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B. H. SHORT ET AL

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ENGINE STARTER CONTROL SYSTEM

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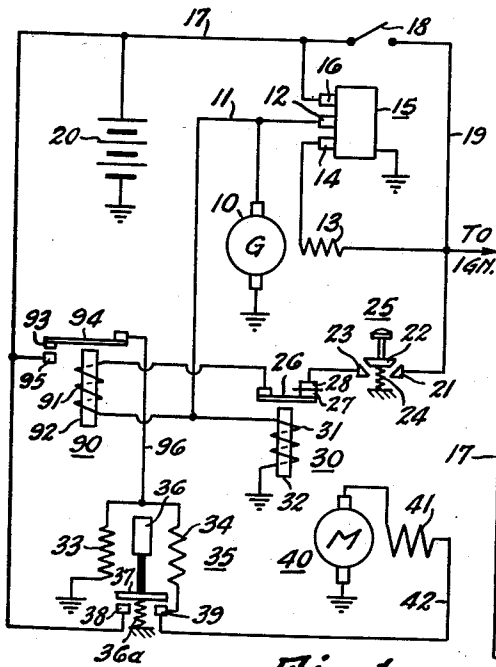


Fig. 1.

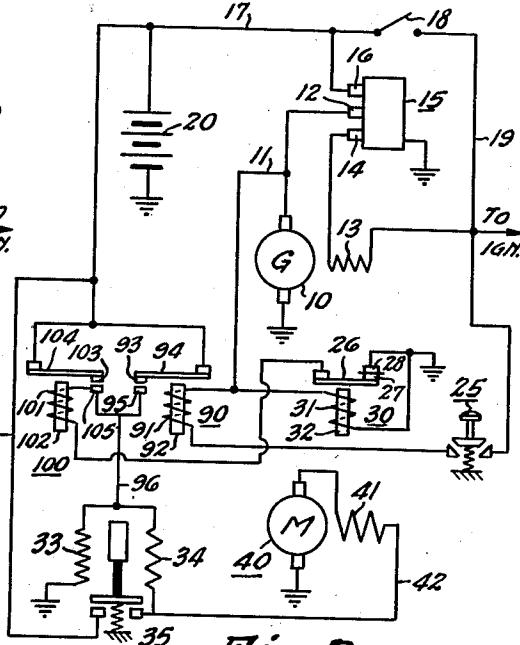


Fig. 2.

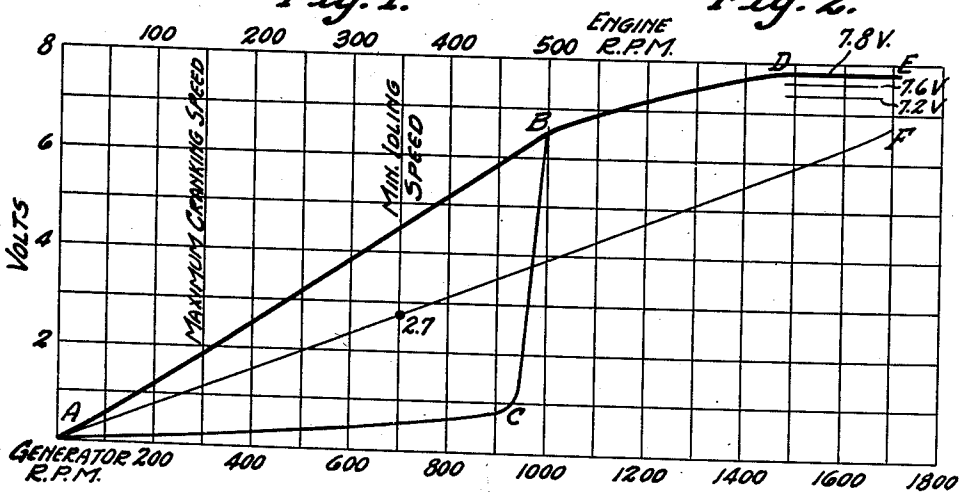


Fig. 3.

