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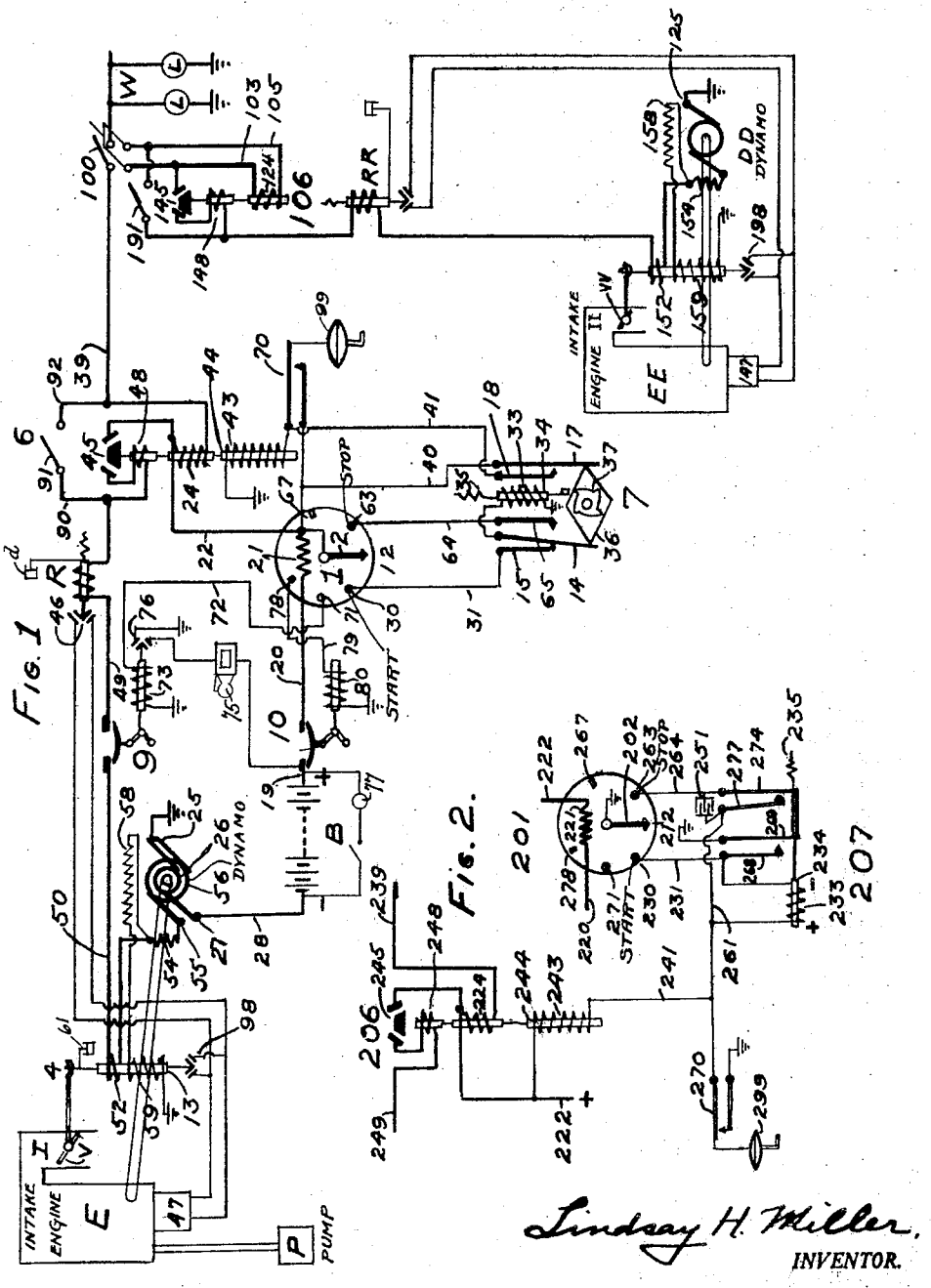
L. H. MILLER

ELECTRICAL SYSTEM

Original Filed Aug. 19, 1916



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UNITED STATES PATENT OFFICE.

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ELECTRICAL SYSTEM.

Application filed August 19, 1916, Serial No. 532,859. Renewed January 30, 1922.

To all whom it may concern:

Be it known that I, LINDSAY H. MILLER, a citizen of the United States, and residing at Chicago, in the county of Cook and State of Illinois, have invented a new and Improved Electrical System, of which the following specification is a full disclosure.

This invention relates to an electrical system, and with regard to certain more specific features, to a power plant embodying an internal combustion engine, a dynamo connected therewith, a work circuit and a storage battery. This invention is an improvement on the invention set forth in the application of Harvey S. Pardee for patent on electrical system, Serial Number 92,421, filed April 20, 1916.

One of the objects of the present invention is to provide an electrical system constructed of parts easily obtained on the market, readily assembled, and capable of operation for an extended period without expert attention.

Another object is the provision of simple, durable and efficient apparatus for furnishing current to a work circuit by means of a generator driven by an internal combustion engine or other engine, inherently incapable of starting itself.

