DC Power Distribution Basics

Best-Practice Guidelines for Telecommunications Power Management and Wiring

As communications networks continue to evolve, the integrity of infrastructure continues to be of vital importance; not only for the exchange of data, but also for the revenue-earning potential the lines represent to the industry and the customers it serves.

Given the expense involved, the emphasis for network growth is frequently placed on the architecture of the lines, yet industry dynamics can leave some service providers vulnerable. Prior to industry deregulation, much of the engineer, furnish, and install (EFI) was performed by specialized staff within the provider. Today, competitive forces have led many to outsource EFI. Equipment vendors are increasingly called upon to configure equipment, including power distribution. While standards exist for these procedures, in actuality DC installation practices have been known to vary.

This paper will present guidelines that Telect considers “best-practice” for power distribution and wiring. Adhering to these recommendations is an important measure for protecting the system investment over its service life. As systems change, these practices can also help providers control lost revenue costs due to power-related downtime.

Best-Practice Power Distribution

By design, the cumulative output rating of virtually every power distribution panel can exceed the maximum input rating of the panel. While this provides users with design flexibility, it is imperative that system engineers design for the cumulative load current requirements. If a load drawn by connecting equipment surpasses either the maximum rated amperage of any individual fuse, or the maximum rated input value for a group of fuses, system downtime costs will be incurred. Consequently, when selecting a secondary power distribution system, it is important to give consideration to the overall load that will be drawn by connecting equipment, as well as to the maximum amperage rating of the individual loads, and to the DC input level.

Fuses and Magnetic Breakers

Fuses and magnetic circuit breakers are two of the most commonly used devices in power distribution panels. Understanding how best to leverage the advantages offered by the various circuit interrupt protection devices can help improve system integrity and maximize the cost-effectiveness of operating the panel.

Fuses

Two widely-used fuses for low-amperage equipment-feed applications are the Type 70 and the GMT. A cylindrical-shaped fuse, Type 70s are typically rated for a maximum output of 10 amps. Color-coded GMT fuses are available in variety of sizes up to a maximum of 20 amps. (Refer to Table 1.) A popular advantage to the GMT fuse is that each requires less space than Type 70 fuses, which allows greater fuse density on a given power distribution panel.

Max. Amperage Rating	GMT Fuse Color Code
1/4A	Violet
1/2A	Red
3/4A	Brown
1A	Gray
1-1/3A	White
1-1/2A	White/Yellow
2A	Orange
3A	Blue
4A	White/Brown
5A	Green
7-1/2A	Black/White
10A	Red/White
12A	Yellow/Green
15A	Red/Blue
20A	Green/White

Table 1: GMT color-coding of fuse ratings.

Several other fuse types are available for larger loads. Intermediate fuses are commonly used to supply power to equipment, or to the small fuses noted above. Included in this category is the KLM fuse. It is suitable for applications up to 30 amps. Where even larger capacities are required, the 50-amp TPA fuses may be used.

Regardless of the type of fuse selected for an application, adhering to a few best-practice guidelines can help ensure trouble-free operation. Within their respective class types, the physical fuse dimensions are the same irrespective of the specific fuse amperage. Although this makes it physically possible to use a higher amperage fuse in a fuse position rated for a lower amperage fuse, this must be avoided. Additionally, while wiring to the use is selected based on the fuse’s maximum value, a best-practice policy is to ensure that the load supported by the fuse is not more than 75% of the fuse's rated capacity.

Magnetic Circuit Breakers

Another option for power protection involves the use of magnetic circuit breakers. These too are available in a variety of sizes; however, unlike fuses, the breaker description represents the maximum output the circuit will hold. Consequently, a 50-amp breaker will typically trip if the output required reaches or exceeds approximately 125% (62.5 amps) of the breaker's rated value. This trip point is determined by the breaker manufacturer.

An advantage to the use of breakers is that in the event the circuit becomes overloaded and trips, resuming operation may be as simple as resetting the switch after the fault has been corrected. Comparatively, fuses need to be replaced when overloaded. This feature makes breakers an attractive power distribution method where it may be inconvenient to replace fuses, or where fuse availability may be limited. However, time and overloads will unpredictably degrade the trip point of a breaker. This makes the identification of degraded breakers difficult during proactive maintenance. Additionally, it is more difficult and time-consuming to replace a defective breaker versus a faulty fuse.

Output, Input and Load Considerations

Electing to use breakers or fuses is an initial step in determining what type of power distribution panel is best suited for the application. Evaluating the specific input power needs of the equipment that will connect to the distribution panel will help determine suitable fuse/breaker sizes.

