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Dixon et al.

[11] **3,723,750**

[45] **Mar. 27, 1973**

[54] **MARINE ENGINEROOM MONITOR AND CONTROL SYSTEM**

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[52] **U.S. Cl.** **307/64,** 307/84

[51] **Int. Cl.** **H02j 9/00**

[58] **Field of Search**..........307/64, 65, 66, 85, 86, 87, 307/43, 84, 57, 52

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Primary Examiner—Herman J. Hohauser
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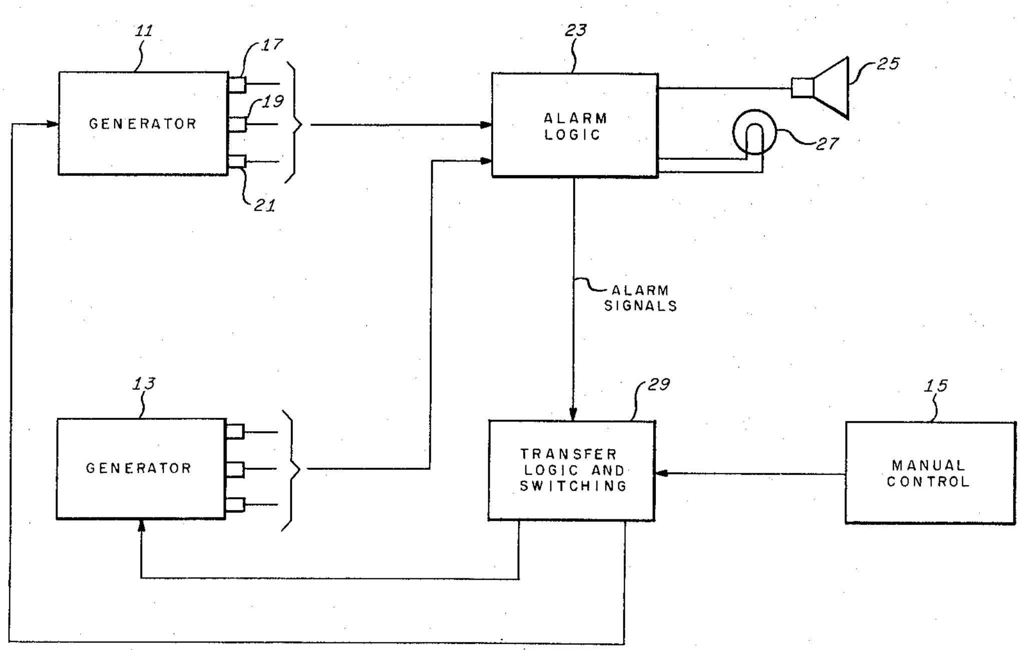
[57] **ABSTRACT**

A monitor and control system for a ship's electrical power supply of the type having a standby generator. The system includes a variety of threshold detector sensing means responsive to various conditions relating to the operation of the generator. Upon the occurrence of a malfunction, the threshold detectors provide digital signals to an alarm logic circuit which actuates an audible alarm and enables a gating means so as to pass a pulse train to a lighting circuit and thereby provide a flashing visual alarm. The alarm logic circuit also contains acknowledge means operable by a member of the sbip's crew. Operation of the acknowledge means switches a flip-flop so as to silence the audible alarm and maintain the visual alarm in a constantly illuminated condition. Correction of a malfunction returns the corresponding threshold detector to its normal condition, resets the alarm logic circuit and extinguishes the visual alarm. The system further contains an automatic transfer logic circuit which responds to the threshold detectors so as to remove the operating generator from the line when a malfunction occurs, determines if the standby generator is operative, and connects the standby generator across the line when its voltage and frequency have reached acceptable levels.

