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NOTICE

Multiplexed Computer-Controlled Protective System.

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MULTIPLEXED COMPUTER-CONTROLLED PROTECTIVE SYSTEM

ABSTRACT OF THE DISCLOSURE

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

BACKGROUND OF THE INVENTION

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

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circuit-interrupting devices under predetermined circumstances.

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

SUMMARY OF THE INVENTION

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

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

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

BRIEF DESCRIPTION OF THE DRAWINGS

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

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

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

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

DETAILED DESCRIPTION OF THE INVENTION

The present invention will be described herein with specific reference to its application to the outboard circuits of a DSV. However, it should be noted that it has a more general application to the protection of paralleled individual branch load circuits fed from a common source of supply and protected by a circuit breaker which consists of an interrupter of the contactor or relay type and a current sensor in each leg of the circuit which will activate the interrupter if the current sensor signals fed to the computer indicate that a current greater than a predetermined value for a predetermined period of time is flowing in the circuit. Hereinafter, the term "contactor " will be used for circuit interrupters used to open the main power circuit and "relay" for interrupters that open branch load circuits.

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

The protective system governs the distribution of power outside the pressure hull of the DSV. Operator control of motors, lights and other loads is established through a system of battery contactors and load relays. These can be tripped open or closed in response to operator commands received over a data communications buss from the operator's computer. The computer also protects the vehicle by detecting system faults and responding automatically to these faults. A fault, or overload, is a condition that causes a load to draw an abnormally large current (e.g., 500% normal load current) for an extended period of time (e.g., 0.4 seconds). The system therefore measures the magnitude of current delivered to each load as well as the amount of time the current exceeds a predetermined limit. The ability to monitor the length of time that an overload persists enables the system to distinguish transient phenomena (power-up) from actual faults. A fault can be defined as a point on a time-current curve (see Fig. 2, for example) that plots the duration of an overload versus the magnitude of the overload. When the system has determined that a fault exists, it responds by opening the appropriate interrupter to cutoff current to the faulted load.

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

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

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

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

Shunts (current sensors) 16 and 18, which provide an output voltage proportional to the current flowing through them, are placed in the positive and negative legs of the power circuit. Contacts 20 and 22 of a source contactor are also placed in the positive and negative legs of the power circuit. The contacts are opened when coil 30 of the contactor is energized. The coil 30 is energized by a small power source 24, such as a small battery, through the closing of the contacts 26 of an energizing circuit relay, the coil 28 of which is under control of the computer 68.

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

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

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

Once outside the hull, the multiplexer output is fed to a demultiplexer 76, the outputs of which are coupled to the proper energizing circuit coils by the computer memory which directs a closing signal to the energizing coil of the faulted circuit. Thus, if the computer input signal came from sensor 36 or 38, the demultiplexer 76 would be directed to couple the computer output signal to relay 50 (the demultiplexer would have an output signal if comparison of the input sensor signal to the computer with the fault condition information stored there indicates that a fault exists). Contacts 48 would then be closed to energize load-relay coil 44 to open contacts 40 and 42, thereby cutting off current to the load 12.

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

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

The invention may be implemented with a single, computer as shown in Fig. 1 or, as shown in Fig. 3, with an operator's panel computer 80 inside the pressure hull 64 and load computers 82(1) - 82(N) or source computer 82(S) outside the hull, each associated with a different load and load relay 84(1) - 84(N) or contactor 84(S) and power buss. In this case, each load or source computer would store the fault condition data for its associated load, make the comparison, and open the load circuit if necessary. Circuit status information would be transmitted to the operator's computer 80 and panel. The operator, through his computer, would be able to close the source contactor and load relays at the start of an operation and open them at the finish of an operation. To make the system more reliable, a second, or redundant, data link is used. The operator's computer and each other computer communicate with each other to indicate circuit status and possible errors in transmitted information. The invention may also be implemented using a central computer/slave computer arrangement as shown in Fig. 4. Each slave computer 96 monitors several loads and communicates with the central computer 94. Essentially this arrangement is the same as Fig. 3 with the slave computer replacing load computers 1, 2,......N.