Another object is the provision of a system of the above type in which a small storage battery may be effectively employed, in place of the large battery now commonly in use, the present system affording automatic operation, accuracy of regulation, and protection to the battery.

Another object is the provision of an efficient and inexpenisve charging system for a storage battery, so designed that the generator may supply the lamps and charge the battery simultaneously without subjecting the lamps or other translating devices, to a voltage higher than the normal discharge-voltage of the battery.

Another object is the provision of improved apparatus of the above type in which notice is automatically given to the operator in case his attention is needed at any time, and this prior to any disconnection of the lamps from their source of current.

Another object is the provision of reliable and efficient means for controlling the operation of a pumping plant.

Another object is the provision of inexpensive protective means operating to minimize or prevent danger of over-speeding of the engine, without involving the use of a governor on the engine.

Another object is the simplification of the relay 7.

Other objects will be in part obvious from the annexed drawings and in part indicated in connection therewith by the following analysis of this invention.

This invention accordingly consists in the features of construction, combination of parts, and in the unique relations of the members and in the relative proportioning and dispositions thereof; all as more completely outlined herein.

To enable others skilled in the art so fully to comprehend the underlying features thereof that they may embody the same by the numerous modifications in structure and relation contemplated by this invention, drawings depicting diagrammatically a preferred form have been annexed as a part of this disclosure; and in said drawings,

Figure 1 is a diagrammatic representation of an electrical system incorporating certain features of the present invention; and

Figure 2 illustrates a modification, relating primarily to a simplification of the relay 7.

In considering the relation of this invention to the prior art, it may be noted that for many years there has been a demand for an electrical system in which a work circuit, for lamps, motors, or other translating devices, could be supplied with current from a dynamo driven by an internal-combustion engine, with provision for furnishing a small amount of current as for night-lights, without requiring the operation of the engine and generator at such times; a further requirement has been that the entire system should be sufficiently automatic that no frequent or expert attention is needed, durable so that no expert inspection or repair would be required for long periods of time, and inexpensive both as regards first costs and operating costs, so

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that the system is commercially applicable to small, isolated installations. In many, if not all of the present-day apparatus designed for isolated power plants, the first cost and depreciation of the storage battery is a large factor in the total expense incident to the purchase and maintenance of the plant. As the description of the present invention proceeds, it will be seen that these rigid requirements have been met, in an apparatus which is at once inexpensive, automatic, efficient and reliable.

Briefly, the present invention utilizes a combined generator and battery-charging booster which supplies a voltage to the line equal to the discharge voltage of the battery and an excess charging voltage to the battery greater than the voltage supplied to the line, whenever the generator is running normally. When the generator is not running, the booster armature winding of the combined generator remains in the battery circuit but generates no voltage because it is at rest. There is preferably provided an ampere-hour meter with certain contacts and electrical connections to a main switch which operate that switch and automatically start up the plant and shut it down at the proper times, depending upon the state of charge of the battery. The main switch is arranged also to close automatically and start up the plant whenever the lamp load draws a current in excess of the capacity of the battery, which in this case may be relatively small. The main switch automatically opens when the lamp load drops down below the capacity of the battery and the battery has reached a state near full charge. Various auxiliary devices may be added to protect the apparatus, give an alarm, and to cut off the engine-starting circuit when the engine fails to start with reasonable promptness, due to the failure of the fuel supply or other abnormal causes, and to shut down the engine when faults develop in the control mechanism. The driving engine is of the variable-speed type and is preferable so regulated as to run at a higher speed at full load than at no load, thus tending to maintain a more constant mixture and a saving of fuel. The battery, it should be noted, is of small capacity and relatively high internal resistance and thus is subject to a considerable drop of voltage during the momentary rush of current at the first instant of starting the engine.

This fluctuation of the lamp voltage and candle-power has the advantage of giving a distinct warning to the operator whenever the engine is started.

Referring now to the accompanying drawings, there is illustrated at I a portion of the intake of an internal-combustion engine E; a butterfly or other valve V is located in the intake I and is adapted to be operated by means hereinafter described, so as to increase the fuel supply to the engine at certain times and to move in the opposite direction to decrease the fuel supply at other times. Mechanically connected to the engine E is a dynamo-electric machine D, which is utilized as a motor to start the engine and when the engine is running is utilized as a generator to furnish current to the storage-battery B and to the work circuit W.

An integrating meter 1, preferably an ampere-hour meter as here illustrated, has a contact-making pointer or other indicator 2 which indicates the state of charge of the battery B and, in addition, effects certain circuit-changing operations hereinafter described. A valve-operating regulator 4, a main switch 6, a relay 7, a dynamo trip-switch 9 and a battery trip-switch 10, may also be provided.

