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MAGNETIC SHUNT COMPENSATED VOLTAGE REGULATOR

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2 Sheets-Sheet 1

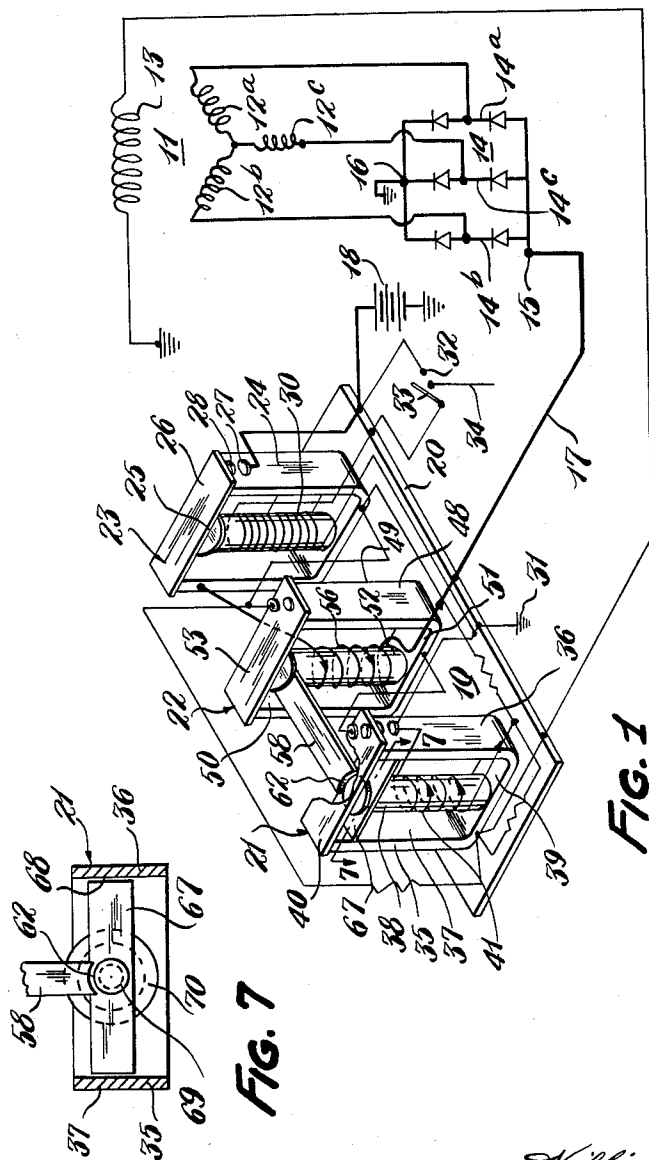


FIG. 1

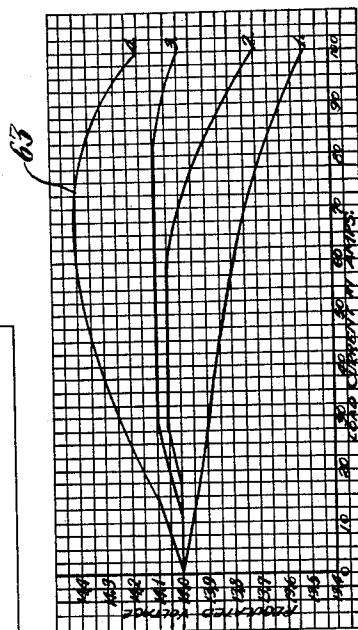


FIG. 6

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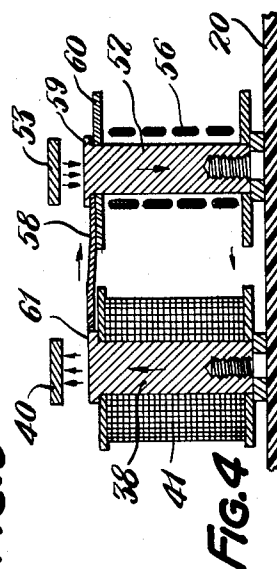
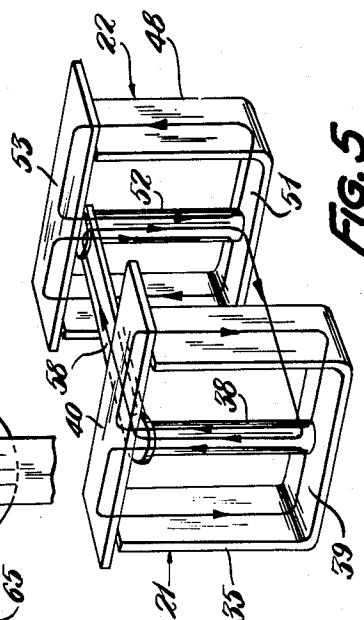
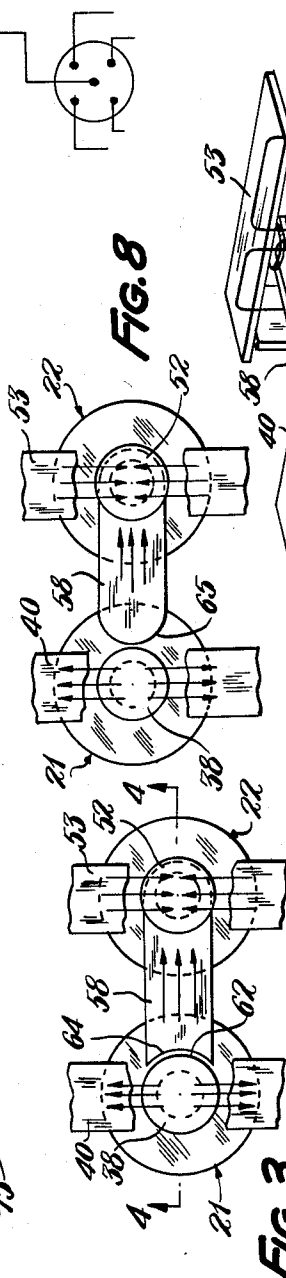
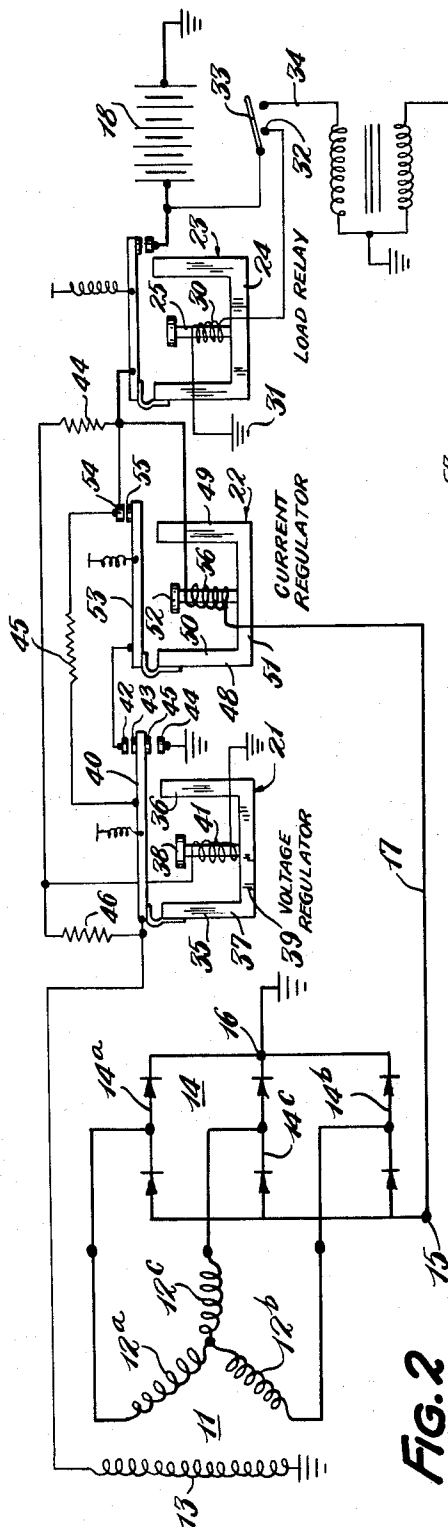
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2 Sheets-Sheet 2



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2,723,323

MAGNETIC SHUNT COMPENSATED VOLTAGE REGULATOR

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1 Claim. (Cl. 200—98)

This invention relates to generator control devices and, more particularly, to voltage and current regulators of the relay type having vibratory switch contacts for automatically controlling the field excitation of the generator.