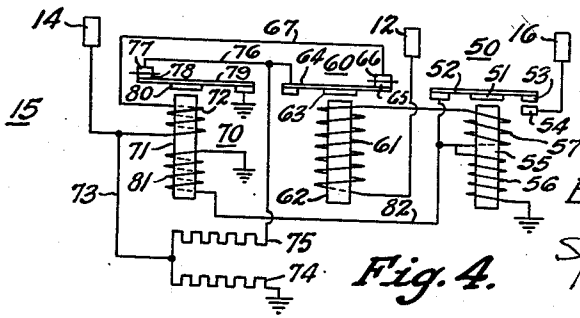


Fig. 4.

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ENGINE STARTER CONTROL SYSTEM

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2 Claims. (Cl. 290—36)

This invention relates to engine starter control systems and aims to prevent use of the starter while the engine is running.

The object of the invention is accomplished by the use of a relay switch which at the maximum cranking speed maintains its contacts closed so that the starting motor can be operated in the usual manner by a starter switch. The electromagnet of the relay is responsive to the voltage of the generator which, below the cut-in speed when the cutout relay is open, is separately excited from the battery and is self-excited when the cutout relay closes. By such arrangement, the relay switch will separate its contacts in the starter control circuit at a speed above the maximum cranking speed of the engine and well below the cut-in speed so that the cranking is discontinued automatically before engine speed increases very much above the maximum cranking speed after the engine becomes self-operative. This is of advantage to the engine starter because the starting motor pinion is automatically disengaged from the engine flywheel gear at a speed considerably lower than the minimum sustaining speed of the engine. Another advantage is that the relay switch holds its contacts open until the engine speed falls to practically zero. This result is obtained because below engine cut-in speed, the generator changes from self-exciting status to separately-exciting status whereby its voltage output below cut-in speed is very much higher than it would be if the generator were self-excited below cut-in speed. Consequently, the relay holds its contacts open until generator speed practically is zero.

Further objects and advantages of the present invention will be apparent from the following description, reference being had to the accompanying drawings, wherein preferred embodiments of the present invention are clearly shown.

In the drawings:

Figs. 1 and 2 are examples of wiring diagrams embodying the invention.

Fig. 3 is a chart for illustrating the operation of the generator when self-excited and when separately-excited.

Fig. 4 is a wiring diagram showing, in detail, one of the units of the other diagrams.

Referring to Fig. 1, a generator 10 driven by the engine has one terminal grounded and the other connected with a wire 11 connected with a terminal 12 of a regulator and cutout relay unit 15. One end of the field winding 13 of the generator is connected with terminal 14 of unit 15 and the other end is connected with a wire 19.

Terminal 16 of unit 15 is connected with wire 17. A switch 18 connects wire 17 with wire 19 connected with the ignition apparatus as well as field coil 13.

Wire 17 is connected with the battery which is grounded and with a contact 33 of a main starter switch, designated generally by numeral 35, having another fixed contact 39 which is connected with a starting motor 40 which is grounded and has its field coil 41 connected by wire 42 with said contact 39. A movable contact 37 is adapted to engage the contacts 33 and 39 to cause operation of the starting motor and this contact is carried by an armature 36 of an electromagnet which is controlled in a manner to be described, to control the operation of said starting motor.

Unit 15, shown in detail in Fig. 4, is a combined voltage regulator, current regulator and cutout relay. The cutout relay 50 comprises an armature 51 attached to a spring blade 52 carrying a contact 53 adapted to engage a contact 54 connected with the terminal 16. The relay includes a core 55 carrying a fine winding 56 which is grounded and carrying a coarse winding 57 connected at one end to blade 52.

Current regulator 60 has a coil 61 connected at one end with winding 57 of relay 50 and at the other end with the terminal 12. Coil 61 surrounds a core 62 facing an armature 63 carried by a spring blade 64 carrying a contact 65 normally engaging a contact 66 connected with a wire 67.

The voltage regulator 70 comprises a core 71 surrounded by a coil 72 connected at one end with wire 67 and at the other end with terminal 14 and with a wire 73 connected with a resistance 74 which is grounded and with a resistance 75 which is connected with wire 76 which connects blade 64 of regulator 60 with a contact 77 normally engaged by a contact 78 carried by a spring blade 79 which is grounded and which carries an armature 80 facing the core 71. Core 71 is surrounded also by a coil 81 which is grounded at one end and which is connected at the other end with wire 82 connected with the cutout relay windings 59 and 56 and with the spring blade 52.