Load requirements determine the output fuse/ breaker sizes required on the power distribution panel. Load is determined by the maximum continuous operating load drawn by either the equipment or the equipment shelf, as determined by the equipment manufacturer. Distribution fuses must be equal to, but no greater than, 1.5 times the equipment's, or the equipment shelf's, load fuse. While it may be necessary to use a protective device with a time delay to accommodate some surge conditions, generally the following formula can help approximate the output fuse/breaker size required to allow for the upper voltage limit:

Output breaker/fuse size =
(Maximum continuous operating current) x 1.5

When powering switch-mode devices (also known as power cards), the maximum input current rating should be determined by the lowest operating voltage of the equipment. This is usually 42 volts. Switch-mode power devices increase their current demands as the input voltage decreases in order to maintain their output voltage and wattage demands. Using the following equations can help define the highest maximum input current.

Operating Watts =
Float voltage x (max. continuous operating current)

Maximum low-voltage operating current =
$$\frac{\text{Operating Watts}}{\text{-42 Low voltage}}$$

Given the heat-sensitive nature of fuses and thermal breakers, the conditions in which the fuse/ breaker will be used can cause the rated trip points of the devices to deteriorate. Ambient temperature, heat dissipated by surrounding equipment, or placing high amperage loads next to each other in the power distribution panel may produce thermal conditions that can hinder part performance. To minimize the effect of heat generated by these sources, best practice guidelines recommend increasing the spacing between components to promote air circulation, or using a magnetic breaker that is not as effected by thermal conditions.

The function of output fuse/ breaker is primarily to provide required wire protection, since in most instances with active devices, the equipment connected to the output load is required to be fused for circuit protection. However, best-practice policy recommends that individual output fuses/breakers should not be operated continuously at more than 75% of their rated amperage, nor should the combined amperage of individual fuses/breakers exceed 75% of the input from the interrupting device feeding the power distribution panel.

Using these guidelines, it is then possible to determine the type of fuse best suited for the application. Local practice or application may dictate the standardization on a specific distribution panel featuring only one fuse type; e.g., GMTs or KLMs.

Applications requiring a mix of high- and low-amp outputs may find the use of two-in-one type fuse panel advantageous. These panels, for example, provide both GMT fuses for low-amp needs *and* KLM fuses for higher amp requirements.

There are also both single-feed and dual-feed type panels designed to offer power redundancy. If a single-feed power source is used for a dual-feed panel, the power bay breaker/fuse size cannot be greater than one of the dual inputs. If using a single-feed source greater than one of the dual inputs, input fuses/breakers are required in the panel.

It is important to remember that the load is likely to be affected if the connecting equipment configuration is changed. Should any component of the configuration change, it is imperative that the power requirements and installation be reviewed and revised as needed.

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Best-Practice Wiring

Having defined a sound power distribution system in accordance with the best-practice guidelines mentioned above, the next step in assuring network integrity is to implement the power distribution system using best-practice wiring methods. These guidelines recommend that wire installations be rated for worst-case applications, making it important to understand the factors that influence wire size selection.

Fuse/Breaker	Wire Size (AWG)	Circular Mils
1/8A	26	254
1/4A	24	404
1/2A	22	643
1A	20	1022
3A	18	1624
5A	16	2583
15A	14	4110
20A	12	6530
30A	10	10380
40A	8	16510
55A	6	26420
70A	4	41740
95A	2	66360
110A	1	83690
125A	1/0	105600
145A	2/0	133100
165A	3/0	167800
195A	4/0	21160

Table 2: Wire sizing guidelines based on a maximum wire length

Voltage Drop and Wire Length

Voltage drop occurs in every configuration and is attributed to the physical length of the wire and the application's requirements. In every installation, the inherent voltage drop from the power bay to the equipment is determined by the length and size of the power wires and the operating temperatures. As noted below, this drop can be estimated using either the load amperage, or the fuse size:

Typical Voltage Drop =

$$\frac{(11.1) \times (\text{load amps}) \times (\text{total wire length in feet})}{(\text{circular mils of wire used})}$$

Maximum Voltage Drop =

$$\frac{(11.1) \times (\text{fuse size used}) \times (\text{total wire length in feet})}{(\text{circular mils of wire used})}$$

In most instances, the service provider will specify the allowable voltage drop. In this case, the company will also provide its own inherent voltage drop wire length charts to meet these parameters. These charts are generally developed with consideration to several factors, including:

- Whether the wire composition is a solid core or stranded;
- The number of strands, as well as the grade of material making up the conductor;
- Whether the power leads are exposed in an open-air condition or bundled together in a closed-air condition;
- Ambient operating temperature;
- Dielectric strength of the insulating material; and
- Fire resistance requirements.

