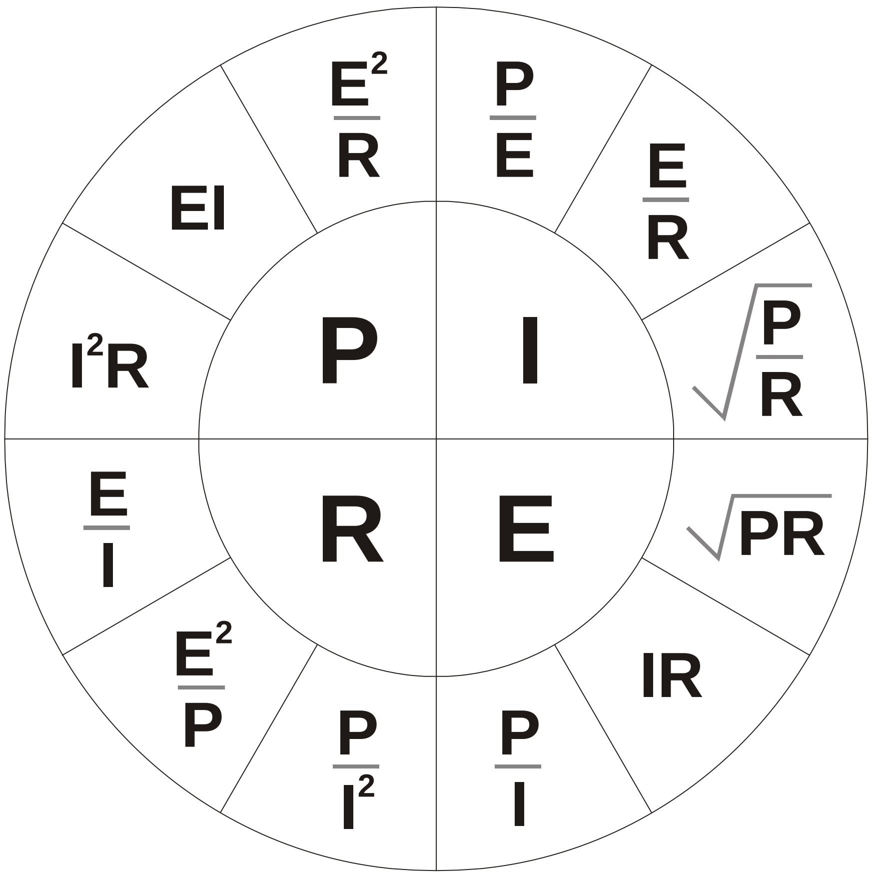
Secondary DC Distribution

Technical Reference Guide



Telect®
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Secondary DC Distribution

Technical Reference Guide, Part Number 118101

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1.0 Purpose and Scope

This document describes the fundamentals of the DC distribution system operation to help you understand general installation requirements. This document does not establish a standard for engineering design, but it does reference existing standards that point to the best practice methods used throughout the industry.

Adhering to best-practice methods promotes the safe installation and operation of a robust power distribution system. Best-practice power distribution and wiring practices help protect the system investment over its service life. As the system changes, these practices can also help the operating company control lost revenue due to power-related downtime.

2.0 The Secondary DC Distribution System Description

A secondary DC distribution system's main function is to provide the power required by the operating equipment and protect the interfacing power cables between the distribution points and the equipment through properly rated fuses/breakers and wire sizes. Distribution panels can be fused and cabled in numerous circuit configurations for many applications.

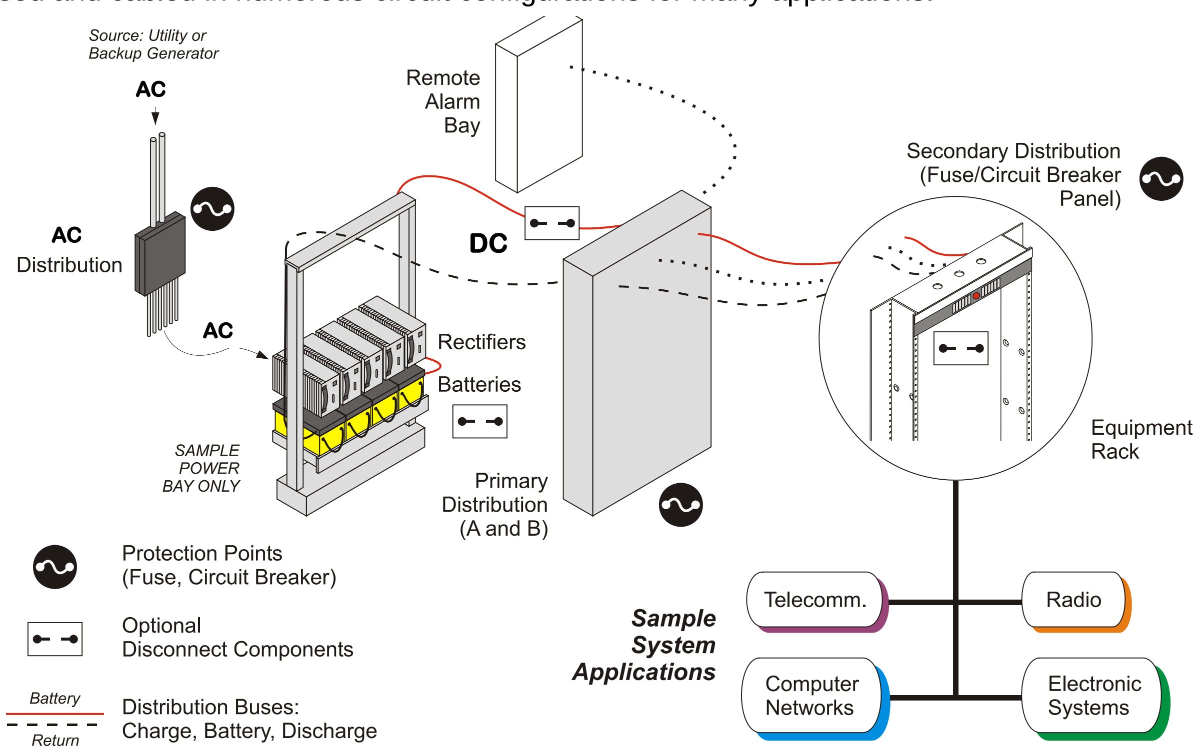


Figure 1 - Overview

2.1 Distribution Fuse/Breaker and Alarm Panel

The distribution fuse/breaker and alarm panel (DF/BAP) has three major functions:

- Safely and reliably distribute DC current to the equipment.
- Safely and reliably open the fuse or breaker without damage to any components in the event of a fault current at the equipment.
- Provide alarms through visual and remote indicators when fault currents happen.

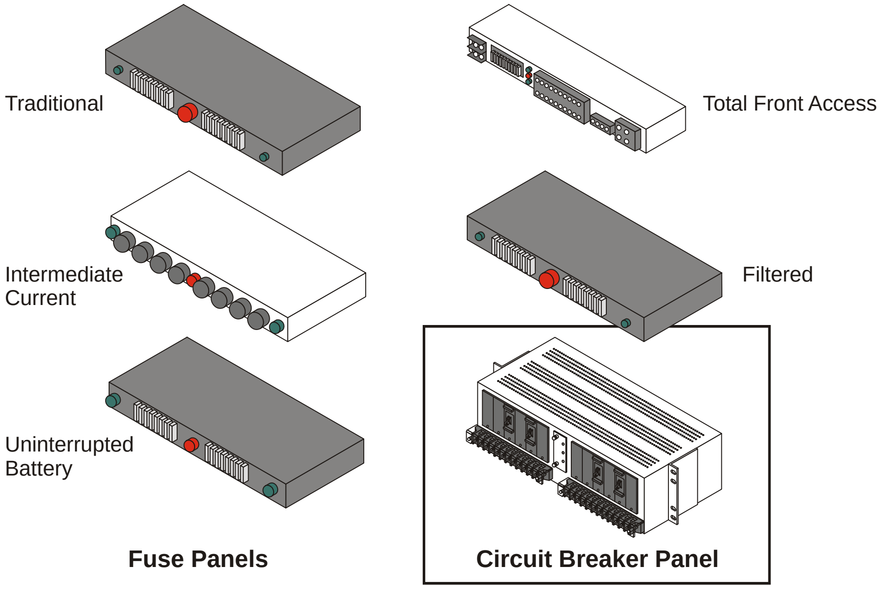


Figure 2 - Examples of DF/BAPs

3.0 DF/BAP System Criteria

3.1 DC Power Plants

The AC distribution subsystem connects the commercial or standby AC power source to rectifiers within the DC plant while providing over-current protection. The rectifiers convert the AC to the DC voltage level required to charge and float the batteries and provide power to the equipment.

The battery has noise filtering and energy storage capability to provide uninterrupted power to the equipment during any loss of AC power to the rectifiers. The charge and discharge subsystems (mains) connect the rectifiers to the primary distribution frames (PDFs) or battery distribution fuse boards (BDFBs) or battery distribution circuit breaker board (BDCBB) that furnish over-current protection to the DF/BAPs.

The DF/BAP subsystem provides power distribution and over-current protection to the equipment. The alarm system assesses the status of the elements of the power plant and reports that status with visual and remote indicators.

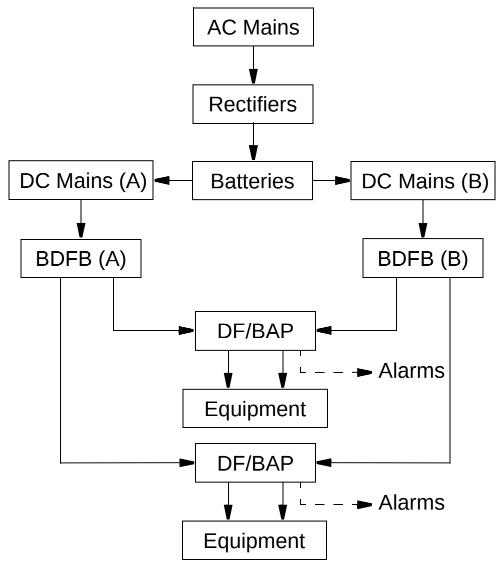


Figure 3 - Subsystem

3.2 Total Plant Power

The operating voltage for any plant is constant for the given environment, except during an AC power failure, at which time the battery backup picks up the load. The combined output amperage capabilities of the rectifiers determine total plant power. Plant loads normally are not operated greater than 50% to 75% of the total plant power. This allows the plant to provide redundancy in the event of a rectifier failure.

3.3 Battery Backup

In the event of an AC power failure, the batteries (without interruption to the equipment) pick up the load and drop to the nominal voltage rating of the plant (2 Vdc per battery cell).

Batteries are rated in amp/hours. This is the total time the batteries can maintain the output voltage with a rated load amperage drain. For example, a battery rated at 100 amp/hours would last one hour with a 100A load or two hours with a 50A load.

3.4 Plant Polarity

Standard plant voltage polarities for communication equipment have been established for different operating environments. A telephone central office uses a nominal –48 Vdc, radio communications normally use +24 Vdc, and other applications use –24 Vdc.

