Primary DC Distribution
Technical Reference Guide

Telect®
CONNECTING THE FUTURE®

Primary DC Distribution

Technical Reference Guide, Part Number 123927

About Telect

Telect offers complete solutions for physical layer connectivity, power, equipment housing and other network infrastructure equipment. From outside plant and central office to inside the home, Telect draws on more than 25 years of experience to deliver leading edge product and service solutions. Telect is committed to providing superior customer service and is capable of meeting the dynamic demands of customer and industry requirements. This commitment to customer and industry excellence has positioned Telect as a leading connectivity and power solution provider for the global communications industry.

Technical Support

E-mail: getinfo@telect.com

Phone: 888-821-4856 or 509-921-6161

Primary DC Distribution Technical Reference Guide

Table of Contents

Telect®

List of Figures

Primary DC Distribution Technical Reference Guide

1.1 Purpose and Scope

The telecommunications industry requires highly reliable and safe power to provide continuous service to its customers.

Telect Inc. serves the telecommunication industry, providing primary and secondary DC distribution circuit-protection panels for a variety of electronic, telecommunication, radio, and computer network applications.

We take for granted that telephones are always at the ready — will always work reliably. To measure up to that expectation, operating companies go to great lengths and great cost in designing, installing, and maintaining communication services.

Specialty services such as *911* lifeline services, where people's lives and well-being are at stake, are among the main driving forces behind reliability. Also, in today's *tele-charged* economy, the accurate and reliable transfer of high-volume data over telecommunications networks, such as the Internet, is an absolute necessity.

The power plant with its DC distribution systems is the heart of all telecommunications services. The power plant provides the life-force, the AC/DC fuel, that makes network transmission possible.

This guide provides you with the basic requirements for a telecommunications power plant. This guide contains a general description of the power plant and the DC distribution system — their operation and installation — with special emphasis on primary DC distribution. What this guide doesn't do is *specify* a standard for engineering design and installation, but it does *recommend* and promote best practice methods used throughout the industry for primary DC distribution.

Overall, by adhering to best-practice methods of implementation and installation, you can obtain and maintain a secure, safe, and robust power distribution system. Best-practice power distribution and wiring practices are important measures for protecting a system investment over its service life. And, as the system changes, these practices will help operating companies mitigate losses in revenue due to power-related problems.

The main functions of a primary DC distribution system is to distribute power to secondary systems. Specifically, the system

- distributes adequate power to the operating equipment or equipment shelves
- protects the interfacing power cables between the distribution points and the equipment using properly rated cables and fuses/breakers

Not all telecommunication central offices are equipped identically. Each is unique. Each requires a variety of power plants and distribution schemes to accommodate special office loads.

Distribution panels can be protected and cabled in a tremendous number of circuit configurations for a vast amount of applications. In this guide, we'll cover the main functions and touch on some applications as they apply to primary DC power distribution equipment — whether they be Telect's or anyone else's.
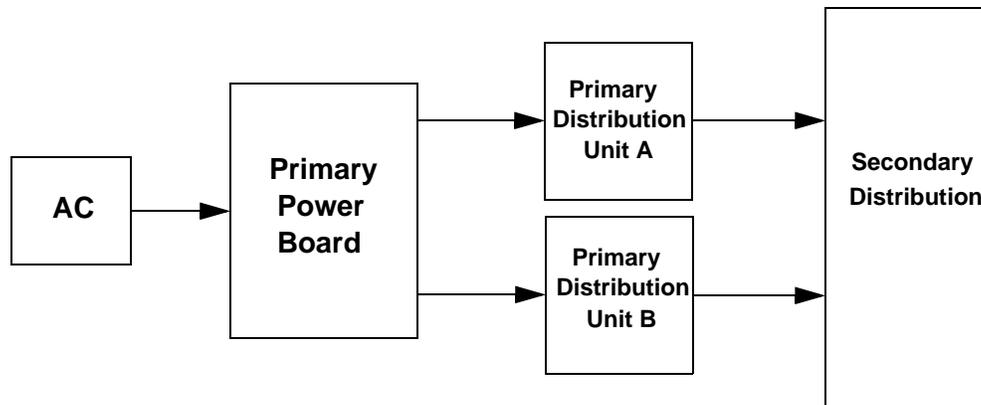
Figure 1 - Basic System Schematic

1.2 General Requirements

- Design, construction, and installation of a power system must always meet local health and safety codes as well as Occupational Safety and Heath Administration (OSHA) requirements.

- AC and DC power equipment and the associated systems must be designed to meet the applicable requirements of the National Electric Code (NEC), equipment listing requirements for product safety, Federal Communications Commission (FCC), and all other applicable Federal, State, and local requirements, including, but not limited to, statutes, rules, regulations, orders, or ordinances, or any requirements otherwise imposed by law.

Where requirements conflict that are specified by both the local operating company or manufacturers' requirements (consistent with industry standards), apply the most stringent class of standards.

Power equipment and installation must be designed to meet the operating spatial and environmental conditions for the system application. The equipment suppliers and installation organizations are ultimately responsible for the electrical and mechanical integrity of the power system. All components must meet the appropriate requirements to insure the inherent safety and reliability needed to operate a telecommunications system.

This guide contains design and installation criteria and recommendations needed to properly configure a primary DC distribution system in accordance with the general requirements listed in Table 1.

Table 1 - Table of Reference Documentation

Document Number	Document Name
ANSI T1.304-1997	Ambient Temperature and Humidity Requirements for Network Equipment in Controlled Environments
ANSI T1.315, 1994	Voltage Levels for DC-Powered Equipment — Used in the Telecommunication Environment
ASTM D-257-78 1983	Test Methods for DC Resistance
Bell Canada, DS_8171, Feb. 1986	60Hz AC and -48V DC Power Interface Requirements for Telecommunications Systems
CS-1518.10	Nortel Corporate Standard, Human Factors Design Requirements for LED Indicators on Field Replaceable Units (FRU's)
CS-2701.01	Nortel Corporate Standard for Finish
GR-63-CORE	Network Equipment — Building Systems (NEBS), Physical Protection
GR-78-CORE	General Requirements for the Design and Manufacture of Telecommunications Equipment
GR-136-CORE 1995	General Requirements for Distributing Frame Wiring
GR-499-CORE, 02, Dec 1998	Transport Systems Generic Requirements (TGSR): Common Requirements
GR-513-CORE, 01 Sept 1995	LSSGR: Power, Section 13, Functional Requirements
GR-1089-CORE, Issue 2, Revision 1, Feb. 1999	Electromagnetic Compatibility and Electrical Safety — Generic Criteria for Network Telecommunications Equipment
IEC 60950	Safety of Information Technology Equipment, Including Electrical Business Equipment
NEC	National Electrical Code, current guidelines
TR-332	Reliability Prediction Procedure for Electronic Equipment
TR-EOP-000151	General Requirements for 24, 48, 130 and 140 Volt Central Office Power Plant
TR-NWT-000154 1992	Generic Requirements for 24-, 48-, 130-, and 140-Volt Central Office Power Plant Control and Distribution Equipment
TR-NWT-000295, July 1992	Isolated Ground Planes: Definition and Application to Telephone Central Offices
TR-NWT-000928 1990	Generic Requirements for Rack-Mountable Fuse Panels Used In Central Offices
UL1950	Standard for Safety for Information Technology Equipment

2.1 The Power Plant

To properly design the power plant to meet system requirements, determine the following three major factors:

1. the total plant load requirements
2. AC/DC power system and redundancy considerations
3. power plant requirements for future expansion of the telecommunications network

Also, you will need to incorporate safety requirements, subject to local, national, and operating company guidelines, throughout the system to help shield personnel from harm.

The power plant consists of five basic elements:

- Alternating Current (AC) Source
- Direct Current (DC) Source
- DC Distribution System
- Grounding
- Alarm, Monitoring, & Control

Size each of the first four elements of the system in relationship to the others to produce a properly designed power plant system. In addition, you will need to incorporate alarm, monitoring, and control throughout the entire power system to ensure the integrity of all elements.

Design a power plant by reverse engineering, starting with what you want and working back to what you'll need.

The first step in designing a power plant is to add up the individual load requirements to get the total load requirement so that you can determine the DC power system and redundancy. From there, you can determine the AC power system, as well as standby AC requirements. Failing to adequately size up your wants and needs at the very start of the design process can be very costly if rework is necessary to correct a power plant design deficiency or lack or capacity.

2.1.1 Essential Loads

Essential loads encompass the equipment that must operate during an AC power outage. This *essential* equipment can be divided up into four basic groups:

1. **Telephone Equipment:** Toll and switch equipment, transmission equipment, clocks and timers, inverter plants, test equipment convenience outlets, status monitoring equipment, in-house telephone system, computers, etc.
2. **Building Equipment**: heating-venting-air conditioning (HVAC) systems, pumps, every day lighting, electronic security systems, elevators, etc.
3. **Business Office Equipment**: equipment used to protect company revenues, back-up systems, etc.

4. **Emergency Lighting**: operator positions, power rooms, engine rooms, rest rooms, etc.

2.1.2 Nonessential Loads

Nonessential loads involve equipment that *doesn't* need to operate during an AC power outage. This is any type of equipment not used to protect the integrity of the network during an AC service failure. Typically, nonessential loads are sourced directly from commercial AC power.