In the event that service provider guidelines are not provided, Table 2 outlines best-practice guidelines that are within Underwriter's Laboratory (UL) and National Electric Code (NEC) specifications, and are based on a total wire length of both battery and return leads being no more than 50 feet. Applications with wire runs in excess of 50 feet should be estimated using the formulas noted above.

Input Wiring

One fundamental consideration in selecting the appropriate input wire is determining the input size of the distribution panel to be installed, which can be obtained from manufacturer specifications. In the event that the primary power distribution source feeding the interrupt device is fused lower than the breaker/fuse panel input specified by the panel's manufacturer, it is necessary to de-rate and re-label the panel to indicate the maximum load current. Voltage drop should always be considered at the rated full load of the distribution panel.

Output Wiring

Proper wire sizing is a critical part of the installation since it ensures that fuses/breakers will activate before any harmful damage is passed to the connecting power distribution panel wiring. At a minimum, output wire size is strictly determined by the output fuse/breaker size and the footage length chart (refer to figure), with longer wire runs warranting an increase in wire size to reduce the inherent voltage drop.

Grounding and Bonding

Fuse/breaker panels are rack-mounted devices that require a wire connected from the appropriate frame, or aisle earth ground point, to the panel's designated chassis ground terminations. Grounding is an important part of a safe installation, since it protects operation and service personnel from exposure to hazardous voltages, and ensures the safe operation of interruption devices when a ground fault current is accidentally applied to the metal framework.

Although mechanically connected to the return lead at the primary distribution source, the ground lead is not a current-carrying wire. Only the battery and return leads serve as current-carrying wires that provide power for proper equipment operation. Since electrically the ground wire is not the same point as the return lead, the ground and return should never be tied together at the secondary distribution panel.

The ground wire must be suitably sized to withstand instantaneous interruption of the ground fault current without sustaining damage to the ground wire. (This type of interrupt will activate the fuse or breaker input device that is feeding the secondary distribution panel.) To determine the recommended wire size, refer to the manufacturer's specifications or Bellcore standards on installation and grounding requirements.

Conclusion

Inadequate power distribution and wiring installation practices will affect even the most complex communications system. Consequently, it is prudent to use best-practice methods in order to avoid power-related downtime. Power distribution systems should be correctly configured with fuses tailored to meet output, input and load considerations. It is also imperative that wiring to the power distribution system is properly sized and performs within voltage drop specifications.

Following best-practice guidelines contributes to a safe, fire-hazard-free operating environment. As the network develops, it is necessary to re-assess power distribution to ensure all of the network elements can perform to their desired effect. Adhering to the best-practice guidelines will ensure the safe operation of the network environment.

Additional References:

1. Bellcore Technical Advisory TA-NWT-001373, *Engineering, Installation/Removal Service Provider Generic Requirements*, Issue 1, July 1993.

2. Bellcore Technical Advisory TA-NWT-000137, *Generic Requirements for Central Office Cable*, Issue 2, December 1993.

3. Bellcore Technical Advisory TA-NPL-000286, *NEBS Generic Engineering Requirements for Systems Assembly and Cable Distribution*, Issue 2, January 1989.

4. Bellcore Technical Reference TR-NWT-000154, *Generic Requirements for 24-, 48-, 130 and 140-Volt Central Office Power Plant Control and Distribution Equipment*, Issue 2, January 1992.

5. Bellcore Generic Requirements GR-1089-CORE, *Electromagnetic Compatibility and Electrical Safety—Generic Criteria for Network Telecommunications Equipment*, Issue 1, November 1994.

6. Bellcore Generic Requirements GR-1275-CORE, *Central Office Environment Installation/Removal Generic Requirements*, Issue 2, April 1997.

7. Bellcore Generic Requirements GR-63-CORE, *Network Equipment Building System (NEBS) Requirements: Physical Protection* (a module of LSSGR, GR-64, TSGR, FR-440, and NEBS FR, FR-2063), Issue 1, October 1995.

8. Bellcore Technical Reference TR-EOP-000295, *Isolated Ground Planes*, Issue 1, November 1987.

9. National Electrical Code Handbook 1996, *Conductors for General Wiring* Section.

10. National Electric Code Handbook 1996, *Sizing Conductors*.

11. National Electric Code Handbook NPFA 70 1996, *Ampacities*.