A –48V DC plant has all its circuit-interrupting devices (fuse/breakers) in the negative battery lead; all positive or return leads are referenced to the earth ground plane. A +24V plant has the circuit-interrupting devices in the positive lead; all negative or return leads are referenced to the earth ground plane.

Polarity can be indicated by labels marked with voltage and polarity or with “battery” and “return.” *Battery* refers to the plant system’s fused polarity, and *return* refers to the polarity referenced to earth ground. When colored cables are used for power distribution, the red wire always indicates the fused lead and black always indicates the return.

3.5 Nominal Voltage

Equipment connected to the DF/BAP is rated at a nominal operating voltage of 48 Vdc (typical range 42–56.7V) or 24 Vdc (typical range 21–28.35V). Power equipment range is typically 40–60 Vdc (48V nominal) or 20–30 Vdc (24V nominal).

A load equipment’s input power requirement is rated in either wattage or amperage. Unless the equipment specifications state otherwise, assume that this requirement has been determined at nominal and not operating voltage. Equipment power requirements for proper fuse sizing are discussed in further detail in this document.

3.6 Float Voltage

Individual battery cells must be charged and floated above the nominal 2V per cell, resulting in a higher plant operating voltage. This voltage, which can be from 2.1 to 2.25 volts per cell, is critical to battery performance and life expectancy. The float voltage of the individual cells of the batteries combined determines DC power plant float voltage.

To determine the overall float voltage, multiply the battery manufacturer’s recommended per-cell float voltage by the number of battery cells connected in series.

3.7 Operating Voltage

Plant operating voltage is determined by the voltage required to properly float the batteries. Equipment that connects to the power distribution system is normally designed to operate between 42–54 Vdc (48V nominal), and from 21–27 Vdc (24V nominal). The 54V and 27V are the high limits.

3.8 Operating Current

Proper fuse and wire sizes are determined at nominal or “List 2” voltages. Operating current is the actual current being drawn by the equipment under normal operating conditions and operating voltage.

3.9 DC Distribution

The primary distribution begins at the first over-current protection device from the battery discharge bus. All subsequent over-current devices are considered secondary distribution devices.

In most cases, primary distribution begins at the main power board and includes the power board's interconnections and the wire and cable from the output of the first over-current device to the input of the DF/BAP. The DC secondary distribution subsystem normally begins at the using system or external distribution systems.

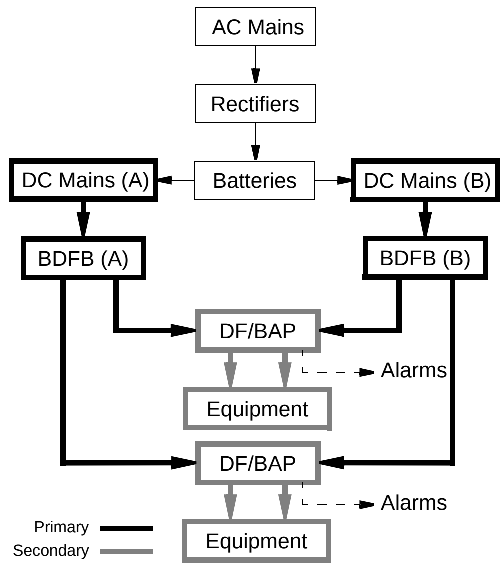


Figure 4 - Distribution Systems

3.9.1 Primary Distribution

The first downstream connection after the common discharge bus is the PDF, BDFB, or BDCBB, any of which is commonly known as the primary distribution point. In some applications, a DC mains disconnect device is located between the discharge bus and the primary distribution bay for maintenance and emergency conditions. Two different power bays are separated from the discharge bus into *A* and *B* primary distribution systems. Any system that feeds secondary power distribution panels is considered to be the primary distribution point.

3.9.2 Secondary Distribution

Secondary devices (the next downstream systems) are sourced and fused from the primary *A* and *B* distribution systems. These systems are the last distribution points to the equipment. All systems or equipment connected to the secondary distribution are considered to be subsystems of the secondary distribution point.

3.9.3 Single and Dual Feed

Single-feed panels are used when no secondary input source is provided for input power. Single-feed panels are designed for use with normally non-service-affecting equipment that has a single power input.

Dual-feed panels are considered split panels with two isolated sides. Two input sources are provided, commonly known as *A* and *B* feeds. Dual-feed panels are designed for equipment that has dual power-feed inputs and is normally service-affecting.

If a single-feed power source is supplied to both *A* and *B* of a dual-feed panel, neither of the panel's power input fuses/breakers can be greater than the input. If a single-feed source is greater than the rating of the dual inputs, the panel must use input fuses/breakers.

3.9.4 Equipment Load

Load is the amount of current the equipment draws. Load demand depends on the type of equipment and the active and reactive components involved.

3.10 Constant Power Supplies

Generally known as switch-mode power supplies (DC-to-DC converters), these devices isolate and convert the higher DC voltage (48V or 24V) to lower levels, such as ±5V and ±12V. The amount of power input to the supply (V x A = W), less the efficiency factor of the supply, is the same as the power out of the unit (W/V = A). These devices demand input current based on the total power requirements of the secondary. If input voltage decreases, these supplies increase the input current demands to maintain the constant output wattage demanded by the secondary loads.

3.11 Constant-Load Equipment

Constant-load systems draw a constant load *per feed.* The *A* equipment and the *B* equipment have a relatively constant load demand, even in the event of single-input power failure.

3.12 Paralleled Constant Power Devices

Constant power supplies use separate *A* and *B* inputs with paralleled outputs. For example, an equipment shelf can have two power modules that receive single, separate inputs. But the power outputs are parallel, sharing the load. If one of the power inputs fails, the other power module and its associated source must pick up the entire load. Ideally, such power modules should load-share and divide the current evenly.

The full-load amperage (in the event of a single-input feed failure) must be considered when designing fuse and input wire sizes. For example, if *A* and *B* feeds were both 10A constant loads, the total load size for each feed would be 20A in case of a single-input failure. The fuse and wire size for each power module should be designed around the 20A criteria.

3.13 Class 1 Amperage

The load current at nominal voltage is referred to as Class 1 or List 1 amperage. Fuse and wire sizes are normally designed around Class 1 criteria.

3.14 Class 2 Amperage

The increased load current that results from increased amperage demand by a constant-wattage device during low-voltage conditions is referred to as Class 2 or List 2 amperage.

3.15 Fault Currents

Fault currents can result from equipment failure or accidental shorts between power conductors or equipment frames. Such shorts cause the operating voltage to spike low, causing service-affecting outage.

3.16 Over-Current Interruption Protective Devices

Most distribution systems can potentially deliver high short-circuit currents to equipment. The components and conductors may not be able to handle this amperage and thus be damaged, destroyed, or cause fires. Properly rated over-current protective devices and associated cabling will limit the let-through energy to within the ratings of these components.

3.17 Operating Environment

Standard fuse panels meet operating environments of –10°C to +55°C (14°F to 131°F) at 90% humidity.

4.0 DF/BAP Operational And Component Criteria

(!) ALERT

ALERT! The cumulative output fuse rating of most power distribution panels can exceed their maximum input rating. While this allows load design flexibility, the cumulative constant-load amperage must not exceed the maximum input amperage rating of the fuse panel.

4.1 Input Rating

Input terminals are rated for both maximum input load amperage and maximum input fuse/breaker size. The input fuse/breaker is typically rated at 125% of the total load amperage of the DF/BAP.

4.2 Input Power

The distribution panel's input amperage can be rated from zero to the maximum allowed input load. The cumulative output load amperage determines total input load.

NOTE: Re-label the panel with the actual load capability and input fuse/breaker size if the panel is used for an application that is less than its maximum-rated input amperage.

The recommended or calculated output fuse from the PDF, BDFB, or BDCBB determines the input rating of the distribution panel. See "4.13 Wire Size and Composition" on page 12.

NOTE: The fuse/breaker size, not the load current, determines the wire size. See Section "7.1 Wire Charts" on page 37 for proper wire sizing and how to determine the inherent voltage drop due to wire length.

4.3 Distribution Panels Equipped With Input Fuse/Breakers

Though not required for most applications, some secondary distribution panels are equipped with internal fuse/breakers, normally rated for maximum input amperage, that protect the internal input wires. These fuse/breakers do not protect the input cables from the primary distribution system. Input cables must be protected by an interrupting device at the primary distribution panel.

4.4 Output Ratings

Output terminals are rated for both the maximum load amperage and the maximum fuse/breaker size, per position. Equipment (load) amperage is typically 75% to 80% of the maximum fuse/breaker rating of the distribution position, determined at nominal voltage.

4.5 Output Power

Distribution panel output amperage can be up to the maximum load allowed per output terminal. The load equipment amperage requirements determine the distribution panel's fuse size. The fuse/breaker size, not the load current, determines the wire size. See Section "7.1 Wire Charts" on page 37 for proper wire sizing and how to determine the inherent voltage drop due to wire length.

4.6 Load

The load is the "maximum continuous operating amperage" (MCOA) of the equipment. MCOA should be provided by the equipment manufacturer. Load ratings come in either amperage or continuous power rating (watts). If only the input amperage is provided, assume that this is at the nominal voltage of the DC power system.

Power rating is computed as follows:

MCOA x nominal voltage = continuous power (wattage)

Most equipment is fused for circuit protection. This is the load fuse (LF), also called the secondary subsystem fuse, of the equipment. The distribution fuse should be equal to, or no greater than, 1.5 times the value of the load fuse.

4.7 Fuse Types

Fuses, in various shapes and styles, are designed for a wide variety of applications. Two types of fuses are generally used for DC applications—signal-type fuses, which mechanically activate the alarms, and non-signal fuses, which require electronic detection for alarming. Distribution panels use only DC fuses with specified amperage ratings. A fuse designed for a particular circuit application can only be replaced with a fuse of the exact same rating and physical characteristics.

The interrupt rating is the breaking point at which a fuse can safely interrupt a fault current. Time delay or slow-blow fuses are used in circuits that experience a large amount of in-rush current at equipment turn-on. To comply with the listing standards to which a distribution panel is designed, use fuses that meet the panel manufacturer's specifications. Refer to the product manual for information about the DF/BAP fuse ratings.

4.8 Breakers

To comply with listing standards, only use breakers that meet the panel manufacturer's specifications (detailed in the product manual).

4.9 Thermal

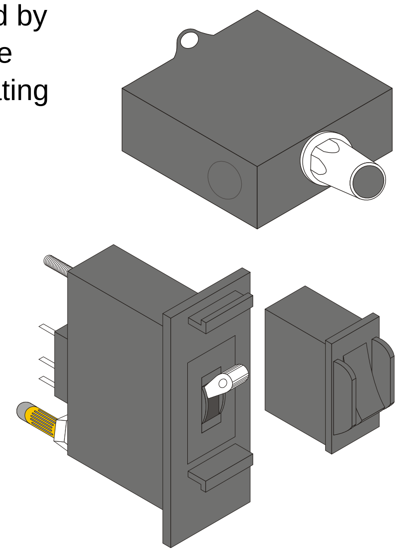


Figure 5 - Breakers

Thermal breakers are like fuses activated by heat that is produced by the current flowing through thermal elements in the breaker. These breakers are susceptible to trip-point change when ambient operating temperatures or surrounding equipment temperatures increase.

