

# DC for Data Centers: Grounding

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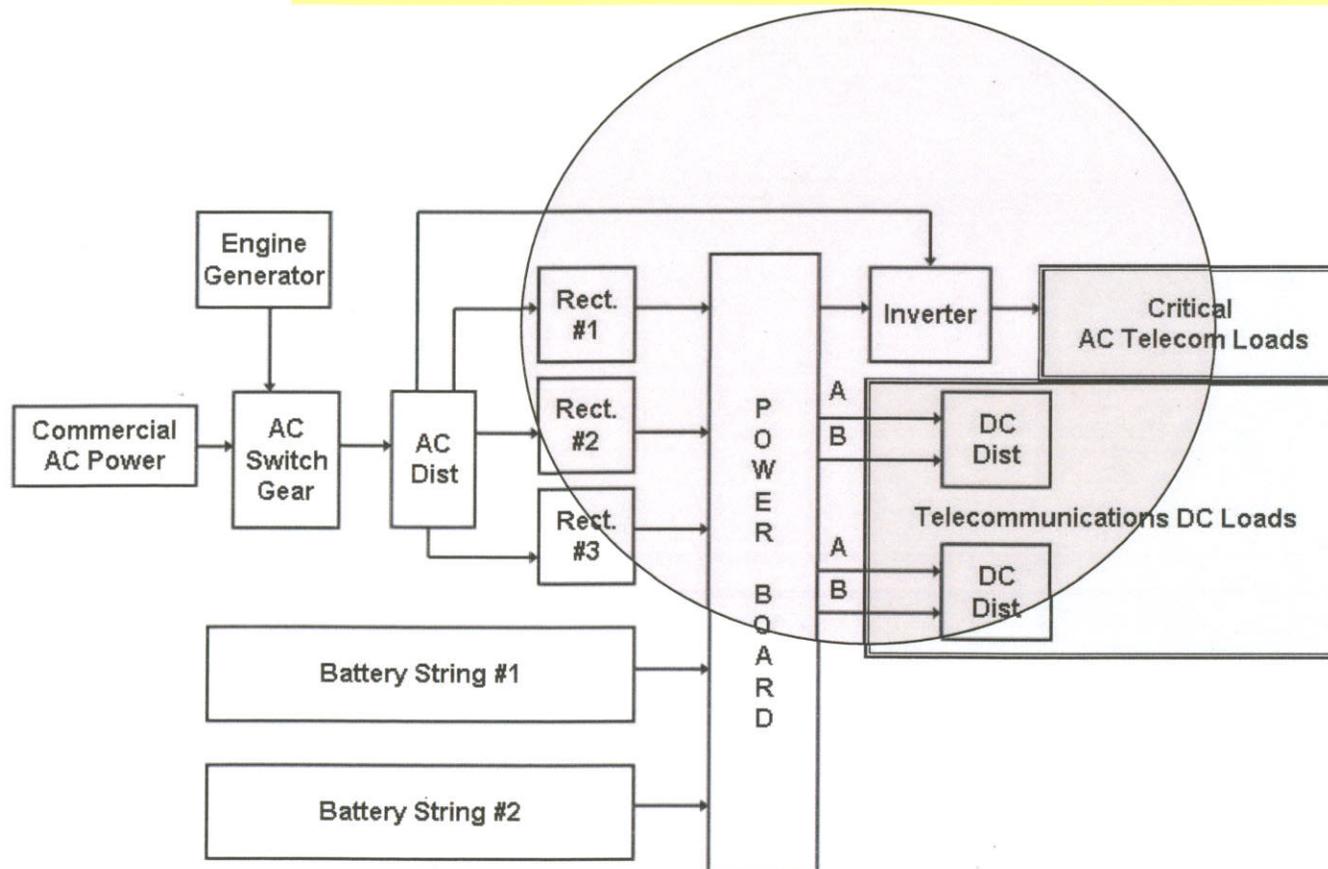
# William Bush

- Director of Research – Power & Grounding
  - Chair of Ch 9 (ITE), IEEE Std. 1100™-2005 Recommended Practice for Powering and Grounding Electronic Equipment
  - Also involved with related standards work with organizations such as IEEE, ATIS T1, TIA and BICSI