2.1.3 Special Loads

Special loads refer to special telephone power loads typically used for operating company administrative services, aspects of the revenue systems, service systems, and operation and maintenance systems. Although *basically* essential, special loads aren't normally included in planned power plant maintenance tests.

All types of loads can require conditioning of the incoming commercial AC power for the safety, proper operation, and protection of the equipment.

Several types of power conditioning equipment are used for protecting the different types of loads; these include isolation transformers, line-voltage regulators, surge suppressors, and uninterruptible power systems.

2.1.4 Load Block Diagram
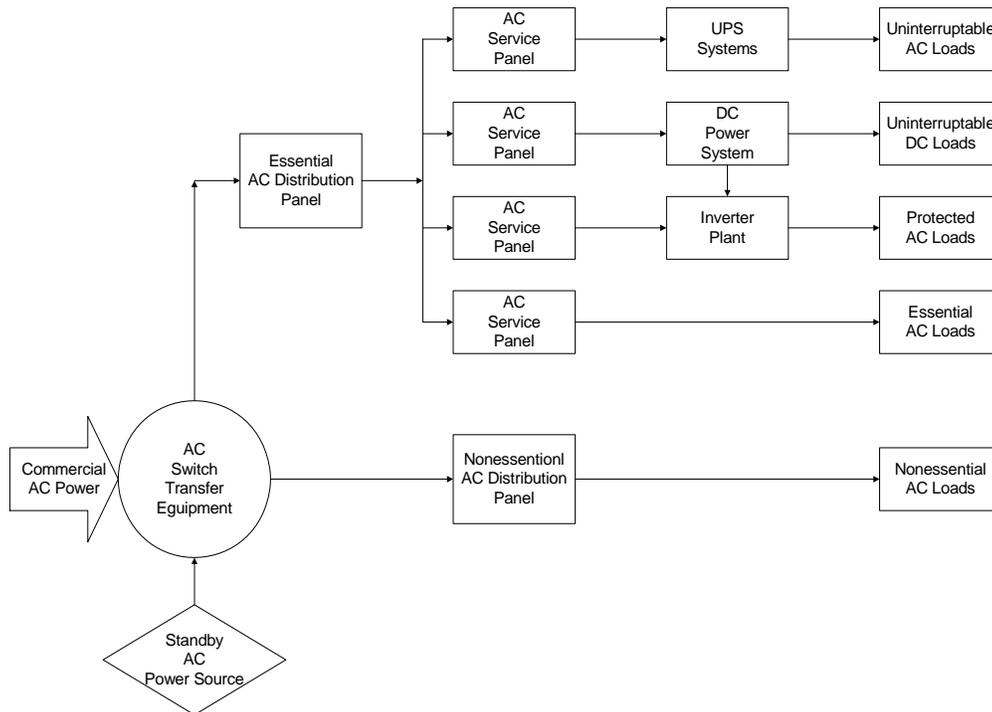
Figure 2 - Load Distribution System for a Local Switching Office

---

3.1 The AC Power System

Design the AC power system to accommodate the combined essential and nonessential load requirements, as well as future expansion capabilities.

In selecting the appropriate AC service, consider these factors:

- AC source

- AC operating voltages

- Number of AC services

- Standby AC service

- AC input transfer switch equipment

- AC distribution system

- AC backup systems for protected and uninterruptible loads

- Single-phase vs three-phase power

Commercial AC power is subject to a great number of outside influences, such as lightning strikes, automobile collisions with utility poles, system circuit faults, load switching induced impulses, etc., requiring over-voltage or surge protection. Surge protectors should be installed in the building AC power system to protect the telecommunications network from these occurrences.

Over-voltage protection is divided into three categories or stages:

1. Primary protection, protection on the incoming line or above the utility side of the system

2. Secondary protection, protection at the immediate secondary side of the high-voltage, set-down transformer, below the utility side of the system

3. Tertiary protection, protection at or close to the loads

This three-tiered protection scheme reduces the incoming transient levels at each stage, providing protection for utility company equipment as well as communications equipment.
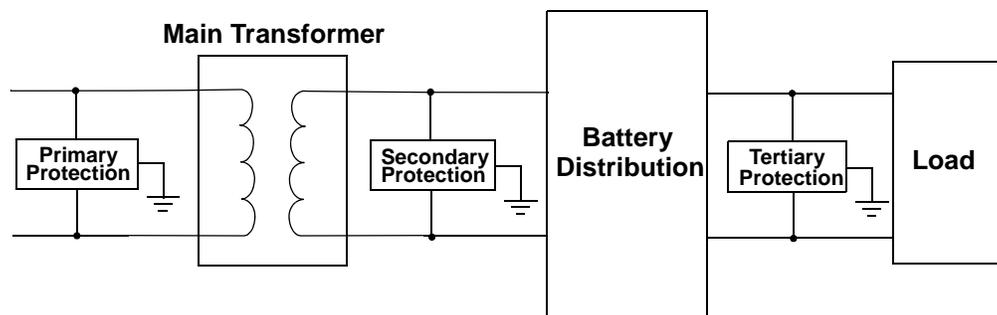
Figure 3 - Stages of Over-voltage Protection

"Sequential start" is another important consideration for both commercial and standby AC sources. Sequential start reduces immediate in-rush loads on the AC system, allowing the system to maintain voltage levels at turn on. Sequential start can be either automatic or manual operation; some equipment such as rectifiers have an automatic, built-in, stagger-start function.

NOTES:

- AC power service installations follow strict local and national code guidelines. Engineer and install all AC services using trained, qualified, certified personnel only.

- The AC power system described in this guide is based on United States standards of 60Hz ± 3Hz cycling. AC standards for other countries can vary in voltage amplitudes and frequency. Always refer to the standards for the country where the equipment is to be installed.

3.1.1 AC Source

The local utility companies provide the commercial AC power source. Typically, this is done through large transformers that step down the power line voltages to workable voltage levels.

The transformers provide single-phase and three-phase voltage levels for distribution throughout the AC power system. The main power transformers must handle all load requirements plus expected growth.

Local and national codes require that the AC power equipment and conductors be rated at 125% of the continuous peak power requirements.

3.1.2 AC Operating Voltages

The various operating voltages have significant impact on the equipment types and installation costs incurred when developing the power plant. Pay special attention when determining the proper AC services for the essential and nonessential loads.

AC operating voltages come in various amplitudes; the most common are 120Vac single-phase, 208Vac single- and three-phase, 240Vac single- and three-phase, 277Vac single-phase, and 480Vac three-phase.

Distribution and configuration of single-phase versus three-phase is heavily dependent on load demand of equipment to be powered in a given office. Although costing more to built, three-phase systems are generally more efficient than single-phase, thus reducing overall operating costs. Higher operating voltages can reduce cable size and installation costs, but require greater safety requirements and insulation factors.

3.1.3 Number of AC Services

The number of AC services requires careful planning and foresight.

Firmly establish all current and future load requirements before designing the AC power sources for a given office. After determining the main power source, the next consideration is branch circuit division of the essential and nonessential loads. Branch circuits normally require different power levels per distribution depending on the type of loads. Equipment ratings, cables, conduit,

input breakers, distribution boxes are dependent on the operating voltage and power levels distributed throughout the office.

Standby AC service, where needed, depends greatly on the essential load factor during a commercial AC failure. The loads must tolerate an AC power interruption of 5 seconds or more; recovery time for automatic systems range from 10 to 90 seconds and up to 15 minutes or more for manual systems.

3.1.4 Standby AC Service

Selecting a standby AC power source — sometimes referred to as emergency, reserve, or auxiliary power systems — involves various choices:

- Stationary versus portable

- Prime mover by natural gas, propane, butane, liquefied petroleum gas (LPG), gasoline, or diesel

- Automatic or manual control

- Single or multiple units

- Distribution and transfer switch equipment

- Operating voltage and phases required

- Type of loads required to be powered

- Pollution control, fuel storage, and noise abatement

- Type of start battery system

Size standby AC to power all essential loads, as well as meet all local codes, national codes, and operating company guidelines. Unattended or partially unattended AC power plants may require automatic start and transfer capabilities for the standby plant. Reliable standby AC sources are essential in maintaining the load requirements and environmental controls.

3.1.5 AC Input Transfer Switch

Main AC input transfer switches supply the equipment essential loads with standby power during a commercial AC outage.

The system can operate the transfer switch either automatically or by manual intervention. The switching equipment and conductor must be rated to accommodate the peak load requirements plus meet local codes, national codes, and operating company guidelines. Other design considerations include

- Branch circuit protection

- Ability to close against high in-rush current

- Ability to withstand fault currents

- Ability to interrupt six times the full load current

Telect®

A transfer switch is usually located in the main distribution bus that feeds the branch circuits. Because of its location in the AC power system and the function the transfer switch performs, the design requirements are more extensive than other branch circuit feeder devices.

3.1.6 AC Distribution System

The AC distribution system division is based on essential and nonessential load requirements and can be divided into single, sectional, or dual-bus distribution.

Distribute the service cabinets to provide access to the equipment you are powering; review long cable lengths for voltage drop considerations. You must rate each branch feeder service for proper input and output capabilities. The AC distribution system must meet all local codes, national codes, and operating guidelines for conductor ratings, installation, and grounding requirements.

3.1.7 AC Backup System for Protected & Uninterruptible Loads

Protected loads normally refer to DC-to-AC converters or inverters that provide clean (free from commercial transients) AC power to essential AC-powered equipment. Power provided to protected loads is sometimes referred to as house-protected power.

