

A GENERATION SHEDDING SCHEME FOR
THE JIM BRIDGER STEAM-ELECTRIC PLANT

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INTRODUCTION

Jim Bridger Plant, jointly owned by PacifiCorp and Idaho Power Company, is located forty miles east of Rock Springs, Wyoming, and is a typical mine-mouth, coal-fired, electrical generating station. It is equipped with four 500 MW units, and is connected through three 345 KV lines, to the eastern Idaho transmission system. There are three 345/230 kV transformers at Jim Bridger, and three 230 kV lines connecting to the Wyoming transmission system. The bulk of Bridger's output is transferred west across Idaho; thus both the Bridger lines and the lines across Idaho are crucial to stable operations. Figure 1 shows a simplified diagram of the Idaho and Wyoming Transmission System, and Figure 2 shows a one-line diagram of the Jim Bridger Substation.

Loss of any of these lines will cause a surplus of generated power at Bridger, and may result in system instability, depending on the total generation at the time. The Generation Shedding Scheme was developed to shed a block of generation (one or two machines) quickly upon loss of one or more of the critical transmission lines, if the plant output at the time exceeds the remaining transmission capacity.

The requirements for the Generation Shedding Scheme are to provide a set of fast, reliable, automatic controls to ensure system stability. The speed requirement is 16 milliseconds throughput time, from input detection to output trip initiation. The scheme must be reliable and respond correctly when action is required, and must be available for operation at all times.

The benefits of a correctly operating scheme are higher generation and power transfer levels throughout the transmission system. Failure of the scheme to operate correctly can cause unnecessary tripping of generators in the case of over-tripping, or can cause widespread tripping of transmission lines, loads, and other generators, in the case of failure to trip.

This paper describes first an electromechanical scheme, which has served for the past two decades, with one major rebuild. The paper then continues with a description of a new triply-redundant, microprocessor-based scheme, which performs the same functions as the original scheme, and is more adaptive to changing system conditions. The microprocessor scheme was placed in service as the primary Remedial Action Scheme (RAS-A) in September 1992, and the electromechanical scheme will be used as the backup Remedial Action Scheme (RAS-B). Figure 3 shows a block diagram of the Jim Bridger Generation Shedding Scheme.

ELECTROMECHANICAL SCHEME

FUNCTIONAL DESCRIPTION

The primary functions of the Generation Shedding Scheme are the determination of need to trip generation, and then which generators to trip. Within RAS-B, the Bridger Tripping Logic and Idaho Tripping Logic determine if there is a need to trip generation, and then the Bridger Unit Selection Logic and Idaho Unit Selection Logic determine which generators will be tripped.

Bridger Tripping Logic

Figure 4 shows the block diagram of the RAS-B Bridger Tripping Logic. The transmission lines that are monitored are the Bridger - Borah 345 kV Line, Bridger - Goshen 345 kV Line, Bridger - Kinport 345 kV Line, and the Bridger - Rock Springs 230 kV Line. The number of Jim Bridger generators to be tripped is shown on the block diagram. The generators to be tripped are determined by the Bridger Unit Selection Logic.

Bridger Unit Selection Logic

The Bridger Unit Selection Logic is used to determine which generators will be tripped to meet the trip requirements of the Bridger Tripping Logic. The logic follows the general requirements of tripping the unit associated with the line that trips out, in order to reduce the risk of splitting the two 345 kV buses. For two unit tripping, which is initiated by the two line out or three line out logic, the first line out will determine the first unit to be tripped, and the second line out will determine the second unit to be tripped.

The following is an example of the Unit Selection Logic for the Borah Line being the first one out:

1. Unit 1 will be tripped, provided Unit 1 is on line and not disabled from tripping by Disable Switch 43D1.
2. If Unit 1 is not available, another unit will be tripped, in the order 4,3,2, provided the unit is on line and not disabled from tripping by its disable switch.

The following is an example of the Unit Selection Logic for the Kinport Line being the second one out:

1. Unit 2 will be tripped, provided Unit 2 is on line, has not been selected in the first unit selection logic, and is not disabled from tripping by Disable Switch 43D2.
2. If Unit 2 is not available, another unit will be tripped, in the order 3,4,1, provided the unit is on line, has not been selected in the first unit selection logic, and is not disabled from tripping by its disable switch.

Idaho Tripping Logic

Figure 5 shows the RAS-B Idaho Tripping Logic. The trip signals come from Midpoint Substation in Idaho. The number of Jim Bridger generators to be tripped is shown in the block diagram. The line power levels are settings for devices at Midpoint Substation. The generation tripping levels are settings in RAS-B. The generators to be tripped are determined by the Idaho Unit Selection Logic.

Idaho Unit Selection Logic

The Idaho Unit Selection Logic is used to determine which generators will be tripped to meet the trip requirements of the Idaho Tripping Logic. The logic follows the general requirements of tripping Unit 4, to reduce the risk of splitting the two 345 kV buses.

The order of unit selection for the first unit to be tripped is as follows:

1. Unit 4 will be tripped, provided Unit 4 is generating above 350 MW, and not disabled from tripping by Disable Switch 43D4.
2. If Unit 4 is not available, another unit will be tripped, in the order 1,2,3, provided the unit is generating above 350 MW, and not disabled from tripping by its disable switch.

The order of unit selection for the second unit to be tripped is as follows:

1. Unit 1 will be tripped, provided Unit 1 is generating above 350 MW, has not been selected by the Trip First Unit Logic, and is not disabled from tripping by Disable Switch 43D1.
2. If Unit 1 is not available, another unit will be tripped, in the order 2,3, provided the unit is generating above 350 MW, has not been selected by the Trip First Unit Logic, and is not disabled from tripping by its disable switch.

HARDWARE DESCRIPTION

The RAS-B hardware consists of an intricate mesh of diodes, relays, timers, and level detectors. High speed operation is achieved through the use of logic circuits that operate concurrently, pre-armed circuits for power levels, and 1/8 cycle auxiliary relays with diode interfaces. Figure 6 shows the RAS-B Panels. This complex logic network is described below.

The RAS-B Generator Available Logic is shown in Figure 7. Since the circuit breaker common to the line and generator is hard-wired to the line, and the generator breaker is hard-wired to the bus, closure of either breaker indicates that the generator is on-line, provided that the generator disconnect switch is closed (89GnXA) and the manual disable switch has not excluded the generator from being selected (43DnX). The breaker disconnect switches are assumed closed. If all these conditions are met, the relay 03Gn will be energized, and provide input to the rest of the logic that the generator is available.

The RAS-B Switchyard Switching Device Position Logic is shown in Figure 8. In order to minimize multiple cable conductor runs out to the breaker pallet switches, a single breaker "b" pallet switch is brought in and operates a multi-contact auxiliary relay called bX. Likewise, contacts on the existing 89GnXB relay are used for the generator disconnect logic input. These bX contacts are stacked in such a way as to provide for a "key facility" loss trip, should the breaker configuration become such that the 345 kV yard buses are electrically split apart. The relays 3A through 3H represent groupings of contacts and circumvent the need to restack individual contacts each time the grouping is needed in the Line Tripping and Status Logic.

The RAS-B Line Tripping and Status Logic is shown in Figure 9. Relay contacts 94G and 94W are from the 345 kV line protective relay trip outputs, with G indicating the General Electric relays and W indicating the Westinghouse relays. These activate the line trip relay 94Ln directly and immediately upon line fault detection, which should trip the line breaker and the common

breaker that separate the line from the switchyard. The pallet switch auxiliary relays (bX) follow through to continue the open breaker input to the logic; otherwise reset of the 94G and 94W relays following fault clearing might not permit the scheme to complete its functions. Other inputs to the relay 94L are the groupings of contacts which monitor the other pathways through the buswork, as described in the Switchyard Switching Device Position Logic.

The RAS-B Power Level Processing is shown in Figure 10. The output power of the four generators and the three 345 kV lines, are represented by watt transducers. The watt transducer outputs are summed with solid-state, plug-in, operational amplifier modules. The summing modules drive analog control modules with relay outputs, six for the generation total, and one for the 345 kV lines west flow total, whose contacts close as the input to the module rises past the module setpoint. These contacts in turn activate multi-contact auxiliary relays, in order to provide outputs to the logic and the Sequence of Events Recorder.

The core of the RAS-B Generation Shedding Scheme is shown in Figure 11. At the top of the figure is the contact and diode logic, which provides information to the Unit Selection Logic as to which line has relayed or is open, as well as to the Power Level Logic as to how many lines are open.

The Power Level Logic determines how many generators need to be shed, one or two, to maintain stability if one, two, or three lines are open. For example, if the plant output is above 1300 MW (32-4X) and one line relays with a multi-phase fault, verified by the SPCU relays, the relay 94T1 will be activated to trip one unit. Meanwhile, the Unit Selection Logic is already searching for a unit to trip, as will be described in the Unit Selection Logic. On the other hand, if the fault is a single-line-ground fault, 94T1 will not be activated until the 345 kV lines west flow is above 2050 MW (32-7X) if the Idaho transmission system is normal (ISSR/Normal), or until the plant output is above 1750 MW (32-6X) if the Idaho transmission system is abnormal (ISSR/Abnormal). The Idaho System Status Relay (ISSR) is operated by the PacifiCorp Dispatchers at the request of the Idaho Power Dispatchers.

Loss of a second line will activate relay 94T1 to trip one unit if the plant output is above 1100 MW (32-3X), and will activate relay 94T2 to trip a second unit if plant output is above 1550 MW (32-5X). Loss of a third line will activate relay 94T1 to trip one unit if the plant output is above 525 MW (32-1X), and will activate relay 94T2 to trip a second unit if plant output is above 1050 MW (32-2X). No discrimination is required between multi-phase faults and single-line-ground faults for the two and three line out tripping logic.

The Unit Selection Logic determines which generators shall be tripped when shedding is required. Figure 12 shows the RAS-B Level 1 Unit Selection Logic, for selection of the first unit to trip. The Unit Selection Logic is supplied with outputs from the Line-Out Logic, indicating which lines are open, and outputs from the Generator Available Logic, indicating which units are on-line to be shed.

For example, if Generator 1 is available, indicated by contact 03G1 closed, and the Borah Line relays (in the same switchyard bay), this will energize the "1" bus in the Unit Selection Logic. Current will flow through diode D17, through the closed contact of 03G1, through the closed back contacts of the other selection output relays (94-2X, 94-3X, 94-4X) to verify that none of the other units is currently being selected, which activates relay 62-1X, which in turn activates relay 94-1X. Concurrently, if the power level logic has called for a first unit trip, by energizing relay 94T1, the unit tripping relay 94D1 will be activated by the 94T1 and 62-1X contacts in series. Multiple contacts from the 94D1 relay trip the Generator 1 lockout relay, if enabled by the Failover System. Figure 13 shows the RAS-B Unit Tripping Relay Logic.

However, if the Borah Line relays, but Generator 1 is unavailable, current will flow through diode D17, through the back contacts of the de-energized relay 03G1, through diode D19, to contact 03G4. If relay 03G4 is energized, Generator 4 will be tripped, in a similar manner to that described above, through relay 94D4. If relay 03G4 is not energized, current will continue through diode D23 and try to select Generator 3, and so forth.

If the shedding of a second generator is required, similar logic is used, except that the order of default is 1-2-3-4, instead of 1-4-3-2 (the diodes are reversed). First preference is still a generator in the same bay as an open line.

Figure 14 shows the Jim Bridger portion of the RAS-B Idaho Tripping Logic. There are redundant transmitters, communication channels, and receivers for the Level 1 and Level 2 trip signals that are sent from Midpoint Substation in Idaho to Jim Bridger Substation. The same receivers energize separate auxiliary relays that provide inputs to the RAS-A (94MWn, 94TLn) and RAS-B (94RXn) systems. There are analog setpoint devices (96Gn) that pick up when the individual generator outputs exceed 350 MW, energizing the 96Xn relays, which provide the generator available input to the Idaho Unit Selection Logic. Selection of a unit for tripping is similar to the Bridger Unit Selection Logic, with the addition of logic to steer selection to the same unit as selected by the Bridger Selection Logic if simultaneous operation of both schemes happens to occur. Otherwise, the selection will default to Generator 4, if available, with the sequence of 1-2-3 if 4 is unavailable.