4.9.1 Magnetic Trip

Magnetic trip breakers use the magnetic field developed by the current flowing through the breaker to activate. They are not as susceptible to increased thermal conditions as thermal breakers or fuses.

Normally, magnetic breakers trip at 125% of their rated value, allowing higher continuous amperage ratings up to 100% for normal operation. Plan wire sizes to the 125% trip rating.

4.9.2 Time Delay

Time delay breakers, which are a variation of the breakers illustrated above, can be used in circuits that experience a large amount of in-rush current when the equipment is switched on.

4.9.3 Operation

In case of a Class 2 low-voltage condition, do not operate any breaker at greater than 80% of the continuous load current.

4.10 Sizing Fuses and Breakers

Most operating companies have guidelines to determine the proper fuse/breaker rating. Here are some general principles:

- When determining input or output fuse/breaker sizes, never exceed the rating of the distribution panel's terminal connections.
- Use the maximum combined load or the maximum value of the input terminals to determine input fuses/breakers and wire size.
- The MCOA, LF, or the maximum value of the output terminal determines output fuse/breaker size of the individual load.
- Each individual load requires adequate input amperage, with an adequate operating range, to accommodate plant voltage variances.
- The fuse/breaker should be operated at no more than 75% to 80% of its rated amperage value. These devices operated at greater than this value may activate due to power plant voltage change, load variances, and thermal conditions, or they can weaken after a period of time.

When calculating fuse/breaker value for given loads use a multiplication factor not less than 1.25 and no greater than 1.5 to determine fuse amperage size. Use the formulas in the following subsections.

4.10.1 Output Amperage

MCOA = Maximum continuous operating amperage of the equipment, not to exceed 80% of the panel output fuse/breaker rating.

LF = Load fuse. Its rating should not exceed 80% of the distribution panel output fuse/breaker rating.

MCOA x 1.5 (multiplication factor) = Output distribution fuse/breaker size, not to exceed maximum output terminal rating.

Example: 5A load x 1.5 = 7.5A fuse/breaker size

LF x 1.5 (multiplication factor) = Output distribution fuse/breaker size, not to exceed maximum output terminal rating.

Example: 5A equipment fuse x 1.5 = 7.5A fuse/breaker size

4.10.2 Input Amperage

Total accumulated output loads = maximum input amperage
(i.e., total output load cannot exceed the input amperage ratings).

Example: $\underbrace{\text{5 amps + 5amps + 5 amps + 5 amps}}_{\text{Max. Outputs}} = \underset{\text{Input capacity of distribution panel}}{\text{20 amps}}$

Max. input amperage x 1.5 (multiplication factor) = Input fuse/breaker size, not to exceed panel's maximum input fuse/breaker rating.

Example: 20A x 1.5 = 30A (input fuse/breaker size)

4.10.3 Low-Voltage Conditions

In low-voltage conditions, constant-power supplies ("power cards") at the equipment end will draw more current to maintain their output wattage. Low-voltage threshold is typically 42 Vdc for a 48V nominal system and 21 Vdc for a 24V nominal system.

MCOA or LF x nominal voltage rating = operating watts

Example: 5A load x 48V = 240 operating watts

Operating watts ÷ low voltage = maximum low-voltage operating amperage

Example: 240 operating watts ÷ 42V low voltage = 5.7A low-voltage operating amperage

Now determine fuse/breaker size:

Example: 5.7A x 1.5 = 8.5A worst-case output distribution fuse/breaker

Calculate fuse/breaker sizes using nominal voltage. The interrupt devices derived from such calculation can operate normally throughout plant voltage changes. Calculate low operating-voltage amperage to make sure the rated fuse/breaker value is sufficiently above the load amperage. Re-rating the interruption device at the low-voltage value may be necessary if the device tends to activate unnecessarily from plant voltage changes, load variances, or increased thermal conditions.

4.11 Spacing Fuses or Breakers in the Distribution Panel

Consider thermal conditions before placing high-amperage fuses/breakers next to each other in the distribution panel. Fuses/breakers can be affected by heat from each other or surrounding equipment. Spacing of these devices may be required if the application involves high thermal conditions.

4.12 Inherent Voltage Drop

Because the power cable has inherent resistance, a voltage drop develops across the cable, lowering the actual voltage and power levels to the equipment. The longer the wire, the larger the voltage drop. To compensate, increase the circular mils or gauge of the wire. (See the operating company guidelines.)

The typical power plant design limits the voltage drop of the discharge bus loop—between the battery terminals and the loads in the equipment frame—to a maximum of 2 Vdc at Class 2 amperage. (This includes the drop across the overcurrent protection devices.) Most operating companies limit the power-cable drop between the BDFB and the DF/BAP to 0.5 volt.

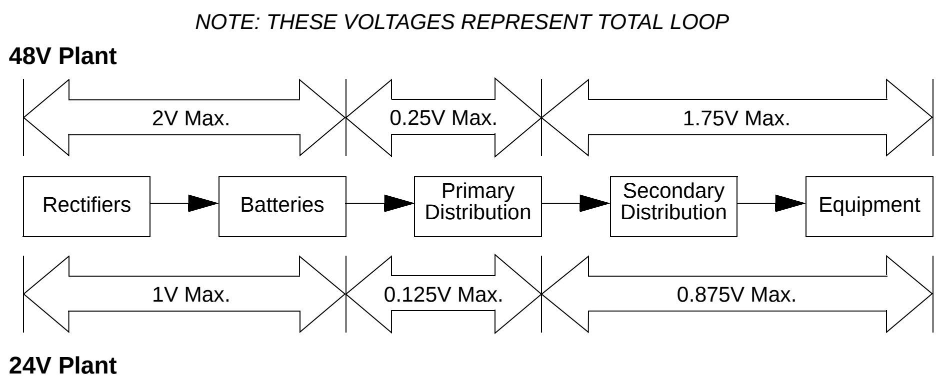


Figure 6 - Inherent Voltage Drop

However, each site is different, and it may be necessary to measure actual voltages to determine the allowable drop. Refer to the operating company specifications for criteria relating to voltage drop.

With the allowable voltage drop known, refer to the cable charts at the end of this guide for circular mils per conductor size, or use the following formulas.

4.12.1 Typical Voltage Drop

This formula is based on the actual current draw of the equipment.

$$\text{Typical } V_{drop} = \frac{11.1 \times \text{Load Amp} \times \text{Total Wire Length (ft.)}}{\text{Circular Mils of Wire}}$$

4.12.2 Maximum Voltage Drop

This formula for the maximum voltage drop is based on the amperage rating of the interruption device (fuse or breaker). This is the recommended method for determining allowable voltage drop.

$$\text{Max. } V_{drop} = \frac{11.1 \times \text{Fuse Amp Rating} \times \text{Total Wire Length (ft.)}}{\text{Circular Mils of Wire}}$$

4.13 Wire Size and Composition

Fuse/breaker size, not the load amps, determines wire size. The power cables must be large enough to ensure that the interrupt device opens before any damage occurs to conductors or components.

Wires are designed around a variety of criteria:

- AC or DC current
- Single-strand or multistranded
- Bare or tinned
- Dielectric strength
- Insulating material
- Fire resistance

Conductors must be rated at 125% of the equipment continuous load rating. Therefore, if the equipment exceeds the capacity of the branch-circuit wiring by 80%, technicians must use the next higher capacity wire gauge.

Some operating companies require special types of cables for power distribution. Check the company's guidelines for types of cables and specified applications. If no specific guidelines exist, use cable properly rated for size, voltage drop, insulation, and fire resistance.

4.14 Terminations

The most common types of input and output connections are compression, screw-tight, and wire-binding terminals.

NOTE: Some operating companies only allow compression-type terminal connections with specific lugs for field wiring.

4.14.1 Compression

Compression terminations are used with compression lugs connected at or crimped onto the ends of the power cables. A variety of lugs are available:

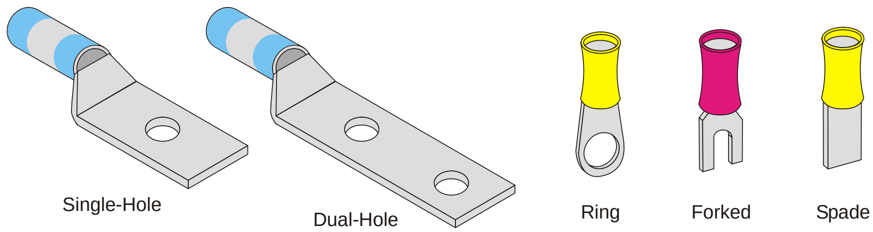


Figure 7 - Lug Types

Follow the panel manufacturer's recommendations for sizing a connector.

Compression lugs are normally used with stranded-wire applications. If you plan to use compression lugs with solid-core wire, the lug and wire should also be soldered for a reliable connection. Compression lugs are rated for particular wire sizes and require specified crimping tools.

4.14.2 Screw-Tight

Screw-tight terminals are used in low-power applications—a number of small loads are distributed with small-gauge wire. Connection is by stripping the insulation from the end of the wire, inserting the bare wire(s) into the terminal, and screwing down the connector. Both single-strand and solid-core wire can be used in screw-tight terminals.

NOTE: Tin the bare stranded wire before inserting it into the connector.

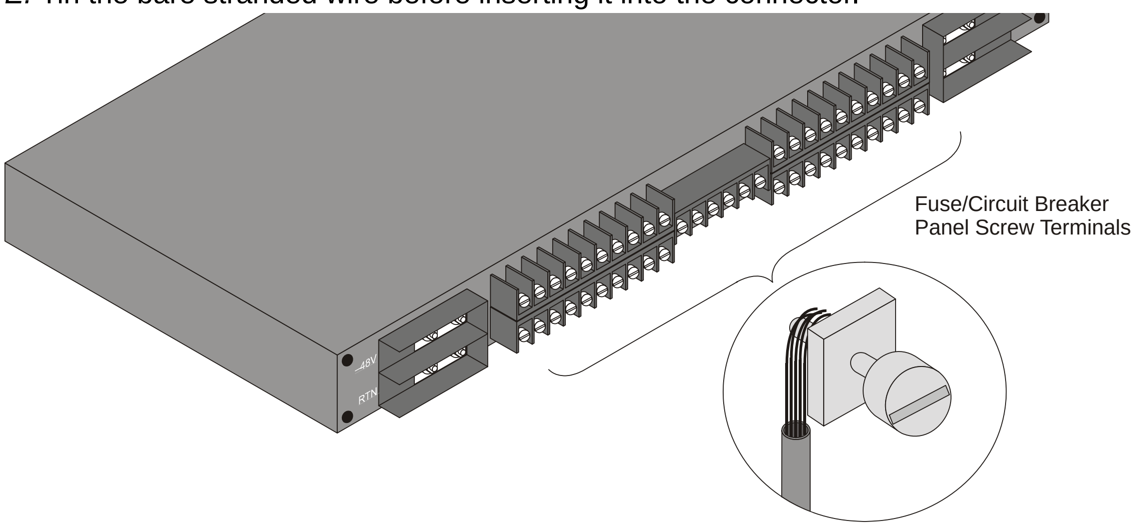


Figure 8 - Screw-Tight Terminals

4.14.3 Wire-Binding

Wire-binding terminals consist of a screw with a square-plate washer that can either be connected with compression lug for the rated wire size or a bare wire connection up to a 14 AWG wire. Both single-strand and solid-core wire can be used in wire-binding terminals.

