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CIRCUIT EXTENDING RANGE OF CURRENT-RESPONSIVE DEVICE

Filed Dec. 17, 1956 2 Sheets-Sheet 1

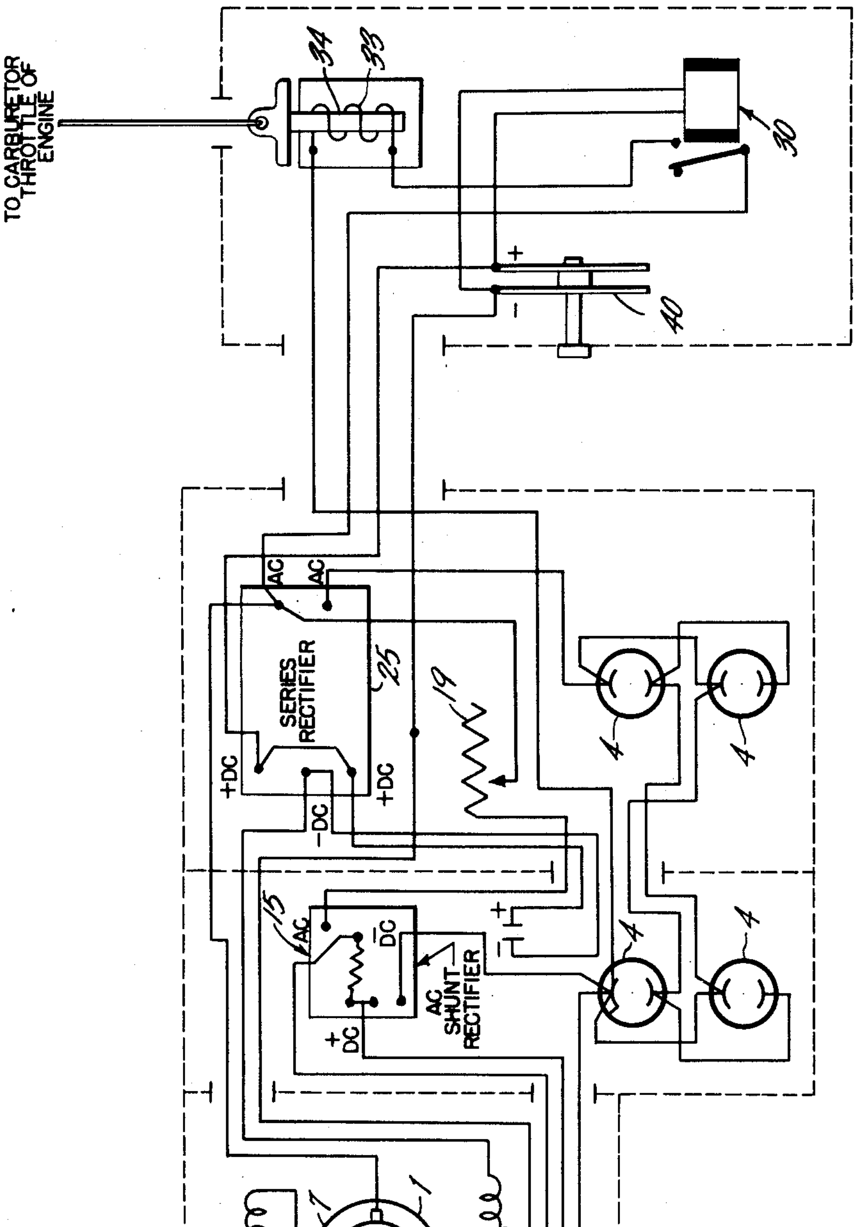

FIG. 1.

CIRCUIT EXTENDING RANGE OF CURRENT-RESPONSIVE DEVICE

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FIG.2.

