

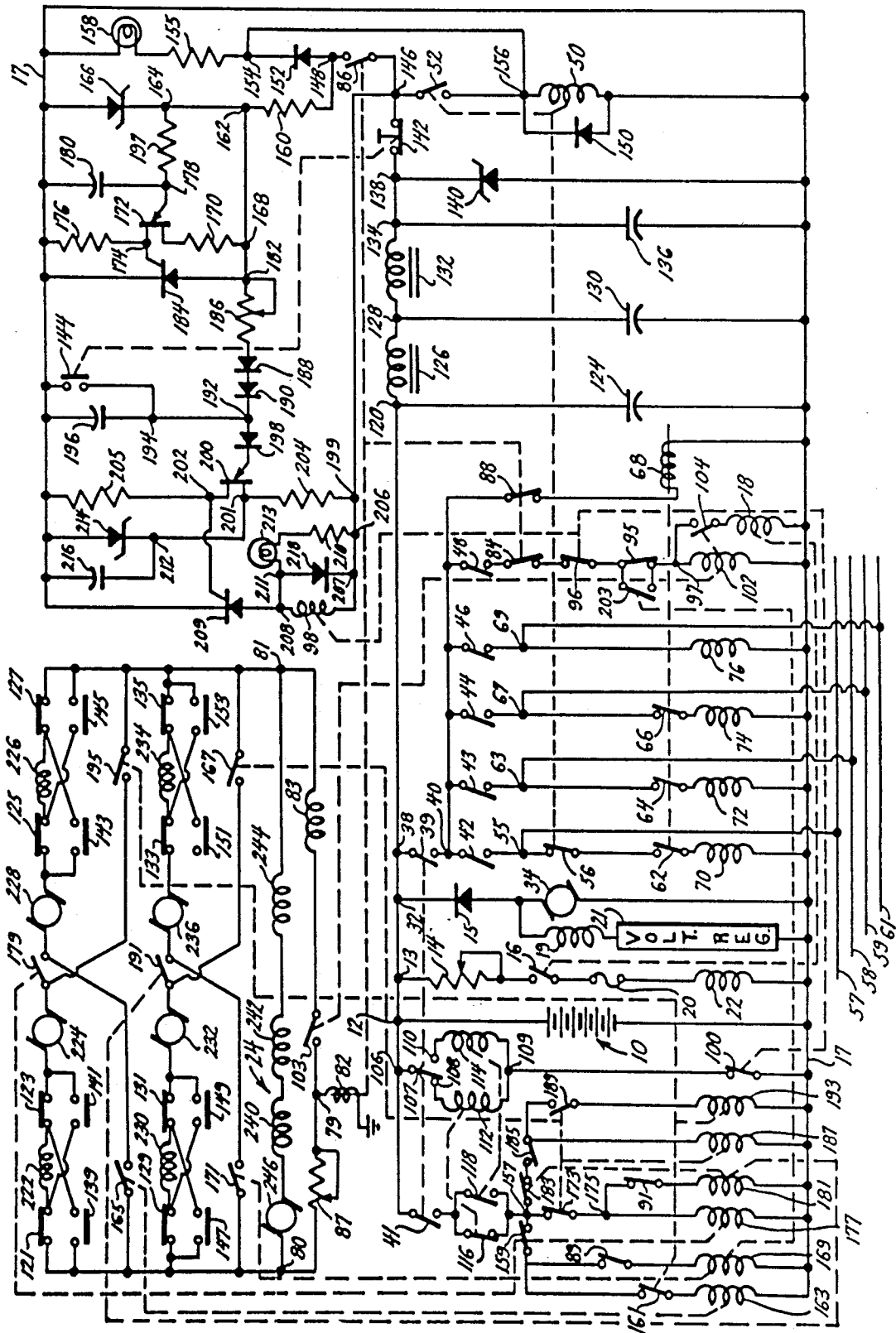
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CONTROL SYSTEMS FOR DIESEL-POWERED UNIT DURING FLASH CONDITION

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1

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CONTROL SYSTEMS FOR DIESEL-POWERED UNIT DURING FLASH CONDITION

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ABSTRACT OF THE DISCLOSURE

The ground relay of a diesel-powered unit automatically responds to a flash or ground in the high voltage electrical system of that unit to limit the speed of the diesel engine of that unit to "run 7" or below and to actuate an indicator showing that a flash or ground has occurred in that high voltage electrical system.

This invention relates to improvements in Control Systems. More particularly, this invention relates to improvements in control systems for diesel-powered units which can be interconnected to constitute a railroad locomotive.

It is, therefore, an object of the present invention to provide an improved control system for diesel-powered units which can be interconnected to constitute a railroad locomotive.

A diesel-powered unit is customarily equipped with a "ground relay" that is normally de-energized but that will become energized whenever a "flash" or "ground" develops in the high voltage electrical system of that diesel-powered unit. A flash usually develops adjacent the commutator of the high voltage generator, or adjacent the commutator of one of the high voltage traction motors, of the diesel-powered unit; and, while some flashes can be of short duration—and thus relatively harmless—some flashes can tend to continue and thus tend to be quite harmful. A ground can develop in various portions of the high voltage electrical system of the diesel-powered unit; and, while some grounds can be of short duration—and thus relatively harmless—some grounds can tend to continue and thus tend to be quite harmful. Flashes tend to develop more frequently, and those flashes tend to be of greater intensity, when the throttle of the diesel-powered unit is set in its highest speed—"run 8"—position. Consequently, it would seem desirable to instruct the engineer of a railroad locomotive, whenever a flash has occurred in the high voltage electrical system of one of the diesel-powered units of that locomotive, to restrict the throttle settings of that one diesel-powered unit to positions below the "run 8" position. However, because the throttle settings of all of the diesel-powered units of a railroad locomotive are electrically interconnected, the restriction of the throttle settings of that one diesel-powered unit to positions below the "run 8" position would tend to restrict the throttle settings of all of the other diesel-powered units to positions below the "run 8" position; and that would be undesirable, because it would limit the power output level of that locomotive. It would be desirable to provide a control system, for a diesel-powered unit, which could respond to a flash or ground in the high voltage electrical system of that diesel-powered unit to permit the diesel engine of that diesel-powered unit to operate at various speeds, but which would limit the speed of that diesel engine to values below "run 8"—even when the throttle of that diesel-powered unit was set in the "run 8" position. With such a control system, the diesel-powered unit could be interconnected with other diesel-powered units to constitute a railroad locomotive, and the throttles of all of those diesel-powered units could be set in the "run 8"

2

position—so that locomotive could be operated at high power levels—and the diesel engine of the one diesel-operated unit could be operated at "run 7" speed but would be kept from operating at its "run 8" speed. The present invention provides such a control system; and it is, therefore, an object of the present invention to provide a control system for a diesel-powered unit which can respond to a flash or ground in the high voltage electrical system of that diesel-powered unit to permit the diesel engine of that diesel-powered unit to operate at various speeds but to keep the speed of that diesel engine below "run 8"—even when the throttle of that diesel-powered unit is set in the "run 8" position.

The "ground relay" of a diesel-powered unit customarily is a mechanically-latched relay; and that relay becomes energized, and mechanically latches itself in open position, whenever a flash or ground develops in the high voltage electrical system of that diesel-powered unit. In that open position, that relay will remove the battery-induced excitation for the field winding of the high voltage generator, and will also open the "forward" and "reverse" power contactors which are intermediate that generator and the high voltage traction motors of that railroad locomotive. In addition, that relay will de-energize the engine relay, and thereby restrict the speed of the diesel engine of that diesel-powered unit to "run 1." The ground relay is customarily un-latched, and is thus permitted to re-set itself in closed position, if the flash or ground is of a continuing nature. However, if that flash or ground is of a continuing nature, or if a second flash or ground develops shortly after that relay is un-latched, that relay will become energized and will mechanically latch itself in open position a second time. Customarily, that relay is un-latched, and is thus permitted to re-set itself, a second time; and, customarily, if that relay becomes energized and latches itself a third time, that relay will be un-latched and permitted to re-set itself a third time. However, if that relay becomes energized and latches itself a fourth time, it is customarily left in latched position; and, in that position, it will keep the high voltage generator from generating any appreciable voltage, and it will keep the diesel engine of that diesel-powered unit from operating at any speed other than "run 1." If that diesel-powered unit is part of a railroad locomotive which includes other diesel-powered units, and if the engineer of that locomotive sets the throttle of any of those diesel-powered units to call for "run 5" or "run 6" speeds, the diesel engine of the said diesel-powered unit will stop operating; because a diesel engine that can only operate at "run 1" will automatically stop whenever its throttle is set in the "run 5" or "run 6" position. When that diesel engine stops, an alarm will sound; and that alarm will continue to sound as long as that diesel engine remains stopped. The continuous sounding of that alarm would be very objectionable, not only because of its impact upon the nerves of the engineer, but also because it would keep that alarm from indicating to the engineer when a further problem arose. It would be desirable to provide a control system for a diesel-powered unit which would enable the ground relay of that diesel-powered unit to remove the battery-induced excitation for the field winding of the high voltage generator and to open the "forward" and "reverse" power contactors which are intermediate that generator and the high voltage traction motors of that diesel-powered unit, but which would keep that ground relay from limiting the speed of the diesel engine of that diesel-powered unit to "run 1." The present invention provides such a control system; and it is, therefore, an object of the present invention to provide a control system for a diesel-powered unit which will enable the ground relay of that diesel-powered unit to remove the battery-induced excitation for the field winding of the high voltage gen-

erator and to open the "forward" and "reverse" power contactors which are intermediate that generator and the high voltage traction motors of that diesel-powered unit but which will keep that ground relay from limiting the speed of the diesel engine of that diesel-powered unit to "run 1."

Other and further objects and advantages of the present invention should become apparent from an examination of the drawing and accompanying description.