A rectifier source along with battery backup powers the inverter, providing isolation from the commercial source, as well as redundancy against a commercial AC failure. Normally, these inverters are connected to the load through a transfer switch, which then provides commercial power in the event of an inverter failure.

The transfer switches are of two types:

- fast-switching solid-state devices that can transfer the AC power within microseconds
- slow-switching mechanical relays that transfer the AC power within milliseconds

Typically, inverters are inefficient compared to using direct commercial power, but the inverters do provide good clean power for essential and sensitive AC-powered equipment.

Another scheme for AC backup for protected load is to choose the inverter's AC source as the redundant source, thus backing up the equipment from the main commercial AC power source. Although more efficient, this scheme doesn't provide isolation from transients that can occur in commercial AC power.

Uninterruptible loads normally refer to loads powered from the commercial power source through an uninterruptible power supply (UPS). The UPS contains all redundancy as well as battery backup time to maintain the loads until commercial power is restored.

Uninterrupted AC loads are of great importance to the operating companies. Uninterrupted AC loads support non-DC-operated systems and terminals, such as personal computers, that are required to support network elements during a commercial power outage.

4.1 The DC Power System

The DC Power System is the main component for maintaining the telecommunications transmission equipment in normal and redundant operations.

The DC power system contains several main elements that support the equipment loads. These equipment loads consist mostly of DC essential loads or service-affecting equipment that provide telecommunications for customers, as well as some non-service-affecting equipment, such as circuit tracer lamps and test equipment.

The total DC power required is determined by the type, quantity, and mix of telecommunications equipment distributed throughout the office. Once you determine the load, along with redundancy, distribution losses, and future expansion requirements, you can design the AC power plant and distribution system.

The following factors are important in selecting the appropriate DC service:

- Equipment — Switch, Toll, or Both

- Equipment loads

- Rectifier AC service

- Plant voltage, polarity, & regulation

- Rectifiers

- Batteries

- Main distribution bus

- Over-current protection devices

- Current shunts

- Primary distribution power board

- A/B distribution & redundancy

- Secondary distribution system

- Distribution losses

- Grounding scheme — SPG, isolated, or integrated

A DC power plant can serve multiple switching, transmission, and other telecommunications systems throughout the plant. A DC power system should be modular in design to provide incremental growth appropriate to office demand.
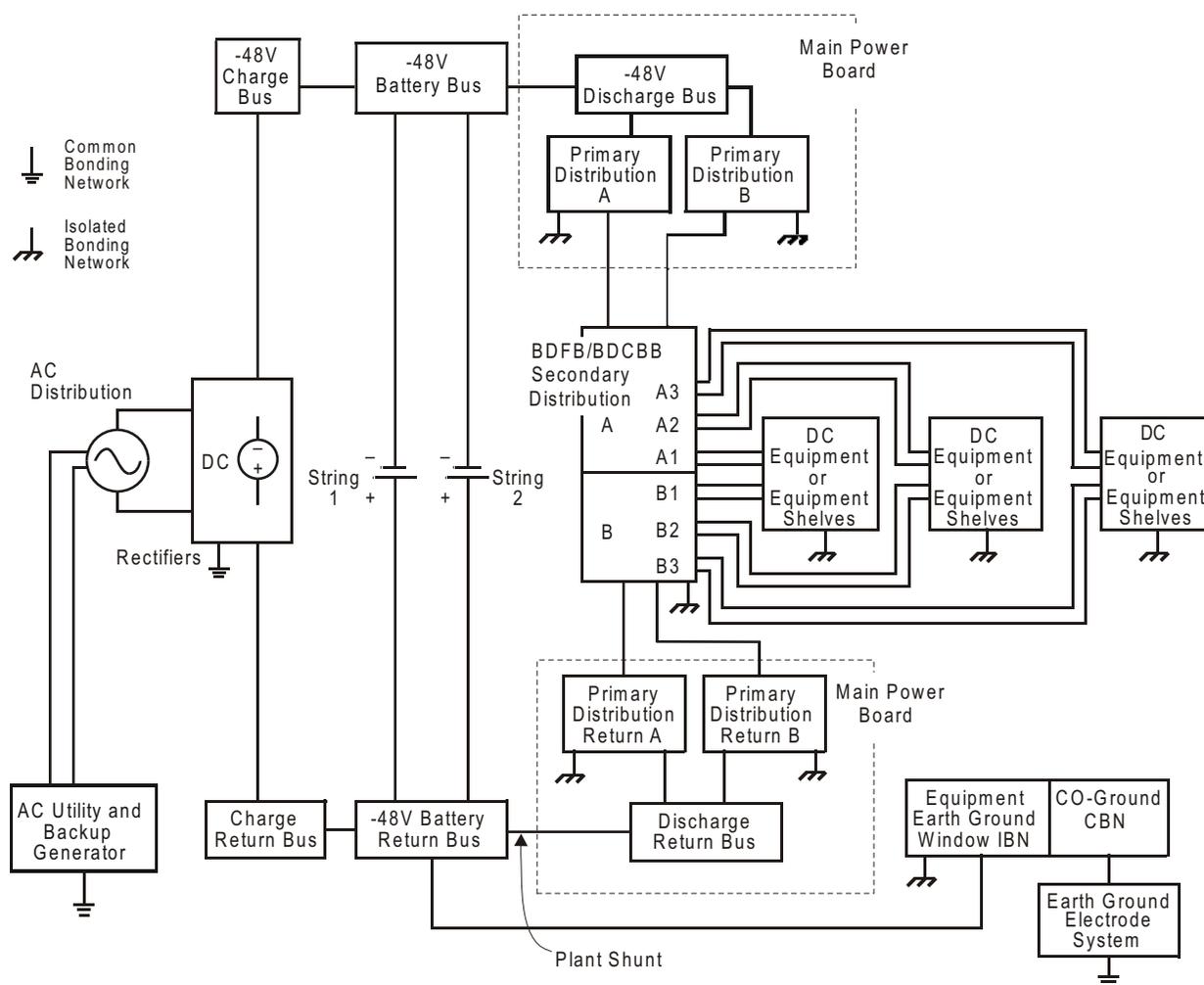
Figure 1 - Schematic

4.1.1 Equipment Loads

Most newer telecommunications equipment use constant power DC-to-DC converters to power the equipment shelves. (Converters support equipment that use voltages other than the standard –48V: specifically, the ±5V and ±12V supply voltages needed to operate the transmission equipment.)

With constant wattage devices such as DC-to-DC converters, as the input supply voltage decreases the input current demand to maintain system power increases. This increase in current impacts the available reserve time of the batteries, making this issue a major consideration when designing a DC system.

The two types of current demands in the industry are referred to as List1 and List2 current drains:

- **List1** current drain is the average busy-hour operating current at plant voltage, and is nor- mally used to size the batteries and rectifiers.

- **List2** current drain is the maximum current draw at the minimum working plant voltage, typically –42V. This represents the peak current for a circuit and is used to determine feeder cables and fuse sizes.

Equipment loads are available in two types of DC input power feeds: single feed and dual feed. Single-feed equipment has no built-in redundancy factor. (Backup for single-feed loads can be accommodated using power diodes, or configuration or load-sharing distribution panels.) In dual-feed equipment, commonly known as A/B redundancy, the output converters (±5V and ±12V) on the power cards are combined together to provide power for the transmission equipment. In a power system, the equipment power cards are redundant and fed from two branch circuits that have a common source.

4.1.2 Rectifier AC Service

The rectifier AC input feeds, along with over-current protection devices that supply power to the rectifiers, should be separate and individual feeders.

4.1.3 Plant Voltage, Polarity, & Regulation

Plant voltage, commonly called the operating voltage or float voltage, is determined solely by the battery manufacturers recommended per-cell voltage. The per-cell voltage is then multiplied by the number of cells in the string to determine correct operating voltage. (For a 48V plant, this is typically 52-to-54V.)

This per-cell voltage is greatly affected by temperature: as the temperature increases, you need to decrease the float voltage; conversely, as the temperature decreases, you need to increase the float voltage. This scheme of battery temperature maintenance, referred to as Battery Temperature Compensation (BTC), is normally available from today's rectifier manufacturers.

BTC improves the life of batteries, especially where large variations of temperature occurs, for example, at remote sites, huts, Controlled Environmental Vaults (CEV), etc. In well-regulated environments, such as a central office, BTC is less of a concern.

Plant polarity in a three-conductor system is determined by the interrupted power feed or fused leg, commonly referred to as Battery (BATT or Batt).

In a conventional telecommunications DC system, the power feed or fused leg is -48V. The negative symbol indicates that the interrupted Batt polarity is negative and that the return leg, called Return (or RTN), is positive. Return is then referenced to earth ground using either a Common Bonding Network (CBN) or an Isolated Bonding Network (IBN). Earth grounding via a CBN or IBN creates a DC fault current loop path that will interrupt an over-current device in case of accidental contact of a Batt lead to exposed conductive parts (equipment chassis, frames, racks, etc.)

Batt and Return are the conducting power elements of the three-conductor system, whereas the third wire, Ground (GND), is used only for electrical safety and mitigating electrical noise and transients.

⚠ ALERT

ALERT! The ground conductor must not carry any supporting DC current to DC loads.

Color-coding for polarity is specified per operating company guidelines and local codes: however

- Ground wires and cables are always green (GRN) or green/yellow (GRN with YEL stripe).