8 Claims, 3 Drawing Figures



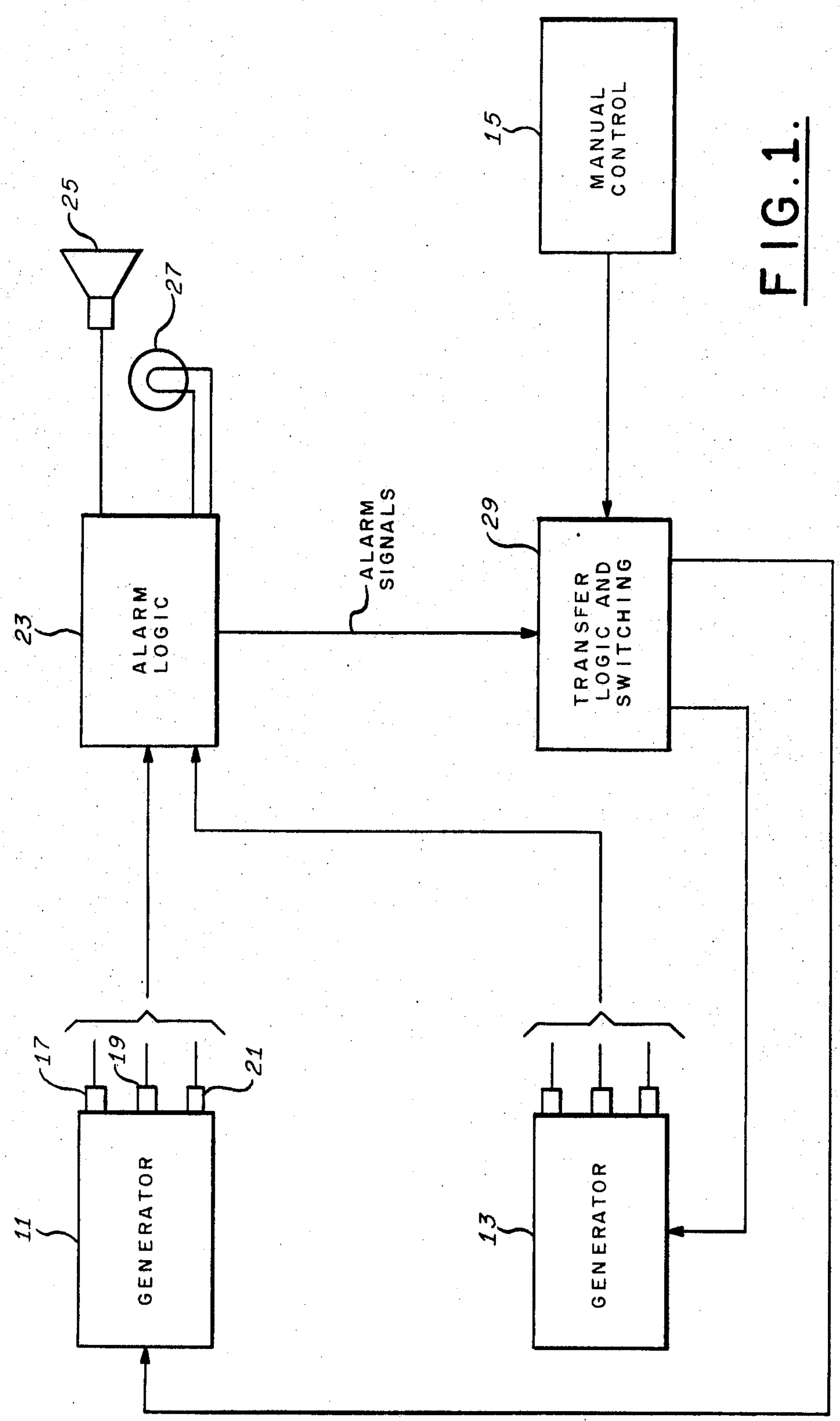

MANUAL CONTROL
15
25
27
ALARM LOGIC
23
ALARM SIGNALS
TRANSFER LOGIC AND SWITCHING
29
17
19
21
GENERATOR
11
GENERATOR
13

FIG. 1.

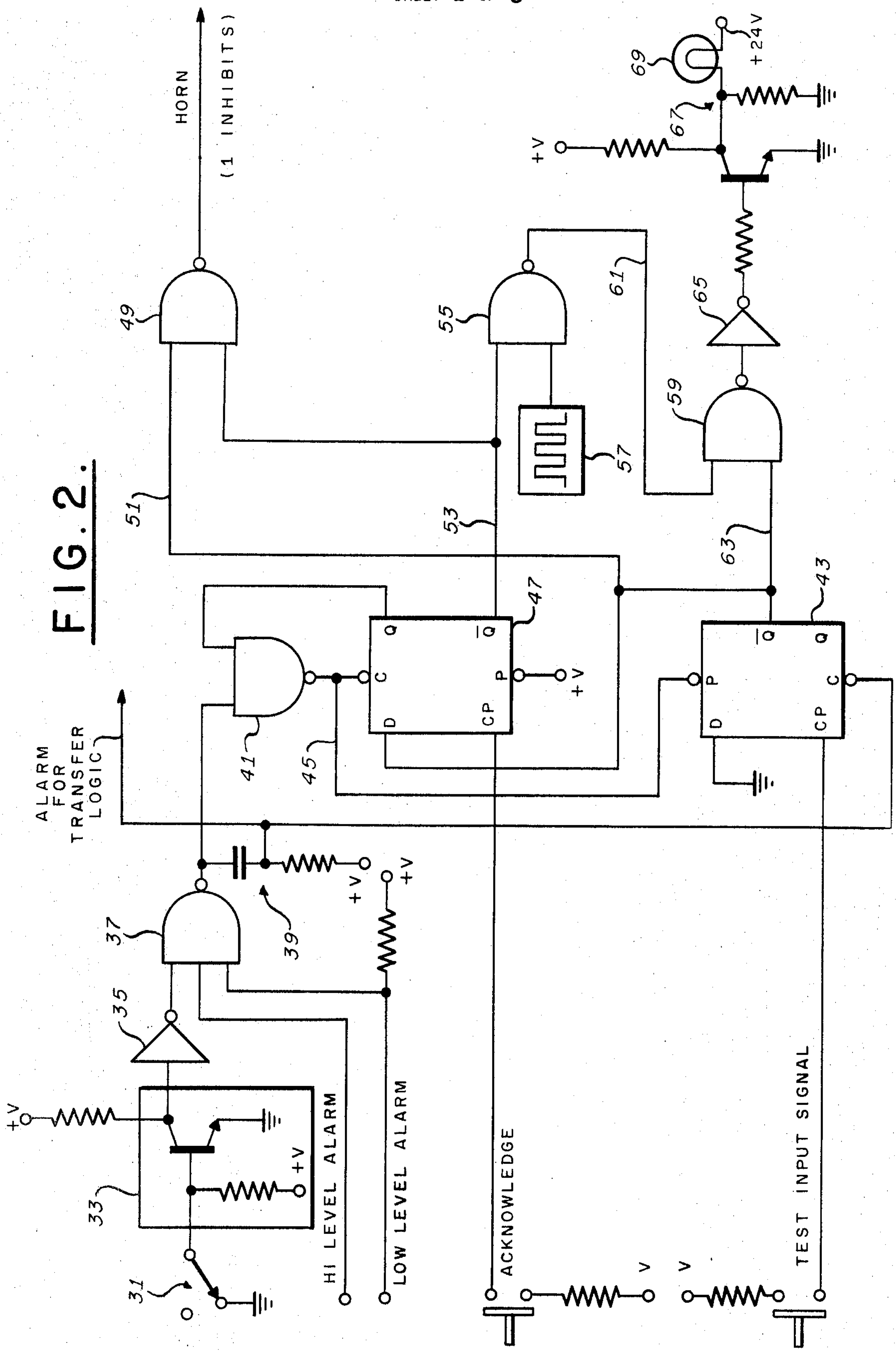

HORN
(1 INHIBITS)
ALARM FOR TRANSFER LOGIC
HI LEVEL ALARM
LOW LEVEL ALARM
ACKNOWLEDGE
TEST INPUT SIGNAL
+24V

FIG. 2.