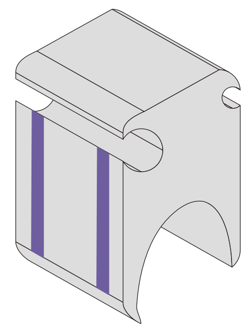
NOTE: Tin the bare stranded wire before inserting it into the connector.

4.15 Double Crimp Lugs

Some operating companies require double-crimped lugs. For smaller gauge wire, both the insulation and the conductor are crimped in the same lug. For larger wire, the conductor is crimped twice in the same lug.

4.16 Half-Taps

These are commonly known as H-taps. They connect a large cable, which produces a lower inherent voltage drop, to a smaller one, which is rated for and connected to the equipment or BDFB. H-taps can be used at one or both ends of the larger cable. Compression- or crimp-types are the standards. Under most circumstances, do not use threaded pressure mechanical type H-taps. Do not use H-taps to extend total cable length of the same size wire.



4.17 Bonding

Bonding is critical to personnel safety and equipment reliability in terms of ESD, electrical noise, and fault-current protection. All exposed, conductive dead-metal parts of the chassis must be connected, with less than 0.1 ohm of resistance, to the grounding lug. This connection must reliably pass fault currents without damage to conductors or components that may be imposed on the equipment.

4.18 Grounding

Proper grounding ensures personnel safety, equipment protection and proper operation, noise reduction, and reliability. The grounding methods, used separately or in conjunction, are the isolated bonding network (IBN) and the common bonding network (CBN). IBN is single-point grounding and is the preferred method of grounding digital equipment. CBN, sometimes referred to as the integrated ground plane or mesh bonding network, is often used in older ground systems and integrated with the IBN.

4.18.1 Common Bonding Network

A CBN is created when building steel, water pipes, cable racks, vertical and horizontal equalizer conductors, bonding conductors, and electrical metallic raceways are bonded together by deliberate or incidental connections. The CBN is also connected to the building's grounding electrode system for lightning and fault-current protection.

4.18.2 Isolated Bonding Network

An IBN is a set of interconnected equipment frames that is intentionally grounded by a single-point connection to the CBN of the building. This IBN, taken as a conductive unit with all of its metallic surfaces and grounding conductors bonded together, is insulated from contact with any other grounded metal work in the building by a minimum of 100,000 ohms. A single-point connection is then provided to the CBN through the ground window. Faults can occur in the IBN, but they are controlled through the single-point connection.

4.18.3 Ground Window

The ground window—a spherical transition zone with a maximum radius of 3 feet—is the interface point between the building's CBN and the AC or DC grounding conductors included in the IBN. The window must be insulated and provide single-point connection to the CBN.

4.18.4 Preparing Ground Connections

- Bonding and grounding conductors must be copper (tinned or nontinned); do not use aluminum conductors.
- Buff all nonplated connectors and bus bars to a bright finish, then coat them with a corrosion-reducing agent.
- Clean tinned and plated connectors and make sure they are free of contaminants before connecting the terminals.
- Remove nonconductive coatings, such as paint or enamel, from threads and other contact surfaces to ensure electrical continuity.
- Do not secure multiple ground connections by the same bolt assemblies.

4.18.5 Ground Loop

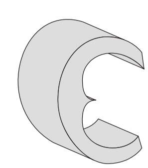
A ground loop occurs when an IBN ground system is connected intentionally or by incidental contact to another IBN ground system or to the CBN, thus violating the single-point ground.

WARNING

WARNING! Ground loops create unidentified current paths that can be hazardous to personnel or equipment.

4.18.6 C-Taps

These are copper taps that connect the same size wires together on a ground system. C-taps are not normally used for power-conducting circuits.



4.18.7 Grounding Summary

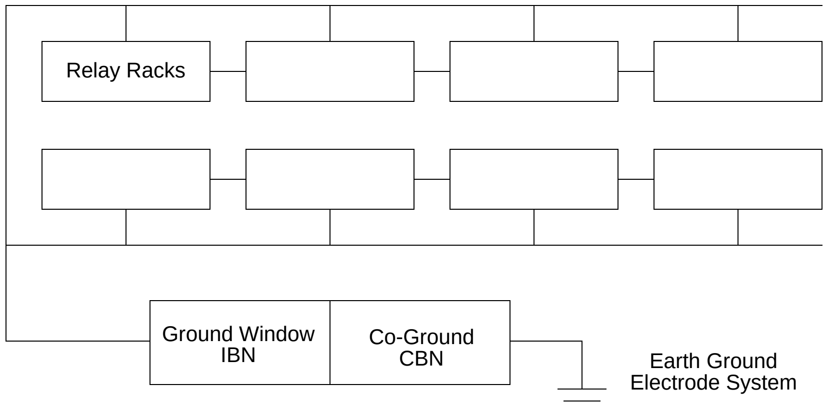
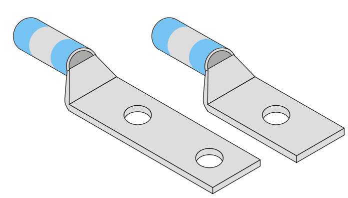


Figure 9 - Grounding Summary

The main difference between IBN and CBN is that no current is allowed to flow in an IBN grounding system, other than noise and temporary short-circuit fault currents. During a frame fault current, the IBN provides a least-resistance path through the ground conductor, ensuring quick interruption of the fault current and keeping voltage potentials to a minimum across the equipment. When lightning strikes, the current is shunted through the CBN and around the IBN, preventing the high-voltage potentials that can cause insulation to break down and affect the operating equipment. The input fuse/breaker to the secondary distribution panel determines the maximum fault current available for a given circuit.

The ground cable has to be large enough to interrupt the short-circuit fault current and prevent thermal damage to the cables. A minimum of a #6 AWG wire is required for most frame-grounding applications.

Use two-hole, compression-type connectors to bond racks, frames, bus bars, or other flat surfaces to an IBN or CBN. Single-hole connectors are acceptable on subassemblies within cabinets, racks, or frames if antirotation parts, such as barriers or star washers, are used to inhibit loosening.



4.19 Alarm Systems

Standard distribution panel alarm systems contain combinations of visual alarm codes and dry form C contacts for audible and remote alarms.

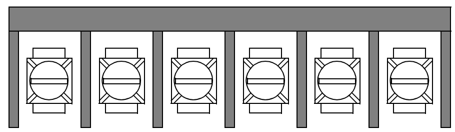
4.19.1 Alarm Codes

Green Normal operation
Off Failure
Yellow Minor, non-service-affecting condition
Red Critical or major, service-affecting condition

4.19.2 Relay External Contacts

Relays are provided with two sets of contacts of opposite closures with a common center conductor for monitoring both a closed and open condition. There are two methods for configuring external relay contacts at the terminal block connections; the second is the reverse of the first:

- When the relays are in the powered-off state, whether in a circuit or out of a circuit, the contact closure is between the common (C) terminal and the normally closed (NC) terminal. When the relay is powered on, the closure is between the C terminal and the normally open (NO) terminal.
- The relay is in the powered-on state and the closure is between the C terminal and the NC terminal. When the relay powers off, the closure is between C terminal and the NO terminal.



Refer to the panel manufacturer's specifications to determine the proper state for alarm contact closures.

4.19.3 Relay Contact Ratings

Most relays have both an AC and DC rating for the contact points. A common standard for single-contact ratings is 1A at 120 Vac, 0.6A at 60 Vdc, and 2A at 30 Vdc. Most monitoring systems need only milliamps of direct current to activate the appropriate alarm.

4.19.4 Power Input Alarm

This circuit detects input power failure. A green light "on" indicates normal operation. If input power has been lost, this light is off. In normal operation, the power input alarm external relay contacts are in an energized or powered state. The contacts are in a de-energizing or powered-off state when input power is lost, providing C to NC closure for the alarm state.

4.19.5 Fuse/Breaker Alarm

Fuse/breaker alarms operate in one of two ways. Both methods have a red indicator light "off" for normal operation and "on" when the alarm circuit is activated.

The first method uses indicating type fuse/breakers that provide a mechanical connection to activate the alarm card. The second method uses open-circuit electronic sensing across the fuse holder. Open-circuit detection usually requires a reset switch to clear the fuse/breaker alarm.

Both methods have the fuse/breaker alarm external relay contacts de-energized or in a powered-off state for normal operation and energized or in a powered-on state when a fuse/breaker alarm is detected, providing C to NO closure for the alarm state.

4.19.6 Bay Alarms

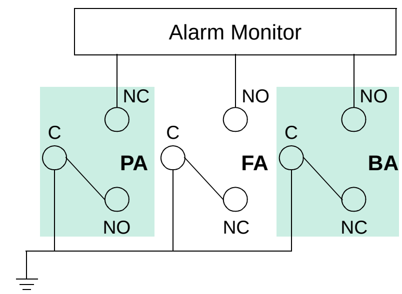
Bay alarms are visual indications for the rack frame (system level). These alarms can be a combination of three different levels: critical, major, and minor. Critical alarms are red; a major alarm can either be a red or yellow; and the minor alarm is always yellow.

The external alarm contacts are de-energized or in a powered-off state for normal operation and energizing or going to a power-on state when an external alarm is detected. Activation of these types of alarms comes from external equipment alarm contacts that are either in the rack frame or system and provide an alarm ground to the input ports of the alarm system.

4.19.7 Alarm Circuits

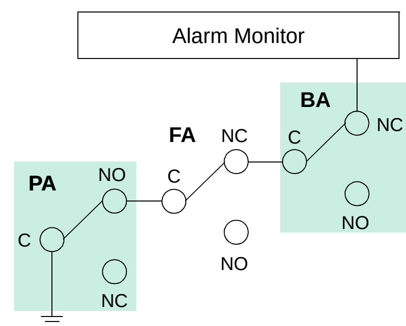
Most monitoring alarm systems require an alarm ground signal to activate the individual alarms. There are two types of alarm configurations.

The first, and most common, is a single-point contact or paralleled contact configuration. An alarm ground wire connects to the common of the external relay contact, and the associated NC or NO contact connects to the alarm monitoring system. When the alarm activates, the relay closure between the C and either the NC or NO sends an alarm ground to the alarm monitoring system, activating the appropriate alarm. Multiple relay contacts can be paralleled in this configuration to activate a single or multiple input to the alarm monitoring system.