In generating systems heretofore used in which the terminal voltage of the generator is controlled by a voltage regulator of the electromagnetic vibratory relay type, it has been found that the performance curve representing the current delivered to an external load circuit has an undesirable voltage droop for the higher load current values. Although this undesirable drooping voltage characteristic has been recognized, this applicant is not aware that any satisfactory solution of the problem has been devised heretofore.

The present invention overcomes this difficulty by providing an improved regulator unit of a simple and inexpensive construction but which will effectively control the generator of a generating system so as to maintain the terminal voltage substantially steady throughout a given working range of current values for the load current being delivered.

As another of its objects this invention provides an improved regulator unit comprising voltage and current regulators of the electromagnetic vibratory relay type in which the use of a load compensating magnetic shunt between these regulators substantially eliminates the undesirable voltage droop in the load current curve, and in which a second magnetic shunt having a negative temperature coefficient of permeability and associated with the voltage regulator compensates for variations in the functioning of the voltage regulator due to changes in the operating temperature thereof.

This invention can be further briefly summarized as consisting in certain novel arrangements and combinations of parts hereinafter described and particularly set out in the claim hereof.

In the accompanying sheets of drawings,

Fig. 1 is a perspective view, partially diagrammatic in form, showing a regulator unit embodying the load compensating and temperature compensating magnetic shunts of the present invention;

Fig. 2 is a wiring diagram illustrating an electric generating system in which the improved regulator unit is used;

Fig. 3 is a partial plan view of the regulator unit further illustrating the load compensating magnetic shunt;

Fig. 4 is a partial vertical section taken through the regulating unit as indicated by section line 4—4 of Fig. 3;

Fig. 5 is a diagrammatic perspective view showing the paths of the magnetic flux in a regulator unit embodying the load compensating magnetic shunt;

Fig. 6 is a graph illustrating the load current characteristics of the improved regulator unit;

Fig. 7 is a partial transverse section taken through the voltage regulator of Fig. 1, substantially as indicated by the section line 7—7, and further illustrating the load

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compensating and temperature compensating magnetic shunts; and

Fig. 8 is a plan view similar to Fig. 3, but showing a modified form of the load compensating magnetic shunt.

In Fig. 1 of the drawings the improved regulator unit 10 is shown as being used in an electrical generating system which includes an alternator 11. The generating system here shown can be used to deliver electric current for various purposes, but is especially suitable for use as a vehicle electrical system in which the alternator is driven by the vehicle engine.

The alternator 11 is here shown as being a three-phase alternator having inductor windings 12a, 12b and 12c and a field winding 13. This generating system also includes a rectifier 14 having direct current terminals 15 and 16 for connection with an external load circuit which is here represented by the load conductor 17 and the storage battery 18. The rectifier 14 can be of the dry-plate type and is here shown as being a three-phase full-wave bridge-type rectifier having circuit arms 14a, 14b and 14c with which the respective inductor coils 12a, 12b and 12c of the alternator 11 are connected.

The regulating unit 10 comprises a base 20 formed by a sheet or panel of suitable rigid insulating material and a group of electromagnetic devices 21, 22 and 23 mounted in adjacent side-by-side relation on such base. The electromagnetic device 21 is a voltage regulator of the relay type. The electromagnetic device 22 is a current regulator of the relay type and the electromagnetic device 23 is a load relay.

The load relay 23 serves merely as an automatic switch for connecting and disconnecting the alternator 11 from the storage battery 18. This relay comprises a frame 24 of the yoke type which includes a core 25 and an armature 26. This relay also includes a pair of stationary and movable contacts 27 and 28 located in series relation in the load circuit and of which the movable contact is carried by the armature 26 and is normally held in an open relation to the stationary contact by a spring.

