

Nov. 8, 1938.

W. J. McLACHLAN

2,136,248

ELECTRICAL REGULATION

Filed Jan. 30, 1937

Fig. 1.

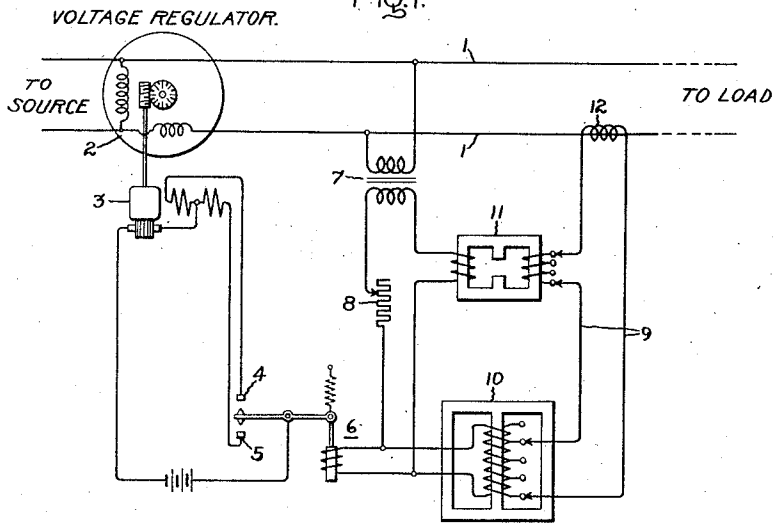
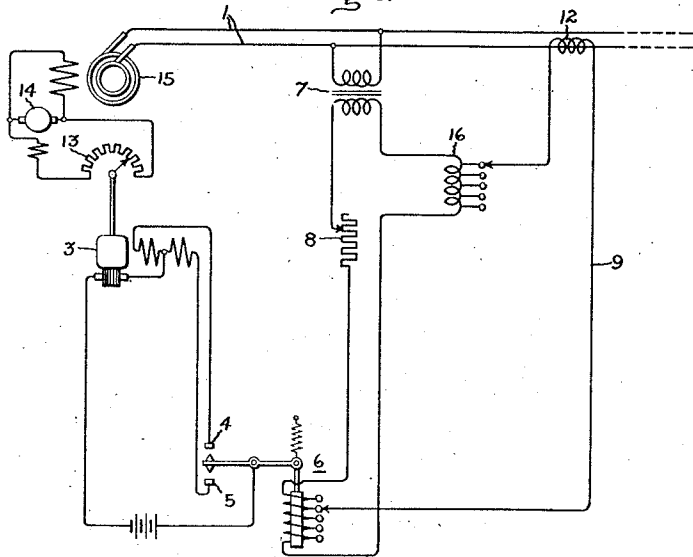


Fig. 2.



Inventor:
Willard J. McLachlan,
by *Harry E. Dunham*
His Attorney.

UNITED STATES PATENT OFFICE

2,136,248

ELECTRICAL REGULATION

Willard J. McLachlan, Scotia, N. Y., assignor to
General Electric Company, a corporation of
New York

Application January 30, 1937, Serial No. 123,212

3 Claims. (Cl. 171-119)

My invention relates to electrical regulation and more particularly to improvements in the line drop compensation of automatic alternating current voltage regulators.

5 The normal function of an automatic voltage regulator is to hold constant voltage at the place to which the main control device of the regulator is connected. When a load is connected to an alternating current circuit at a point which is
10 different from the place where an automatic voltage regulator for this circuit is connected, the load voltage will ordinarily have a drooping characteristic with increases in load value because of the line drop in the circuit between these two
15 places. This drooping characteristic is ordinarily undesirable and in order to eliminate it regulators are provided with auxiliary equipment known as line drop compensators.

Heretofore, conventional commercial line drop
20 compensators have included a resistance element in which the compensator current is circulated. This has introduced appreciable losses into the system.

The principal object of my invention is to
25 provide a line drop compensator without purposely imposing I^2R losses in the compensator circuit.

Another object of my invention is to provide
30 a line drop compensator which is simple and inexpensive to construct.

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.

35 In the drawing, Fig. 1 is a diagrammatic illustration of a preferred embodiment of my invention as applied to a feeder voltage regulator, and Fig. 2 is a diagrammatic showing of a simplified embodiment of my invention as applied to a generator voltage regulator.

