

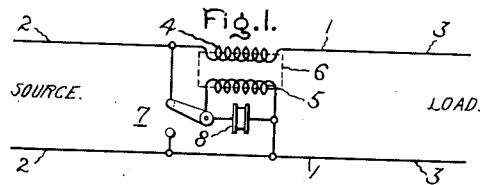
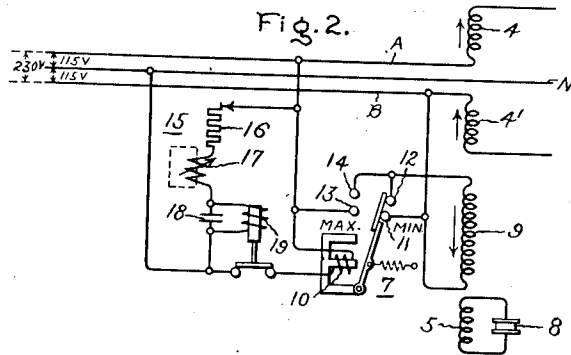
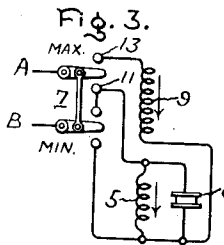
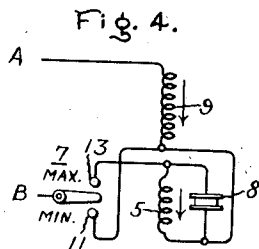
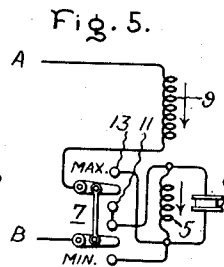
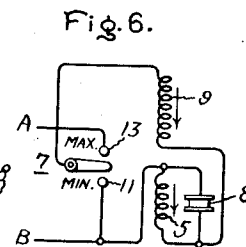
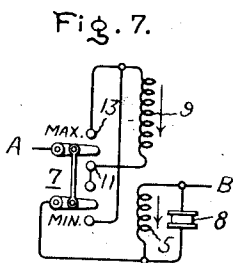
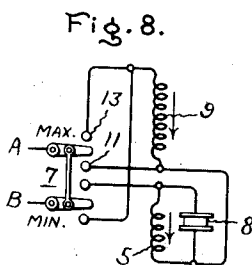
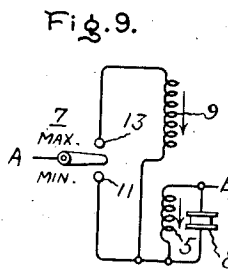
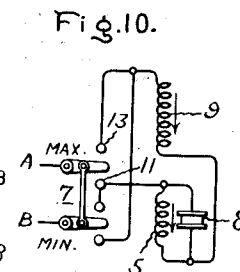
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O. P. McCARTY

2,063,693

TRANSFORMER VOLTAGE REGULATOR

Filed June 20, 1936



Inventor:
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UNITED STATES PATENT OFFICE

2,063,693

TRANSFORMER VOLTAGE REGULATOR

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New York

Application June 20, 1936, Serial No. 86,413

8 Claims. (Cl. 171-119)

My invention relates to transformer voltage regulators and more particularly to transformer voltage regulators provided with automatic means for changing the transformer ratio under load.

In changing the ratio of a voltage regulating transformer while it is under load it is very desirable that the change be made without interrupting the load current and with the production of minimum voltage disturbance in the transformer circuit. Heretofore I have done this by changing taps on the secondary or series winding of the transformer and during the tap changing operation I have caused the transformer load current to flow through a non-linear characteristic current by-pass.

In accordance with my present invention I provide a novel and simple transformer voltage regulating circuit in which the connections in the main load current carrying circuit are not changed during a regulating step and the change in voltage is secured by changing the connections of the transformer exciting winding and I provide a non-linear characteristic impedance for limiting the voltage across the exciting winding and hence, limiting the voltage drop across the secondary or series winding of the transformer during a voltage or ratio changing operation.

An object of my invention is to provide a new and improved voltage regulating transformer.

Another object of my invention is to provide a new and improved automatic transformer voltage regulator.

Another object of my invention is to provide a new and improved way of changing the ratio of a transformer under load.

My invention will be better understood from the following description taken in connection with the accompanying drawing and its scope will be pointed out in the appended claims.

In the drawing Fig. 1 is a simplified diagrammatic showing of one form of my transformer voltage varying circuit; Fig. 2 is a diagrammatic showing of an automatic transformer voltage regulator embodying my invention and which is adapted for operation on a three-wire alternating current secondary distribution circuit; and Figs. 3 to 10 inclusive illustrate various modified connections between the ratio changing switch or contactor and the transformer exciting windings for securing various different combinations of maximum and minimum voltage.