As shown in Fig. 1, the wire 19 is connected to the fixed contact 21 of a manually operated switch, designated generally as 25, which is closed by the operator when it is desired to start the engine. This switch has a second fixed contact 23 and a manually operable contact 22 normally held out of engagement with the fixed contacts by a spring 24 and movable into engagement therewith by the operator. The fixed contact 23 is connected by a wire to the fixed contact 28 of a

normally closed relay switch 30, which has a movable contact 27 carried by an armature 26 of a magnet having a winding 31 and a core 32, the winding being grounded as indicated and connected to the armature 26, so that when the switch 25 is closed, current is caused to flow through the winding 31.

As already stated, the movable contact 37 of the main starter switch 35 is carried by the armature 36. This magnet has two coils 33 and 34 which, when energized, effect movement of the contact 37 into engagement with fixed contacts 38 and 39 against the force of a spring 36a which normally holds the switch open. Both coils are effective to move the armature 36 to close said switch, but as soon as the switch is closed, the coil 34 is short circuited so that the switch is held closed only by the coil 33 during the cranking of the engine to effect starting.

Energization of coils 33 and 34 is controlled by a normally open relay switch designated generally by the numeral 90, which has a fixed contact 95 connected with the wire 17 leading from the battery and a movable contact 93 carried by an armature 94, connected by a wire 96 with the coils 34 and 35. This relay switch includes a winding 91 surrounding a core 96 and in series with the winding 31 and armature 26 of the switch 30. When current flows through winding 91, the contacts 93 and 95 are engaged and current flows from the battery through such contacts and wire 96 to the coils 33 and 34 to effect closing of the circuit between the battery and the starting motor 40.

To start the engine, the ignition is turned on by closing switch 18. Current then flows from the battery 20 to the ignition apparatus through wire 17, switch 18 and wire 19 and also to the generator field 13 and out through the terminal 14 and to ground through coil 72 of regulator 70, wire 67, contacts 66, 65 of the regulator 60, blade 64, wire 76, contacts 77 and 78 of regulator 70 and armature 79 which is grounded. The switch 25 is then closed which causes current to flow from the battery through wire 19, switch 25, and the wire leading from contact 26 through winding 91 and winding 31 to ground. The current flowing through winding 91 effects engagement of contacts 93 and 95 so that current flows from the battery through wire 17, the contacts 93, 95, armature 94 and wire 96 to the coils 33 and 34 to effect movement of contact 37 into engagement with contacts 38 and 39 so as to close the main switch 35. As already stated, when this takes place the coil 34 is short circuited and the magnet remains in circuit closing status solely by reason of the energization of coil 33, which exerts sufficient force to hold the switch 35 closed during the cranking operation.

The closing of the switch 25 to cause cranking of the engine places the winding 91 and winding 31 in series with the battery 20 after the ignition switch 18 is closed. At a generator speed slightly above maximum cranking speed the excitation of coil 31 of relay switch 30 is increased sufficiently to cause opening of the contacts 27 and 28. This results in de-energization of winding 91 of relay switch 90 and operation of the starting motor 40 ceases. In case the relay switch 30 fails to open, relay switch 90 will open when the generator cuts in because coil 91 is then short circuited by reason of the connection 11. This short circuit is established through conductor 11, terminal 12, current coil 61, current coil 57, blade 52, contacts 53 and 54,

which are closed when the generator cuts in by operation of voltage coil 56, terminal 16, ignition switch 18, wire 19 and switches 25 and 26. With the arrangement shown, the relay switches 30 and 90 provide double protection.

During the cranking of the engine, the generator operates as a separately-excited generator and produces an output represented by the line A—B (Fig. 3). The battery supplies current to the field at 5.5 volts, for example, if the battery is fairly well charged. Below maximum cranking speed, about 300 R. P. M. generator speed or 150 R. P. M. engine speed, the maximum voltage output of the generator is below two volts which is insufficient to cause relay 30 to separate its contacts 27 and 28. Relay 30 is constructed so as to separate its contacts at 2.25 volts and to close its contacts when the voltage impressed on its coil is 1.2 volts. Therefore, when the engine becomes self-operative, the generator output when self-excited, will reach 2.25 volts at about 360 R. P. M. generator speed or 180 R. P. M. engine speed. Therefore, long before the speed of the engine can rise to cut-in speed or even minimum idling speed which is about 700 generator speed and 350 engine speed, the circuit of the solenoid 35 and of the motor 40 will have been interrupted.