The load relay 23 also includes a magnet coil 30 located on the core 25. One end of this coil is connected with ground, as indicated in the drawings, and its other end is connected with the contact 32 of switch 33 which is the ignition switch of the vehicle. When the ignition switch 33 is closed for energizing the ignition circuit through the conductor 34, the relay coil 30 will also be energized from the battery 18 to thereby close the main contacts 27 and 28 of the load circuit.

This invention is particularly concerned with the voltage regulator 21 and the current regulator 22 and the particular regulators, which are here shown by way of example, will now be described in greater detail. The voltage regulator 21 comprises a frame 35 of the yoke type having a pair of substantially parallel upright arms 36 and 37 and a core 38 located between these arms and also extending in upright relation. The lower ends of the arms 36 and 37 are integrally connected by a transverse frame portion 39 to which the lower end of the core 38 is connected. The regulator 21 also includes a vibratory armature 40 located at the open end of the yoke and bridging the arms 36 and 37.

As shown in the drawings, the voltage regulator 21 also includes a magnet coil 41 located on the core 38 and two pairs of switch contacts controlled by the armature 40. The upper pair of these contacts comprises a stationary contact 42 and a movable contact 43 carried by the armature. The lower pair of these contacts comprises a stationary contact 44 and a movable contact 45 cooperating therewith and also carried by the armature. A spring acting on the armature 40 normally urges the same in a direction to close the upper pair of contacts

42 and 43. The voltage regulator 21 also includes a ballast resistance 44 and a pair of regulating resistances 45 and 46.

The voltage regulator 21 employs substantially the same circuits and functions in substantially the same manner as the voltage regulator disclosed in my earlier application Serial No. 40,340, filed July 23, 1948, now Patent No. 2,520,689 granted August 29, 1950, and therefore need be only briefly described herein so far as its operation is concerned. The magnet coil 41 of this voltage regulator is a voltage coil which responds to the operation of the alternator 11 in magnetically energizing the regulator frame 35. One end of this coil is connected with the direct current portion of the load circuit 17 through the ballast resistance 44 and its other end is connected with ground.

The regulating resistance 45 is a so-called point resistance which is inserted into the energizing circuit for the field winding 13 when the regulator contacts 42 and 43 are open and is short-circuited out of the field circuit when these contacts are closed. When the regulator contacts 42 and 43 are closed, the regulating resistance 46 is in shunt relation to the ballast resistance 44 and assists in supplying energizing current to the magnet coil 41. When the lower pair of regulator contacts 44 and 45 are closed, the regulating resistance 46 is in shunt relation to the magnet coil 41 and at this time causes a decrease in the energizing current of this coil.

The current regulator 22 comprises a magnet frame 48 which is similar to the frame 35 of the voltage regulator 21 and is of the yoke type having a pair of upright substantially parallel yoke arms 49 and 50 which are integrally connected at the lower end by a transverse frame portion 51. The magnet frame 48 also includes a core 52 disposed in upright relation between the arms 49 and 50 and having its lower end connected with the transverse frame portion 51. The current regulator 22 also includes a vibratory armature 53 and a pair of cooperating switch contacts comprising a stationary contact 54 and a movable contact 55 cooperating therewith and carried by the armature 53. Additionally, the current regulator 22 comprises a magnet coil 56 disposed around the core 52 and located in series relation in the load circuit 17.

A spring connected with the armature 53 normally urges the same toward a closed position for the regulator contacts 54 and 55. These regulator contacts are located in series relation to the point resistor 45 and also in series relation to the upper pair of voltage regulator contacts 42 and 43 so that when the current regulator contacts 54 and 55 are closed, current will be supplied from the load circuit to the voltage regulator contacts without passing through the point resistor 45, but whenever the contacts of either the voltage regulator or the current regulator are open the point resistor will be inserted into the energizing circuit for the field winding 13.

