

June 9, 1964

I. J. C. SCOTT

3,136,939

TRANSISTORIZED VOLTAGE REGULATOR

Filed Feb. 9, 1960

2 Sheets-Sheet 1

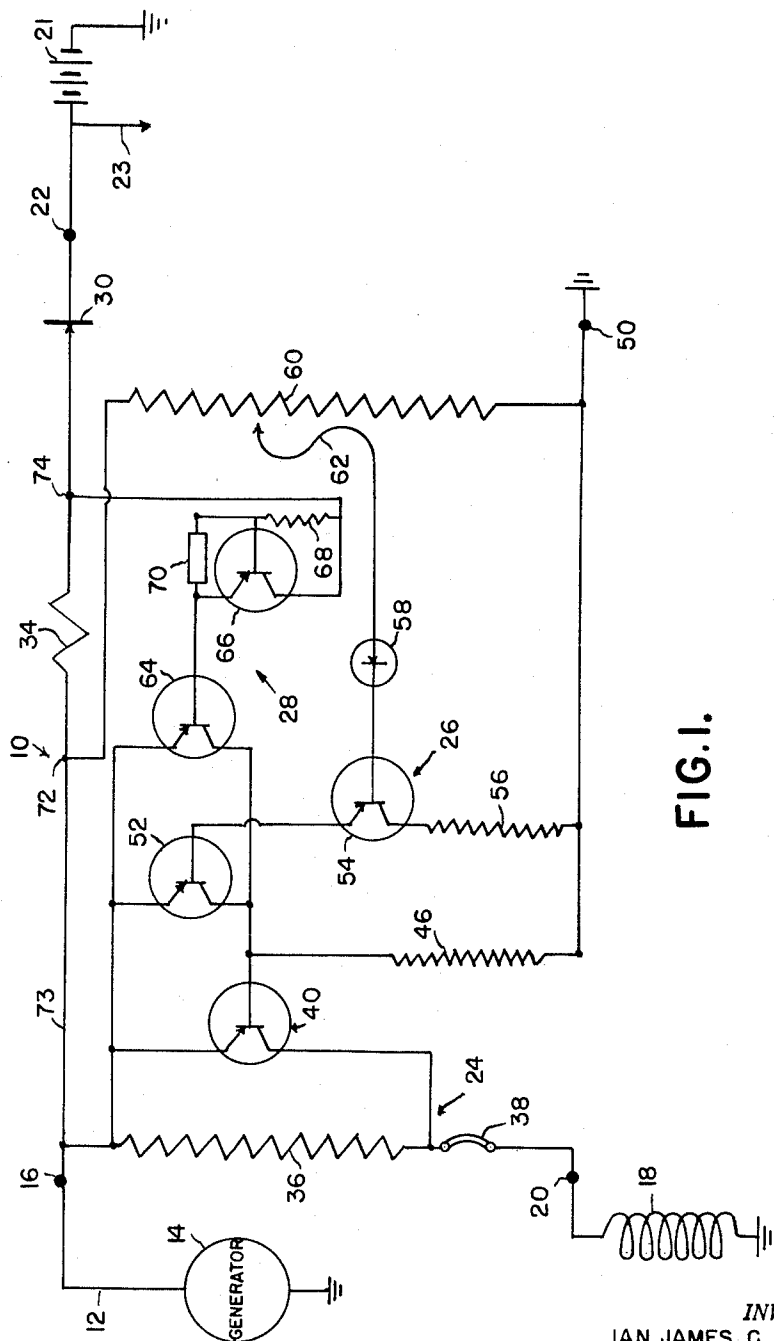


FIG. 1.