The structural details of the various elements and their assembly perhaps can be best described in connection with an explanation of the various operations and circuit changes that occur in the several phases or events of the cycle of operations of the system. Assume, therefore, that the engine and dynamo are at rest, that no current is flowing in the work circuit and that the battery is in a state of partial charge such that the indicator 2 of the meter 1 stands at point 12. At this time the switches 9 and 10 are closed, the contacts 46 are closed, the main switch 6 is open (down), the regulator 4 is in its open-throttle position (solenoid 13 down) and the relay 7 is in the position indicated in Figure 1, with the left-hand movable contactor 14 thereof contacting with its left-hand contactor 15, and the right-hand movable contactor 17 of the relay is separated from its contactor 18. If now a lamp load of less than, for example, one ampere, be turned on in the work circuit W, then current will flow from the positive side of the battery B, through the lead 19, battery trip-switch 10, lead 20, coil 21 of the meter 1, lead 22, lamp-current coil 24 of the main switch 6 and lead 39 thence through any lamps L, L, that are turned on, thence to the ground, from ground to the grounded terminal 25 common to the two armature windings of the dynamo D, through the low-voltage armature winding 26, negative brush 27 thereof, and lead 28, to the negative pole of the battery. The flow through the armature winding 26 encounters none but ohmic resistance, since the dynamo is at rest and the field excitation dead. This lamp load causes a slow discharge of the battery and consequently a slow clockwise movement of the indicator 2, which moves toward the start-charge contact 30.

When the indicator 2 reaches the contact 30, a circuit is closed from the positive side

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of the battery, through elements 19, 10, 20, 21, 2, 30, lead 31, left-hand fixed contact 15 of the relay 7, left-hand movable contact 14, coil 33 of the relay 7, ground, elements 25, 26, 27, and 28 to the negative pole of the battery. This energizes the relay coil 33, which thereupon pulls downwardly its solenoid-core 34 against the pull of the retractile spring 35, and this downward stroke of the core 34 imparts to the diamond-shaped spacing-block 36 a quarter-turn, through the ratchet 37. This rotation of the spacing-block 36 breaks the relay circuit at the contactors 14. 15, de-energizing the relay winding 33 and allowing the plunger 34 to be withdrawn upward by its spring 35, into position for another throw. At the same time the contacts 14—65 and 17—18 are closed. The contactors 17—18 close a circuit from the positive side of the battery through elements 19, 10, 20, 21, lead 40, right-hand movable contact 17, contact 18, lead 41, voltage coil 43 of the main switch 6, ground, elements 25, 26, 27 and 28 to the negative side of the battery. This energizes the voltage coil 43 of the main switch, which thereupon pulls upwardly its solenoid-core 44, with sufficient force to close the contacts 45.

At about the same time, the relay R is sufficiently energized to separate the contacts 46 to remove a short-circuit around the engine magneto 47, or,—depending upon the style of ignition used for the engine—the circuits might be altered so that the operation of the relay R would close the ignition circuit; in either case, the contacts 46 are intended to render the engine ignition operative when the relay R is sufficiently energized and inoperative at other times.

The effect of closing the main contacts 45 is to close a circuit from the positive side of the battery, through elements 19, 10, 20, 21, 22, 45, dynamo-current coil 48 of the main switch 6, coil of relay R, lead 49, dynamo trip-switch 9, lead 50, current coil 52 of the regulator 4, series field 54 of the dynamo D, positive brush 55, high-voltage armature winding 56, intermediate or grounded terminal 25, low-voltage winding 26, brush 27, and lead 28 to the negative side of the battery.

Simultaneously the shunt-field winding 58 and the voltage coil 59 of the regulator 4, connected in series, are energized; these coils are, for the moment, energized but slightly, however, owing to the heavy ohmic drop in the battery. A strong current flows through the circuit including the armatures and series field of the dynamo, causing the dynamo to rotate substantially as a series motor, with a large starting-torque, the series field 54 at this time predominating over the shunt field 58; this rotation of the dynamo rotates the engine E through the mechanical connections between them, and this serves to start the engine. The current through the current coil 48 of the main switch at this time tends to assist in closing the contacts 45 thereof more tightly, thus securing a firm and positive contact.

After the engine has started to rotate under its own power, the counter electromotive-force generated in the armature windings 26, 56, raises the voltage across the terminals of the dynamo, thereby increasing the power of the coil 59 and shunt field 58 and reducing the power in the series field 54, until the dynamo voltage equals and then exceeds the battery voltage. Then the series field reverses, and thereafter, during the operation of the dynamo as a generator, the series field opposes the effect of the shunt field. The series field is preferably strong enough relatively to the shunt field to afford a marked drooping of the dynamo-voltage characteristic.

Now that the engine is running under its own power, current is delivered from the positive lead of the dynamo through the elements 52, 50, 9, 49, R, 48, 45, and thence in two branches. The first branch includes the lamp current coil 24, main 39, lamps L, L, ground, and grounded terminal 26 of the dynamo, giving at the lamps a voltage equal to the voltage across the high-voltage winding 56 of the dynamo; in practice this is preferably 110 volts, although obviously any other suitable standard of voltage may be used. The second branch includes the elements 22, 21, 20, 10, 19, thence through the battery to charge the same, thence through low-voltage or booster winding 26 of the dynamo, to the grounded terminal 25 of the dynamo; so that the voltage across the battery is at this time equal to the sum of the voltages across the two windings 56, 26, of the dynamo. The high-voltage winding carries preferably a pressure of 110 volts, and by proportioning the low-voltage, winding for, say, approximately 14 volts, the battery on charge receives 124 volts at its terminals, which is a suitable charging voltage for a lead battery whose discharge voltage is 110; however, these proportions may naturally be varied to meet the requirements of the particular battery to be used.

