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POWER SUPPLY SYSTEM

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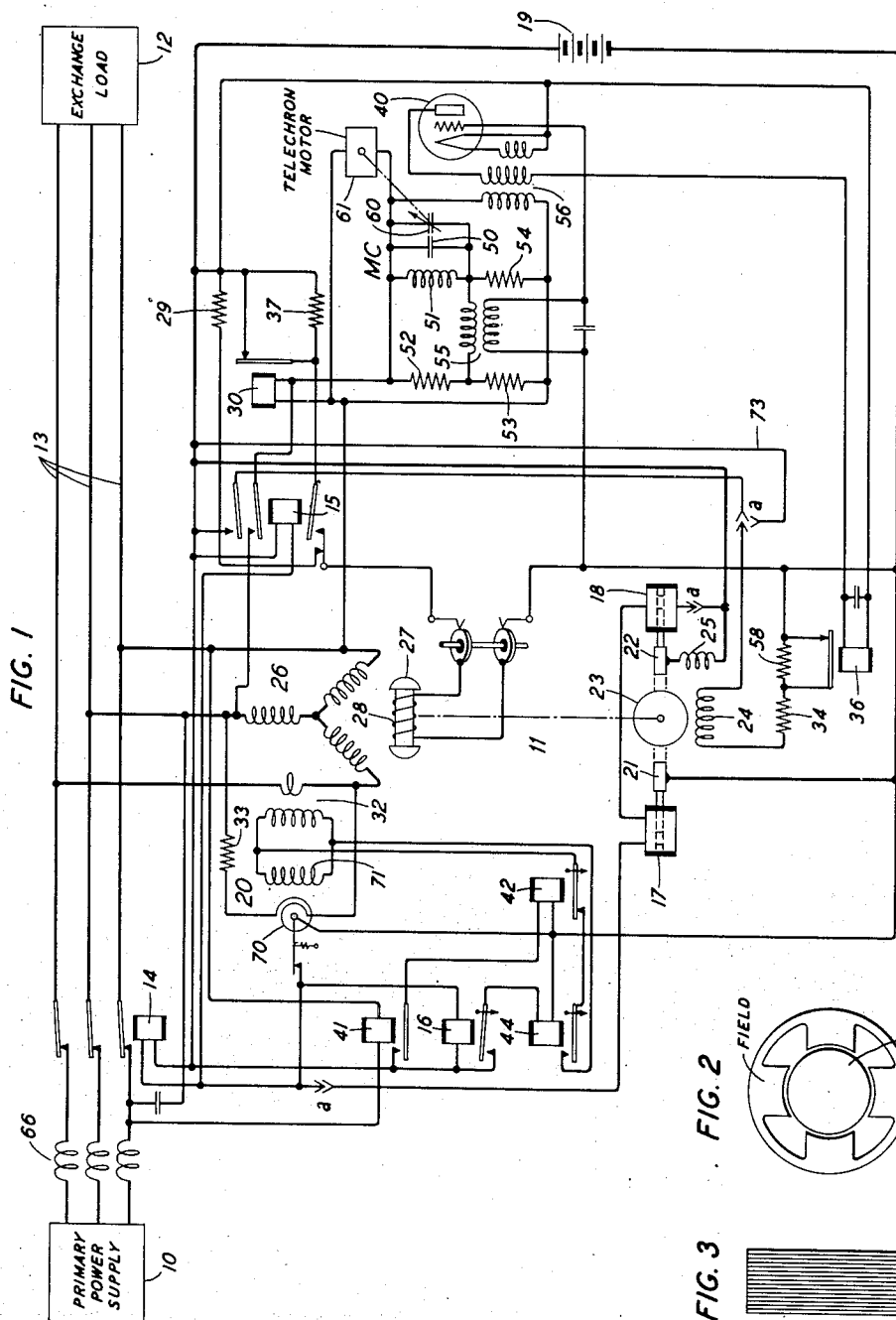


FIG. 3

FIG. 2

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## POWER SUPPLY SYSTEM

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This invention relates to power supply systems and particularly to an alternating current power supply system which involves primary and reserve sources of power.