40 Referring now to Fig. 1 of the accompanying drawing, there is shown therein a main alternating current circuit 1 provided with a feeder voltage regulator 2. This regulator is illustrated
45 conventionally as an induction voltage regulator, but it might equally well be any other well-known form of feeder voltage regulator, such, for example, as a step regulator. The regulator 2 is driven by means of an ordinary reversible motor 3, whose
50 direction of operation is automatically controlled in response to the voltage of circuit 1 by means of sets of contacts 4 and 5 on a voltage regulator control relay 6. Relay 6 is connected to respond to the voltage of circuit 1 by connecting it across
55 this circuit, preferably through an ordinary po-

tential transformer 7. A conventional rheostat 8 is connected in circuit with the relay 6 for modifying the current in its winding.

The line drop compensating means consists of a circuit 9 having connected therein in series the
5 primary windings of a pair of transformers 10 and 11. The circuit 9 is energized in accordance with the current in the main circuit 1 by connecting it to the secondary winding of a current
10 transformer 12 which is connected in the main circuit 1. The secondary winding of transformer 10 is connected across the operating winding of the main control relay 6 and the secondary winding of transformer 11 is connected in series with
15 the winding of the main control relay 6.

The transformer 10 is preferably an ordinary insulating current transformer whose primary and secondary windings are interleaved or interwound so as to reduce to a minimum the leakage
20 reactance. With such a transformer, there is little or no phase displacement between the currents in its primary and secondary windings.

The transformer 11 is a so-called reactance transformer. In such a transformer, the primary and secondary windings are relatively widely separated so that there is a relatively large amount
25 of leakage flux associated with each of its windings. If desired, such a transformer may be provided with a shunt magnetic path as indicated by the air gap. It may be described as a mutual
30 reactor, that is to say, a reactor having some mutual inductance. The voltage across its secondary winding is substantially at right angles to the current in its primary winding.

In order that the outputs of transformers 10
35 and 11 may readily be adjusted, their ratios are made variable in any well-known manner, as by providing their primary windings with the plurality of taps shown in the drawing.

The operation of Fig. 1 is as follows:

40 If circuit 1 is energized by a suitable source of supply (not shown) and no load is connected thereto, the regulator 2 and the regulating relay 6 will automatically maintain constant voltage at
45 the place on circuit 1 to which the potential transformer 7 is connected. Thus, for example, if the voltage at this place falls below a particular normal value for which the relay 6 is adjusted to balance, its contact 4 will close, thereby energizing the motor for operation in such direction
50 that the regulator will raise the voltage. If, on the contrary, the voltage rises above the normal value for which the regulating relay is set to balance, its other set of contacts 5 will close, thereby energizing the motor for reverse opera-
55

tion and causing the regulator to lower the voltage. In each case, this raising or lowering action will continue until the relay again becomes balanced, at which time both sets of contacts will be opened, the motor 3 will be de-energized, and the regulator will be stationary.

If now a load is connected to the right-hand end of circuit 1, the line drop compensating means will, in the manner to be described below, automatically change the setting of the relay 6 so as to cause the voltage of the circuit 1, at the place where the potential transformer is connected thereto, to increase enough to exactly compensate for the line drop between this place and the place where the load is connected to the circuit. Before describing how the line drop compensating means produces this result, it is best to point out two facts.

The first is that the line drop is made up of two separate and distinct components, namely a resistance component and a reactance component. This is because all power circuits and feeder circuits have both resistance and reactance. It is the line current flowing through the line resistance which produces the resistance component of the line drop and it is the line current flowing through the line reactance which produces the reactance component of the line drop. Because the current in the main circuit 1 is alternating, the resistance and reactance components of the line drop are alternating quantities. Because the resistance component is proportional in magnitude to the instantaneous magnitude of the alternating current whereas the reactance component is proportional in magnitude to the instantaneous value of the rate of change of current the reactance component is out of phase with the resistance component by a quarter of a cycle or 90 electrical degrees.

The second fact is that the current in the secondary winding of potential transformer 7 is substantially in phase with the voltage of the main circuit 1 because the winding of control device 6 is composed of relatively fine wire having a relatively high resistance and this taken in connection with the resistance of rheostat 8 produces a relatively high power factor circuit; that is to say, a circuit whose resistance is relatively high compared with its reactance.

The transformer 10 constitutes the portion of the line drop compensating equipment devoted to compensation for the resistance component of the line drop. As the transformer 10 produces substantially no phase displacement between the currents in its primary and secondary windings, the secondary winding current is in phase with the load current in the main circuit 1 and this secondary current is circulated by the transformer 10 as an auxiliary current in the coil of the relay 6. The connections are such that at unity power factor on the main circuit, that is to say when the current and voltage are in phase with each other, the auxiliary current produced by the current transformer 10 subtracts arithmetically from the current produced by the potential transformer 7 in the coil of the relay 6. This has the effect of weakening the effective energization of the relay so that in effect the relay acts as though the voltage is too low, thereby causing it to raise the voltage in the manner previously described until a balance is again obtained. By properly selecting the taps on the primary winding of transformer 10 to which the circuit 9 is connected, the magnitude of this auxiliary current may be made

such as exactly to compensate the system for the resistance line drop in the main circuit 1.