The dynamo voltage is maintained constant by suitable means such as the regulator 4, whose solenoid 61 is pulled upwardly in case of a tendency to excessive voltage across the coil 59, to move the valve V toward its closed position, thereby reducing the fuel supply and speed of the engine and consequently restoring the dynamo voltage to its normal value. Similarly a slight reduction or tendency to reduction of the voltage causes a lessened power of the coil 59, which allows the solenoid core 13 to drop slightly, thereby opening the valve, admitting more fuel, speeding up the engine and dynamo,

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and restoring the voltage to normal. By means of this regulator, then, the dynamo-voltage characteristic is determined so that despite changes in load, or the condition of the battery or other variables such as temperature and quality of fuel, the voltage on the load is not affected. It is possible by means of the compound winding on the regulator to give a rising characteristic to the dynamo voltage in order to compensate for voltage drop in the line leading to the lamp load. The compounding is effected by the current coil 52, which carries the output current of the dynamo and during normal operation opposes magnetically the potential winding 59. By properly proportioning the ratio of ampere-turns on the current and the potential windings 52, 59, it is possible to give a flat, a rising, or a falling characteristic to the voltage across the work circuit. This regulator compensates for the inherent drooping characteristic of the dynamo as well as for all other conditions. It is preferably equipped with a dashpot or other suitable damping means 61 to prevent hunting or over-regulation during ordinary load fluctuations and sudden closing of the valve due to the strong action of the current coil at the instant of starting the engine.

As the charging of the battery progresses, the meter indicator 2 moves counter-clockwise. When the indicator reaches the stop-charge contact 63, a circuit is closed from the positive main 49 of the dynamo circuit, through elements 22, 2, 63, 64, contactors 65 and 14 (closed as previously explained), coil 33 of relay 7, to ground. This energizes the relay coil 33, which thereupon pulls downwardly its solenoid core 34, imparting a quarter-turn through the ratchet 37, to the diamond-shaped spacing-block 36. This rotation of the spacing-block 36 breaks the circuit at the contactors 65, 14, and opens the circuit at the right-hand contacts 17, 18. The break at 65, 14, opens the circuit through which the relay had been previously energized, thus allowing the plunger 34 to be withdrawn by the spring 35 into position for another throw. The separating of the contactors 17, 18, opens the circuit through the voltage coil 43 of the main switch 6, and causes the switch to open its contacts 45, assuming still that the lamp load is one ampere or less. The opening of the main-switch contacts 45 disconnects the dynamo from the battery and work circuit and de-energizes the coil of the underload relay R, which thereupon closes its contacts 46, de-energizing the engine ignition and causing the engine to stop. The conditions previously assumed are now restored, namely, the engine and dynamo are at rest, and battery is on slow discharge and supplies the one ampere or less that is required for the work circuit. As the battery slowly discharges, the meter pointer 2 reaches again the start-charge contact 30, and the cycle above described is repeated.

An object of the relay 7 is to relieve the contacts on the meter 1 of the duty of carrying the current and breaking the inductive current through the voltage coil 43 of the main switch.

If at any time the current in the work circuit rises above, say, one ampere when the dynamo is not running, the starting of the dynamo is effected at once, without waiting for the battery to discharge to the state indicated by the start-charge contact 30 on the meter. This immediate starting of the engine is effected through the lamp-current coil 24 on the main switch; this coil, when energized with more than, say, one ampere of current, raises the core 44 of the main switch 6, after which the starting of the dynamo is effected as in the preceding instance, where the coil 44 was raised by means of the voltage coil 43. If now the battery becomes sufficiently charged to cause the indicator 2 to reach the stop-charge contact 63, the relay 7 will not be affected, as it is in its Figure 1 position. The voltage coil 43 of the main switch is de-energized at this time, but the core 44 thereof does not drop, because there is more than one ampere of current in the lamp-current coil 24, and this coil is thus energized sufficiently to keep the main switch closed even though the voltage coil 43 is de-energized. Nor does the underload relay R operate to close the ignition contacts 46, because the current flowing through the coil of this relay is sufficient to keep the relay energized and the contacts 46 separated. The charging of the battery therefore continues, but at a decreasing rate, because the counter electromotive-force of the battery is increasing, and the impressed voltage (from the dynamo) is constant. As the charging progresses, the meter indicator rotates further counter-clockwise, until it reaches the stop 67, indicating full charge, or if preferred, an overcharge. Further movement of the meter indicator is prevented by this stop; this does no harm to the meter, and serves to indicate that the battery is fully charged, and also tends to insure that the indicator of the meter is in harmony with the condition of the battery. Then, when the lamp current falls below one ampere, the lamp-current coil 24 permits the core 44 to drop, thereby opening the main switch, disconnecting the dynamo from the battery and lamps, and open-circuiting the underload relay R, which thereupon closes its contacts 46, de-energizing the engine ignition and stopping the engine. The reason for preferably separating the stop-charge contact 63 and full charge stop 67 by an interval determined by the constants of the system, is