If the generator were not separately-excited below the generator cut-in speed, 1000 R. P. M., for example, the voltage generated would be that represented by the curve A—C—B which drops off rapidly to a low value as generator speed decreases. Therefore, it is necessary to provide for separate excitation of the generator, otherwise the relay 30 would close its contacts while the engine is idling, thereby making it possible to operate the starter by closing the starter switch 25 while the engine is in operation. Even with a relatively weak battery supplying the separately-excited field at 3 volts for example, the relay 30 would remain open at idling speed because the voltage then would be about 2.7 volts.

Coil 56 of cutout relay 50 is in circuit with coil 57 of the relay and coil 61 of the current regulator 60 and terminal 12. When the generator attains speed of about 1000 R. P. M., the excitation of the coil 56 is sufficient to cause the attraction of armature 51 of the cutout relay to close its contacts 53 and 54, thereby causing current to flow from the generator to terminal 12, coil 61 of current regulator 60 and coil 57 of relay 50. Relay 50 remains closed until generator voltage falls sufficiently below battery voltage to cause reversal current in coil 57 to buck the magnetism produced by coil 56 whereupon the relay 50 opens to prevent discharge of the battery.

While relay 50 is closed, the generator voltage for various speeds above 100° R. P. M. is indicated by the line B—D—E. The maximum voltage, represented by line D—E, is limited by the voltage regulator 70 which operates in the usual manner to separate contact 78 from contact 77, thereby causing the reduction of field excitation by resistances 75 and 74. The regulator will maintain the voltage between 7.2 and 7.8, for example, when cold and between 7.2 and 7.6 when hot. Current output is limited by current regulator 60 which, on exceeding a predetermined current flow through its winding 61, causes contact 65 to separate from contact 66 whereby resistance 74 becomes effective to reduce field excitation.

In the form shown in Fig. 2, the circuit between

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the battery wire 17 and the wire 96 includes parallel circuits, one being the contacts 93 and 95 of relay 90, the other being the contacts 103 and 105 of a relay 100 having a core 102 surrounded by a coil 101 which is connected with contact 195 and with blade 26 of relay 30. The closing of ignition switch 18 and starter switch 25 causes current to flow from the battery to the coil 91 of relay 90 and coil 31 of relay 30; but, during cranking, the contacts 27 and 28 of relay 30 remain closed while contacts 93 and 95 of relay 90 are closed.

In addition to causing the solenoid 35 to complete the starting motor circuit, the closing of contacts 93 and 95 energizes coil 101 of relay 100, causing contacts 103 and 105 to close. The starting motor load on the battery and the rising generator output reduces voltage sufficiently to release the contacts of relay 90 almost immediately, the circuit being maintained through contacts 103 and 105 which will remain closed until the contacts 27 and 28 are opened. Once released, relay 100 cannot be energized until the contacts of relay 90 are closed. Relay 90 will not close until engine rotation has practically stopped. Therefore, if the engine makes a false start due to misfire or other causes, the relay 30 is thereby opened, the solenoid cannot be reenergized until the engine approaches standstill and the voltage between battery and the generator armature becomes sufficient to operate relay 90. When a normal start is made, relay 30 opens, deenergizing coil 101, and relay 100 opens, causing cranking to cease. At generator cut-in, the generator armature is connected to the battery in the regulator 15 and the closing of the starting switch 25 short-circuits the coil 91 of relay 90 preventing contacts 93 and 95 from closing. In case the engine has been running and coasts down, the engine starter cannot be operated by pressing the button 25 because battery excitation of coil 31, acting cumulatively with generator excitation, would cause relay 30 to open its contacts so that coil 101 of relay 100 would not be excited. Coil 91 of relay 90 would not be excited because excitation of coil 91 by the battery would be bucked by excitation produced by the generator when separately excited.

Relay 30 is known as a "high" relay because it operates at relatively high voltage differential between the generator armature terminal and ground. It opens its contacts when the voltage of the generator (self-excited) is slightly above that attained at maximum cranking speed. It closes its contacts at a much lower voltage attained at a very low generator speed at which the corresponding engine speed is below that which will sustain engine operation.

Relay 90 of Fig. 2 is known as a "low" relay because it operates at a relatively low voltage differential between the generator armature terminal and ground. It is adjusted to close at no-load battery voltage or slightly less and to release when battery voltage falls, due to loading of the battery when the starting motor 40 receives current from the battery.