It is common practice in power supply systems to supplement the normal, or primary source of power with an auxiliary, or standby source of power, and to provide means for transferring the load from the primary source to the standby source, either manually or automatically, when the primary source fails. In general, the changeover from primary power to standby power is effected through the medium of a switching device. Such a switching operation, whether performed manually or automatically, introduces a momentary opening of the load circuit and a consequent interruption of power thereto which manifests itself in the load by fluctuations in lamp signals, untimely release of switching instrumentalities and in numerous other ways. In many instances such power interruptions are permissible or, at least, can be tolerated. However, in other applications, the slightest interruption of power to the load cannot be tolerated and an absolute continuity of power is required.

One particular application in which the continuity of power under all conditions is an essential requirement is that of the telephone exchange. It is obvious, for example, that should a slight interruption of power, resulting from a failure of the primary source of power, occur in the telephone exchange, the communication facilities provided thereby would be disrupted and a condition of confusion would ensue. Such a power interruption, for example, would be interpreted as a disconnect signal on established telephone connections with the resulting untimely interruptions of incompleted telephone communications and a general breakdown of telephone service. Such a contingency is met in the telephone exchange today by the use of storage batteries which float on the line and are, therefore, at all time available to carry the load when the primary source of power fails, and since no switching operation is required, the supply of power to the load is continuous and uninterrupted telephone service is assured. While this method of supplying power to the telephone exchange is adequate to supply present normal requirements of existing telephone equipment, it imposes some restrictions on engineering progress in systems and apparatus design. For example, it necessitates the design of a major portion of the telephone equipment to be predicated on a direct current basis. A considerable portion of

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the apparatus and circuits could be advantageously designed for alternating current operation if the continuity of alternating current power could be assured.

It is the object of this invention to provide a power supply system which insures absolute continuity of power to an alternating current load circuit under conditions which necessitate a changeover from primary to reserve, or standby, power sources.

This object is attained in accordance with a feature of the invention by utilizing as the reserve, or standby, power source, a motor-generator set and a storage battery. The motor-generator set consists of an alternating current component, or generator, and a direct current component, or motor. The alternating current generator is connected to the line over which power is supplied to the load so that, under normal conditions of the primary power source, it derives power therefrom and drives the direct current motor whose armature and field winding are normally open circuited. Thus, the motor-generator set floats on the line as an idle motor and normally operates on motor action of the generator. Upon the occurrence of an abnormal condition of the primary source, such as a failure or short circuit, the alternator instantly becomes a generator driven for the first few seconds by the mechanically stored energy of the rotating members. Within a second the armature and field windings of the direct current motor are connected to the storage battery in a manner which permits the direct current motor to quickly develop full torque and drive the alternating current generator, causing it to supply power to the load. Thus, the storage battery becomes the source of power and drives the motor-generator set to furnish alternating current power to the load and the load experiences no power interruption whatsoever.

Another feature of the invention resides in the use of a compound wound motor as the direct current component of the motor-generator set having a low inductance series field therefor which insures a rapid build-up of current in the motor and consequently the substantially instantaneous attainment of maximum torque by the motor.

A further feature of the invention resides in the use of choke coils in the supply line from the primary source of power which function to limit the flow of reverse current back into the power mains in the event the power mains are short-circuited, thereby insuring an adequate portion of the generator output being fed to the load

under short-circuit condition of the power mains.

A still further feature of the invention resides in the combination of a fast acting relay control circuit and in the use of a laminated field, as well as armature, structure in the direct current component of the motor-generator set. The completely laminated magnetic circuit avoids induced secondary currents and permits the flux to build up quickly with the current through the series field. The motor torque, therefore, also is instantly proportional to the current and insures a substantially instantaneous assumption of the load by the direct current motor upon the occurrence of an abnormal condition of the primary power supply.

Still another feature of the invention contemplates the modulation of the frequency of the output of the alternating current generator for purposes of resynchronization.

A further feature of the invention utilizes the mechanically stored energy of the rotating mass of the motor-generator set to sustain power for the short interval between the occurrence of a power failure and the assumption of the load by the direct current component of the motor-generator set.

These and other features of the invention will be readily understood from the following description when read in connection with the accompanying drawings, in which:

Fig. 1 is a circuit diagram illustrating a continuous alternating current power supply system embodying the features of this invention; and

Figs. 2 and 3 show, respectively, front and side views of the magnetic circuit of the direct current element of the motor-generator set.

Before entering into a detailed description of the operation of the system disclosed in the drawing, a brief descriptive reference to the more pertinent elements of the system will be made.