Transformer 11, being substantially a reactor, produces a voltage in the main voltage responsive energizing circuit for the relay 6 which is at right angles to the current in the line drop compensating circuit 9, and therefore, this voltage is at right angles to the current in the main circuit 1. By making the proper connections of the secondary winding of this transformer in the secondary winding circuit of potential transformer 7, this voltage may be made to bear the same phase relation to the voltage of the secondary winding of transformer 7 as exists between the reactance line drop component and the voltage of main circuit 1. By selecting the proper taps on the primary winding of transformer 11, the magnitude of this component may be adjusted so that it corresponds to the reactance component of the line drop. This voltage produced by the transformer 11 in series with the coil of the relay 6 biases the energization of this coil so as to cause the regulating system to hold a voltage which is different than normal by an amount corresponding to the reactance component of the line drop.

Changes in power factor on the main circuit 1 cause the current in the main circuit to be displaced in phase with respect to the voltage of the main circuit and this phase shift appears in the compensating circuit 9 thereby shifting the phase of the auxiliary current in the coil of the relay 6 produced by the transformer 10 and correspondingly shifting the phase of the voltage in series with the coil of the relay 6 produced by the transformer 11. In this manner, the compensator secures true line drop compensation regardless of the power factor on the main circuit.

In the modification shown in Fig. 2, the voltage regulator is a generator voltage regulator instead of a feeder voltage regulator. This regulator consists, by way of example, of a rheostatic element 13 arranged to be driven by the motor 3. This rheostatic element controls the shunt field excitation of an exciter 14 for a main alternator 15 for energizing the circuit 1.

The line drop compensating equipment in Fig. 2 has been simplified in that transformers 10 and 11 have been omitted. In place of transformer 10, there are merely provided a plurality of taps on the winding of relay 6 while in place of the reactance transformer 11, there is provided merely a tapped reactor 16 in series with the coil of relay 6.

In the operation of Fig. 2, the current produced by the secondary winding of current transformer 12 flows directly in the winding of relay 6 and it flows directly in the reactor 16. The auxiliary current in the coil of relay 6 subtracts from the main voltage responsive current exactly as in Fig. 1. The voltage across the reactor 16 will be at right angles to the current in it and can be made to bear the same relation to the voltage of the secondary winding of potential transformer 7 as does the voltage of the secondary winding of reactance transformer 11 in Fig. 1.

By means of the taps on the winding of relay 6 and on the reactor 16, the magnitude of the resistance component and the magnitude of the reactance component of the line drop compensator may be adjusted to correspond to the magnitude of the actual resistance and reactance drops in the line.

The compensating arrangement shown in Fig. 1 is more expensive than the compensating arrangement shown in Fig. 2, but it has the advantage

that one side each of the potential and compensating circuits may be separately grounded because of the insulating ability of transformers 10 and 11.

While I have shown and described particular 5 embodiments of my invention, it will be obvious to those skilled in the art that changes and modifications may be made therein and consequently I aim in the appended claims to cover all such changes and modifications as fall within the true 10 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 voltage regulator therefor having a main 15 control device connected to respond to the voltage of said circuit, means for providing a voltage in series with said device which corresponds in magnitude and phase with the reactance voltage drop in said circuit, and means in parallel circuit relation 20 with said device for circulating in said device an auxiliary current which corresponds in magnitude and phase with the resistance voltage drop in said circuit.

2. In combination, an alternating current circuit, a voltage regulator therefor having a main control coil connected to respond to the voltage of said circuit, a reactor connected in circuit with said coil, and a compensating circuit containing 5 said coil and reactor in series connected to carry a current proportional in magnitude and variable in phase with respect to the current in said alternating current circuit.

3. In combination, an alternating current circuit, a voltage regulator therefor having a main control coil connected across said circuit through a potential transformer, a variable ratio relatively high leakage reactance transformer having its secondary winding connected in series with 15 said coil, a variable ratio relatively low leakage reactance transformer having its secondary winding connected in parallel with said coil, and a current transformer connected in said circuit and having its secondary winding connected in series 20 with the primary windings of said high and low leakage reactance transformers.

WILLARD J. McLACHLAN.