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that the charging current tapers off markedly toward the end of the charge and considerable time is required for the indicator to move over this part of its travel. If the stop-charge contact 63 were at a point representing full charge, and the lamp load below one ampere, the engine would be kept running a long time with an insignificant current and consequently low efficiency. It is preferable to place this stop-charge contact 63 at a point representing about eighty to ninety per cent of full charge and to depend upon the exigencies of load conditions to run the engine long enough to effect a complete charge and occasionally a desirable overcharge of the battery; this will bring the indicator 2 up against the stop 67 and when the battery next goes on discharge the meter will be still in step with it. It will thus be seen that the engine is started at any time when the lamp current exceeds one ampere, and remains in operation as long as the lamp current remains above that value, and supplies current to the lamps and to the battery, and that with the lamp current less than one ampere, the engine is started automatically when the battery becomes sufficiently discharged, and is automatically stopped when the charging has progressed to a predetermined extent. It will be clear, moreover, that when the dynamo is at rest the lamps are supplied from the battery through a circuit including the low-voltage winding of the dynamo, which, however, offers at this time only an ohmic resistance to the passage of the current therethrough, since the armature is not rotating and the field is not energized; on the other hand, when the dynamo is in operation, the battery is charged at a constant voltage equal to the sum of the voltages across both of the dynamo armature windings, while the lamps are supplied from the high-voltage winding only, and at a constant voltage equal to the discharge voltage of the battery. In this way, the lamps receive practically the same voltage whether the battery is on charge or discharge, the battery receives on charge a constant impressed voltage in excess of its discharge voltage, and the ratio of charge to discharge voltages may be predetermined to meet the characteristics of the battery by properly proportioning the relative voltages of the two armature windings of the dynamo. Again, the regulator provided for the purpose of maintaining a definite voltage characteristic operates directly upon the fuel supply to the engine, thus avoiding the losses and complication incident to other types of regulation; and by suitable design of this regulator in combination with the drooping characteristic of the dynamo, the engine is caused to run at a higher speed at full load than at light load, thereby effecting an engine operation conducive to fuel economy, since at light load, when less fuel needs to be taken into the engine, a lower speed is advisable in order to reduce the amount of throttling needed, and to maintain a more nearly constant and economical mixture of fuel and air throughout the ranges of speed and load.

So much for the normal operation of the system. It happens occasionally that the dynamo will fail to start the engine, through engine trouble, or lack of fuel, or other causes. In such a case, the battery discharges rapidly, owing to the heavy current flowing through the dynamo, and this causes the meter indicator 2 to travel clockwise until it reaches the contact 71; this closes a circuit from the positive side of the battery, through the elements 19, 10, 20, 21, 2, contact 71, lead 72, coil 73 of the dynamo trip-switch 9, ground, and elements 25, 26, 27 and 28, to the negative side of the battery. This energizes the coil 73 which opens the trip-switch 9, thereby disconnecting the dynamo from the battery and lamps, and protecting the battery from further discharge through the dynamo. At the same time, an alarm circuit may be closed either by the closing of the circuit at 2, 71, or by the movement of the trip-switch 9 to its open-circuit position; the latter device is illustrated conventionally as comprising the bell 75, the contacts 76 adapted to be closed when the switch 9 is open and connections to battery and to ground; this bell would naturally be located within hearing distance of the operator, and would continue to ring, using a negligible amount of current from the battery, until the operator responds to the warning. An additional warning, inherent in the apparatus consists in the decreasing voltage and candle-power of the lamps as the rapid discharge of the battery causes its voltage to drop to a marked extent. It will be noted that this opening of the dynamo trip-switch 9 does not disconnect the lamps from the battery, so that the operator has the use of the lighting circuit for locating the trouble, and the work circuit is available for illumination and other purposes. If the battery discharges still further before the trouble is removed, the battery may be prevented from being permanently damaged, by another safety device, comprising the battery-trip contact 78, which is engaged by the meter indicator 2 when the latter has moved clockwise far enough to indicate a nearly-discharged condition of the battery. When the indicator reaches this contact 78, a circuit is closed from the positive side of the battery, through elements 19, 10, 20, 2, contact 78, lead 79, coil 80 of battery trip-switch 10, ground, and elements 25, 26, 27 and 28, to the negative side of the battery. This energizes the coil 80, which opens the battery trip-switch 10, thereby disconnecting the

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battery from the lamps and preventing any further discharge of the battery, except possibly the small current needed for the alarm circuit 75, 76 and for a trouble lamp 77 if these circuits are connected to the battery side of the switch 10. Contact 78 also serves as a mechanical stop to the meter movement.

As an emergency device the hand-controlled switch 91 is provided, which in connection with the leads 90 and 92 is arranged to short-circuit the main switch 6 and eliminate its use in connection with the system whenever it becomes inoperative for any reason or is removed for repairs. By the use of this emergency switch 91, it is possible to continue the operation of the system non-automatically whenever trouble develops in the control mechanism.