MICROPROCESSOR SCHEME

FUNCTIONAL DESCRIPTION

Within RAS-A the Bridger Tripping Logic and Idaho Tripping Logic determine if there is a need to trip generators, and then the Unit Selection Logic determines which generators will be tripped.

Bridger Tripping Logic

Figure 15 shows the block diagram of the RAS-A Bridger Tripping Logic. The transmission lines that are monitored are the Bridger - Borah 345 kV Line, Bridger - Goshen 345 kV Line, Bridger - Kinport 345 kV Line, and the Bridger - Rock Springs 230 kV Line. The minimum amount of Jim Bridger generation to be tripped is calculated using the formulas listed in the block diagram. The generators to be tripped are determined by the Unit Selection Logic.

The following definitions explain the terms used in the formulas:

- G = variable representing the amount of Bridger generation to be tripped, in MW
- F = a variable representing the sum of the three 345 kV lines real power flow west, in MW, prior to a disturbance, measured at the Jim Bridger 345 kV terminal
- P = a variable representing the total Plant net real power output, in MW, prior to a disturbance, measured at the 345 kV terminal
- Q = a variable representing the total Plant net reactive power output, in MVAR, prior to a disturbance, measured at the 345 kV terminal
- B = a variable representing the analog Bias signal from Idaho, which represents a reduction of the Idaho system capability to transfer power flows from Jim Bridger
- S = a variable representing the total series compensation remaining on the 345 kV lines after a disturbance
- F1 = a constant setting representing unit tripping sensitivity for two lines out

F2 = a constant setting representing the 345 kV lines real power flow west, in MW, prior to a disturbance, above which generation is tripped for two lines out

F3 = a constant setting representing unit tripping sensitivity for three lines out

F4 = a constant setting representing the total Plant net real power output, in MW, above which generation is tripped for three lines out

K1, K2 = constant settings representing unit tripping sensitivity to total series compensation on the three 345 kV lines

K3 = a constant setting representing unit tripping sensitivity to the Idaho Bias signal

K4, K5 = constant settings representing unit tripping sensitivity to the total Plant net reactive power output; Q-K5 is only valid as a positive number, if $Q < K5$ then $Q - K5 = 0$

P1 = a constant setting representing the amount of Jim Bridger generation, in MW, to be tripped for a one line out with a multi-phase-fault condition

The following example shows a calculation for a normal system with a Kinport Line single-line-ground fault:

Preconditions:

Plant loading = 2100 MW, 400 MVAR
345 kV line loading = 2080 MW
All series capacitors in service
Idaho Bias = 50

One Line Out Calculation for Bridger Tripping Requirement:

Variables:

F = 2080
S = $90/135 = 0.667$
B = 50
Q = 400

One Line Out Formula:

$G = F - [(K1 * S + K2) - K3*B - K4*(Q - K5)]$
 $G = 2080 - [(570*0.667 + 1670) - 2*50 - 0.5*(400-350)]$
 $G = 2080 - [(380 + 1670) - 100 - 25]$
 $G = 2080 - [2050 - 100 - 25]$
 $G = 2080 - 1925 = 155 \text{ MW}$

The Bridger Tripping Requirement is 155 MW; the unit to be tripped will be determined by the Unit Selection Logic; generally this will be the unit(s) with the minimum output above the tripping requirement.

Idaho Tripping Logic

Figure 16 shows the RAS-A Idaho Tripping Logic. The trip signals come from Midpoint Substation in Idaho. The minimum amount of Jim Bridger generation to be tripped is shown in the block diagram. The line power levels are settings for devices at Midpoint Substation. The generation tripping levels are settings that are programmed into the RAS-A. The generators to be tripped are determined by the Unit Selection Logic.

Unit Selection Logic

The same Unit Selection Logic is used to determine which generators will be tripped to meet the trip requirements of the Bridger Tripping Logic and the Idaho Tripping Logic. If trip requirements are present from both the Bridger Tripping Logic and Idaho Tripping Logic, the larger of the two will be used.

The Unit Selection Logic follows the general requirements of (1) select the minimum number of generators that exceed the trip requirement, (2) use the dispatcher's preference (disable or arm a unit for tripping) if all other conditions are met, (3) the two 345 kV switchyard buses will not be split after the units have been tripped, and (4) a maximum of two generators will be selected.

The order of unit selection is as follows:

1. Find a single unit which will not split the buses and will satisfy the trip requirement.
 - 1.1 Select the unit that is selected by the dispatcher, will not split the buses, and has a power output greater or equal to the trip requirement.
 - 1.2 Select the lowest unit that is not disabled by the dispatcher, will not split the buses, and has a power output greater or equal to the trip requirement.
 - 1.3 Select the lowest unit that will not split the buses, and has a power output greater or equal to the trip requirement.

2. Find a pair of units that will not split the buses, and will satisfy the trip requirement.
 - 2.1 Select the lowest pair of units that will not split the buses, and have a power output greater or equal to the trip requirement.
3. Find a single or pair of units that will not split the buses.
 - 3.1 Select the largest pair of units that will not split the buses.
 - 3.2 Select the largest single unit that will not split the buses.
4. Last resort.
 - 4.1 Select the unit with the largest power output.

HARDWARE DESCRIPTION

The major hardware components of RAS-A are the Programmable Logic Controller (PLC), SCADA (Supervisory Control And Data Acquisition) Protocol Converter, Video Display Unit (VDU), Input/Output (I/O) Control Panel, Failover Control Panel, Power Supply System, and Surge Protection. Figure 17 shows the RAS-A Panels.

The PLC is an industrial-hardened, fault-tolerant, triplicated computer system. Fault tolerance is defined as the ability to operate correctly when one or more components have failed. The high-speed Hardware-Implemented-Fault-Tolerance (HIPT) is achieved through the use of Triple-Modular-Redundant (TMR) architecture. Redundancy is implemented with triple Central Processing Units (CPU), triple power supplies, triple analog and digital inputs, and redundant digital outputs. Figure 18 shows a simplified diagram of this architecture.

TMR provides for masking and detection of single contingency component failures through two-out-of-three voting on all I/O and memory operations. Figure 19 shows the three possible voted results and the actions that follow. In a vote, if all three agree, then normal operation continues. If one of the three disagrees, then the failed component is detected, masked, and annunciated, and operation continues. After one component has failed, and before the failed component is replaced, if the remaining similar components disagree on a vote, the failure is detected and annunciated, and the system fails over to the backup system without taking any control action.

Through use of the redundant modular components and the triplicated voting scheme, the RAS-A has been designed with a mean-time-between-failure (MTBF) rate of 20 years.

The SCADA Protocol Converter is an industrial-hardened personal computer that translates between the SCADA communication protocol and the PLC communication protocol. The software is written in a programming language known as C. Through the Protocol Converter, the RAS-A appears just like a Remote Terminal Unit (RTU) to the SCADA master computer, and can provide the SCADA dispatcher the same status reporting and control functions of an RTU. Two special RAS-A screens have been programmed into the SCADA master computer to provide the interface to RAS-A: Figure 20 shows the RAS-A Bridger One Line Screen, and Figure 21 shows the RAS-A Alarm Screen. The SCADA dispatcher will input to the RAS-A changes in the Idaho Bias, and unit selection for arming or disabling tripping. The RAS-A will report back to SCADA the status of the generators and transmission lines, next contingency trip requirements, units armed, and a number of alarms.

The VDU is a personal computer system, with keyboard, monitor, disk drives, and printer. The VDU software consists of an interface program written in the C programming language, and the Program Development System used to program and communicate with the RAS-A PLC. The VDU serves as a local maintenance and backup dispatcher interface to the RAS-A. The technicians will use the VDU during maintenance for programming and setting changes, diagnostics, and testing the RAS-A. In the event the SCADA dispatcher interface is not available, the VDU can be used as a backup dispatcher interface to input the Idaho Bias or unit tripping selection, and monitor the RAS-A. The backup dispatcher interface contains a Bridger One Line Screen and an Alarm Screen, which are nearly identical to the SCADA screens.

The I/O Control Panel contains test switches, and interposing relays. The test switches are used to disconnect the RAS-A from field wiring, and connect the RAS-A to a simulator for testing. The interposing relays are used to trip the 345 kV circuit breakers, and are used in the failover system control.

The Power Supply System includes a triplicated set of DC to AC inverters, and redundant circuit breakers for distribution of power within the RAS-A system. The inverters convert the 130 VDC substation battery voltage to 115 VAC for use by the PLC. Redundant circuit breakers within the RAS-A system allow replacement of failed components.

Surge Protection is provided for all RAS-A components to protect them from power surges that may be introduced by transients in the substation. Surge protection is installed on all I/O, power supply inputs, and data communication circuits.

SOFTWARE DESCRIPTION

The RAS-A PLC operates on an application software program consisting of several Function Blocks, to provide the necessary remedial actions. The software is written in a programming language known as Relay Ladder Logic. Many parts of the RAS-A program are the software equivalent to the RAS-B hardwired logic.

The Function Blocks are called Digital, Analog, Dispatch, Bridger, Idaho, Select, and Output. The Digital and Analog Function Blocks provide input verification and scaling for the digital and analog inputs to the RAS-A. Figure 22 shows part of the Analog Function Block where the Unit 1 MW inputs are voted. The Dispatch Function Block monitors the SCADA and VDU dispatcher inputs for changes in the Idaho Bias and unit tripping selection. The Bridger Function Block monitors the Bridger transmission lines and generators, and determines how much generation to trip in response to a line fault or outage. Figure 23 shows part of the Bridger Function Block where the generation tripping requirement is calculated. The Idaho Function Block determines how much generation to trip for loss of key Idaho transmission lines. The Select Function Block determines which Bridger generators to trip. The Output Function Block turns on the outputs for tripping generators, and annunciates to the Sequence of Events Recorder (SER) and SCADA system. Figure 24 shows part of the Output Function Block with the Unit 1 trip output.

FAILOVER SYSTEM

The Failover System provides control over RAS-A and RAS-B outputs, such that only one system has its outputs enabled at a time. Normally the RAS-A will be inservice with its outputs enabled, and RAS-B outputs will be disabled. Both systems will have their inputs connected and be operational.

If RAS-A has a second contingency failure, the Failover System will automatically transfer control from RAS-A to RAS-B. Manual control is required to move from RAS-B back to RAS-A, and manual control is provided to change from RAS-A to RAS-B. The Failover System consists of a selector switch, and self-resetting auxiliary relays which are held energized by RAS-A. Figure 25 shows Failover System Wiring for a typical generator trip output. The RAS-A and RAS-B outputs to the SCADA RTU and Sequence of Events Recorder are not connected through the Failover System.

MONITOR SYSTEMS

Many status and alarm points are wired from RAS-A and RAS-B to the Sequence of Events Recorder (SER) at Jim Bridger Substation. The SER is time synchronized to 1 millisecond with a satellite clock receiver. The status and alarm points are printed on the local SER printer at the substation, and also at remote SER printers in the local operations office and in the operations support office in Portland. The SER data is used for post-disturbance analysis of RAS operations.

Status and alarm points are also wired into the SCADA RTU at Jim Bridger Substation. In the event of a hardware failure in RAS-B or a hardware or software failure in RAS-A, the SCADA dispatchers will receive an alarm indication that there is a problem, and Technicians will be sent to the substation to investigate the problem.

On the front of the RAS-A and RAS-B panels there are many alarm and status lights that indicate the status of the inputs and hardware components; these lights will be used by technicians to diagnose problems. In addition, the technicians can use the RAS-A VDU to view the software or look at fault history logs within the programmable controller system to locate problems.