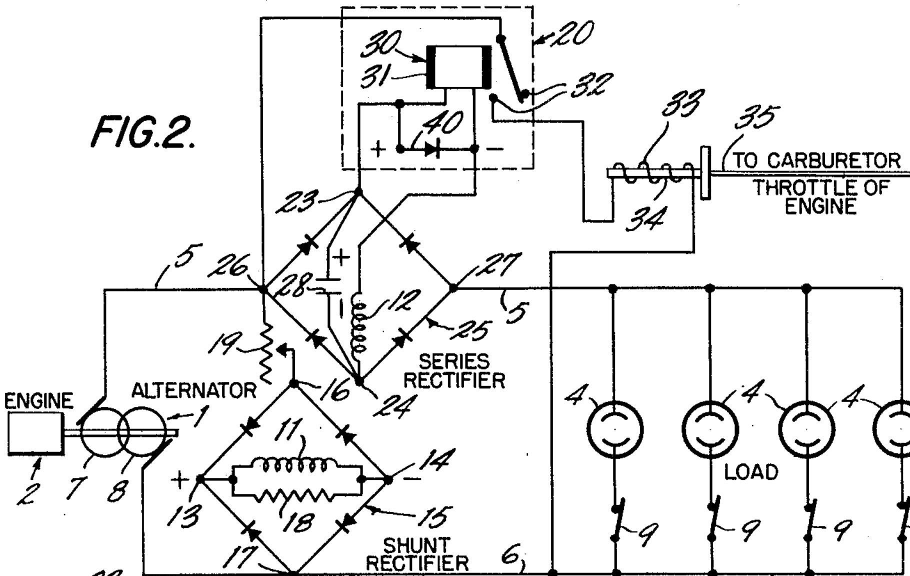
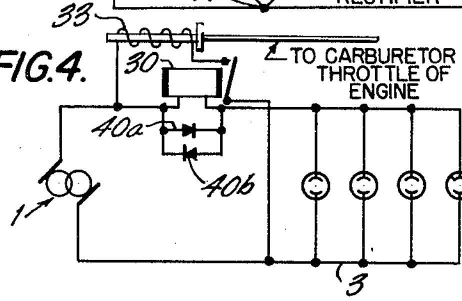


FIG.4.



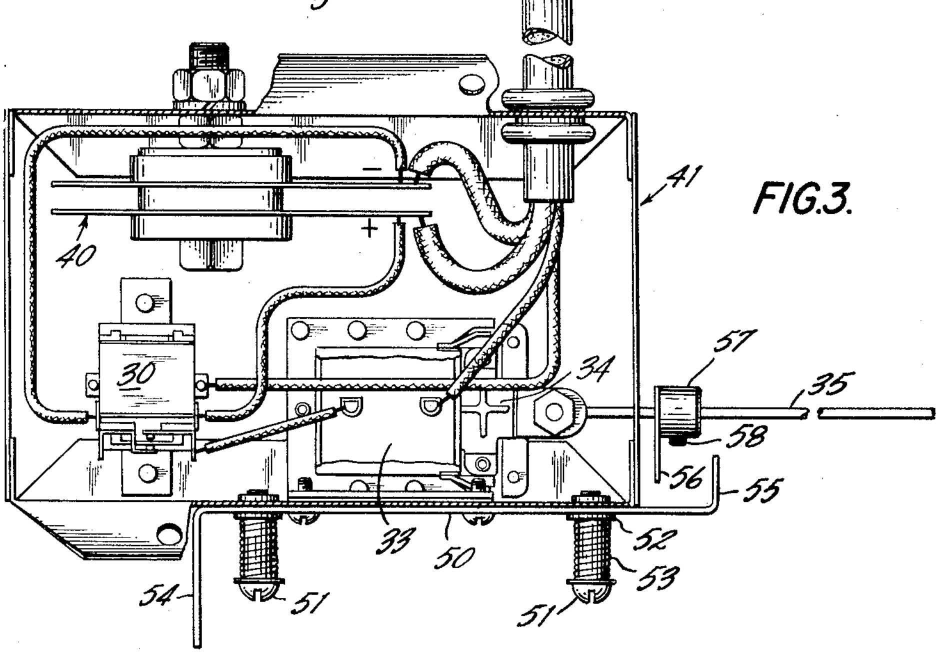


FIG.3.

