July 31, 1945. E. H. HAUG 2,380,521

ELECTRIC REGULATING APPARATUS

Filed March 3, 1944

Fig. 1

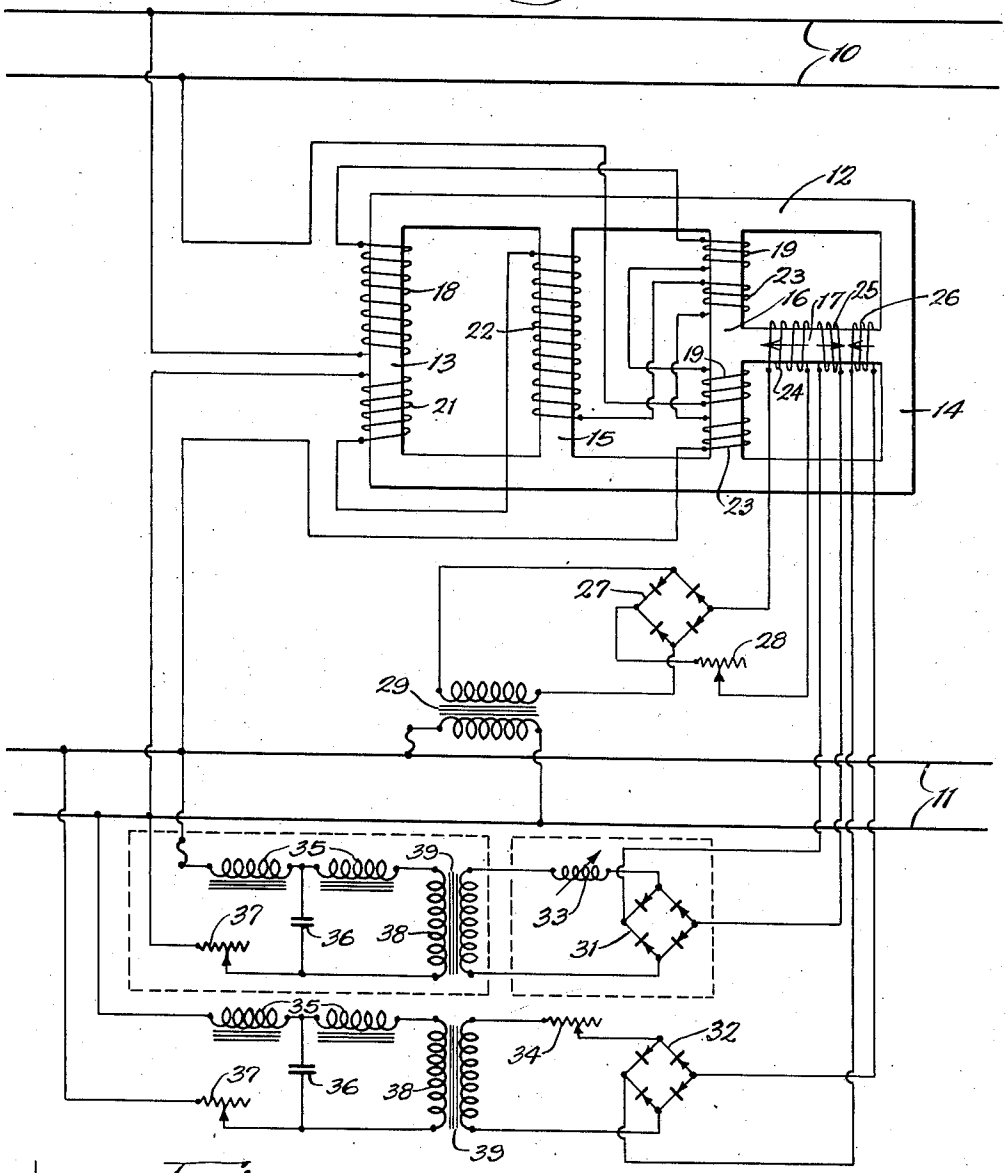
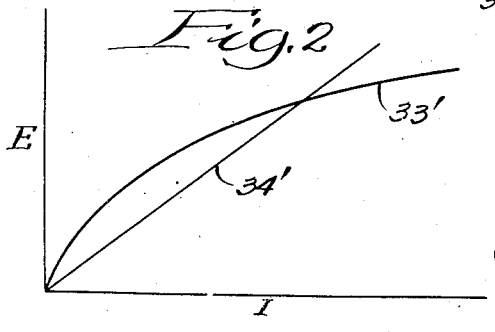


Fig. 2



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ELECTRIC REGULATING APPARATUS

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8 Claims. (Cl. 171—119)

This invention relates to electric regulating apparatus and more particularly to apparatus for automatically maintaining constant conditions in a circuit.

