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ENGINE STARTING CONTROL SYSTEM

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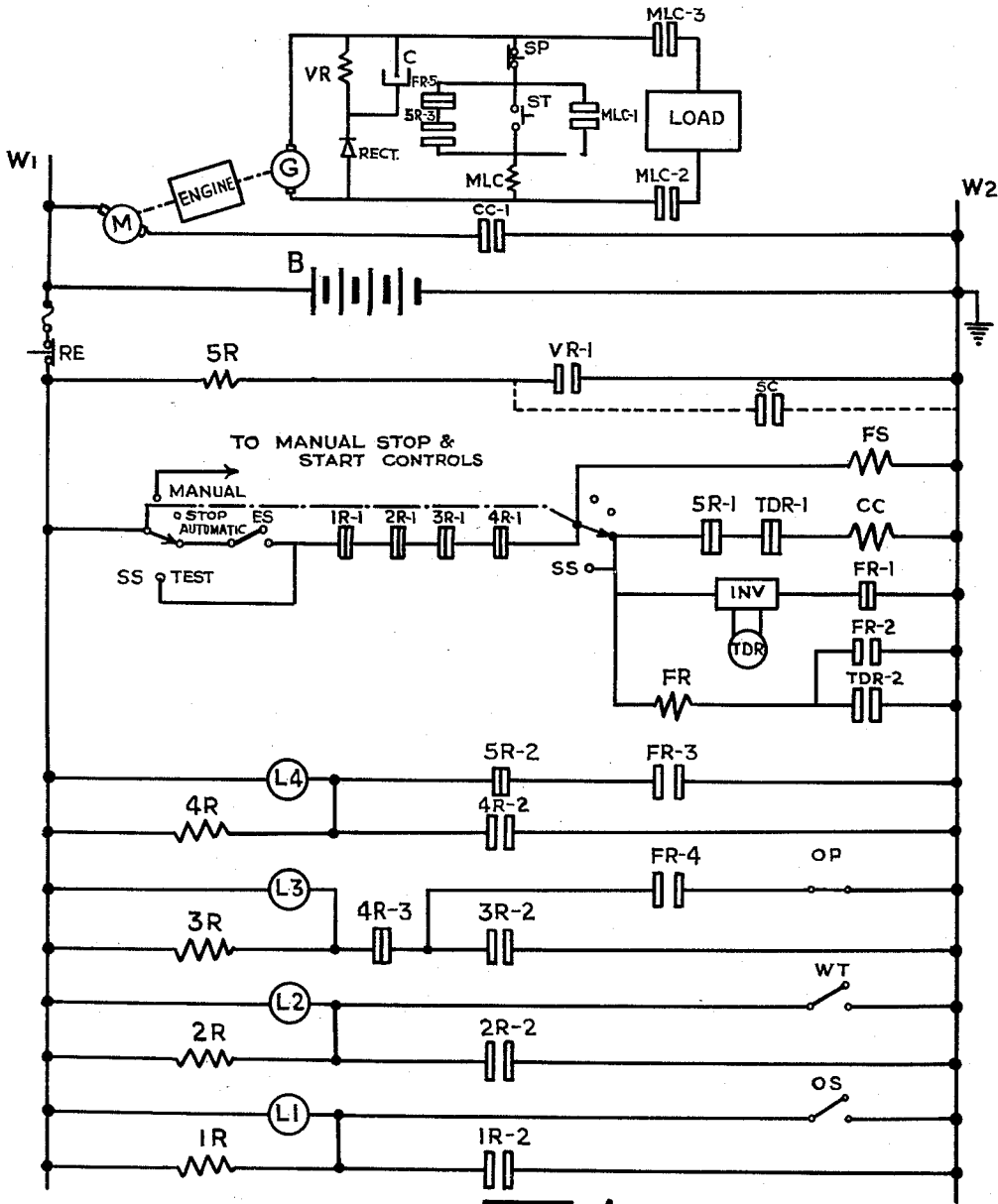


Fig. 1.