- Batt A (for A system polarity) is commonly red (RED) whereas Batt B is commonly blue (BLU).

- Return A and Return B are both commonly black (BLK) or with no apparent color marking.

Always use a voltmeter to verify DC distribution voltage and polarity.

Regulation is the rectifier plant's capability of maintaining the plant voltage, typically within ±.5% of the established plant voltage based on any combination of 0 to 100% output load changes and a +6% and –12% AC input voltage change. This regulation point is established at the battery terminals and is fed back to the rectifiers in what is called remote sensing.

4.1.4 Rectifiers

Rectifiers are a critical part of the DC plant. The main function of the rectifier plant is to convert the AC power source to a highly regulated DC power source to power the telecommunication loads and to float-charge the DC reserve backup battery system.

Rectifier power is obtained from the commercial AC source in a variety of voltage ranges and input phases. Standby AC power is used to bring the rectifiers on line during a commercial AC outage. In some applications, however, a redundant, commercial power source may be required as backup.

Rectifiers are equipped with a variety of features and functions: status alarm outputs, current limiting, walk-in or ramp-up time, selective shut-downs, external controller inputs, etc. Requirements for these features are dependent on the operating company guidelines and the location where the power system is to be installed.

Rectifiers have evolved technologically into two basic types: the larger, robust, controlled ferro-resonant rectifiers; and the smaller, more efficient switch-mode rectifiers.

In **ferro-resonant rectifier technology**, the rectifier transformer and associated capacitors resonate with the power-line frequencies. The closer to resonance,

- the better the power is transferred from the primary side of the transformer to the secondary side, *and*

- the lesser the AC line distortion, typically greater than 95% power factor correction at full load.

A ferro-resonant rectifier normally puts out full power, and therefore must be turned off to decrease power during rectification.

Telect®

To control the voltage output regulation of the ferro-resonant rectifier, its transformer is equipped with a control winding and semi-conductor switching that distorts the magnetic coupling between the primary and secondary transformer windings. In turn, the transformer output is regulated and filtered to produce clean, highly controlled DC output power.

Ferros have many attractive features: highly reliable, convection-cooled, current-limited at 110% (typically), equipped with active current sharing, feature a high rejection ratio to AC transients (95% power factor), up to 85% efficient, and designed for 20 years of service. Their main drawback is that the feed-back control circuitry is susceptible to oscillation; if control is completely lost, high voltage runaway can occur. Also, ferros require a larger space and are typically more expensive to install than switch-mode rectifiers.

Switch-mode rectifier technology is based on high-frequency switching (20KHz to 200KHz), which greatly reduces the size of the main power transformer. This type of technology is based on a three-stage event:

- The AC source is first rectified to a high DC voltage level through a power factor correction stage. This first stage is designed to source the AC current without distorting the AC wave-forms, typically around 99% power factor correction.

- The second stage switches the high DC voltage source using field effect transistors (FET's) through the main power transformer.

- The third stage then rectifies and filters the lower-voltage, higher-current output of the secondary winding.

Unlike a ferro, *switch-modes* are normally off and must be turned on to increase power during rectification. Switch-mode technology requires extensive electronic control circuitry, but greatly reduces the size of the units, typically a third of the space required to house a ferro-resonant rectifier of equal power. Switch-modes are more efficient than ferros by averaging around 90% at full-load capabilities, thus reducing long-term power costs. Also, component quality in switch-mode designs has increased significantly, thereby improving reliability.

Switch-mode designs incorporate both convection and forced-air cooling; higher density units typically require forced air, and are usually equipped with thermal and fan-fail detection.

Switch-mode systems typically are *hot-swappable*, normally current limited at 100%, equipped with active current sharing, and typically have a service life of 10 to 15 years. Unlike ferros, switch-modes are modular (shelf) designs and require less space and time to install. On the down side, switch modes are more susceptible to AC transients than ferros.

Rectifier redundancy is commonly referred to as N+1 redundancy. N+1 redundancy is the total load requirements, plus 125%, plus one rectifier extra in the event of a single rectifier failure. (If one rectifier malfunctions, the remaining rectifiers should operate no more than 80% of capacity to maintain the office load.)

Redundancy fills two basic needs: maintaining the DC rectifier plant power during a single rectifier failure, and providing extra current for battery recharging after a discharge due to a commercial AC outage. The amount of extra available current determines the batteries' recovery

time and the length of time the rectifiers are in current-limit state. Rectifier capacity should be sufficient to recharge the battery plant to 95% within 24 hours or less.

4.1.5 Batteries

Batteries have three main purposes in a DC power system:

- The first is to provide a backup power source for the equipment loads in the event of a commercial AC failure.

- The second is to provide filtering.

- The third is to provide large amounts of fault-clearing current to the over-current protection devices in the event of a system fault condition.

Batteries are electro-chemical power sources; each type having unique operating characteristics. Pay special attention to battery characteristics in selecting a suitable style of battery for a DC power system. Also, batteries require special environmental considerations when transporting, installing, storing, and removal.

There are two main styles of batteries used in today's telecommunications industry: flooded lead-acid cells, and recombination type cells referred to as Valve Regulated Lead Acid cells (VRLAs). Central office applications normally use 2V, flooded lead-acid storage cells that require ventilation above and around the batteries; venting is necessary for removing hydrogen gas given off by the batteries during charging. VRLAs, sometimes referred to as sealed lead-acid batteries, are said to be free from gassing and can be located in less-ventilated areas.

Most batteries have a specific gravity of around 1.2 and a float voltage of approximately 2.15V per cell. In colder locations, higher specific gravity cells are used due to the lower freezing point of high specific-gravity electrolytes. These high specific-gravity cells require a higher float voltage per cell than low specific gravity cells.

Flooded lead-acid cells are typically available in two types, lead-antimony and lead-calcium. (Lead-antimony batteries are like those used in automobiles.)

In the **lead-antimony battery**, antimony is added to the lead plates to increase mechanical strength. This type of cell construction has a higher self-discharge rate and requires larger trickle current during float charge. In turn, increased electrolysis creates more gassing than conventional lead-acid cells, thus requiring ventilation and increased water maintenance. Although lead-antimony cells have been used extensively in CO's in the past — some models are still in service — lead-antimony will probably not be used much in the future. Expected life of lead-antimony batteries in CO applications on float at 77°F is 14 years, based on experience.

Lead-calcium batteries are the most common flooded cells in the CO today. Some advantages as compared to lead-antimony batteries include lower self-discharge, lower trickle current during float charge, and less water maintenance due to a lower gassing rate. It is sometimes difficult to determine the condition of these types of cells during maintenance by specific gravity and voltage readings due to the limited electrolyte gravity change. The expected life of these batteries in a CO application on float at 77°F is 15 years, based on experience.

Recombination type cells (VRLA batteries) are of two types: one using absorbed electrolyte, where the electrolyte is contained in glass-mat separators between the plates; and the second using a gelled electrolyte contained in a silica-gel around the plates.

Under normal voltage and temperature operating conditions, this type of cell is free from problems involving gassing. VRLAs have regulated valves to vent excess internal pressure that can occur during over-temperature and high-float-voltage conditions. Also, VRLAs recombine hydrogen and oxygen at the negative plates, thus eliminating the need for water maintenance, and at the same time reducing ventilation requirements.

NOTE: Less ventilation is required for sealed cells than flooded cells, but ventilation still must meet local codes for air exchange in a given location.

Sealed cells are available in a large range of capacities, from about 25 ampere-hours to 4150 ampere-hours or more. Also, sealed cells are available in a variety of physical models for a variety of applications. Advantages of recombination cells over lead-acid cells include lower maintenance (cost savings), higher adaptability, flexible installation options, and space savings. Life expectancy of sealed cells can vary depending on environmental conditions, from as low as 5 years to as high as 20 years.

Float is the charge voltage level needed to properly maintain the battery condition; float voltage is specified by the battery's manufacturer. Another charge voltage, also specified by the manufacturer, is called the equalize voltage. (Manufacturers recommend adjusting float and equalize voltages based on voltage readings taken at the battery terminals.) Equali*ze* is a higher voltage charge rate used to balance the internal resistance of the individual cells. The internal resistance is measured by the voltage drop across the *individual cells* because cells have unequal cell voltages with different charge and discharge characteristics which affect the entire battery string.

Follow strict manufacturing guidelines of voltage levels and time when equalizing a string or strings of batteries. Flooded wet cells may require equalizing on a periodic basis, typically every 3-to-6 months for no more than 72 hours; whereas, you should only equalize sealed cells at installation, for a short period of time, and usually never during their remaining life.

NOTE: Sealed batteries left under high voltage conditions can swell and explode violently.

Battery monitoring equipment is available from a variety of manufacturers of rectifiers and battery systems. Battery monitoring is necessary for determining battery reserve times. A combination of cell voltage monitoring along with charge and discharge current time constants are used with these monitoring systems to determine the reliability and life expectancy of the battery systems.

Battery reserve time is critical to the reliable operation of the DC power system. During an AC commercial outage, the batteries must maintain the telecommunications load until the standby AC source is brought on line or the commercial source is restored. Battery reserve time is measured in ampere-hours: the amount of discharge current or amperage available over one hour while reducing the per-cell voltage as documented by the manufacturer. The typical low-voltage threshold of the per-cell voltage is 1.75V, or 42V per string; this is consistent with low-voltage limitations of the communications equipment.