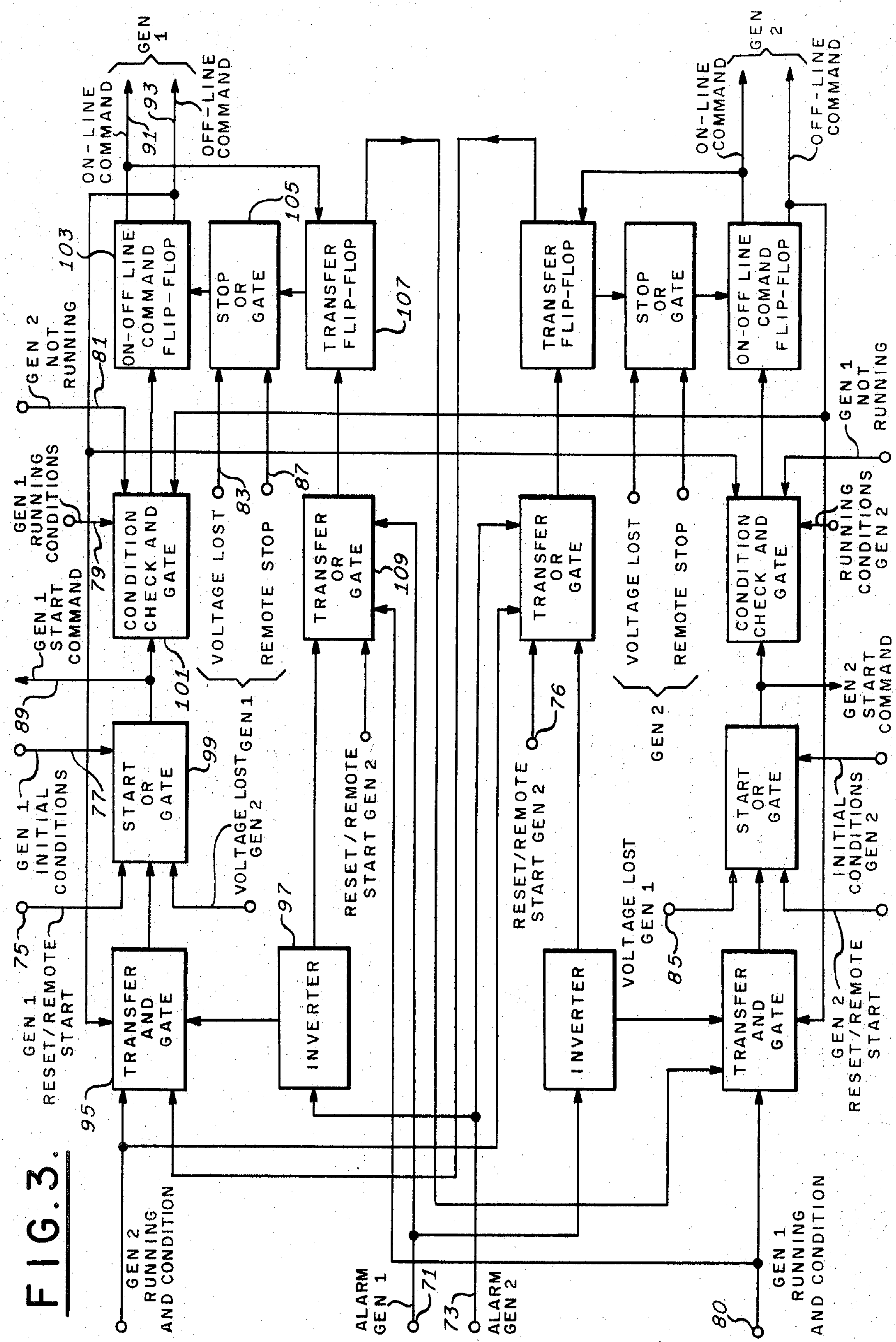

GEN 1
ON-LINE COMMAND
OFF-LINE COMMAND
91
93
103
105
107
ON-OFF LINE COMMAND FLIP-FLOP
STOP OR GATE
TRANSFER FLIP-FLOP
GEN 2 NOT RUNNING
81
GEN 1 RUNNING CONDITIONS
79
CONDITION CHECK AND GATE
VOLTAGE LOST
REMOTE STOP
83
87
GEN 1
TRANSFER OR GATE
109
GEN 1 START COMMAND
101
89
START OR GATE
99
GEN 1 INITIAL CONDITIONS
77
VOLTAGE LOST GEN 2
75
GEN 1 RESET/REMOTE START
RESET/REMOTE START GEN 2
TRANSFER AND GATE
95
INVERTER
97
GEN 2 RUNNING AND CONDITION
ALARM GEN 1
71
73
ALARM GEN 2
GEN 2
ON-LINE COMMAND
OFF-LINE COMMAND
ON-OFF LINE COMAND FLIP-FLOP
GEN 1 NOT RUNNING
RUNNING CONDITIONS GEN 2
GEN 2 START COMMAND
INITIAL CONDITIONS GEN 2
GEN 2 RESET/REMOTE START
RESET/REMOTE START GEN 2
76
VOLTAGE LOST GEN 1
85
80
GEN 1 RUNNING AND CONDITION

FIG. 3.

MARINE ENGINEROOM MONITOR AND CONTROL SYSTEM

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention relates to condition monitoring and control systems and more specifically to marine engineroom monitoring and control systems for dual engine vessels having dual generators.

2. Description of the Prior Art

Dual engine marine vessels frequently employ dual generators for supplying the vessel's electrical requirements. Only one generator is operated on-line. The remaining generator is shut down and used as a standby power source. Control of the generators is available in the wheelhouse as well as the engineroom. In the event of a malfunction in such systems, the ship's crew must be alerted in time to disable the operative system before additional damage occurs and to place the standby generator on the line with a minimum of disruption.

Furthermore, in such systems severe damage could result if a generator were started in the presence of such conditions as insufficient lubrication or cooling water.

