CHAPTER 7

Power Distribution

"Gimme gimme shock treatment."

- *The Ramones*

The power distribution system is the system that includes the main power feed into the data center (or the building), the transformers, power distribution panels with circuit breakers, wiring, grounding system, power outlets, and any power generators, power supplies, or other devices that have to do with feeding power to the data center equipment.

This chapter contains the following sections:

- "Power Distribution System Design"
- "Grounding and Bonding"
- "Signal Reference Grid"
- "Input Power Quality"
- "Wiring and Cabling"
- "Electromagnetic Compatibility"
- "Electrostatic Discharge"
- "Site Power Analyses"

Power Distribution System Design

A well-designed electrical system for the data center ensures adequate and consistent power to the computer hardware and reduces the risk of failures at every point in the system. The system should include dedicated electrical distribution panels and enough redundancy to guarantee constant uptime. A well-designed electrical system will provide consistent power and minimize unscheduled outages. Equipment subjected to frequent power interruptions and fluctuations is susceptible to a higher component failure rate than equipment connected to a stable power source.

Electrical work and installations must comply with local, state, and national electrical codes.

Assessing Power Requirements

Usually, your electrical design firm will tell you how much power is coming into the building as DC (Direct Current) which is expressed by KVA (Kilo Volt Amps). The easiest way to express this is in watts. When using DC power, volts × amps = watts (V×A=W). For example, you might be told that there is 7500KVA and that 7000KVA is available to the data center. The other 500KVA is needed for the rest of the building for offices, copiers, lighting, smoke detectors, soda machines, etc.

You can use the rack location units (RLUs) you've determined for your design to calculate how much power you need for equipment. The RLU definitions should include not only servers and storage equipment, but also network equipment such as switches, routers, and terminal servers. Add to this the power requirements of your HVAC units, fire control systems, monitoring systems, card access readers, and overhead lighting systems.

From your RLU definitions, you know that you'll need 800 30Amp 208V L6-30R outlets to power all of your racks. However, most circuit breakers will trip when they reach 80 percent of their rated capacity (this is sometimes referred to as a 0.8 diversity factor). A 30Amp breaker will really only allow a maximum of 24Amps through it before it trips and shuts down the circuit. Each circuit can handle about 5000 watts (24 amps × 208 volts = 4992 Watts) or 5KVA so the worst case electrical draw per outlet is 5KVA × 800 outlets = 4000KVA. No problem, because this is well within the 7000KVA you have allocated. However, most of the watts that these racks consume go into producing heat, and it will take quite a bit more electricity (for HVAC) to remove that heat.

A good rule of thumb is to take your total equipment power and add 70 percent for the HVAC system. The electrical usage will vary depending on the system and climatic conditions. Your HVAC and electrical designers should be able to give you a more precise multiplier once the HVAC system specifics are known.

4000KVA × 1.7 = 6800KVA, and that is within the 7000KVA you have been allocated. So, now you know that you have a large enough power in-feed to meet your electrical requirements.

The previous example uses the maximum draw that the breaker can accommodate before it trips. Most racks will not draw the full 5KVA, and it is possible that they could draw considerably less. The example of watt usage for RLU-A in Chapter 4, "Determining Data Center Capacities" is 3611 watts. This works out to a diversity factor of .58 (30Amps × 208 volts × .58 = 3619.2 watts). If you are building a data center that will be filled with just RLU-A racks, you could use a .58 diversity factor. However, this would mean that your average watts per RLU could not exceed 3619 watts. If you need to use a diversity factor below .80, you should use the highest wattage definition from all of your RLUs to determine the diversity factor. Also you must consider that power requirements will go up over time, so adding in an extra 3 to 5 percent to the diversity factor will also provide some headroom for next generation products that you can't anticipate during the design stages.

Finally, consider all possible future modifications, upgrades, and changes in power needs. For example, installing 50Amp wiring when only 30Amp is currently needed might be worth the extra cost if it is likely, within a few years, that machines will be added that need 40 to 50Amp wiring. The initial cost could be insignificant compared to the cost of dismantling part of the data center to lay new wire.

Consider the following questions during the design process:

- Is a certain amount of power allocated for the data center?
- Will power sources be shared with areas outside the data center?
- Where will the power feeds come from?
  - Will redundant power (different circuits or grids) be available?
  - Historically, how often do multiple grids fail simultaneously?
  - If power availability or dependability is a problem, can a power generating plant be built?
- Will the data center need single-phase or three-phase power (or both)?
- If the existing site is wired with single-phase, can it be retrofitted for three-phase?
- If you intend to use single-phase, will you eventually need to upgrade to three-phase?
  - Can you use three-phase wire for single-phase outlets, then change circuit breakers and outlets later when three-phase is needed?
- Where will the transformers and power panels be located? Is there a separate space or room for this?
- Which RLUs and their quantities need two independent power sources for redundancy?
- Will there be UPS? Where will the equipment be located?
- If there is only one external power feed, can half the power go to a UPS?
- Can a UPS be connected only to mission-critical equipment?