The motor-generator is designated by the numeral 11 in the drawing and may be, in general, of any well-known design. Preferably, this set is a two-bearing, 1800 revolutions per minute set with ring-oiled sleeve bearings. This type of flood lubrication permits continuous rotation with negligible bearing wear. The alternating current component of the set is provided with a three-phase stator, the windings of which are indicated at 26, and a direct current excited field member for the rotor, such as schematically indicated at 27. The field winding is shown at 28. The alternating current component of the set is designed for somewhat lower than normal flux density in the iron and low current density in the field copper in order to minimize floating power losses. The direct current component 23, when not in use, will operate with its brushes 21 and 22 held off the commutator by brush magnets 17 and 18, respectively, thereby avoiding commutator wear. The field windings 24 and 25 of the direct current component of the set are open-circuited, thereby avoiding standby power losses under normal conditions. The field structure, as well as the armature, is of laminated construction to permit rapid flux build-up.

If desirable, a fly-wheel may be added to the motor-generator set to increase its mechanically stored energy.

The system of relays and the voltage and speed control mechanisms about to be described are designed to instantly convert the motor-generator set, which normally floats on the line 13 as an idle motor, from motor to generator action so as to deliver power to the exchange load 12 if

the outside, or primary, power source 10 fails either by open circuit interruption or short circuit which would cause a reversal of power flow. The direct current component 23 of the set is brought into action receiving its primary power from the exchange battery 19 and the alternating current component of the set delivers a regulated voltage at a regulated frequency for the duration of the outside power failure. Upon restoration of the power supply, the relay system automatically resynchronizes the alternating current component of the set with the primary power supply and closes the main line switch, restoring the system to its initial condition.

The main line switch, schematically shown at 14, is a three-pole contactor of suitable rating provided with a direct current excited magnet.

Relay 20 is a mechanically biased reverse power relay which operates on generator action and releases on motor action of the alternating current component of the motor-generator set. Though schematically illustrated, relay 20 preferably is a fast acting and fast releasing relay of the watt-meter type with a moving potential coil 70 and a fixed current coil 71 and provided with back contacts. The in-phase component of current through the current transformer 32 is applied to the winding 71 of relay 20. The winding 70 of relay 20 is connected through resistance 33 across the line.

At 30 is indicated an alternating current voltage regulator, which may be of any well-known type, for controlling the current in the field winding 28 of the alternating current component of the motor-generator set. The speed regulator MC of the direct current component 23 of the motor-generator set has a frequency bridge as the primary controlling element which, through a phase detector tube 40, controls regulator relay 36 which, in turn, controls the shunt field 24 of the direct current component.

Reference to further individual elements of the system disclosed need not be made at this time, since such elements and their functions in the system will be readily understood from the following description of the operation of the system.

All relays are fast operating, but relays 16, 42 and 44 are slow releasing, as indicated by the small arrows through the armatures thereof.

When the system is operating normally, that is, when the load 12 is being supplied with power from the primary source 10 by way of the line 13, the switch 14, the relays 15 and 16, and the brush magnets 17 and 18 are energized, all being connected in parallel across battery 19 by way of the back contact and armature of relay 20, which relay, as hereinbefore mentioned, is a reverse current relay which operates on generator action of the alternating current component of the motor-generator set 11. Also the stator windings 26 of this component of the set are permanently connected to the line 13 on the load side of the switch 14. The direct current field winding 28 of this component is also normally connected across the battery 19 in series with a fixed resistance 29. The direct current component of the motor-generator set 11, as hereinbefore indicated, is open-circuited. Thus, the alternating current component of the set functions as an idling motor on the line 13 and, through the indicated mechanical coupling, drives the direct current component 23. Therefore, during normal conditions, the alternating current component of the motor-generator set is constantly functioning under motor action. As hereinbefore stated, relay 20 op-

erates only on generator action of the alternating current component of the set so that, normally, relay 20 is unoperated.

It will now be assumed that the primary source of power 10 fails so that power is no longer supplied to the stator windings 26 of the alternating current component of the set 11 from the source 10. The mechanically stored energy in the rotating mass of the motor-generator set maintains rotation so that the normal counter electromotive force of the alternating current component is maintained and the failure of the primary alternating current power source instantly causes a reversal of power flow and generator action commences causing relay 20 to operate. Relay 20, being fast operating, instantaneously opens its back contact, thereby opening the energizing circuits for relays 15 and 16, switch 14 and brush magnets 17 and 18. These instrumentalities accordingly are deenergized.