Referring now to the drawing and more par-

ticularly to Fig. 1, I have shown therein a simple two-wire alternating current circuit 1 having a source end 2 and a load end 3. Connected in the circuit 1 is a regulating transformer having a series winding 4 and a shunt or exciting winding 5, both wound on the same core which is represented by the dotted line 6.

For controlling the connections of the exciting winding 5 there is provided a single-pole, double-throw switch 7 and for limiting the impedance of the transformer during a positional change of the switch 7 a negative impedance-current characteristic impedance 8 is connected across the exciting winding 5.

The impedance 8 is preferably one or more pieces of the ceramic resistance material known as Thyrite, the composition of which is disclosed and claimed in Patent 1,822,742, granted September 8, 1931 on an application of K. B. McEachron and assigned to the assignee of the present application. This resistance material has the property of reducing its resistance instantaneously and to a very marked extent with increases in voltage across it or current through it. In fact the decrease in resistance is so great that as the current through the resistance increases its resistance decreases until the voltage drop across the resistance becomes substantially constant and independent of the current.

The switch 7 is so arranged that in one position the exciting winding 5 is connected across the circuit 1 while in the other position the winding 5 is short circuited.

In the operation of Fig. 1, when the circuit 1 is connected to a source (not shown) and the switch 7 is in the position shown, a predetermined amount of voltage boost or buck, depending upon the relative direction of the current in the windings 4 and 5, will be produced by the series winding 4 in the main circuit. The impedance 8 is so proportioned that for the normal circuit voltage its impedance or resistance is practically infinite so that substantially all of the current in the shunt circuit flows through the shunt winding 5 and substantially none of the current flows through the impedance 8. If now the switch 7 is moved to the other position the transformer will saturate, if circuit 1 is carrying load current, as the movable contact of the switch is passing from one position to the other. The effect of this saturation is to limit to a certain extent the reactance and voltage drop of the winding 4. While switch 7 is passing between its two contact making positions the series winding 4 will be acting as a primary winding and will tend to induce a rela-

tively very high voltage in the exciting winding 5. For example, if the transformer produces a 10% boost, the voltage tending to be induced in the exciting winding 5 during the operation of the switch will be ten times the circuit voltage. However, before the voltage can reach anywhere near this high value the resistance of the device 8 will decrease so much that the voltage across the exciting winding will be limited to a relatively low value which is not much higher than normal circuit voltage. The importance of this is that it causes the impedance of the regulating transformer, referred to the secondary winding 4, to be not much greater than its impedance when the exciting winding 5 is connected across the circuit. Consequently the voltage drop across the winding 4 during the operation of the switch 7 will be relatively low and will cause hardly any voltage disturbance in the circuit and will not cause lamp flicker if incandescent lamps are energized from the load end 3 of the circuit 1. As soon as the switch 7 engages the lower fixed contact the exciting winding 5 and impedance 8 will be short circuited. As the impedance of the short circuit of the winding 5 is substantially zero the impedance of the transformer as a whole will be substantially zero and no voltage buck or boost will be produced in the circuit 1.

If the switch 7 is moved back again to the upper contact the saturation of the transformer due to the load current combined with the voltage limiting effect of the impedance 8 will be the same as before until the positional change has been completed when the exciting winding will be connected across the circuit and a definite voltage boost or buck will be produced in the circuit 1.

In tests on an arrangement as shown in Fig. 1 in which the load voltage was 220 volts and the transformer produced a 10% voltage boost of 22 volts and the load current was 33 amperes, the current switched by the switch 7 was 3.3 amperes and the switch made 350,000 operations with practically no wear on the contacts.

From the above description of Fig. 1 it will be seen that no switching operation takes place in the main load current carrying circuit and that the switching current during the regulating operation is very much less than the main load current so that the switch may be made smaller and less expensive than a switch capable of carrying the main load current. Furthermore, the negative impedance-current characteristic impedance 8 may be made of small size and consequently at low cost in comparison with an ordinary load current by-pass impedance of this type which is capable of carrying the entire circuit load current.

The complete automatic voltage regulator shown in Fig. 2 is made for operation in a three-wire alternating current secondary distribution circuit. This circuit has outer conductors A and B and a neutral conductor N. The usual voltage of such circuits is 230 volts between the outer conductors and 115 volts between each outer conductor and the neutral, as is indicated at the left-hand or source end of the circuit. The regulating transformer is provided with two series windings 4 and 4' connected respectively in the outer conductors A and B. This transformer is also provided with two separate exciting windings 5 and 9. The winding 5 corresponds to the same winding in Fig. 1 and has the negative impedance-current characteristic impedance 8 connected in parallel therewith.