Multiple Utility Feeds

The availability profile of the data center could be the determining factor in calculating power redundancy. Ideally, multiple utility feeds should be provided from separate substations or power grids to ensure constant system uptime. However, those designing the center must determine whether the added cost of this redundancy is necessary for the role of the data center. It will be related to the cost of downtime and whatever other power delivery precautions you are taking. If you have a requirement for your own power generation as backup for data center power, then the additional costs of multiple utility feeds might not be cost effective. You should get historical data from your power supplier on the durations of outages in your area. This can be valuable information when making these decisions.

Uninterruptible Power Supply

An Uninterruptible Power Supply (UPS) is a critical component of a highly-available data center. In the event that power from the grid should fail, the UPS should be able to power 100 percent of the hardware for at least the amount of time needed to transfer power from an alternative utility feed or from backup generators. It should also be able to carry 150 percent of the power load to accommodate fault overload conditions. Don’t forget to factor in the minimum HVAC power requirements. Also, include the power requirements needed for emergency lighting and any electronic equipment needed to access the data center, such as access card readers.

FIGURE 7-1 Control Panel and Digital Display of a UPS System

You might size your UPS to accommodate the actual power draw rather than the total power draw. For example, a machine might use 1500 watts for “normal” load. However, when it’s powered on, it might initially draw 2200 watts. This load of 2200 watts is the “peak” load. You should size the UPS to handle this peak load.

However, this means a larger and more costly UPS. If budget is an issue, you will be taking a risk if you use a UPS rated for your normal load as it might fail to meet the peak load.

The UPS should be continually online, used to filter, condition, and regulate the power. Battery backup should be capable of maintaining the critical load of the room for a minimum of 15 minutes during a power failure to allow for the transfer of power from the alternate source, or to bring machines down cleanly if an alternate power source is not available. If a UPS is not used, surge suppression should be designed into the panels and a stand-alone isolation/regulation transformer should be designed into the power system to control the incoming power and protect the equipment.

Backup Power Generators

Backup power generators should be able to carry the load of the computer equipment, as well as all support equipment such as HVACs and network equipment. Depending on the availability status of the data center, it might be acceptable to use the UPS and multiple utility feeds without generators. If, by researching the power supply history, you determine that outages of 15 minutes or less are likely, you should install a UPS system with 20 minutes of battery power. This will sustain the data center until power is back on. If there is an outage of longer than 20 minutes, the data center will go down. This decision must be based on risk exposure determinations. The probability of a 20-minute outage might not outweigh the cost of generators.

If you plan for the use of generators, you'll need to think about code compliance, where they will be located (they give off exhaust), where the fuel tanks will be placed (one company used the same size tank used in gas stations, and it had to be buried), whether or not additional concrete pads must be installed, etc. You must also consider contracts with diesel suppliers.

Sharing Breakers

Though it is sometimes a necessary evil, sharing breakers is not recommended. As described in the earlier sections, machines don't use all of the capacity of their resident circuits. You have a normal load and a peak load. Two machines, each with a normal load of 1500 watts and a peak load of 2200 watts, could share the same 5KVA 30Amp circuit. However, if the configuration of these devices is changed over time, for example, if more memory is added, this might change the normal and peak loads, over the amount that the circuit could handle. While you might be forced to do this, you must be very careful and accurate in your power usage calculations for any circuit that you share.

FIGURE 7-2 Breaker Panel

Maintenance Bypass

The power system design should provide the means for bypassing and isolating any point of the system to allow for maintenance, repair, or modification without disrupting data center operations. The system should be designed to avoid all single points of failure.

Installation and Placement

The power distribution equipment for computer applications should be installed as close as possible to the load. All loads being supported must be identified and evaluated for compatibility with the computer equipment. Heavy loads that are cyclic, such as elevators, air conditioners, and large copy machines, should not be connected directly to the same source as the data center equipment.

Grounding and Bonding

Grounding is the creation of a path to an electrically conductive body, such as the earth, which maintains a zero potential (not positively or negatively charged) for connecting to an electrical circuit. This is usually done by connecting the data center equipment at the power source to an earth-grounding electrode subsystem which is a network of interconnected rods, plates, mats, or grids installed to establish a low-resistance contact with the earth. The purpose of the earth connection is to provide safety from shock to personnel and to protect the data center equipment from voltage gradients which could cause failures or fires. All metallic objects at the site that enclose electrical conductors or that are likely to be energized by electrical currents (for example, circuit faults, electrostatic discharge, or lightning) should be grounded for human safety, reducing fire hazards, protecting equipment, and to maintain optimal system performance.

