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NOTICE

③ Multiplexed Computer-Controlled Protective System.

④ PAT-APPL 276 593

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1 MULTIPLEXED COMPUTER-CONTROLLED PROTECTIVE SYSTEM

2 ABSTRACT OF THE DISCLOSURE

3 A computer-controlled system for protecting a feeder
4 circuit (or power supply) and one or more branch load circuits,
5 each circuit supplied by a power buss fed through current sensors.
6 Each of the source and branch circuits has a current sensor in
7 each positive and negative leg and a set of contacts (circuit
8 interrupters) in each leg. The current sensors feed data to a
9 microcomputer 17 which stores fault-condition information for
10 each separate sensed circuit. The data fed into the computer
11 is compared to the stored information in look-up tables, and, when
12 a fault-condition is sensed, the computer sends a fault output
13 signal to the current interrupter associated with the circuit from
14 which the fault signal has come, the fault output signal acting to
15 open the contacts in that circuit and inactivate it. If the fault
16 condition is severe, the source interrupter is activated immediately,
17 the branch circuit interrupter is then opened and the computer then
18 directs the closing of the source interrupter. The branch circuit
19 interrupters, however, are not closed until the fault condition is
20 cleared. The whole operation and sequence of events before, during
21 and following fault conditions is performed automatically and managed
22 by the computer.

23 BACKGROUND OF THE INVENTION

24 This invention relates to protective systems and especially
25 to a computer-controlled protective system for automatically opening

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1 circuit-interrupting devices under predetermined circumstances.

2 Existing deep-submergence vehicles (DSV's) employ circuit
3 breakers, each comprising two current sensors and a current
4 interrupter of the heavy-duty-contactor type, to protect the outboard
5 circuits which may include various lights, propeller motors, and
6 hydraulic pump motors. These are supplied through two 30-volt DC
7 and two 60-volt DC systems. Each circuit breaker has two current
8 sensors, there being 15 contactors and 35 current sensors in the
9 complete system. These are installed in two oil-filled boxes out-
10 board of the pressure hull of the DSV which may be exposed to 9000
11 psi pressure or more and temperatures up to 32°F. Operation in
12 this formidable environment requires yearly inspection and tri-yearly
13 recalibration of the current sensors, operations which can be quite
14 expensive and time-consuming. Additionally, the reaction time of the
15 existing circuit breakers, installed in compensated oil-(Dow Corning-
16 200-1) filled boxes, increase with depth as the viscosity of the
17 fluid increases with depth.

18 SUMMARY OF THE INVENTION

19 Accordingly, an object of this invention is to save time
20 and money expended on inspections and recalibrations of the current
21 sensors now used in the protective system of DSV's.

22 Another object is to provide an automatic, pre-programmed,
23 computer-controlled system for use with protective systems which
24 employ current-interrupting and sensing devices which will be
25 impervious to environmental influence.

1 The present protection system is for use with branch load
2 circuits which take power from a power source, the source and each
3 load circuit being provided with its own current interrupter and
4 current sensors. The current sensors provide current-value informa-
5 tion to one or more computers which are pre-programmed to compare the
6 current value for each circuit with its particular fault-condition
7 curve, decide whether a fault condition exists and, if so, open the
8 branch circuit and, if a massive fault exists, also open the supply
9 source circuit. The supply circuit is reclosed after a predeter-
10 mined period of time elapses, but the branch circuit remains open
11 until it can be checked.

12 BRIEF DESCRIPTION OF THE DRAWINGS

13 Fig. 1 is a schematic diagram of an embodiment of the
14 invention.

15 Fig. 2 is a curve showing the time delay for opening a
16 typical relay after application of various overload values of
17 current to the relay coil.

18 Fig. 3 is a block diagram of an embodiment of the invention
19 which employs a plurality of computers.

20 Fig. 4 is a block diagram of an embodiment of the invention
21 which employs a central computer and a slave computer, the number of
22 slave computers determined by the number of circuits requiring
23 protection.