The switch 7 is arranged to be operated electromagnetically by means of the winding 10. It is arranged to provide double breaks in the circuit in both directions of operation and has no flexible connection to the moving parts. As shown, it has a movable bridging contact member which in the illustrated position is connecting two contacts 11 and 12 and in the other position will bridge two contacts 13 and 14. Essentially, however, it is a single-pole, double-throw switch.

The terminals of the winding 9 are connected respectively to the contacts 11 and 12 so that the winding 9 is short circuited when the switch 7 is in the position shown. This position will be referred to as the minimum position of the switch. The contacts 12 and 14 are interconnected by a jumper and contacts 13 and 11 are connected respectively to the line conductors A and B. With this arrangement, when the coil 10 is energized the switch moves over to its other or maximum position and as the bridging member engages contacts 13 and 14 the winding 9 will be connected between the line conductors A and B. Consequently, the exciting winding 9 will be energized in such a manner as to induce a regulating voltage boost in the secondary or series windings 4 and 4'.

Switch 7 is controlled automatically in response to voltage by means of a known type of resonant relay 15 comprising an adjustable resistance 16, an adjustable inductance 17 and a capacitor 18 connected in series between the conductor A and the neutral conductor N. An auxiliary relay 19 is connected across the capacitor 18 and the contacts of this relay control the energization of the operating winding 10 of the switch 7.

The reactor 17 has a magnetically saturable core and the resonant relay circuit is so arranged that at a predetermined critical voltage the magnetic saturation of the core of reactor 17 causes the inductance of the reactor to neutralize the capacitance of the capacitor 18 throughout a portion of each cycle of the applied voltage thereby producing a condition of partial resonance in the series circuit. At a lower voltage than the critical voltage the circuit is dissonant. At resonance the current through the resonant circuit increases thereby increasing the voltage across the capacitor 18 and causing the auxiliary relay 19 to open its contacts.

The adjustments on the resistor 16 and the reactor 17 provide for adjusting the regulating band, that is to say the difference in voltage between the critical value at which the relay picks up and the value at which it drops out, and also for adjusting the drop-out voltage value of the relay 19.

The parts are shown in Fig. 2 in the position they will occupy when the system is deenergized. When voltage is applied at the source end of the circuit, the winding 10 will be energized through the closed contacts of the relay 19 and the switch 7 will be bridging the contacts 13 and 14 thereby energizing the shunt winding 9 and causing a predetermined voltage boost in the circuit. If the circuit voltage increases to the critical value relay 19 will pick up thereby deenergizing the winding 10 and causing the switch 7 to snap over to its minimum position in which the contacts 11 and 12 are bridged thereby to short circuit the winding 9.

While the switch 7 is changing positions the regulating transformer saturates as in Fig. 1 and the voltage and the impedance of the transformer

are limited by the negative characteristic of the impedance 8 because as the winding 5 is on the same core as the other windings it is inductively coupled to all of them. As soon as the switch 7 reaches its minimum position and the winding 9 is short circuited the impedance of the transformer with respect to the main circuit is substantially zero, so that the regulator may be said to be in its neutral position as it is neither bucking nor boosting. If now the voltage falls below the critical value the resonant circuit becomes dissonant, relay 19 closes thereby energizing winding 10 causing the switch 7 to move over to its maximum position and energize the winding 9 so as to cause a desired voltage boost in the main circuit.

The regulator of Fig. 2 can easily be adapted for use with two-wire instead of three-wire circuits by merely making an interconnection between the conductors B and N. In this case the voltage applied to the exciting winding or windings of the transformer will be half that with the three-wire circuit and consequently the regulating voltages will be half of what they would be for three-wire operation.

If the ratio of the number of turns of the exciting windings 9 and 5 is 3 to 2 it is possible by changing the connections between these windings and the switch 7 to secure a great many different ranges of regulation. First, if the winding 9 when excited alone across the conductors A and B produces a six-volt raise or boost, then reversing this connection will produce a six-volt buck or lower. If now the contacts 11 and 12 of switch 7 are connected to the winding 5 instead of to the winding 9 the difference in turns between the winding 5 and the winding 9 will cause the winding 5 to produce a nine-volt raise if the connections correspond to those in the drawing but if they are reversed they will produce a nine-volt lower. Incidentally, this connection corresponds to that shown in Fig. 1 in that the winding 5 is alternately short circuited and excited across the main circuit. If now the windings 5 and 9 are connected differentially in series the number of effective turns will be half the number of turns in the winding 5. Consequently, with this differential connection it is possible to secure either an 18-volt raise or an 18-volt lower. If now the windings are connected in series cumulatively instead of differentially the number of effective turns will be five times that of the differential connection so that the voltage will be $\frac{1}{5}$ of the voltage of the differential connection. That is to say, it will be 3.6 volts either raise or lower, depending upon the polarity of the connections to the series cumulative connection.