One of the objects of the invention is to provide electric regulating apparatus in which regulation is effected automatically with no moving parts.

Another object of the invention is to provide electric regulating apparatus which maintains constant regulating characteristics regardless of changes in external conditions such as temperature, humidity, aging of the parts and the like.

Still another object is to provide apparatus in which regulation is accomplished automatically by varying the saturation of a transformer connected in the circuit.

A still further object of the invention is to provide electric regulating apparatus including a transformer having a plurality of windings a portion of which are controlled in response to variations in the output circuit to maintain the output circuit constant.

The above and other objects and advantages will be more readily apparent from the following description when read in connection with the accompanying drawing, in which—

Figure 1 is a circuit diagram of regulating apparatus embodying the invention; and

Figure 2 illustrates characteristic curves of a portion of the apparatus.

The circuit shown in Figure 1 connects a supply circuit 10 to an output circuit 11 in which the voltage is to be maintained constant regardless of voltage variations in the supply circuit. The supply and output circuits are connected through a transformer including a core 12 of generally rectangular outline with a first leg 13, an opposite end leg 14 and a pair of intermediate legs 15 and 16. This construction provides in effect two interconnected closed sections. A cross leg 17 is provided in one of the sections extending centrally between the legs 14 and 16.

The core carries a series of primary windings connected to the supply circuit and including a main primary winding 18 on the leg 13 and spaced primary windings 19 on the leg 16 on opposite sides of the cross leg 17. The several primary windings are connected in series.

The core also carries a plurality of secondary windings connected to the output circuit 11 including a small winding 21 on the leg 13, a main secondary winding 22 on the leg 15 and spaced secondary windings 23 on the leg 16 on opposite sides of the cross leg 17. The secondary windings 23 may be omitted, if desired, but are preferably included to prevent wave form distortion. The windings 19 and 23 are controlled by variably saturating the portion of the core on which they are carried and for this purpose the cross leg 17 carries three saturating windings. The main or base saturating winding shown at 24 is opposed by a buck winding 25 and is assisted by a boost winding 26. When the current in the windings 25 and 26 is equal the degree of saturation depends entirely on the winding 24. By unbalancing the current in the windings 25 and 26 the degree of saturation of the core can be controlled.

The base saturating winding 24 is supplied with current through a rectifier 27 connected to the winding through a rheostat 28 and supplied from a transformer 29 whose primary is connected across the output circuit 11. The buck and boost 25 and 26 are supplied from rectifiers 31 and 32 which are also supplied from the output circuit 11.

In order to vary the current supply to the buck and boost windings to a different degree in response to variations in the voltage supplied to the rectifiers 31 and 32, an inductive reactance 33 is connected in series with the rectifier 31 and a resistance 34 is connected in series with the rectifier 32. Both the reactance 33 and resistance 34 may be made adjustable for setting the voltage value to be maintained in the output circuit. Figure 2 shows characteristic curves for the reactance 33 and resistance 34, the reactance curve being indicated at 33' and resistance curve at 34'. The values of the reactance and resistance are adjusted so that the curves will cross at the point where the output circuit voltage is to be maintained. Upon an increase in voltage above this value the current supplied to the buck winding 25 will exceed that to the boost winding 26 so that the effective saturation of the transformer core is reduced. This causes an increase in the alternating current flux in the leg 16, increasing the number of effective primary turns. The effective secondary turns are also increased but the percentage of increase is less since there are more total secondary turns. Accordingly the voltage induced in the secondary windings will be reduced until it again reaches the desired value. Similarly, on a decrease in voltage the current in the boost winding 26 will exceed that in the buck winding 25 to increase the saturation of leg 16 and reduce the effective number of

primary turns relative to the number of secondary turns. An increase in primary current will result to produce a corresponding increase in secondary voltage.

In order to maintain the current from the rectifiers 31 and 32 directly proportional to the voltage in the output circuit regardless of changes in temperature, humidity or unequal aging of the rectifier elements, these rectifiers are preferably supplied through constant potential to constant current type regulating devices. As shown such regulating devices are of the resonant type and include a pair of inductive reactors 35 connected in series with a condenser 36 connected across the line between them to form a T-resonant circuit. Adjustable rheostats 37 are preferably provided to vary the voltage supply thereby to vary the current output of the circuits. The resonant circuits are connected to primary windings 38 of transformers 39 whose secondary windings are connected through the reactor 33 and resistance 34 to the rectifiers 31 and 32 respectively. With this construction the current supplied to the transformer 39 will vary only with the voltage in the output circuit 11. Thus the current supplied to the buck and boost windings will be independent of any slight variations in the rectifiers and will be controlled solely in response to voltage variations in the output circuit as modified by the reactance 33 and resistance 34.