A final reason for proper grounding is noise control, an important aspect of power quality.

Bonding is the means by which two or more grounding rods are connected. Proper bonding techniques are critical to proper grounding. You don't want to connect a grounding electrode to the central ground using a material that would act as an insulator, as this would add resistance to the path the electricity would take. The means by which you bond different grounding materials is specified by code. NFPA 70 1999, Article 250, sections 90 through 106, gives specific information on bonding. NFPA 70, section 250-90, defines bonding in general as "Bonding shall be provided where necessary to ensure electrical continuity and the capacity to conduct safely any fault current likely to be imposed."

A solid and well-bonded grounding system will allow circuit breakers to perform correctly, and ensure that devices like surge protectors and power sequencers connected to grounded outlets have a safe path to ground if an overcurrent situation occurs. In areas where overcurrent situations are likely, you can ground the metal chassis of a rack to the grounding system.

The common point of grounding can be connected to any number of sources at the service entrance (main power feed), for example:

- Driven earth rod
- Buried grid
- Building steel
- Water pipes

Whatever the sources, the ground should be carried through the entire system from these sources. Ideally, the central point of grounding at the service entrance will be connected to redundant ground sources such as building steel, buried grid, and cold water piping. A single source sets up the potential for a broken ground. A water pipe might be disjointed. Building steel could accumulate resistance over several floors. By tying into multiple grounds, ground loops are avoided, disruptions are minimized, and redundancy is achieved.

A university on the eastern seaboard lost all power from a problem with poorly grounded generators on the main power line. In the postmortem, it was found that there really was a postmortem. A raccoon seeking warmth had climbed into the generator housing and shorted out the circuit, creating a grounding loop, and knocking out the power. When everything was finally back online, another raccoon climbed into the generator and self-immolated, taking the power with it. After that, chicken wire was installed around the generator.

Compliance With the NEC

All grounding design should comply with the National Electrical Code (NFPA 70 or NEC) unless superseded by other codes. Article 250 of NFPA 70 1999 “ covers general requirements for grounding and bonding of electrical installations, and specific requirements in (1) through (6).

1. Systems, circuits, and equipment required, permitted, or not permitted to be grounded.
2. Circuit conductor to be grounded on grounded systems.
3. Location of grounding connections.
4. Types and sizes of grounding and bonding conductors and electrodes.
5. Methods of grounding and bonding.
6. Conditions under which guards, isolation, or insulation may be substituted for grounding.”

NFPA 70 1999 in section 250-2 (d) “Performance of Fault Current Path” states:

- **“...shall be permanent and electrically continuous.”** The ground should be continuous from the central grounding point at the origin of the building system. If the path is installed in such a way that damage, corrosion, loosening, etc. could impair the continuity, then shock and fire hazards can develop. The ground should be dedicated and continuous for the whole system to avoid a ground differential that can occur from using various grounds.
- **“...shall be capable of safely carrying the maximum fault likely to be imposed on it.”** Fault currents can be many times normal currents, and such high currents can melt or burn metal at points of poor conductivity. These high temperatures can be a hazard in themselves, and they can destroy the continuity of the ground-fault path.

- **"...shall have sufficiently low impedance to facilitate the operation of overcurrent devices under fault conditions."** A properly designed system will have as low an impedance as possible. If the ground-fault path has a high impedance, there will be hazardous voltages whenever fault currents attempt to flow. Also, if the impedance is high, the fault current will be limited to some value so low that the fuse or circuit breaker will not operate promptly, if at all.
- **"The earth shall not be used as the sole equipment grounding conductor or fault current path."** You have to use circuit breakers and valid grounding systems. You can't just rely on the fact that the building is connected to earth as the sole means of grounding.

NFPA 70 1999 Section 250-50 state that each of the items below "...shall be bonded together to form the grounding electrode system."

- Metal underground water pipe
- Metal frame of the building, where effectively grounded
- Concrete-encased electrode
- Ground ring

Furthermore, if metal underground water pipe is used, "continuity of the grounding path or the bonding connection to interior piping shall not rely on water meters or filtering devices and similar equipment." Additionally, a supplemental electrode is required.