In the following table are listed all the various combinations of the above connections so as to give in all 36 different ranges of regulation. Each of the first eight of the listed connections are illustrated in one of the detailed Figures 3 to 10, inclusive, and in the table each figure in the drawing, including Figs. 1 and 2, corresponding to each range of regulation is tabulated. The voltage V will be 18 volts if the windings 5 and 9 are the same as in Fig. 2 but this need not necessarily be true. However, the table is based on a ratio of turns in the windings 9 and 5, of 3 to 2. Other ratios may be employed if desired. The table and Figures 3 to 10 are arranged in descending order of magnitude of the maximum voltage coupled with a descending order of magnitude of the minimum voltage.

Range of regulation

Figs.	Maximum		Minimum		
	Volts	Connections	Volts	Connections	
3	+V	Winding 9 boosting in series with winding 5 bucking.	+ $\frac{1}{2}$ V	Winding 5 boosting	5
4	+V	do.	+ $\frac{1}{4}$ V	Winding 9 boosting.	10
5	+V	do.	+ $\frac{1}{8}$ V	Winding 5 boosting in series with wdg. 9 boosting.	
6	+V	do.	0	Wdgs. 9 and 5 shorted in series.	
7	+V	do.	- $\frac{1}{8}$ V	Wdg. 9 bucking in series with wdg. 5 bucking.	15
8	+V	do.	- $\frac{1}{4}$ V	Winding 9 bucking.	
9	+V	do.	- $\frac{1}{2}$ V	Winding 5 bucking.	
10	+V	do.	-V	Wdg. 5 boosting in series with wdg. 9 bucking.	
	+ $\frac{1}{2}$ V	Winding 5 boosting.	+ $\frac{1}{4}$ V	Winding 9 boosting.	20
	+ $\frac{1}{2}$ V	do.	+ $\frac{1}{8}$ V	Wdg. 5 boosting in series with wdg. 9 boosting.	
1	+ $\frac{1}{2}$ V	do.	0	Winding 5 shorted.	
	+ $\frac{1}{2}$ V	do.	- $\frac{1}{8}$ V	Wdg. 5 bucking in series with wdg. 9 bucking.	25
	+ $\frac{1}{2}$ V	do.	- $\frac{1}{4}$ V	Winding 9 bucking.	
	+ $\frac{1}{2}$ V	do.	- $\frac{1}{2}$ V	Winding 5 bucking.	
	+ $\frac{1}{2}$ V	do.	-V	Wdg. 5 boosting in series with wdg. 9 bucking.	
	+ $\frac{1}{4}$ V	Winding 9 boosting.	+ $\frac{1}{8}$ V	Wdgs. 5 and 9 in series boosting.	30
2	+ $\frac{1}{4}$ V	do.	0	Winding 9 shorted.	
	+ $\frac{1}{4}$ V	do.	- $\frac{1}{8}$ V	Wdgs. 5 and 9 in series both bucking.	
	+ $\frac{1}{4}$ V	do.	- $\frac{1}{4}$ V	Winding 9 bucking.	
	+ $\frac{1}{4}$ V	do.	- $\frac{1}{2}$ V	Winding 5 bucking.	
	+ $\frac{1}{4}$ V	do.	-V	Wdg. 9 bucking in series with wdg. 5 boosting.	35
	+ $\frac{1}{8}$ V	Wdg. 5 boosting in series with wdg. 9 boosting.	0	Wdgs. 5 and 9 shorted in series.	
	+ $\frac{1}{8}$ V	do.	- $\frac{1}{8}$ V	Wdgs. 5 and 9 in series bucking.	
	+ $\frac{1}{8}$ V	do.	- $\frac{1}{4}$ V	Winding 9 bucking.	40
	+ $\frac{1}{8}$ V	do.	- $\frac{1}{2}$ V	Winding 5 bucking.	
	+ $\frac{1}{8}$ V	do.	-V	Wdg. 9 bucking in series with wdg. 5 boosting.	
	0	Wdgs. 5 and 9 shorted in series.	- $\frac{1}{8}$ V	Wdgs. 5 and 9 in series both bucking.	
	0	Winding 9 shorted.	- $\frac{1}{4}$ V	Winding 9 bucking.	45
	0	Winding 5 shorted.	- $\frac{1}{2}$ V	Winding 5 bucking.	
	0	Wdgs. 5 and 9 shorted in series.	-V	Wdg. 9 bucking in series with wdg. 5 boosting.	
	- $\frac{1}{8}$ V	Wdg. 5 bucking in series with wdg. 9 bucking.	- $\frac{1}{4}$ V	Winding 9 bucking.	50
	- $\frac{1}{8}$ V	do.	- $\frac{1}{2}$ V	Winding 5 bucking.	
	- $\frac{1}{8}$ V	do.	-V	Wdg. 9 bucking in series with wdg. 5 boosting.	
	- $\frac{1}{4}$ V	Winding 9 bucking.	- $\frac{1}{2}$ V	Winding 5 bucking.	55
	- $\frac{1}{4}$ V	do.	-V	Wdg. 5 boosting in series with wdg. 9 bucking.	
	- $\frac{1}{2}$ V	Winding 5 bucking.	-V	Do.	

