June 20, 1944. E. H. HAUG 2,351,681

CONSTANT CURRENT CONTROL

Filed Dec. 24, 1942

Fig. 1

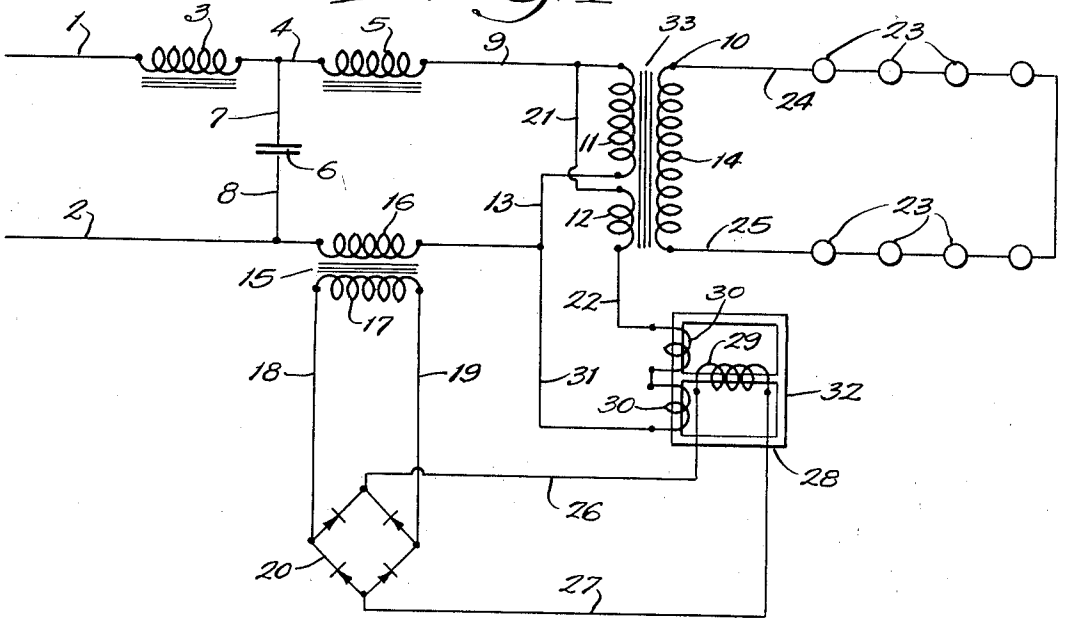
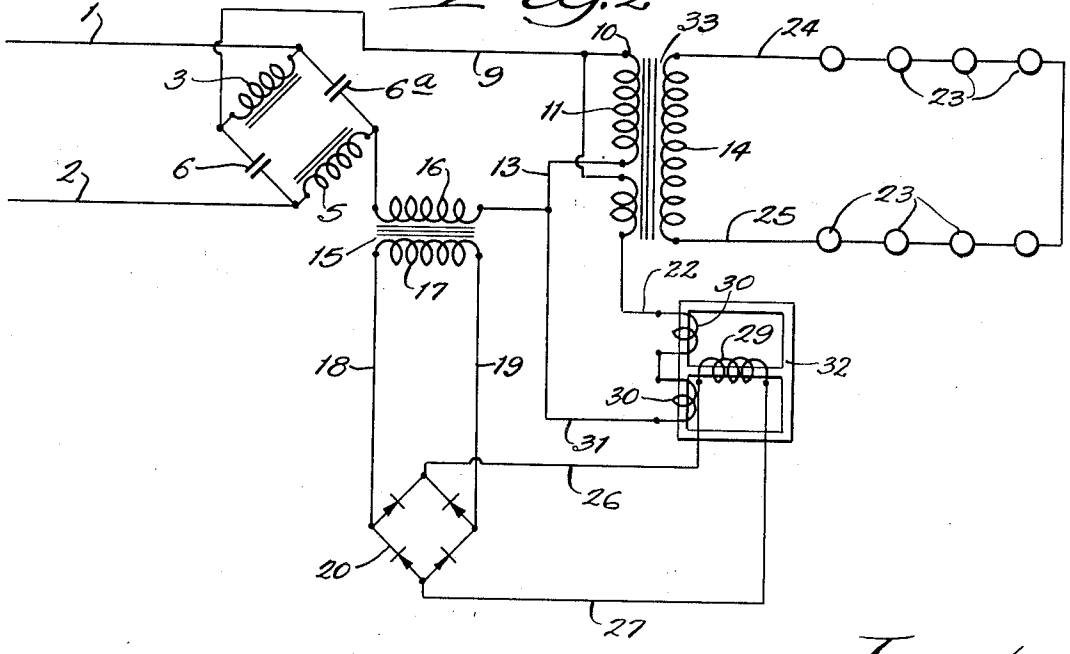


Fig. 2



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CONSTANT CURRENT CONTROL

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6 Claims. (Cl. 171—119)

My invention relates to electric regulating circuits and more particularly to such circuits utilizing electric resonant circuits of the constant potential to constant current type for regulating the current as may be required.