In the event of a hardware component failure in RAS-A or RAS-B, a complete set of spare parts is stored at Jim Bridger Substation for use by the technicians in correcting problems.

TEST SYSTEMS

Test simulators have been built for both the RAS-A and RAS-B systems to provide closed-loop simulations for periodic testing of the logic, hardware, and settings. The RAS systems have test switches which provide isolation from the field devices, and connection to the test simulator hardware. The RAS-A Test Simulator hardware consists of a personal computer input/output system, and the RAS-B Test Simulator hardware is a small programmable controller; both provide simulated input and output connections to the RAS systems. Test cases have been programmed into the test simulators with the same sequences and timing as the field devices to simulate real events. To fully test each system requires running over one hundred test cases, and usually takes two work days to complete.

PERFORMANCE

The critical transmission lines for the Jim Bridger Generation Shedding Scheme trip due to fault conditions 50-75 times per year, and the Generation Shedding Scheme is called upon to trip units 5-15 times per year. With this high frequency of remedial action, the RAS-A and RAS-B systems have had plenty of opportunity to prove themselves.

The RAS-B system has performed very well over the years, with over fifty operations. There have been some problems with burned tripping contacts, analog component failures, and analog calibration problems.

The RAS-A system has been monitored for the past year and has reported correct performance to the SER for all events. There have been some hardware problems with input transducer failures, and one inverter failure, but all were alarmed, and repaired as first contingency problems.

Both the RAS-A and RAS-B have shown operating times on the SER of 13-20 milliseconds, from input detection to trip output, which is within the expected performance of the systems.

CONCLUSION

The design of a remedial action scheme for system stability control requires high reliability and fast response. The Jim Bridger Generation Shedding Scheme has met these requirements with two separate hardware schemes over the past two decades.

The original electromechanical scheme, known now as the backup Remedial Action Scheme (RAS-B), has performed very well for twenty years. The RAS-B has hardwired logic, made up of relays, timers, diodes, and analog setpoint devices, and is limited in its logic capability and flexibility to system changes.

The new microprocessor-based scheme, known as the primary Remedial Action Scheme (RAS-A), has performed well over the past year. The RAS-A has the advantages of being software programmable and therefore more easily adaptable to system changes, and of having a triple-modular-redundant architecture, which provides for component failure detection and therefore more reliable operation.

ACKNOWLEDGEMENTS

The authors want to acknowledge the efforts many individuals that have contributed to the design of the Jim Bridger Generation Shedding Scheme. Dave Franzel, Floyd Hammerquist, and Tarcy Lee from PacifiCorp, and Charles Childers and Ajay Sood from Idaho Power Company, worked on the original electromechanical scheme. Charles Charman, from PacifiCorp, worked on a major rebuild of the electromechanical scheme. Wade Batchelor, Dharam Gupta, Dave Harries, Jeff Littman, Tarcy Lee, Dean Miller, Bernie O'Connell, and Dave Reynolds from PacifiCorp, and Jerry Jardine, John Prescott, and Ajay Sood from Idaho Power Company, were on the Design Team for the new microprocessor-based scheme. Dan Dodge, from Advanced Control Technology, the RAS-A Project Contractor, coordinated the Project Team at Advanced Control Technology. Craig Twete, from Industrial Control Services, the RAS-A programmable controller vender, provided factory support.