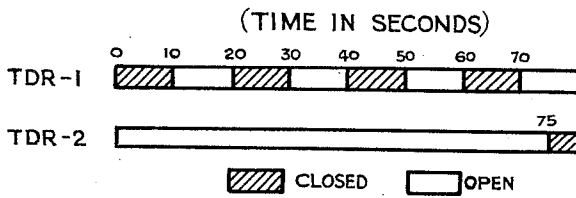


Fig. 2.

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ENGINE STARTING CONTROL SYSTEM
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This invention relates generally to electrical control systems, and, more particularly, to an electrical control system for automatically starting and stopping an engine which serves as the prime mover for an electric generator.

The type of power plant installation for which the invention is primarily intended is one in which a stand-by engine-generator set is to be automatically set into operation in the event of failure of a normal power supply. In a system of this character, it is common practice to provide a starting motor for cranking the engine when the latter is to be started, and a switch which is periodically operated by means of a timer, to energize and de-energize the starting motor and thereby furnish a sequence of cranking operations separated by periods during which there is no cranking. A relay or other means is generally provided for preventing further cranking operations of the motor once the engine has started, and in addition the timer is usually adapted to operate the switch, and hence crank the engine, for only a predetermined number of cycles. Consequently, the starting motor will be rendered inoperative upon the happening of one of two circumstances, namely, the starting of the engine, or the completion of the predetermined number of cranking cycles.

According to previous circuits, the relay which is operative to prevent further cranking once the engine has started, accomplishes this result by deactivating the timer, thus interrupting the sequence of switch operations which successively energize and de-energize the starting motor.

It is an object of the present invention to provide an improved engine starting control system in which the starting motor may be deactivated and hence the cranking operations halted once the engine has started, without disturbing the operation of the timer. In this way, the timer is permitted to complete its pattern of operation, comprising a predetermined number of cycles, just as it would do if the engine had not started. As a result, the timer affords a convenient time-delay mechanism which can be used to operate certain other elements of the control circuit which must be actuated, not when the engine starts, but only after a short period thereafter.

An example of how the time-delay feature of this invention can be used may be had by considering a safety circuit which serves to shut down the engine upon the occurrence of an abnormal condition, which condition also exists when the engine is at rest. If, for example, the abnormal condition referred to is low oil pressure, i.e., oil pressure below a value desirable for proper performance of the engine, and if the safety circuit is to be rendered operative to shut down the engine upon the occurrence of oil pressure below the proper value, it is obvious that the safety circuit will also be operative when the engine is not running (since there is no oil pressure at that time), and will thus prevent the starting of the engine. This situation is alleviated in accordance with the present invention, by placing in the safety circuit a means operated by the timer which prevents the safety circuit from becoming operative until the timer has completed its pattern of operation. Consequently, by the time this means permits operation of the safety circuit, the engine is running and the oil pressure has built up to a value above that at which the circuit is designed to operate and shut down the engine.

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Other examples of how the time-delay feature provided by the timer of the present circuit may be utilized will be set forth in the following description, from which other objects and advantages of the improved engine starting control system will also be apparent.

In the drawings:

FIGURE 1 is a diagrammatic view of an engine starting control circuit embodying the teachings of the present invention; and

FIGURE 2 is a diagrammatic showing of the sequence of operations of the timer.

FIGURE 1 is an elementary diagram showing the circuits in "straight" or "across-the-line" form. The contacts of a relay are shown separated from the relay coil which operates them and are arranged in the circuits which they control, thus making it possible to arrange each coil circuit in a "straight" line between parallel lines, W_1 and W_2 , representing the power source.

In the across-the-line diagram the following relays will be found:

VR—voltage relay
MLC—main line contactor relay
CC—cranking contactor relay
FR—delayed-action relay
1R—overspeed relay
2R—high-water-temperature relay
3R—low-oil-pressure relay
4R—over-cranking relay
5R—control relay

Throughout the description which follows, these letters will be applied to the coils of the relays, and with numerals appended thereto, they will be applied to the contacts of these relays. The relay contacts are all shown in the deenergized condition.