As has been indicated above, a transfer of leakage flux takes place between the voltage regulator 21 and the current regulator 22 during the normal functioning of this control apparatus. It has been determined by laboratory tests that when the direction of current flow in the magnet coils 41 and 56 of these regulators is in the direction indicated by the arrows in Fig. 1, the direction of the leakage flux is from the voltage regulator to the current regulator between the upper portions of these devices and from the current regulator to the voltage regulator between the lower portions of these devices. It has also been determined that this leakage flux ordinarily is substantially evenly distributed between the iron parts of these two devices. By the use of the compensating magnetic shunt of this invention, however, this leakage flux is so controlled that it is made to accomplish an important new function in the operation of this regulating apparatus and which will now be described.

For controlling this leakage flux between the voltage and current regulators 21 and 22 and utilizing the same to correct the above-mentioned objectionable voltage droop, a compensating magnetic shunt 58 is provided in bridging relation between these regulators and is preferably located at or adjacent the upper or open end of the magnet frames 35 and 48. The shunt 58 may comprise a flat bar or strip of soft iron, such as the iron which is commercially available under the trade-name Armco iron. The shunt 58 extends in a direction substantially normal to the general planes of the voltage and current regulators 21 and 22 and has one end thereof mounted on the core of one of the regulators and its other end located in adjacently spaced relation to the core of the other regulator. In this instance the magnetic shunt 58 has its fixed end mounted on the upper end of the core 52 of the current regulator 22, as by being clamped between the head 59 (see Fig. 4) of this core and the conventional insulating fiber disk 60.

The compensating magnetic shunt 58 has its other end disposed in closely spaced relation to the head portion 61 of the core 38 of the voltage regulator 21. This end of the magnetic shunt can be located in actual abutting engagement with the core 38 but is preferably spaced therefrom, as here shown, so as to provide an intervening air gap 62 of small width such as three-sixteenths of an inch. The width of the air gap 62 is not considered to be critical and this gap can therefore be varied as may be found necessary or desirable for the accomplishment of the regulating function intended to be obtained.

By the use of the magnetic shunt 58 between a pair of voltage and current regulators of the relay type, it has been found that a very small change in value in the electrical energy of the generating system will be effective through the regulating unit to produce a very strong regulating function on the alternator 11. Thus when the voltage of a generating system of this character tends to droop with the increase in load current, as pointed out in the early part of this specification, the increments of increasing load current will produce a magnetizing effect in the regulator unit which through the action of the compensating magnetic shunt 58 will be very effective in producing an increase in the terminal voltage of the alternator to counteract this droop.

A theory of operation for the compensating magnetic shunt 58 will now be explained and represents what this applicant believes to take place. As the load current passing through the series coil 56 of the current regulator 22 increases, the magnetic flux of the current regulator also increases. With this increase in the ampere-turns of the current regulator coil 56 the leakage flux between the regulators 21 and 22 also increases and this, in turn, produces a greater flux density in the magnetic shunt 58. The increase of flux density in the magnetic shunt 58 is accompanied by an increase in the permeability or flux carrying capacity of this shunt which accordingly provides a magnetic path of higher permeability for the leakage flux of the voltage regulator 21.

When this path of higher permeability is thus provided for the leakage flux of the voltage regulator 21, a greater amount of the flux produced by the voltage regulator coil 41 will pass through the shunt 58, thereby decreasing the amount of flux traversing the armature 40 and thus decreasing the magnetic pull on this armature. The decreased effect thus produced by the magnet coil 41 on the armature 40 permits the spring to maintain the upper pair of contacts 42 and 43 in engagement for a greater period of time, thereby supplying a greater amount of exciting current to the field winding 13 and producing an increase in the terminal voltage of the alternator.

This theory of operation can be further explained by pointing out that the voltage regulator 21 and the compensating magnetic shunt 58 normally operate below the knee of the magnetic curve, as well as below the peak

of the permeability curve, that is to say, in the flux density range of from 30,000 to 45,000 lines of force per square inch. The magnetic curves here referred to are not illustrated but their characteristics are well understood by those skilled in the art relating to electricity and magnetism. In accordance with this theory of operation it will, therefore, be seen that small changes or increments of energy supplied to the regulating unit 10, in accordance with changes occurring in the electrical values of the generating system, produce large changes in flux density and in the regulating function of the unit 10, such as to produce an effective and rapid response by which the desired regulating effect is produced on the alternator 11 for overcoming the voltage droop characteristic in the load current curve.