## Topics of concern

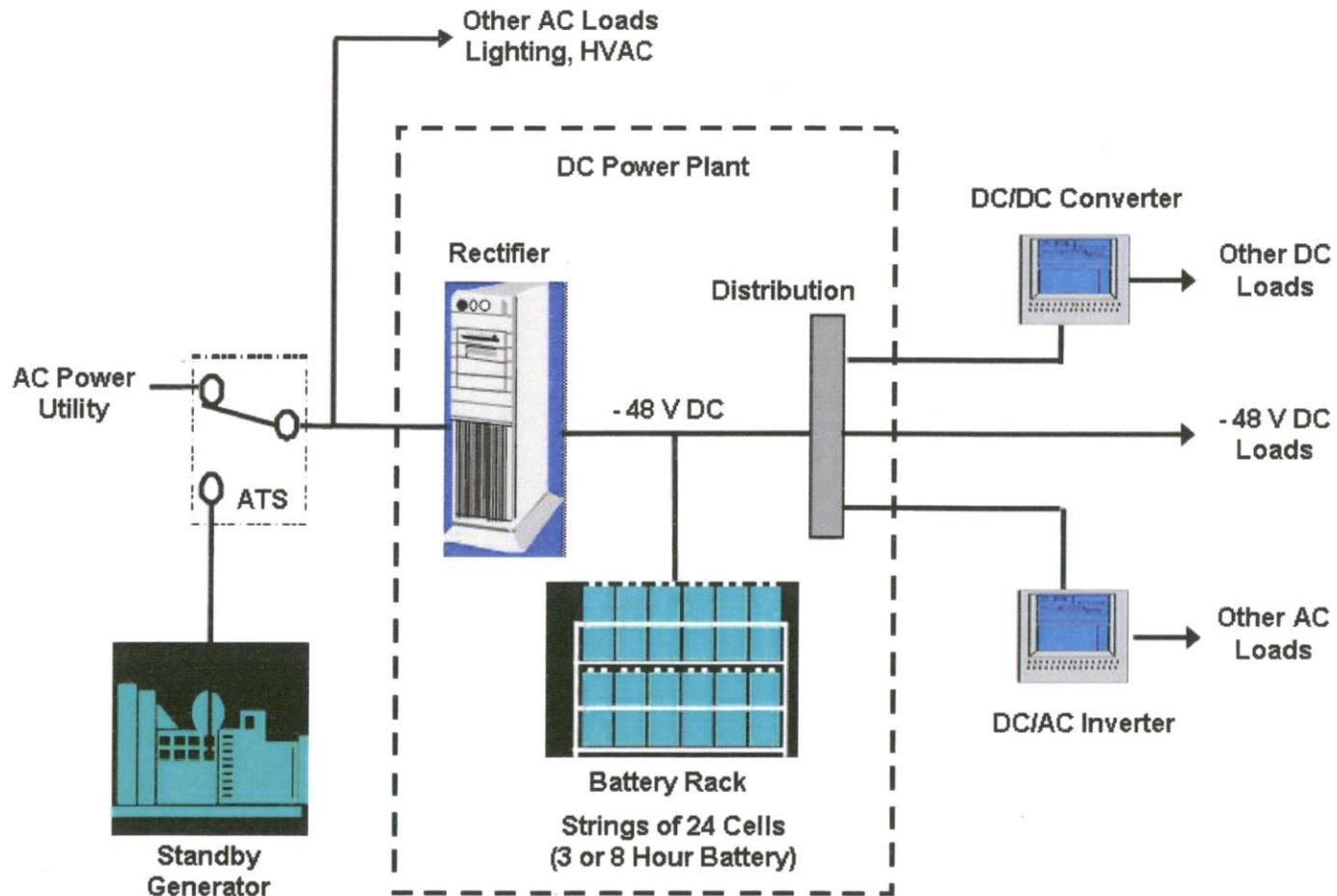
1. Relevance of historical grounding of dc TLE/ITE
2. Grounding dc at  $<600\text{ V}$  but  $>160\text{ V}$
3. Which lead is Return path (plus vs. minus wire)?
4. Grounding the Return lead (source vs. load)
5. Use of the equipment grounding conductor DCEG
6. Grounding of alternate power source (batteries?)
7. Sizing and routing of grounding conductors for load, fault and EMC
8. Grounding for protection scheme and EMC
9. Supplemental grounding and bonding (MCBN; SRG)