SUMMARY OF THE INVENTION

The system of the present invention utilizes a plurality of condition sensors to monitor the operation of a ship's dual generator system. A logic circuit provides a distinctive alarm signal upon the occurrence of a malfunction in an operative generator. A second logic circuit may be used for automatically removing a malfunctioning generator from the line and connecting the second generator across the line after its output has reached a suitable voltage and frequency.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a functional block diagram illustrating the organization of the component parts of the invention;

FIG. 2 is a schematic diagram of an alarm logic circuit useful in practicing the invention; and

FIG. 3 is a block diagram of an automatic generator transfer logic circuit useful in practicing the invention.

DESCRIPTION OF THE PREFERRED EMBODIMENT

FIG. 1 illustrates the organization and relationship of the various components in a system utilizing the present invention. First and second generators **11** and **13** are used in a redundant system such that failure of one generator permits the other to be connected across the line. Ordinarily, the generators **11** and **13** are driven from individual engines in a dual engine vessel. Either one or the other of the generators may be started or stopped through conventional manual control means **15**. Typically, the generators are conventional alternators producing an output voltage having a frequency of 60 hertz.

A plurality of condition sensors **17, 19** and **21** on the generator **11** respond to various operating conditions of that generator. Similar sensors are applied to generator **13** and monitor the corresponding conditions in that generator. Signals from each group of sensors are applied to the alarm logic and the transfer logic from the sensors associated with each generator.

Each sensor functions to convert a given parameter such as oil pressure, liquid level or cooling water temperature, into a usable electrical signal. The sensors are essentially switches containing an adjustable range within which the operating threshold may be field adjusted. Thus the sensors produce output voltages essentially of a digital character having a first binary value when the parameter being sensed is within normal limits and a second binary value when the condition being sensed exceeds the threshold value. Included in each group of sensors is a voltage sensor and a frequency sensor for detecting any abnormality in the output voltage and frequency of the associated generator.

In general, all sensor switches operate in the normally closed position so that when such a switch opens, an alarm condition is presented.

As presently preferred, the alarm logic circuit **23** actuates a horn **25** and a lamp **27** in response to a detected malfunction. A transfer logic and switching means **29** serves to automatically disconnect an operative generator from the line and substitute the standby generator when a malfunction is detected. The alarm logic and transfer logic circuits will be described in detail. The switching circuits associated with the transfer logic are conventional relay circuits suitable for starting and stopping the generators in response to output signals from the transfer logic circuit.

In a typical ship-board installation, control of the main engines may be provided from the wheelhouse; control of the generators is available from the wheelhouse and in the engineroom. Control of the generators from the engineroom ordinarily consists of automatic transfer of the power source should the operating generator malfunction. Generators ordinarily may be remotely started, stopped, or placed on-line from the wheelhouse.

FIG. **2** illustrates a circuit that may be used as an alarm logic circuit in the present invention. A single sensor illustrated functionally as a normally closed switch **31** has been shown with the alarm logic circuit as a matter of convenience. It will be appreciated that each of the sensors ordinarily would be coupled into the alarm logic circuit through conventional OR gating means. The condition of the sensor switch typically may be applied to a transistor circuit **33**. When the sensor detects a normal condition, the transistor is cut off and the circuit **33** produces a high level, or logic 1, voltage. When the sensor **31** detects an abnormal condition, the switch **31** effectively opens. The output signal from circuit **33** is inverted in an inverter **35** and applied to a NAND gate **37**. The NAND gate **37** has been depicted in FIG. **2** with a variety of input means to illustrate how various types of input signals may be applied to the alarm logic circuit.

The output of the NAND gate **37** is applied to a pulse forming R-C network **39** and to a NAND gate **41**. A signal from the network **39** is applied to the clear terminal of a first D-type flip-flop **43**. The output of the NAND gate **41** is applied to the preset terminal of the same flip-flop **43** through a line **45**. The output of the gate **41** is also applied to the clear terminal of a second D-type flip-flop **47**. The Q terminal of the flip-flop **47** is applied to a second input on the gate **41**. The clock pulse terminal of the flip-flop **47** is connected to receive acknowledge signals. The preset terminal of the flip-flop **47** is connected to a source of positive voltage.

The D terminal of the flip-flop **43** is grounded and its clock pulse terminal is connected to receive a test input signal. The $\bar{Q}$ terminal of the flip-flop **43** is connected to the D terminal of the flip-flop **47** and to the input of a NAND gate **49** through a line **51**.

The $\bar{Q}$ terminal of the second flip-flop **47** is applied to the NAND gate **49** through a line **53**. The output of the NAND gate **49** is used to actuate the audible alarm. Typically, the signal from the gate **49** is amplified in conventional circuitry in a fashion such that a logic **1** acts to inhibit the amplifying means.

The $\bar{Q}$ terminal of the flip-flop **47** is also connected to a NAND gate **55**. The NAND gate **55** is further connected to receive signals from a suitable source of rectangular waves **57**.

The output of the gate **55** is applied to a NAND gate **59** through a line **61**. A second input terminal on the gate **59** is connected to the $\bar{Q}$ terminal of the flip-flop **43** through a line **63**. The output of the gate **59** is inverted in an inverter **65** and applied to a lamp circuit **67**.

The lamp circuit is arranged so that a high level logic **1** output signal from the inverter **65** saturates an input transistor and illuminates a lamp **69**.

The logic circuit of FIG. **2** may be considered to have three operating modes: A first or no-alarm mode, a second or alarm mode and a third or acknowledge mode.

The alarm logic circuit operates in the no-alarm mode when the operative generator is functioning normally. The circuit operates in the second or alarm mode after a malfunction has been detected. When the alarm mode occurs, the logic circuit provides a signal which causes a horn or audible warning device to sound continuously and a second signal which causes the lamp to flash periodically. The third or acknowledge mode occurs after the alarm has been acknowledged by a member of the crew. In this mode, the lamp is illuminated continuously, but the audible alarm is silenced. During the alarm and acknowledge modes, an alarm signal is available for generator transfer.