In addition, the diagram contains a fuel solenoid, FS; a motor-driven cycling timer, TDR; an inverter, INV; a two-pole, 4-position selector switch, SS; a starting motor, M; and a generator G.

The diagram further contains the following indicating lamps:

L1—overspeed lamp
L2—high-water-temperature lamp
L3—low-oil-pressure lamp
L4—over-cranking lamp

and the following switches:

OS—overspeed switch
WT—high-water-temperature switch
OP—low-oil-pressure switch
RE—reset switch
ES—engine-start switch
ST—start switch
SP—stop switch
SC—optional speed responsive switch

A suitable supply voltage is applied between the lines W_1 and W_2 by the battery B or equivalent power source. Now, assuming that the selector switch "SS" is positioned on "automatic" as shown in FIGURE 1, the control circuit is conditioned to automatically start the engine upon receiving some external signal. If, for example, the generator G is an auxiliary generator which is to be brought into action when the voltage from a main generator falls below a predetermined value, then the external signal will be the low voltage output of the main generator. Whatever may be the source of the external signal, its function is to close the engine-start switch ES.

At the moment that switch ES closes, a circuit is completed from line W_1 , through one pole of the selector switch SS, the switch ES, the normally engaged contacts 1R-1, 2R-1; 3R-1 and 4R-1, the other pole of the se-

lector switch, the inverter INV, and the normally engaged contacts FR-1 to line W₂, thus energizing the inverter INV. The purpose of the inverter is to provide a source of alternating current for driving the motor-driven cycling timer "TDR." Therefore, at the moment the inverter is energized, the timer TDR begins operation. Note that the inverter is not necessary, and in its absence the timer may be connected directly into the line.

Referring to FIGURE 2, the manner of operation of the timer is diagrammatically shown. The timer may be of any known type, and controls two switches, TDR-1 and TDR-2, preferably cam operated. The inverter or other driving power causes the timer to perform in accordance with a predetermined pattern of operation and to return ultimately to its home or starting position. The cams are so arranged that in the home position of the timer, the switch TDR-1 is closed, and the switch TDR-2 is open. The moment at which the switch ES closes and the timer TDR begins running is indicated at time zero in FIGURE 2. The switch TDR-1 then remains closed for a selected short duration, e.g., for ten seconds, then opens for ten seconds, and so on. As the timer continues to run, the switch TDR-1 alternately closes and opens for a predetermined number of such ten second intervals. On the other hand, the switch TDR-2 remains open for a longer period, e.g., seventy-five seconds, at which time the switch TDR-2 closes. It will be understood that the time intervals mentioned are entirely optional and may be altered as desired. In addition, the timer may be adjusted to operate through any number of cycles between the time it begins operation and the time it is returned to its home position. For purposes of the present example, the timer has been adjusted to operate through four cycles, i.e., the switch TDR-1 closes and opens four times.

Referring back to FIGURE 1, it may now be seen that when the engine-start switch ES closes, not only is the inverter INV energized, but in addition, since the switch TDR-1 is initially closed, a circuit is also completed to energize the cranking contactor relay coil CC. Upon energization of the latter, the contacts CC-1 engage to complete a circuit for energizing the starting motor M. As a result, the engine is cranked for a period corresponding to the time that the switch TDR-1 remains closed, or in the present example, for ten seconds. When the switch TDR-1 opens, the cranking stops for ten seconds, until the switch TDR-1 closes again, at which time the engine is cranked again for a period of ten seconds. Furthermore, in addition to providing periodic cranking of the engine, closing of the engine start switch ES completes a circuit for energizing the fuel solenoid FS, which opens a valve in the fuel line (not shown) and permits fuel to be supplied to the engine during the cranking operation. In the usual case, one of the cranking operations will cause the engine to start.