## Where does the higher voltage dc get placed?



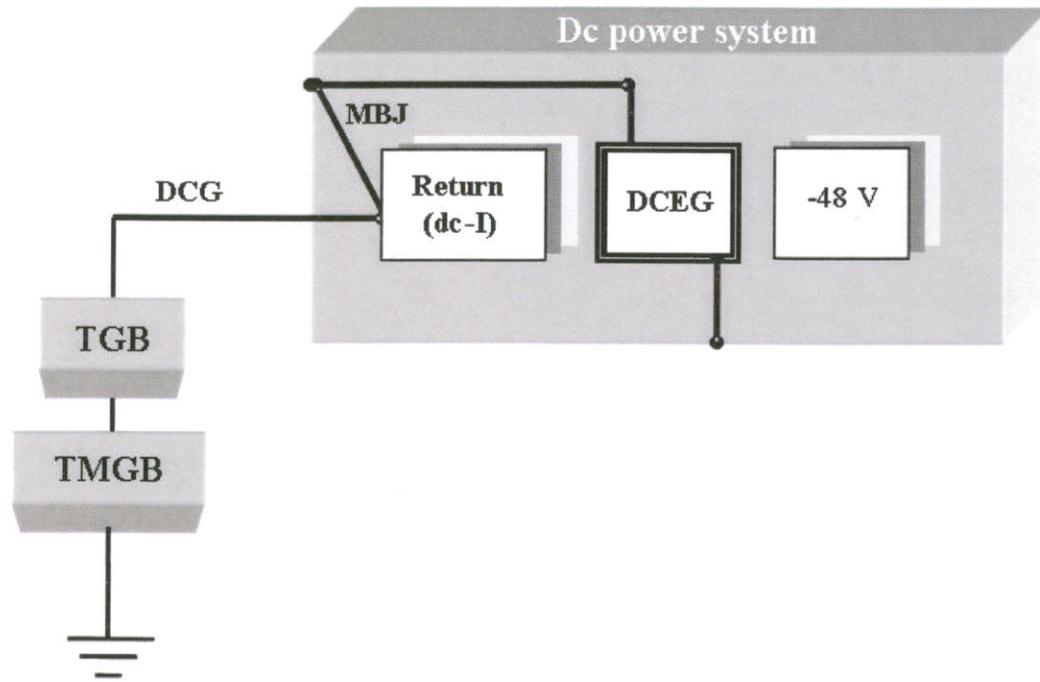
## Restricted access environment for centralized dc powering

Workshop: DC for Data Centers – W. Bush, Panduit Corp.



**In traditional telco, rounding occurs at all entities!**

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**SPG for the Return of the dc power source**