In accordance with the present invention, the effectiveness of the compensating magnetic shunt 58 can be varied to suit the requirements of different generating systems and regulator units by using different thickness values for this magnetic shunt. Thus when the thickness of this magnetic shunt is increased by only small amounts on the order of some thousands of an inch, the permeability of the shunt is also increased and the effectiveness of the voltage regulator unit in preventing the voltage droop in the load current curve is correspondingly increased. To graphically illustrate this feature of the invention, reference is made to Fig. 6 in which a set of load current curves 63 is presented. In this graph four load current curves, designated 1, 2, 3 and 4, have been plotted to show regulated voltage values for load current values ranging from 0 to 100 amperes.

Curve No. 1 illustrates the droop which occurs in the regulated voltage when no magnetic shunt is provided and shows that the droop takes place throughout the entire range of load current values.

Curve No. 2 illustrates the regulated voltage values obtained when an Armco iron load compensating magnetic shunt 58 of thirty-five thousandths of an inch thickness is employed. As shown by this curve, the voltage droop is entirely eliminated in the range of load current values extending from approximately 25 amperes to 60 amperes.

Curve No. 3 illustrates the regulated voltage obtained by the use of a load compensating Armco iron magnetic shunt 58 of fifty thousandths of an inch thickness is employed and shows that the voltage droop is substantially eliminated in the range of load current values extending from 30 amperes to 80 amperes.

Curve No. 4 is submitted as a further example of the effectiveness of the load compensating magnetic shunt 58 and represents the regulated voltage obtained when an Armco iron magnetic shunt of sixty-five thousandths of an inch thickness is employed. The curve 63 represents a condition in which the voltage droop is over-compensated.

With respect to the width of the load compensating magnetic shunt 58, it should be explained that this shunt can be of various widths but preferably should have a width substantially equal to the diameter of the cores 52 and 38, or to the head portions 59 and 61 of these cores of the regulators, as shown in Figs. 3 and 4. The performance curves 2, 3 and 4 of the graph shown in Fig. 6 were obtained by the use of magnetic shunts having the thicknesses specified above and all having a width substantially equal to the diameter of the heads of the cores of the regulators and which was a width of one-half inch.

As shown in Fig. 3 of the drawings, the end of the magnetic shunt 58 which cooperates with the core of the voltage regulator 21 in defining the air gap 62 is preferably provided with a concavely curved end face 64 having a radius of curvature such that the air gap will be of a substantially uniform width throughout its arcuate length. Instead of the magnetic shunt 58 having such a concavely recessed end adjacent the core of the voltage

regulator it can, if desired, have a convexly curved end 65, as shown in Fig. 8.

Fig. 5 of the drawings shows the paths of the magnet circuits for the voltage and current regulators 21 and 22. As shown in this view, the upper end of the core 38 of the voltage regulator 21 is a north pole and the upper end of the core 52 of the current regulator 22 is a south pole. This view also shows the path of the leakage flux between the voltage and current regulators and shows the direction of travel for the leakage flux at the upper end of these devices as being from the voltage regulator core 38 to the current regulator core 52. It will be understood, of course, that the direction of flux travel in these magnetic circuits is dependent on the direction of the current flow in the magnet coils of the regulators and if the direction of current flow or the helix direction of the wire coil is changed in the magnet coil of one regulator of the unit 10, it should also be changed in the magnet coil of the other regulator.

Another important feature of this invention is the provision of a temperature compensating magnetic shunt 67 in the voltage regulator 21. The temperature compensating shunt 67 is located adjacent the upper end of the frame 35 of the voltage regulator and extends in bridging relation between the arms 36 and 37 of the yoke and in shunt relation to the armature 40. The magnetic shunt 67 is here shown as being a flat bar or strip of magnetic material which has the intermediate portion thereof mounted on the upper end of the core 38 and its opposite ends extending to, or substantially to, the yoke arms 36 and 37. The ends of the shunt 67 can be in abutting contact relation to these arms or, if desired, small air gaps 68 can be provided between these arms and the adjacent ends of the shunt. This shunt 67 can be mounted on the core 38 by being clamped between the head 69 of the core and the conventional insulating fiber disk 70.