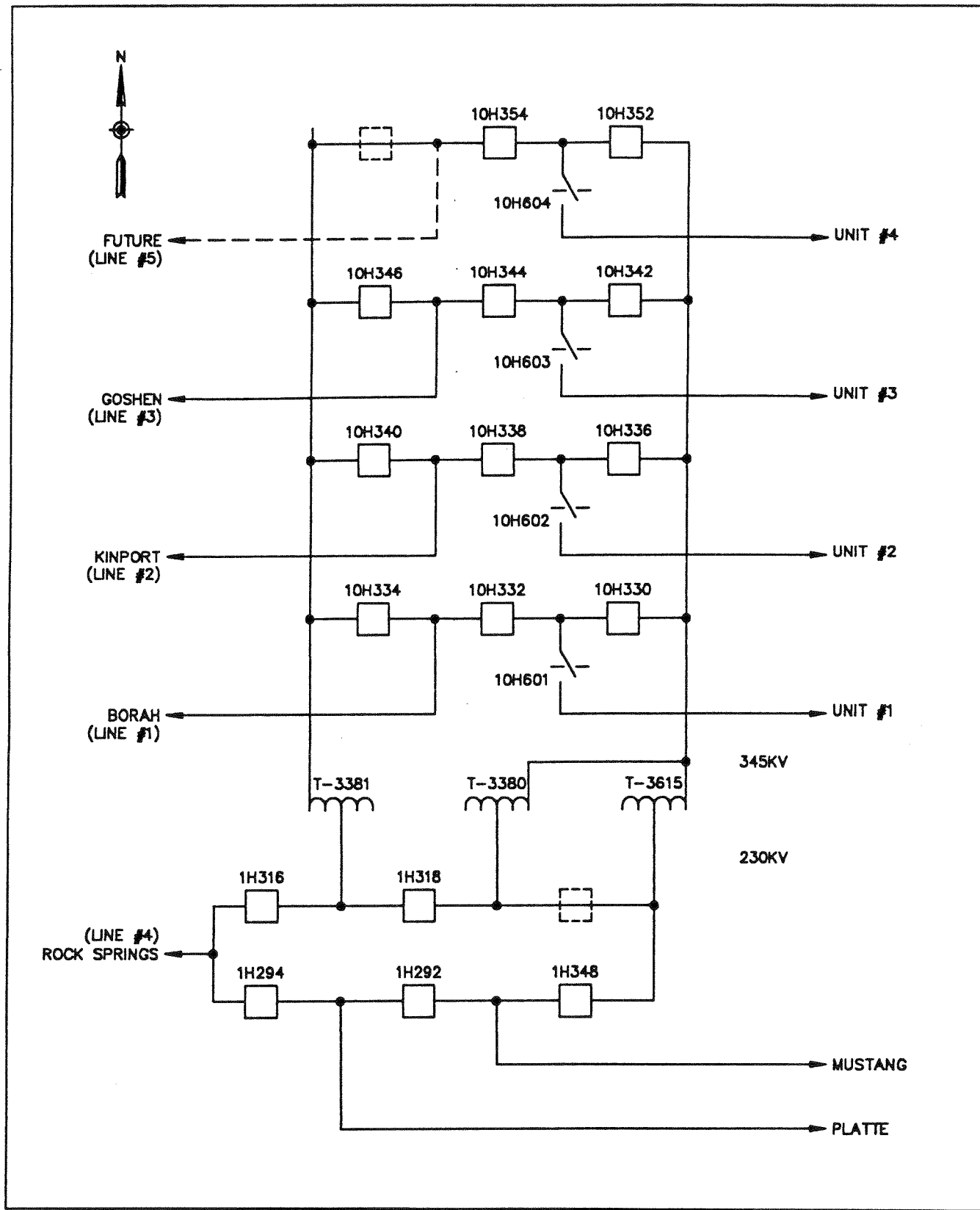


FIGURE 2 JIM BRIDGER SUBSTATION

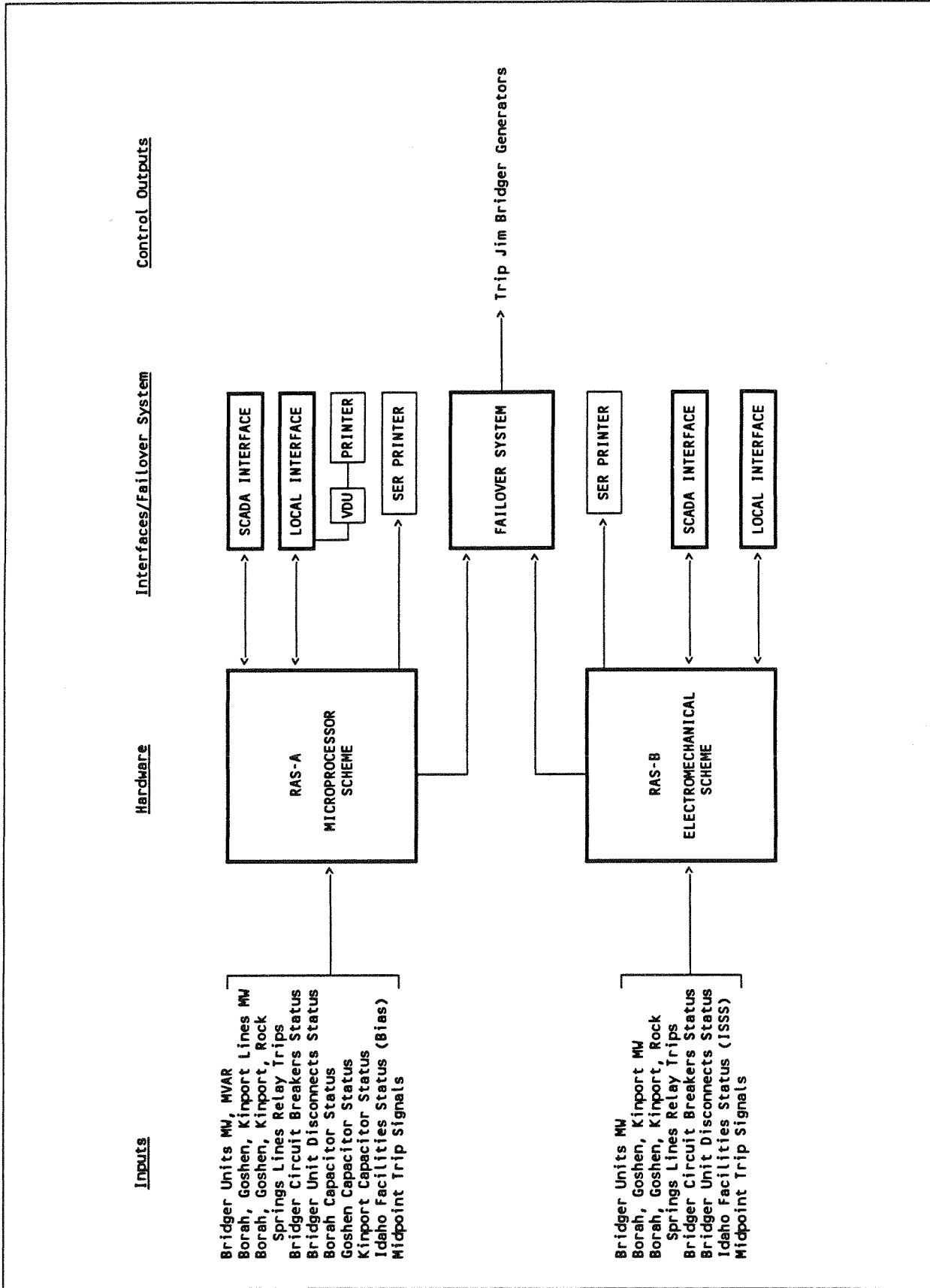


FIGURE 3 JIM BRIDGER GENERATION SHEDDING SCHEME

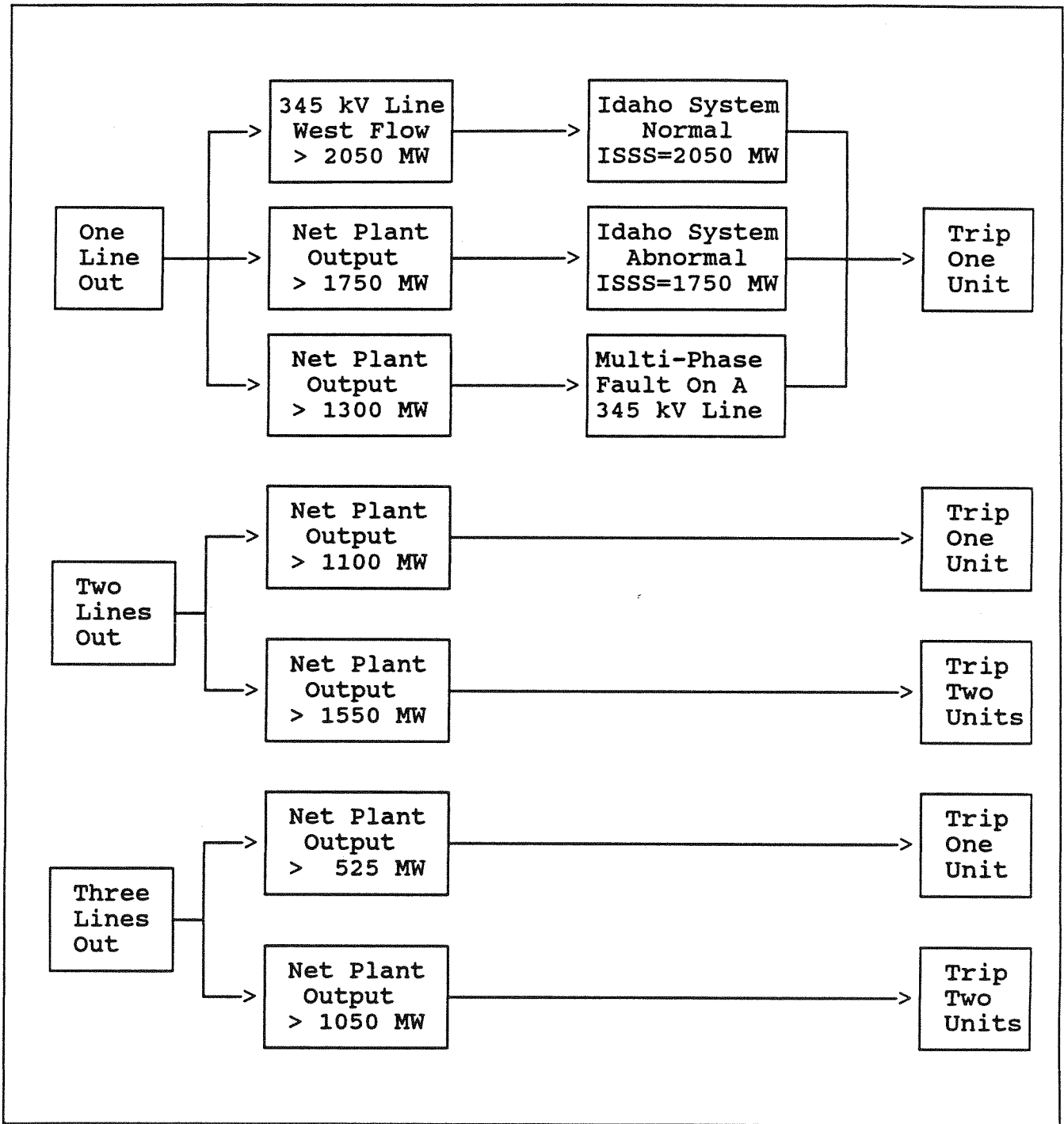


FIGURE 4 RAS-B BRIDGER TRIPPING LOGIC

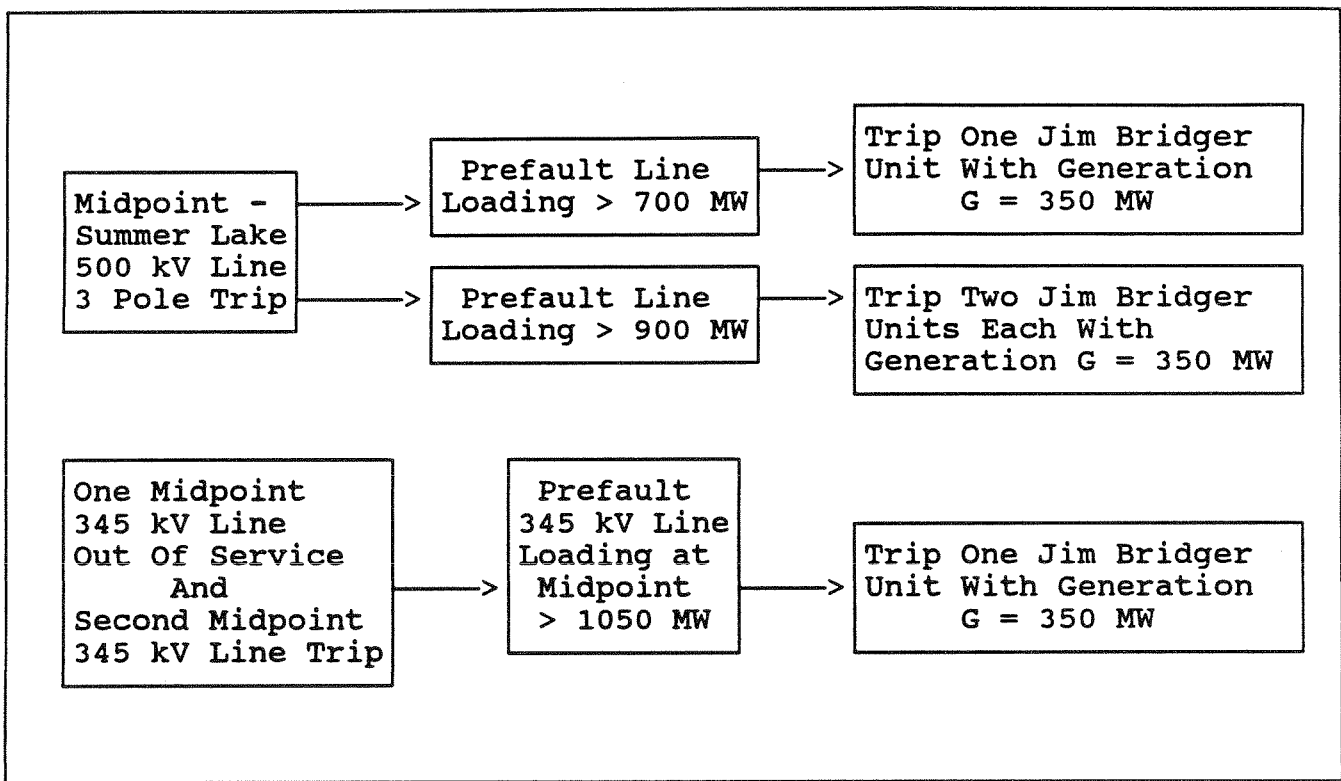


FIGURE 5 RAS-B IDAHO TRIPPING LOGIC