## CDCPS main powerboard

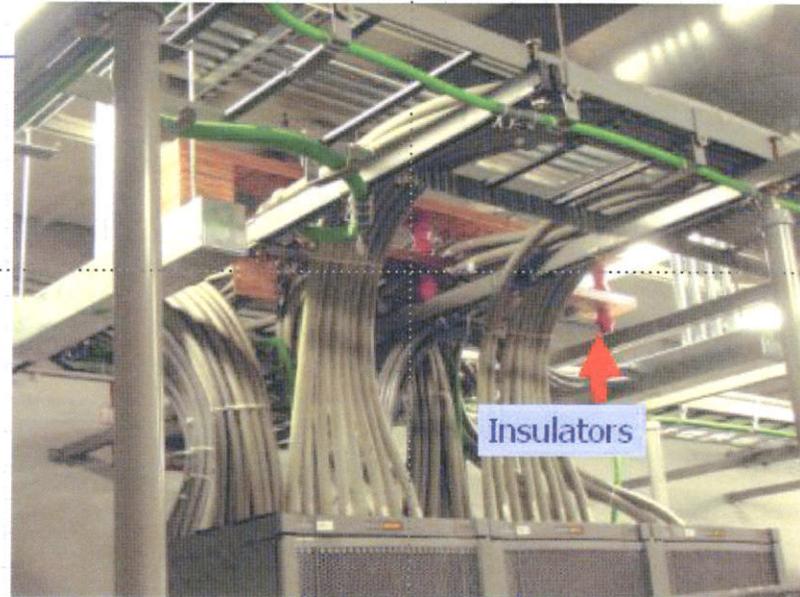


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## DC-I Return at CDCPS

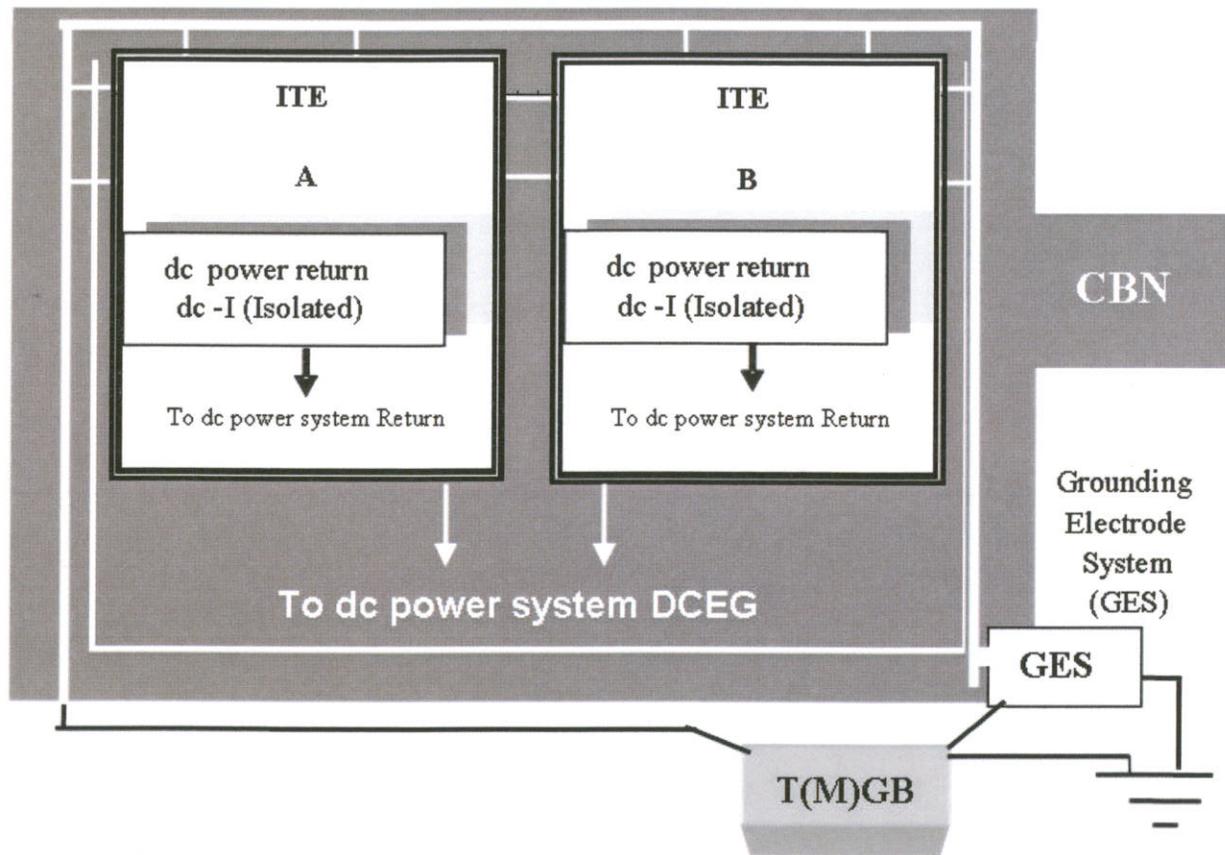


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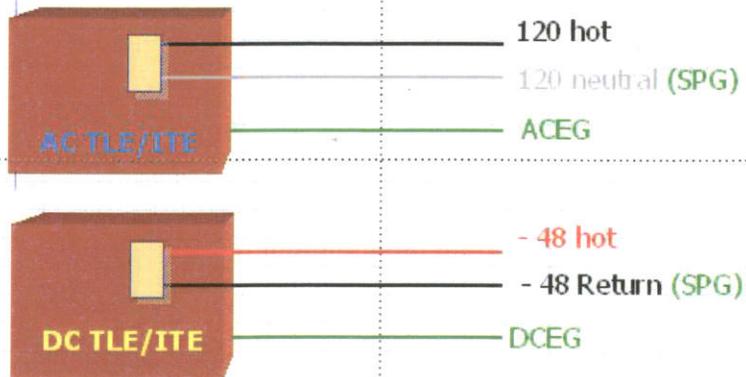


## Maintaining SPG of dc at TLE/ITE

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## Equip – RAA location



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## Equip – RAA UL permitted dc



- ◆ Effectively, multi-grounds the Return at the load location!
- Not recommended by Chapter 9!
- Cheap design against EMC between Return and DCEG

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AC and DC grounding equivalency is desirable!

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# Grounding dc (apply telecom guidance?)

- ◆ Single-point ground at source  
Regrounding return at load is not advised
- ◆ Use insulated co-routed conductors  
Supply, Return and equipment ground  
Dedicated circuits
- ◆ Mapping of grounding circuits at facility  
Where does current actually route within the building?
- ◆ Impact of electromagnetic forces on conductors co-routed

# Recommendations

1. Adaptation of dc grounding practices standardized for TSP to work properly at higher voltages (<600 V)?
2. Harmonize to AC TN-S topology as much as feasible.
  - ◆ Lessen the strain on the AHJ
3. Verifiable control of Return and equipment ground paths (similar to AC system)
4. Minimize or otherwise mitigate the impact(s) of common impedance at the source and any shared grounded or grounding paths

# DC Distribution Adoption Requirements

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- Lightning and Surge Protection
- Grounding and Bonding
- Safety
  - Circuit Protection Issues
  - UL Listings
  - Personnel Training
- Controllable issues and Non-controllable issues



# DC Distribution Safety Related Issues

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- Building wiring (insulation levels) are already 600V rated (Yes..... we get one check mark!)
- Electricians and service personnel may not be familiar with DC distribution systems above 48 Volts
- Instrumentation used for measurements are not identical
  - Some type of personnel certification will be necessary