BA	Bay Alarm	NC	Normally Closed
FA	Fuse Alarm	NO	Normally Open
PA	Power Alarm	C	Common

The second alarm circuit is a multiple-point or series contact configuration. This system uses an absence of the alarm ground to activate the alarm monitoring system. When the system alarms are in normal operation, the alarm closures between C and either the NC or NO contacts are in a single or series configuration, thus providing a constant alarm ground to the input of the alarm monitoring system. When the alarm monitoring system detects an open circuit, it activates and issues the appropriate alarm. This type of circuit design also detects any open wire or connection that is in the series path of the relay contacts.



BA	Bay Alarm	NC	Normally Closed
FA	Fuse Alarm	NO	Normally Open
PA	Power Alarm	C	Common

4.20 Options

DC distribution system requirements determine any need for options such as battery and load disconnects, line and load filtering, coupling diodes, or C-source supplies.

4.20.1 Disconnects

These devices, activated either mechanically or electrically, open or reconnect a specified DC path. Disconnects can be switches, breakers, shunt trip breakers, or contactors. Disconnects are used in maintenance, emergency, battery protection, and equipment protection applications.

4.20.2 DC Mains Disconnect

A mains disconnect can be a switch, contact, breaker, or fuse placed between the DC main bus and the primary distribution system. This device is used primarily for circuit interruption, maintenance, and emergency disconnect of the DC power source. If the operating company uses a distribution panel as a primary distribution source (smaller systems), the technician should place a switch or interrupt device between the battery discharge bus or DC mains supply and the primary distribution panel.

4.20.3 Battery Disconnects

A typical battery disconnect device is an electronically controlled contact, located between the battery terminals and the DC main bus. Battery disconnects protect the batteries during an extensive load-current drain. These devices are suitable for low voltage, high voltage, battery thermal runaway, maintenance, and emergency conditions.

The most common use for a battery disconnect is low-voltage protection—commercial AC power fails, and the equipment loads receive the power directly from the batteries. As battery output decays, voltage can drop low enough to flatten or even reverse the battery cells. The standard disconnect trip point for a 48V plant is 42 Vdc. When AC power returns, the rectifiers pick up the load current. The standard reconnect point at which the battery disconnect circuit re-engages the contactor is 49 Vdc.

A large amount of battery current can cause the rectifiers to go into current limit, and the voltage may drop, depending on the output current capability of the rectifiers. If the voltage drops below the 42V threshold, the contactor disengages (unless designed with a time-delay circuit) causing the power system to oscillate back and forth until the batteries have reached a certain level of charge. The 7V difference between the disconnect/reconnect points is usually adequate to prevent contactor oscillation.

NOTE: Closer threshold points can cause severe oscillation in the plant power.

4.20.4 Load Disconnects

A typical load-disconnect device is an electronically controlled contact located between the DC mains and one or several distribution systems that supply equipment loads. Besides protecting batteries under extensive load current drains, the disconnect can also be used for low voltage, high voltage, remote shutdown, battery thermal runaway, maintenance, and emergency conditions.

The most common use is low voltage—AC commercial power has failed and batteries are experiencing extensive current drain. When the batteries decay to 42 Vdc, the load disconnect opens, leaving only the rectifier outputs connected to the batteries. When commercial AC is restored, the rectifiers deliver full amperage, slowly raising the float voltage as batteries recharge. When battery float voltage reaches 49 Vdc, the load reconnect trips, engaging the contactor and reconnecting the load. The battery voltage drops slightly because the rectifiers are still in current limit, but rectifier power should be sufficient to carry the load as well as recharge the batteries to the proper float voltage.

Load disconnects allow the batteries to recharge to an acceptable level before the load reconnects to the circuit. They also can be used to keep selected loads operating—such as 911 or other emergency services—during a battery discharge.

NOTE: Remote load disconnects are required in information technology equipment rooms, per NEC, Section 645-10.

4.20.5 Battery/Load Disconnect Conflict

Using battery and load disconnects in the same distribution circuit can cause power plant oscillation if the reconnect settings for both are at the same voltage trip point. If the battery and loads reconnect at the same time, the resulting combined load can cause the contacting circuit controllers to oscillate, as the rectifiers, while still in current limit, try to accommodate the combined load demand.

By setting the battery reconnect to 49V and the load reconnect to 50V, the battery contact will take the current first. Although the float voltage will lower because the rectifiers are in current limit, it will still recharge the batteries. Once the float voltage has increased to 50V, the load contact will reconnect and add the load current to the total load. This again will put the rectifiers into current limit, but voltage should not drop to the 42V disconnect point, which causes power plant oscillation.

4.20.6 Filtering

Extra filtering of AC noise, beyond what the DC power source and batteries do, is not necessary for most applications. Such filtering is desirable when the DC source filtering is not adequate or when long power leads supply the equipment loads. Inductive filters in-series with the load equipment must be rated for the full DC amperage rating of the distribution panel.

Electrolytic capacitors can often short. If they are not properly fused, they can cause the input voltage to spike low when they short. The result is power interruption or failure as well as exploding or venting electrolyte.

WARNING

WARNING! When connecting either of the filters described in the next two subsections to a DC supply, use a safe method of capacitor precharge/discharge to eliminate arcing or shock hazard caused by the charge/discharge of the capacitors. See the manufacturer's instructions when installing these filters.

4.20.7 DC Power Line-Noise Filtering

Use this type of filter when various frequencies of AC noise are getting through to the DC power feed cables. The filter removes AC noise generated from the source. It also prevents noise from the equipment load getting back to the source.

The filter is a standard pie configuration consisting of a large inductor with input and output filtering capacitors. Typical filtering characteristics are: 60 Hz, –44 dB; 200 Hz, –58 dB; 1 kHz, –96 dB; 10 kHz, –102 dB.

4.20.8 DC Bulk-Capacitance Filtering

This method of filtering works well in these AC noise situations:

- Long power cables between the DC power source and the equipment loads have inherent induction that does not allow transient limit protection and proper filtering by the power source.
- Short-circuit faults in the output distribution can cause transients that lower the input voltage below the operating voltage of the equipment, resulting in service-affecting interruptions.
- Currents generated by the DC-to-DC switching supplies or power modules create AC noise at the equipment load end of the cables.

Inductor filtering would only add to the problem of the inherent induction of the cables. A bank of bulk capacitors at the load end can filter transients and greatly reduce AC noise.

4.20.9 C-Source Circuit

Commonly referred to as redundant load share, fail safe, or Schottky coupling diode circuit, C-source adds redundancy to a dual-feed distribution panel. Inside the panel, the returns are connected together in order to be able to source both returns in the event one of the sources fails. The battery inputs are connected through a two- to four-diode coupling circuit using large amperage Schottky diodes. The diodes provide isolation and allow the load to somewhat balance between the two input sources depending on the exact voltage drops of the supply voltages to the DF/BAP. If one of the input sources fails, the remaining source picks up the entire load.

The problem with C-source is that if a short-circuit fault current occurs at one of the distribution panel's output terminals, a transient could spike both *A* and *B* sources. This could possibly interrupt service to the equipment connected to adjacent outputs. Therefore, if the load equipment has redundant input feeds, do not use C-source distribution. But if the load equipment has a single-input power feed, C-source distribution provides power redundancy in the event of input power failure.

The total load for this distribution panel must not exceed the input amperage rating of one of the dual inputs. Diodes develop approximately a 0.7 Vdc drop (varies with load current) that adds to the total voltage drop between the load and the power source.

The diodes develop a large amount of heat that is dissipated through internal heat sinks. This creates a high temperature at the external surface of the panel. Provide for adequate ventilation when installing these panels, and add safety labels to warn service personnel.

4.20.10 C-Sourced Input Configuration

The most common C-source panel uses a two- or four-diode configuration that couples the input sources. With the two-diode configuration, all outputs share the common output side of the diodes. With the four-diode configuration, the outputs are divided into two groups, providing transient protection between the two halves of the panel.

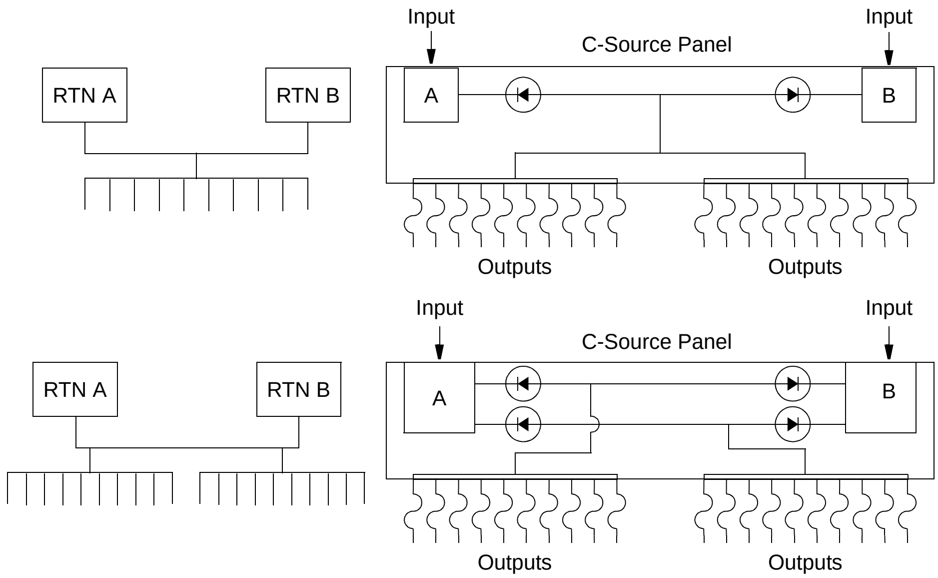


Figure 10 - C-Source Configurations

5.0 DF/BAP Electrical/Mechanical Engineering Considerations

There are many factors to consider when designing a DC distribution system. Good site planning and preparation determines the reliability and safety of the DC distribution system.