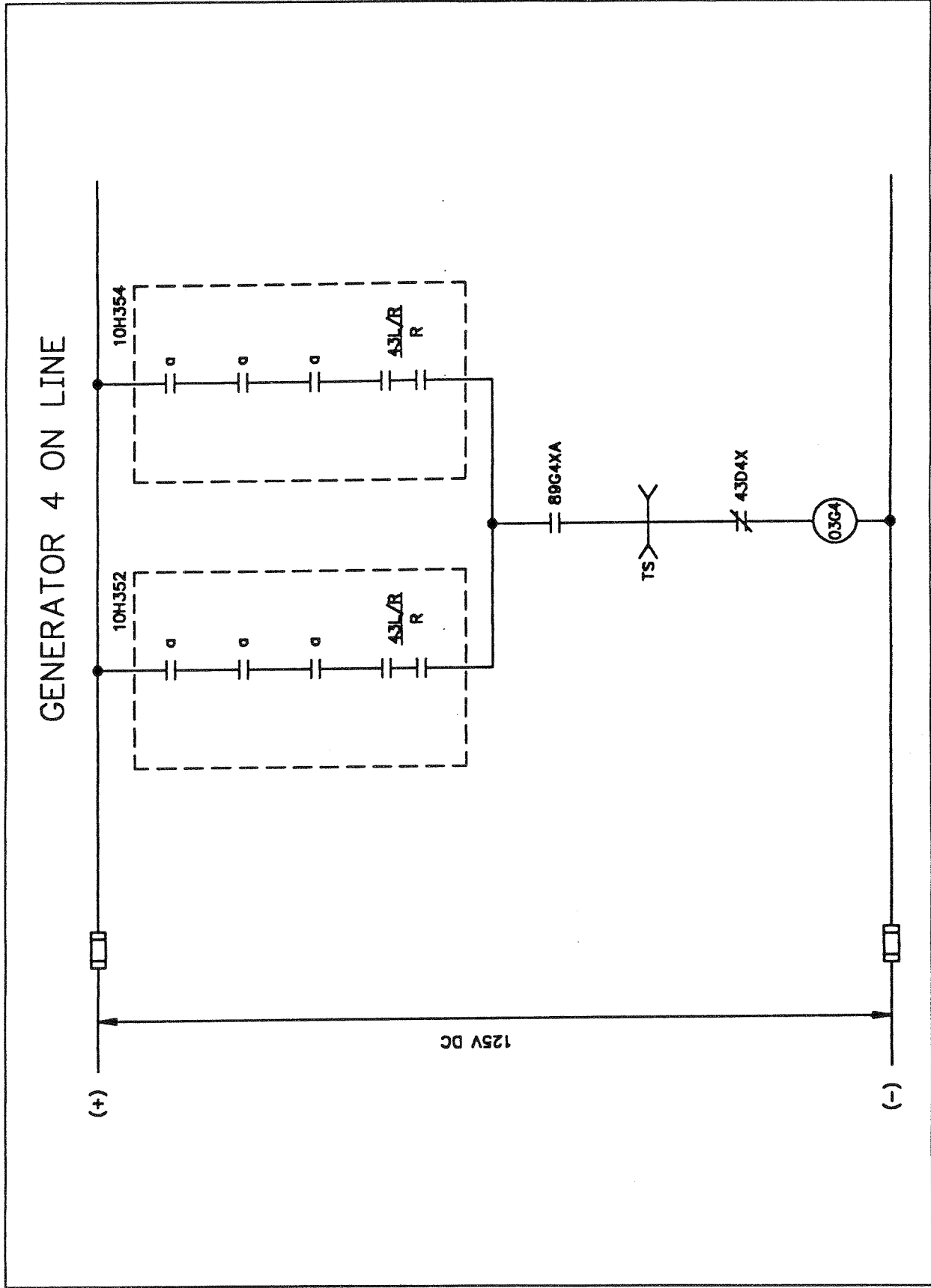


FIGURE 7 RAS-B GENERATOR AVAILABLE LOGIC

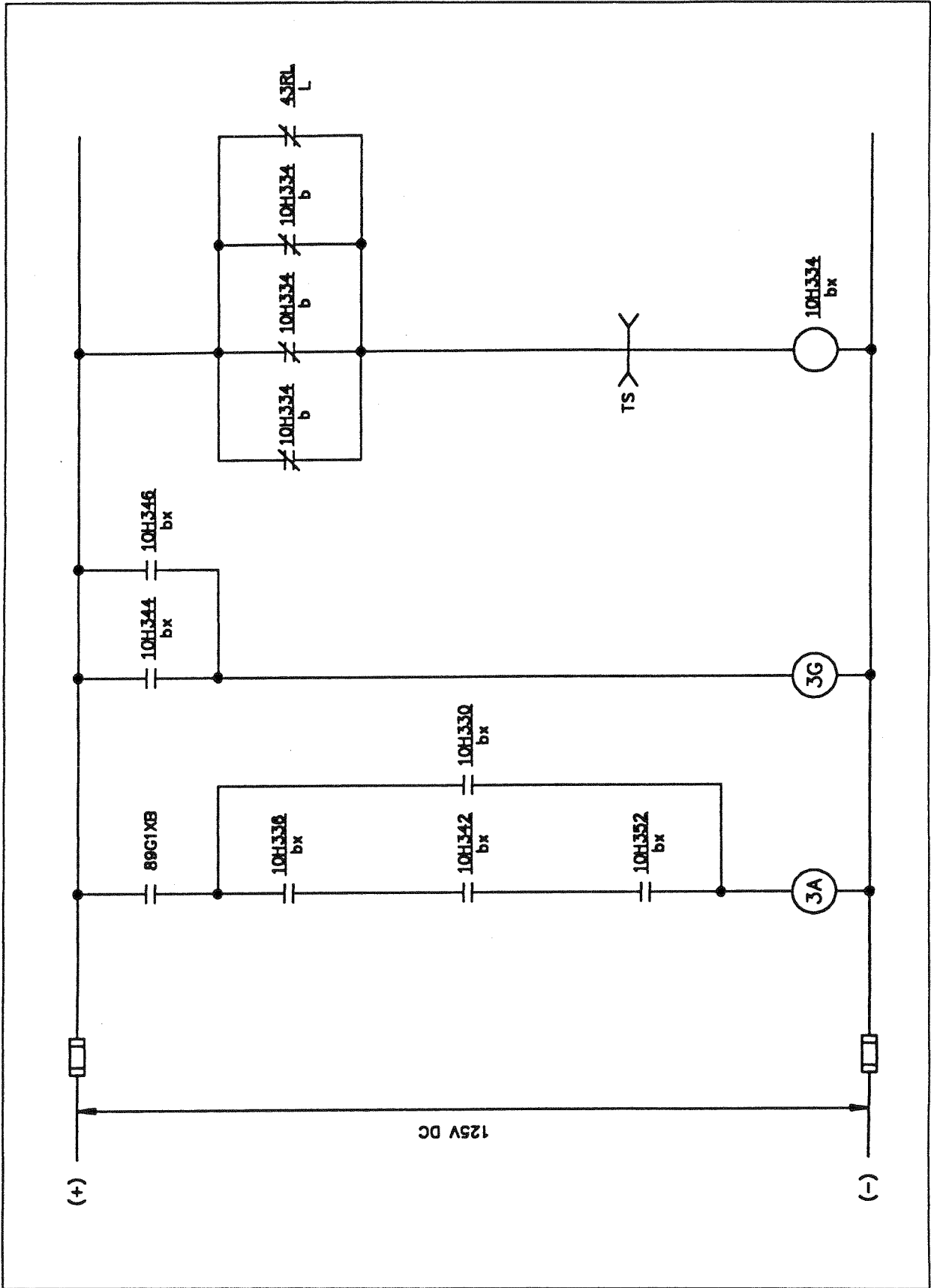


FIGURE 8 RAS-B SWITCHYARD SWITCHING DEVICE POSITION LOGIC

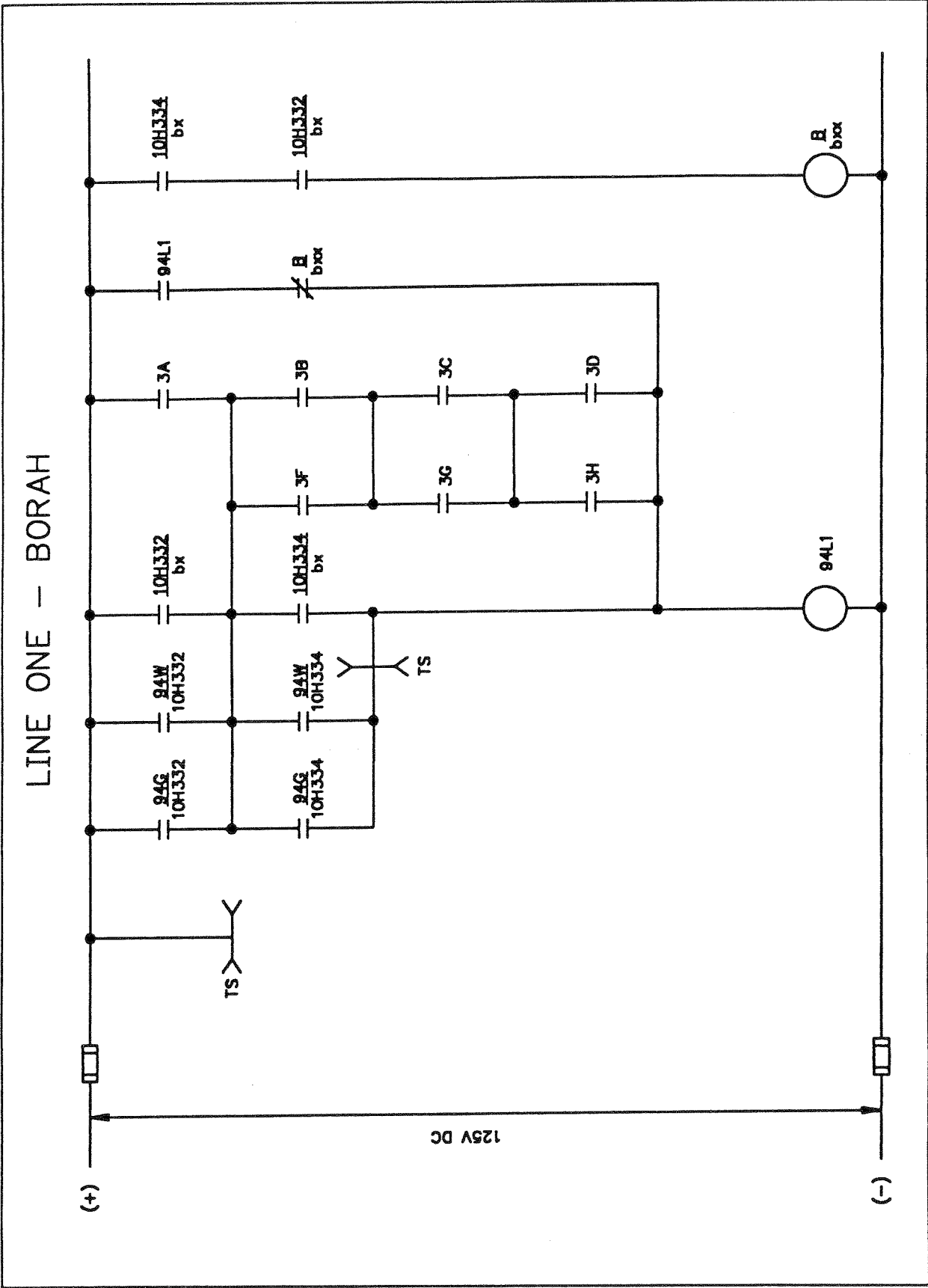


FIGURE 9 RAS-B LINE TRIPPING AND STATUS LOGIC

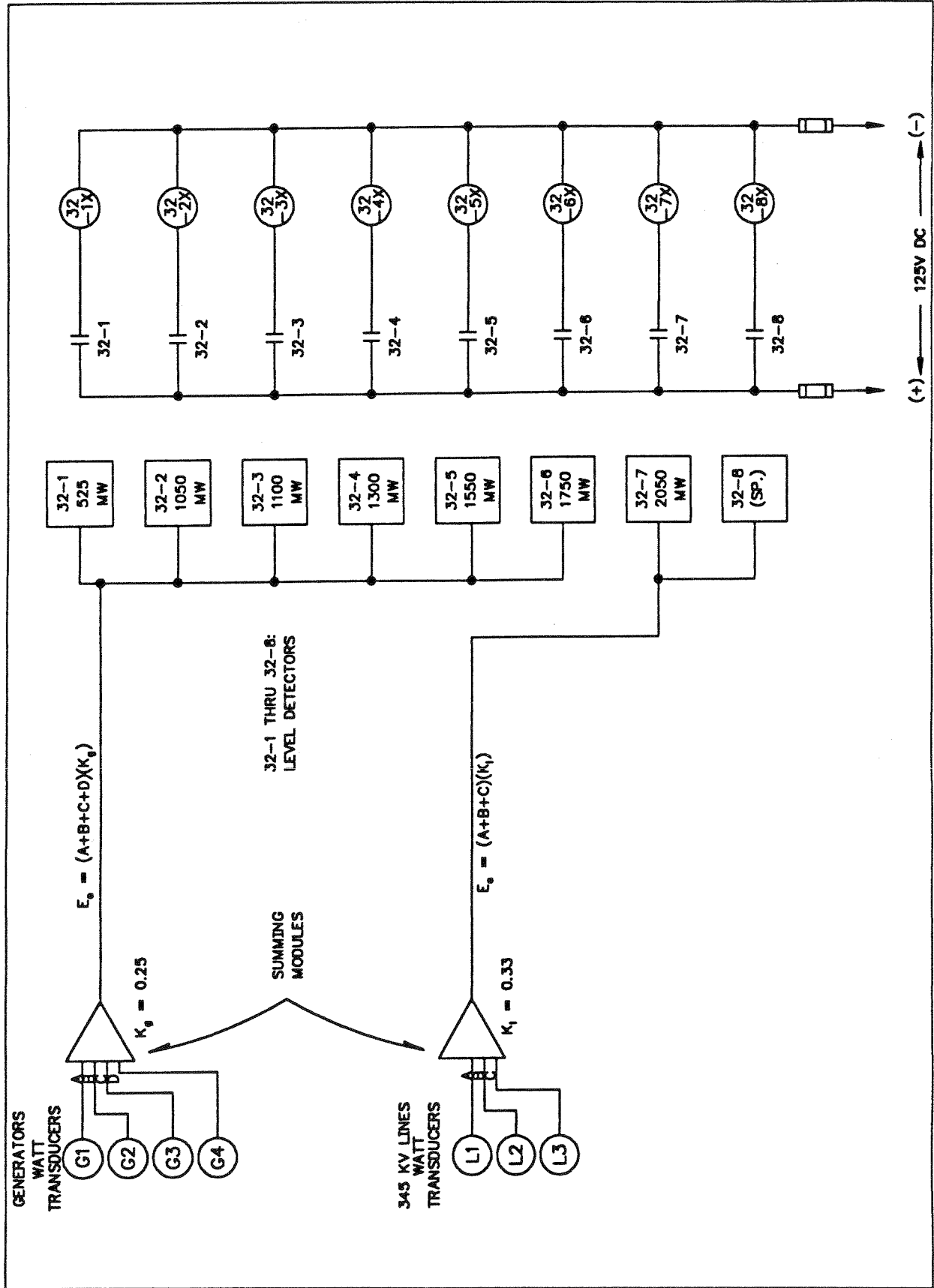


FIGURE 10 RAS-B POWER LEVEL PROCESSING