NFPA 70 1999 section 250-52 states that if none of the previous grounding items are available, then, and only then, should you use the following:

- Other local metal underground systems or structures
- Rod and pipe electrodes
- Plate electrodes

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Equipment Grounding Conductor Impedance

The data center must have its own grounding plan which will tie into the earth ground for the rest of the building. The system should have sufficiently low resistance to allow circuit breakers, surge protectors, and power sequencers to respond to this overcurrent state very quickly. This resistance should be in the 1 to 5 ohm range. In the U.S., a 25-ohm maximum resistance value is the minimum standard for most "normal" grounding systems, according to the NEC. While this level of resistance is acceptable in a normal office environment, data centers should use the 5 ohms of resistance as the acceptable maximum resistance level for their grounding system.

The NEC and local codes require electronic equipment to be grounded through the equipment grounding conductor and bonded to the grounding electrode system at the power source. The impedance of the equipment grounding conductor from the electronic equipment back to the source neutral-ground bonding point is a measure of the quality of the fault return path. Poor quality connections in the grounding system will give a high impedance measurement. Properly installed equipment grounding conductors will give very low impedance levels. Equipment grounding conductors should have levels meeting code requirements with a value of less than 0.25 ohm.

Signal Reference Grid

A Signal Reference Grid (SRG) is a means to reduce high-frequency impedance (also called noise) so that a device or outlet has the lowest impedance path to earth ground. This grid has multiple paths to ground to ensure that grounding loops do not develop.

The SRG should be designed for the data center. This provides an equal potential plane of reference over a broad band of frequencies through the use of a network of low-impedance conductors installed throughout the facility. The following figure shows part of an SRG in a blueprint detail.

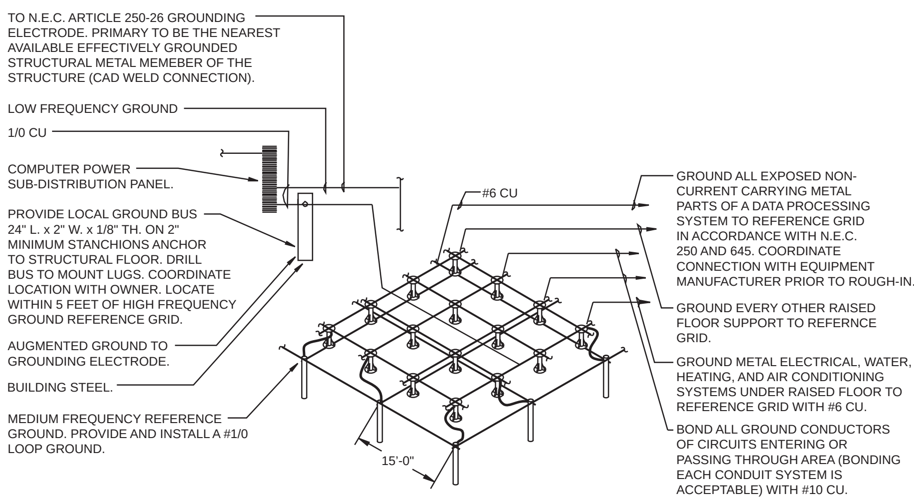

FIGURE 7-3 Blueprint Plan of a Signal Reference Grid

Recommended Practices

The following is a list of recommended practices for an SRG. This information should be well understood by the electrical engineer/contractor but should be used only as a reference because electrical codes in your area might be subject to different requirements.

1. **Follow applicable codes and standards for safe grounding.**

   There is no conflict between safe grounding for people and effective high-frequency grounding for sensitive electronic equipment.

2. **Install equipment ground bus.**

   Use sized 10" long, 1/4" thick, 4" high on 4" insulators. Bond via exothermic weld with #2 AWG bare copper to grounding ring.

3. **Provide exothermic weld or other code compiant connection between intersecting ground grid connectors.**

4. **Provide grounding/bonding for raised floor pedestal system in data center as follows:**

   Install #4 AWG bare copper for MFG (raised floor pedestal) grid. Bond to every other raised floor pedestal.

5. **Route #3/0 from equipment grounding bus bar to grounding bus bar in main electrical room.**

   Make sure that you have a path to earth ground.

6. **Bond HVAC units to perimeter ground or medium frequency ground loop via #6CU conductor.**

7. **Keep data and power cables on or near SRG.**

   All data and power cables should lay on or be very close to the SRG.

8. **Complete documentation.**

   Documentation should be complete in all details, including the proper grounding and bonding of heating, ventilation, and air-conditioning equipment, piping, raceways, and similar items. The responsible engineer should not expect the installers to complete the design.

Input Power Quality

The plans for the data center should include a well-designed power and grounding system to maintain appropriate conditions and avoid unplanned power outages. Numerous factors can disrupt, degrade, or destroy electronic systems. High-frequency, high amplitude noise, high ground currents, low power, surges and sags in voltage, harmonic distortion, and other factors will affect the proper functioning of equipment. It is essential that power conditioning technology be used to protect the data center equipment.