When the engine starts, it begins to drive the generator G. As the speed of the generator increases, it produces a voltage sufficient to energize the voltage relay coil VR. The relay VR may, of course, be adjusted so as to be energized when the output voltage of the generator reaches any particular value, however, preferably the relay VR becomes energized when the output of the generator reaches about one-third of its full output voltage. When the VR relay is energized, the contacts VR-1 are engaged to energize the control relay coil 5R. In response to this energization, the contacts 5R-1 become disengaged thus breaking the circuit which energizes the cranking contactor relay CC. Consequently, the contacts CC-1 are disengaged, and cranking of the engine stops. Note, however, that the cranking of the engine has been stopped without interfering with the operation of the timer TDR. Therefore, regardless of when the engine starts, the timer is permitted to complete its four cycles of operation.

The voltage relay VR has been described as being responsive to voltage output of the generator G. Optionally, a speed contact switch SC, which is responsive to the speed of the engine, could be employed in place of the relay VR. In such a case, when the speed of the engine reaches a predetermined value, the speed contact switch is closed, thus causing energization of the relay 5R.

Upon energization of the control relay 5R, the contacts 5R-3 are engaged thus completing the circuit for energizing the main line contactor relay coil MLC. The contacts MLC-1 then engage to form a self-holding circuit for the relay MLC. Since it is the function of the relay MLC to connect the load to the generator G, this relay is preferably designed to operate so as not to actuate the contacts MLC-2 and MLC-3 until the generator has reached, say, 80% of its output. At that time the latter two sets of contacts are engaged and the load is connected to the generator.

When seventy-five seconds have elapsed after the closing of the engine-start switch ES, the switch TDR-2 closes momentarily, thus completing a circuit for energizing the special delayed-action relay coil FR. The contacts FR-2 then engage to lock-in the relay FR, and the contacts FR-1 disengage to break the circuit energizing the inverter INV. As a result, a spring (not shown) is permitted to return the timer TDR to its home position.

Note that some period of time always elapses between the time the engine starts and the time the switch TDR-2 closes to energize the relay FR. In the present example, the shortest possible such period of time is five seconds. This would occur if the engine happened to start during the fourth cranking cycle of the timer i.e., during the cycle ending 70 seconds after time zero in FIGURE 2. Five seconds would then elapse before the switch TDR-2 closes and the relay FR is energized. It is this time delay between the start of the engine and the energization of the relay FR which is conveniently provided by permitting the timer TDR to complete its pattern of operation regardless of when the engine starts, and which is utilized by the present circuit arrangement in the manner now to be described.

This time delay can be utilized to advantage in connection with a safety circuit which is intended to detect the occurrence of an abnormal condition in the engine while it is running, which condition also exists when the engine is at rest. As an example of this type of condition, assume that the engine has been running for some time, and as would be normal, the contacts FR-4 are closed, and the low-oil-pressure switch OP is open (since the oil pressure is up). Now, assume that the abnormal condition which develops is the reduction of the oil pressure below a desirable value. The low-oil-pressure switch OP is adapted to detect such an occurrence, and to close upon its happening. When switch OP closes, a circuit is completed from line W₁ through the low-oil-pressure relay coil 3R, the closed contacts 4R-3, the engaged contacts FR-4, and the now closed low-oil pressure-switch OP to line W₂. The relay 3R is thus energized whereupon the contacts 3R-1 are disengaged thus breaking the circuit which energizes the fuel solenoid FS, and as a result the engine will stop. At the same time that the circuit was completed to energize the relay 3R, a circuit was completed to light the indicating lamp L3 which will indicate to an attendant the reason for the stoppage of the engine. Furthermore, contacts 3R-2 engage to lock-in the relay 3R until an attendant alleviates the abnormal condition.

After the cause of the trouble has been eliminated, the attendant merely presses the reset switch RE which momentarily opens and then closes. As a result, the relay 3R is deenergized, thus permitting the contacts 3R-1 to reengage. Furthermore, the relay FR is deenergized, thus permitting the inverter INV to be reenergized and the cranking cycles, as described above, to be reinitiated.