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CIRCUIT EXTENDING RANGE OF CURRENT-RESPONSIVE DEVICE

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The present invention relates to an electric circuit for extending the operative range of a current responsive element.

A current responsive device, for example a relay, has a predetermined current range within which it will operate satisfactorily. If the current is below this range, the device does not respond. On the other hand excessive current will damage the relay or conversely the relay will limit the amount of current that can be passed. If a relay is made sensitive enough to operate on very low current, it will not tolerate a high current.

In many applications it is desirable to have a current responsive element with a very wide current range. For example, in the control circuit of an internal combustion engine or other prime mover driving an electric generator supplying an intermittent load, it is desirable to provide a relay or other current responsive device connected in series with the load and operative to reduce engine speed to idling when there is no load. When a load, for example an electric lamp, is connected or "turned on," the engine must come back up to operating speed to provide the required voltage. However, when the engine is idling, the voltage and hence the current resulting from connecting a load are so low that the series connected relay controlling the engine speed must be very sensitive in order to operate. This is particularly true if the initial load is relatively small, for example a low wattage electric lamp. On the other hand, with the generator operating at full voltage and full load, the current through the relay is many times that of the initial current and may exceed the current toleration of the relay.

It is an object of the invention to provide an electrical circuit that will greatly extend the operative range of a relay or other current responsive elements. In accordance with the invention, there is connected in parallel with the current responsive element a non-linear current control unit having the characteristic that the voltage across it remains approximately constant regardless of the current passing through it. The voltage need not be entirely constant since even a sensitive current responsive element will tolerate a certain range of current values. However, it should be sufficiently constant to keep the current through the current responsive element within its operative range.

In applying the invention to the idling control of a generator driven by an internal combustion engine or other prime mover, the operating coil of a sensitive relay controlling the idling of the engine is connected in series with the load and a non-linear current controlling unit is connected in parallel with the operating coil of the relay. When a load is connected to the generator while the engine is idling, a relatively low current flows through the relay operating coil and energizes the relay to bring the engine up to operating speed. As the current increases with increase of generator voltage—and perhaps with increased load—a major portion of the load current flows through the current control unit, the voltage across the operating coil of the relay and hence the current

through it remaining approximately the same. Thus the relay can be made sufficiently sensitive to operate at a low current value and yet is protected from the high current value that occurs when the generator is operating at full load. The effective range of operation of the relay is thus greatly extended.

It has been found that semi-conductors, for example rectifiers, can be used as the non-linear current control unit of the circuit in accordance with the invention. When a rectifier is used, it is connected so as to pass current in the direction of flow of the load current. The rectifier is thus used not for the purpose of rectifying current but rather to supply the required voltage across the current responsive element to activate the element even at low values of line current while bypassing a major portion of the current at high current values and keeping the voltage drop across the current responsive element approximately the same.

While the invention is applicable to current responsive elements of a variety of kinds for example relays, tubes, lamps, motors, solenoids, etc. it is of particular value as applied to relays and is accordingly illustrated by way of example in the accompanying drawings as a relay idling control circuit for a prime mover driving an electric generator.

In the drawings:

Fig. 1 is a circuit diagram of a circuit embodying the invention.

Fig. 2 is a simplified circuit diagram of the circuit shown in Fig. 1.

Fig. 3 is a view showing control components of the circuit of Fig. 1 assembled in a control box which is shown in section to disclose the components inside.

Fig. 4 is a simplified diagram of a modification of the circuit shown in Fig. 1.