Relay 15, at its outer upper armature and back contact, connects the shunt field winding 24 of motor 23 in series with resistance 34 and the armature and back contact of regulator relay 36 across battery 19. At its inner upper armature and back contact, relay 15 connects the voltage regulator 30 and speed control circuit MC across the generator output. At its lower armature and associated make-before-break contacts, relay 15 substitutes regulator resistance 37 for resistance 29 in the field circuit 28 of the generator.

Switch 14, in releasing, disconnects the load 12 from the primary power source 10.

Brush magnets 17 and 18, in releasing, cause the brushes 21 and 22 to engage the commutator of motor 23 and to simultaneously complete the connection of series field 25 to battery 19. The build-up of current in motor 23 is rapid due to the low inductance of the series field and armature. With a laminated field circuit the flux build-up is equally rapid. The motor 23, therefore, substantially instantaneously with the occurrence of the power failure assumes the load, deriving its power from battery 19. The motor 23 drives the alternating current component of the set 11 as a generator, causing it to supply power to the load 12 over the line 13. The full assumption of the load by motor 23 occurs within about a second of the failure of the source 10 and the mechanically stored energy in the rotating mass of the motor-generator set sustains generator action until the motor takes up the load. Obviously, therefore, the flow of power to the load 12 is absolutely continuous and the transition from normal to reserve power is not accompanied by any interruption whatsoever in the supply of power to the load.

Upon opening of switch 14, the winding of relay 41 is energized by the sum of the voltages of one phase of the generator and one phase of the power supply. The armature and front contact of relay 41 completes the connection of relay 42 to the battery 19. The operation of relay 42 precludes the completion of a shunting circuit for the winding 71 of relay 20, thereby insuring the continued operation of relay 20 on generator current. When slow-releasing relay 16 releases its armature, the winding of relay 44 is connected across the battery 19 causing the operation of this relay. The circuit is thus prepared for reclosing upon the resumption of the power source 10.

It will now be assumed that the primary power source 10 is restored. It will be observed that the winding of relay 41 is connected across one

pole of switch 14 so that it is subject to frequency beats between the primary source 10 and the alternating current component of the set 11. As will be explained later, the frequency of the latter is modulated slightly by the control circuit so that sooner or later it will become equal and opposite in phase to that of the supply 10. When the two voltages become sufficiently equal, relay 41 will stop beating and if the release intervals are sufficiently long, slow-releasing relay 42 will release and close its back contact which short-circuits the current coil 71 of relay 20. Relay 20 then releases, closing the energizing circuit for main line switch 14, and operating relays 15 and 16 and brush magnets 17 and 18. The operation of relay 15 disconnects the voltage and speed regulators, and magnets 21 and 22 open the motor circuit. After a time lag, relay 44 releases restoring the system to its initial condition.

During the time that the standby power source supplies the load 12, the output voltage of the generator is regulated by means of the regulator 30 which may be of any well-known design. As previously described, the field winding 28 is normally connected to the battery 19 in series with the fixed resistor 29, and when relay 15 released this resistor was replaced by the resistance 37. The regulator 30 follows the fluctuations in voltage of the generator to automatically include in, or exclude from, the field circuit the resistance 29, thereby maintaining the output voltage constant.

The speed control circuit MC comprises essentially a Wheatstone bridge which includes a resonant circuit consisting of a condenser 50 and an inductance coil 51 connected in parallel in one arm, and resistances 52, 53 and 54 connected in the other arms. One set of the bridge terminals is connected across the alternating current generator output by way of the back contact and inner upper armature of relay 15 and the other set of opposite terminals of the bridge is connected to the primary of transformer 55, the secondary winding of which is connected to the input of a three-electrode electric discharge device 40, the output of which is connected through a transformer 56 to the winding of regulator relay 36. The transformer 56 also has one winding connected across the input terminals of the bridge and, therefore, across the output of the alternating current generator component of the motor-generator set 11. The theory of operation of this bridge circuit will now be described in general terms. The speed control circuit functions to control the speed of the direct current motor 23. The alternating current component of the motor-generator set is driven by the motor 23 and a frequency wave proportional to the speed of the motor is obtained therefrom and applied to the input set of terminals of the Wheatstone bridge circuit, one arm of which, as above described, is composed of a resonant circuit which is tuned to the frequency of the wave generated when the motor 23 is running at normal speed. The voltage at these terminals of the bridge is applied to the input circuit of tube 40 by way of transformer 55, which tube obtains its space current directly from the alternating current generator so that the amplitude of the output current will be determined by the phase and magnitude of the output produced by the bridge circuit. When the frequency of the wave supplied to the bridge lies at one side of the frequency at which the bridge is balanced, the two voltages supplied to the discharge device will