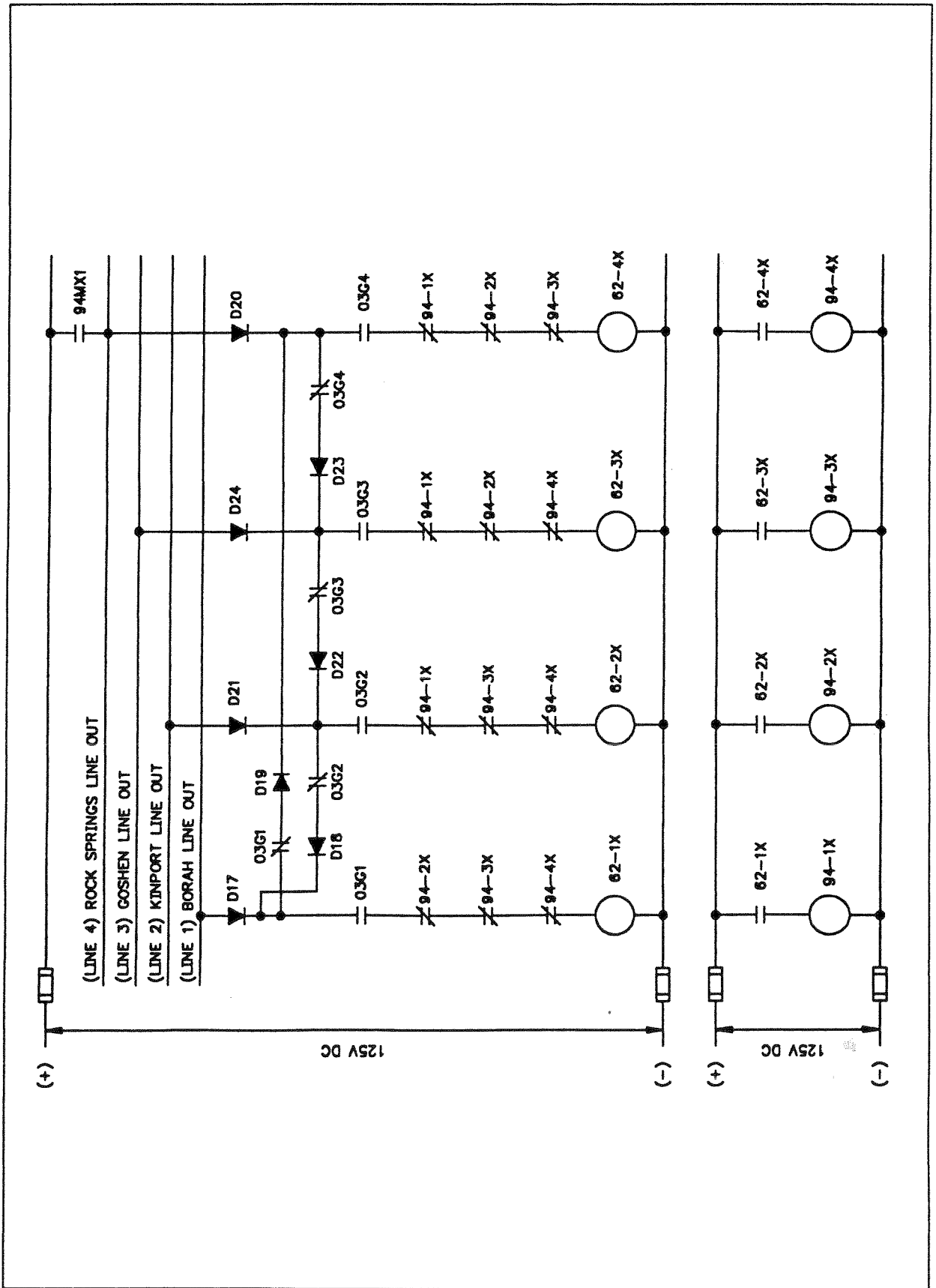


FIGURE 12 RAS-B LEVEL 1 UNIT SELECTION LOGIC

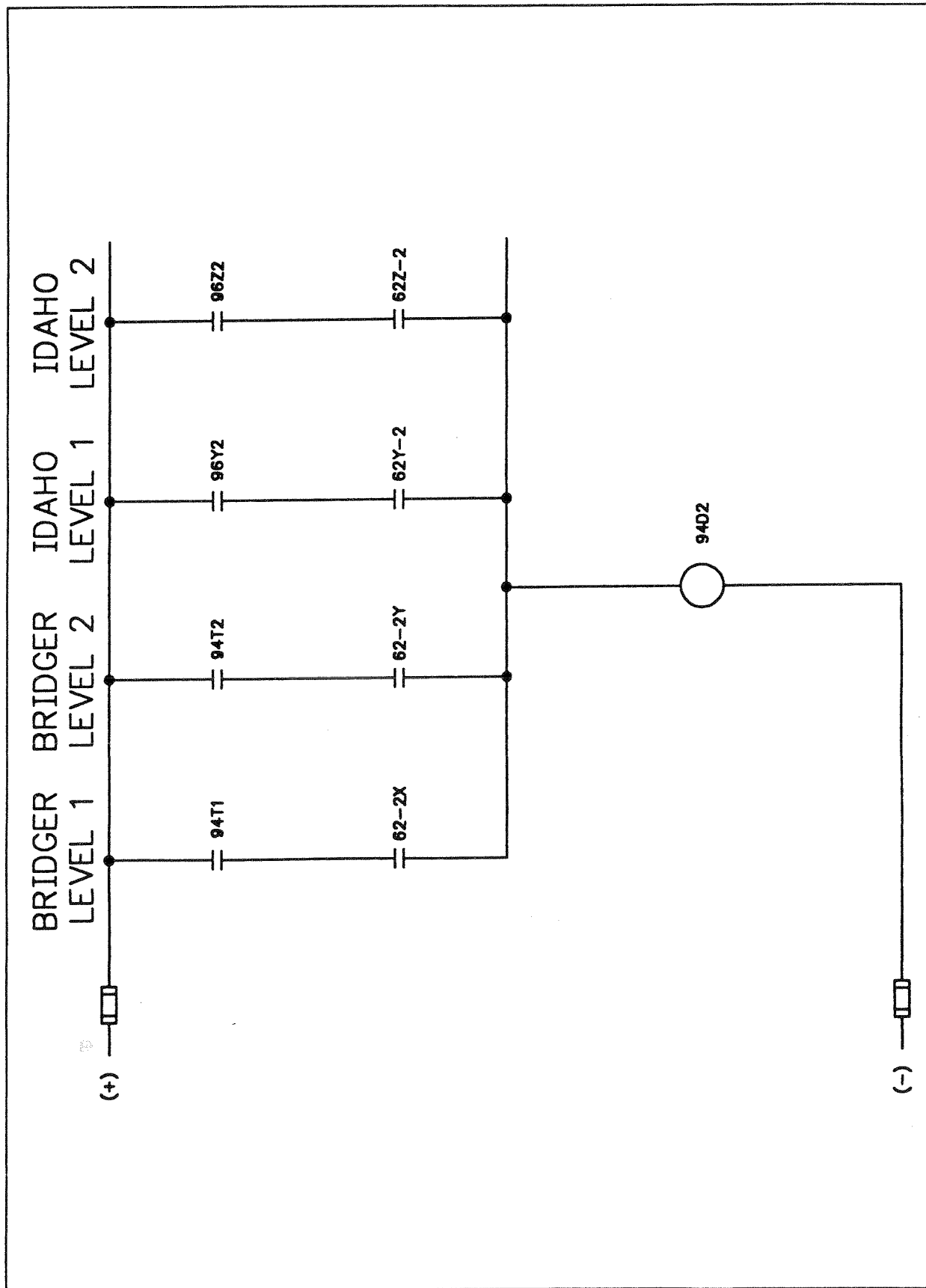


FIGURE 13 RAS-B UNIT TRIPPING RELAY LOGIC

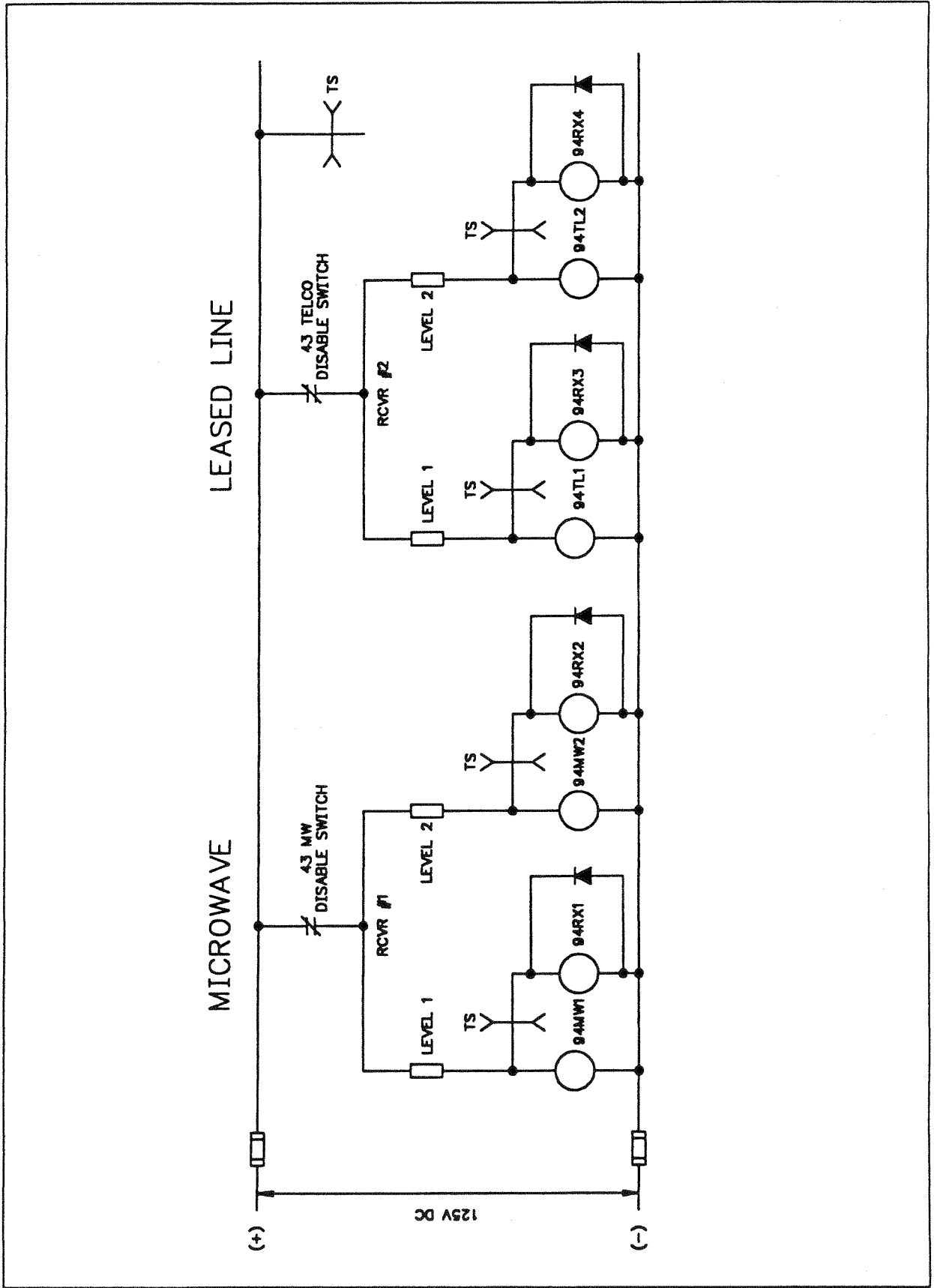


FIGURE 14 RAS-B IDAHO TRIPPING LOGIC

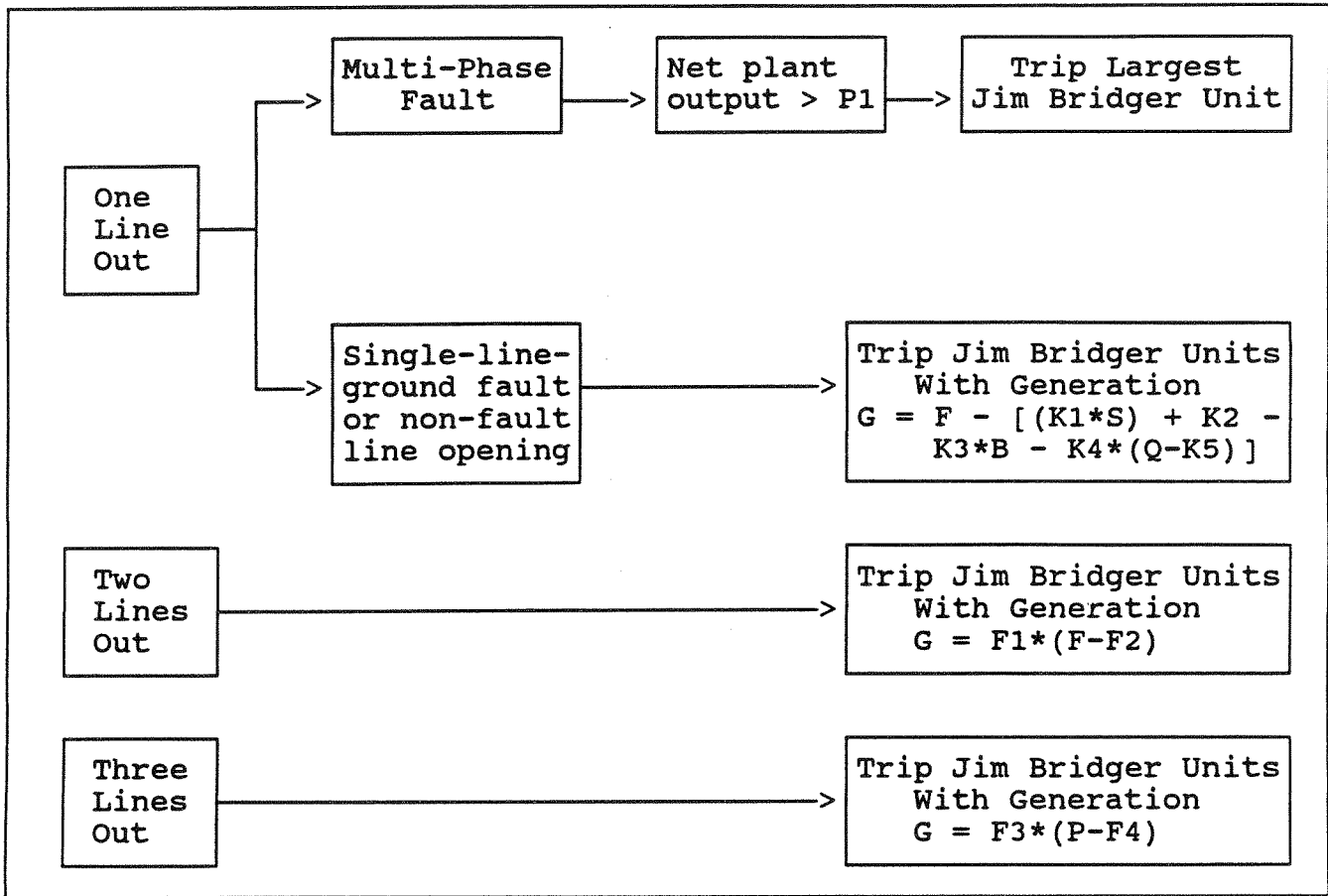


FIGURE 15 RAS-A BRIDGER TRIPPING LOGIC

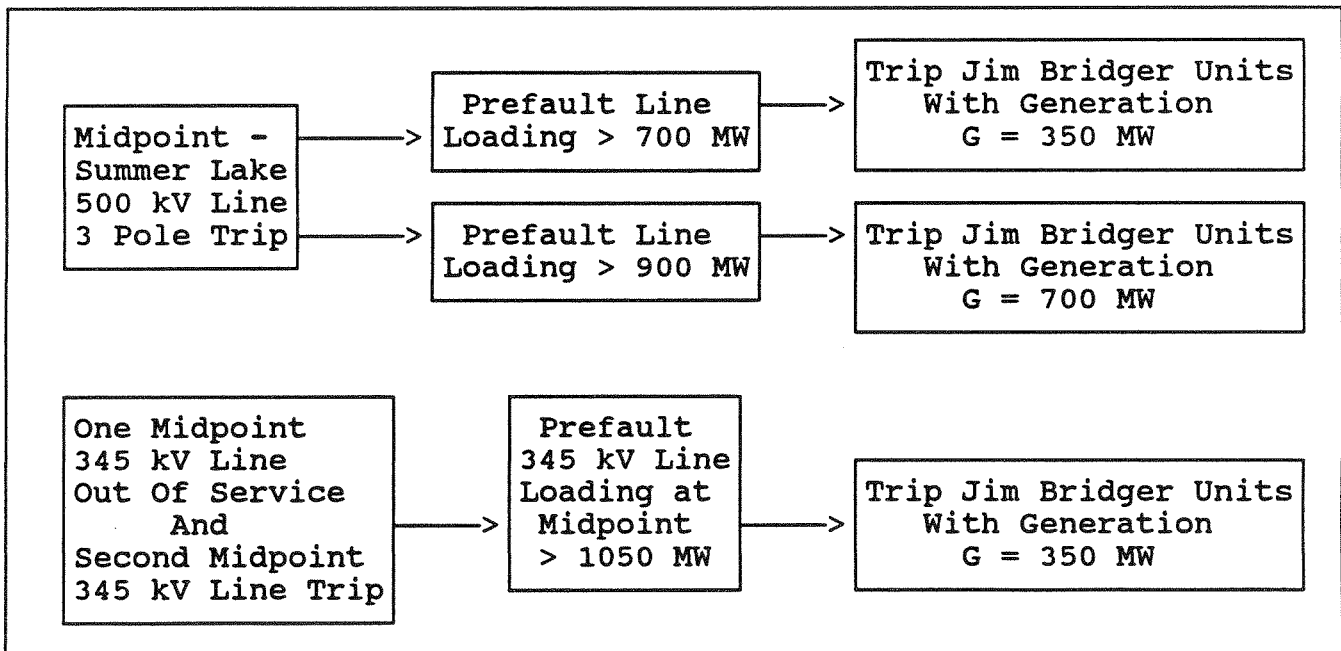