The circuit shown by way of example in Figs. 1 and 2 comprises an electric generator illustrated as an alternator **1** driven by a prime mover indicated as an engine **2** and supplying current to a load circuit **3**. The load is illustrated schematically as comprising a plurality of output receptacles **4** connected in parallel with one another across lines **5** and **6** which are connected respectively to collector rings or slip rings **7** and **8** of the alternator **1**. Means illustrated as switches **9** are provided for turning individual load units on or off. The output receptacles **4** provide for connecting electric lights, electric tools or other electrically operated units to the load circuit of the alternator.

The alternator **1** is self-excited and is compound wound, being provided with a shunt winding **11** and a series winding **12**. The shunt winding **11** is connected across the D.C. terminals **13** and **14** of a shunt rectifier bridge **15**, the A.C. terminals **16** and **17** of which are connected respectively to the collector rings **7** and **8** of the alternator. The rectifiers of the shunt rectifier bridge **15** are preferably silicon or germanium dry rectifiers. A resistance **18** is connected across the D.C. terminals **13** and **14** of the shunt rectifier bridge **15** in parallel with the shunt winding **11** to protect the rectifiers from transient voltage peaks resulting from switching a load on or off, or from other causes. A variable resistance **19** which is shown connected in a series between one of the A.C. terminals **16** of the shunt rectifier bridge and the corresponding collector ring **7** of the alternator is used to adjust the no-load voltage of the alternator to the desired value.

The series field winding **12** is connected in series with a control unit **20**—described more fully below—across the D.C. terminals **23** and **24** of a series rectifier bridge **25** the A.C. terminals **26** and **27** of which are connected into the line **5** so that the rectifier bridge **25** is connected in series with the load circuit **3**. The series field winding **12** of the alternator is thus connected in series with the load, but by reason of the rectifier bridge **25** the current through the field winding **12** is always in the same direction despite the fact that the output of the alternator and the load are A.C. It will thus be seen that the alternator is self-excited but that excitation is achieved without the use of a commutator. This is referred to as static excitation. The rectifiers of the series rectifier bridge **25** are preferably magnesium copper sulfide rectifiers or other suitable rectifiers having sufficient current capacity. A capacitor **28** is shown connected across the D.C. terminals of the series rectifier bridge **25** in parallel with the series field winding **12** in order to reduce inverse voltage peaks. If silicon or other rectifiers having a higher blocking voltage are used, the capacitor **28** may be omitted.

The control unit **20** may be utilized for various purposes, for example to control voltage, frequency or speed or to operate signal or other devices. In the embodiment illustrated in the drawings it is used to control automatically the idling of the engine **2** driving the generator **1**. When a load is connected to the output circuit **5**, **6** of the generator, the engine runs at a selected speed under control of a governor to provide current at the selected voltage and frequency. If the load is then disconnected it is desirable to reduce the speed of the engine to idling speed to reduce fuel consumption and the wear and tear on the engine and generator. With the engine running at idling speed, the frequency and voltage output of the generator are correspondingly low. When a load is again connected to the generator, the engine and the generator must be brought back up to operating speed in order to provide the required voltage and frequency. In the circuit illustrated in the drawings the engine is automatically controlled by the control unit **20** so as to idle when there is no load and to run at rated speed whenever a load is connected.

The control unit **20** is shown as comprising a D.C. relay **30** having an operating coil **31** and contacts **32** which are open when the relay is de-energized. The operating coil of the relay is connected in series with the series field winding **12** of the generator **1**. A solenoid **33** is connected across the output mains **5**, **6** of the generator through contacts **32** of the relay so that the solenoid is energized when the relay **30** is energized. The solenoid has an armature **34** which is connected by suitable connections illustrated as a rod **35** with the governor or throttle of the engine so that when the solenoid **33** is energized the throttle (or governor) is actuated to bring the speed of the engine to rated operating speed. The throttle is suitably biased, for example by a spring, to return it to idling position when the relay **30** and hence the solenoid **33** are de-energized.