In the drawing and accompanying description, a preferred embodiment of the present invention is shown and described, but it is to be understood that the drawing and accompanying description are for the purpose of illustration only and do not limit the invention and that the invention will be defined by the appended claims.

The drawing is a diagrammatic showing of one form of control system that is made in accordance with the principles and teachings of the present invention.

Referring to the drawing in detail, the numeral 10 denotes a storage battery which is carried by a diesel-powered unit that utilizes the control system provided by the present invention and that can be interconnected with one or more other diesel-powered units to constitute a railroad locomotive. In one preferred embodiment of that control system, that battery is dimensioned to supply a D.C. voltage of sixty-four volts. Junctions 12 and 13, a load regulator 14, relay contacts 16, and a fuse 20 connect the positive terminal of the battery 10 to one terminal of the battery-energized field winding 22 of a high voltage generator 24; and the other terminal of that field winding is connected to the negative terminal of that battery by negative conductor 17. The relay contacts 16 are controlled by a relay coil 18; and those relay contacts will be open whenever that relay coil is de-energized but will be closed whenever that relay coil is energized. The load regulator 14 is associated with the governor of the diesel engine of the diesel-operated unit; and the movable contact of that load regulator will respond to the load demand on that diesel engine to move up or down and thereby "short" different lengths of the lower section of that load regulator.

Junctions 12 and 13, a junction 32 and a diode 15 connect the armature winding 34 of an auxiliary generator to the positive terminal of the battery 10; and that armature winding also is connected to the negative conductor 17. The field winding 19 of that auxiliary generator and a voltage regulator 21 are connected in series with each other across that armature winding. That auxiliary generator will act, whenever the diesel-powered unit is operating, to develop a voltage of about seventy-four volts; and that auxiliary generator will keep the battery 10 charged.

The numerals 42, 43, 44, 46 and 48 denote contacts on a drum-type, throttle-controlled switch; and those contacts are connected to the junction 32 by a junction 38, switch contacts 39, and a junction 40. The switch contacts 39 are "ganged" with switch contacts 41 to constitute the "isolation" switch of the diesel-powered unit. The contacts 48 will be closed but the contacts 42, 43, 44 and 46 will be open whenever the throttle, not shown, of the diesel-powered unit is set in the "run 1" position. The contacts 42 and 48 will be closed but the contacts 43, 44 and 46 will be open whenever the throttle is set in the "run 2" position. The contacts 44 and 48 will be closed but the contacts 42, 43 and 46 will be open whenever the throttle is set in the "run 3" position. The contacts 42, 44 and 48 will be closed but the contacts 43 and 46 will be open whenever the throttle is set in the "run 4" position. The contacts 43, 44, 46 and 48 will be closed but the contacts 42 will be open whenever the throttle is set in the "run 5" position. All of the contacts 42, 43, 44, 46 and 48 will be closed whenever the throttle is set in the "run 6" position. The contacts 43, 44 and 48 will be closed but the contacts 42 and 46 will be open whenever the throttle is set in the "run 7" position; and the

contacts 42, 43, 44 and 48 will be closed but the contacts 46 will be open whenever the throttle is set in the "run 8" position.

A junction 55, relay contacts 56 and relay contacts 62 connect the "A" solenoid 70 of the diesel-powered unit to the throttle-controlled contacts 42; and the lower terminal of that solenoid is connected to the negative conductor 17. The relay contacts 56 are controlled by a relay coil 50; and those relay contacts are closed whenever that relay coil is de-energized, but will open whenever that relay coil is energized. The relay coil 50 also controls relay contacts 52; and those relay contacts are open whenever that relay coil is de-energized but will close whenever that relay coil is energized. The relay contacts 62 are controlled by the coil 68 of the engine relay of the diesel-powered unit; and that relay coil also controls relay contacts 64 and 66. The relay contacts 62, 64 and 66 will all be open whenever the coil 68 of the engine relay is de-energized, but those relay contacts will all be closed whenever that coil is energized. A junction 63 and the relay contacts 64 connect the throttle-controlled contacts 43 to the "B" solenoid 72 of the diesel-powered unit, a junction 67 and the relay contacts 66 connect the throttle-controlled contacts 44 to the "C" solenoid 74 of that diesel-powered unit, and a junction 69 connects the throttle-controlled contacts 46 to the "D" solenoid 76 of that diesel-powered unit. The lower terminals of the solenoids 72, 74 and 76 are connected to the negative conductor 17. The "A," "B," "C," and "D" solenoids 70, 72, 74 and 76 control the amount of fuel that is supplied to the diesel engine of the diesel-powered unit, and thus control the speed of that diesel engine. The junctions 55, 63, 67 and 69 are connected, respectively, to conductors 57, 58, 59 and 61 of the "train line." As a result, those junctions will be connected to corresponding junctions in all other diesel-powered units which are connected to that "train line" to electrically interconnect the "A," "B," "C," and "D" solenoids of all of those diesel-powered units.

The diesel engine of one diesel-powered unit, with which a preferred embodiment of control system provided by the present invention has been used, was designed to "idle" at two hundred and seventy-five revolutions per minute, to experience an increase of seventy-five revolutions per minute whenever the "A" solenoid 70 is energized, to experience an increase of three hundred revolutions per minute whenever the "B" solenoid 72 is energized, to experience an increase of one hundred and fifty revolutions per minute whenever the "C" solenoid 74 is energized, and to experience a decrease of one hundred and fifty revolutions per minute whenever the "D" solenoid 76 is energized. Whenever the throttle of that diesel-powered unit is set in the "run 1" or "idle" position, the engine of that diesel-powered unit will operate at two hundred and seventy-five revolutions per minute; and, whenever that throttle is set in the "run 2" position, that diesel engine will operate at a speed of three hundred and fifty revolutions per minute. Whenever that throttle is set in the "run 3" position, that diesel engine will operate at a speed of four hundred and twenty-five revolutions per minute; and, whenever that throttle is set in the "run 4" position, that diesel engine will operate at a speed of five hundred revolutions per minute. Whenever that throttle is set in the "run 5" position, that diesel engine will operate at a speed of five hundred and seventy-five revolutions per minute; and, whenever that throttle is set in the "run 6" position, that diesel engine will operate at a speed of six hundred and fifty revolutions per minute. Whenever that throttle is set in the "run 7" position, that diesel engine will operate at a speed of seven hundred and twenty-five revolutions per minute; and, whenever that throttle is set in the "run 8" position, that diesel engine will operate at a speed of eight hundred revolutions per minute.

Switch contacts 39, junction 40 and relay contacts 88 can connect the coil 68 of the engine relay to the junction 38, and the lower terminal of that coil is connected to the negative conductor 17. The relay contacts 88 are controlled by the coil 82 of the "ground relay" of the diesel-powered unit; and that coil also controls relay contacts 84 and the relay contacts 86. The relay contacts 84 and 88 are closed and the relay contacts 86 are open whenever the coil 82 is de-energized; but the relay contacts 84 and 88 will be open and the relay contacts 86 will be closed whenever that coil is energized. The lower terminal of the coil 82 is connected to ground; and the upper terminal of that coil is connected to a junction 79. That junction is connected to the terminal 80 of the high voltage generator 24 by an adjustable resistor 87; and it is connected to the terminal 81 of that generator by normally-open relay contacts 103 and a further field winding 83 of that generator. The movable contact of the adjustable resistor 87 is set to make the voltage drop across the left-hand portion of that adjustable resistor approximate the average voltage drop which will develop across the field winding 83. Once the setting of that movable contact has been established, it will not be disturbed.

A relay coil 102 controls the relay contacts 103; and it also controls relay contacts 104. The relay contacts 103 and 104 are open whenever the relay coil 102 is de-energized, but those relay contacts will be closed whenever that relay coil is energized. The relay coil 102 is connectable to the junction 38 by switch contacts 39, junction 40, throttle-controlled contacts 48, relay contacts 84, relay contacts 96, normally-closed relay contacts 95 or normally-open relay contacts 203, and junction 97; and the lower terminal of that relay coil is connected to the negative conductor 17. The relay contacts 96 are operated by a relay coil 98; and that relay coil also operates relay contacts 100. The relay contacts 96 and 100 will be closed whenever the relay coil 98 is de-energized, but they will be open whenever that relay coil is energized. The relay contacts 104 can connect the relay coil 18 to the junction 97; and the lower terminal of that relay coil is connected to the negative conductor 17. The relay contacts 95 are controlled by the coil, not shown, of the transfer relay of the diesel-powered unit. That coil also controls relay contacts 89 and 91; and the relay contacts 91 and 95 will be closed and the relay contacts 89 will be open whenever that coil is de-energized, but the relay contacts 91 and 95 will be open and the relay contacts 89 will be closed whenever that coil is energized.

The relay contacts 100 can complete a circuit from junction 12 via junction 106, movable contact 107, "forward" contact 108, "forward" coil 112 and junction 109 to negative conductor 17 or can complete a circuit from junction 12 via junction 106, movable contact 107, "reverse" contact 110, "reverse" coil 114 and junction 109 to that negative conductor. The "forward" coil 112 controls relay contacts 116; and the "reverse" coil 114 controls relay contacts 118. Whenever the "forward" coil 112 is energized, the relay contacts 116 will be closed; but whenever that coil is de-energized, those relay contacts will be open. Also, whenever the "forward" coil 112 is energized, "pick up" coils, not shown, will close "forward" power contactors 121, 123, 125, 127, 129, 131, 133 and 135; and, whenever that "forward" coil is de-energized, those pick up coils will permit those "forward" power contactors to re-open. Whenever the "reverse" coil 114 is energized, the relay contacts 118 will be closed; but whenever that coil is de-energized, those relay contacts will be open. Also, whenever the "reverse" coil 114 is energized, "pick up" coils, not shown, will close "reverse" power contactors 139, 141, 143, 145, 147, 149, 151 and 153; and, whenever that "reverse" coil is de-energized, those pick up coils will permit those "reverse" power contactors to reopen.