In Figs. 3 to 10, inclusive, only the switch and the exciting windings 5 and 9 are shown and it is to be understood that these figures merely represent the changes in Fig. 2 necessary to give the various ranges of regulation specified in the table.

It will be noted that in Figs. 3, 5, 7, 8, and 10 it is necessary to employ a double-pole, double-throw switch instead of the single-pole, double-throw switch shown in the other figures. This, however, can readily be done in Fig. 2 by merely adding another movable lever, and two other sets of contacts bridged thereby, to be operated by the coil 10.

In Fig. 6 it will be noted that when the switch 7 is in its minimum position the two windings 5 and 9 are short circuited in series with each other. This produces substantially the same ef-

fect as though one winding were short circuited.

While I have shown and described particular embodiments of my invention, it will be obvious to those skilled in the art that changes and modifications may be made therein and therefore I aim in the appended claims to cover all such changes and modifications as fall within the true spirit and scope of my invention.

What I claim as new and desire to secure by Letters Patent of the United States is:

1. In combination, an alternating current circuit, a transformer having a plurality of windings including a series winding in said alternating current circuit and an exciting winding, a negative impedance current characteristic impedance connected across one of the windings of said transformer other than said series winding, and a circuit controller for selectively connecting said exciting winding across said alternating current circuit and disconnecting it therefrom.

2. In combination, an alternating current circuit, a transformer having a series winding connected in said alternating current circuit and having an exciting winding, a negative impedance-current characteristic impedance connected across said exciting winding, and a circuit controller for selectively connecting said exciting winding across said alternating current circuit and short circuiting said winding.

3. In combination, an alternating current circuit, a transformer having a plurality of windings including a series winding in said alternating current circuit and a plurality of exciting windings, a negative impedance-current characteristic impedance connected across one of said exciting windings, and a circuit controller for selectively connecting one of said exciting windings across said alternating current circuit and short circuiting one of said exciting windings.

4. In combination, an alternating current circuit, a transformer having a plurality of windings including a series winding in said alternating current circuit and a plurality of exciting windings, a negative impedance-current characteristic impedance connected across one of said exciting windings, and a circuit controller for selectively connecting said exciting windings in

series relation across said alternating current circuit and for changing the connections of said exciting windings relative to said alternating current circuit.

5. In combination, an alternating current circuit, a transformer having a series winding in said circuit and having two exciting windings with different numbers of turns, a negative impedance-current characteristic impedance connected across one of said exciting windings, and a two-position switch connected so that in one position one of said exciting windings is connected across said circuit and in the other position said exciting winding is connected in another circuit.

6. In combination, an alternating current circuit, a transformer having a series winding in said circuit and having two exciting windings with different numbers of turns, a negative impedance-current characteristic impedance connected across one of said exciting windings, and a two-position switch connected so that in one position one of said exciting windings is connected across said circuit and in the other position the other one of said exciting windings is short circuited.

7. In combination, a single phase, three-wire alternating current circuit, a regulating transformer having series windings connected respectively in the two outer conductors of said circuit and having an exciting winding, and a switch for selectively connecting said exciting winding across said circuit and disconnecting it therefrom.

8. In combination, a main alternating current circuit, a transformer having a series winding in said circuit and an exciting winding adapted to be connected across said circuit, a negative impedance-current characteristic impedance connected across said exciting winding, a switch for selectively connecting said exciting winding across said circuit and connecting it in another circuit, and means responsive to the voltage of said main circuit for controlling the operation of said switch.

ORIN P. McCARTY.