The following table shows a chart that was published by the U.S. Government as a Federal Information Processing Standard or FIPS. The source is FIPS PUB 94, "Guideline On Electrical Power for ADP Installations." The U. S. Government withdrew this standard July 29, 1997 because these tolerances or tighter tolerances had been adopted as industry standards. It is presented here only as a reference.

TABLE 7-1 FIPS PUB 94 Tolerances Chart

		Typical Acceptable Limits for Computers and Power Sources		
Environmental Attribute	**Typical Environment**	**Normal**	**Critical**	**Units Affected and Comments**
Line frequency	0.1% - 3%	1%	0.3%	Disk packs, tape, regulators
Rate of frequency change	0.5-20 Hz/s	1.5 Hz/s	0.3 Hz/s	Disk packs
Over- and under-voltage	5-6%, -13.3%	+5%, -10%	3%	Unregulated power supplies
Phase imbalance	2%-10%	5% max	3% max	Polyphase rectifiers, motors
Power source: tolerance to low power factor	0.85-0.6 lagging	0.8 lagging	<0.6 lagging or 0.9 leading	Indirectly limits power source or requires greater capacity unit with reduced overall efficiency
Tolerance to high steady state peak current	1.3-1.6 peak/rms	1.0-2.5 peak/rms	>2.5 peak/rms	1.414 normal; departures cause wave shape distortion
Harmonics (voltage)	0-20% total rms	10-20% total; 5-10% largest	5% max total 3% largest	Voltage regulators, signal circuits

TABLE 7-1 FIPS PUB 94 Tolerances Chart *(Continued)*

Environmental Attribute	Typical Environment	Typical Acceptable Limits for Computers and Power Sources: Normal	Critical	Units Affected and Comments
DC load current capability of power source	Negligible to 5% or more	<0.1% w/ exceptions	As low as 0.5%	Half wave rectifier load can saturate some power source, trip circuits
Voltage deviation from sine wave	5-50%	5-10%	3-5%	Affects regulators, signal circuits
Voltage modulation	Negligible to 10%	3% max	1% max	Voltage regulators, servo motors
Transient surges/sags	+10%, -15%	+20%, -35%	+5%, -5%	Regulated power, motor torques
Transient impulses	2-3 times nominal peak value (0-130% V-s)	Varies: 1,000-1,500V typical	Varies: 200-500V typical	Memory, disks, tapes having data transfer rates, low level data signals
RFI/EMI and "tone bursts," normal and common modes	10V up to 20 Khz; less at high freq.	Varies widely-3V typical	Varies widely-0.3V typical	Same as above
Ground currents	0-10 A rms + impulse noise current	0.001-0.5 A or more	0.0035 A or less	Can trip GFI devices, violate code, introduce noise in signal circuits

Power Conditioning Technology

When the power source does not meet the equipment requirements, additional hardware might be required for power conditioning. These power conditioning systems can be separate or can be integrated into UPS equipment. The use of power conditioning systems is much like the use of UPS systems. A "power sag" or "brownout" is an event that can bring the delivery of power to under 80 percent of nominal power for a brief duration, usually two seconds or less, sometimes even in the milliseconds range. You can think of a power conditioning system as a three-to-five second UPS that will maintain the power flow through a brownout.

Harmonic Content

Harmonics problems can be caused by the interaction of data center equipment with the power loads or by switching power supplies. Harmonic distortion, load imbalance, high neutral current, and low power factor can result in decreases in equipment efficiency and reliability. Eliminating harmonics problems is difficult, because the computer hardware contributes to them, and any changes in the room load or configuration to fix the problem can create new problems.

Sun Microsystems equipment has been designed to address the problems of harmonic distortion and is generally compatible with similar modern equipment. Equipment that does not have the advantages of modern harmonic-correction features should be isolated on separate circuits.

Voltage Spikes

Voltage spikes are rises in the voltage caused most often within the power distribution circuits by components turning on and off, such as the cycling of compressor motors. Large spikes can interfere with energy transfer, or the associated electrical noise can cause signal corruption.

A UPS and/or filtering system will usually stop most spikes originating upstream of the UPS. If a UPS will not be installed, some other form of regulation or surge suppression should be designed into the system.

Lightning Protection

The potentially damaging effects of lightning on computer systems can be direct or indirect. It might be on the utility power feed, directly on the equipment, or through high-frequency electromagnetic interference or surge currents. Lightning surges cannot be stopped, but they can be diverted. The plans for the data center should be reviewed to identify any paths for surge entry, and surge arrestors that provide a path to ground should be included to provide protection against lightning damage. Protection should be placed on both the primary and secondary sides of the service transformer.