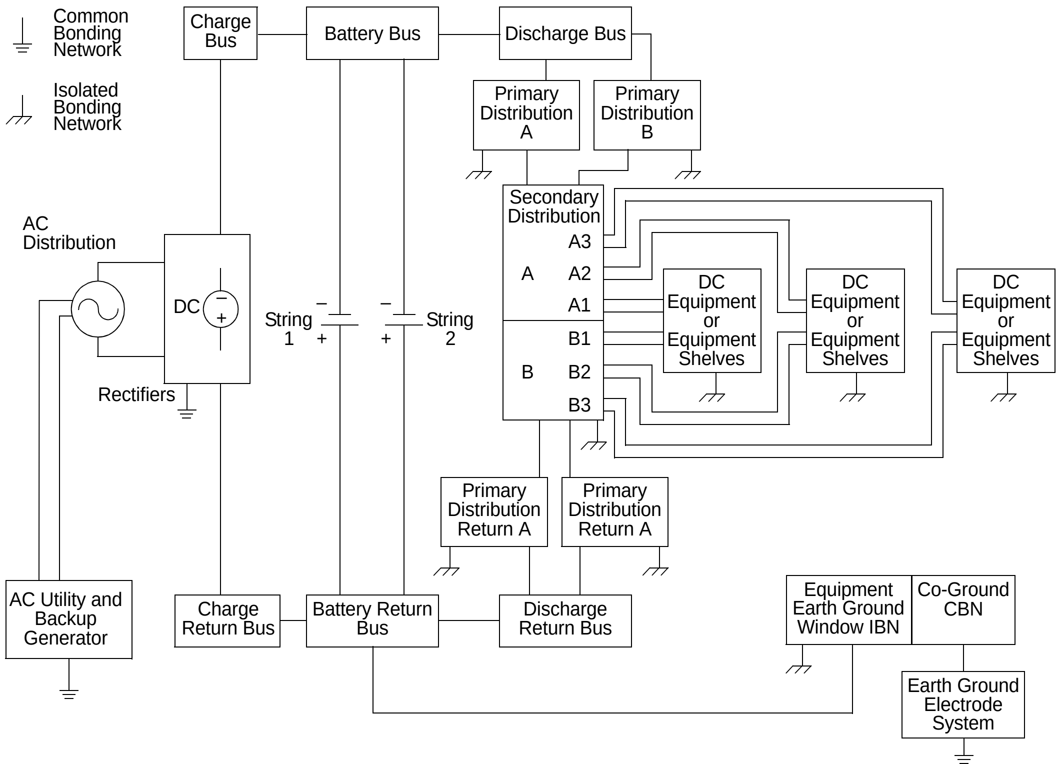


Figure 11 - DC Distribution System Schematic

5.1 Available Power

Determine the available power at the site where the distribution system is to be installed. Do not compromise the total load capability of the power plant, and keep in mind the redundant capabilities of the plant. Confirm that the primary distribution source has available enough positions with adequate amperage ratings for the new secondary distribution system.

5.2 Spacing Considerations

Verify the physical location of the new distribution system along with the cable management requirements to complete the install.

5.3 Mounting Brackets

Most DF/BAP mounting brackets can fit in both EIA and WECO relay racks in 19" or 23" widths. Additionally, most DF/BAPs have both a flush and 4" extended mounting capability. Prior to mounting the DF/BAP, adjust the mounting bracket positions to the desired flush or extended position and 19" or 23" rack configuration. Mounting brackets are available in European ETSI standards to meet vertical and horizontal requirements.

5.4 Polarity Markings

Label or mark the power cables with their polarity—plus or minus (+ or –) and *battery* or *return*.

Battery refers to the fused power lead from the DC plant, whether positive or negative voltage. Circuit-interrupting devices (fuse/breakers) are in the battery lead. *Return* refers to the polarity referenced to the earth ground plane. A –48 volt plant is one in which the battery source is the negative lead; the positive (return) leads are referenced to ground. A +24 volt plant is one in which the battery source is the positive lead and the negative (return) leads are referenced to the earth ground plane.

If you run colored power cables, always use the red wire for the fused lead and black for the return lead.

5.5 Input Terminals

Design all input power cables for maximum input current (based on input interruption device). Determine the inherent voltage drop. It may be necessary to use a half-tap with a larger cable to reduce the inherent voltage drop and meet the maximum input to the DF/BAP.

5.6 Output Terminals

Design all power cables for maximum output current based on the output interruption device. Output cables are normally short, and the inherent voltage drop is negligible.

5.7 Corrosion-Reducing Agents

Some operating companies require these agents to hinder the oxidation that eventually occurs between electrical joint connections. Use a corrosion-reducing agent that is compatible with planned metal types and anticipated temperature limits.

When using any of these compounds, always preclean the mating surfaces of any oxidation and remove any excess material. Apply a light uniform coat between the mating surfaces and remove any excess compound outside the surface-to-surface connection. (Excessive amounts of these agents can become electrically resistive when they dry.)

NOTE: If the operating company’s site plans do not specify the use of corrosion-reducing agents, the connection mating surfaces should at least be buffed to remove any existing oxidation.

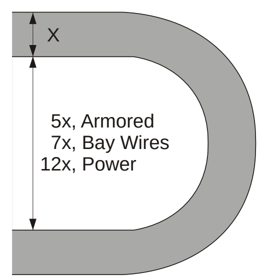
5.8 Fire Stops

Review the operating company’s regulations pertaining to fire stops before opening holes in floors or walls to route cables through. Temporarily close all holes at the end of each shift; permanently close them when cable operation is complete, ensuring fire-stop integrity. When holes are open in floors for cabling operations, the installer must provide adequate protection against falling for personnel and equipment.

5.9 General Cabling Practices

Cables shall be installed, routed, supported, protected and secured according to the job specifications. Here are other guidelines:

- Do not stress or damage new or existing cables.
- Before running power cables, tape the unterminated ends.
- Protect existing cables in the racks.
- Install cable guide rings for equipment racks to prevent cables from rubbing on the framework, threaded rods, and other cables.
- Run battery and battery return leads from the primary distribution service as pairs adjacent to each other. Identify these cables with designation tags, noting the far-end termination on both sides of the tag. Tag the grounding conductors with a “Do Not Disconnect” label.
- Secure cables temporarily when laying them in racks.
- Power cables that are not clearly identifiable as textile jacketed should be protected from contact with cable brackets, cable ties, and twine using fiber paper wrap that is a minimum of 1/32" thick.
- Do not splice power cables for continuous runs; use half-taps only at the ends of the cables, as necessary.
- This illustration shows the minimum bending radius for different types of cable, measured on the inner side of the bend. When forming power cable into turns or bends, avoid damaging the cable sheathing.



- Secure the cables in such a way as to not allow the opposing force to terminal connections having a service loop of six or more inches. In other words, when there is a loop in the cabling, make sure the cable isn’t pulling against the terminal connection; otherwise, there will be strain placed on the cable after you torque the nuts.
- Follow all rules and regulations for the office or site for vertical and horizontal cable rack cabling requirements that are specified by the operating company.

5.10 Half-Tap Installation

Verify the H-tap is correct for the wire gauge and that the correct crimping die is placed in the crimper head. Physically locate the tap in the cable rack at an accessible location so that it can be inspected and verified for minimal heat displacement.

1. Six to 12 inches from the end of the larger power cable (depending on horizontal tie-down bars), remove enough insulation to place the tap around the power cable. Leave the rest of the insulation at the end of the cable for securing to the cable rack.
2. Remove the insulation from the end of the smaller cable to the physical depth of the tap. Clean both wires and apply a corrosion-reducing agent to them before crimping.

3. Place the cables in their associated positions on the tap. Using the recommended hydraulic crimper, compress the tap to the foot-pounds recommended by the H-tap manufacturer.
4. Completely wrap the tap and exposed conductor wire with tape that has a UL 94V-1 rating or greater.
5. Place the insulating cover over the completed assembly and lock.
6. Using lacing chord or nylon cable ties, add two secondary locks around the tap cover.
7. Place a shrink-tubing cap, rated at UL 94V-1 or greater, over the exposed end of the larger power cable and shrink into place using a heat gun.
8. Fasten the power cable to the cable racks using the recommended cabling practice methods. Connect the smaller power cable to the equipment and/or primary distribution source.

5.11 C-Taps

C-Taps are used primarily to connect the bay or rack grounds to the aisle ground cable.

1. Clean and remove appropriate insulation.
2. Apply a corrosion-reducing agent to both wires to be connected.
3. Place the tap over the wires, and using the manufacturer's recommended crimping device, crimp both sides of the tap.

It may be necessary to cover the connection with an insulated cover.

5.12 Installing Compression Lugs

Compression lugs are normally used for all power connections in most operating companies. Follow the job documentation and the connector manufacturer's specifications.

Compression lugs are designed for use with stranded wire. Using solid-core wire requires soldering the terminal to the wire after compression. Use an approved crimping tool for the specified manufacturer's compression lug. Some operating companies require special double-crimped lugs. (See the installation specifications.)

1. Cut away the wire insulation so that, when inserted, the wire extends the full depth of the connector barrel. The space between the cable insulation and the conductive body of the connector must not exceed 1/16 inch.
2. Clean the wire end and coat it with a corrosion-reducing agent before terminating it in the barrel of the connector.
3. Using the proper crimping tool, compress the specified crimp area of the lug. Do not extend the crimp into the tang or inspection area of the connector. If the crimp is poor, discard the connector; recrimping the same connector is not acceptable.
4. Though usually not required, the installer may choose to cover the non-insulated connector with shrink tubing or tape. Use either tape or tubing rated at UL 94V-1. Cover only 1/4 inch of the barrel up to the tang hole. (Visual confirmation that the wire is fully inserted is necessary.)

Using transparent heat shrink permits covering the entire length of the crimp. (The end of the lug needs to be visible to verify the proper wire installation and crimping. If the heat shrink is transparent, it can cover that area.)

5.12 Sizing Compression Lugs

Refer to the operating company specifications when sizing lugs. Refer to the individual panel specifications for terminal size specifications. Size the lugs according to these criteria:

- Wire gauge
- Terminal stud size
- Center-to-center spacing (for two-hole lugs)
- Maximum width of the terminal connection
- Type of connection—ring, fork, or spade

Some operating companies require lugs rated by a nationally recognized testing laboratory.

5.13 Double-Crimp Lugs

There are two types of double-crimp lug styles—larger, non-insulated and smaller, insulated lugs. The non-insulated lugs (#8 AWG and larger) come in short-barrel and long-barrel lengths. The long-barrel lugs require two crimps per lug to the conductor. The insulated lugs (#10 AWG or smaller) require one crimp to the conductor and one crimp to the insulation to prevent creepage.

5.14 Screw-Tight Terminals

Screw-tight terminals are typically used for bare-wire terminations. These terminals come in minimum-to-maximum wire-size ratings for either stranded or solid-core wire. Only use wire that meets the specified ratings. To use these terminals,

1. Remove the insulation from the end of the wire to the same depth as the connector receptacle.
2. Clean the wire of all insulation and lightly coat the wire with a corrosion-reducing agent. The insulation must be flush with the connector and not expose any of the wire conductors.

   If a crimp connection is desired, a special crimped-wire pin terminal for wire gauges 10–22 can be used on the end of stranded wire for easier insertion and better physical contact.
3. Use the manufacturer’s recommended tool for tightening the screw-tight connector to the wire; torque to the rated foot-pounds.

5.15 Wire-Binding Terminals

You can use these terminals for field wiring, with either stranded wire compression lugs, or solid-core wire terminations up to 14 AWG. Follow standard compression lug procedures described in Section “5.12 Installing Compression Lugs” on page 26. For solid-core termination, remove the insulation and wrap the wire at least one full turn under the binding washer in a clockwise direction. Refer to the customer information for torque specifications.