oppose each other, and when it lies on the other side of this frequency the two voltages will aid each other, so that there will be an abrupt and substantial variation in the value of the output current as the frequency of the wave passes through this point. The output current is supplied to the winding of the regulator relay 36 which functions to include in, or exclude from, the field winding 24 the regulating resistance 58 to hold the motor speed at the value at which the frequency of the generated wave is the frequency at which the bridge is balanced. The theory and operation of this speed control circuit are set forth in greater detail in my Patent 1,695,035 of December 11, 1935.

A supplementary condenser 60 is included in the tuned circuit of the speed control bridge circuit and is driven by a small telechron motor 61 through a large gear reduction (not shown) at a slow rate and modulates the frequency of the tuned circuit over a range corresponding to the maximum frequency variation of the primary power supply 10. Thus, the frequency of the standby generator will sooner or later become equal in magnitude and phase to the primary source 10 and thus prepare the circuit for resynchronization.

The foregoing description has been directed chiefly to the functioning of the system in the event of an open circuit failure of the primary power source 10. It is to be understood that the system also functions in the same manner in the event of a short-circuit on the power mains of the primary source. To limit the flow of reverse current back into the power mains in such a case, the choke coils 66 are provided in each of the supply leads.

In case the power supply fails, due to low voltage, a low voltage release relay (not shown) will open the power supply 10 and the system will function as first described.

The system has been described as applied to one phase of the power source 10. It is obvious that a duplicate system could be applied to another phase or phase interlocking means provided as is well known in the art.

It is apparent from the foregoing descriptions that the system of this invention insures an absolutely continuous supply of power to the load at all times and that the failure of the primary source of power, or the occurrence of an abnormal condition therein is not reflected to any objectionable degree in the load circuit. The only effect on the load circuit will be a small momentary drop in frequency for less than a second until the direct current motor takes up the load. Even during this interval the voltage regulator of the alternator will maintain voltage.

In the drawing, the conductors leading to the brush magnets 17 and 18 of the direct current unit of the motor-generator set include two small arrow heads *a*, as does also the conductor which connects the shunt field 24 of the direct current motor to the outer upper armature of relay 15, and the conductor 73 is shown connected directly to one terminal of the battery 19 and terminating in a small arrow head. These conventions are used to indicate an alternative circuit arrangement. In large telephone central offices there are usually a plurality of motor-generator sets used for battery charging. If desirable, one of these sets may be maintained continuously in operation with the exchange battery across it under charge or floating, and employed also as the reserve source of alternating current

power. In such a case the commutator brushes 21 and 22 would be in continuous engagement with the commutator of the direct current motor 23 and the armature, series field 25 and shunt field 24 would be permanently connected to the battery 19, so that during the normal operation of the motor-generator set, that is, under normal condition of the primary power source 10, the direct current component of the motor-generator set would function as a charging generator. The alternative circuit connections indicated at *a* in the drawing, illustrate how the disclosed circuit arrangement would be modified to provide for this method of operation. In the indicated modification, the brush magnets 17 and 18 are omitted; the brushes 21 and 22 constantly engage the motor commutator; the shunt field 24 is directly connected to the battery 19 by way of conductor 73; and the outer upper armature and back contact of relay 15 is omitted, or performs no circuit function.