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As was mentioned above, it is the closing of the low-oil-pressure switch OP upon the occurrence of an abnormally low oil pressure in the engine, which causes the energization of the relay 3R and hence the stoppage of the engine. Note, however, that before the engine starts, there is little or no oil pressure, i.e., the "abnormal" condition of the running engine also exists when the engine is at rest. Therefore if the contacts FR-4 were not present in the circuit which energizes the relay 3R, the engine would never start. Since almost immediately after the engine starts, sufficient oil pressure is developed to open the low-oil pressure switch OP, what is called for is a pair of contacts which will remain open for a short time after the engine starts, and then remain closed throughout the running of the engine. The contacts FR-4, which are operated by the relay coil FR, admirably serve this function. Thus, at the time the engine starts the contacts FR-4 are open. Almost immediately thereafter the low-oil-pressure switch OP opens and a short time after that the timer TDR reaches its home position, the switch TDR-2 is closed, and the contacts FR-4 are engaged. Thus, there is no possibility that the relay 3R will be energized due to the inherent low oil pressure existing in the engine before it is running. This is due to the utilization of the time delay afforded by permitting the timer TDR to complete its pattern of operation.

A number of other safety circuits are provided. The high-water-temperature switch WT is adapted to close when the temperature of the water in the cooling system of the engine reaches an undesirably high level. When this happens a circuit is completed to energize the high-water-temperature relay coil 2R, thus causing the contacts 2R-1 to disengage and deenergize the fuel solenoid FS, whereupon the engine will be stopped. In addition, the high-water-temperature lamp L-2 is energized to indicate the cause of the engine stoppage. Similarly an over-speed switch OS is provided, which closes when the engine reaches an undesirably high speed. At this time the circuit will be completed to energize the over-speed relay coil 1R, which causes the contacts 1R-1 to open, with the result that the engine will be stopped. In addition, the indicating lamp L-1 will be lighted. Self-holding circuits are provided for both relays 1R and 2R to maintain the engine in arrested condition, and to keep the indicating lamps lit, until the reset switch RE is actuated.

It sometimes happens that after the timer TDR completes its four cranking cycles of operation, the engine fails to start. In such a case, when the timer completes its operation and the relay FR is energized, thus engaging the contacts FR-3, a circuit will be completed from the line W₁ through the over-cranking relay coil 4R, the contacts 5R-2, and the contacts FR-3, to line W₂, thus energizing the relay 4R. As a result, the contacts 4R-1 will open to deenergize the fuel solenoid, and in addition the indicating lamp L-4 will be lighted to indicate that the engine has failed to start after the usual cranking operation has been completed. It should be noted that if the engine starts, the relay 5R is energized, thus causing the contacts 5R-2 to disengage. When this happens, closing of the contacts FR-3 will, of course, not result in the energization of the relay coil 4R. Note also the presence of the normally engaged contacts 4R-3 in the circuit which energizes the low-oil-pressure relay coil 3R. Should the engine fail to start, these contacts disengage and prevent a false indication of low oil pressure.

Another point in the present circuit where the relay FR is advantageously employed is in the circuit which energizes the relay coil MLC. Normally the contacts FR-5 are engaged, thus permitting the relay MLC to be energized upon the engagement of the contacts 5R-3, as mentioned above. If, after the generator G is running, the load is for some reason to be disconnected from the generator, the stop-switch SP can be pushed, thus momentarily deenergizing the relay MLC. As a result, the con-

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tacts MLC-2 and MLC-3 will open to disconnect the load. When the stop-switch SP again closes, the relay MLC will not be reenergized, thus maintaining the load permanently disconnected. Note, however, that if the contacts FR-5 (which are now disengaged) were not present, then a reclosing of the stop switch would complete a circuit through the still engaged contacts 5R-3 to energize the relay MLC and thus reconnect the load to the generator prematurely. Since, however, when the timer TDR completes its operation the contacts FR-5 open, and remain open as long as the engine is running, the relay MLC is not reenergized when the switch SP recloses. It should here be mentioned that the relay MLC may be energized, and the load connected to the generator G, by means of the start-switch ST as well as by means of the circuit containing the contacts FR-5 and the contacts 5R-3.