The alarm logic circuit of FIG. **2** may be operated from a normally closed or normally open set of contacts, thereby presenting an opening or closure upon an alarm condition. As pictured in FIG. **2**, the sensors such as represented by the switch **31** are in a normally closed condition and the output of the circuit **33** is applied to the gate **37** through the inverter **35**. If it were preferred to use normally open sensors, the output of the circuit **33** would be applied to the high level alarm input of the gate **37**. Furthermore, any alarm condition can be prevented from allowing the alarm to occur by applying an electrical ground to the low level inhibit input of the gate **37**.

For the purposes of this explanation, however, assume that normally closed sensors are to be used so that the circuit **33** will be coupled to the gate **37** through the inverter **35**. Assume further that the high level alarm and the low level inhibit inputs are maintained at logic 1 so that the gate **37** effectively inverts the signal from the inverter **35**. In the following discussion, positive logic will be used wherein a logic 1 represents a high voltage level and a logic 0 represents a low voltage level. Finally, assume that the rectangular wave source **57** provides an alternating signal which changes states from 0 to 1 at a rate of about 2 hertz.

When the circuit is operating in the no-alarm mode, the sensor **31** will produce a logic 0 voltage which will cause a logic 1 to appear at the output of the gate **37**. The $\bar{Q}$ output terminal of the flip-flop **43** will be at a 0 level which will cause the gate **59** to produce a logic 1 regardless of the voltage on the line **61**. The logic 1 from the gate **59** will be inverted in the inverter **65** and the lamp **69** will remain darkened. The logic 0 at the $\bar{Q}$ terminal of the flip-flop **43** also inhibits the gate **49** so that this gate produces a logic 1 regardless of the voltage applied to its input terminal from the line **53**. Since a logic 1 from the gate **49** was considered to inhibit the audible alarm, the horn or other audible device remains silent during this mode of operation.

During the no-alarm mode of operation, the flip-flop **47** produces a logic 0 signal at its Q terminal so that the gate **41** produces a logic 1 signal.

When a malfunction occurs, the sensor **31** opens and the logic circuit is switched to its alarm mode of operation. The output of the gate **37** drops to logic 0. When this change in voltage occurs, the circuit **39** causes the voltage at the clear terminal of the flip-flop **43** to drop momentarily to 0 level. This changes the state of the flip-flop **43** so that the $\bar{Q}$ terminal voltage goes to logic 1. Under these conditions, the gate **41** now receives a logic 0 from the gate **37** but it still receives a logic 1 from the Q terminal of the flip-flop **47**. Thus the output of the gate **41** remains at logic 1. The flip-flop **47** remains in its original state wherein a logic 1 is still produced at the $\bar{Q}$ terminal **47** which is applied through the line **53** to the gates **49** and **55**. Since the gate **49** now receives two logic 1 signals, its output becomes logic 0 and the horn is actuated.

During both the no-alarm and alarm modes, the gate **55** receives a logic 1 from the line **53** and a periodic logic 1 from the square wave source **57**. Thus during both of these modes, the gate **55** produces a rectangular wave train on the line **61**. During the time that the logic circuit was operating in the no-alarm mode, the gate **59** received a logic 0 signal from the flip-flop **43** which provided a steady logic 1 at its output and which prevented illumination of the lamp **69**. During the alarm mode, however, gate **59** receives a logic 1 from the flip-flop **43** thereby producing an output pulse train in accordance with the pulse train received via the line **61**. This causes the lamp **69** to flash intermittently.

When a crew member recognizes the alarm and closes the acknowledge switch, the logic circuit is switched into its acknowledge mode. The acknowledge signal, applied to the clock pulse terminal of the flip-flop **47**, switches this flip-flop so that the $\bar{Q}$ output terminal goes to logic 0 and the $\bar{Q}$ output terminal of the flip-flop **47** goes to logic 1. The logic 0 of the Q terminal is applied to the gates **49** and **55** through the line **53**. This provides a logic 1 at the output of the gate **49** so as to inhibit the horn and a logic 1 at the output of the gate **55** so as to produce a steady logic 1 on the line **61**. The flip-flop **43** is unaffected by the acknowledge signal so that it continues to provide a logic 1 to the gate **59** through the line **63**. Since the gate **59** now receives two logic 1 signals, its output becomes logic 0 which is inverted by the inverter **65** and causes the lamp **69** to glow steadily. The alarm logic circuit remains in this mode until the malfunction is corrected so that the sensor returns to its normally grounded position, whereupon the output of the gate **37** again produces a logic 1 signal. When the output of the gate **37** first returns to the logic 1 level, the gate **41** is still receiving a logic 1 signal from the Q terminal of the flip-flop **47**. During this interval, therefore, the output of the gate **41** drops to logic 0. This resets the flip-flop **47** so that the voltage at the Q terminal goes to logic 0 and the voltage at the $\bar{Q}$ terminal goes to logic 1. The output of the gate **41** is also applied to the preset terminal of the flip-flop **43** through the line **45**. This resets the flip-flop **43** so that the voltage at its $\bar{Q}$ terminal returns to logic 0. This logic 0 is applied to the gates **49** and **59** so as to produce logic 1 signals at the output terminals of each gate and thereby inhibit both the audible and visual alarms. The alarm logic circuit has now been reset to its no-alarm mode.

In the event of a momentary alarm, the output of the gate **37** goes to a logic 0 and then returns to logic 1. This serves to switch the flip-flop **43** so that the $\bar{Q}$ terminal of this flip-flop becomes logic 1. This logic 1 is applied to the gates **49** and **55** through the lines **51** and **63** respectively. This causes a steady audible alarm and a flashing visual alarm. The output of the gate **41** remains at logic 1 because the Q terminal of the flip-flop **47** remains at logic 0. When an acknowledge signal is subsequently applied to the clock pulse terminal of the flip-flop **47**, the flip-flop **47** is switched so that the Q output terminal goes to logic 1. The gate **41** now is receiving logic 1 signals at both of its input terminals and its output drops to logic 0. This resets both flip-flops to the no-alarm mode and thus indicates that the malfunction was only momentary.