Relay 100 of Fig. 2 is known as the "hold-in" relay. The closing of relay 90 causes coil 101 of relay 100 to be energized. The closing of contacts 103, 105 of relay 100 causes coil 101 to remain energized although the contacts 93, 95 of relay 90 may open. However, once the hold-in relay 100 opens, it cannot be reenergized until battery voltage exceeds generator voltage by an amount sufficient to cause the "low" relay 90 to close its contacts.

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The control circuit of Fig. 2 prevents, on false starts, the starting motor pinion from crashing into mesh with the engine flywheel gear when the engine falters. In a false start, the engine usually fires once or more, opening the "high" relay switch 30, then stops, due to misfire or something else. It is possible that such switch might close at this time and a cycle be started where the pinion was forced to engage and disengage rapidly until the engine became self-operative. However, experience shows that when the switch 30 has once opened, it will remain open until rotation of the flywheel has ceased.

This application is a division of Serial No. 706,618, filed October 30, 1946, now Patent No. 2,572,397, granted October 23, 1951.

While the embodiments of the present invention as herein disclosed, constitute preferred forms, it is to be understood that other forms might be adopted.

What is claimed is as follows:

1. An engine starter control system comprising a generator having a field winding, a storage battery charged by the generator, an engine starter including an electric motor operated by battery current, a normally open switch for connecting the battery with the motor, an electromagnet for closing said switch, a switch for connecting the generator field winding with the battery in order that the generator will be initially separately excited, a cutout relay for connecting the generator with the battery when generator voltage attains a certain value whereby the generator becomes self-exciting at cut-in speed, said relay disconnecting the generator from the battery when the generator voltage falls below battery voltage in consequence of which the generator returns to separately excited status, and means for controlling the connection between the battery and said electromagnet and including two relay switches having switch-closing electromagnets and having their contacts connected in parallel, the closing of either of these relay switches causing energization of the first mentioned electromagnet, one of the relays being a "low" (voltage differential) relay which closes contact on no-load battery voltage and opens contact when the battery is supplying current to the starting motor, the other of said relays being a "hold-in" relay whose electromagnet is initially energized by closing of the contacts of the "low" relay, energization of the electromagnet of the "hold-in" relay being maintained by the closing of the "hold-in" relay, a "high" (voltage differential) relay having normally closed contacts which control the circuit of the electromagnet of the "hold-in" relay, said "high" relay having an electromagnet sensitive to the voltage of the generator when separately excited, said "high" relay being so constructed as to remain closed at a generator speed corresponding to maximum cranking speed and to open above maximum cranking speed and below cut-in speed and to reclose at a speed substantially below engine minimum idling speed, and including a normally open, manually closed switch for connecting the battery with the electromagnet of the "low" relay.

2. An engine starter control system comprising a generator having a field winding, a storage battery charged by the generator, an engine starter including an electric motor operated by battery current, a normally open switch for connecting the battery with the motor, an electromagnet for closing said switch, a switch for connecting the generator field winding with the bat-

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tery in order that the generator will be initially separately excited, a cutout relay for connecting the generator with the battery when generator voltage attains a certain value whereby the generator becomes self-exciting at cut-in speed, said relay disconnecting the generator from the battery when generator voltage falls below battery voltage in consequence of which the generator returns to separately excited status, and means for controlling the connection between the battery and said electromagnet and including two relay switches having switch-closing electromagnets and having their contacts connected in parallel, a series circuit including the battery, said contacts of the two relay switches in parallel, a normally open, manually closed switch and the normally closed contacts of a third relay switch having an electromagnet sensitive to the voltage of the generator when separately excited, said third relay being a "high" (voltage differential) relay so constructed as to remain closed at a generator speed corresponding to maximum cranking speed and to open above maximum cranking speed and below cut-in speed and to reclose at a speed substantially below engine minimum idling speed,

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one of the relays first mentioned being a "low" (voltage differential) relay which closes contact on no-load battery voltage and opens contact when the battery is supplying current to the starting motor, the other of said relays being a "hold-in" relay whose electromagnet is initially energized by closing of the contacts of the "low" relay, energization of the electromagnet of the "hold-in" relay being maintained by the closing of the "hold-in" relay.

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