Besides the amount of equipment loads backup batteries need to maintain during a commercial AC outage, you need to consider other factors when determining battery backup reserve time:

- Standby AC source availability

- Automatic vs manual start

- Attended vs unattended office

- Quality of commercial power

- Travel time

- Local regulatory requirements

Operating company guidelines and local regulatory requirements are the main criteria when designing for backup reserve time. Some general guidelines for determining standby power include the following:

- **For UPS-type systems, 15 minute reserve time** allows automatic start of standby AC source and allows orderly shutdown of computer systems, which typically cannot operate for more than 15 minutes without environmental conditioning.

- For attended central offices with *automatic* standby starts and transfers, 3 hours reserve time.

- **For attended central offices requiring *manual* standby start and transfer, 4 hours reserve time**.

- **For unattended offices *with* a portable standby power source, 4 hours reserve time** plus a factor based on travel time and connection of the portable power source.

- **For unattended offices *without* a standby power source, 8 hours reserve time**.

The life expectancy of batteries is determined by the cell's aging characteristics. The initial capacity of the cells is usually in the 90% to 100% range; within the first two years of life, this capacity can increase to slightly above 100% followed by a gradual decrease. As the batteries age, the effects of positive plate growth and grid deterioration result in loss of cell capacity. Typically, you should replace batteries at around 75% to 80% of manufacturer's initial capacity rating. Test capacity by discharging the batteries at a constant rate and then monitoring the voltage decrease versus time.

4.1.6 Main Distribution Bus

A main distribution bus system or DC Mains is the configuration of cables, charge and discharge bus work, current-measuring shunts, over-current protection devices, and plant power monitoring equipment that provides the first stage of the DC power circuit distribution. The main distribution bus system is the junction point where the rectifiers, batteries, and the primary over-current protection devices meet.

The main distribution bus system, above all DC systems, requires the most care and safety during installation.

Telect®

| Charge Bus | | Battery Bus | | Discharge or load Bus |

SH1B — Total Rectifier Load Current

SH3B — Total Equipment Load Current

SH2B — Battery Charge/Discharge Currents

RECT1 / RECT2 / RECT3

Primary Distribution Power Board -48 Split A/B System

A B A B A B

* Rem Sense

* Battery strings

+ +

Primary Distribution Unit 1

Primary Distribution Unit 2

Primary Distribution Unit 3

Supplemental Loads

SH2R

Primary Distribution Power Board Return Split A/B System

Return charge Bus

SH1R

Return Battery Bus

SH3R

Return Discharge or Load Bus

CO Common Earth Ground

Earth Ground Window

Isolated Ground System

* *

∿∿∿ = Current measuring shunts, can be located in the either polarity feed.

—∿— = Fuses, located in hot feed only.

*NOTE: * Normally, shunts are located on either Batt or Return buses, not both.*

Figure 2 - Generic Block Diagram of a Primary Main Distribution System

Rectifier/battery/distribution systems are available in a number of configurations for a wide variety of applications. In these systems, a combination of distribution copper bus work and cables connect the rectifiers and the battery strings together in a charge and discharge bus-work arrangement.

The main DC distribution bus system combines the multiple pieces of rectifiers and battery strings, and, together with large-current measuring shunts, measures the rectifiers distributed loads along with the charge/discharge currents of the battery strings.

Next, from the main DC distribution bus system, is the branch circuit distribution system. The first stage of the branch circuit distribution system is the over-current protection devices.

4.1.7 Over-Current Protection Devices

Circuit protection devices are of two basic designs:

- Self-contained, burnable elements that open upon excessive heat dissipation. Generally, these are referred to as fuses.

- Switch-type devices that use either magnetic or thermal mechanics to interrupt the switch to a tripped setting that requires mechanical intervention to reset. Commonly, these are called circuit breakers.

Fuses come in various shapes and styles designed for a wide variety of applications. Two types of fuses are used for DC applications: signal-type fuses, which mechanically activate alarms, and non-signal fuses, which require external detection for alarming.

Much design criteria goes into the development of fuses for specific applications. For DC distribution panels, only DC-rated fuses can be used with specified amperage ratings. Once a fuse has been designed for a particular circuit application, it can only be replaced with a fuse of the same ratings and physical characteristics.

Interrupt ratings are important in the application of fuses: an interrupt rating is the breaking capacity wherein a fuse can safely interrupt a fault current. Time-delay or slow-blow fuses are used in circuits where there is a large amount of in-rush amperage at turn on of the equipment.

NOTE: For compliance with UL standards, you must install and/or replace fuses or circuit breakers in distribution panels with the manufacturer's rated fuses or circuit breakers for that application and distribution panel. Refer to the product manual for specific information about DF/BAP fuse ratings.

Circuit breakers come in two basic types, thermal and magnetic trip. Thermal breakers are like fuses and activate by heat that is produced by the amperage flowing through thermal elements in the breaker. Thermal breakers are susceptible, however, to trip-point change when ambient operating temperatures or surrounding equipment temperatures increase or decrease. Magnetic trip breakers on the other hand use the magnetic field developed by the amperage flowing through the breaker to activate. Normally, magnetic breakers trip at 125% of their rated may-trip value, thus allowing higher-than-normal, continuous amperage flow for normal operation.

Magnetic breakers are not as susceptible to increased thermal conditions as thermal breakers or fuses. When using magnetic breakers, local electrical and operating company guidelines recommend that the wire size be compatible with the 125%-trip-value of the breaker.

Regardless of the type of breaker (thermal or magnetic trip), never use a breaker rating greater than 80% of the continuous load current set for that circuit. Using a larger-rated circuit breaker than specified may allow the circuit to exceed its current-carrying capacity during a List2 or Class 2 increased-amperage condition.

Time-delay breakers can be used in circuits where there is a large amount of in-rush amperage at turn-on of the equipment.

When determining proper input or output fuse/breaker size ratings, never exceed the rating of the distribution panels input and output terminal connections. Input fuses/breakers are determined by the rated design for maximum combined load or by the maximum value of the input terminals. The MCOA or LF value (defined in Figure xx) determines output fuse/breaker size of the individual loads or by the maximum value of the output terminal. Each individual load requires adequate input amperage, with adequate operating range to accommodate plant voltage variances due to power outages.

Local electrical and operating company guidelines further recommend that the interrupting device (fuse/breaker) be no more than 75% to 80% of its value at nominal volts. Interrupting devices operated at greater than this value may activate due to power plant voltage change, load variances, and thermal conditions; also, time may lessen their rated current-carrying capacity.
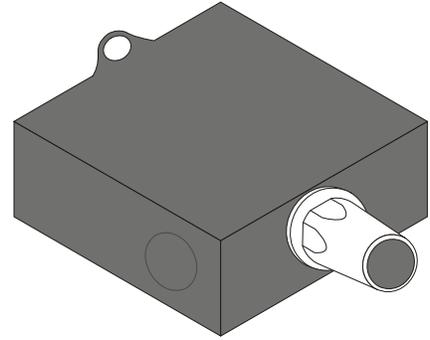
Figure 3 - Thermal Circuit Breaker
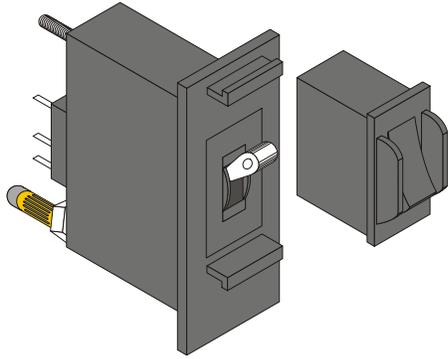
Figure 4 - Magnetic Trip Circuit Breakers

Most operating companies have guidelines to determine the proper fuse/breaker rating for an application. Follow the guidelines where applicable. Also, 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. If no guidelines are available use the following recommended formulas:

- **Total Accumulated Output Loads = Max.Input Amperage** **F1**

    Example: 5 amps + 5 amps + 5 amps + 5 amps = 20 amps
    (not to exceed maximum input load rating)

- **Max. Input Amperage x 1.5 = Input Fuse/Breaker Size** **F2**

    Multiplication Factor

    Not to Exceed Max. Input Fuse/Breaker Rating
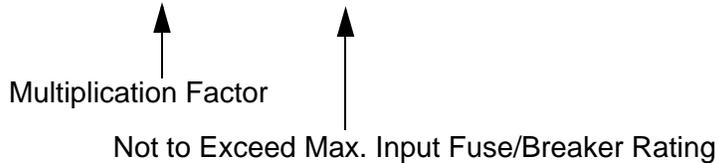
    Example: 20 amps x 1.5 = 30-amp input fuse/breaker size

- **MCOA = Max. Continuous Operating Amperage** **F3**

    Not to Exceed 80% of Output Rating at Nominal Voltage

- **LF = Load Fuse (Not to Exceed 80% of Output Rating at Nominal Voltage)** **F5**

- **MCOA x 1.5 = Output Distribution Fuse/Breaker Size**   **F6**

          ↑   ↑

Multiplication Factor   Not to Exceed Max. Output Rating

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

- **LF x 1.5 = Output Distribution Fuse/Breaker Size**   **F7**

       ↑   ↑

 Multiplication Factor   Not to Exceed Max. Output Rating

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

NOTE: Under low-voltage conditions, constant power supplies, commonly known as power cards, will increase their amperage demands in order to maintain their output wattage demands. This low voltage threshold is typically 42V for a 48V nominal system and 21V for a 24V nominal system.