The logic alarm circuit also contains means to apply a test input signal to the clock pulse terminal of the flip-flop **43**. This switches the flip-flop **43** so that the $\bar{Q}$ terminal goes to logic 1. The circuit now behaves in the same fashion as if a momentary malfunction had occurred. The circuit is reset to the no-alarm mode by applying an acknowledge signal.

FIG. **3** is a block diagram of an automatic generator transfer circuit useful in practicing the present invention. The automatic generator transfer circuit consists essentially of two identical logic circuits interconnected to perform the required functions. The logic circuit of FIG. **3** provides control signals for operating dual generator sets wherein one is assumed to be carrying the load and the other is maintained in a standby condition. The circuit also provides signals for starting a generator from a remote station and placing it under load.

The automatic transfer logic circuit of FIG. **3** will order a standby generator to start if the operative generator is running and develops an alarm condition indicating, for instance, that the lubrication oil pressure or jacket cooling water temperature becomes abnormal or if the operative generator experiences a loss of voltage output. After the standby generator has been started, the circuit of FIG. **3** will permit this generator to assume the load only if the standby generator does not produce an alarm condition indicating abnormal lubrication oil pressure or jacket cooling water temperature and only when the output of the standby generator reaches the proper voltage and frequency. If these conditions are met, the circuit of FIG. **3** will order the operative generator to be transferred to the standby condition and the original standby generator to assume the load.

When the malfunction is corrected, the circuit of FIG. **3** will be automatically reset thus permitting the transfer sequence to reverse in the event that a malfunction occurs in the now operating generator. It will be noticed by referring to FIG. **3** that the transfer means comprises two essentially identical logic circuits. One of these individual logic circuits is associated with each of the two generators and the two circuits are interconnected to perform the required functions.

The transfer logic circuit contains a pair of input terminals **71** and **73** which may be connected to receive signals from the various sensors discussed previously. Typically, alarm sensors responsive to parameters such as lubrication oil pressure or jacket cooling water temperature may be coupled to the terminals **71** and **73**. Input terminals **75** and **76** are coupled to receive reset signals or remote starting signals for initially conditioning the logic circuit to represent the actual generator operation or to start a generator from a remote position and place it under load. An input terminal **77** is arranged to receive a logic signal that indicates whether or not generator **1** has proper levels of lubrication oil and jacket cooling water before this generator can be started. Input terminals **79** and **80** are connected to receive signals from condition sensors indicating that the output of generator **1** has reached suitable levels of voltage and frequency after this generator has been started, but before it is placed across the line. An input terminal **81** receives an input signal indicating that the opposite generator, generator **2**, is not running so that in the event that generator **1** is to be placed across the load, generator **2** will have been previously stopped. Terminals **83** and **85** are coupled to receive a logic signal that represents a malfunction if the output of generator **1** fails while this generator is in a nominally operative condition. Finally, an input terminal **87** is coupled to receive a stop signal from a remote point when the generator **1** is stopped manually.

An output terminal **89** provides a voltage to external switching means to start generator **1** when desired. Output terminals **91** and **93** are used to actuate external switching means to connect generator **1** across the line or to remove generator **1** from the line respectively.

Because of the symmetry of the circuit of FIG. **3**, input and output terminals identical to those described with relation to generator **1** are also provided for generator **2**.

A transfer AND gate **95** receives signals to insure that the opposite generator is running and providing a proper voltage and frequency. The gate **95** also receives a signal indicating that the generator **1** is off the line. Finally, the gate **95** is coupled to receive a signal from an inverter **97** if an alarm condition arises in the opposite generator system. The inverter **97** is used to provide the proper polarity signal to the gate **95**. A start OR gate **99** receives signals from the input terminals **75** and **77** as well as a signal indicating if the opposite generator voltage output has failed. Thus, in general, the gate **99** looks for an alarm signal from the transfer gate **95**, generator **1** reset or remote start, and for a voltage lost condition from the opposite generator. Gate **99** provides a start signal only if generator **1** initial conditions are suitable.

In summary, the gate **99** will produce a generator **1** start command signal at the output terminal **89** which will actuate exterior circuits so as to cause generator **1** to start under a variety of conditions. Assuming that a logic signal at terminal **77** indicates that the initial conditions such as suitable lubrication oil pressure and cooling water temperature exists at generator **1**, the gate **99** will produce a start command signal at terminal **89** if a manual remote start signal is applied to terminal **75**, if generator **2** is operative but the voltage output fails, or if conditions surrounding generator **2** provide an alarm signal to input terminal **73**. Although generator **1** will be started in response to a command signal at the terminal **89**, the generator will not be connected across the line until an on-line command signal is subsequently produced at terminal **91**. The decision as to when the generator is to be connected across the line is made in the condition check AND gate **101**. The gate **101** passes a switching signal to an on-off line command flip-flop when conditions sensed by the gate **101** are suitable.

Thus gate **101** receives a signal at its input terminal **79** when generator **1** has come up to speed so that its output voltage has reached suitable voltage and frequency levels. Gate **101** receives a second condition signal at its terminal **81** when drive power to generator **2** has been discontinued. Finally, gate **101** receives a condition input signal indicating that generator **2** is off-line. When all of the foregoing conditions are satisfactory, the gate **101** passes a switching signal to the flip-flop **103** which is then switched into a condition so that an on-line command signal is provided at terminal **91**. This actuates exterior switching circuits which connect generator **1** across the line.