A junction 157 is connected to the relay contacts 116 and 118, and relay contacts 159 and 161 can connect that

junction to a relay coil 163; and the lower terminal of that relay coil is connected to the negative conductor 17. That relay coil controls contacts 165; and those contacts will be open whenever that relay coil is de-energized, but will be closed whenever that relay coil is energized. The relay contacts 159 and the relay contacts 89 can connect the relay coil 169 to the junction 157; and the lower terminal of that relay coil is connected to the negative conductor 17. That relay coil controls contacts 171 and 203; and whenever that relay coil is de-energized the relay contacts 171 and 203 will be open, but those relay contacts will be closed whenever that relay coil is energized. Relay contacts 173 and a junction 175 connect a relay coil 177 to the junction 157; and the lower terminal of that relay coil is connected to the negative conductor 17. That relay coil controls relay contacts 159 and relay contact 179. The contacts 159 will be closed and the contact 179 will be open whenever the relay coil 177 is de-energized; but the contacts 159 will be open and the contact 179 will be closed whenever that relay coil is energized. The relay contacts 91 can connect a relay coil 181 to the junction 175; and the lower terminal of that relay coil is connected to the negative conductor 17. That relay coil controls the relay contacts 183 and relay contact 191; and those relay contacts will be closed and that relay contact will be open whenever that relay coil is de-energized, but those relay contacts will be open and that relay contact will be closed whenever that relay coil is energized. Relay contacts 183 and 185 can connect a relay coil 187 to the junction 157; and the lower terminal of that relay coil is connected to the negative conductor 17. That relay coil controls the relay contacts 173, relay contacts 189, and contacts 167. The relay contacts 173 will be closed but the contacts 167 and 189 will be open whenever that relay coil is de-energized; but the relay contacts 173 will be open and the contacts 167 and 189 will be closed whenever that relay coil is energized. The relay contacts 185 are controlled by the coil, not shown, of the field shunting relay of the diesel-powered unit. The relay contacts 189 can connect a relay coil 193 to the junction 157; and the lower terminal of that relay coil is connected to the negative conductor 17. That relay coil controls the relay contacts 161 plus relay contacts 195; and those relay contacts will be open whenever that relay coil is de-energized, but those relay contacts will be closed whenever that relay coil is energized.

A junction 120 connects a capacitor 124 to the junction 38; and the lower terminal of that capacitor is connected to the negative conductor 17. In the said one preferred embodiment of control system provided by the present invention, that capacitor is an eight microfarad four hundred volt capacitor. A filter choke 126 is connected to the junction 120, and a capacitor 130 is connected to that filter choke by a junction 128; and the lower terminal of that capacitor is connected to the negative conductor 17. That capacitor preferably is a thirteen hundred microfarad, one hundred and twenty-five volt capacitor. A filter choke 132 is connected to the junction 128, and a capacitor 136 is connected to that filter choke by a junction 134; and the lower terminal of that capacitor is connected to the negative conductor 17. That capacitor preferably is identical to the capacitor 130. The numeral 140 denotes a Zener diode which is connected to the junction 134 by a junction 138; and that Zener diode is connected in parallel with the capacitor 136. That Zener diode will preferably be dimensioned to maintain a voltage of sixty-eight volts across it.

The capacitors 124, 130 and 136 coact with the filter chokes 126 and 132 to remove substantially all high frequency signals appearing at the terminal 120, and to smooth out any low frequency signals applied to that terminal. As a result, a substantially pure D.C. voltage of about sixty-eight volts will be developed across the Zener diode 140.

The numeral 142 denotes the normally-closed contacts of a push button switch, and the numeral 144 denotes the normally-open contacts of that push button switch. The contacts 142 and 144 of that push-button switch are interconnected so whenever that push button switch is actuated to open the contacts 142 the contacts 144 will close. That push button switch will preferably be located in the high voltage cabinet of the diesel-powered unit. A junction 146, the contact 86 of the ground relay, a junction 148, a diode 152, and junctions 154 and 156 can connect the relay coil 50 to the contacts 142 of the push button switch; and the lower terminal of that relay coil is connected to the negative conductor 17. A resistor 155 and a lamp 158 are connected in series with each other, but in parallel with the relay coil 50. The numeral 150 denotes a diode which has the cathode thereof connected to the junction 156, and thus is connected in parallel with the relay coil 50. That diode will provide a discharge path for any inductive energy which is stored within that relay coil as that relay coil is energized.

A resistor 160 is connected to the junction 148; and junctions 162 and 164 connect that resistor and a Zener diode 166 in series relation. The anode of that Zener diode is connected to the negative conductor 17, and that Zener diode preferably will maintain a voltage of eighteen volts across it. Junctions 168 and 174 serially connect a resistor 170, the base-two base-one circuit of a unijunction transistor 172 and a resistor 176 between the junction 162 and the negative conductor 17. A resistor 197 and a junction 178 connect the emitter of that unijunction transistor to the junction 164; and a capacitor 180 is connected between the junction 178 and the negative conductor 17. A junction 182 connects the anode-to-cathode circuit of a controlled rectifier 184 between the junction 212 and the negative conductor 17, and thus is that controlled rectifier is a silicon controlled rectifier.

An adjustable resistor 186, a diode 188, a diode 190, and a capacitor 196 are serially connected between the junction 182 and the negative conductor 17 by junctions 192 and 194. The junction 194 can be connected directly to the negative conductor 17, to discharge the capacitor 196, by the normally-open contacts 144 of the push button switch. Junctions 199, 201 and 202 serially connect a resistor 204, the base-two base-one circuit of a unijunction transistor 200 and a resistor 205 between the junction 146 and the negative conductor 17. The emitter of that unijunction transistor is connected to the junction 192 by a diode 198.

A junction 212 connects a Zener diode 214 between the junction 201 and the negative conductor 17. Preferably, that Zener diode will develop a voltage of eighteen volts across it. A capacitor 216 is connected between the junction 212 and the negative conductor 17, and thus is connected in parallel with the Zener diode 214. That capacitor preferably is a five hundred microfarad twenty-five volt capacitor; and it will tend to hold the voltage across the Zener diode 214, and hence at the base-two of the unijunction transistor 200, substantially constant.

Junctions 206, 207 and 208 serially connect relay coil 98 and a controlled rectifier 209 between the junction 199 and the negative conductor 17. Preferably that controlled rectifier is a silicon controlled rectifier. Junction 211 serially connects a resistor 210 and a lamp 213 between junction 206 and junction 208, and thus in parallel with the relay coil 98. A diode 218 has the cathode thereof connected to the junction 207 and has the anode thereof connected to the junction 211, and thus is connected in parallel with the relay coil 98. That diode will provide a discharge path for any inductive energy which is stored within the relay coil 98 as that relay coil is energized.

The shunt winding and the armature winding of one of the traction motors of the diesel-powered unit are denoted, respectively, by the numerals 222 and 224; and the shunt winding and the armature winding of a second of the traction motors of that diesel-powered unit are de-

noted, respectively, by the numeral 226 and 228. The shunt winding and the armature winding of a third of the traction motors of that diesel-powered unit are denoted, respectively, by the numerals 230 and 232; and the shunt winding and the armature winding of a fourth of the traction motors of that diesel-powered unit are denoted, respectively, by the numerals 234 and 236. The differential, compounding and commutating windings of the generator 24 are denoted, respectively, by the numerals 240, 242 and 244. The armature winding of that generator is denoted by the numeral 246.

Current will flow from the positive terminal of the battery 10 via junctions 12, 13, 32, 38 and 120, choke coil 126, junction 128, choke coil 132, junction 134 and 138, switch contacts 142, junctions 146 and 199, resistor 204, junctions 201 and 212, Zener diode 214, and negative conductor 17 to the negative terminal of that battery. That flow of current will enable that Zener diode to develop and maintain a voltage of eighteen volts at the base-two of the unijunction transistor 200.

Current will tend to flow from the positive terminal of the battery 10 via junctions 12, 13, 32, 38 and 120, choke coil 126, junction 128, choke coil 132, junctions 134 and 138, contacts 142 of the push button switch, junctions 146 and 199, and then either through resistor 204, junction 201, the base-two base-one circuit of unijunction transistor 200, junction 202 and resistor 205 or through junctions 206 and 207, relay coil 98, junction 208, and controlled rectifier 209, and then through the negative conductor 17 to the negative terminal of that battery. However, that unijunction transistor and that controlled rectifier will be non-conductive and will effectively block any such current flow.