24 DETAILED DESCRIPTION OF THE INVENTION

25 The present invention will be described herein with specific

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1 reference to its application to the outboard circuits of a DSV.
2 However, it should be noted that it has a more general application
3 to the protection of paralleled individual branch load circuits fed
4 from a common source of supply and protected by a circuit breaker
5 which consists of an interrupter of the contactor or relay type
6 and a current sensor in each leg of the circuit which will activate
7 the interrupter if the current sensor signals fed to the computer
8 indicate that a current greater than a predetermined value for a
9 predetermined period of time is flowing in the circuit. Hereinafter,
10 the term "contactor " will be used for circuit interrupters used to
11 open the main power circuit and "relay" for interrupters that open
12 branch load circuits.

13 Power on a DSV is delivered to different loads (i.e.,
14 branch load circuits comprising outboard lights, motors, etc.). The
15 present invention incorporates programmed computers, preferably
16 microcomputers, to control the closure and opening of contactors
17 and load relays external to the pressure hull. The microcomputers
18 are programmed to monitor the current drawn by each load including
19 the supply current and to interrupt the current should any current
20 exceed its current limit value (viz., magnitude and time duration)
21 which was previously defined as a fault condition.

22 The protective system governs the distribution of power
23 outside the pressure hull of the DSV. Operator control of motors,
24 lights and other loads is established through a system of battery
25 contactors and load relays. These can be tripped open or closed

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1 in response to operator commands received over a data communications
2 buss from the operator's computer. The computer also protects the
3 vehicle by detecting system faults and responding automatically to
4 these faults. A fault, or overload, is a condition that causes a
5 load to draw an abnormally large current (e.g., 500% normal load
6 current) for an extended period of time (e.g., 0.4 seconds). The
7 system therefore measures the magnitude of current delivered to each
8 load as well as the amount of time the current exceeds a predetermined
9 limit. The ability to monitor the length of time that an overload
10 persists enables the system to distinguish transient phenomena (power-
11 up) from actual faults. A fault can be defined as a point on a time-
12 current curve (see Fig. 2, for example) that plots the duration of
13 an overload versus the magnitude of the overload. When the system
14 has determined that a fault exists, it responds by opening the
15 appropriate interrupter to cutoff current to the faulted load.

16 The protective system is designed to incorporate relatively
17 small relays to deliver power through contacts to a load. The
18 advantage of using small relays is that they provide considerable
19 savings in size and weight with respect to conventional contactors
20 (e.g., the BD-241). The disadvantage is that smaller relays are
21 incapable of interrupting the current associated with extreme fault
22 conditions (e.g., 1000% normal load). What is done, therefore, is
23 to use a large contactor as the supply source (battery) breaker to
24 deliver current to smaller load relays. The system discriminates
25 between nominal fault conditions (overloads) and extreme, or massive,

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1 fault conditions (short circuits). The small load relays are
2 adequately rated to interrupt nominal faults and the larger con-
3 tactors are adequately rated to interrupt massive faults.

4 Upon detection of a short circuit, the system responds
5 by tripping open the battery or source contactor that delivers
6 current to the shorted load. Power is momentarily (milliseconds)
7 interrupted to all loads serviced by that contactor while the
8 system trips open the small relay in the branch where the fault
9 occurred. Once the faulted load is removed from the power buss,
10 the system recloses the battery breaker and thus restores current
11 to non-faulted loads.

12 Fig. 1 shows an embodiment of the protector system in
13 abbreviated form, that is, only one load circuit is shown. It is
14 to be noted that there is a plurality of load circuits each of
15 which has the same protective devices and arrangement as load 12 shown,
16 which may be a light, motor, pump, etc. These other load circuits
17 would be paralleled loads and take 60V power from the positive (32)
18 and negative (34) supply busses.