Resonant type of constant current transformation devices are old in the art, having been known since the time of Boucherout in 1893 who demonstrated their operation. But these resonant circuits were of no practical value in series constant current lighting circuits due to the fact that input voltage variations cause variations in the current output.

The modern incandescent lamp is primarily a constant-voltage device, that is, at constant-voltage supply, the life of the lamp is greater than at constant current supply, assuming the same percentage fluctuation from constancy. The reason is: a variation of voltage at the lamp terminals, by p percent, gives a variation of current of about $0.6p$ percent, and thus a variation of power of about $1.6p$ percent, while a variation of current in the lamp, by p percent, gives a variation of voltage of about

$$\frac{p}{0.6}$$

percent, and thus a variation of power of about

$$\left(1+\frac{1}{0.6}\right)p=2.67p$$

percent. Thus, with the increasing use of incandescent and vapour discharge lamps in series constant current operation, the constancy of the current becomes of increasing importance.

Heretofore there have been proposed several arrangements for controlling the constant current in the output circuit of the resonant type of constant current transformers. All these arrangements will not automatically regulate to hold the current constant with both constant potential input variation and load variation. Furthermore all prior arrangements require anti-hunting and other devices to stabilize the automatic regulation. The addition of these anti-hunting devices lowers the efficiency and dependability of the constant current transformer.

It is the object of my invention, therefore, to provide an improved constant current regulator which will hold the current constant although the constant input potential may vary or the amount of load in the constant current circuit may vary, or both the input voltage and the load may vary simultaneously.

In accordance with my invention, a resonant constant potential to constant current transforming device has the constant current output circuit connected to a special type of automatic ratio changing transformer which regulates in a manner to hold the current in the output circuit constant although the input current or load may vary, or both input current to the automatic ratio transformer may vary.

For a better understanding of my invention together with other and further objects thereof, reference is had to the following description, taken in connection with the accompanying drawing, and its scope will be pointed out in the appended claims.

Figure 1 of the drawing illustrates an arrangement embodying my invention for operating a series lighting system using a T type resonant circuit. Figure 2 of the drawing illustrates an arrangement embodying my invention for operating a series lighting system using a monocyclic square type resonant circuit.

Referring now to Figure 1 of the drawing there is illustrated an arrangement for obtaining constant current to a load circuit, although the constant input potential may vary, or the load may vary, or both input potential and load may vary simultaneously. 1 and 2 indicates the constant potential supply which may vary 15 percent. Reactor 3 is connected at one terminal to supply line 1 and at its other terminal to reactor 5 by means of line 4. Reactor 5 has one of its terminals connected to line 4 and the other terminal to line 9. A capacitor 6 is connected to line 4 by means of lead 7 and to line 2 by means of lead 8. The reactance of reactor 3, reactor 5, and capacitor 6 are of equal reactance, hence in resonant condition. 10 is the automatic ratio change transformer of which 11 and 12 are the two primary windings and 14 the secondary winding. Primary winding 11 has one of its terminals connected to line 9 and the other terminal to line 13. Primary winding 12 has one of its terminals connected to line 9 by means of lead 21, and its other terminal connected to line 22. Primary winding 11 has more turns than primary 12. Secondary 14 of transformer 10 is connected to the load 23 by means of leads 24 and 25. Current transformer 15 has one terminal of its primary 16 connected to line 2, and its other terminal connected to line 13. The secondary 17 of current transformer 15 has one of its terminals connected to rectifier 20 by means of lead 19, and its other terminal connected to oxide rectifier 20 by means of lead 18. Rectifier output terminals are connected to the D. C. winding 29 of saturating transformer 28. Reactance winding 30 of

saturating transformer 26 has one of its terminals connected to line 13 by means of lead 31, and its other terminal connected to line 22.

The operation of the above described apparatus is as follows: a constant potential to lines 1 and 2 will be transformed into constant current to lines 9 and 2. This constant current is fed to the primaries 11 and 12, and the current in windings 11 and 12 will be of a value depending upon the respective impedance of each winding. The current to the load 23 from the secondary 14 will depend upon the ratio of primary ampere turns to the secondary ampere turns. The current transformer 15, which has its primary 16 connected in series circuit relation to the output of the resonant constant current device and to the primaries 11 and 12 of the automatic ratio changing transformer 10, has the function of introducing a voltage supply to rectifier 20 that is proportional to the output current of the resonant constant current device. Hence the output circuit of rectifier 20 introduces a current to the direct current winding 29 of saturating reactor 28, which is also proportional to the output current of the resonant constant current device. The direct current winding 29 therefore saturates the core 32 proportional to the output current of the rectifier 20 and therefore controls the reactance of winding 30 of the saturating reactor proportionally to the output current of the resonant constant current device. Since the primary 12 of transformer 10 is connected in series circuit relation with reactance winding 30 of the saturating reactor 28 and the output circuit of the resonant constant current device, the current introduced to winding 12 of transformer 28 will therefore be proportional to the reactance value of the winding 30 of saturating transformer 28. Should the supply voltage feeding lines 1 and 2 increase, the current output of the resonant constant current device will increase proportionally in lines 9 and 2. This will increase the current to transformer 15, thereby increasing the voltage to the rectifier 20, and thereby increasing the direct current output of rectifier 20 to the direct current winding 29 of saturating transformer 28, thereby decreasing the reactance value of winding 30 and thereby increasing the current to primary 12 of transformer 10. Since the current fed to the primaries 11 and 12 is approximately constant the current to each of these primaries will be proportional to their respective impedances. Hence, the current will be transferred from winding 11, which has more ampere turns, to primary 11, which has less ampere turns, and therefore decreasing the flux in the core 33 of transformer 10, and which in turn decreases the voltage of secondary 14 in a manner to hold the current constant to the load 23.