INVENTOR.
IAN JAMES C. SCOTT

BY *Whittemore, Hulbert & Becknap*
ATTORNEYS

1

3,136,939

TRANSISTORIZED VOLTAGE REGULATOR

Ian James C. Scott, Madison Heights, Mich., assignor to Holley Carburetor Company, Van Dyke, Mich., a corporation of Michigan

Filed Feb. 9, 1960, Ser. No. 7,579

8 Claims. (Cl. 322-73)

The present invention refers to voltage regulators and relates more specifically to a transistorized electronic voltage regulator for maintaining generator current and voltage below a predetermined amount without the use of mechanical relay contacts.

In the past voltage regulators for regulating the current and voltage output of generators of the type used in motor vehicles wherein the generator field current is regulated to reduce the generator armature voltage and current output below a desired maximum have been subject to the defect of burning the relay contacts therein during operation. The deteriorating of the mechanical relay contacts of the field control relay in the usual voltage regulators due to burning is especially rapid and often requires the eventual replacement of the unit. Therefore it is desirable to eliminate relays having mechanical type contacts in voltage regulator circuits.

Thus, one of the objects of the present invention is to provide a voltage regulator including no mechanical relay contacts.

Another object is to provide a transistorized electronic voltage regulator operable to regulate generator voltage and current and having no mechanical relay contacts.

Another object is to provide a transistorized electronic voltage regulator wherein the field current of the generator is regulated by means of a relay transistor in parallel with a current limiting resistor which resistor is in series with the generator field coil, conduction through said relay transistor being controlled by separate voltage and current control means in accordance with generator, voltage and current.

Another object is to provide a voltage regulator as set forth above wherein the voltage control means comprises a first voltage control transistor operably associated with the relay transistor to prevent conduction through the relay transistor on conduction of a second voltage control transistor which is operable to conduct on the voltage output of the generator exceeding a predetermined value.

Another object is to provide a voltage regulator as set forth above wherein the current control means comprises a first current control transistor operably associated with the relay transistor to prevent conduction through the relay transistor on conduction of a second current control transistor which is operable to conduct on the current output of the generator exceeding a predetermined value.

Another object is to provide a voltage regulator as set forth above wherein said current limiting resistor is separated into two parts in series with each other and a relay transistor is provided in parallel with each of the parts and voltage and current control means as set forth above are connected to each of the relay transistors to regulate the voltage and current from the generator in steps.

Another object of the invention is to provide a voltage regulator as set forth above wherein the voltage control means comprises a first voltage control transistor having an emitter connected to the emitter of the relay transistor, a collector connected to the base of the relay transistor and a base connected to the emitter of a second voltage control transistor, said second voltage control transistor having its collector connected to ground through a resistor and having its base connected through a reference voltage diode to a voltage divider connected between the generator armature and ground.

Another object is to provide a voltage regulator as set

2

forth above wherein the current control means comprises a first current control transistor having an emitter connected to the emitter of the relay transistor, a collector connected to the base of the relay transistor and a base connected to the emitter of a second current control transistor, said second current control transistor having a collector connected directly to the load side of a shunt in the generator output conductor and a base connected to the emitter thereof through a variable resistance heat responsive device and to the collector thereof through a resistor.

Another object of the present invention is to provide a voltage regulator as set forth above wherein the voltage and current control means each comprise a first control transistor having an emitter connected to the base of the relay transistor, a collector connected to ground through a resistor, and a base also connected through a resistor to ground, said control means each further including a second control transistor having an emitter connected to the base of the relay transistor, and a collector connected to the base of the first control transistor, the emitter and base of said second transistor being connected between different points on a voltage divider connected between the generator output and ground in the voltage control means and being connected across a shunt in the generator output conductor in the current control means, the emitter of the second transistor in each control means being connected to the point of higher potential through a suitable resistor.

Another object is to provide a voltage regulator as set forth above in which the second current control transistor has an emitter which is connected to the base of the first current control transistor, a collector which is connected to ground through a resistor, and a base which is connected on the load side of a shunt in the generator output conductor through a reference voltage diode.