19 The power source is shown as a 60-volt battery 14. In the
20 DSV, there are two 60V. sources and two 30V. sources, each supplying
21 separate loads and each having its own protective system of sensors
22 and interrupters. The units inside the pressure hull 64 could be
23 designed to service all outside load circuits, or separate units
24 could be employed for each supply source group of loads.

25 Shunts (current sensors) 16 and 18, which provide an output

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1 voltage proportional to the current flowing through them, are placed
2 in the positive and negative legs of the power circuit. Contacts
3 20 and 22 of a source contactor are also placed in the positive and
4 negative legs of the power circuit. The contacts are opened when
5 coil 30 of the contactor is energized. The coil 30 is energized by
6 a small power source 24, such as a small battery, through the closing
7 of the contacts 26 of an energizing circuit relay, the coil 28 of
8 which is under control of the computer 68.

9 A shunt is a calibrated resistor connected in series with
10 a circuit. A voltage proportional to the current is picked off the
11 shunt and used as a measure of current flow therein. Shunts are
12 insensitive to pressure and temperature and therefore more useful
13 in an underseas environment than the present electro-mechanical
14 current sensors used in DSVs. These devices are installed in pressure-
15 compensated enclosures filled with insulating fluid and exposed to
16 pressure equivalent to 20,000 feet of sea pressure. The shunts are
17 maintenance-free while Hartman devices are not.

18 Each load circuit has shunts (current sensors) 36 and 38,
19 one in each leg. Contacts 40 and 42 of a load relay are operated by
20 the coil 44 of the relay and are opened upon energization of the
21 coil 44 by the flow of current from a energizing circuit power source
22 46, such as a small battery. Current flow occurs when contacts 48
23 of a small energizing circuit relay are closed.

24 The output voltage of each current sensor, e.g., sensor 16,
25 is fed (the dashed lines indicate information lines, the solid lines

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1 indicate power lines) to an analog-to-digital (A/D) converter, e.g.,
2 58, which provides a digital signal that is indicative of the
3 magnitude of the analog input signal. The signals from all A/D
4 converters whose input signals derive from sensors in the positive
5 and negative legs are fed to the multiplexer 62. Multiplexers are
6 used to reduce the number of lines entering the pressure hull of the
7 DSV. Once inside the pressure hull 64, the multiplexer lines are
8 fed to a demultiplexer 66, the output lines of which are fed to the
9 input/output unit 70 and then to the computer 68. There is an output
10 line from the demultiplexer for each sensor signal. The computer 68,
11 which may preferably be a microcomputer, compares each sensor signal
12 with stored information which indicates a fault condition for the
13 circuit whose current is being sensed if an out-of-specification
14 condition occurs. The outputs of the computer 68 are fed through the
15 input/output unit 70 to another multiplexer 74 to place the output
16 signals on a single line (or single pair) for passage through the
17 pressure hull 64.

18 Once outside the hull, the multiplexer output is fed to a
19 demultiplexer 76, the outputs of which are coupled to the proper
20 energizing circuit coils by the computer memory which directs a
21 closing signal to the energizing coil of the faulted circuit. Thus,
22 if the computer input signal came from sensor 36 or 38, the demulti-
23 plexer 76 would be directed to couple the computer output signal to
24 relay 50 (the demultiplexer would have an output signal if comparison
25 of the input sensor signal to the computer with the fault condition

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1 information stored there indicates that a fault exists). Contacts 48
2 would then be closed to energize load-relay coil 44 to open contacts
3 40 and 42, thereby cutting off current to the load 12.

4 The control board unit 72 has its own microcomputer. This
5 unit will control the interrupter contacts 50, 42 and 20, 22 on/off
6 by commanding the energizing coils 40 and 28, respectively, to open/
7 close their respective contacts.