5.16 Connecting Inputs to the DF/BAP

Always verify through a continuity test that the input power cables are correctly marked for polarity before connecting either end to their respective input terminals. A simple method for this is looping the open ends of the cable through the common bonding network and using an ohmmeter to measure for continuity at one end.

Set up the secondary distribution system in a non-powered state before connecting input power, as follows:

1. Remove all output fuses from the DF/BAP circuits to be terminated, and remove all cards from the equipment. Also remove any input fuse or breaker.
2. Connection-mating surfaces of compression lugs should be flat and corrosion-free to ensure maximum contact. Use a nonabrasive, nonconducting pad to clean the surfaces and buff away oxidation without removing plating material.
3. Apply a thin and uniform coat of a corrosion-reducing agent to the connecting side of the terminal.
4. Connect the input wire from the primary distribution bay and torque the tightening nuts, bolts, or screws to the rated value as per the customer drawing.

5.17 Connecting to Primary Distribution (BDFB, BDCBB)

Refer to the operating company's guidelines for making connections to primary distribution bays. Such guidelines commonly require power personnel to be on-site.

Primary distribution bays are available in two basic configurations:

- The fuse/breaker battery terminations and the return bus are contained within the same bay.
- The fuse/breaker terminations are contained in a bay and the return bus is located outside the bay.

Follow these guidelines before connecting the secondary distribution system to the primary distribution bays:

- Always verify the correct fuse/breaker position assignments and associated return bus connections at both the primary and secondary distribution systems.
- Do not connect the returns to any bus bars marked for CO ground.
- Verify that the power fuses and any signal indication fuses are removed from the primary distribution bay before connecting the secondary distribution system.
- Verify, with a DC voltmeter, that no voltage is present at the output terminals of the primary distribution bay.

- Run the DC battery and return cables in a neat, uniform manner and secure using standard office practices.
- Use correct lug sizes for the cable and termination point. Clean, and then apply a corrosion-reducing agent to the lug.
- Provide one fuse/breaker position per battery cable termination. *Do not combine separate loads on the same fuse/breakers!*
- The installer may combine the *A* and *B* return feeds in a back-to-back arrangement, sandwiching the bus bar between the two lugs, as shown in Figure 12.

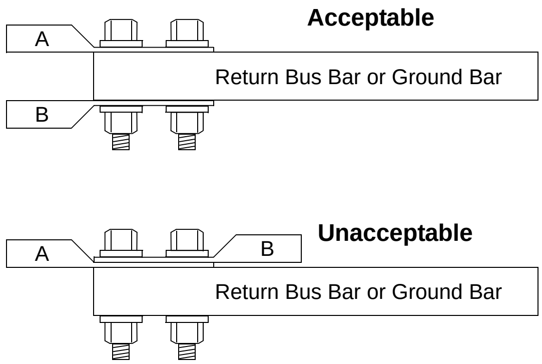


Figure 12 - Connection Examples

  - Apply input power by inserting the rated input interruption device (fuse/breaker) into the distribution circuit.
  - Measure voltage at both the *A* and *B* inputs of the secondary distribution panel, also checking for proper polarity.
  - Reinstall input covers.

NOTE: Test the primary distribution bay for proper output terminal polarity and all alarm functions for proper operation before cabling the output terminals to the secondary distribution system or to the alarm connections. See Section “6.0 DF/BAP Testing And Maintenance Requirements” on page 34.

5.18 DF/BAP Output Connections

1. Run the equipment power cables in a neat, uniform manner and secure to the vertical rails using standard practices.
2. One output terminal at a time, connect the properly rated wire to the appropriate terminals for both the distribution panel and the equipment.

   NOTE: Twisted-wire pairs, with four twists per foot, are recommended.
3. Insert the rated equipment fuse/breaker.

4. Measure polarity at both the output terminal of the distribution panel and the equipment power input terminal. Repeat for all outputs on both *A* and *B* sides.
5. Only when polarity is verified should you insert circuit cards into the equipment.

   NOTE: When connecting to distribution panels that use an open fuse/breaker type alarm detection circuit, it is possible to measure some voltage across the output terminals with no fuse/breaker installed. This voltage should be of correct polarity and can only produce microamps of current.

5.19 Grounding Connection Guidelines

- A single-point ground cable for connection to the relay rack or bay is normally provided in an IBN ground network.
- When connecting to the IBN, it is critical that no incidental ground paths are created to the CBN or other IBN systems.
- Ground cables should be "run exposed" to allow visual inspection of the entire ground system and all connectors.
- The ground cables should not share the same cable racks, supports, or openings with any other type of cable.
- For single-hole terminals, place a star washer between the metal surface and the terminal lug connection to prevent cable rotation.
- Bonding and grounding conductors must be copper (tinned or non-tinned); do not use aluminum conductors.
- Connections should be coated with an appropriate corrosion-reducing agent before crimping.
- Buff all non-plated connectors and bus bars to a bright finish, then coat them with a corrosion-reducing agent before connecting terminals.
- Clean all tinned and plated connectors before connecting terminals.
- To ensure electrical continuity, remove nonconductive coatings, such as paint or enamel, on the contact surfaces of equipment to be bonded or grounded.
- For better servicing, do not use the same bolt to secure multiple ground connections.
- Connect the relay racks to the grounding network with a minimum of 6 AWG wire.
- Each ground cable must be properly sized. The cable shall be large enough to ensure interruption of a short-circuit fault current without thermal damage to the cable. Refer to the manufacturer's specifications or to the National Electric Code, Table 250-95, for minimum-size grounding wire.
- The output fuse/breaker feeding the equipment determines the maximum fault current.

5.20 Fuse Installation Guidelines

- Always wear eye protection when installing open-type fuses, such as GMT.
- Only install a fuse that is rated for the distribution position.
- Leave dummy fuses in place during installation; remove them only to test the fuse positions.
- Do not install a fuse until all cabling has been installed and verified for polarity.
- Test the alarm operation before the output and alarm cabling has been completed. (Refer to Section “6.0 DF/BAP Testing And Maintenance Requirements” on page 34.)
- Always clean any oxidation and remove debris from the contact surfaces of the fuses.
- Apply a light coat of a corrosion-reducing agent having high operating temperature characteristics on the contact surfaces of the fuse.
- Inspect the fuse holders for any debris or abnormalities.
- Install fuses one at a time.
- Install dummy fuses in all vacant positions.
- Job specifications may require you to test the functionality of the rack system. After completing all polarity checks, reinstall the equipment cards one at time, watching for abnormalities such as arcing or smoking. Verify power on the cards.
- Place spare fuse holders, equipped with fuses, as close as possible to the equipment.

5.21 Fuse Designation Labels

Record this information on the designation labels of the distribution fuse panel:

- Rack location
- Equipment location
- Fuse type, position, and size

Place these labels, or a label holder, close to the distribution panel for easy access by service personnel.

Place fuse capacity designation pins at all fuse positions. The pins must be color-coded to match the fuse installed and located directly adjacent to the associated fuse.

5.22 Breaker Installation Guidelines

- Leave blank covers in place during installation; remove them only to test breaker positions.
- Do not activate a breaker until all cabling has been installed and verified for polarity.
- Test alarm operation before the output and alarm cabling has been completed. (Refer to Section “6.2 Alarm Testing for Breakers” on page 35.)
- Only install a breaker that is rated for the distribution position.

- Always clean any oxidation and remove debris from the contact surfaces of the breakers.
- Apply a light coat of a corrosion-reducing agent having high operating temperature characteristics on the contact surfaces of the breaker.
- Install breakers one at a time.
- Install blank covers in all vacant positions.
- Job specifications may require you to test the functionality of the rack system. After completing all polarity checks, reinstall the equipment cards one at time, watching for abnormalities such as arcing or smoking. Verify power on the cards.
- Locate spare circuit breaker holder assemblies, equipped with breakers, as close as possible to the equipment.

5.23 Breaker Label Designation

Record this information on the designation labels of the distribution breaker panel:

- Rack location
- Equipment location
- Breaker type, position, and size

Place these labels, or a label holder, close to the distribution panel for easy access by service personnel.

5.24 Internal Office Alarms

Check with the operating company for alarm assignment and circuit configuration. Alarms should be tested under actual conditions by removing either *A* or *B* input power for power fail alarms and by creating a fuse alarm. If it is not feasible to create a fuse alarm, short across the alarm terminal connections at the distribution panel to verify alarms at the alarm monitoring system. Check any associated bay alarms by applying the correct potential to any of the alarm activation input positions. Mark all alarm pin-out assignments in the office or site alarm designation manual.

5.25 Securing With Twine

Before using sewing twine, refer to the operating company's guidelines for application and proper use. Unless otherwise specified, use two strands of nine-ply, waxed polyester twine. Proper stitching or sewing of cables follows strict procedures; refer to the Bellcore practices.

Use securing twine on power cables that leave or go to the horizontal cable racks and at the first uppermost vertical rack securing position. Power cables that are not clearly identifiable as textile jacketed should be protected from contact with cable brackets, cable ties, and twine with a minimum of 1/32" of fiber paper wrap.

5.26 Nylon Cable Ties

NOTE: Use twine, not cable ties, on cables that leave or go to the horizontal cable racks and at the first, uppermost, vertical rack securing position. Protect power cables that are not clearly identifiable as textile-jacketed from contact with cable ties with a minimum of 1/32" thick fiber paper wrap.

When using cable ties, refer to the operating company's guidelines for application and proper use. Cable ties should be a flame-retardant nylon that meets the requirements of UL 94V-0 and be of adequate size, type, and strength for the application.

- Tension and cut cable ties with an approved tensioning/cutting tool.
- Do not let the cut end of the tie protrude past the locking head; the cut end cannot be sharp or jagged. ("Sharp" means sharp to the touch.)
- Tighten cable ties enough to hold the cables together but not so tight as to damage them.
- The tie should be able to rotate when slight or moderate pressure is applied to the head.
- Locate the tie-locking head in a position that does not interfere with other cables or equipment.

5.27 Fiber Protection

If power cables are not clearly identifiable as textile-jacketed, use fiber paper wrap that is a minimum of 1/32" thick to buffer these cables from contact with cable brackets, cable ties, and twine. In general, use sheet fiber or insulating materials anywhere cables

- Turn off the rack.
- Are close to the rack retaining brackets.
- Are routed next to exposed metal surfaces other than the rounded edges of the ladder rack cross members.

Secure fiber protection independently to the metal surfaces with twine or nylon ties.

5.28 Tape

Use gray electrical tape that meets UL 94V-0 flammability ratings. Do not use tape where it comes in contact with hot surfaces. During application, keep the tape clean and apply it in even, half-lapped layers. Overlap the last two layers and apply it without any tension before cutting it loose from the tape roll.

5.29 Shrink Tubing

Shrink tubing must be UL 94V.0, with an oxygen index of 28 or greater. Use rated-size shrink tubing for recommended wire size and the correct color for polarity identification. When applying heat to shrink the tubing, do not over-heat the insulation of the material being covered.

6.0 DF/BAP Testing And Maintenance Requirements

6.1 Alarm Testing for Fuses

NOTE: Never activate a fuse with plant current for testing purposes.