The flip-flop **103** can be switched back to its original state so as to provide an off-line command signal at terminal **93** thereby causing the generator **1** to be disconnected from the line in response to a signal from a stop OR gate **105**. The stop OR gate will pass such a signal to the flip-flop **103** upon receipt of a voltage lost signal at its input terminal **83** indicating that the output voltage of generator **1** has failed or a remote stop signal at its input terminal **87** received in response to a manual stop command. The gate **105** is also connected to receive input signals from a transfer flip-flop **107** actuated in response to the output signals from a transfer OR gate **109**.

The transfer OR gate **109** will provide a switching signal to the transfer flip-flop **107** in response to a reset or remote start signal ordering the start of generator **2** when there is no alarm signal being received from generator **2** on input terminal **73**. The transfer OR gate **109** will also pass a switching signal to the transfer flip-flop **107** when generator **1** is operative if an alarm signal is received at input terminal **71** or if a signal is received at input terminal **80** indicating that the output of generator **1** is unsatisfactory.

The transfer flip-flop **107** is preferably a D-type flip-flop with active clear and preset terminals. It is toggled by an alarm command signal from the gate **109** and reset by an on-line command signal from the flip-flop **103**. The flip-flop **107** also produces an output transfer command signal which is applied to the transfer AND gate in the channel controlling the operation of the opposite generator.

Because of the symmetry of the circuit of FIG. 3, each of the components heretofore described in the channel controlling the operation of generator **1** has a counterpart in the channel controlling the operation of generator **2**.

The operation of the transfer logic circuit can be considered in three modes: A remote start/stop mode, a generator voltage loss mode, and a mode in which the generator transfer is ordered in response to an alarm condition.

The remote start/stop mode obtains when both generators are stopped and it is desired to place one of them across the line. Under these conditions, an off-line command signal is being produced in each channel. If generator **1** is to be started, a start command signal will be applied to the input terminal **75**. If a signal is received at the input terminal **77** indicating that the initial conditions pertaining to generator **1** are satisfactory, a generator **1** start command signal will be produced at output terminal **89**. After the generator has started, the condition check AND gate **101** will determine when the output of generator **1** has reached the proper voltage and frequency, and after a delay that the generator is running. When these conditions are satisfied, generator **1** will be ordered on-line.

When generator **1** is ordered to stop, the flip-flop **103** is switched in response to a signal from the gate **105** so as to produce an off-line command signal which removes the generator from the line after which it can be stopped by external circuitry.

The generator voltage loss mode occurs when the output of the operative generator fails. Assume, for instance, that generator **1** is running. If during this operation, the voltage is lost, a signal will be produced at input terminal **83** and the OR gate **105** will produce a switching signal which will switch the flip-flop **103** and disconnect generator **1** from the line. The voltage lost signal is also applied to the input terminal **85** on the start OR gate in the generator **2** channel. The generator **2** start command signal will then be produced and if conditions are suitable, generator **2** will then be ordered on-line.

The third mode of operation obtains when a generator transfer is ordered in response to an alarm condition. Assume, for instance, that generator **2** is the operative generator and a condition occurs that would cause a transfer. Transfer AND gate **95** in the generator **1** channel senses that generator **2** is running and that generator **1** is off-line. An alarm signal pertaining to generator **2** is received at input terminal **73**, is inverted in inverter **97** and applied to gate **95**. This provides an output signal from the gate **95** which is applied to the start OR gate **99**. If the initial conditions pertaining to generator **1** provide a suitable signal at the input terminal **77**, a generator **1** start command signal is produced at output terminal **89**. Once generator **1** has produced the proper voltage and frequency, it is ready to be connected across the line. If generator **1** also produces an alarm signal, the transfer OR gate **109** would prohibit generator **1** from being connected across the line. Assume, however, that no alarm condition exists with respect to generator **1**. A signal will be applied to input terminal **80** indicating that generator **1** is running and providing a proper output voltage and frequency. This signal will be applied to the transfer

AND gate in the generator 2 channel along with a signal from the transfer flip-flop **107**. Generator **2** will be removed from the line and generator **1** will assume the load.

When the malfunction associated with generator **2** is corrected, an alarm signal will no longer be presented to the transfer logic circuit and the on-line command signal from the flip-flop **103** will be applied to the transfer flip-flop **107**. In this way, the transfer logic will be reset so as to permit generator **1** to transfer the load back to generator **2** should a subsequent malfunction occur in the generator **1** system.

In summary, the system of the present invention provides means to alert crew members to the existence of a malfunction in a power supply system and to automatically switch a standby generator on the line until the malfunction is corrected. It will be appreciated that an alarm channel can be provided for each malfunction sensor so that individual warning lights can be connected in the alarm circuit. By this means, the particular malfunction which needs to be corrected can be readily identified.

By virtue of the alarm system, the crew members are alerted to any malfunction when it first occurs. The automatic transfer circuit permits rapid transfer to the standby generator so that a minimum of disturbance is experienced. The multi-mode operation capabilities of the warning system require only that a crew member acknowledge the existence of the malfunction at the time such malfunction occurs. The condition can then be rectified as soon as a crew member is available for this purpose. In the meantime the electrical system continues to operate without further damage to the entire electrical system.

While the invention has been described in its preferred embodiment, it is to be understood that the words which have been used are words of description rather than limitation and that changes within the purview of the appended claims may be made without departing from the true scope and spirit of the invention in its broader aspects.