8 As has been previously stated, if a massive fault condition
9 exists, the supply source contactor is opened (contacts 20 and 22 in
10 Fig. 1) temporarily and is re-closed after a predetermined period
11 of time. This period of time depends on factors which may be specific
12 for a particular environment in which the protective system is
13 operative. For existing DSV's, 70 milliseconds is a typical time
14 period.

15 The invention may be implemented with a single, computer
16 as shown in Fig. 1 or, as shown in Fig. 3, with an operator's panel
17 computer 80 inside the pressure hull 64 and load computers 82(1) -
18 82(N) or source computer 82(S) outside the hull, each associated with
19 a different load and load relay 84(1) - 84(N) or contactor 84(S) and
20 power buss. In this case, each load or source computer would store
21 the fault condition data for its associated load, make the comparison,
22 and open the load circuit if necessary. Circuit status information
23 would be transmitted to the operator's computer 80 and panel. The
24 operator, through his computer, would be able to close the source
25 contactor and load relays at the start of an operation and open them

1 at the finish of an operation. To make the system more reliable, a
2 second, or redundant, data link is used. The operator's computer
3 and each other computer communicate with each other to indicate
4 circuit status and possible errors in transmitted information. The
5 invention may also be implemented using a central computer/slave
6 computer arrangement as shown in Fig. 4. Each slave computer 96
7 monitors several loads and communicates with the central computer 94.
8 Essentially this arrangement is the same as Fig. 3 with the slave
9 computer replacing load computers 1, 2,.....N.

10 The protective system of the invention is very flexible in
11 that the computer can be programmed to perform other valuable
12 functions. For example, the computer can be made to subtract the
13 currents in the sensors located in the + and - legs of each branch
14 so that leakage currents can be detected. A record of leakage
15 currents can be stored so that the development of fault conditions
16 can be monitored. This will allow detection of incipient faults
17 and opening of interrupters / relays before an actual fault condition
18 occurs. This will permit trouble shooting before rather than after,
19 a fault occurs.

20 The computer-controlled protection system also lends itself
21 to application in alternating-current power networks. Frequency,
22 current, voltage, power and power factor are easily monitored, given
23 the proper interface.