Another object is to provide a transistorized electronic voltage regulator having no mechanical relay contacts which is simple in structure, economical to manufacture and efficient in operation.

Other objects and features of the invention will become apparent as the description proceeds, especially when taken in conjunction with the accompanying drawings, illustrating a preferred embodiment of the invention, wherein:

FIGURE 1 is a schematic diagram of a transistorized electronic voltage regulator according to the invention.

FIGURE 2 is a schematic diagram illustrating a portion of a modified voltage regulator such as shown in FIGURE 1 whereby voltage regulation may be accomplished in steps.

FIGURE 3 illustrates a possible modification of the voltage and current control circuits of the voltage regulator illustrated in FIGURE 1.

FIGURE 4 is a schematic diagram of another possible modification of a portion of the current control circuit of the voltage regulator of FIGURE 1.

With reference to the figures, a specific embodiment of the voltage regulator of the invention will now be disclosed.

The voltage regulator generally indicated 10 is shown in FIGURE 1 connected to the armature output conductor 12 of generator 14 at junction 16 the generator field coil 18 at junction 20 and to a battery 21 and electrical system 23 at junction 22 in the usual manner. The voltage regulator 10 comprises the regulating circuit 24, the voltage control circuit 26, the current control circuit 28 and rectifier diode 30.

In operation regulating circuit 24 controls the current through generator field winding 18 when the generator output over armature conductor 12 exceeds a predetermined voltage as determined by the voltage control means 26 or exceeds a predetermined current as determined by

current control means 28. Rectifier diode 30 operates as a voltage regulator cut-out relay to prevent discharge of the battery when the generator voltage falls below that of the storage battery 21.

More specifically in the usual operation of the generator 14 a voltage will be generated on output conductor 12 sufficient to cause current to flow through shunt 34 in series with conductor 12 through rectifier diode 30 to the storage battery 21 and the electrical system 23. This voltage and current may become large enough to damage the battery or components of the electrical system or the generator itself if not regulated. Therefore voltage regulator 10 is provided to limit this voltage and current below a predetermined maximum.

The regulating circuit 24 for voltage regulator 10 comprises current limiting resistor 36 in series between the generator armature output conductor 12 and the generator field coil 18, fuse 38 connected between the resistor 36 and field coil 18 and relay transistor 40 in parallel with resistor 36. With no current flowing through transistor 40 resistor 36 is of a value to limit the current flowing in the field coil 18 to a value at which the voltage and current produced by the generator on output conductor 12 will be below the desired maximum.

During normal operation of the generator the voltage and current on conductor 12 will be such that transistor 40 is allowed to conduct current between its emitter and collector. The value of resistor 46 connected between the base of the transistor 40 and ground through junction 50 is chosen to allow current to flow in the emitter base circuit of the transistor 40 during normal operation of the generator to permit the emitter collector conduction of transistor 40 in accordance with the usual manner of operation of transistors.

The voltage control circuit 26 is operable on the voltage produced by generator 14 on conductor 12 exceeding a predetermined amount to by-pass the current flowing through resistor 46, away from the emitter base junction of transistor 40. This stops transistor 40 from conducting from its emitter to its collector and so removes the current path in parallel with resistor 36. Resistor 36 is thus allowed to regulate the current through the field coil 18 of the generator to a value such that the generator is caused to produce a voltage below the desired maximum.

The voltage control circuit 26 includes transistor 52, transistor 54, resistor 56, reference voltage diode 58, voltage divider resistor 60 and movable arm 62 connected as shown in FIGURE 1.

In operation, when the voltage produced by generator 14 on output conductor 12 exceeds a predetermined amount, that portion of the voltage tapped off the voltage divider 60 by movable arm 62 will exceed the reference voltage of diode 58 which will allow emitter base current to flow in transistor 54 through transistor 52. Emitter base current in transistor 54 will cause a greater current to flow in the emitter collector circuit thereof to produce a current flow in the emitter base circuit of transistor 52 large enough to cause transistor 52 to conduct in the emitter collector circuit thereof through resistor 46.