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

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

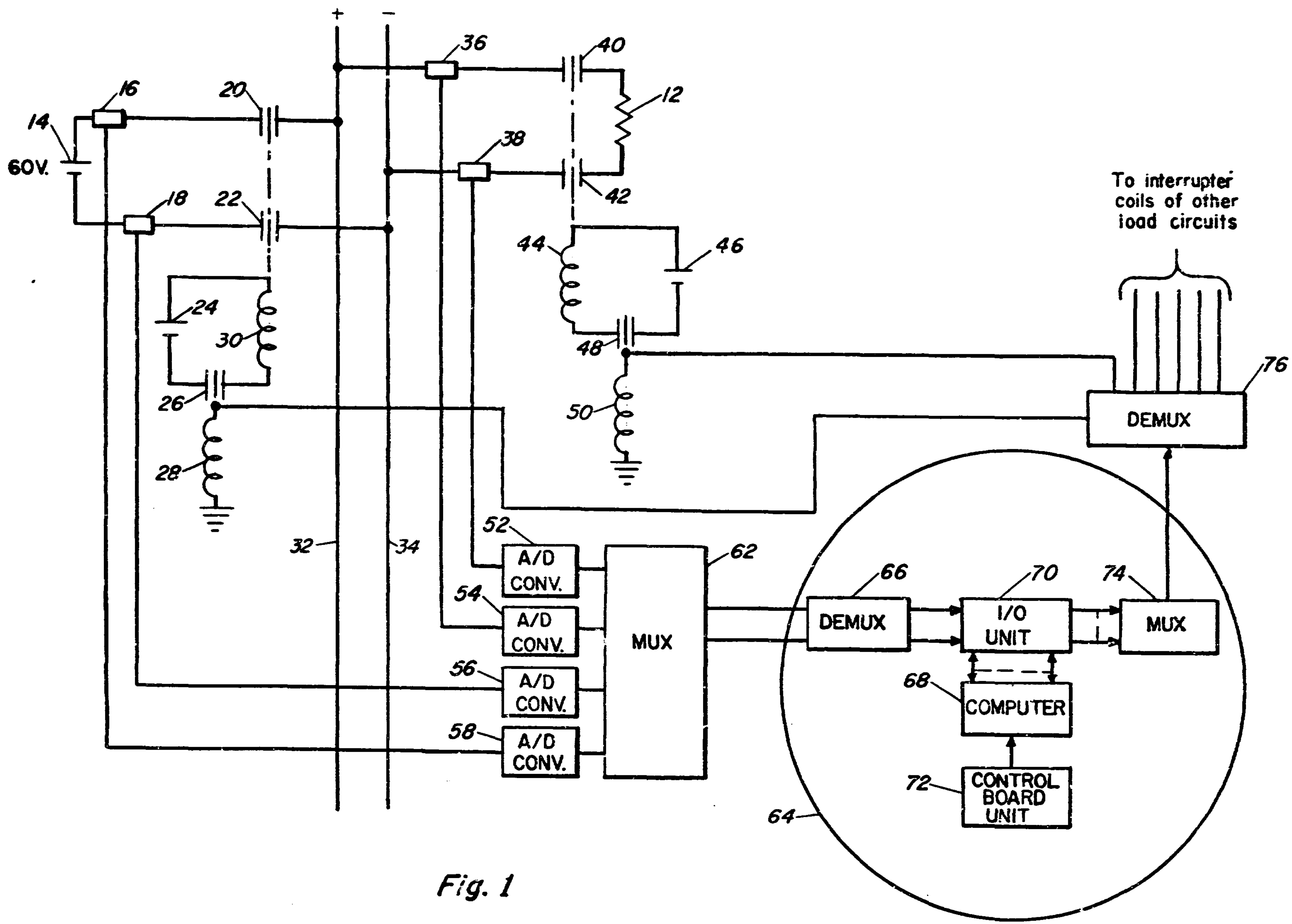

60V.
To interrupter coils of other load circuits
DEMUX
A/D CONV.
A/D CONV.
A/D CONV.
A/D CONV.
MUX
DEMUX
I/O UNIT
MUX
COMPUTER
CONTROL BOARD UNIT