As a protective device to prevent the wide opening of the throttle V whenever the coil 59 of its connections should open-circuit for any reason, tending to cause the engine to run away, there is provided a system of contacts and connections 98, which render the engine ignition inoperative when the switch is de-energized, thus operating in a manner similar to the operation of the underload relay R and its contacts 46.

It is to be noted that the compounding of the regulator 4, depends to a certain extent upon the resistance of the battery. Thus, if the battery were large with practically zero resistance, the voltage characteristic of the regulator 4 would preferably be somewhat drooping, since the dynamo unit D operates in parallel with the battery unit B and electrical units in parallel will ordinarily not divide the load to the best advantage if their voltage characteristics are flat or rising. However, since in this case the resistance of the battery is of considerable magnitude, its characteristic is markedly drooping and the characteristic of the regulator may be made flat or somewhat rising and still not act to cause the unit D to assume an excessive load in charging the battery in addition to the load of the work circuit. It is understood that the current winding 52 of the regulator 4 may either aid or oppose the winding 59, the proportioning and relations of these windings depending upon the constants of the system. In respect to parallel operation, the division of load between the units D and B is somewhat analogous to the parallel operation of units DD and D.

Furthermore, means are provided for preventing excessive speed of the engine due to accidental dropping of the load while the engine throttle is open, without requiring the use of a speed limiting governor on the engine. This means is found in the underload relay R, which becomes de-energized if an open circuit occurs in the generator or generator mains, and renders the engine ignition ineffective, thereby stopping the engine. Without such means, an open circuit, as for example, between the brush 55 and commutator 56, would cause the dynamo to drop its load, and the armature winding 26 would then motorize from the battery through a circuit 10, 20, 21, 22, 24, 39, L, L, ground, 25, 26, 27 and 28; the resulting heavy ohmic drop in the battery would weaken the regulator coil 59, which would tend to open the engine throttle, and there would be danger of the engine running away unless a speed limiting device were provided. The underload relay R, however, automatically stops the engine in an emergency such as this, and the necessity for a speed limit device to protect the engine from this danger is obviated. Means for protecting the engine from over-speeding if the dynamo shunt field is accidentally rendered inoperative, is provided in the series connection between the regulator voltage coil 59 and the dynamo shunt field 58; if the shunt field is open-circuited, the regulator coil 59 will be completely de-energized, so that the plunger 13 will close the ignition contacts 98 and stop the engine; on the other hand, if the shunt field is short-circuited, the increased current in the regulator coil 59 will move the regulator core 13 to valve-closing position, in which case the fuel supply to the engine would be cut down: and as a matter of fact the regulator coil 59 would probably burn out, so that it would be completely de-energized, and then the regulator core 13 would close the ignition contacts 98 and stop the engine; so that in any event, the engine would be automatically protected from over-speeding without requiring the use of a speed limiting device.

The underload relay R serves to simplify the construction of the main switch 6 as compared with the main switch 6 of the Pardee application 92,421, above mentioned, since it is ordinarily desirable to have a main switch close its main contacts when the flux through its core attains a definite value, and the closing of the switch should take place at or practically at this predetermined value of the flux. To do this, the pull due to the flux should be balanced fairly accurately against the spring, or other counteracting force, so that a slight increase in the flux will cause the operation of the switch; however, if the switch in its open-circuiting position, is required to close tightly a set of auxiliary contacts, it is difficult to secure this nicely-balanced action for accurate closing of the main contacts and at the same time preserve a tight auxiliary contact until the moment of actually closing the main contacts. The present invention, by eliminating any auxiliary contacts on the main switch 6, thus simplifies materially the construction of the switch.

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In order to prevent the opening of the dynamo trip-switch 9 when the pointer is approaching the contact 71 in a counter-clockwise direction, the contact 71 is insulated on its side nearest the contact 78 so that the indicator slides by the contact 71 without making electrical contact with it when approaching it in a charging direction (counter-clockwise), but does make electrical contact when approaching in a discharging direction (clockwise), that is, when the battery is discharging.

The description thus far has been directed to a system utilizing a single engine. In certain instances, it is more economical to divide the power supply of the plant among two or more units, and to have one of these units of larger capacity than the other; for example, in a typical installation a lamp load of one ampere or less would be supplied by the battery alone; the ordinary load of, say, fifteen amperes, would be supplied by a small engine such as the engine E, driving the double-current dynamo D, at approximately its full-load rating; a maximum load, of, say, fifty amperes, would be carried by a larger engine EE and dynamo DD, running either alone or in parallel with the smaller unit E, D. This is conducive to efficiency of fuel consumption, because the units then operate at approximately full load, whereas an internal combustion engine running at low loads is relatively inefficient.