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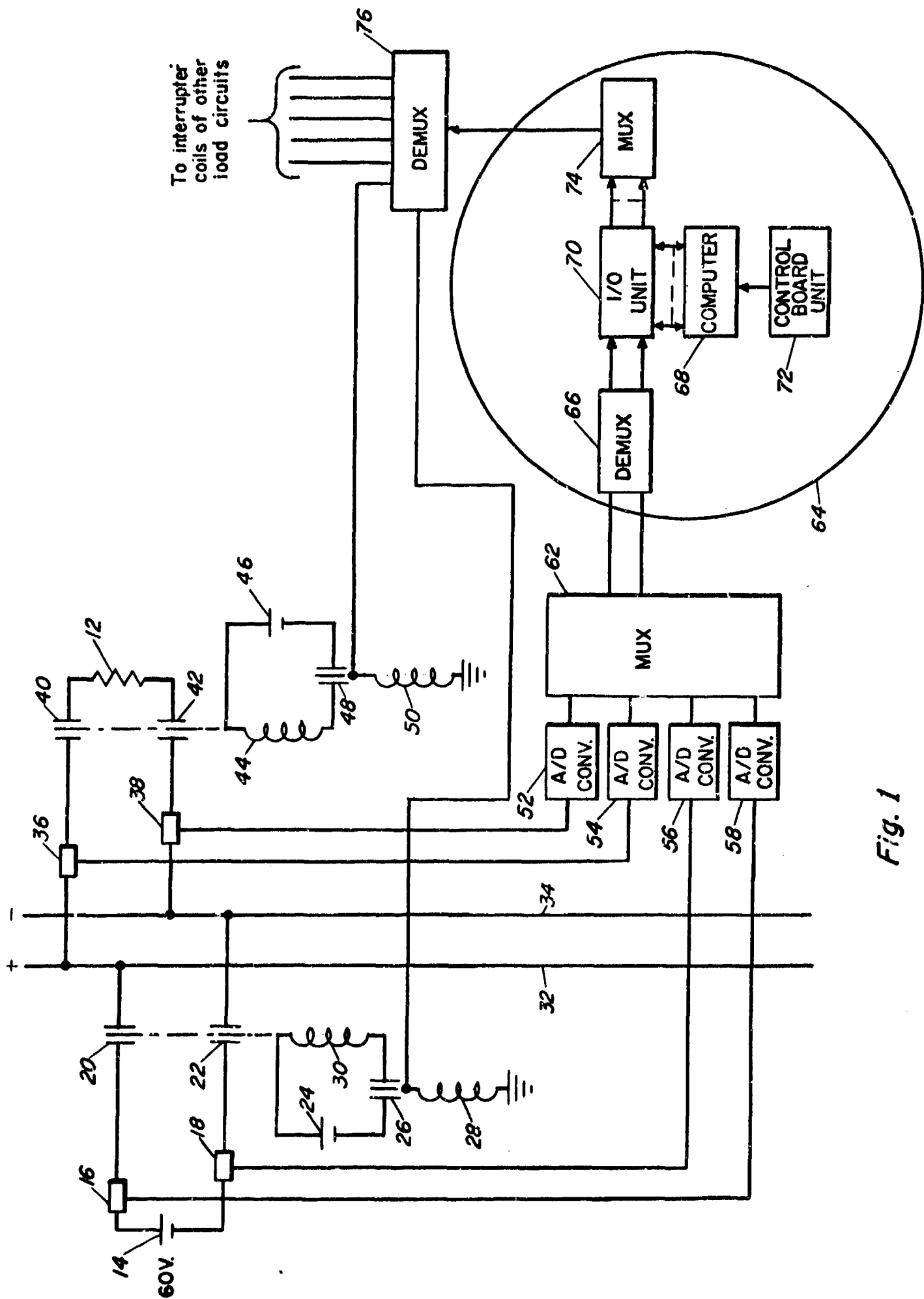