During the operation of the diesel-powered unit which utilizes the control system provided by the present invention, the diesel engine will operate continuously and will rotate the rotors of the high voltage generator 24 and of the auxiliary generator. To cause that diesel-powered unit to develop a propelling force, the engineer will close the switch contacts 39 and 41 of the isolation switch, will shift the movable contact 107 into engagement with the "forward" contact 108 or the "reverse" contact 110, and will set the throttle in the desired "run" position. For purposes of illustration, it will be assumed that the engineer shifts the movable contact 107 into engagement with the "forward" contact 108, and that he sets the throttle in the "run 2" position. Thereupon, current will flow from the positive terminal of the battery 10 via junctions 12 and 106, movable contact 107, "forward" contact 108, "forward" coil 112, junction 109, normally-closed relay contacts 100, and negative conductor 17 to the negative terminal of that battery. The resulting energization of that "forward" coil will close the relay contacts 116, and will cause the "forward" power contactors 121, 123, 125, 127, 129, 131, 133 and 135 to close. The closing of relay contacts 116 will cause current to flow from the positive terminal of the battery 10 via junctions 12 and 106, switch contacts 41, relay contacts 116, junction 157, relay contacts 173, junction 175, relay coil 177, and negative conductor 17 to the negative terminal of that battery. Current will also flow from the positive terminal of the battery 10 via junctions 12 and 106, switch contacts 41, relay contacts 116, junction 157, relay contacts 173, junction 175, relay contacts 91, relay coil 181, and negative conductor 17 to the negative terminal of that battery. The resulting energization of relay coils 177 and 181 will open the relay contacts 159 and 183; and will close the contacts 179 and 191. The opening of the relay contacts 159 and 183 will prevent energization of the relay coils 163, 169, 187 and 193; and will thus keep the contacts 165, 167, 171 and 195 open, will keep the relay contacts 161, 189 and 203 open, and will permit the relay contacts 173 to remain closed. The overall result is that "forward" power contactors 121, field winding 222, "forward" power contactors 123, armature wind-

ing 224, contact 179, armature winding 228, "forward" power contactors 125, field winding 226, and "forward" power contactors 127 will be connected in series relation across the output terminals 80 and 81 of the generator 24; and "forward" power contactors 129, field winding 230, "forward" power contactors 131, armature winding 232, contact 191, armature winding 236, "forward" power contactors 133, field winding 234, and "forward" power contactors 135 also will be connected in series relation across those output terminals.

As the switch contacts 39 of the isolation switch were closed, current flowed from the positive terminal of the battery 10 via junctions 12, 13, 32 and 38, switch contacts 39, junction 40, relay contacts 88, the coil 68, and negative conductor 17 to the negative terminal of that battery. The resulting energization of that coil closed relay contacts 62, 64 and 66; and, when the throttle was advanced to the "run 2" position, current flowed from the positive terminal of the battery 10 via junctions 12, 13, 32 and 38, switch contacts 39, junction 40, throttle-controlled contacts 48, relay contacts 84, relay contacts 96, relay contacts 95, junction 97, relay coil 102, and negative conductor 17 to the negative terminal of that battery, and further current flowed from the positive terminal of the battery 10 via junctions 12, 13, 32 and 38, switch contacts 39, junction 40, throttle-controlled contacts 42, junction 55, relay contacts 56, relay contacts 62, "A" solenoid 70, and negative conductor 17 to the negative terminal of that battery. The resulting energization of relay coil 102 will close relay contacts 103 and relay contacts 104; and the closing of the latter relay contacts will cause the relay coil 18 to become energized and close the relay contacts 16. As the relay contacts 103 close, the residual magnetism in the field winding 83, the differential winding 240, the compounding winding 242, and the commutating winding 244 of the generator 24 will tend to develop a voltage across the output terminals 80 and 81. As the relay contacts 16 close, current will flow from the positive terminal of the battery 10 via junctions 12 and 13, the upper section of the load regulator 14, relay contacts 16, fuse 20, field winding 22 of the generator 24, and negative conductor 17 to the negative terminal of that battery; and the resulting magnetic field developed by that field winding will sharply increase the voltage across the output terminals 80 and 81. As the "A" solenoid 70 becomes energized, it will increase the speed of the diesel engine to three hundred and fifty revolutions per minute; and the generator 24 will thereupon develop the power needed to cause the four traction motors to drive the diesel-operated unit at the "run 2" speed.

If the engineer wishes to operate the diesel-powered unit at the "run 3" speed, he will advance the throttle to open the throttle-controlled contacts 42 and close the throttle-controlled contacts 44. Thereupon, the "A" solenoid 70 will become de-energized and the "C" solenoid 74 will become energized; and the speed of the diesel engine will increase to four hundred and twenty-five revolutions per minute and will increase the power developed by the generator 24. Operation at the "run 4" speed can be attained by advancing the throttle far enough to re-close the throttle-controlled contacts 42 while also keeping the throttle controlled contacts 44 closed. At such time, both the "A" and "C" solenoids 70 and 74 will be energized; and the speed of the diesel engine will increase to five hundred revolutions per minute and will increase the power developed by the generator 24. Operation at the "run 5" speed can be attained by advancing the throttle far enough to open throttle-controlled contacts 42 and to close throttle-controlled contacts 43 and 46 while keeping the throttle-controlled contacts 44 closed. At such time, the "B," "C" and "D" solenoids 72, 74 and 76 will be energized; and the speed of the diesel engine will increase to five hundred and seventy-five revolutions per minute and will increase

the power developed by the generator 24. Operation at the "run 6" speed can be attained by advancing the throttle far enough to close the throttle-controlled contacts 42 while keeping the throttle-controlled contacts 43, 44 and 46 closed. At such time, the "A," "B," "C" and "D" solenoids 70, 72, 74 and 76 will all be energized; and the speed of the diesel engine will increase to six hundred and fifty revolutions per minute and will increase the power developed by the generator 24. Operation at the "run 7" speed can be attained by advancing the throttle far enough to open the throttle-controlled contacts 42 and 46 while keeping the throttle-controlled contacts 43 and 44 closed. At such time, the "B" and "C" solenoids 72 and 74 will be energized; and the speed of the diesel engine will increase to seven hundred and twenty-five revolutions per minute and will increase the power developed by the generator 24. Operation at the "run 8" speed can be attained by advancing the throttle far enough to re-close the throttle-controlled contacts 42 while keeping the throttle-controlled contacts 43 and 44 closed. At such time, the "A," "B" and "C" solenoids 70, 72 and 74 will be energized; and the speed of the diesel engine will increase to eight hundred revolutions per minute and will increase the power developed by the generator 24.

At a desired setting of the throttle, which is intermediate the "run 1" setting and the "run 8" setting, the coil, not shown, of the field shunting relay of the diesel-powered unit will become energized. Thereupon, shunts, not shown, will shunt the field windings 222, 226, 230 and 234 of the four traction motors; and the relay contacts 185 will close. The closing of those relay contacts will not be significant at that time because the relay contacts 183 are held open by the energized relay coil 181. The shunting of the field windings 222, 226, 230 and 234 will cause the four traction motors to operate at a greater speed.

At a higher desired setting of the throttle, the coil, not shown, of the transfer relay of the diesel-powered unit will become energized; and that coil will open the relay contacts 91 and 95 and will close the relay contacts 89. The opening of the relay contacts 95 will de-energize the relay coils 18 and 102; and, thereupon, the voltage across the output terminals 80 and 81 of the generator 24 will start to fall. The opening of the relay contacts 91 will de-energize the relay coil 181—with a consequent re-opening of contact 191 and re-closing of relay contacts 183. Thereupon, current will flow from the positive terminal of battery 10 via junctions 12 and 106, switch contacts 41, relay contacts 116, junction 157, relay contacts 183, relay contacts 185, relay coil 187, and the negative conductor 17 to the negative terminal of that battery. The resulting energization of that relay coil will close relay contacts 167 and 189 and will open relay contacts 173. The closing of the relay contacts 189 will cause current to flow from the positive terminal of battery 10 via junctions 12 and 106, switch contacts 41, relay contacts 116, junction 157, relay contacts 183, relay contacts 185, relay contacts 189, relay coil 193, and the negative conductor 17 to the negative terminal of that battery; and the resulting energization of that relay coil will close relay contacts 161 and 195. The opening of the relay contacts 173 will de-energize the relay coil 177, with a consequent re-opening of contact 179 and re-closing of relay contacts 159. The closing of relay contacts 161 will coact with the re-closing of relay contacts 159 to cause current to flow from the positive terminal of battery 10 via junctions 12 and 106, switch contacts 41, relay contacts 116, junction 157, relay contacts 159, relay contacts 161, relay coil 163, and the negative conductor 17 to the negative terminal of that battery; and the resulting energization of that relay coil will close relay contacts 165. Also, current will flow from the positive terminal of battery 10 via junctions 12 and 106, switch contacts 41, relay contacts 116, junction 157, relay contacts 159, relay contacts

89, relay coil 169, and the negative conductor 17 to the negative terminal of that battery; and the resulting energization of that relay coil will close relay contacts 171 and 203. The re-opening of the contacts 179 and 191 will coact with the closing of the contacts 165, 167, 171 and 195 to serially-connect "forward" power contactors 121, shunted field winding 222, "forward" power contactors 123, armature winding 224, and contacts 195 across the output terminals 80 and 81 of the generator 24, to serially-connect contacts 165, armature winding 228, "forward" power contactors 125, shunted field winding 226, and "forward" power contactors 127 across those output terminals, to serially-connect "forward" power contactors 129, shunted field winding 230, "forward" power contactors 131, armature winding 232, and contacts 167 across those output terminals, and to serially-connect contacts 171, armature winding 236, "forward" power contactors 133, shunted field winding 234, and "forward" power contactors 135 across those output terminals. The closing of the relay contacts 203 will re-energize the relay coils 18 and 102, and will thus enable the voltage across the output terminals 80 and 81 of the generator 24 to rise again. At such time, the four traction motors will be connected in parallel with each other; and they will operate at the desired high speed.

If, instead of shifting the movable contact 107 into engagement with the "forward" contact 108, the engineer had shifted that movable contact into engagement with the "reverse" contact 110, the "reverse" coil 114 would have been energized and the "reverse" power contactors 139, 141, 143, 145, 147, 149, 151 and 153 would have been moved into closed position. As a result, the current would have flowed in the "reverse" direction through the field windings 222, 226, 230 and 234 of the four traction motors; and the diesel-powered unit would have moved in the "reverse" direction. However, in all other respects the operation of the diesel-powered unit and of the control system thereof would have been the same.