We claim:

1. Monitoring and control apparatus for a ship's electrical supply system of the type employing operative and standby electrical generators; said apparatus comprising a plurality of sensing means for providing digital signals indicative of the operating conditions of each generator; alarm logic circuit means for indicating a malfunction in an operative generator and transfer logic circuit means for automatically transferring a load to the standby generator in the event of a malfunction in the operative generator; each of said sensing means producing a logic signal having a first binary value in response to a normal operating condition and a second binary value in response to an abnormal operating condition; said alarm logic circuit including first and second bistable means, each of said bistable means have Q and $\bar{Q}$ output terminals; audible and visual alarm means coupled to each of said $\bar{Q}$ output terminals; said audible alarm means including audible alarm gating means for producing an inhibit signal when and only when a logic 0 signal is applied to said gating means from either of said $\bar{Q}$ output terminals; said visual alarm means including a source of rectangular waves and visual alarm gating means, said visual alarm gating means including a first NAND gate connected to pass a rectangular wave from said source in response to a logic 1 signal from the $\bar{Q}$ terminal of said second bistable means and a logic 1 signal in response to a logic 0 signal from the same terminal, said visual alarm gating means further including a second NAND gate coupled to receive the output signals from said first NAND gate and signals from the $\bar{Q}$ output terminal of said first bistable means whereby said second NAND gate inverts and passes the signal from said first NAND gate in response to a logic 1 signal at the $\bar{Q}$ output terminal of said first bistable means and a steady logic **1** signal in response to a logic 0 signal from the same $\bar{Q}$ output terminal, said visual alarm means still further including a switching means to actuate said visual alarm means when and only when the output from said second NAND gate is at a logic 0 level; means in said logic alarm circuit for switching said first bistable means and said second bistable means to a state wherein they produce logic 0 and logic 1 signals, respectively, in response to a normal operating signal from the associated sensing means; means to reverse the binary state of each of said bistable means when the associated sensing means detects a malfunction; means to return the second bistable means to its original bistable state in response to an acknowledge signal; said transfer logic circuit means including means to start a standby generator in response to a malfunction indication from said sensing means; means to substitute said standby generator for the originally operative generator after the output of said standby generator reaches predetermined voltage and frequency levels.

2. Monitoring and control apparatus for a ship's electrical supply system of the type including operative and standby electrical generators, said apparatus including sensing means for providing digital signals indicative of the operating conditions of each generator; alarm means for indicating a malfunction in an operative generator and transfer means for automatically transferring a load to the standby generator in the event of a malfunction in the operative generator; said alarm means including alarm logic means for providing actuating signals to audible and visual indicators; said alarm logic means including a source of rectangular pulses, first and second bistable means, means to actuate said bistable means and gating means for actuating said indicators in response to output signals from said bistable means; said means to actuate said bistable means including means to set said first and second bistable means in first and second bistable states respectively in the absence of a malfunction and means to reverse the binary state of said second bistable means upon the occurrence of a malfunction, means to receive an acknowledge signal after the occurrence of a malfunction, means to reverse the binary state of said second bistable means in response to an acknowledge signal, and means to return the first and second bistable means to the first and second bistable states respectively when the malfunction has been corrected; said gating means including means to inhibit said audible indicator whenever said first bistable means is in said first bistable state or whenever said second bistable means is in said reversed binary state; said gating means further including means to actuate said visual indicator in synchronism with pulses from said source when and

only when said first and second binary means are in said first and reversed binary states, respectively, said gating means further including means to actuate said visual indicator steadily when and only when both of said bistable means are in their respective reversed binary states.

3. The apparatus of claim 2 wherein said first and second bistable means are D-type flip-flops each having Q and $\bar{Q}$ output terminals, said D-type flip-flops being arranged so that the $\bar{Q}$ output terminal on said first bistable means is at a logic 0 level when that bistable means is in said first bistable state and the $\bar{Q}$ output terminal on said second bistable means is at a logic 1 level when that bistable means is in said second bistable state; said means to inhibit said audible indicator including an inhibit NAND gate connected to each of said $\bar{Q}$ output terminals and said means to actuate said visual indicator includes first and second NAND gates serially coupled to said $\bar{Q}$ output terminals.

4. The apparatus of claim 3 wherein said inhibit NAND gate receives input signals only from the $\bar{Q}$ output terminals on said first and second bistable means respectively and wherein said first NAND gate is connected to receive signals only from the $\bar{Q}$ output terminal on said second bistable means and said source of rectangular pulses, said second NAND gate being connected to receive signals only from the $\bar{Q}$ output terminal on said first bistable means and said first NAND gate.

5. The apparatus of claim 4 wherein each bistable means includes clear and preset terminals and wherein said means to actuate said bistable means includes additional gating means to provide logic 1 and logic 0 signals when the associated sensor detects normal and malfunction conditions, respectively, the output of said additional gating means being capacitively coupled to the clear terminal on said first bistable means so that this bistable means is switched to said reversed binary state in response to a momentary pulse produced in said capacitor coupling means upon the occurrence of a malfunction.

6. The apparatus of claim 5 wherein each bistable means further includes a clock pulse terminal, said apparatus further containing means to provide a momentary test signal to the clock pulse terminal on said first bistable means, said first bistable means being connected so as to be switched to its reverse binary state upon the receipt of a test signal in the presence of a logic 1 signal from said additional gating means.

7. The apparatus of claim 6 further including means to apply an acknowledge signal to the clock pulse terminal of said second bistable means, said second bistable means being connected so as to be switched to said reversed binary state upon the receipt of an acknowledge signal in the presence of a logic 0 from said additional gating means.

8. The apparatus of claim 2 wherein said transfer means includes a dual channel transfer logic circuit, each of said channels including means to receive signals from the sensing means associated with the corresponding generator, each of said channels further including means to supply start, on-line and off-line command signals to the corresponding generator; each of said channels further including means to receive initial condition signals from sensors associated with the corresponding generator, said initial condition signals indicating that the system of the corresponding generator is in satisfactory operating condition; each of said channels further including means to provide a start command signal only when a satisfactory initial condition signal exists during the occurrence of a signal indicating a malfunction in the opposite generator; transfer means in each channel to order the transfer of operation from the opposite generator to the corresponding generator; each of said channels further including condition checking means coupled to receive a running condition signal from sensor means indicating that the corresponding generator has been started in response to a start command signal and is providing an output signal of desired voltage and frequency, said condition checking means being coupled to receive an off-line command signal from the opposite channel, said condition checking means being further arranged to provide a switching signal in response to a start command signal only in the presence of a satisfactory running condition signal and an off-line command signal; means to provide an on-line command signal in response to a switching signal from said condition sensing means, said on-line command signal being suitable for actuating external switch means so as to connect the corresponding generator across the line.

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