When the engine is to be stopped, assuming that it has been running satisfactorily, all that need be done is to move the selector switch SS from "Automatic" position to "Stop" position. This results, as may be seen, in deenergizing the fuel solenoid FS thus cutting off the fuel supply to the engine. When the engine is to be started by means of manual stop-and-start controls (not shown), the selector switch SS is moved to the "Manual" position shown. Finally, when it is desired to test the operation of the engine control system, as well as the engine itself, the selector switch SS is moved to the "Test" position. In this position, the circuit operates exactly as described above, except for the fact that the engine-start switch ES has been by-passed, thus making it unnecessary for an external signal which closes the switch ES to occur before the circuit is put into operation.

It should also be noted that the voltage relay VR may, if desired, be provided with a capacitor C which furnishes a time delay on drop-out of the relay. This feature prevents recranking of the engine for a definite period of time after the generator voltage has been reduced to a low value. Thus, as long as the relay VR is energized the relay 5R remains energized, and the contacts 5R-1 disengaged, hence there is no chance that the engine will be cranked while it is running.

The invention has been shown and described in preferred form only, and by way of example, but many variations and modifications may be made therein and in its mode of application, which will still be comprised within its spirit. For example, if the voltage relay VR were provided with additional sets of contacts, the control relay 5R could be eliminated, and all the contacts of that relay could be replaced by contacts controlled by the relay coil VR. It is understood, therefore, that the invention is not limited to any specific form or embodiment, except insofar as such limitations are specified in the appended claims.

What is claimed is:

1. In a control system for an engine having a cranking motor and being connected in driving relation to a generator: a timer, a motor for driving said timer through a complete pattern of operation which defines repetitive operating intervals and then restores the timer to its start position after an accurate total interval, a cranking circuit including a first switch actuated by said timer to engage and disengage once during each of a series of said repetitive intervals, cranking control means in said circuit responsive to the operation of said switch for connecting the cranking motor to a source of power, a circuit including a control relay and a switch for energizing it responsive to generator speed, switches actuated by said control relay including one which opens said cranking circuit thus deenergizing the cranking control means without interrupting the pattern of operation of the timer, a circuit for said timer-driving motor, a circuit including a delayed-action relay and a switch for energizing it, said last-mentioned switch being a second switch actuated by said timer upon completion of its pattern of operation, and a switch actu-

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ated by said delayed-action relay for opening said motor circuit to discontinue timer operation.

2. In a control system of the character described, the combination with the elements defined in claim 1, of a safety circuit for stopping the engine upon the occurrence of a condition which is abnormal during running conditions but normal while the engine is at rest, said safety circuit having in it a normally open switch actuated by said delayed-action relay.

3. In a control system of the character described, the combination with the elements defined in claim 1, of a circuit controlling flow of fuel to the engine, and a safety circuit for severing said fuel circuit if the timer returns to start position without the engine having started, said safety circuit including an over-cranking relay, said fuel circuit including a switch controlled by said overcranking relay, and said safety circuit having in it a normally closed second switch actuated by said control relay and a normally open second switch actuated by said delayed-action relay.

4. In a control system of the character described, the combination with the elements defined in claim 1, of a circuit controlling flow of fuel to the engine, a safety circuit for severing said fuel circuit if the timer returns to start position without the engine having started, said safety circuit including an over-cranking relay, said fuel circuit including a switch controlled by said over-cranking relay, said safety circuit having in it a normally closed

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second switch actuated by said control relay and a normally open second switch actuated by said delayed-action relay, and a second safety circuit for stopping the engine upon the occurrence of a condition which is abnormal during running conditions but normal while the engine is at rest, said second safety circuit having in it a normally open third switch actuated by said delayed-action relay.

5. In a control system of the character described, the combination of elements defined in claim 4, in which said second safety circuit also has in it a normally closed second switch controlled by said over-cranking relay.

6. In a control system of the character described, the combination with the elements defined in claim 1, of a load circuit connected to the output of the generator, and means for severing said load circuit and preventing inadvertent reestablishment thereof, said means comprising a stop circuit having in it a momentarily acting stop switch, a normally open switch actuated by said control relay, and a normally closed switch actuated by said delayed-action relay.

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