- **(MCOA *or* LF) x Nominal Voltage Rating = Operating Watts**   **F8**

   Example: 5 amp load x 48.0 volts = 240 operating watts

- $\dfrac{\textbf{Operating Watts}}{\textbf{Low Voltage}}$ **= Max. Low Voltage Operating Amperage**   **F9**

   Example: 240 operating watts / 42 volts = 5.7 amps low voltage operating amperage

      Using F1, the worst case output distribution fuse/breaker size would be:
            5.7 amps x 1.5 = 8.5 amps

NOTES:

<u>At a minimum</u>, rate the fuse/breaker at the nominal voltage criteria. Doing so usually provides adequate operating range for the interruption device throughout plant voltage changes.

<u>At best</u>, the low operating voltage should be calculated to make sure the load amperage will be at least below the rated fuse/breaker value. <u>Recommended</u>: Rate the fuse/breaker at the low-voltage condition if the interruption device activates due to plant voltage changes, load variances, increased thermal conditions, or a weakened fuse/breaker.

Telect®

4.1.8 Current Shunts

Two types of current shunts are used for measuring distributed plant current loads at various stages throughout the DC power system:

- The most common is the **precision resistor shunt** that develops a small DC voltage (typically no more than 100 mV at full rating) across the resistive element of the shunt. This small voltage is then represented through a corresponding analog deflection meter, or electronically scaled and represented by a digital display. Resistive shunts produce heat as well as increased voltage drop to the equipment loads.

- The newer **hall-effect shunt** makes use of the magnetic field that is generated when current passes through a conductive element. This magnetic field represents a level of amperage that can be electrically scaled and represented by a digital display. Hall-effect technology is typically less accurate and not as linear in representation as resistive shunts, requiring increased electronic support circuitry. Less heat dissipation and no voltage drop are the benefits in using this type of current monitoring.

Both resistive and magnetic shunts are available in a variety of sizes and adapt well within the main bus distribution and equipment configurations. Shunts, along with over-current devices, bus-bars, and cabling determine the safety, reliability, and operation of the primary distribution point of the system, most commonly referred to as the Primary Distribution Power Board (PDPB).

4.1.9 Primary Distribution Power Board

The PDPB panel system consists of over-current protection devices, load current shunts, branch circuit alarming, and monitoring capabilities necessary to meet all load and future load requirements.

This PDPB panel system can be divided into a number of divisions and ratings, depending on the type of equipment loads. Supplemental, modular panels built into this system typically have fuse ratings from 30A to 800A in several combinations of output positions. The PDPB panels may or may not be fed directly from the main bus system.

In some applications the input to these PDPB panels may require a large, upstream interrupt over-current device. In most applications, the PDPBs are fed directly off the main bus system. For safety and system reliability concerns, access to the main-bus-to-PDPB connection point is usually limited to trained and experienced, installation and operation personnel.

The PDPB is the junction point where the system divides into two main branch circuits, typically known as A/B redundancy or split-bus power.

Telect®

4.1.10 A/B Distribution & Redundancy

The telecommunication equipment loads or power cards divide the load current between the A/B feeder circuits.

Both A and B sides must individually meet the full load requirements of the equipment in the event of a single-side failure. Another benefit is that A/B redundancy protects the equipment operation from fault currents caused by either equipment failure or installation errors.

The inherent resistance, inductance, and length of the power cables provide voltage separation between the faulted and un-faulted sides. This inherent isolation allows the un-faulted power card to remain at an affected but higher voltage level during the fault transition, thereby providing greater circuit reliability. In short, path separation between A and B minimizes the effect that a fault on one feed has on the other.

The primary A/B branch circuits distribute power to the secondary system through a cable management system. The number and locations of these secondary systems is determined by the load distribution throughout the office.

4.1.11 Secondary DC Distribution System

The first point of the individual secondary systems begins with distribution systems commonly referred to as Primary Distribution Frames (PDF), Primary Distribution Unit (PDU), Battery Distribution Fuse Boards (BDFBs), and Battery Distribution Circuit Breaker Boards (BDCBBs).
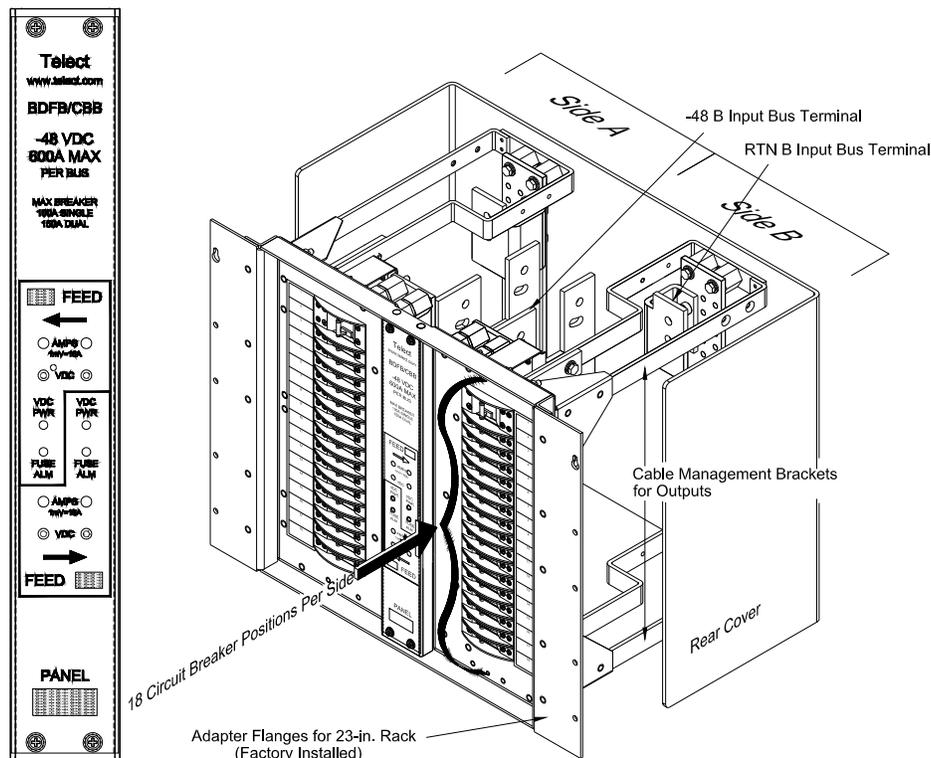

Figure 5 - Battery Distribution Circuit Breaker Board (BDCBB)

Depending on the office setup, you can distribute single or multiple secondary systems throughout the office floors. Normally, secondary systems reside within single bays or a system of bays, and are responsible for lower-level power branch distribution for the equipment bays.

Primary distribution frames (PDFs) — used for primary distribution to the secondary DC distribution systems — are available in a number of single modular or bused-modular configurations. Typically, these frames contain an A/B split bus configuration for dual-feed equipment. Typical standard features of primary distribution frames include fuse/breaker and power-fail alarms. Additional features can include voltage and current monitoring.

Outputs from the PDFs to the secondary systems require extensive cable management. Common configurations can contain up to 72 Side A and 72 Side B, #2 AWG output feeds per bay system. Return bus bars can be located within the same bay or may be located on an external bus system.
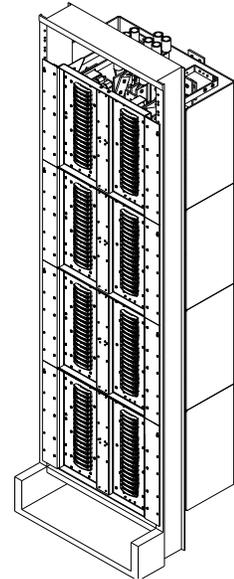

Figure 6 - BDCBB Bay

NOTE: After initially power-up of a PDF, it's rarely if ever powered down, even for installation and removal of secondary systems fed by the PDF. PDFs must be on at all times to service customers, even during installation and maintenance.

A major consideration when implementing a PDF is the type of interruption or over-current output device needed to protect telecommunications system integrity. Combinations of both fuse and circuit breaker models are available and are normally regulated for use by operating company guidelines.

5.1 Distribution Losses

5.1.1 Inherent Voltage Drop

Resistance causes a voltage drop when current flows through power cables and interruption devices, thereby lowering the actual voltage and power to the equipment or equipment shelves. The power is lost as heat dissipated in the cables.

The longer the length of wire the larger the voltage drop. To compensate for this voltage drop it may be necessary to increase the circular mils or gauge of the wire within the specifications set forth by operating company guidelines.

The discharge bus loop voltage drop, including the drop across the over-current protection devices, between the battery terminals and the loads in the equipment frame, should be limited to a maximum of 2.00V at Class 2 amperage. (This limit applies to typical power-plant voltages and is not representative of the actual voltages in the plant where the fuse/breaker panels are to be installed. You may need to determine the allowable drop based on actual plant voltage measurements.) Generally, most operating companies limit the power cable drop between the

Telect®

BDFB and the DF/BAP to .5 volts. Refer to the operating company for specific criteria relating to the required voltage drop.