If a second engine EE and single-voltage dynamo DD are to be added to the plant above described, the switch 100 in the work circuit is opened, and to its terminals are connected the leads 103, 105 to the main switch 106 and thence to the dynamo DD. A preferred arrangement of parts is indicated in the drawings as comprising shunt and series windings 158, 154, the latter connected to the current coil 152 of the engine-regulator 104, thence to the dynamo-current coil 148 of the main switch 106, to the lead 103 above described. A manual switch 191 is provided in shunt to the main switch 106; and an underload relay RR is provided with contacts 146 so designed as to render the engine ignition inoperative when the dynamo current falls below a predetermined value. A voltage coil 159 on the regulator solenoid 113 is connected in series with the shunt field 158. The lamp current coil 124 of the main switch 106 is connected across the leads 103, 105, and carries lamp-current except when the manual short-circuiting switch 191 is closed; this switch 191 is used, however, only when the main switch 106 is out of order. In operation, when the lamp current exceeds fifteen amperes, the lamp-current coil 124 of the main switch is energized sufficiently to close the switch, whereupon current from the dynamo D flows through the dynamo DD to start the latter and after the engine EE has begun to rotate under its own power, the dynamo DD assists in carrying the load of the work circuit.

The division of load between the two machines depends to a certain extent upon the design and adjustment of the regulators 4 and 104. This adjustment may be arranged to cause the unit EE, DD to assume all of the load when first cut in and thus cause the main switch 6 to open and shut down the smaller unit D, E until such time as the lamp load exceeds the capacity of EE, DD and causes a current greater than one ampere to flow from the battery, when the main switch 6 closes and starts the unit D, E in the usual manner. Or the regulators 4 and 104 may be so adjusted that when both units are running the division of load is at all times proportioned to the capacities of the respective units. Whenever the lamp-current drops to a predetermined extent, below the assumed standard of fifteen amperes, the coils of the main switch 106 allow the switch 106 to open, thereby disconnecting the dynamo DD from the load, and leaving the circuits in the condition in which they were before the lamp load first exceeded the standard of fifteen amperes; that is, the small engine E remains in operation, driving the small dynamo D to supply the lamps and charge the battery B.

It is obvious that the different units previously described need not be of unequal size.

The engine E may be connected to drive a pump P, preferably provided with a diaphragm or other type of valve 99 arranged so that when the pressure on the valve falls below a predetermined minimum, the valve will close the contacts 70, causing the voltage coil 43 of the main switch 6 to be energized, thereby closing the contacts 45, and energizing the underload relay R, which thereupon opens the ignition contacts 46, to start the engine independently of the magnitude of the lamp load or the condition of the battery, thus providing a pressure-controlled pump-starting apparatus. The pump is preferably provided with suitable means (not shown), such as a by-pass valve, acting as an automatic unloading device to prevent excessive pressure.

As a modification, in the nature of a refinement and a simplification of the above system, the main switch 6 may be combined with the trip switch 9.

The underload relay R is preferably provided with a retarding device such as a dashpot *d*, to prevent the relay from closing the contacts 46 during the moment of reversal of dynamo current when the engine has been started and the dynamo begins to generate.

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The trip switches 9 and 10 may be provided with auxiliary contacts (not shown), arranged to open the circuit of their respective windings, when the switches are tripped. These contacts relieve the meter contacts 71 and 78 of the duty of breaking an inductive circuit.

In Figure 2 there is illustrated a modified construction differing from Figure 1 primarily in the relay 7, which in Figure 2 is numbered 207. In the modification the relay 207 comprises an operating coil 233 whose core 234 is mechanically connected to the movable contactors 269 and 274 adapted to co-operate respectively with the relatively fixed contactors 268 and 277. The meter contact 263, which corresponds to a substantially full-charge condition of the battery is connected by the lead 264 to the right-hand movable contactor 274. The start-charge meter contact 230 is connected by the lead 231 to the left-hand fixed contactor 268 and to the negative side of the relay coil 233, whose positive terminal is connected, first, through the lead 241 to the voltage coil 243 of the main-switch 206; second, through the lead 261 to the right-hand fixed contactor 277 of the relay 207; and third, to one of the pump-controlled contacts 270, the other of these contacts being grounded.

The operation of the modification illustrated in Figure 2 follows the description above given for Figure 1, save for certain differences which may be briefly enumerated. Assume that the voltage coil 243 is de-energized and that the contacts 245 of the main switch 206 are open. If now a lamp-load of say less than one ampere is turned on in the work-circuit, the battery discharges slowly until the meter pointer 202 travels clockwise to the start-charge contact 230. Current will then flow from the positive pole of the battery, through the lead 222, voltage coil 243, lead 241, relay coil 233, lead 231, start-charge contact 230, meter pointer 202, to ground, and thence (referring now to Figure 1) through the intermediate terminal 25 of the dynamo D, armature winding 26, negative terminal 27, and lead 28, to the negative pole of the battery. This energizes both the relay coil 233 and the main-switch voltage-coil 243.

The energizing of the relay coil 233 closes first the right-hand contactors 274, 277, and later closes the left-hand contactors 268, 269. No circuit changes are effected at this time by the closing of the right-hand contactors 274, 277, because the circuit in which said contactors are located is open at the stop-charge meter contact 263. The closing of the left-hand relay contactors 268, 269, short-circuits the start-charge meter contact 230 and electrically locks the relay 207 in its closed position, by connecting the negative terminal of the relay coil 233 directly to ground.