FIGURE 16 RAS-A IDAHO TRIPPING LOGIC

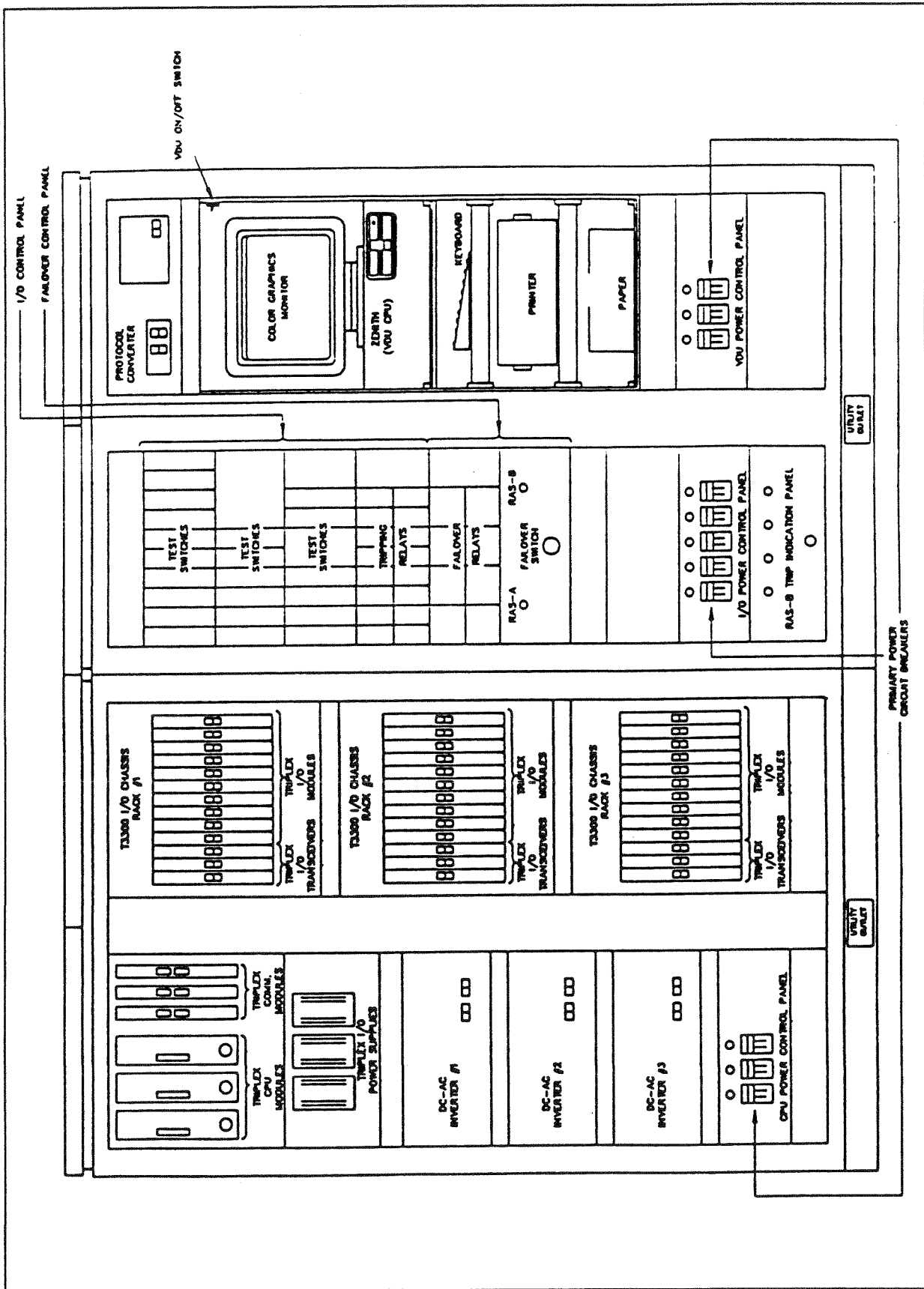


FIGURE 17 RAS-A PANELS

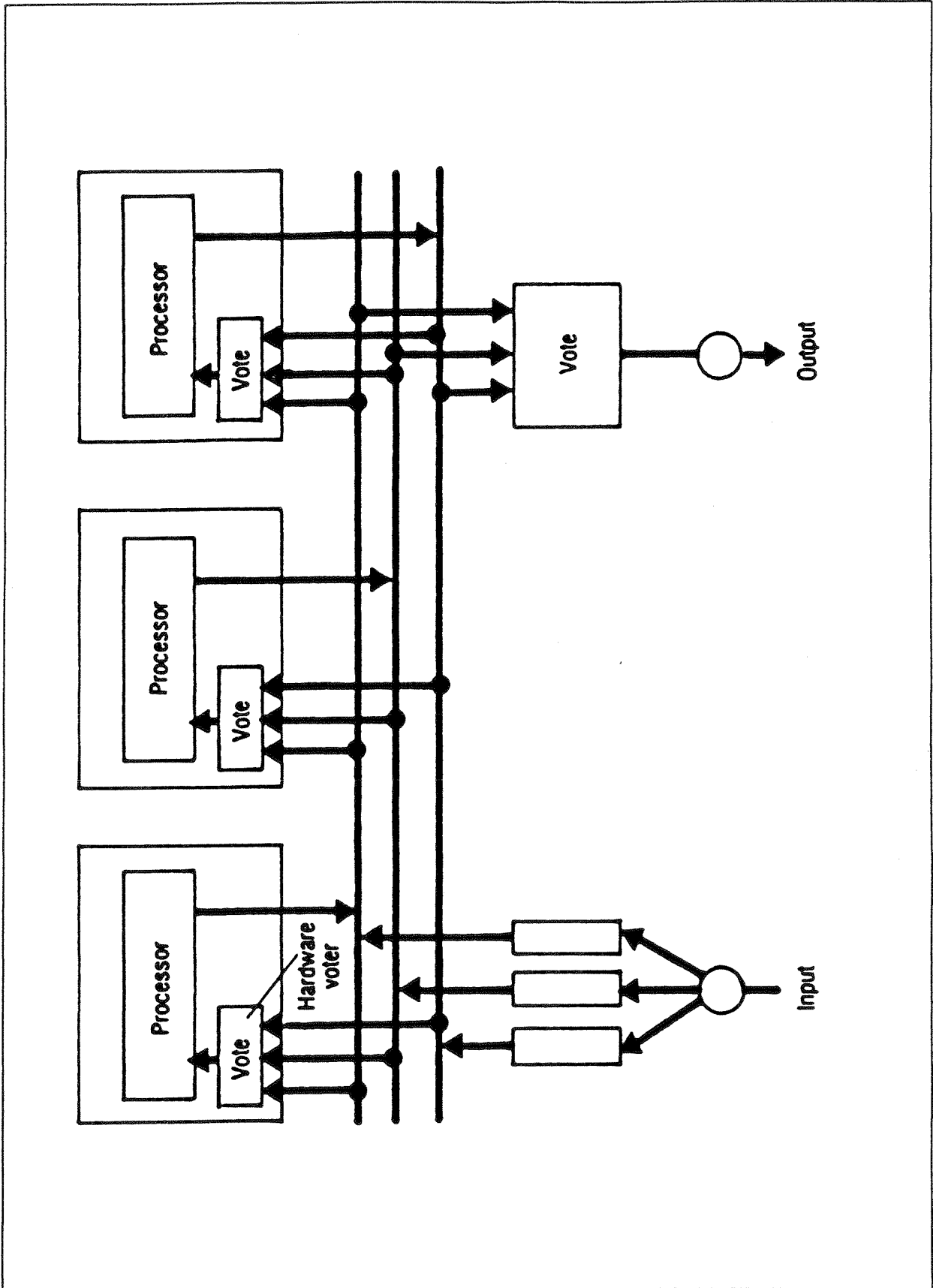


FIGURE 18 TRIPLE-MODULAR-REDUNDANT ARCHITECTURE

THREE CONTROLLERS OPERATE IN PARALLEL, PERFORM THE SAME TASKS SIMULTANEOUSLY, AND MAJORITY VOTE ALL INPUTS, PROGRAM LOGIC, AND OUTPUTS.