The armature winding 246, the differential winding 240, the compounding winding 242, the commutating winding 224, and the field winding 83 of the generator 24, the relay contacts 103, the adjustable resistor 87, the coil 82 of the ground relay, the "forward" power contactors 121, 123, 125, 127, 129, 131, 133 and 135, the "reverse" power contactors 139, 141, 143, 145, 147, 149, 151 and 153, the contacts 179 and 191, the relay contacts 165, 167, 171 and 195, the armature windings 224, 228, 232, and 236 of the four traction motors, and the field windings 222, 226, 230 and 234 of those traction motors constitute portions of the high voltage electrical system of the diesel-powered unit. The voltage developed across the output terminals 80 and 81 of the generator 24 will usually be in the range of six hundred volts but it can rise to as much as one thousand volts.

In the event a "flash" or "ground" develops in the high voltage electrical system of the diesel-powered unit, the voltage at the junction 79 will increase—usually to a value closely approaching one-half of the value of the voltage being developed across the output terminals 80 and 81 of the generator 24. The coil 82 of the ground relay will respond to the voltage at that junction to become energized; and the contacts 84 and 88 will open but the contacts 86 will close. The opening of the contacts 88 will de-energize the coil 68 of the engine relay, and will thus permit the relay contacts 62, 64 and 66 to re-open—thereby making sure that the "A" solenoid 70, the "B" solenoid 72, and the "C" solenoid 74 will become de-energized. The opening of the relay contacts 84 will de-energize the relay coil 18 and the relay coil 102, with a consequent re-opening of the relay contacts 16, 103 and 104; and the re-opening of relay contacts 16 will remove the battery-induced excitation provided by the field winding 22, and the re-opening of the relay contacts 103 will remove the excitation provided by the field winding 83. As a result, the voltage across the output terminals 80

and 81 of the generator 24 will start to fall toward zero. The de-energization of the "A," "B," and "C" solenoids 70, 72 and 74 will cause the speed of the diesel engine of the diesel-powered unit to start to drop toward "run 1."

As the contacts 86 close, when the coil 82 of the ground relay becomes energized, current will flow from junction 146 via those relay contacts, junction 148, resistor 160, junctions 162, 168 and 182, adjustable resistor 186, diodes 188 and 190, junctions 192 and 194, and capacitor 196 to the negative conductor 17; and the resulting flow of current through that capacitor will partially charge that capacitor and will cause the voltage at the junction 192 to increase.

Simultaneously, current will flow from junction 146 via the relay contacts 86, junction 148, resistor 160, junctions 162 and 164, and Zener diode 166 to the negative conductor 17; and the resulting flow of current through that Zener diode will quickly establish a voltage of eighteen volts at the junctions 162 and 164. Current will then flow via resistor 197, junction 178 and capacitor 180 to the negative conductor 17; and that current flow will develop an increasing charge across the capacitor 180 and will thus develop an increasing voltage at the emitter of the unijunction transistor 172. The voltage at the junction 162 will be eighteen volts, and hence the voltage at the base-two of the unijunction transistor 172 will be close to eighteen volts; and, when the voltage at the emitter of that unijunction transistor reaches the emitter peak point voltage, that unijunction transistor will become conductive. Thereupon, the capacitor 180 will discharge through the emitter base-one circuit of that unijunction transistor and through the resistor 176; and the resulting voltage drop across the resistor 176 will make the voltage at the junction 174 sufficiently positive to cause enough current to flow through the gate-to-cathode circuit of the controlled rectifier 184 to render that controlled rectifier conductive. As that controlled rectifier becomes conductive, it will drop the voltage at the junction 182 close to the negative voltage at the negative conductor 17, and will thus halt further charging of the capacitor 196. In the said one preferred embodiment of control system provided by the present invention, the controlled rectifier 184 will become conductive about one-half of a second after the coil 82 of the ground relay closes the relay contacts 86.

As the coil 82 of the ground relay closed the relay contacts 86, current flowed from junction 146 via those relay contacts, junction 148, diode 152, junction 154, resistor 155, and lamp 158 to the negative conductor 17; and the resulting flow of current through that lamp illuminated it, thereby giving an indication that the ground relay had become energized. Also, as the coil 82 of the ground relay closed the relay contacts 86, current flowed from junction 146 via those relay contacts, junction 148, diode 152, junctions 154 and 156, and relay coil 50 to the negative conductor 17; and the resulting flow of current through that relay coil energized that relay coil and caused relay contacts 52 to close and relay contacts 56 to open. The closing of the relay contacts 52 established a holding circuit for the relay coil 50 which permitted current to flow from terminal 146 via relay contacts 52, junction 156, and relay coil 52 to the negative conductor 17; and also established a holding circuit for the lamp 158 which permitted current to flow from junction 146 via relay contacts 52, junctions 156 and 154, resistor 155, and lamp 158 to the negative conductor 17. Those holding circuits will keep the relay coil 50 energized and will keep the lamp 158 illuminated until the switch contacts 142 of the push button switch are opened.

The opening of the relay contacts 56 is not significant at this time because the relay contacts 62 are already open. However, the fact that the relay contacts 56 will remain open until the switch contacts 142 of the push button switch are opened, to de-energize the relay coil 50, is significant; because it will keep the "A" solenoid

70 de-energized until those switch contacts are opened. This is important; because it means that until such time as those switch contacts are opened, to de-energize the relay coil 50, the diesel engine of the diesel-powered unit cannot be operated at "run 8" speed, even if the throttle of that diesel-powered unit or the throttle of an inter-connected diesel-powered unit is set to call for that speed.

At this time the capacitor 196 will have a charge stored within it, and the series-connected diodes 190 and 188 will keep that charge from leaking off through the adjustable resistor 186 and the controlled rectifier 184. Also, the diode 198 will keep any leakage of current in the base-two emitter circuit of the unijunction transistor 200 from increasing the charge within the capacitor 196. That charge will not be great enough to make the voltage across the capacitor, and thus at the emitter of the unijunction transistor 200, exceed the emitter peak point voltage of that unijunction transistor; and hence that unijunction transistor, and the controlled rectifier 209, will remain non-conductive.

The voltage across the output terminals 80 and 81 of the generator 24 will start to drop toward zero as soon as the relay contacts 16 and 103 re-open; but that voltage will not drop to zero immediately. Instead, that voltage will take from two to ten seconds—depending upon the speed of the diesel-powered unit and upon the load on that diesel-powered unit at the instant the "flash" or "ground" occurred—to drop to a level at which the coil 82 of the ground relay will permit the contacts 84 and 88 to re-close and the contacts 86 to re-open. Usually, the coil 82 will permit the contacts 84 and 88 to re-close and the contacts 86 to re-open when the voltage across that coil falls below about sixty volts.

The re-opening of the relay contacts 86 will de-energize the controlled rectifier 184, and it also will disconnect the junction 162 from the positive terminal of the battery 10. As a result, the charge stored within, and the voltage developed across, the capacitor 196 will remain unchanged.

The re-closing of the relay contacts 88 will re-energize the coil 68 of the engine relay, with a consequent re-closing of the relay contacts 62, 64 and 66. The re-closing of the relay contacts 64 and 66 will enable the diesel engine to operate at the "run 1," "run 3," "run 5," or "run 7" speed, if the throttle of the diesel-powered unit or the throttle of an inter-connected diesel-powered unit is set in the "run 1" or "run 2," the "run 3" or "run 4," the "run 5" or "run 6," or the "run 7" or "run 8" positions. The re-closing of the relay contacts 84 will re-energize the relay coil 102, with consequent re-closing of the relay contacts 103 and 104; and the re-closing of the latter relay contacts will re-energize the relay coil 18, with consequent re-closing of the relay contacts 16. The re-closed relay contacts 103 and 16 will cause current to again flow through the field windings 83 and 22; and, thereupon, the voltage across the output terminals 80 and 81 of the generator 24 will rise.

In the event a further flash or ground does not develop in the high voltage electrical system of the diesel-powered unit, the coil 82 of the ground relay will remain de-energized but the relay coil 50 will remain energized and the lamp 158 will remain illuminated. As a result, the engineer will know that a flash or ground has occurred in the high voltage electrical system of the diesel-powered unit; but the diesel engine of that diesel-powered unit will be able to respond to a "run 1" or "run 2" throttle setting to operate at the "run 1" speed, to respond to a "run 3" or "run 4" throttle setting to operate at the "run 3" speed, to respond to a "run 5" or "run 6" throttle setting to operate at the "run 5" speed, or to respond to a "run 7" or "run 8" throttle setting to operate at the "run 7" speed. While the number of speeds at which that diesel engine can operate will be limited, and while the top speed of that diesel engine will be limited, that diesel engine will be able to cause the electric generator 24 to

generate substantial amounts of power; and the four traction motors will be able to respond to those amounts of power to drive the diesel-powered unit.

In the event a second flash or ground occurs shortly after the coil 82 of the ground relay becomes de-energized, and permits the voltage across the output terminals 80 and 81 to rise, that coil will again become energized; and the consequent re-opening of relay contacts 84 and 88 will again de-energize the relay coil 102 and the coil 68 of the engine relay, and the consequent re-closing of the relay contacts 86 will again cause current to flow through the capacitor 180 to charge that capacitor and will again cause current to flow through the capacitor 196 to additionally charge that capacitor. The coil 68 will re-open the relay contacts 62, 64 and 66, and the re-opening of the latter two relay contacts will cause the speed of the diesel engine to start to fall toward "run 1." The coil 102 will re-open the relay contacts 103 and will cause the relay coil 18 to re-open the relay contacts 16; and hence the voltage across the output terminals 80 and 81 of the generator 24 will again start to fall toward zero.

The capacitor 196 will continue to charge until the voltage across the capacitor 180 again reaches the emitter peak point voltage of the unijunction transistor 172, and thus causes that unijunction transistor to become conductive and thereby cause the controlled rectifier 184 to again become conductive. The charge stored within the capacitor 196 will not be great enough to make the voltage across that capacitor, and thus at the emitter of the unijunction transistor 200, exceed the emitter peak point voltage of that unijunction transistor; and hence that unijunction transistor, and the controlled rectifier 209, will continue to remain non-conductive.