Lightning protection systems should be designed, installed, and maintained in accordance with NFPA 780 (1997 edition), *Standard for the Installation of Lightning Protection Systems*, or any superseding local or national code.

Emergency Power Control

NFPA 70 and NFPA 75 require a single point of disconnect for all electronic systems in the data center, at each point of entry. Multiple disconnects are also acceptable, but in either case, the switches must be unobstructed and clearly marked, as shown in the following figure.

FIGURE 7-4 Emergency Power Disconnect and Manual Fire Alarm Pull Station

Protective covers can be placed over the buttons to avoid accidental contact, but access cannot be locked out. The switch, or switches, should disconnect power to all computer systems, HVAC, UPS, and batteries. If the UPS is located within the data center, the disconnect should stop power to the unit. If the UPS is located remotely, the disconnect should stop the supply from the unit into the room.

Though not required by code, it is recommended that all power sources in the room be controlled by the disconnect to provide the highest degree of safety to personnel and equipment.

Wiring and Cabling

All wiring and cabling should be designed and installed in accordance with NFPA 70 of the National Electrical Code, or superseding national or local codes. All wiring and cabling should be run in an orderly and efficient manner, not like the "spaghetti" shown in the following figure.

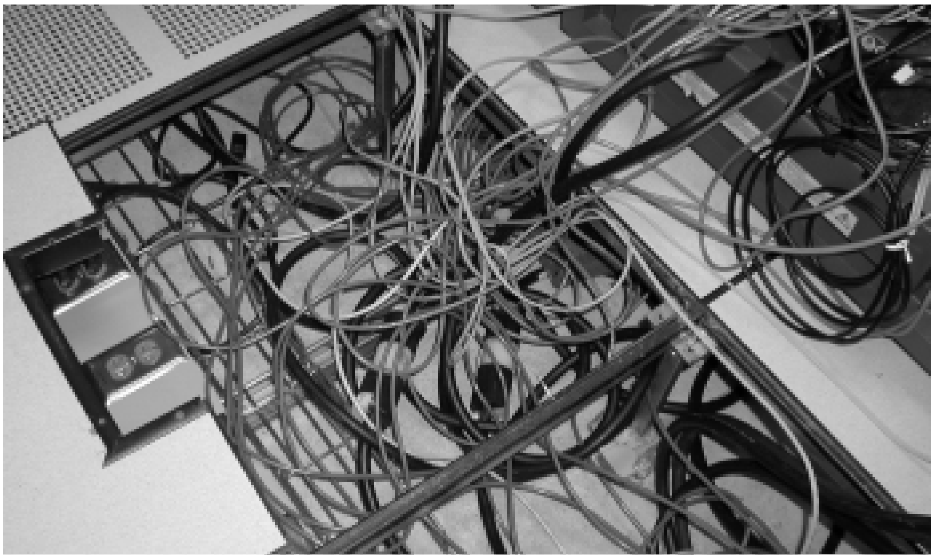

FIGURE 7-5 Disorganized Cabling Under Floor Tiles

Data centers undergo frequent modifications, so any obsolete cabling should be removed to avoid air flow obstructions and minimize confusion and possible disconnection of the wrong cables during modification.

Note – Temporary extension cords should not be used in the subfloor void. If used above the raised floor, precautions should be taken to ensure that they don't pose a tripping hazard, and that they are not damaged.

Higher Amps and Single-Phase or Three-Phase

The main power feeds that enter a building are usually three-phase. Devices called transformers take the three phases of that power and convert them to three separate single phases. However, some computer equipment and support equipment runs on three-phase power only. Single-phase and three-phase power use different outlets, wiring, and circuit breakers. Use RLU definitions (see Chapter 4, “Determining Data Center Capacities”) to determine how much single- and three-phase power you will need.

However, flexibility is an important part of design methodology, and we know that technology changes. It is possible that computer and network equipment suppliers will need to move larger systems to the use of three-phase power or higher amperage. Some already offer three-phase power as an option. So how can you design flexibility into your power system? One way is to gauge up your wiring requirements (pardon the pun).

Consider this scenario: Currently all of your RLU definitions use only single-phase power, L6-30R 30 Amp outlets. If you were to use the standard wire gauge for these outlets it will be fine. You can reuse this wire if you move to a three-phase outlet, provided that it still uses 30 Amps. However, if you were to use a standard wire gauge for 50 Amps, then this wire gauge would meet or exceed code requirements for the L6-30R 30 Amp outlets. Basically, you can use a larger gauge wire than is standard, but, not a smaller gauge wire. If you think you will need to change or upgrade power in the future, putting in the larger gauge wire for future use is a good idea. With this larger gauge wire in place, if you need to change some outlets to run at a higher amperage, you already have the wire ready and waiting under the floor.