5.1.2 Inherent Voltage Drop Formulas

Knowing the voltage drop required, use the following formulas to determine the wire size.

$$\text{Typical Voltage Drop} = \frac{11.1 \times \textbf{Load Amps} \times \text{Total Wire Length in Feet}}{\text{Circular Mils of Wire Used}} \qquad \text{F10}$$

$$\text{Max. Voltage Drop} = \frac{11.1 \times \textbf{Fuse Size Used} \times \text{Total Wire Length in Feet}}{\text{Circular Mils of Wire Used}} \qquad \text{F11}$$

The first formula is for typical voltage drop that depends on equipment actual amperage draw. The second formula is for the maximum voltage drop determined at the rating of the interruption device; this second formula is the recommended method of determining allowable voltage drop. Refer to the cable charts for circular mils per conductor size.
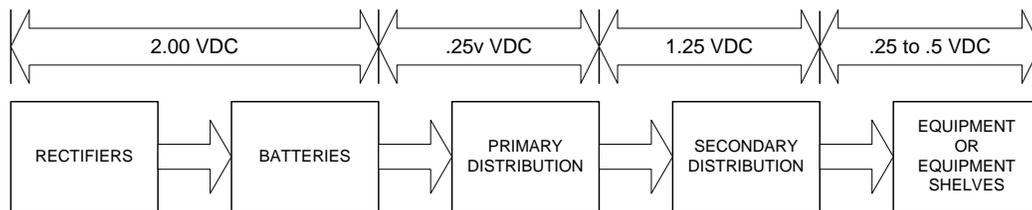

Figure 7 - Typical Allowable Total Loop Voltage Drops for a –48V Plant DC Distribution System

6.1 Grounding

Personnel safety and equipment protection in a telecommunications office depend largely on proper grounding. *Follow all grounding regulations established by local/national codes and operating company guidelines.*

Grounding provides two basic functions for proper equipment operation: the first, to reliably contain electrical noise issues that arise under normal operation; and the second, to safely contain and direct fault currents.

Electronic equipment systems are susceptible to various transients that can occur within a telecommunication office. These systems can be protected from harsh transient levels with a properly designed ground system. Designing properly grounded systems is an extensive task requiring detailed knowledge of all regulations affecting the ground system and all components used within the ground system.

Design of ground systems involves several key objectives:

• Personnel safety

• Over-current protection

- Current flow direction control

- Reduce potentials between ground systems

- Reduce electrical Internal/external noise transients

- Reduce cable inductance

- Reliable equipment operation

We'll cover these individually in the following subsections. But first, you need to be familiar with some common terminology used to describe electrical and mechanical properties of ground systems.

6.1.1 Grounding terminology

Ground — The principal ground point at which all non-current carrying equipment conductors are referenced, typically earth ground or some conductive body serving as earth ground.

Ground Electrode — The tie point or conducting connection between an electrical connection and earth is considered to be the earth grounding electrode system.

Grounding Electrode Conductor — The conductive element used to make the connection between the electrical equipment ground system and the earth grounding electrode system.

Grounded — To intentionally connect an electrical system to earth ground.

Grounding Conductor — Any conductive element intentionally or unintentionally used to connect equipment or grounded wiring circuits to the grounding electrodes.

Grounded Electrical Systems — Electrical distribution systems intentionally referenced to ground to provide voltage stability during normal operation and to prevent excessive voltage from occurring during unintentional high-voltage contact, line surges, and lightning strikes.

Bonding — The intentional joining of exposed conductive parts to form an electrically conductive path that will ensure electrical continuity with the capacity to conduct safely any electrical current likely to be imposed.

Bonding Jumper — The conductive element used to connect the equipment housing to the grounding system.

Grounded Electrical Equipment — Conductive materials housing electrical conductors or electrical equipment that are intentionally bonded and grounded to limit the voltage to ground.

Intentional Fault Current Path — The most critical element comprised of a permanent and electrically continuous conductive path with sufficiently low impedance that is capable of supporting any fault current likely to be imposed. Over-current protection devices must operate safely and reliably with no ground conductor damage.

Short Circuit — An electrical fault path between any of the conducting elements of an electrical system containing the electrical current within the conductor paths.

Ground Fault — An electrical fault path between any of the conducting elements of an electrical system and the system ground, thereby causing electrical current to flow through the grounding conductors.

Insulation Resistance — The insulating material and/or spacing that prevents connection between electrical conductors.

Dielectric Strength — The measured ability of insulating materials and spacing to prevent electrical current flow at high-voltage potentials.

Ground Circuit Impedance — The inherent inductive/capacitive reactance that accompanies the resistance in a given ground circuit path and affects the volume and timing of an electrical fault current.

Central Office Ground — A system of conductors designed to provide a low-impedance reference to the principal ground point.

Ground Window — The ground window is the interface point between the building's CBN and the AC or DC grounding conductors included in the IBN. A dimensional transition zone consisting of a sphere with a maximum three-foot radius where the IBN conductors, after passing through the window, shall be insulated and isolated from the CBN.

Common Bonding Network (CBN) — Building steel, water pipes, cable racks, vertical and horizontal equalizer conductors, bonding conductors, and electrical metallic raceways within a building when 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.

Connections to the CBN are made from equipment frames to reduce voltage differences to acceptable levels when current flows through these frames — flowing either during fault occurrences in the AC or DC power systems, or when lightning strikes.

Isolated Bonding Network (IBN) — 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 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.

During *internal* AC or DC fault conditions within a line-up, fault currents are single-pointed-to-ground to prevent flow through other isolated systems. During *external* faults — fault occurrences in the AC or DC power systems or when lightning current flows in the building — fault currents are shunted around the IBN through the single-point connection to prevent flow through the IBN of the equipment or line-ups.

Telect®

6.1.2 Personnel Safety

A properly grounded system greatly minimizes the risk of electrical shock to personnel.

Normal operating conditions place personnel at the same voltage potential as the ground system and its exposed conductive equipment elements. *Abnormal* conditions cause large electrical currents to flow through the ground system, creating potentially hazardous voltage levels between the conductive grounded elements of equipment and the ground system. By reducing the impedance of the fault path, the potential voltage difference between the two-grounded elements is minimized, thereby minimizing risk to personnel.

All power systems (AC or DC) derived within a given office environment should be referenced to the ground system to prevent unknown potentials from being present on the exposed conductive elements, and to allow the proper operation of the over-current protection devices.

6.1.3 Over-Current Protection

Grounding the electrical power systems to a common reference provides a fault current path that can be used by the power systems during a ground fault condition. The grounding conductors, along with the power system conductors, comprise a three-wire system that ensures the safe, quick, and reliable operation of the over-current protection devices in both the DC and AC ground loop paths.

The following illustration shows how over-current protection devices (fuses F1 and F2) limit damage during a ground fault caused by a KABOOM!!! that effectively crosses Batt to chassis ground.
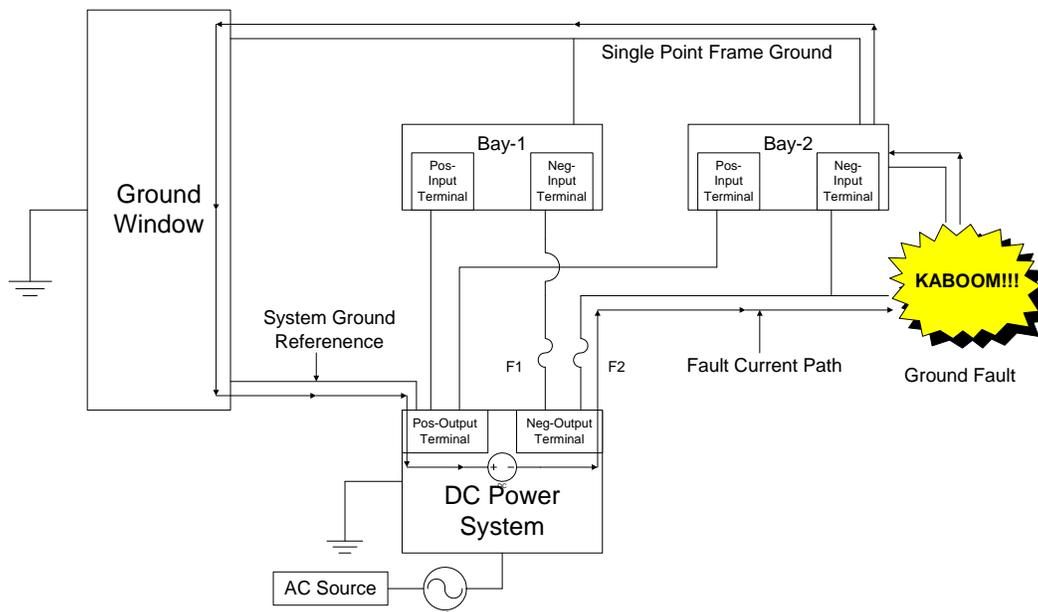

Figure 8 - DC Loop Path

When a DC ground fault occurs, the current path seeks the referenced side of the DC power system through the earth ground window and the system ground reference conductor. A solidly grounded system ensures that the over-current device (F2) opens and that the voltage potentials created by the high fault currents are kept to a minimum in the IBN ground system.

The AC loop path uses the same type of three-wire scheme where the neutral leg is referenced to the ground window through the CO ground system and the CBN ground system. This AC loop path ensures the operation of the AC over-current device in the event of an AC power system fault.

NOTES:

> Pay special attention to the mixing of the DC and AC fault current loop paths.