Conduction of transistor 52 through resistor 46 will restrict the emitter base current through transistor 40 to an extent sufficient to cause transistor 40 to stop conducting in its emitter collector circuit to produce the desired regulation of generator 14 as previously indicated.

Similarly when the current through output conductor 12 exceeds the predetermined amount transistor 40 is caused to stop conducting by means of current control circuit 28 to remove the parallel path across resistor 36 to permit resistor 36 to regulate the current through field coil 18 so that the current output of generator 12 will be regulated to a value below the desired amount.

The current control circuit 28 comprises transistor 64, transistor 66, resistor 68, the temperature variable resistance 70 which may be of the Thermister type oper-

able to provide an increase in resistance as the temperature increases, and shunt 34 in conductor 12.

The voltage drop between junctions 16 and 72 in conductor 73 and between junctions 72 and 74 in conductor 73 is substantially zero with current below the desired maximum flowing in conductor 73. Current in excess of the desired maximum flowing in conductor 73 will cause a voltage drop across shunt 34 sufficient to cause enough current to flow parallel to shunt 34 through resistor 70 to raise the resistance of the resistor 70 so that it no longer shunts the emitter base circuit of transistor 66. Emitter base current in transistor 66 through transistor 64 is thus allowed to flow, which in turn causes emitter collector current to flow in transistor 66 through the emitter base circuit of transistor 64 to produce conduction in the emitter collector circuit of transistor 64 through resistor 46.

Conduction of emitter collector current in transistor 64 as in the consideration of transistor 52, will prevent current from flowing in the emitter base circuit of transistor 40 and will therefore stop conduction through the emitter collector circuit of transistor 40. Removing the current path in parallel with resistor 36 by causing transistor 40 to cease conduction in the emitter collector circuit will allow regulation of the current below the desired value by resistance 36.

The rectifier diode 30 acts in the usual manner of a voltage regulator cut-out relay to prevent current from flowing from the storage battery 21 of an electrical system as shown in FIGURE 1 into the voltage regulator whereby the battery may be discharged when the generator voltage falls below that of the battery.

Thus, it will be seen that applicant provides a voltage regulator capable of regulating both the voltage and current supplied by a generator through controlling the current applied to the field winding of the generator in the usual manner as well as providing generator cut-out means through the use of a transistorized electronic circuit including no relays having mechanical contacts.

FIGURE 2 illustrates a possible modification of the voltage regulator of the invention wherein voltage regulation may be accomplished in steps by means of substituting a pair of resistors 36a and 36b for resistor 36, as shown in FIGURE 1, between conductor 73a connected to generator output conductor 12a at junction 16a and the field winding 18 of generator 14 through fuse 38a and junction 20a respectively.

Thus on providing two relay transistors 40a and 40b in parallel with the resistors 36a and 36b and providing complete voltage and current control circuits as described above for each of the transistors 40a and 40b voltage and current regulation in steps may be accomplished as will be understood by those in the art.

With particular reference to FIGURE 3 a modified control circuit for either voltage or current is illustrated. The control circuit shown in FIGURE 3 comprises transistor 76, transistor 78, resistor 80, resistor 82 and resistor 83. It will be understood that the modified control circuit shown in FIGURE 3 will be connected to the base of a relay transistor 40 as shown in FIGURE 1 over conductor 84 and to either junctions 72 and 74 across a shunt 34 as shown in FIGURE 1 through conductors 86 and 88 if the modified control circuit is to be used as a current control and across two points of different voltage on a voltage divider resistor, such as 60 in FIGURE 1, through conductors 86 and 88 if the modified control circuit is to be used as a voltage control.