As the operating coil of the raly **30** is connected in series with the series field winding **12** of the generator it is responsive to the series field current and hence to the current in the load circuit **3**. When a load is connected, current flowing in the load circuit and hence through the series field winding energizes the relay **30** so as to close the relay contacts **32** and energize the solenoid **33** to bring the engine up to rated speed. When the load is disconnected, the relay **30** and hence the solenoid **33** are de-energized so as to permit the engine to idle. With the engine running at idling speed the voltage of the generator is relatively low. For example if the generator is rated at 100 volts, the voltage may drop down to 10 volts when the engine is idling. Because of the low voltage, the initial current when a load is connected to the generator is correspondingly low. For example if a 25 watt lamp is turned on, the initial current at 10 volts is only 0.025 amp. Hence in order to operate whenever a load is turned on, the relay **30** must be very sensitive. On the other hand, the full load current of a 1 kv., 100 volt generator would be about 10 amps. The difficulty thus arises that a relay sensitive enough to operate on .025 amp will not tolerate a current of 10 amps.

In accordance with the invention this difficulty is overcome by connecting in parallel with the relay **30** or other current responsive element a non-linear current controlling unit having the characteristic that the voltage across it remains approximately constant regardless of the current passing through it. The voltage need not be entirely constant since even a sensitive relay or other current responsive element will tolerate a certain range of current values. However, it should be sufficiently constant to keep the current through the current responsive element within its operative range.

In the embodiment illustrated in the drawings the non-linear control unit for controlling current through the relay **30** is shown as a rectifier **40** connected in parallel with the operating coil of the relay. As the current is already direct current—having been rectified by the series bridge rectifier **25**—and as the rectifier **40** is connected in a direction to pass the direct current, it is not used as a rectifier but rather as a non-linear current control unit for controlling the amount of current that flows through the operating coil of the relay **30**. If there is only a low current in the series field circuit, for example when the engine is idling and a small load is first connected, substantially all of the current will flow through the operating coil of the relay **30** because of the threshold voltage of the rectifier **40**. This current energizes the relay **30** so that the contacts **32** are closed and the solenoid **33** is energized to bring the engine up to operating speed. As the speed voltage and current increase, the voltage applied to the rectifier **40** exceeds the threshold voltage and the rectifier passes current, thus partially by-passing the winding of relay **30**. However, because of the voltage current characteristic of the rectifier **40**, a portion of the current continues to flow through the relay winding so that the relay **30** is kept energized. If the load is increased, the resulting increased current will flow largely through the rectifier **40** with a relatively small portion of the current continuing to energize the relay **30**. The control unit **20** comprising the relay **30** and the rectifier **40** thus has a very wide current range being sufficiently sensitive as to be actuated by very low current and yet capable of tolerating relatively high current.

It has been found that good results are obtained by using a magnesium copper sulfide dry rectifier having a threshold voltage of about one half volt as the rectifier **40** constituting a current control unit for the relay **30**. However, other semiconductors and in particular silicon, germanium, selenium and copper oxide rectifiers may be used depending on the current carrying capacity and threshold voltage desired for each particular application. The threshold voltage of the current control unit needs to be sufficiently high to operate the relay or other current sensitive element. As the voltage and current increase, the voltage drop across the current control unit should remain approximately the same so that the relay or other current sensitive element continues to be energized while excess current is by-passed through the current control unit.

In Fig. 3 the automatic idle control elements including the relay **30**, solenoid **33** and rectifier **40** are shown assembled as a compact unit housed in a casing **41**. The unit is also provided with cutout means for incapacitating the automatic idle control, for example during the starting of the engine. The cutout means is shown as comprising a slide member **50** which is mounted on the casing **41** for longitudinal movement by means of studs **51** extending through longitudinal slots in the slide **50**. Washers **52** on the studs **51** are pressed by springs **53** into frictional engagement with the slide so as to hold it in selected position. The slide is movable manually by means of a handle portion **54** and has an inturned end portion **55** adapted to engage an arm **56** on a sleeve **57** which is adjustably fixed by a set screw **58** on the rod **35** connecting the armature of solenoid **33** with the engine throttle. The slide **50** is shown in a position permitting the automatic idle control to function. If it is desired to incapacitate the control, for example during the starting of the engine, the slide **50** is moved to the left as viewed in Fig. 3 so that the inturned end portion **55** engages the arm **56** on the sleeve **57** and thereby holds the engine throttle in a predetermined open or partially opened position.