The circuit as above described will maintain the voltage in the output circuit 11 substantially constant within very close limits under all operating conditions. By varying the arrangement of the several windings on the transformer core it is possible with the same circuit to regulate for constant power or for other conditions than voltage.

While one embodiment of the invention has been shown and described in detail herein, it will be understood that this is for the purpose of illustration only and is not intended as a definition of the scope of the invention, reference being had for this purpose to the appended claims.

What is claimed is:

1. Electric regulating apparatus comprising a magnetic core, a primary winding on the core connected to a supply circuit, a secondary winding on the core connected to an output circuit, three saturating windings on the core including a base winding, a buck winding and a boost winding, rectifiers connecting said windings respectively to one of the circuits, an inductive reactance in series with the rectifier for the buck winding, and a resistance in series with the rectifier for the boost winding.

2. Electric regulating apparatus comprising a magnetic core, a primary winding on the core connected to a supply circuit, a secondary winding on the core connected to an output circuit, three saturating windings on the core including a base winding, a buck winding and a boost winding, a rectifier connecting the base winding to one of the circuits, a pair of constant potential to constant current regulating devices connected to the output circuit, rectifiers connecting said devices to the buck and boost windings respectively, an inductive reactance in series with one of the last named rectifiers, and a resistance in series with the other of the last named rectifiers.

3. Electric regulating apparatus comprising a magnetic core, a primary winding on the core connected to a supply circuit, a secondary winding on the core connected to an output circuit, three saturating windings on the core including a base winding, a buck winding and a boost winding, a rectifier connecting the base winding to one of the circuits, a pair of constant potential to constant current regulating devices connected to the output circuit, transformers connected to the regulating devices, rectifiers connecting the transformers to the buck and boost windings respectively, an inductive reactance in series with the rectifier for the buck winding, and a resistance in series with the rectifier for the boost winding.

4. Electric regulating apparatus comprising a magnetic core having a pair of connected closed sections and a cross leg in one of the closed sections, a plurality of primary windings in series on the core with one winding on said one of the sections on each side of the leg, a secondary winding on the core, a plurality of saturating windings on said leg including a base winding, a buck winding and a boost winding, rectifiers connecting the saturating windings to the secondary winding, and means connected to the rectifiers for the buck and boost windings to cause the current to change different amounts in the buck and boost windings in response to a change in voltage in the secondary winding.

5. Electric regulating apparatus comprising a magnetic core having a pair of connected closed sections and a cross leg in one of the closed sections, a plurality of primary windings in series on the core with one winding on said one of the sections on each side of the leg, a secondary winding on the core, a plurality of saturating windings on said leg including a base winding, a buck winding and a boost winding, rectifiers connecting the secondary winding to the saturating windings, an inductive reactance in series with the rectifier for the buck winding, and a resistance in series with the rectifier for the boost winding.

6. Electric regulating apparatus comprising a magnetic core having a pair of connected closed sections and a cross leg in one of the closed sections, a plurality of primary windings in series on the core with one winding on said one of the sections on each side of the leg, a secondary winding on the core, a plurality of saturating windings on said leg including a base winding, a buck winding and a boost winding, a rectifier connecting the base winding to the secondary winding, a pair of constant potential to constant current regulating devices connected to the secondary winding, rectifiers connecting the regulating devices to the buck and boost windings, an inductive reactance between the regulator and rectifier supplying the buck winding, and a resistance between the regulator and rectifier supplying the boost winding.

7. Electric regulating apparatus comprising a magnetic core having a pair of connected closed sections and a cross leg in one of the closed sections, a plurality of primary windings in series on the core with one winding on said one of the sections on each side of the leg, a plurality of secondary windings on the core with one on each side of the leg on said one of the sections, a plurality of saturating windings on said leg including a base winding, a buck winding and a boost winding, rectifiers connecting the secondary winding to the saturating windings, an inductive reactance in series with the rectifier for the buck winding, and a resistance in series with the rectifier for the boost winding.

8. Electric regulating apparatus comprising a magnetic core having a pair of connected closed sections and a cross leg in one of the closed sections, a plurality of primary windings in series on

the core with one winding on said one of the sections on each side of the leg, a plurality of secondary windings on the core with one on each side of the leg on said one of the sections, a plurality of saturating windings on said leg including a base winding, a buck winding and a boost winding, rectifiers connecting the secondary winding to the saturating windings, a pair of constant potential to constant current regulating devices connected to the secondary winding, transformers connecting said devices to the rectifiers for the buck and boost windings, an inductive reactance between the transformer and rectifier supplying the buck winding, and a resistance between the transformer and rectifier supplying the boost winding.

EUGENE H. HAUG.