In operation, assume conductors 86 and 88 to be connected to junctions 72 and 74 in FIGURE 1 so that the modified control circuit acts as a current control circuit, the transistor 76 will then be conducting during normal operation of the generator through resistors 80 and 82. Emitter base current of transistor 76 will flow through transistor 40, through resistor 82 to ground which will therefore allow emitter collector current to flow through

5

transistor 76 providing a path for the emitter base current of the relay transistor 40 whereby relay transistor 40 conducts during normal operation of the generator as before. Transistor 78 will be non-conducting since there is insufficient voltage drop produced across shunt 34 to produce a signal through resistor 83.

On the current through shunt 34 becoming excessive a voltage drop is felt across the shunt 34 whereby a bias is applied to transistor 78 to cause emitter base current to flow therein so that transistor 78 conducts in the emitter collector circuit through resistor 82 thereby causing the emitter base current of transistor 76 to be reduced to the point where transistor 76 will not conduct the emitter base current of relay transistor 40 in its emitter collector circuit through resistor 80 so that transistor 40 will be rendered non-conductive as before.

The operation of the modified control circuit of FIGURE 3 when used as a voltage regulator is entirely similar to that described above. Thus both control circuits 26 and 28 shown in FIGURE 1 could be modified to provide a voltage regulator wherein control circuits, such as FIGURE 3, are provided.

FIGURE 4 illustrates a possible modification of part of the current control circuit shown in FIGURE 1. The modified current control circuit shown in FIGURE 4 includes transistor 92, resistor 94 and voltage reference diode 96 connected as shown. In substituting the circuit of FIGURE 4 in that of FIGURE 1 it will be understood that conductor 98 of FIGURE 4 must be connected to the base of transistor 64, resistor 94 must be connected between the collector of transistor 92 and ground, while the conductor 102 is connected to junction 74 in output conductor 73. The structure of FIGURE 4 will thus replace transistor 66, resistor 68 and the temperature sensitive resistor 70 shown in FIGURE 1.

Thus in operation when the voltage drop across shunt 34 becomes sufficiently large indicating that excessive current is flowing through the shunt, emitter base current will be allowed to flow through transistor 92 through transistor 64 and reference diode 96 whereupon transistor 92 will conduct sufficient emitted base current for transistor 64 through the emitter collector circuit of transistor 92 and resistor 94 to cause transistor 64 to conduct emitter collector current. Thus as before the control transistor 64 will be caused to conduct on the current through shunt 34 becoming larger than desired, whereby the relay transistor 40 is caused to cease conducting as desired.

Although a specific embodiment of the present invention has been described and possible modifications thereof indicated it will be understood by those in the art that many other possible variations of the transistorized voltage regulator of the invention are contemplated. Thus applicant does not wish to be limited to the specific embodiment and variations thereof set forth in the specification but intends to include within the scope of the invention all such modifications as suggest themselves to those skilled in the art.

The drawings and the foregoing specification constitute a description of the improved voltage regulator in such full, clear, concise and exact terms as to enable any person skilled in the art to practice the invention, the scope of which is indicated by the appended claims.

What I claim as my invention is:

1. A regulator for a generator having an output circuit and a field coil, said regulator comprising control means including a plurality of resistors in series with the generator field coil across the generator output operable to limit the generator output signal, and separate electronic means associated with each said resistors each including a first transistor having the emitter collector circuit in parallel with one of said plurality of resistors for controlling the effective resistance in series with the generator field coil in accordance with the emitter collector resistance of the first transistors, and separate control means

6

associated with each of said first transistors including a second transistor operable to control the emitter collector resistance of the associated first transistor in accordance with the condition of conductance of the second transistor and each said separate control means also including a third transistor associated with the second transistor responsive to a particular parameter of the generator output signal for controlling the state of conductance of the second transistor whereby the generator output signal is regulated in steps.

2. Structure as claimed in claim 1 and including a first and second load resistor wherein the second transistor includes an emitter connected to the base of the associated first transistor, a collector connected to ground through the first load resistor, and a base connected to ground through the second load resistor and to the collector of the third transistor whereby said second transistor is conductive when generator output is below the allowable maximum thereof.