ON ----->

ON -----> -----> ON

ON ----->

NORMAL OPERATION

ON ----->

ON -----> -----> ON

OFF ----->

CONTINUE OPERATION
FAULT DETECTION
ISOLATION
ALARM

ON ----->

OFF -----> -----> FAILSAFE

??? ----->

FAILOVER TO BACKUP
FAULT DETECTION
ISOLATION
ALARM

FIGURE 19 TRIPLE-MODULAR-REDUNDANT VOTING

J I N B K I U G E R G E N E R A I U K U R U P I N G S U M E N E

DISPATCH PREFERENCE		UNITS STATUS			
SCADA CONTROL REQUEST (RED=ARM, YELLOW=DISABLE, GREEN=NORMAL)		*1	*2	*3	*4
CONTINGENCY	TRIP REQUIREMENT	UNITS STATUS	MW ARMED	SPLIT	BUS
BORAH SLG FAULT	9	1 2 3 4	508		
KINPORT SLG FAULT	9	1 2 3 4	508		
GOSHEN SLG FAULT	9	1 2 3 4	508		
ROCK SPRINGS SLG FAULT	0	1 2 3 4	0		
IDAHO LEVEL 1	350	1 2 3 4	508		
IDAHO LEVEL 2	700	1 2 3 4	1023		

ALARMS

RAS A STATUS ON STANDBY
 RAS B STATUS IN SERVICE
 RAS A > RAS B ARMING OFF
 VDU STATUS

STATUS		MAX NET GEN...		NO ARMING	
TOTAL NET GEN	2076	MAX FLOW WEST	2050	PERCENT COMP.	IN SERVICE
345KV FLOW WEST	2057				135%
VDU DISABL	0	*SCADA ENABLE	* 0	RTU IN USE	0
IDAHO BIAS	0	* 0			

FIGURE 21 RAS-A ALARM SCREEN


```

1 ; Calculate the "G" for each of the five cases
2 ; Calculate the "G" value for case 5,
3 IF (TYPE = 5)
4   BG=AI01
5   IF (AI02>BG)
6     BG=AI02
7   ELSE
8     IF (AI03>BG)
9       BG=AI03
10    ELSE
11     IF (AI04>BG)
12       BG=AI04
13     ENDIF
14   ENDIF
15   BG=BG-X
16 ELSE
17 ; Calculate the "G" value for case 4,
18 IF (TYPE = 4)
19   BG=0
20 ELSE
21 ; Calculate the "G" value for case 1, one line out
22 IF (TYPE = 1)
23   IF (Q<(K5/10))
24     T4=0
25   ELSE
26     T4=(K4*(Q-K5/10))/10
27   ENDIF
28   BG=F-((K1/10)*(S/135)+(K2/10)-((K3/10)*IUSBIAS)-T4)-X
29 ELSE
30 ; Calculate the "G" value for case 2, two lines out
31 IF (TYPE = 2)
32   BG=(F1*(F-F2/10))/10-X
33 ELSE
34 ; Calculate the "G" value for case 3, three lines out
35 IF (TYPE = 3)
36   BG=(F3*(P-F4/10))/10-X
37 ENDIF
38 ENDIF
39 ENDIF
40 ENDIF

```

FIGURE 23 RAS-A BRIDGER FUNCTION BLOCK

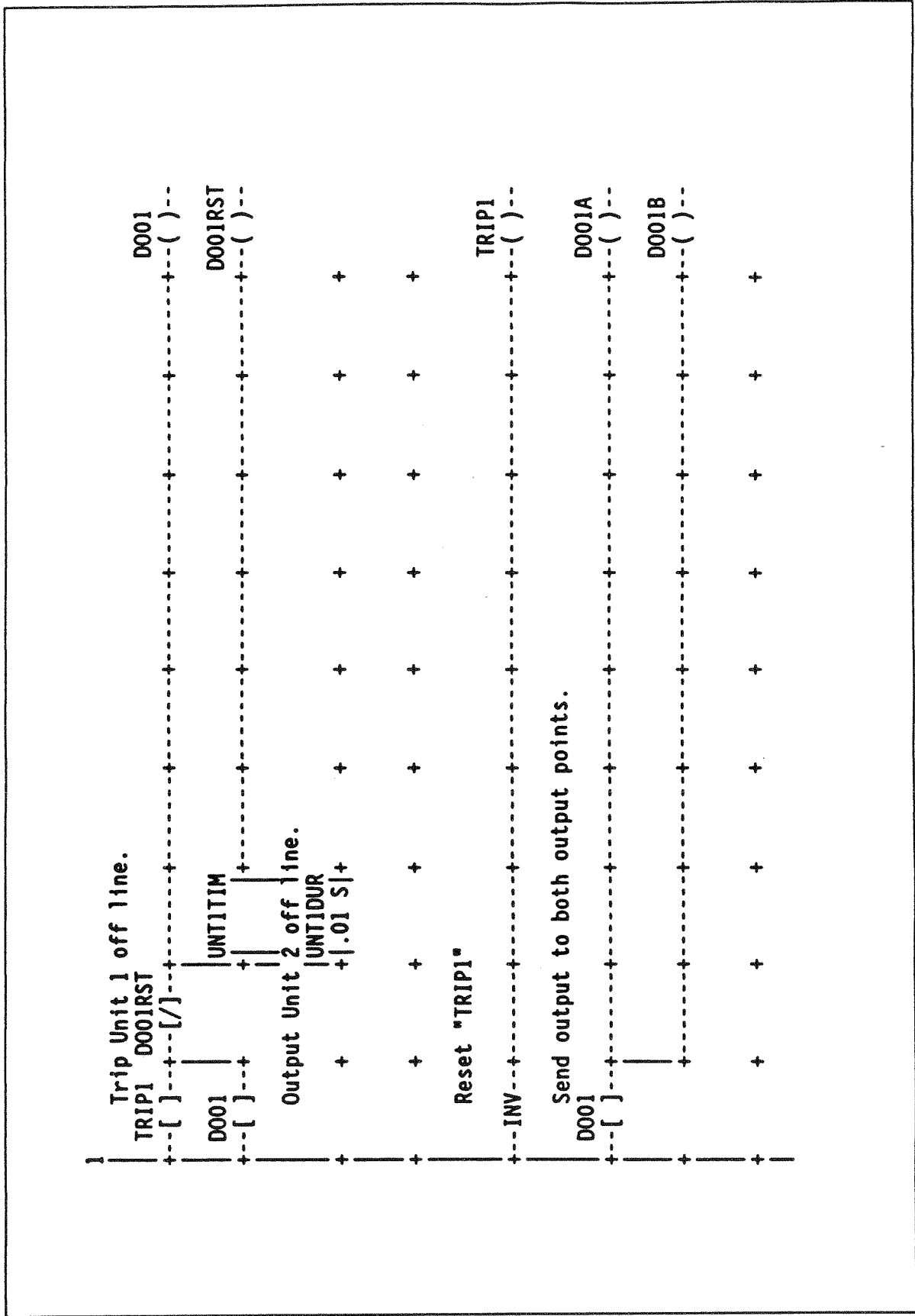


FIGURE 24 RAS-A OUTPUT FUNCTION BLOCK

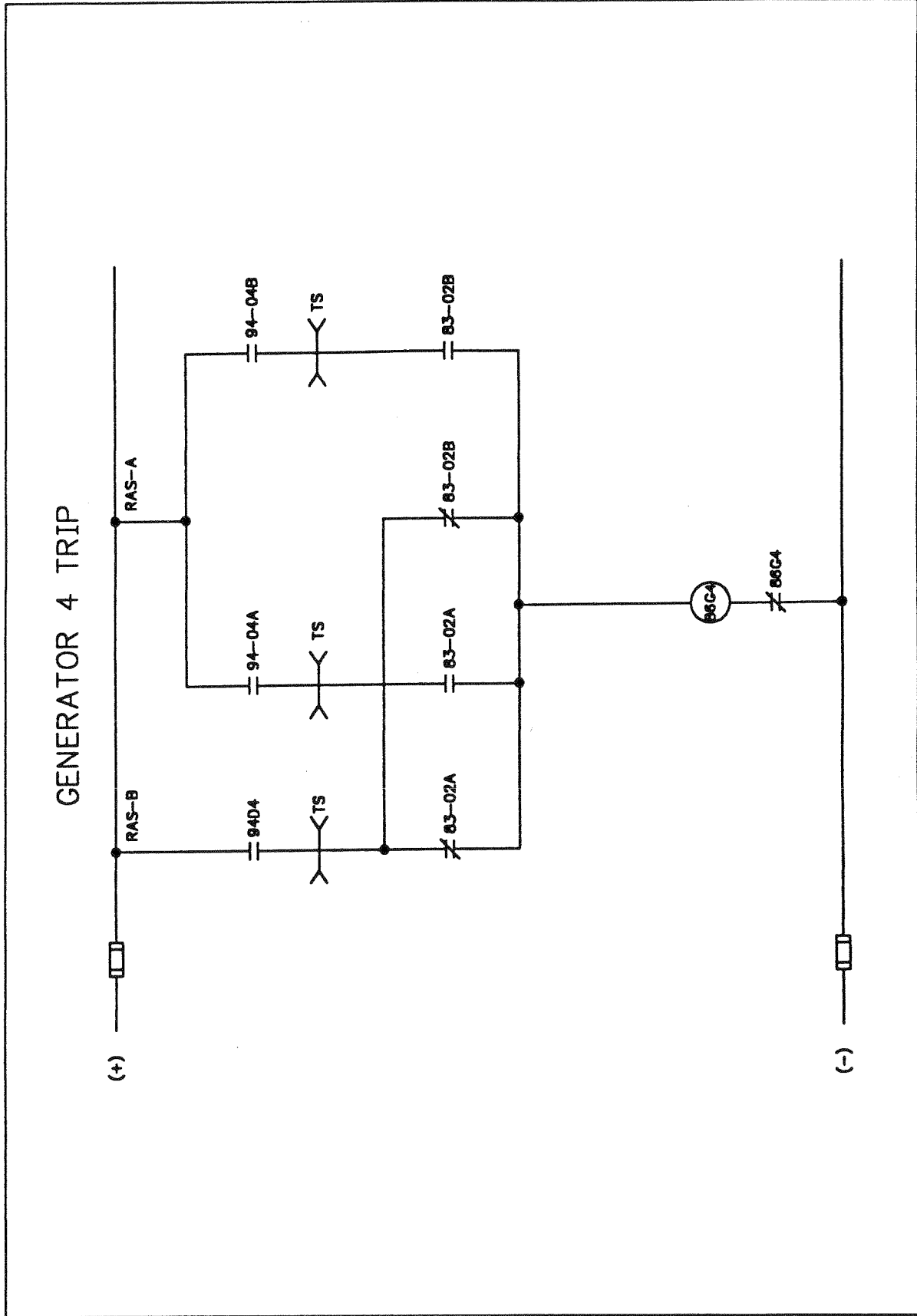


FIGURE 25 FAILOVER SYSTEM