> Combining AC services with DC IBN ground system can create loop paths that violate the isolated single-point grounding scheme. Peripheral equipment, along with the associated ground connections, may need to be physically isolated from equipment bay line-ups.

6.1.4 Current Flow Direction Control

Creating a low-impedance fault path to handle *internal fault conditions* is a major consideration in establishing current flow direction control in a well grounded power system. The other major consideration for current flow direction is handling *external fault conditions* from outside power sources.

External power sources such as high-power AC lines and lightning strikes can create hazardous voltage conditions while the fault current flows through the ground system. These voltages can reach levels that overcome the dielectric strength and insulation resistance of the operating equipment, sometimes causing severe damage to the electronic circuitry.

A properly designed ground system provides two methods in minimizing these hazards from external fault conditions:

1. by reducing the voltage potentials that are developed
2. by directing the current flow around the equipment elements

6.1.5 Reduce Potentials Between Ground Systems

The three-wire system provides the method of maintaining the same potential in reference to earth ground for all extended isolated grounds.

Under normal operating conditions, no current flows through the ground system conductors, resulting in low or non-existent voltage potentials between the ground reference and the grounding system.

6.1.6 Reduce Electrical Internal/External Noise Transients

Electronic equipment is subject to internal electrical noise and static conditions that develop under normal operating conditions. A well-grounded power system needs a way to mitigate noise and static and provide a built-in load path for these electrical disturbances.

External transients such as Electrostatic Discharge (ESD) can have voltage potentials well above the dialectic strength of the insulation. A well-designed, well-grounded power system will direct and reduce these voltage potentials so that they don't compromise equipment operation.

6.1.7 Reduced Cable Inductance

When fault currents occur, large magnetic fields are generated along the cables. These changing states of magnetic flux induce power fluctuations in the adjacent power cables.

The normal practice for reducing these power fluctuations is to install the battery and return power cables as closely paired cables. The opposite electrical current direction through the power cables produces reversed polarity magnetic fields that cancel each other during a short-circuit fault current. The flux cancellation isn't perfect, though, since both cables can't occupy the same space at the same time.

Under ground fault conditions, the electrical fault paths are through the grounding conductors and the over-protection or battery lead. But these conductor systems aren't paired, and therefore don't have the same flux reduction or cancellation affect on adjacent cables. The grounding conductors are typically separated by a short distance from the power cables, reducing the induced effects. The protected or battery lead is contained within the power cable bundles and can cause induced effects on the adjacent cables.

Any inherent inductive reactance — any induced effect on adjacent cables — that occurs during fault currents causes the power cables, in effect, to create a secondary power source. As a result, when the over-current protection device opens, the collapsing magnetic fields create a large power kickback on the DC bus-system. This kickback energy raises the bus voltage well above normal operating parameters.

There are several key factors that determine the severity of this secondary energy source on the system. These factors include degree of fault current, short circuit vs ground fault, amount of system load, and size and length of cables.

6.1.8 Reliable Equipment Operation

Grounding is by far the most misunderstood part of the office environment.

Several factors must be considered in designing the ground system, but personnel safety and protection of equipment are the main objectives.

Code requirements are based on safety issues involving operation personnel. (Normally, complying with safety requirements only means a minimal enhancement to the ground scheme.) But equipment operation and protection require extensive planning and implementation in a properly designed ground system in the central office environment.

Telect®

7.1 Alarm Monitoring and Control

A central office contains several safety and operational control systems. Fire alarms, door alarms, HVAC alarms, and AC and DC power plant status and alarm systems are all incorporated into the site monitoring/control system.

Older generations of alarm monitoring typically required both visual and audible signaling methods for attended plants. The trend now, in unattended plants, is to use computer-based alarm surveillance systems for remote monitoring.

The power plant alarm monitoring and control system is designed for conditions that have an impact on the operation and reliability of the local office telecommunications network. Alarm monitoring and control systems use two types of indicators: status and alarm.

Status indicators specify the equipment's normal operating state rather than a failed or alarm condition. These indicators inform the operator of an on-off state. Power-on LEDs (green-on versus off) are visual examples of status indicators.

Alarm indicators, on the other hand, specify an equipment failure or malfunction that can cause impairment of service or damage to operating equipment. Alarms provide visual indication and remote dry relay contacts for transmitting signals to the internal office and remote monitoring alarm systems.

Alarms come in three levels of urgency:

- Critical — The highest priority level indicates a serious service-affecting condition in the power system that requires immediate attention for correction.

- Major — Less urgent than critical, MAJOR indicates serious disruption of the power plant or distribution system that requires immediate attention for correction.

- Minor — The lowest level indicates operation or power interruption that is not service-affecting to the telecommunication loads and therefore requires less immediate attention.

Visual indicators follow a standard illumination color-code scheme for identifying alarm status:

- Green indicates normal operation of the power system; off indicates loss of normal operation.

- Red indicates an immediate service-affecting condition of the power or distribution system. Commonly used to indicate critical or major alarm conditions.

- Yellow indicates an alarm condition for an abnormal operation that requires attention before service is affected. Commonly used to indicate a minor alarm condition.

- White signifies other conditions that do not fit standard visual alarm categories.

The remote relays used to transmit alarm signals are typically form-C, dry contact relays. "Form-C" means that the relays have a mechanical wiping action at the contact points upon closure. This removes oxidation on the contact surfaces, resulting in increased lifetime performance. "Dry contact" refers to electrical isolation, meaning that the relay contact points are isolated from electrical voltage potentials and frame ground.

The contacts or switch can be incorporated into the remote monitoring systems power source as long as the contact point voltage and current ratings are not exceeded. Typical contact point ratings are 60Vdc at .6A for most standard applications. Some alarm systems require two closures for both visual and audible indications for a single alarm event.

Most relay closures are available in dual-state relay contacts, defined as Common to Normally-Open (C to NO) and Common to Normally-Closed (C to NC). Normality, or what constitutes a norma condition for the closed versus open contacts, varies among equipment manufacturers. Relays that provide only one state are normally the closure state for the alarm condition.

Alarm systems for telecommunications *commonly* use a closure state as the alarm condition; this closes the alarm circuit loop, activating the alarm monitoring system. This *commonality* allows parallel wiring of multiple alarm circuits to a single or combined point or alarm called the alarm concentration or bay alarm. Although a proven reliable design, this type of circuit does not detect open wiring between equipment elements.

To detect open wiring, a series-circuit design (like those found in burglary or door alarm circuits) is used to serially link the alarm contacts with contacts that are closed during normal operation. If either the alarm or wiring opens in a closed-circuit operational loop, the alarm goes off. (Serial alarm circuits are difficult to design when combining multiple alarms into single or concentrated alarms.)

Several subsystem elements and values are monitored for alarm conditions in a power plant system:

- AC Plant Voltage

- AC Plant Current

- AC Phases

- AC Standby Plant

- AC Protection Devices

- Single Rectifier Failure (Minor)

- Multiple Rectifier Failure (Major)

- Rectifier Input/Output Over-Current Devices

- Remote Sense Leads

- Fan Failure

- Plant Control Over-Current Devices

- Plant Voltage

- Rectifier Current Limit Alarms

- High/Low/Very Low Voltage Alarms

- High Voltage Shut-Down

Telect®

- Total Plant Amperage

- Battery Charge/Discharge Amperage

- Battery Temperature Monitoring

- Plant Load Amperage

- Converter Plants

- Inverter Plants

- Primary Distribution Alarms

- Secondary Distribution Alarms

- Sub-Secondary Distribution Alarms

Power plant alarm/status monitoring systems provide the office with in-house alarm/status as well as remote alarm/status indications. Remote alarm/status indication is defined by operating company guidelines for protocol, transmission method, and alarm grouping. Multiple monitors can be contained in a given office and combined to a single monitoring point.

Alarm monitors can be an illuminated visual display, an LED display, or a Cathode Ray Tube (CRT). Much of today's telecommunication equipment report alarms with dry contact relays along with serial data interfaces. Monitoring systems track and provide history logs of the plant power system alarms and power requirements. Special monitoring systems can also provide a limited element of automatic plant control.

Power plant controllers can provide functional control over power system elements, based on alarm inputs and operational programs. Automatic controllers make predetermined decisions based on status and alarms generated in the office. These controllers have highly defined operating parameters and may have full or limited control of the power system elements. Some typical functions a plant controller can provide are

- AC Standby Power Start/Stop Functions

- AC Transfer Switch

- Sequential Load Operation

- Sequential Rectifier Start

- Rectifier High-Voltage Shut-Down

- Rectifier Restart

- Rectifier Temporary Release

- Battery Monitoring

- Temperature

- Energy Management

- Heating, Venting, Air Conditioning (HVAC)

Alarm monitoring and controlling is crucial to telecommunications office safety, reliability, service, performance, and plant maintenance.

8.1 Secondary Distribution Power Systems

Secondary distribution is featured in Telect's publication **Secondary DC Distribution Technical Reference Guide** (Part Number 118101). Contact *telect.com* or call 1-800-551-4567 (domestic) or 509-926-6000 (international) to obtain a copy of this informative handbook.

Telect's **Secondary DC Distribution Technical Reference Guide** outlines the criteria for, components required, and the guidelines to follow in designing and maintaining secondary DC distribution power systems. The guide covers electrical and mechanical engineering considerations, testing and maintenance requirements, along with electrical and component charts for Distribution Fuse/Breaker and Alarm Panels (DF/BAPs).