- Electrical inspectors are not necessarily knowledgeable on labeling, determining adequacy of protection, and acceptability of exposed bus structures
- Special labels and warnings may be required (color coding of wires?)
- UL may require warning labeling

# Drawing from Existing Standards and Application Guidance

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- Lightning and Surge Protection
- Grounding and Bonding
- Other DC applications experience
- Safety
  - Circuit Protection Issues (dealing with faults)
  - UL Listings
  - Personnel Training

# Summarizing the DC Distribution Application Considerations

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- Codes and standards that warrant consideration for a 380VDC power system include at a minimum include:
  - Selecting and locating suitable circuit protection
  - Grounding and bonding methods to insure proper operation of the suitable circuit protection
  - Leakage currents and shock hazards
  - Environmental conditions and maintenance
  - Connection Devices
  - Power distribution equipment within the rack
  - Training and certification of personnel working inside racks
  - Training and certification of personnel installing building power distribution
  - Installation and maintenance of under floor power distribution
  - Warnings and labeling
  - Commission Testing

# Selecting and Locating Suitable Circuit Protection

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- Suitable circuit protection using breakers and fuses does not directly translate from AC to DC and suitable DC circuit breakers will likely need to be selected
- In terms of the breaker ratings, the manufacturers of these devices must be consulted for coordination
- Experience from the FAA critical DC bus power systems work, along with information from photovoltaic inverter industry, the DC drive industry and electromotive (DC train) industry can serve as a reference resource for further information on this topic
- Available fault currents may vary depending upon the source (rectifier? External?) and short circuit current availability from any energy storage devices used
- Fault clearing capabilities of DC rated protection devices may not be sufficient under all fault conditions