In Fig. 4 there is shown a modification in which the control unit is designed to work on alternating current. In this embodiment the rectifier **40** of Fig. 2 is replaced by two rectifiers **40***a* and **40***b* which are connected in parallel with one another but act in opposite directions. The control unit comprising an alternating current relay **30** and the rectifiers **40***a* and **40***b* is connected directly in series with the load circuit **3** of an alternator **1**. The relay **30** controls a solenoid **33** as in the embodiment of Figs. 1 to 3. The rectifiers **40***a* and **40***b* are not for the purpose of rectifying the current but serve the same function as the rectifier **40** in Fig. 2 in controlling the current so as to cause a portion of the current to energize the relay while by-passing excess current.

While preferred embodiments of the invention have been illustrated and described, it will be understood that the invention is in no way limited to these embodiments and that changes may be made without departing from the spirit and scope of the invention as defined by the following claims.

What we claim and desire to secure by Letters Patent is:

1. In an electrical circuit, a driven source of electrical current, a load circuit connected to receive current from said source, a control circuit comprising a sensitive current-responsive means constantly connected in circuit with said load circuit and having an operating coil energized by the load current for controlling the voltage output of said current source under control of the load current and to control the speed at which said source is driven under control of the load current when said current-responsive means is energized with a predetermined minimum load current value, said operating coil being capable of being energized by a predetermined minimum value of load current and capable of passing a predetermined maximum value of load current, means including speed control means under control of the current-responsive means to cause the current source to be driven at a predetermined operating speed in response to the current-responsive means when said minimum value of load current energizes said current-responsive means, said speed control means including means to cause the driven current source to be driven at a predetermined idling speed substantially lower than said operating speed in the absence of said minimum current energizing the operating coil of the current-responsive means, valve means having a preselected back voltage connected in parallel with said current-responsive means constructed and arranged to pass all the load current not passing through the current-responsive means, said maximum value of load current being substantially less than the load current said valve means is able to pass, and said valve means having said preselected back voltge so chosen in value as to block the flow of load current below said minimum value and thereby cause any current below said minimum value to flow through the operating coil of said current-responsive means while by-passing all the load current above said maximum value so that the portion of such current flowing through said current-responsive means is always below said maximum value.

2. In an electrical system, in combination, a generator, a load circuit connected to receive current from said generator, a prime mover driving the generator, said prime mover having speed-control means for varying the speed of the prime mover between a predetermined idling speed and a predetermined operating speed by actuation of said speed-control means, the improvement which comprises an automatic idle control system comprising, in combination, means comprising a control circuit for controlling actuation of said speed-control means, said control circuit comprising a single sensitive relay having an operating coil constantly connected in series with said load circuit and energized by the load current, said operating coil being capable of being energized by a predetermined minimum relatively low value of load current and of passing a predetermined maximum value of current which is substantially less than the full load current, valve means having a preselected threshold current value connected in parallel with said operating coil for blocking a predetermined value of load current sufficient in value to cause said relay to respond and smaller in value than the maximum value of current said relay operating coil can pass, and connected to pass the remainder of the load current not passing through the operating coil thereby to maintain the current passing through the operating coil means constant, said speed control means including means for idling the prime mover in the absence of said minimum current, and means operatively connecting the speed-control means and the current-responsive means, whereby the speed of the prime mover is automatically varied as a function of the presence or absence of a load current and the prime mover idles in the absence of a load on the load circuit.

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