3. Structure as claimed in claim 2 wherein said third transistor includes an emitter connected to the emitter of the second transistor and to the generator output circuit, a collector connected to the base of the second transistor and a base connected to the generator output circuit at a point different from the connection of the emitter thereto whereby said third transistor is conductive only when generator output is above the allowable maximum thereof.

4. Structure as claimed in claim 1 including a shunt resistor in the generator output circuit, a temperature sensitive resistor connected between the emitter and base of the third transistor, a resistance connected between the base and collector of the third transistor, means connecting the emitter of the third transistor to one side of the shunt through the emitter base circuit of the second transistor, and means connecting the collector of the third transistor to the other side of the shunt.

5. A regulator for a generator having an output circuit and a field coil, said regulator comprising a resistor in series with the generator field coil across the generator output, regulating means operable to limit the generator output signal including a first transistor having the emitter collector circuit in parallel with said resistor for regulating the generator output signal in accordance with the emitter collector resistance thereof, and a pair of separate control means each including a second transistor associated with the first transistor operable to control the emitter collector resistance of the first transistor in accordance with the condition of conductance of the second transistor, each of said separate control means also including a third transistor associated with the second transistor one of which is responsive to generator output voltage and the other of which is responsive to generator output current for establishing the condition of conductance of the second transistor associated therewith.

6. A regulator for a generator having an output circuit and a field coil, said regulator comprising a plurality of resistors in series with the generator field coil across the generator output, separate regulating means associated with each of said resistors each including a first transistor having the emitter collector circuit in parallel with one of said plurality of resistors for regulating the effective resistance in series with the generator field coil in accordance with the emitter collector resistance of the respective first transistor, and a pair of separate control means associated with each of said first transistors each including a second transistor associated with the respective first transistor operable to control the emitter collector resistance of the associated first transistor in accordance with the condition of conductance of the second transistor, each of said separate control means also including a third transistor associated with the second transistors one of which is responsive to generator voltage and the other of which is responsive to generator output current for establishing the condition of conductance of the second transistor associated therewith whereby the

generator output voltage and current are regulated in steps.

7. In combination a generator, a generator output circuit including a series shunt and rectifier, a series resistor and generator field coil connected in parallel with the generator output circuit and a generator voltage and current regulating circuit connected between the series resistor and generator field coil and the generator output circuit including a first transistor having an emitter collector circuit in parallel with said resistor, a pair of second transistors having emitter collector circuits in parallel connected across the emitter base circuit of the first transistor, a second resistance connected between the collectors of said second transistors and ground, a pair of third transistors, a third resistor in series with the emitter collector circuit of one of said pair of third transistors between ground and the base of one of said second transistors, a voltage divider resistance having a movable arm connected between one side of the shunt in the generator output circuit and ground, a reference diode connected between the movable arm of the voltage divider and the base of said one of said third transistors, the other of said third transistors having an emitter

collector circuit connected between the base of the other of said second transistors and the other side of the shunt in the generator output circuit, a resistance connecting the base and collector electrodes of the said other third transistor and a temperature variable resistance connecting the emitter and base of said other third transistor.

8. Structure as set forth in claim 7 wherein a pair of separate resistances are provided in series with the generator field coil and a separate generator voltage and current regulating circuit is provided in conjunction with each of said separate resistors whereby both the current and voltage of the generator is regulated in steps.

References Cited in the file of this patent

UNITED STATES PATENTS

2,892,143	Sommer	June 23, 1959
2,912,635	Moore	Nov. 10, 1959
3,022,427	Jensen	Feb. 20, 1962

FOREIGN PATENTS

1,052,526	Germany	Mar. 12, 1959
1,188,085	France	Sept. 18, 1959
1,217,082	France	Dec. 7, 1959