# Grounding Methods to Insure Suitable Operation of Circuit Protection

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- In terms of promoting operation of the circuit protective devices during fault conditions, the recommendations set forth in the National Electric Code (NFPA 780) and the IEEE *Emerald Book* contain the fundamental recommendations that can be incorporated with the previous discussion on suitable circuit protection
- Also it should be considered that lower voltages than the subject 380V DC demonstration may be considered in the future, therefore, the telecommunications related standards may provide some of the useful materials related to the lower voltage DC systems

# Leakage Currents and Shock Hazards

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- Because AC and DC powered information technology equipment can contain noise filters and other components that create leakage currents across the ground paths the requirements outlined in the Underwriters Laboratories document *UL 60950-1* must be taken into consideration as a basic listing for ITE
- The document titled: *Information Technology Equipment – Safety – Part 1: General Requirements* is basically related to leakage current, but the issue of electric shocks is well represented
- This relates to considerations where the grounding conductor inadvertently becomes loose or disconnected and the rack or the equipment case becomes energized

# Shock Hazard Levels

Table 7-1—Current range and effect on a 68 kg (150 lb) human

Current (60 Hz)	Physiological phenomena	Feeling or lethal incidents
<1 mA	None	Imperceptible.
1 mA	Perception threshold	
1–3 mA		Mild sensation.
3–10 mA		Painful sensation.
10 mA	Paralysis threshold of arms	Cannot release hand grip. If no grip, victim may be thrown clear. (May progress to higher current and be fatal.)
30 mA	Respiratory paralysis	Stoppage of breathing (frequently fatal).
75 mA	Fibrillation threshold, 0.5% (greater than or equal to 5 s exposure)	Heart action dis-coordinated (probably fatal).
250 mA	Fibrillation threshold, 99.5% (greater than or equal to 5 s exposure)	Heart action dis-coordinated (probably fatal).
4 A	Heart paralysis threshold (no fibrillation)	Heart stops for duration of current passage. For short shocks, heart may restart on interruption of current (usually not fatal from heart dysfunction).
>5 A	Tissue burning	Not fatal unless vital organs are burned.

Source: Lee [B14].

# Connection Devices and Power Distribution Equipment within the Rack

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- Market adoption of higher voltage DC systems will require the standardization of DC connectors that can be safely used by untrained personnel
- In existing data centers personnel can connect/disconnect servers powered at 120 V without any safety concerns
- Because DC current does not have a zero crossing like AC current, it is more difficult to interrupt, and simple disconnection will cause arcing
- In order to address this concern, some connectors have been developed that can contain the arc until it is extinguished
- Cabling and plug strips used in server racks must also have standard safe designs, so that untrained personnel can reasonably be expected to work in the rack without danger

# Conclusions

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- We don't have all the answers yet
- Important components to enable the market to adopt DC distribution on a large scale include:
  - Agreement on distribution voltages
  - Standardization around electrical connectors
  - Grounding
  - DC power quality
- IEEE (for US) design guidelines and recommended practices will be important

# IEEE and EPRI DC Distribution Efforts

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- October of 2007, IEEE IAS tentatively plans for 75 separate project authorization requests (PARs) to be submitted to IEEE's RevCom
- DC distribution will be one of those 75 PARs. If the PAR is approved, work likely will begin in May 2008
- In the interim, EPRI wants to convene an "industry experts task force" to develop a document that will serve as the potential seed work to for the IEEE materials
- The "industry experts task force" efforts would be offered to the IEEE DC distribution Working Group for inclusion and possible refinement in their work when they are ready to begin the work
- The EPRI industry task force objectives are to:
  - Develop a Needs/Requirements white paper that could be submitted as an IEEE Transactions Paper
  - Develop approximately 20 pages of application material on the topic of DC distribution that could then serve as the seed work for the IEEE effort

# Prioritizing the Safety and Grounding Issues?

- **Selecting and locating suitable circuit protection**
  - Leakage currents and shock hazards
  - Energy Storage considerations
  - Arc Flash
- **Grounding and bonding methods to insure proper operation of the suitable circuit protection**
- Environmental conditions and
- **Maintenance**
- **Connection Devices**
  - Power distribution equipment within the rack
  - Unqualified vs qualified personnel
- **Training and certification of personnel working inside racks**
- **Training and certification of personnel installing building power distribution**
- Warnings and labeling
- Commission Testing
- Others????