Redistributing outlets from single-phase to three-phase is simple if the three-phase outlets run at the same amperage as the single-phase outlets they replace. For example: If you had three L6-30R single phase outlets each on their own circuit breaker, you could move to three-phase outlets of the same voltage by replacing only the outlets and swapping three of these single-phase circuit breakers for two three-phase breakers.

The following figure shows a section of electrical wireway for supporting the electrical requirements of two RLU Superset-A and one RLU-C.

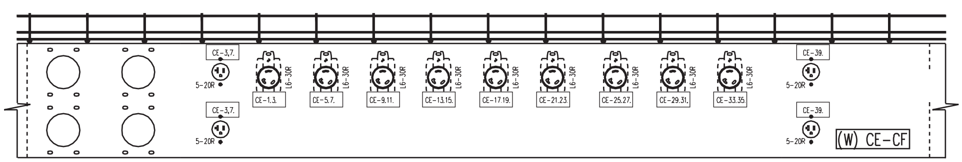

FIGURE 7-6 Blueprint Plan of a Standard Electrical Wireway and Outlets Under the Raised Floor

The wire gauge in the wireway can also support three-phase power as well as the current single-phase L6-30R existing outlets, since they are both running at 30 Amps. You can see four cutouts on the left side. These are already in the wireway so that, should three-phase power be needed later, six of the L6-30R outlets can be removed and the wiring used for four three-phase outlets. You can also see the labels for each outlet's circuit breaker. Six of these breakers can be removed at the sub-panel and replaced by four three-phase breakers.

There is another way to solve this problem: Power Distribution Units (PDUs).

Power Distribution Units

Historically, there was one or more power feeds into the building, and these power feeds fed transformers that would send portions of this electricity to sub-panels. These sub-panels contained the circuit breakers for each outlet on the floor. Wire for each outlet ran from the breakers out to the floor and terminated in an outlet. This is still is a fine system. However, if you need to change the outlet on the floor, you must change the breaker, the wire from the breaker out to the floor, and the outlet itself. In an operational data center, this is a difficult and time-consuming process. To run new wire out to the location on the floor means removing tiles in the raised floor. This leads to decreased pressure that can affect the proper cooling of operational equipment. While you could have flexibility in this system, it comes at a large cost to the smooth running of a working data center.

A Power Distribution Unit (PDU) is a way to integrate the circuit breakers, wire, and outlets in a central location on the floor that can service one or more RLUs. In this example, a PDU has an in-feed of 100A three-phase power by way of a Hubble connector. This Hubble connector plugs into the PDU. Inside the PDU is a smaller version of a sub-panel with circuit breakers for each outlet in the PDU. These circuit breakers have wires which connect to the individual outlets in the PDU. A PDU being fed by a 100Amp three-phase Hubble connector could supply eight 30Amp single-phase circuits. Another might supply ten 20Amp single-phase circuits, and another might supply four three-phase 30Amp outlets.

This gives a lot of flexibility in your electrical system. However, there are a few downsides to this design. The first concern is that it might not meet code. In the U.S., for example, the NEC is interpreted by local building authorities and can be superseded by other local electrical code. There are data centers in San Diego, California and Austin, Texas where PDUs under raised floors are acceptable to the local electrical code requirements. However, in Hillsboro, Oregon and Menlo Park, California, the use of PDUs under the raised floor are not acceptable under the local electrical code. Different states and different counties might have different interpretations of electrical code requirements.

The following figure shows an example of a PDU.