The voltage across the output terminals 80 and 81 of the generator 24 will start to drop toward zero as soon as the relay contacts 16 and 103 re-open for the second time; but that voltage will not drop to zero immediately. Instead that voltage will take a finite length of time—depending upon the speed of the diesel-powered unit and upon the load on that diesel-powered unit and upon the voltage across those output terminals at the instant the second flash or ground occurred—to again drop to a level at which the coil 82 of the ground relay will permit the contacts 84 and 88 to re-close and the contacts 86 to re-open.

The second re-opening of the relay contacts 86 will de-energize the controlled rectifier 184, and it also will disconnect the junction 162 from the positive terminal of the battery 10. As a result, the charge stored within, and the voltage developed across, the capacitor 196 will remain unchanged.

The second re-closing of the relay contacts 88, and the consequent second re-energization of the coil 68 of the engine relay, will again enable the diesel to operate at the "run 1," "run 3," "run 5," or "run 7" speed, if the throttle of the diesel-powered unit or the throttle of an inter-connected diesel-powered unit is set in the "run 1" or "run 2," the "run 3" or "run 4," the "run 5" or "run 6," or the "run 7" or "run 8" positions. The second re-closing of the relay contacts 84, and the ensuing second re-closings of the relay contacts 103 and 16, will again cause current to flow through the field windings 83 and 22; and, thereupon, the voltage across the output terminals 80 and 81 of the generator 24 will rise.

In the event a third flash or ground does not develop in the high voltage electrical system of the diesel-powered unit, the coil 82 of the ground relay will remain de-energized but the relay coil 50 will remain energized and the lamp 158 will remain illuminated. As a result the engineer will have a continuing reminder that a flash or ground has occurred in the high voltage electrical system of the diesel-powered unit; but the diesel engine of that diesel-powered unit will be able to respond to a "run 1" or "run 2" throttle setting to operate at the "run

1" speed, to respond to a "run 3" or "run 4" throttle setting to operate at the "run 3" speed, to respond to a "run 5" or "run 6" throttle setting to operate at the "run 5" speed, or to respond to a "run 7" or "run 8" throttle setting to operate at the "run 7" speed. While the number of speeds at which that diesel engine can operate will be limited, and while the top speed of that diesel engine will be limited, that diesel engine will be able to cause the electric generator 24 to generate substantial amounts of power; and the four traction motors will be able to respond to those amounts of power to drive the diesel-powered unit.

In the event a third flash or ground occurs shortly after the coil 82 of the ground relay again becomes de-energized, and permits the voltage across the output terminals 80 and 81 to start to rise again, that coil will again become energized; and the consequent re-opening of relay contacts 84 and 88 will again de-energize the relay coil 102 and the coil 68 of the engine relay, and the consequent re-closing of the relay contacts 86 will again cause current to flow through the capacitor 180 to charge that capacitor and will again cause current to flow through the capacitor 196 to additionally charge that capacitor. The coil 68 will re-open the relay contacts 62, 64 and 66, and the re-opening of the latter two relay contacts will cause the speed of the diesel engine to start to fall toward "run 1." The coil 102 will re-open the relay contacts 103 and will cause the relay coil 18 to re-open the relay contacts 16; and hence the voltage across the output terminals 80 and 81 of the generator 24 will again start to fall toward zero.

The capacitor 196 will continue to charge until the voltage across the capacitor 180 again reaches the emitter peak point voltage of the unijunction transistor 172, and thus causes that unijunction transistor to become conductive and thereby cause the controlled rectifier 184 to again become conductive. The charge stored within the capacitor 196 will not be great enough to make the voltage across that capacitor, and thus at the emitter of the unijunction transistor 200, exceed the emitter peak point voltage of that unijunction transistor; and hence that unijunction transistor, and the controlled rectifier 209, will remain non-conductive.

In the event a fourth flash or ground does not develop in the high voltage electrical system of the diesel-powered unit, the coil 82 of the ground relay will remain de-energized but the relay coil 50 will remain energized and the lamp 158 will remain illuminated. As a result, the engineer will have a continuing reminder that a flash or ground has occurred in the high voltage electrical system of the diesel-powered unit; but the diesel engine of that diesel-powered unit will be able to respond to a "run 1" or "run 2" throttle setting to operate at the "run 1" speed, to respond to a "run 3" or "run 4" throttle setting to operate at the "run 3" speed, to respond to a "run 5" or "run 6" throttle setting to operate at the "run 5" speed, or to respond to a "run 7" or "run 8" throttle setting to operate at the "run 7" speed. While the number of speeds at which that diesel engine can operate will be limited, and while the top speed of that diesel engine will be limited, that diesel engine will be able to cause the electric generator 24 to generate substantial amounts of power; and the four traction motors will be able to respond to those amounts of power to drive the diesel-powered unit.

In the event a fourth flash or ground occurs shortly after the coil 82 of the ground relay again becomes de-energized, and permits the voltage across the output terminals 80 and 81 to start rise again, that coil will again become energized; and the consequent re-opening of relay contacts 84 and 88 will again de-energize the relay coil 102 and the coil 68 of the engine relay, and the consequent re-closing of the relay contacts 86 will again cause current to flow through the capacitor 180 to charge that capacitor and will again cause current to flow through

the capacitor 196 to additionally charge that capacitor. The coil 68 will re-open the relay contacts 62, 64 and 66, and the re-opening of the latter two relay contacts will cause the speed of the diesel engine to start to fall toward "run 1." The coil 102 will re-open the relay contacts 103 and will cause the relay coil 18 to re-open the relay contacts 16; and hence the voltage across the output terminals 80 and 81 of the generator 24 will again start to fall toward zero.

The capacitor 196 will charge until the voltage across that capacitor reaches the emitter peak point voltage of the unijunction transistor 200. Thereupon, that unijunction transistor will become conductive; and the capacitor 196 will discharge through the emitter base-one circuit of that unijunction transistor and resistor 205 to develop a voltage drop across that resistor. That voltage drop will be great enough to cause sufficient current to flow through the gate-to-cathode circuit of the controlled rectifier 209 to render that controlled rectifier conductive. As that controlled rectifier becomes conductive, current will flow from junction 146 via junctions 199, 206 and 207, relay coil 98, junction 208, and controlled rectifier 209 to the negative conductor 17; and the resulting energization of that relay coil will open the relay contacts 96 and 100. Also as the controlled rectifier 209 becomes conductive, current will flow from junction 146 via junctions 199 and 206, resistor 210, lamp 213, junctions 211 and 208, and that controlled rectifier to the negative conductor 17; and the resulting illumination of that lamp will show that the relay coil 98 has been energized.

The opening of the relay contacts 96 will de-energize the relay coils 18 and 102, with a consequent re-opening of relay contacts 16, 103 and 104; and the opening of the relay contacts 100 will de-energize whichever of the coils 112 and 114 is energized and will prevent energization of the other of those coils. The overall result is that the high voltage electrical system of the diesel-powered unit will become de-energized; and this is desirable because it means that the risk of damage from a flash or ground will be virtually eliminated.

As the voltage across the output terminals 80 and 81 of the generator 26 again falls toward zero, the coil 82 of the ground relay will again become de-energized; and the relay contacts 86 will re-open and the relay contacts 84 and 88 will re-close. The re-opening of the relay contacts 86 will not be significant, because the junction 199 is connected directly to the junction 146 rather than through the relay contacts 86; and hence the controlled rectifier 209 will continue to be conductive and will continue to keep the relay coil 98 energized and the lamp 213 illuminated. The re-closing of the relay contacts 84 will not be significant, because the relay coil 98 will be holding the relay contacts 96 open; but the re-closing of the relay contacts 88 will be significant because it will re-energize the coil 68 of the engine relay. The resulting re-closing of the relay contacts 64 and 66 will enable the diesel engine of the diesel-powered unit to operate at "run 1," "run 3," "run 5" and "run 7" speeds when the throttle of that diesel-powered unit or the throttle of an interconnected diesel-powered unit is set to call for "run 1" or "run 2" speeds, "run 3" or "run 4" speeds, "run 5" or "run 6" speeds, or "run 7" or "run 8" speeds, respectively.

Absent the re-closing of the relay contacts 88, and the consequent re-closing of the relay contacts 64 and 66, the diesel engine of the diesel-powered unit would operate only at the "run 1" speed; and it would stop if the throttle of that diesel-powered unit or the throttle of an interconnected diesel-powered unit was set in the "run 5" or "run 6" position. This is due to the fact that the "D" solenoid 76 will be energized whenever the throttle of that diesel-powered unit or the throttle of an interconnected diesel-powered unit is set in the "run 5" or "run 6" position, and that the "D" solenoid acts to reduce the speed of the diesel engine by one hundred and

fifty revolutions per minute; and the said diesel engine will stop if the "run 1" speed of two hundred and seventy-five revolutions per minute is reduced by one hundred and fifty revolutions per minute. The stopping of the diesel engine would be undesirable, because it would cause an alarm to sound continuously; and the continuous sounding of that alarm would be objectionable because of its impact upon the nerves of the engineer, and because it would keep that alarm from indicating to the engineer when any further problems arose. By causing the de-energization of the coil 82 of the ground relay to re-energize the coil 68 of the engine relay, the control system provided by the present invention keeps the diesel engine running, and thus avoids the continuous sounding of the alarm.

When the source of the flashes or grounds has been pinpointed, and when appropriate steps have been taken to prevent the development of further flashes or grounds, the control system provided by the present invention can be returned to its normal position by pressing the push button to open the switch contacts 142 and to close the switch contacts 144. The closing of the latter switch contacts will discharge the capacitor 196; and the opening of the former switch contacts will render the controlled rectifier 209 non-conductive—with a consequent de-energization of the relay coil 98 and a darkening of the lamp 213. The de-energization of the relay 9 will permit the relay contacts 96 and 100 to re-close. Thereupon, the diesel-powered unit can be operated in the forward or the reverse direction at any desired speed.

