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>Date: Tue, 26 Jan 1999 09:06:26 -0600
>From: rcoll@fnal.gov (Coll, Raphael)
>Subject: FESHM 5045/5046
>X-Sender: rcoll@popgtw.fnal.gov
>To: ESH_Admin@fnal.gov
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>These two chapters were reviewed by the electrical safety subcommittee and
>found to be current. No changes were made. Pls re-issue with a 1/99
>revision date. Do not need to be posted.
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>The Patience Prayer:
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>God grant me patience
>... and I want it right now!
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LOW VOLTAGE, HIGH CURRENT POWER DISTRIBUTION SYSTEMS

INTRODUCTION

The distribution of current from a low voltage power source to one or more loads, though generally not considered to present a personal shock hazard, can present a significant hazard because of possible high current capability of the power source. High currents, coupled with lack of adequate overcurrent protection and/or undersized conductors, can lead to overheating of the conductors between source and load, thus presenting a fire hazard. Arcing from improper termination of high current conductors is an additional fire and personnel hazard. The designer or user of such a system or systems shall take all reasonable steps to assure safe operation under foreseeable fault conditions.

The criteria presented here apply only to the protection of electrical conductors between a low voltage, high current power source, as defined hereafter, and one or more electrical loads. These criteria especially apply to those situations where power is distributed from a low voltage high current source by the conductors of ribbon cable.

These criteria do not apply to the protection of conductors within commercially manufactured electrical equipment that utilizes or requires one or more low voltage, high current power sources. Such equipment includes commercially manufactured standardized crate systems such as, but not limited to, FASTBUS, CAMAC, STD, VME, VXI, MULTIBUS I/II, and NIM. Additional conditions of said non-applicability are that the internal power distribution is enclosed and has not been modified, and that the equipment is utilized within the manufacturer's guidelines as related to power distribution/capability. For those cases where the power source for such equipment is external, these criteria do apply, with the equipment being considered a single load. Additionally, when power is supplied to an external load from such equipment, these criteria do apply, with the equipment here being considered as the power source.

DEFINITIONS

For the purposes of this chapter, these definitions shall apply:

Low Voltage - a voltage which is less than 50 volts AC or DC.

High Current Power Source - a low voltage source, with a designed or rated output current greater than 10 amperes, or with a designed or rated output power greater than 50 volt-amperes.

Overcurrent Trip Condition - a condition for which a current limiting or interrupting means such as a fuse, circuit breaker, resistor, electronic current limit, or other suitable device, has acted to limit or reduce the current from a power source to some lower pre-defined value.

Load - the electrical device or circuit, having resistive and/or reactive impedance, that consumes electrical energy from the power source. A printed circuit board or module is generally considered a single load. However, crate systems, capable of powering one or more modules or printed circuit boards within a single chassis, are a unique special case. For such crate systems: the backplane, its conductors and connectors, and installed boards or modules are all to be considered as a single load to the power source. The power source conductors are considered to terminate at the point of backplane connection.

REQUIREMENTS

1. Power Source Overcurrent Protection

   A low voltage, high current power source may or may not be internally overcurrent protected. The nature and level of protection shall be determined so as to properly specify the source to load conductors. Power sources may be internally or externally modified to provide a known safe level of overcurrent protection. The external addition of overcurrent protection shall be as close to the power source as is reasonably possible.

2. Power Source to Single Load Conductors

   The conductors supplying power to a single load shall be adequately terminated and sized to safely carry the load current under all anticipated load conditions. Occurrence of a short circuit at any point between the source and load, either between the supply conductors or between either of the supply conductors and ground or common, shall not lead to overheating or damage of the conductors or the insulation of the conductors. These criteria shall also apply to sense conductors, when present, between a source and load. Sense leads shall be protected, either by fuses or resistors, from being exposed to the full load capability of the supply.

   a. Overcurrent Types

Application of such a short circuit may or may not result in an overcurrent trip condition at the source depending on the particular overcurrent protection at the source and the impedance of the conductors.

i) For cases where a trip condition does occur, the source to load conductors shall safely support the fault current necessary to cause the trip. If the threshold of the overcurrent trip condition is adjustable, the source to load conductors shall be designed and sized for the highest adjustable threshold.

ii) For cases where a trip does not occur, the conductors shall be adequately sized to safely support the short circuit current.

b. Multiple Conductors

A particularly dangerous situation exists when conductors are wired in parallel to provide sufficient current carrying capability to the load as well as to reduce source to load conductor impedance. The failure of a single conductor may not produce a trip condition or may result in potentially unsafe current levels in the remaining connected conductors. For such cases, each of the conductors between the source and load shall be reasonably protected against inadvertent shorts at any point between the source and load, and connections at both the source and load shall be sufficiently robust to prevent overheating, inadvertent disconnection, or failure. Special circumstances may require overcurrent protection on each of the conductors of an installation using parallel conductors.

3. Connection to Multiple Loads

Connection of a single low voltage, high current power source to multiple loads can result in hazardous conditions if due consideration is not given to the criteria delineated for single loads. Emphasis here is given to the protection of conductors between source and load, given the possibility of a short circuit condition at any point of the power distribution system. The criteria delineated for power source to single load conductors shall also apply for a multiple load configuration.

Installation of passive overcurrent protection devices, such as fuses and circuit breakers, between the source power bus and single load taps is often the most practical solution to the safe powering of multiple loads. Installation of such passive overcurrent protection devices can allow the safe utilization of conductors more appropriately sized to the individual load.

Printed circuit boards and modules, that are powered from a backplane that is supplied by one or more low voltage, high current power sources, are best protected as loads by the interior installation of fuses or other current limiting devices. Installation of such protection is highly recommended.

4. Connection of Source to Load Conductors

Dangerous situations often occur because of poor installation of current carrying conductors at the source or load. Mechanical connections shall be adequately tightened. Lock nuts, lock washers, or belleville washers shall be used where appropriate. Bolts, screws and other fastening devices shall not be used as current conductors unless specifically designed for such purposes. Special caution is advised when dissimilar metals are used for connection in high-current applications.

Connection of conductors between source and load shall be clearly labeled, keyed, or polarized so as to prevent any reasonable possibility of misconnection or shorting of said conductors. Ribbon cables, where used in whole or part for distribution of power, shall employ keyed or polarized connectors. Periodic maintenance and/or infrared scans may be appropriate for certain high current connections.

5. Selection of Source to Load Conductors

The selection of conductor size and type between source and load(s) is an engineering problem which has no simple answer. The designer, following good engineering practice, should consider the overcurrent characteristics of the power source, conductor impedance, distance between source and load, connection/terminal impedance, ratings of the conductor insulation, the nature of conductor paths and raceways, ambient temperatures and component temperature ratings. Proper consideration of these and other applicable factors will assure the selection of a conductor type and size that will ensure safe operations.