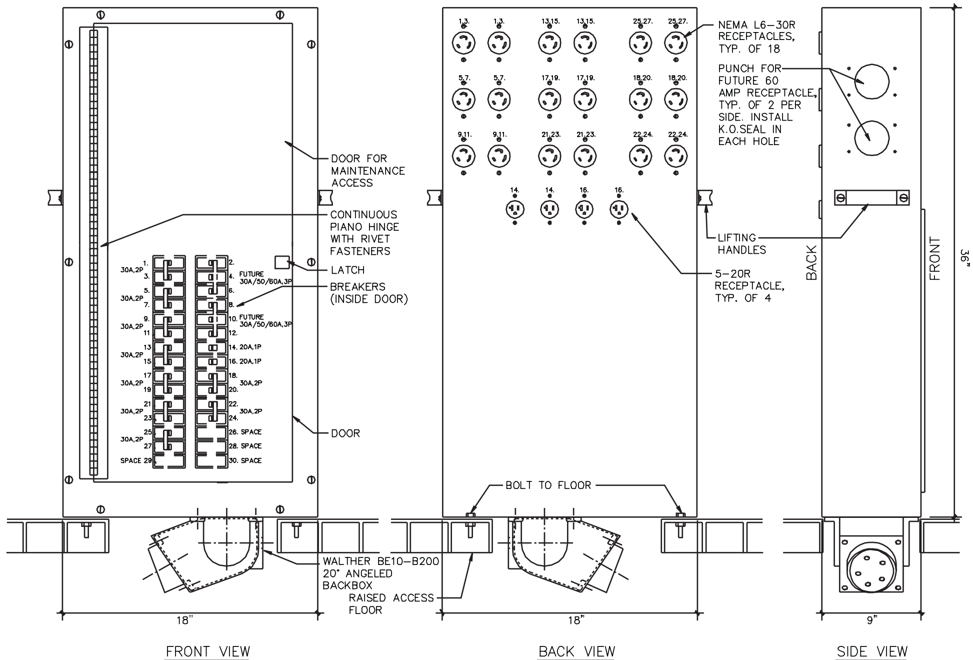

FIGURE 7-7 Blueprint Plan of a Power Distribution Unit

The other downside to the PDU design is availability. Currently, PDUs are custom-made devices and can be subject to lead times of weeks or months to manufacture. This is not a problem if you have a lot of lead time before you make changes to your electrical outlets. However, in the real world, this luxury isn't always available. With foresight, PDUs of whatever type you anticipate the need for can be pre-manufactured, but this involves additional cost for the materials (box, circuit breakers, wiring, and outlets) and labor to make, and the additional cost of storing them.

PDUs can offer a great deal of flexibility to your electrical design. However, your first requirement will be to find out if they will be acceptable to your local code requirements. And even if they are, they might not be the most cost effective model for your data center.

Electromagnetic Compatibility

Electromagnetic interference (EMI) and radio frequency interference (RFI) is radiated and conducted energy from electrical devices that produce electromagnetic fields. The electrical noise currents associated with these can interfere with the signals carried by the electronic components and the cabling of equipment.

Sources of EMI and RFI can be inside or outside the data center environment. Common external sources are airports, telecommunications or satellite centers, and similar facilities. Internal sources include the hardware itself. Sun equipment is tolerant of most common EMI/RFI levels. If high levels are suspected, a study should be conducted to determine whether shielding or other remedial actions are necessary.

Electrostatic Discharge

Electrostatic discharge (ESD) is the rapid discharge of static electricity between bodies at different electrical potentials and can damage electronic components. ESD can change the electrical characteristics of a semiconductor device, degrading or destroying it. It might also upset the normal operation of an electronic system, causing equipment to malfunction or fail.

Today's equipment has a much denser geometry, with thinner, more easily damaged materials. Though changes in design, manufacturing processes, and materials have reduced ESD sensitivity, components can still be damaged if precautions are not taken in the design of the data center and in component handling techniques. The damage can result in catastrophic failures, or it might not cause outright failure, but might make a component more susceptible to failure later on. Low grade failures due to cumulative degradation of components can be subtle and difficult to detect.

There are numerous ways to control static generation and ESD. The following list describes some of the control techniques.

- Since static electricity is a greater problem in an environment with low relative humidity (RH) levels, maintain appropriate relative humidity levels. This will help to dissipate charges.
- Limit or isolate the use of hardware that generates static charges.
- Limit or isolate activities and materials that generate static charges.
- Use only appropriate carts and furniture in the room.
- Don't use carpeted tiles!

- Operators should use appropriate personal grounding equipment such as anti-static lab coats, wrist straps, and heel grounders.
- Never use paper clips to press reset buttons! A good idea is to tape a few wooden toothpicks to the inside of the rack doors for use as reset button depressors.
- Keep covers on equipment racks closed. Covers should be opened only by trained personnel using proper grounding when inspections, repairs, or reconfigurations are necessary.
- The raised floor system should be properly grounded with static dissipative tile surfaces to provide a proper path to ground.
- Use only appropriate cleaning agents on floor tiles to maintain the static dissipative properties of the floor.

Site Power Analyses

Power disturbances can have numerous effects on sensitive electronic equipment, including data errors, system halts, memory or program loss, and equipment failures. Since it is often difficult to determine whether these problems are caused by power disturbances or by unrelated electronic equipment or software failures, a power system survey and analysis could be required. The analysis should be performed by professionals and should determine, at minimum, the following:

- The soundness of the power distribution (wiring) and grounding systems supplying power to the equipment
- The quality of the AC voltage supplying power to the equipment
- The source of power system disturbances
- The impact of power disturbances on data center equipment

The site power survey data should then be thoroughly examined to identify cost-effective improvements or corrections, both immediate and for the future.