The control system provided by the present invention minimizes the risk of damage to the diesel-powered unit, and yet enables that diesel-powered unit to develop powerful propelling forces, by responding to a flash or ground to limit the speed of the diesel engine of that diesel-powered unit to any one of the "run 1" through "run 7" speeds of that diesel engine. Because most flashes or grounds occur when the throttle of the diesel-powered unit is set in the "run 8" position, the action of the control system provided by the present invention in limiting the speed of that diesel engine to any one of the "run 1" through "run 7" speeds of that diesel engine will minimize the likelihood that a further flash or ground develops. However, if three further flashes or grounds develop in rapid succession, the control system provided by the present invention will promptly disable the high voltage electrical system of the diesel-powered unit, and thereby obviate any damage due to flashes or grounds.

It is desirable that the ground relay of a diesel-powered unit re-set itself as quickly as practicable after a flash or ground in the high voltage electric system of that diesel-powered unit has actuated that ground relay. However, that ground relay should not be re-set until after the magnetic field of the generator has decayed to the point where it will not immediately re-actuate that ground relay. It would be undesirable to provide a fixed length of time within which the ground relay of a diesel-powered unit had to re-set itself, because a long period of time would unduly delay the re-setting of that ground relay where the flash or ground developed while that diesel-powered unit was operating at low speed under a light load, and because a short period of time could enable the falling voltage across the coil of that ground relay to be high enough to immediately re-actuate that ground relay. The control system provided by the present invention re-sets the ground relay of a diesel-powered unit as quickly as practicable after a flash or ground in the high voltage electrical system of that diesel-powered unit has actuated that ground relay, and yet re-sets that ground relay only after the magnetic field of the generator has decayed to the point where it will not immediately re-actuate that ground relay; and it does so by using the electromagnetic forces from the coil 82, rather than a mechanical latch, to hold the relay contacts 84 and 88 open and the relay contacts 86 closed. As soon as the

magnetic field of the generator 24 decays to the point where the coil 82 receives insufficient current to hold the relay contacts 84 and 88 open and the relay contacts 86 closed, the contacts 84 and 88 will re-close and the contacts 86 will re-open. If the flash or ground in the high voltage electrical system of the diesel-powered unit developed while that unit was operating at high speed under a heavy load, it may take as long as ten seconds before the magnetic field of the generator 24 decays to the point where the coil 82 receives insufficient current to hold the relay contacts 84 and 88 open and the relay contacts 86 closed; whereas if that flash or ground developed while that unit was operating at low speed under a light load, it may take only two seconds before the magnetic field of the generator 24 decays to the point where the coil 82 receives insufficient current to hold the relay contacts 84 and 88 open and the relay contacts 86 closed. The important fact is that the coil 82 will permit the relay contacts 84 and 88 to re-close and the relay contacts 86 to re-open just as quickly as it can practicably do so.

The Zener diode 166, the resistors 170, 176 and 197, the unijunction transistor 172, the capacitor 180, and the controlled rectifier 184 constitute a timing sub-circuit which determines how long the capacitor 196 can charge after each energization of the coil 82 of the ground relay. The adjustable resistor 186, the diodes 188, 190 and 198, the capacitors 196 and 216, the resistors 204 and 205, the unijunction transistor 200, and the Zener diode 214 constitute a counting sub-circuit which responds to a predetermined number of charging periods for the capacitor 196 to render the controlled rectifier 209 conductive. Preferably, that number of charging periods is four; but, where desired, the contact of the adjustable resistor 186 can be set to render the unijunction transistor 200 conductive after three or two flashes or grounds, or after five or more flashes or grounds. Also, if desired, the isolation switch could have a set of contacts between the junctions 138 and 146; and those contacts would be open whenever the contacts 39 and 41 of that isolation switch were open and would be closed whenever the contacts 39 and 41 were closed.

The control system provided by the present invention is not restricted to use with specially-made ground relays. Instead, that control system can be used with the ground relays of most diesel-powered units by merely removing or disabling the mechanical latches of those ground relays. Once the mechanical latches of those ground relays have been removed or disabled, the contacts 84 and 88 of those ground relays will automatically reclose and the contacts 86 of those ground relays will automatically re-open when the voltage across the output terminals 80 and 81 of the generator 24 falls far enough to effectively de-energize the coils 82 of those ground relays. The automatic re-closing of the relay contacts 88 is important in re-energizing the coil 68 of the engine relay, because the re-energization of that coil keeps the diesel engine of the diesel-powered unit from stopping if the throttle thereof, or the throttle of an inter-connected diesel-powered unit, is set in the "run 5" or "run 6" position.

Whereas the drawing and accompanying description have shown and described a preferred embodiment of the present invention, it should be apparent to those skilled in the art that various changes may be made in the form of the invention without affecting the scope thereof.

What I claim is:

1. A control system for a diesel-powered unit which comprises:

a ground relay that has a coil and normally-open contacts movable by said coil,
said coil of said ground relay being adapted to respond to a flash or ground in the high voltage electrical system of said diesel-powered unit to move said normally-open contacts of said ground relay to closed position,

a second relay that has a coil and normally-closed contacts movable by said coil,
 said coil of said second relay being connected to, and responding to the closing of, said normally-open contacts of said ground relay to move said normally-closed contacts of said second relay to open position,
 said contacts of said second relay being connected to control the "A" solenoid of the diesel engine of said diesel-powered unit so opening of said contacts of said second relay will prevent energization of said "A" solenoid of said diesel engine and will thereby limit the speed of said diesel engine to a value intermediate the idling speed and the maximum speed of said diesel engine,
 said second relay being adapted to hold said normally-closed contacts thereof open, after said coil thereof has responded to the closing of said normally-open contacts of said ground relay to open said normally-closed contacts thereof, and thereby continue to prevent energization of said "A" solenoid of said diesel engine and to limit the speed of said diesel engine to a value intermediate the idling speed and the maximum speed of said diesel engine,
 a lamp that is connected to, and that responds to the closing of, said contacts of said ground relay to become illuminated,
 a third relay that has a coil and that has normally-closed contacts in the excitation circuit of the generator of said diesel-powered unit,
 a variable impedance element that is connected in series with said coil of said third relay and that normally has a high impedance, and
 means, responsive to a predetermined number of closings of said normally-open contacts of said ground relay, to reduce the impedance of said variable impedance element and thereby cause energization of said coil of said third relay,
 said means including a timing sub-circuit to time the charging of a capacitor and also including a counting sub-circuit,
 said control system responding to each closing of said normally-open contacts of said ground relay to store a charge in said capacitor, but each charge stored in said capacitor being too small to be able, by itself, to cause said means to reduce the impedance of said variable impedance element and thereby cause energization of said coil of said third relay.

2. A control system for a diesel-powered unit which comprises:
 a ground relay that has a contact and a coil to effect movement of said contact,
 said coil of said ground relay being connected between ground and the high voltage electrical system of said diesel-powered unit and being adapted to automatically respond to a flash or ground in said high voltage electrical system of said diesel-powered unit to effect movement of said contact of said ground relay,
 a second relay that has a contact and a coil to effect movement of said contact,
 said contact of said ground relay and said coil of said second relay being parts of a circuit which is controlled by said contact of said ground relay,
 said coil of said second relay automatically responding to movement of said contact of said ground relay to effect movement of said contact of said second relay,
 said contact of said second relay being connected so movement thereof to a predetermined position will limit the speed of the diesel engine of said diesel-powered unit to a value intermediate the idling speed and the maximum speed of said diesel engine,
 whereby said control system can automatically respond to a flash or ground in the high voltage electrical system of said diesel-powered unit to limit the speed of said diesel engine to said value intermediate the

idling speed and the maximum speed of said diesel engine.

3. A control system for a diesel-powered unit which comprises:
 a ground relay that has a contact and a coil to effect movement of said contact,
 said coil of said ground relay being adapted to respond to a flash or ground in the high voltage electrical system of said diesel-powered unit to effect movement of said contact of said ground relay,
 a second relay that has a contact and a coil to effect movement of said contact,
 said coil of said second relay responding to movement of said contact of said ground relay to effect movement of said contact of said second relay,
 said contact of said second relay being connected so movement thereof to a predetermined position will limit the speed of the diesel engine of said diesel-powered unit to a value intermediate the idling speed and the maximum speed of said diesel engine,
 whereby said control system can respond to a flash or ground in the high voltage electrical system of said diesel-powered unit to limit the speed of said diesel engine to said value intermediate the idling speed and the maximum speed of said diesel engine,
 said second relay being re-settable to move said contact thereof out of said predetermined position, and
 said contact of said second relay remaining in said predetermined position, and continuing to limit the speed of said diesel engine to said value intermediate the idling speed and the maximum speed of said diesel engine, until said second relay is re-set.

4. A control system for a diesel-powered unit as claimed in claim 2 wherein an indicator responds to movement of said contact of said ground relay to become actuated, said contact of said second relay thereafter maintaining a holding circuit for said indicator as long as said coil of said second relay remains energized, said coil of said second relay remaining energized after said contact of said ground relay has returned to its normal position.