Test all alarm functions and output terminal polarity before cabling the output and alarm wires. Use the following procedure:

1. After installing input power cabling and verifying proper input polarity, check all output polarity using a low amperage fuse in the associated distribution positions.
2. With input power applied, verify that the power indicators for both *A* and *B* inputs are on.
3. Using an ohmmeter, check for proper alarm contact closures as shown in the product manual, or reference this guide for standard alarm configurations.
4. Remove the *A* input power feed by opening the input interrupt device. Make sure the power indicator is off and that the associated alarm contacts have changed state.
5. Close the input interruption device. Repeat this procedure for power input feed *B*.
6. Remove all dummy fuses. On indicating-type fuses, such as GMT, clip the fusible link so the fuse will spring to the alarm position.
7. Carefully insert a fuse into a fuse position and verify there is a red indicator for fuse alarm.
8. Using an ohmmeter, verify that the associated relay contacts change state for closures as shown in the product manual, or reference this guide for standard alarm configurations.
9. Verify a visual indication for all associated fuse positions; it is not necessary to repeat alarm contact test for every position.

Non-indicating fuses use either a paralleled small-amperage signal fuse or an open-fuse detection circuit.

1. Test the signal fuse configuration by opening the larger fuse positions and installing the indicating type signal fuse in its associated position.
2. Most open-detection alarm circuits have a reset button. On initial power up, it may be necessary to reset the alarms.

For the non-indicating fuse with open-detection circuits:

1. Open all fuse positions, then verify all alarms are off. (If alarms are not off, press the reset switch.)
2. One at a time, insert a known-good fuse (preferably low amperage) into the fuse holder.
3. No visual alarm indication should be present at this time. When you remove the fuse, a red fuse alarm indication should light.
4. Verify the associated alarm contacts, reset the alarm board, and repeat for the remaining fuse positions.

5. Check any associated bay alarms by applying a return potential to any of the alarm activation input positions.

6.2 Alarm Testing for Breakers

Breaker alarm detection circuits normally come in two types—an open-breaker detection circuit or auxiliary contacts internal to the breaker.

NOTE: Never activate a breaker with plant current for testing purposes.

Test all alarm functions and output terminal polarity before cabling the output and alarm wires. Use the following procedure:

1. Open the breaker and verify the red visual indicator lights to show that the open-breaker detection circuit has activated.
2. Using an ohmmeter, verify that the relay contact changes state for closures as shown in the product manual, or reference this guide for standard alarm configurations.

Auxiliary contact-type breakers come in two types:

- Standard auxiliary switch, where the alarm contacts are activated by closing and opening the breaker
- Alarm activation trip, where the contacts are activated only when the breaker is tripped or activated.

The first type is generally less used; the second is the most common. Both of these types normally activate only one red visual indicator, and the tripped position is indicated on the breaker by being in détente position, half tripped, or by providing a visual indication on the breaker.

Testing the second type alarm system is difficult without activating the breaker. If testing is possible, use an ohmmeter to verify that the associated relay contacts change state for closures as stated in the product manual, or reference this guide for standard alarm configurations. Alarm boards equipped with a reset function may have to be reset at initial power-up or during testing. Check any associated bay alarms by applying the correct potential to any of the alarm activation input positions.

6.3 Maintenance Requirements

When properly installed and in service, DF/BAPs are considered maintenance free for their operating lifetime. No serviceable parts are contained internal to the distribution panels other than accessible and removable alarm cards. Alarm card update and replacement should follow the manufacturer's specifications and the operating company's requirements for card maintenance.

6.4 Alarm Card Replacement

Alarm cards are either replaceable or nonreplaceable (fixed). You must replace fixed alarm circuit panels if the alarm circuit fails to operate. These panels are designed for simplicity, polarity protection, and high reliability. Replaceable alarm cards are normally used in units that require flexibility between plant voltages and intricate alarm-sensing capabilities.

DF/BAPs with replaceable alarm cards come with safety interlocks that are torqued beyond finger tightness. Use the following procedure:

1. Using the manufacturer's recommended tool, remove or loosen the safety interlocks. Note the orientation of the card.
2. Gently slide the replacement card into the slotted track and fully insert it into the connector.
3. Tighten the safety interlocks beyond finger tightness to meet safety interlock requirements.
4. Test the alarm card according to the alarm testing specifications of the product manual and this guide.

6.5 Fuse Replacement

If a fuse activates, remove the equipment card or open the equipment power switch before replacing the fuse. This prevents arcing or damage to the fuse holder. When working on an open circuit, install a dummy fuse while you are servicing the equipment. Also place a warning tag on the equipment that says, in effect, "Warning! Service Personnel Working on Equipment." This tag should have the name of the contract company. Replace the activated fuse with another having the same type and rating. (Check the fuse labeling chart.) If a corrosion-reducing agent is required, inspect the fuse holder for any debris, clean the fuse holder, apply the agent, and install the replacement fuse.

6.6 Breaker Replacement

When working on an open circuit, install a breaker cover plate. Also place a warning tag on the equipment that says, in effect, "Warning! Service Personnel Working on Equipment." This tag should have the name of the contract company.

Breakers have a long service life. After clearing a fault, you can reset the breaker into service without removing cards from the equipment.

If the breaker becomes non-operational, replacement difficulty depends on whether the breaker is modular or in a wire terminal connection. If the breaker is modular,

1. Place it in the OFF position.
2. Remove the mounting screws, then remove the breaker and mounting plate.
3. Verify that the new breaker has the same rating and value as the one it is replacing, and that it is in the OFF position.
4. If required, lightly clean and apply a corrosion-reducing agent to the contact surfaces.
5. Reinstall the breaker, mounting plate, and screws.

6. Engage the breaker and verify power is applied to the equipment.

For terminal connected type configurations, it may be necessary to remove input power to either the *A* or *B* side in order to replace the breaker. This means the fused leads may be exposed during service. If the power system is redundant *A* and *B*, shutting down one side for servicing is usually not a problem.

1. After removing the input power, verify with a voltmeter that no input power is applied.
2. The breaker may be installed with mounting screws or may be inserted into a positive-lock-type holder. Remove mounting screws or gently pry the breaker out of the position.
3. Remove the terminal connections from the breaker and note the wiring orientation.
4. Verify the new breaker has the proper size and value rating.
5. Lightly clean and apply a corrosion-reducing agent to the terminals, if required.
6. With the new breaker in the “off” position, reconnect the terminals, observing proper orientation. Reinstall the breaker into its position and install any mounting screws.
7. Engage the breaker and verify power is applied to the equipment.

7.0 DF/BAP Electrical And Component Charts

7.1 Wire Charts

Wire charts, used throughout the electronics industry, vary in standards and content. Wires are designed around a variety of criteria:

- Solid core or stranded. If stranded, consider
  - Size
  - Number
  - Coated or tinned
- Insulating material:
  - Dielectric strength
  - Temperature rating
  - Fire resistance
  - Used internally to a product or externally
- Factory or field wire

Rate the wire for worst-case conditions. Factors include type of cables, amount of cables in a bundle, the total loop length, and high ambient or operating temperature. Refer to the operating company’s guidelines for amperage, wire lengths, and flammability requirements.

The chart and the accompanying correction table (below) are compiled from several sources, including the National Electric Code, Underwriters Laboratory, AMP, ALPHA, and OLFLEX. These specifications are based on 90-degree stranded copper wire. The insulation temperature ratings determine the actual operating values of the different cables. The values in this chart are recommended values; actual values depend on the cables in the application.

Table 1 - 90-Degree Cable

Fuse/Breaker (Amps)	Wire Size (AWG)	Metric Ref. Dia. (mm)	Diameter Range		Wire Circular Area Range (Mils)
			U.S. (in.)	Metric (mm)	
0.6	26	0.50	0.018–0.021	0.400–0.533	202–440
1.3	24	0.50	0.023–0.024	0.511–0.610	384–576
2.0	22	0.75	0.030–0.031	0.643–0.787	640–961
2.7	20	1.00	0.035–0.040	0.813–1.016	1000–1600
14.0	18	1.00	0.047–0.052	1.020–1.320	1624–2700
18.0	16	1.50	0.058–0.060	1.473–1.524	2580–3600
25.0	14	1.75	0.068–0.073	1.727–1.854	3830–5329
30.0	12	2.00	0.083–0.096	2.369–2.438	5180–9216
40.0	10	3.00	0.115–0.116	2.921–2.946	9353–13456
55.0	8	3.75	0.128–0.147	3.264–3.734	16625–21609
75.0	6	4.75	0.162–0.184	4.115–4.674	25900–33856
95.0	4	6.00	0.192–0.232	5.000–5.898	41650–53824
130.0	2	7.00	0.250–0.276	6.400–6.543	65475–76176
150.0	1	8.00	0.289–0.328	7.348–8.250	81700–107584
170.0	1/0	9.00	0.330–0.363	8.350–9.250	104636–131769
195.0	2/0	10.50	0.364–0.414	9.260–10.52	132297–171396
225.0	3/0	11.75	0.415–0.470	10.40–11.68	163195–220900
260.0	4/0	13.00	0.480–0.530	11.69–13.26	210386–280900

Table 1 is based on 26–30°C (79–86°F). The table below gives the multiplication factor to use to correct the wire size/metric reference diameter for different operating temperatures:

Ambient Temp. (°C)	Multiply By	Ambient Temp. (°C)	Multiply By
21–25	1.04	41–45	0.87
26–30	1	46–50	0.82
31–35	0.96	51–55	0.76
36–40	0.91		

7.1.1 Inherent Voltage Drop Formulas

$$\text{Typical } V_{drop} = \frac{11.1 \times \text{Load Amp} \times \text{Total Wire Length (ft.)}}{\text{Circular Mils of Wire}}$$

$$\text{Max. } V_{drop} = \frac{11.1 \times \text{Fuse Amp Rating} \times \text{Total Wire Length (ft.)}}{\text{Circular Mils of Wire}}$$

To determine voltage drop for actual feet used, multiply the actual feet used by the voltage drop at 50 feet from this chart and divide by 50 feet.

$$\text{Actual } V_{drop} = \frac{\text{Voltage Drop at 50 Feet} \times \text{Actual Feet Used}}{\text{50 Feet}}$$

Example, Using 4/0 AWG Cable:

$$\frac{0.511 \text{ Volt} \times 37 \text{ Feet Used}}{\text{50 Feet}} = 0.378 \text{ Volt}$$

7.1.2 Desired Voltage Drop

To determine desired voltage drop for increased cable size, use the rated fuse size for the installation and increase the circular mils of the wire in the inherent voltage drop formula until the desired voltage drop is reached.

7.2 Ground Cable Guide

Reference NEC (National Electric Code), Table 250-122.

Input Fuse/Breaker Rating (Amps)	Copper Wire Size (AWG)	Input Fuse/Breaker Rating (Amps)	Copper Wire Size (AWG)
15.0	14	100.0	8
20.0	12	200.0	6
30.0	10	300.0	4
40.0	10	400.0	3
60.0	10		

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