An important characteristic of the temperature compensating shunt 67 is that the permeability of this shunt varies with the operating temperature of the voltage regulator 21 such that the distribution of flux resulting in the regulator frame will modify the action of the regulator to effectively compensate for such temperature changes. For this purpose the shunt 67 is made of a magnetic material which will have a negative temperature coefficient of permeability, that is to say, its permeability will decrease with an increase in an operating temperature of the regulator. To obtain this characteristic, this magnetic shunt 67 is preferably made from strip material comprising a suitable nickel-iron alloy, although any other available material having this property could be used.

When the operating temperature of the voltage regulator 21 increases, a corresponding decrease in the current of the magnet coil 41 will take place as the temperature of the copper wire forming this coil increases. The increase in the operating temperature of the regulator causes heating of the magnetic shunt 67 and the increase in the temperature of this shunt is accompanied by a decrease in its magnetic permeability. The decreased permeability of this shunt results in a decreased flow of flux through this shunt, thus leaving the amount of flux traversing the armature 40 substantially unchanged. The result of thus maintaining the amount of magnetic flux in the armature 40 substantially unaffected by temperature variations is to enable the voltage regulator 21 to efficiently perform its control functions regardless of changes occurring in its operating temperature.

From the foregoing description and the accompanying drawings it will now be readily understood that this invention provides a novel magnetic shunt compensated regulating unit by which the functioning of an electrical generating system can be accurately and reliably controlled. From the detailed description given above, it will be further understood that this compensating shunt

means for voltage and current regulators of the relay type may comprise either or both of a load compensating magnetic shunt extending in bridging relation between the voltage regulator and the current regulator and a temperature compensating shunt provided in the voltage regulator in the form of a magnetic shunt extending in bridging relation between the yoke arms of the regulator frame.

Although the magnetic shunt means of this invention and the functioning of the regulating apparatus embodying the same have been illustrated and described herein to a somewhat detailed extent it will be understood, of course, that the invention is not to be regarded as being limited correspondingly in scope, but includes all changes and modifications coming within the terms of the claim hereof.

Having thus described my invention, I claim:

In a regulator unit of the relay type, a voltage regulator comprising a first magnet frame structure including a first vibratory armature and a voltage magnet coil, said first magnet frame structure comprising a first yoke having an open-end and a first core member located in said first yoke and having said voltage magnet coil thereon, said vibratory armature extending across the open end of said first yoke and the outer end of said first core member, said voltage regulator also comprising a first set of cooperating switch contacts actuated by the vibratory movement of said first armature, a current regulator comprising a second magnet frame structure including a second vibratory armature and a current magnet coil, said second magnet frame structure comprising a second yoke having an open-end and a second core member located in said second yoke and having said current coil thereon, said second vibratory armature extending across the open end of said second yoke and the outer end of said second core member, said current regulator also comprising a second set of cooperating switch contacts actuated by the vibratory movement of said second armature, said voltage and current regulators being disposed in side-by-side relation, a flux permeable first metal bar extending laterally in bridging relation

between said first and second magnet frame structures in a direction substantially normal to the general planes of said voltage and current regulators and forming a first magnetic shunt between said frame structures, said bar having one end thereof metallically connected with the outer end of said second core member and its other end extending into a relatively closely spaced air gap relation to the outer end of said first core member, the magnet frame structures of said voltage and current regulators defining flux circuits which are interlinked through said first magnetic shunt such that increased leakage flux in the latter resulting from increase in the energizing current of the series magnet coil of said current regulator decreases the effectiveness on said second armature of the flux generated in said first frame structure by said voltage coil, and a second flux permeable metal bar defining a second magnetic shunt mounted on the outer end of said first core member and extending substantially across the open end of said first yoke, said second magnetic shunt having a negative temperature coefficient of permeability.

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