The energizing of the main-switch voltage-coil 243 closes the main-switch contacts 245, and serves to start the engine as above described in connection with Figure 1. The consequent charging of the battery causes the meter pointer 202 to travel counter-clockwise toward the stop-charge contact 263. As the pointer 202 leaves the start-charge contact 230, there is no arcing, because this contact has been short-circuited at 268, 269, as above described.

When the meter pointer 202 reaches the stop-charge contact 263, the relay coil 233 is short-circuited through the lead 261, right-hand relay contactors 277, 274, lead 264, contact 263, meter pointer 202, to ground. The relay 7 on being thus de-energized by the short-circuiting of its operating coil 233 releases its core 234, which then returns to its initial position through the influence of a spring 235 or gravity, first breaking the left-hand contacts 268, 269, and later breaking the right-hand contacts 274, 277. The latter break opens the circuit including the main-switch voltage-coil 243, and thus causes the main switch 206 to open, and shut down the engine, unless the lamp current through the main-switch current-coil 224 is sufficient to hold the main-switch contacts 245 closed, as previously described in connection with Figure 1.

It will be noted that during the opening of the relay contacts, the initial break of the circuit including the main-switch voltage-coil 243 occurs at the right-hand relay contacts 274, 277; these contacts may be bridged by a condenser 251, if desired, in order to prevent any objectionable arcing. There is no arcing when the meter pointer 202 leaves the contacts 230 or 263, because in neither instance is there any current flowing through the meter pointer at the time the pointer leaves the contact. The relay 207 may be a small and compact device of simple construction, and the parts therefor may be readily obtained on the market at nominal cost; at no time is there a heavy current passing through any portion of the relay mechanism. In case the meter 201 is removed, as for inspection or repair, the relay 207 may be operated manually to start and stop the charging of the battery at the proper times. In general, the various parts of the apparatus illustrated in Figure 2 are assigned reference numerals two hundred higher than the reference numerals for the corresponding parts in Figure 1. Bearing this in mind, it is believed that the operation of the apparatus of Figure 2 will be clear from the foregoing, without further elaboration.

From the above, it will be seen that the

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several objects of the invention are achieved, and other advantageous results attained.

As various changes might be made in the above construction, and as the above invention might be embodied in different forms, it is intended that all matter set forth in the above description and in the accompanying drawings, shall be interpreted as illustrative and not in a limiting sense.

Having thus revealed my invention, I desire to claim as new and secure by Letters Patent of the United States:

1. An electrical system combining a dynamo adapted to run as a motor to start an engine and to be run as a generator by the engine, a battery, a switch connecting the dynamo to the battery, and a current relay in the dynamo circuit adapted to stop the engine when the dynamo current falls below a predetermined value, said relay being provided with a retarding device to prevent the operation of the relay at the moment of reversal of dynamo current when the engine has been started and the dynamo begins to generate.

2. An electrical system combining a battery; a dynamo provided with shunt and series field windings; an engine coupled to the dynamo; a valve in the fuel supply to the engine; a work circuit; a main switch adapted when closed to connect the dynamo to the battery and work circuit; a relay adapted to render inoperative the ignition of the engine to stop the engine when the dynamo current falls below a predetermined value; a meter provided with an indicator for indicating the state of charge of the battery; means controlled by the indicator for closing the main switch to energize the dynamo to start the engine when the battery is sufficiently discharged, means controlled by the indicator for disconnecting the dynamo from the battery and work circuit and for operating an alarm when the battery is further discharged as by failure of the dynamo to start the engine, means operated by the indicator for disconnecting the battery from the work circuit when the battery is still further discharged; a regulator provided with a work-circuit-voltage coil in series with the dynamo shunt field and adapted to move the valve to regulate the fuel supply to the engine to maintain constant the voltage at the work circuit, and provided with a dynamo-current coil opposing the voltage coil to set a different standard of voltage at high loads than at low loads; a pump driven by the engine; and pump-pressure-controlled means for closing the main switch to start the engine when the pressure of fluid delivered by the pump attains a predetermined value.

3. An electrical system combining a dynamo adapted to run as a motor to start an engine and to be run as a generator by the engine, a battery, a relay responsive to dynamo current adapted to stop the engine when the dynamo current falls below a predetermined value, said relay being provided with a retarding device.

4. An electrical system combining a dynamo adapted to run as a motor to start an engine and to be run as a generator by the engine, a battery, a relay responsive to dynamo current adapted to stop the engine when the dynamo current falls below a predetermined value, said relay being provided with a retarding device, to prevent operation of the relay immediately upon the dropping of said current to zero.

5. An electrical system combining a dynamo adapted to run as a motor to start an engine and to be run as a generator by the engine, a battery, a relay responsive to dynamo current adapted to stop the engine when the dynamo current falls below a predetermined value, said relay being provided with a retarding device, a pump driven by the engine, and pump-pressure-controlled means for starting the engine when the pressure of fluid delivered by the pump attains a predetermined value.

In witness whereof, I hereunto subscribe my name, as attested by the two subscribing witnesses.

LINDSAY H. MILLER.

Witnesses:
M. HAVLICK,
JOSEPH BURKE.