A decrease in the value of supply voltage to lines 1 and 2 effects the control in the reversed order, and thereby holds the current constant in the load circuit.

Mathematically the operation of the automatic ratio changing transformer is as follows: the secondary voltage of a transformer depends upon the flux density interlinking the secondary (neglecting impedances and losses). The flux density depends upon the primary ampere turns. In the automatic ratio changing transformer we have two primary windings and one secondary winding. If the primary has 800 turns on one winding and 400 turns on the other winding, and a constant current of 15 amperes is fed to these two primary windings, the current will divide into these respective windings proportional to their respective impedances. The 800 turn primary will take 5 amperes and the 400 turn primary will take 10 amperes, respectively. Thus, 800×5 amperes=4000 ampere turns, and 400×10 amperes=4000 ampere turns, or a total of 8000 ampere turns. Now suppose that a series impedance of twice the value of the impedance of the 400 ampere turns is connected in series circuit relation with the 400 ampere turn, so that both primary windings will have the same impedance, the 400 turn primary will take 7.5 amperes, and the 800 turn primary will take 7.5 amperes. We will then have 400×7.5 or 3000 ampere turns from the 400 turn primary winding, and 800×7.5 or 6000 ampere turns from the 800 turn primary winding, which makes a total of 9000 ampere turns of both primary windings acting together. Therefore, with no impedance in the 400 turn primary we have a total ampere turns from both primary windings of 8000 ampere turns, while if the primary with 400 ampere turns has an added impedance of twice the value of the 400 ampere turn winding the total ampere turns of both primary windings will be 9000 ampere turns, or an increase of 1000 ampere turns.

Figure 2 illustrates a circuit similar to Figure 1 except for a different type of constant potential to constant current transformer and parts therein corresponding to like parts in Figure 1 are designated by the same reference numerals.

In Figure 2 the T resonant circuit of Figure 1 is replaced by a monocyclic square including a pair of reactors 3 and 4 and a pair of condensers 6 and 6a. This resonant transformer functions in substantially the same manner as the transformer of Figure 1 and the operation of the remainder of the circuit is the same.

While I have described what I at present consider the preferred embodiment of my invention, it will be obvious to those skilled in the art that various changes and modifications may be made without departing from my invention, and I, therefore, aim in the appended claims to cover all such changes and modifications as fall within the true spirit of my invention.

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

1. In combination with an alternating current supply, a resonant type of constant potential to constant current transformer, an automatic ratio changing transformer having two primary windings and one secondary winding, and a load, a saturating reactor connected in series circuit relation to one of the primary windings of said ratio changing transformer, and means to control the saturation of the reactor to maintain the current flow to the load substantially constant.

2. In combination with an alternating current supply, a resonant type of constant potential to constant current transformer, an automatic ratio changing transformer having two primary windings and one secondary winding, and a load, a saturating reactor connected in series circuit relation to one of the primary windings of said ratio changing transformer, and means responsive to the flow of current from the resonant transformer to control the saturation of the reactor.

3. In combination with an alternating current supply, a resonant type of constant potential to constant current transformer, an automatic ratio changing transformer having two primary windings and one secondary winding, and a load, a saturating reactor connected in series circuit re-

lation to one of the primary windings of said ratio changing transformer, and means responsive to the total flow of current to the two primary windings to control the saturation of the reactor.

4. In combination with an alternating current supply, a resonant type of constant potential to constant current transformer, a transformer having two primary windings with different numbers of turns connected in parallel to the resonant transformer, a load circuit connected to the secondary winding of the last named transformer, a saturating reactor connected in series with one of said primary windings, and means to control the saturation of the reactor.

5. In combination with an alternating current supply, a resonant type of constant potential to constant current transformer, a transformer having two primary windings with different numbers of turns connected in parallel to the resonant transformer, a load circuit connected to the secondary winding of the last named transformer, a saturating reactor connected in series with one of said primary windings, and means responsive to the flow of current between the resonant transformer and the primary windings to control the saturation of the reactor.

6. In combination with an alternating current supply, a resonant type of constant potential to constant current transformer, a transformer having two primary windings with different numbers of turns connected in parallel to the resonant transformer, a load circuit connected to the secondary winding of the last named transformer, a saturating reactor connected in series with one of said primary windings, a saturating winding on the reactor, a rectifier connected to the saturating winding, and a current transformer in series with the primary windings for supplying current to the rectifier.

EUGENE H. HAUG.