially connecting one secondary from each of said plurality of transformers with its accompanying resistance and voltage divider into a plurality of n balanceable circuits, a current flow indicator connecting to each of said circuits between the secondary of the transformer having no voltage dividing means across its primary and the remainder of said serially connected secondaries of the other transformers whereby each of said circuits may be individually balanced to have no current flow therethrough, and all of said plurality of circuits brought into balance with one another by the successive adjustment of each of said primary coil adjustable voltage dividers, calibrated voltage measuring means connective with each of said transformers suitable for determining the voltage output from a secondary coil of each of said transformers, and providing thereby, subsequent to the balancing operation, the values of said unknowns and the solution of said equations.

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