Fig. 1

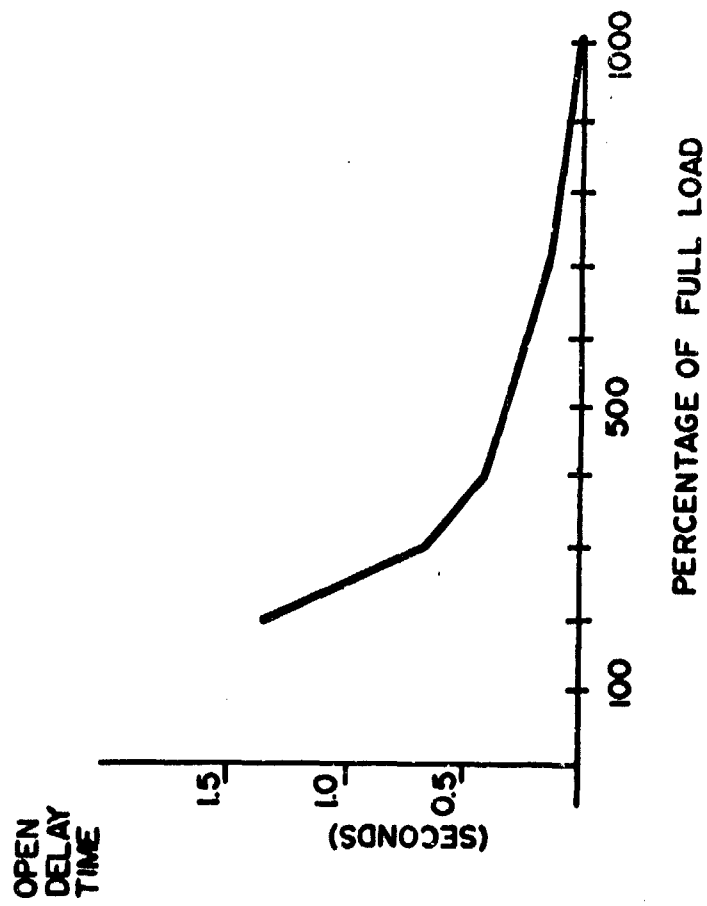


FIG.2