While the system of this invention has numerous applications, its use in the telephone plant would result in many advantages. For example, with the present form of power supply in the telephone plant, the telephone circuit designer is limited to 24, 48 and 130 volts battery supply, all grounded at the plus or minus end. If the system of this invention was utilized, a transformer could supply any number of voltages grounded or ungrounded and with adequate, if not better, voltage regulation. It would then also be a simple matter with copper-oxide or similar type rectifiers to furnish a variety of direct current voltages, in large or small units as desired, grounded or ungrounded. Further, small alternating current motors are more reliable and cheaper than direct current motors which require commutators. Synchronous motors can be used for timing operations, slow acting relays, etc. Also, the circuits for vacuum tube apparatus are generally simpler if the designer has access to alternating current power. It is apparent, therefore, that the advantages of alternating current in the telephone plant are many, and such advantages could be fully realized only by the availability of a reliable and absolutely continuous alternating current power source. The system of the present invention provides such a source.

What is claimed is:

1. A system for supplying uninterrupted alternating current power to an alternating current load comprising, in combination, a primary source of alternating current power, a load, a switch normally interconnecting said load and said primary source of power, an alternating current generator having its armature windings permanently connected to said load between said switch and said load so as to cause said generator to operate on motor action on power from said source and to instantaneously develop generator action incident to the occurrence of an abnormal condition of said primary source of power, a storage battery, a normally open-circuited direct current shunt field motor having an auxiliary low inductance series field, said motor being mechanically coupled to said generator so as to be driven thereby during motor action thereof, means responsive to generator action of said generator for releasing said switch and for connecting the armature and field windings of said direct current motor to said battery, whereupon the series field of said motor experiences a quick build-up of current and said motor quickly develops maximum torque as a motor and drives said gen-

erator to sustain the generator action thereof, means effective incident to a clearing of the abnormal condition of said primary source for synchronizing the alternating current generator output with that of said primary source of power, and means for reoperating said switch when a condition of synchronization is reached.

2. In a power supply system, a primary source of alternating current having a predetermined maximum frequency variation, a load, a line including a switch normally connecting said load to said source, a reserve source of power including an alternating current machine permanently connected to said line on the load side of said switch and normally operating as a motor on power from said primary source, means for driving said alternating current machine as a generator, means responsive to a failure of said primary source for causing said driving means to operate and drive said alternating current machine and for operating said switch to disconnect said primary source from said load, means including a tuned circuit in the output of said alternating current machine when operating as a generator for regulating the speed of said driving means, means for modulating the frequency of said tuned circuit over a range corresponding to the maximum frequency variation of said primary source whereby the frequency of said alternating current generator approaches that of said primary source, and means effective upon a resumption of power by said primary source for recognizing a condition of synchronization between the frequencies of said generator and said primary source and for reoperating said switch when said condition is attained to reconnect said load to said primary source.

3. A system for supplying uninterrupted alternating current power to an alternating current load in accordance with claim 1, and in which said direct current motor is provided with a laminated magnetic structure.

4. A system for supplying uninterrupted alternating current power to an alternating current load comprising a primary source of alternating current, switch means normally connecting said primary source to said load, a secondary source of alternating current comprising an alternating current generator permanently connected to said load on the load side of said switch whereby said generator functions as a motor on power from said primary source when said switch means is in its operated condition, a storage battery, a direct current generator mechanically coupled to said alternating current generator, means responsive to a reversal of power in said alternating current generator incident to an interruption of power from said primary source for releasing said switch

means whereupon said direct current motor operates on power from said battery to drive said alternating current generator and said alternating current generator supplies power to said load, and means effective incident to a resumption of power from said primary source for synchronizing the output frequency of the alternating current generator with that of the primary source, and means responsive to the attainment of a condition of synchronization between the frequencies of said alternating current generator and said primary source for reoperating said switch means.

5. In a system for supplying uninterrupted alternating current power to an alternating current load comprising an alternating current power line, switch means normally connecting said power line to said load, an alternating current generator connected to said load on the load side of said switch means so as to operate as a motor on power from said line and adapted to experience a power reversal therein upon the occurrence of an abnormal condition on said line and the consequent release of said switch means, a normally open-circuited direct current motor coupled to said generator, a storage battery, means including the mechanical energy stored in the rotating masses of said generator and motor for sustaining the power reversal incident to the occurrence of an abnormal condition on said line, means responsive to a power reversal in said generator for connecting said direct current motor to said battery whereby said direct current motor operates on power from said battery to drive said alternating current generator and said generator supplies power to said load, and means effective incident to the correction of the abnormal condition on said power line and responsive jointly to the output of said power line and of said generator for reoperating said switch means only when the power line and generator frequencies are in synchronism.

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