5. A control system for a diesel-powered unit, that has an "A" solenoid and "B" and "C" solenoids for the diesel engine thereof, which comprises:
 a ground relay that has a contact and a coil to effect movement of said contact,
 said coil of said ground relay being connected between ground and the high voltage electrical system of said diesel-powered unit and being adapted to automatically respond to a flash or ground in said high voltage electrical system of said diesel-powered unit to effect movement of said contact of said ground relay,
 a second relay that has a contact and a coil to effect movement of said contact,
 said contact of said ground relay and said coil of said second relay being parts of a circuit which is controlled by said contact of said ground relay,
 said coil of said second relay automatically responding to movement of said contact of said ground relay to effect movement of said contact of said second relay,
 said contact of said second relay being connected so movement thereof to a predetermined position will limit the speed of the diesel engine of said diesel-powered unit to a value intermediate the idling speed and the maximum speed of said diesel engine,
 whereby said control system can automatically respond to a flash or ground in the high voltage electrical system of said diesel-powered unit to limit the speed of said diesel engine to said value intermediate the idling speed and the maximum speed of said diesel engine,
 said contact of said second relay controlling the energization of the "A" solenoid of said diesel engine

21

22

but not controlling the energization of the "B" or "C" solenoids of said diesel engine, whereby said diesel engine can be operated in "run 1" through "run 7" speeds but cannot be operated in the "run 8" speed after said contact of said second relay has moved to said predetermined position.

6. A control system for a diesel-powered unit which comprises:

- a ground relay that has a contact and a coil to effect movement of said contact,
- said coil of said ground relay being connected between ground and the high voltage electrical system of said diesel-powered unit and being adapted to automatically respond to a flash or ground in said high voltage electrical system of said diesel-powered unit to effect movement of said contact of said ground relay,
- a second relay that has a contact and a coil to effect movement of said contact,
- said contact of said ground relay and said coil of said second relay being parts of a circuit which is controlled by said contact of said ground relay,
- said coil of said second relay automatically responding to movement of said contact of said ground relay to effect movement of said contact of said second relay,
- said contact of said second relay being connected so movement thereof to a predetermined position will limit the speed of the diesel engine of said diesel-powered unit to a value intermediate the idling speed and the maximum speed of said diesel engine, whereby said control system can automatically respond to a flash or ground in the high voltage electrical system of said diesel-powered unit to limit the speed of said diesel engine to said value intermediate the idling speed and the maximum speed of said diesel engine,
- an indicator which responds to movement of said contact of said ground relay to become actuated,
- said indicator thereafter remaining in actuated position and thereby continuing to indicate that a flash or ground has occurred in the high voltage electrical system of said diesel-powered unit.

7. A control system for a diesel-powered unit which comprises:

- a ground relay that has a contact and a coil to effect movement of said contact,
- said coil of said ground relay being connected between ground and the high voltage electrical system of said diesel-powered unit and being adapted to automatically respond to a flash or ground in said high voltage electrical system of said diesel-powered unit to effect movement of said contact of said ground relay,
- a second relay that has a contact and a coil to effect movement of said contact,
- said contact of said ground relay and said coil of said second relay being parts of a circuit which is controlled by said contact of said ground relay,
- said coil of said second relay automatically responding to movement of said contact of said ground relay to effect movement of said contact of said second relay,
- said contact of said second relay being connected so movement thereof to a predetermined position will limit the speed of the diesel engine of said diesel-powered unit to a value intermediate the idling speed and the maximum speed of said diesel engine, whereby said control system can automatically respond to a flash or ground in the high voltage electrical system of said diesel-powered unit to limit the speed of said diesel engine to said value intermediate the idling speed and the maximum speed of said diesel engine,
- a further relay which has a contact in the excitation

circuit of the generator of said diesel-powered unit and which has a coil to effect movement of said contact,

said coil of said further relay responding to a predetermined number of movements of said contact of said ground relay to effect movement of said contact of said further relay and thereby interrupt the excitation of said generator.

8. A control system for a diesel-powered unit which comprises:

- a ground relay that has a contact and a coil to effect movement of said contact,
- said coil of said ground relay being connected between ground and the high voltage electrical system of said diesel-powered unit and being adapted to automatically respond to a flash or ground in said high voltage electrical system of said diesel-powered unit to effect movement of said contact of said ground relay,
- a second relay that has a contact and a coil to effect movement of said contact,
- said contact of said ground relay and said coil of said second relay being parts of a circuit which is controlled by said contact of said ground relay,
- said coil of said second relay automatically responding to movement of said contact of said ground relay to effect movement of said contact of said second relay,
- said contact of said second relay being connected so movement thereof to a predetermined position will limit the speed of the diesel engine of said diesel-powered unit to a value intermediate the idling speed and the maximum speed of said diesel engine, whereby said control system can automatically respond to a flash or ground in the high voltage electrical system of said diesel-powered unit to limit the speed of said diesel engine to said value intermediate the idling speed and the maximum speed of said diesel engine,
- said ground relay having a further contact that is connected so movement thereof to a disabling position will disable the engine relay of said diesel engine, and will thereby cause the speed of said diesel engine to start to drop toward idling speed,
- said coil of said ground relay being adapted to respond to a flash or ground in the high voltage electrical system of said diesel-powered unit to effect movement of said further contact of said ground relay to said disabling position,
- said further contact of said ground relay subsequently moving out of said disabling position to enable said engine relay of said diesel engine to cause the speed of said diesel engine to rise to the speed called for by the setting of the throttle of said diesel engine.

9. A control system for a diesel-powered unit which comprises:

- a ground relay that has a contact and a coil to effect movement of said contact,
- said coil of said ground relay being connected between ground and the high voltage electrical system of said diesel-powered unit and being adapted to automatically respond to a flash or ground in said high voltage electrical system of said diesel-powered unit to effect movement of said contact of said ground relay,
- a second relay that has a contact and a coil to effect movement of said contact,
- said contact of said ground relay and said coil of said second relay being parts of a circuit which is controlled by said contact of said ground relay,
- said coil of said second relay automatically responding to movement of said contact of said ground relay to effect movement of said contact of said second relay,
- said contact of said second relay being connected so

movement thereof to a predetermined position will limit the speed of the diesel engine of said diesel-powered unit to a value intermediate the idling speed and the maximum speed of said diesel engine, whereby said control system can automatically respond to a flash or ground in the high voltage electrical system of said diesel-powered unit to limit the speed of said diesel engine to said valve intermediate the idling speed and the maximum speed of said diesel engine,

said ground relay having a further contact that is connected so movement thereof to a disabling position will disable the engine relay of said diesel engine, and will thereby cause the speed of said diesel engine to start to drop toward idling speed,

said coil of said ground relay being adapted to respond to a flash or ground in the high voltage electrical system of said diesel-powered unit to effect movement of said further contact of said ground relay to said disabling position,

said coil of said ground relay holding said further contact in said disabling position until the voltage in said high voltage electrical system of said diesel-powered unit falls close to zero,

said further contact of said ground relay thereupon moving out of said disabling position to enable said engine relay of said diesel engine to cause the speed of said diesel engine to rise to the speed called for by the setting of the throttle of said diesel engine.

10. A control system for a diesel-powered unit, that has a generator and an excitation circuit therefor, which comprises:

- a ground relay that has a contact and a coil to effect movement of said contact,
- said coil of said ground relay being adapted to respond to a flash or ground in the high voltage electrical system of said diesel-powered unit to effect movement of said contact of said ground relay,
- a further relay that has a contact and a coil to effect movement of said contact to disabling position,
- said contact of said further relay being connected to the excitation circuit of said generator of said diesel-powered unit so movement thereof to said disabling position will disable said excitation circuit, and
- a counting sub-circuit that responds to a predetermined number of movements of said contact of said ground relay to cause said coil of said further relay to effect movement of said contact of said further relay to said disabling position,

whereby said control system can respond to a predetermined number of flashes or grounds in the high voltage electrical system of said diesel-powered unit to disable said excitation circuit of said generator.

11. A control system for a diesel-powered unit that has a generator and an excitation circuit therefor, which comprises:

- a ground relay that has a contact and a coil to effect movement of said contact,
- said coil of said ground relay being adapted to respond to a flash or ground in the high voltage electrical system of said diesel-powered unit to effect movement of said contact of said ground relay,
- a further relay that has a contact and a coil to effect movement of said contact to disabling position,
- said contact of said further relay being connected to the excitation circuit of said generator of said diesel-powered unit so movement thereof to said disabling position will disable said excitation circuit, and
- a counting sub-circuit that responds to a predetermined number of movements of said contact of said ground relay to cause said coil of said further relay to effect

movement of said contact of said further relay to said disabling position,

whereby said control system can respond to a predetermined number of flashes or grounds in the high voltage electrical system of said diesel-powered unit to disable said excitation circuit of said generator,

said counting circuit including a capacitor which receives a charge each time said contact of said ground relay is moved, and

said counting circuit including a threshold device connected to said capacitor,

said predetermined number of flashes or grounds in said high voltage electrical system of said diesel-powered unit increasing the voltage across said capacitor above the threshold value of said threshold device.

12. A control system for a diesel-powered unit that has a generator and an excitation circuit therefor, which comprises:

- a ground relay that has a contact and a coil to effect movement of said contact,
- said coil of said ground relay being adapted to respond to a flash or ground in the high voltage electrical system of said diesel-powered unit to effect movement of said contact of said ground relay,
- a further relay that has a contact and a coil to effect movement of said contact to disabling position,
- said contact of said further relay being connected to the excitation circuit of said generator of said diesel-powered unit so movement thereof to said disabling position will disable said excitation circuit, and
- a counting sub-circuit that responds to a predetermined number of movements of said contact of said ground relay to cause said coil of said further relay to effect movement of said contact of said further relay to said disabling position,

whereby said control system can respond to a predetermined number of flashes or grounds in the high voltage electrical system of said diesel-powered unit to disable said excitation circuit of said generator,

said counting circuit including a capacitor which receives a charge each time said contact of said ground relay is moved, and

said counting circuit including a timing circuit,

said timing circuit including a charging sub-circuit for said capacitor and also including a variable impedance device that normally has a high impedance but that can become actuated to have a low impedance and thereby "short circuit" said charging sub-circuit for said capacitor,

said charging sub-circuit for said capacitor applying a charge to said capacitor when said contact of said ground relay is moved but said variable impedance element thereafter becoming actuated to "short circuit" said charging sub-circuit.

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