Fig. 1

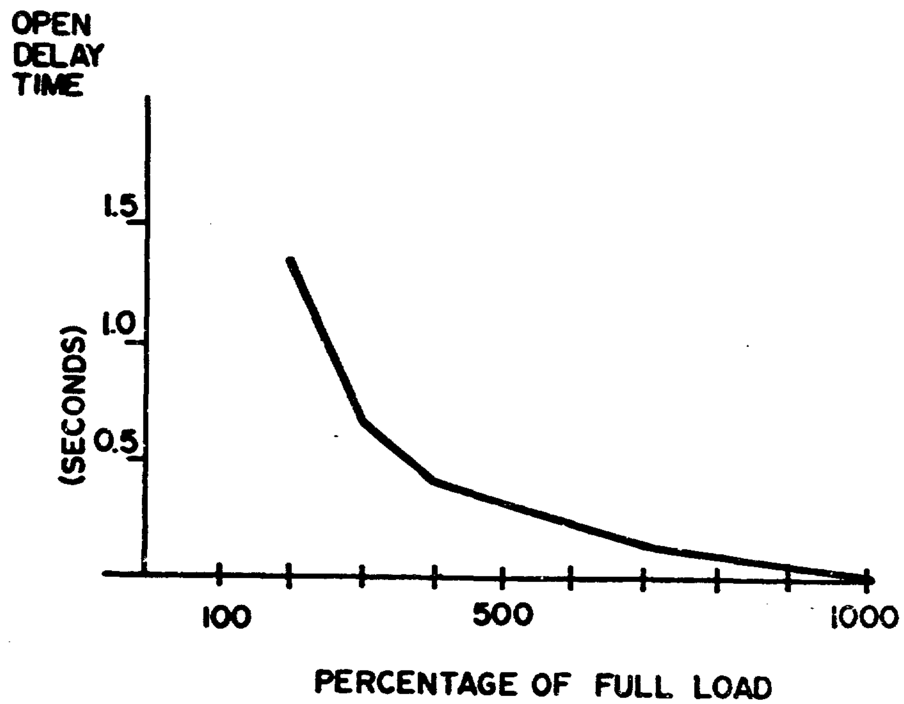

OPEN
DELAY
TIME
(SECONDS)
1.5
1.0
0.5
100
500
1000
PERCENTAGE OF FULL LOAD

FIG. 2

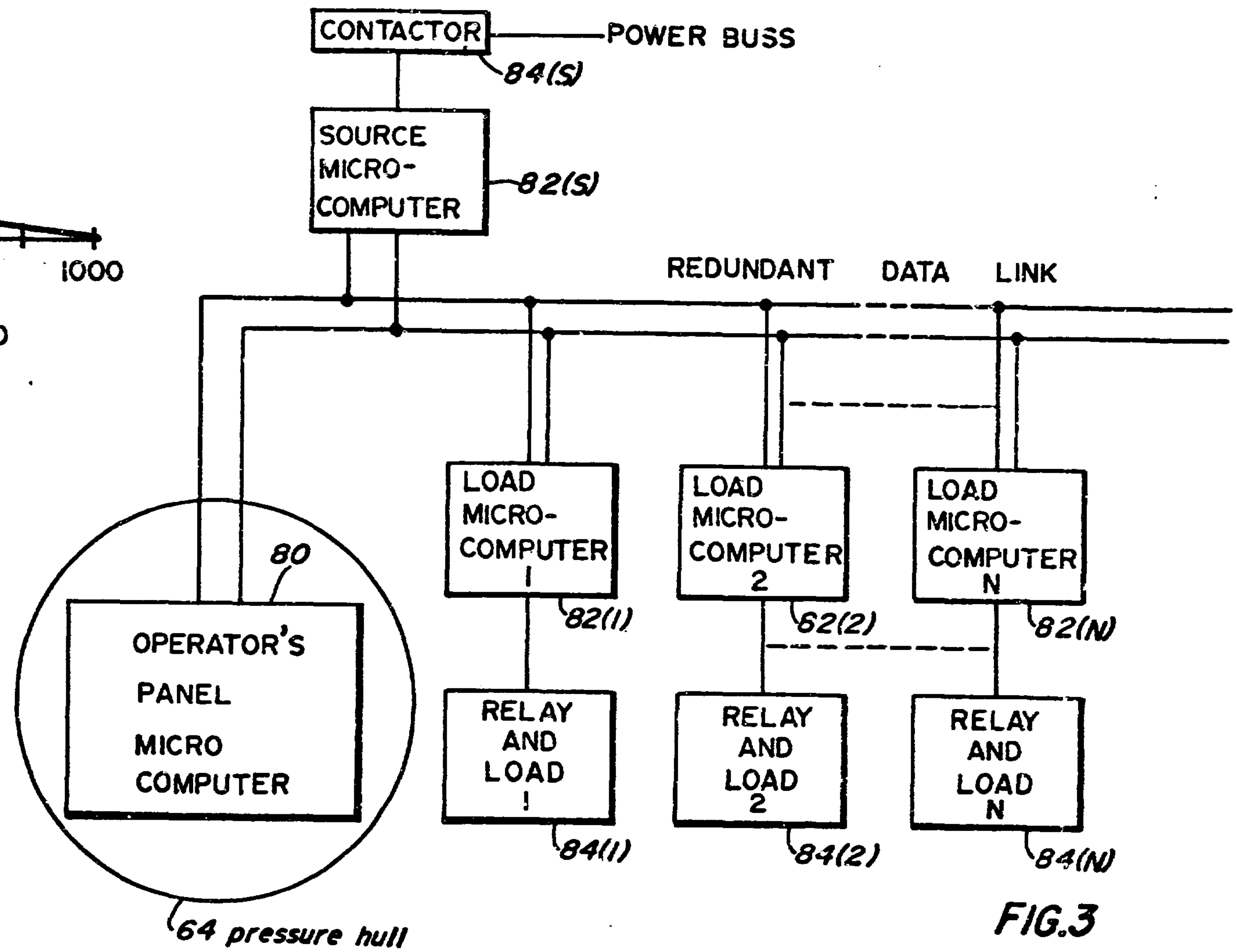
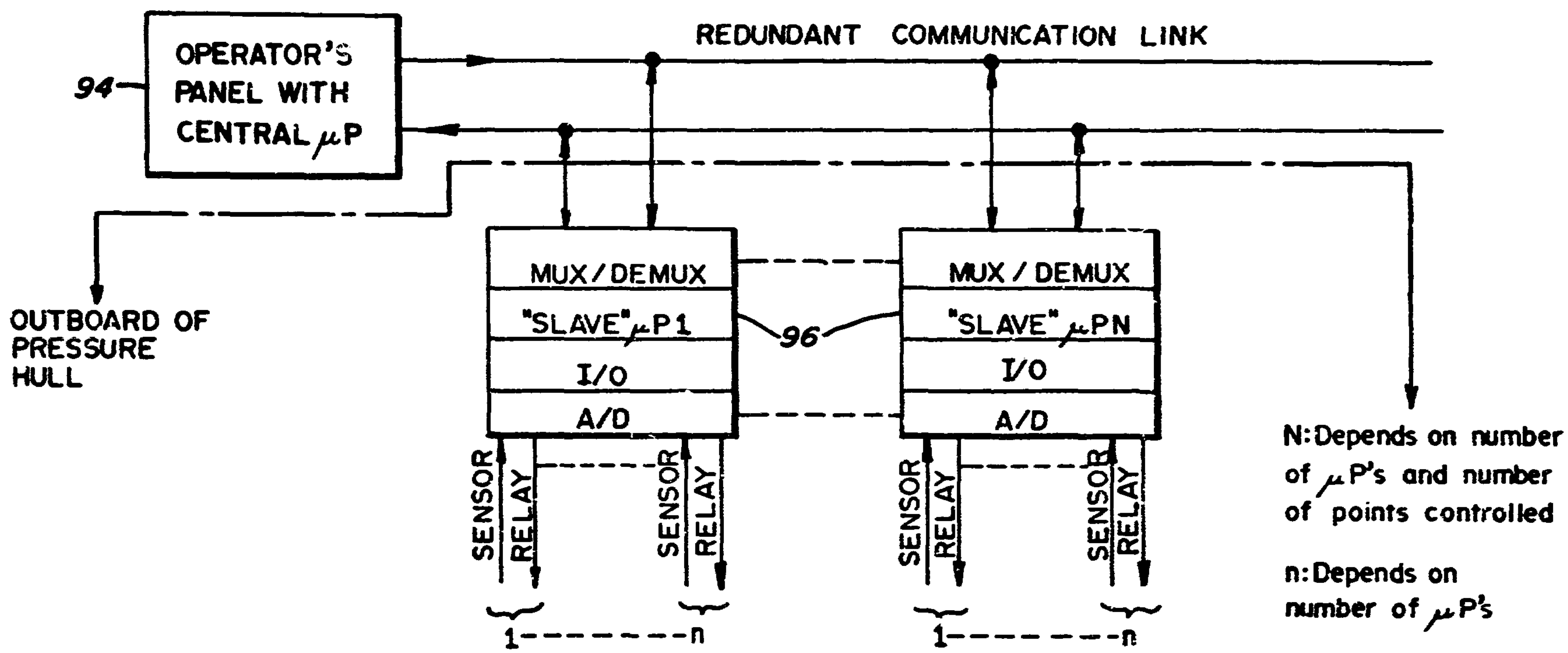

CONTACTOR
POWER BUSS
84(S)
SOURCE MICRO-COMPUTER
82(S)
REDUNDANT DATA LINK
80
OPERATOR'S PANEL MICRO COMPUTER
64 pressure hull
LOAD MICRO-COMPUTER 1
82(1)
RELAY AND LOAD 1
84(1)
LOAD MICRO-COMPUTER 2
62(2)
RELAY AND LOAD 2
84(2)
LOAD MICRO-COMPUTER N
82(N)
RELAY AND LOAD N
84(N)

FIG. 3



OPERATOR'S PANEL WITH CENTRAL μP
94
REDUNDANT COMMUNICATION LINK
OUTBOARD OF PRESSURE HULL
MUX / DEMUX
"SLAVE" μP1
I/O
A/D
96
MUX / DEMUX
"SLAVE" μPN
I/O
A/D
SENSOR
RELAY
SENSOR
RELAY
1--------n
SENSOR
RELAY
SENSOR
RELAY
1--------n
N: Depends on number of μP's and number of points controlled
n: Depends on number of μP's

FIG.4