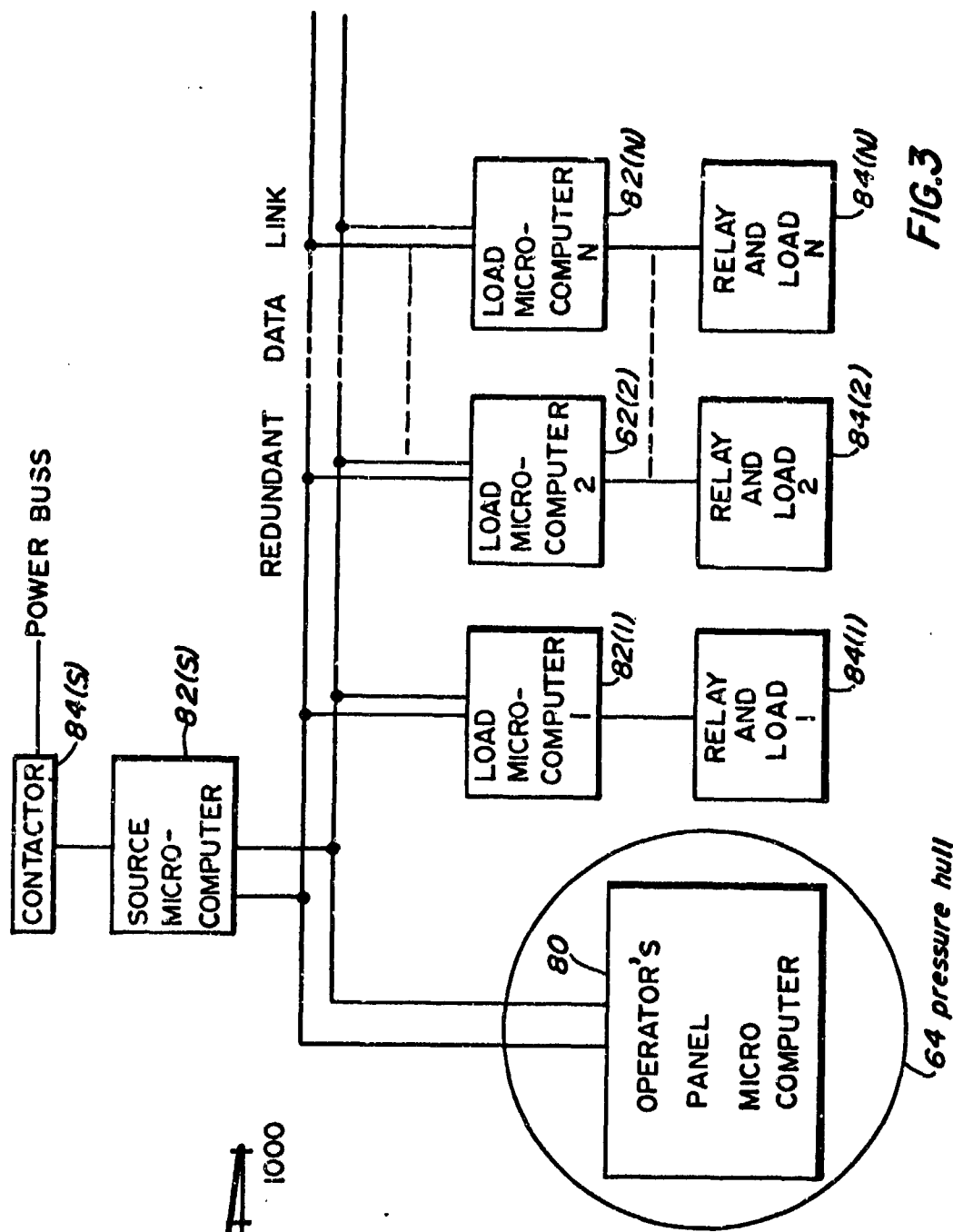


FIG.3

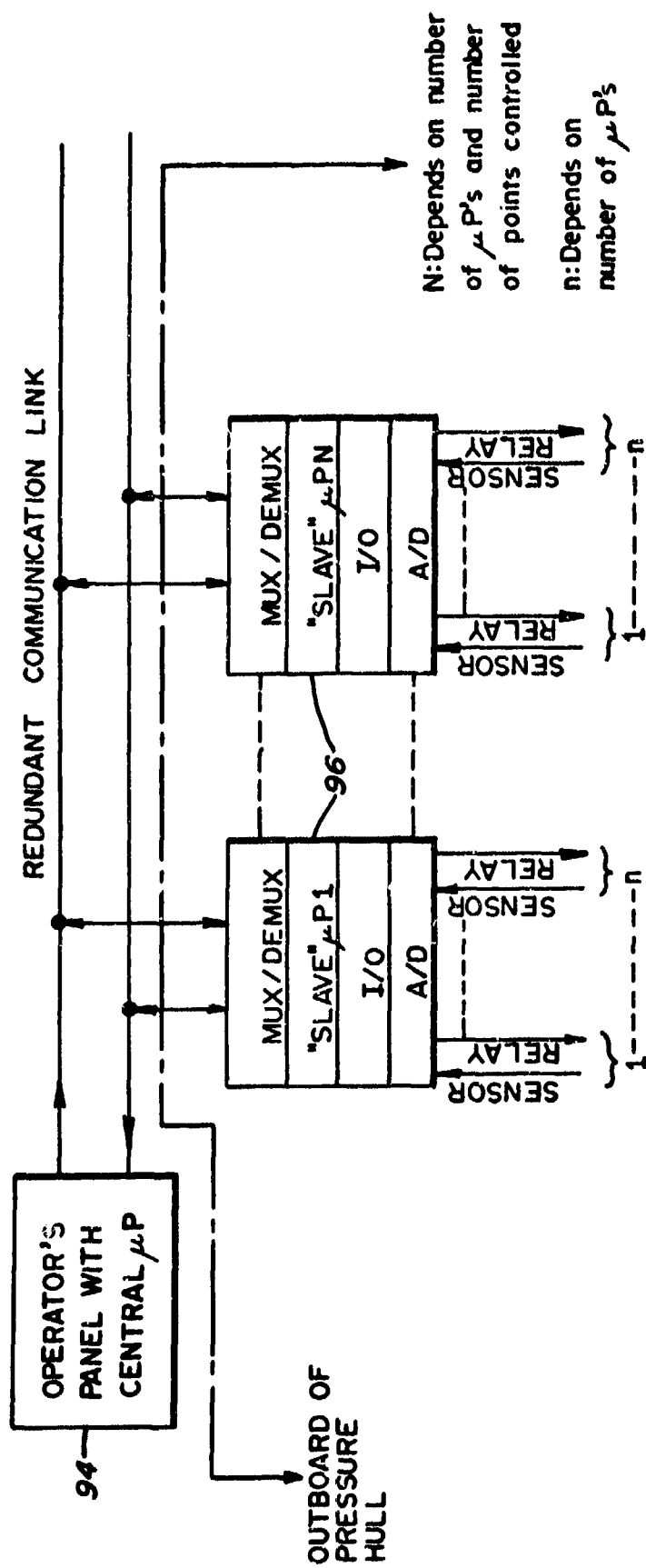


FIG. 4