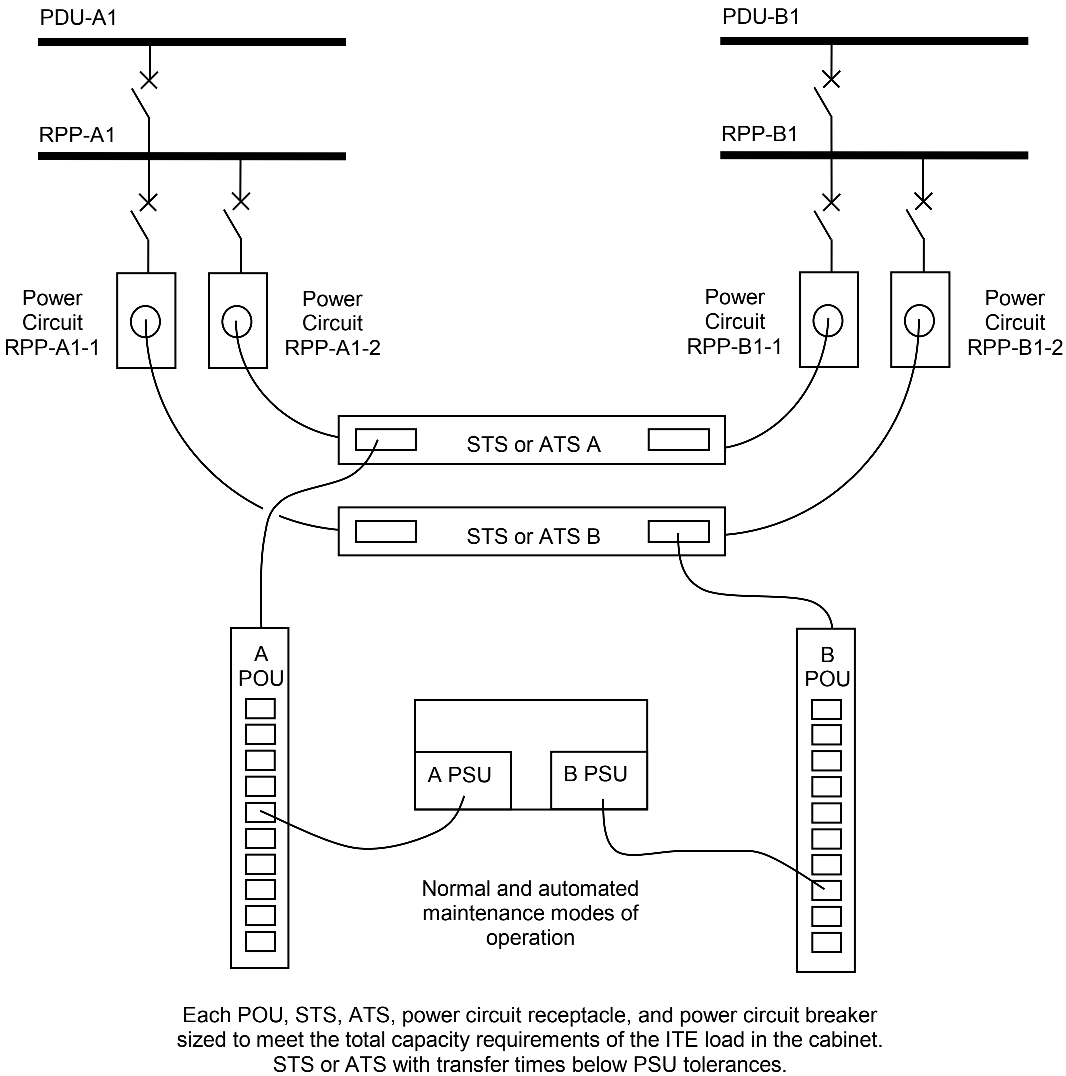


Figure 9-29
Class F3 Circuit Mapping (Automated Operations)

For Class F4, it is not possible to achieve concurrent maintainability plus fault tolerance at the ITE level when the ITE contains dual power supplies (or any N+1 power supply configuration). Only if all the ITE is provided with N+2 power supplies, then the power distribution consists of an "A”, "B”, and "C" redundant power plants all sized to "N" and with power circuits from each power plant connected to the N+2 power supplies is concurrent maintainability and fault tolerance achievable for ITE. This type of ITE power supply configuration and power distribution topology has not typically been implemented. However, Class F4 fault tolerance capabilities can be provided for the power distribution up to the ITE cabinet, ensuring that power distribution component redundancy is provided even when either an "A" or "B" upstream component or system is off-line for maintenance.

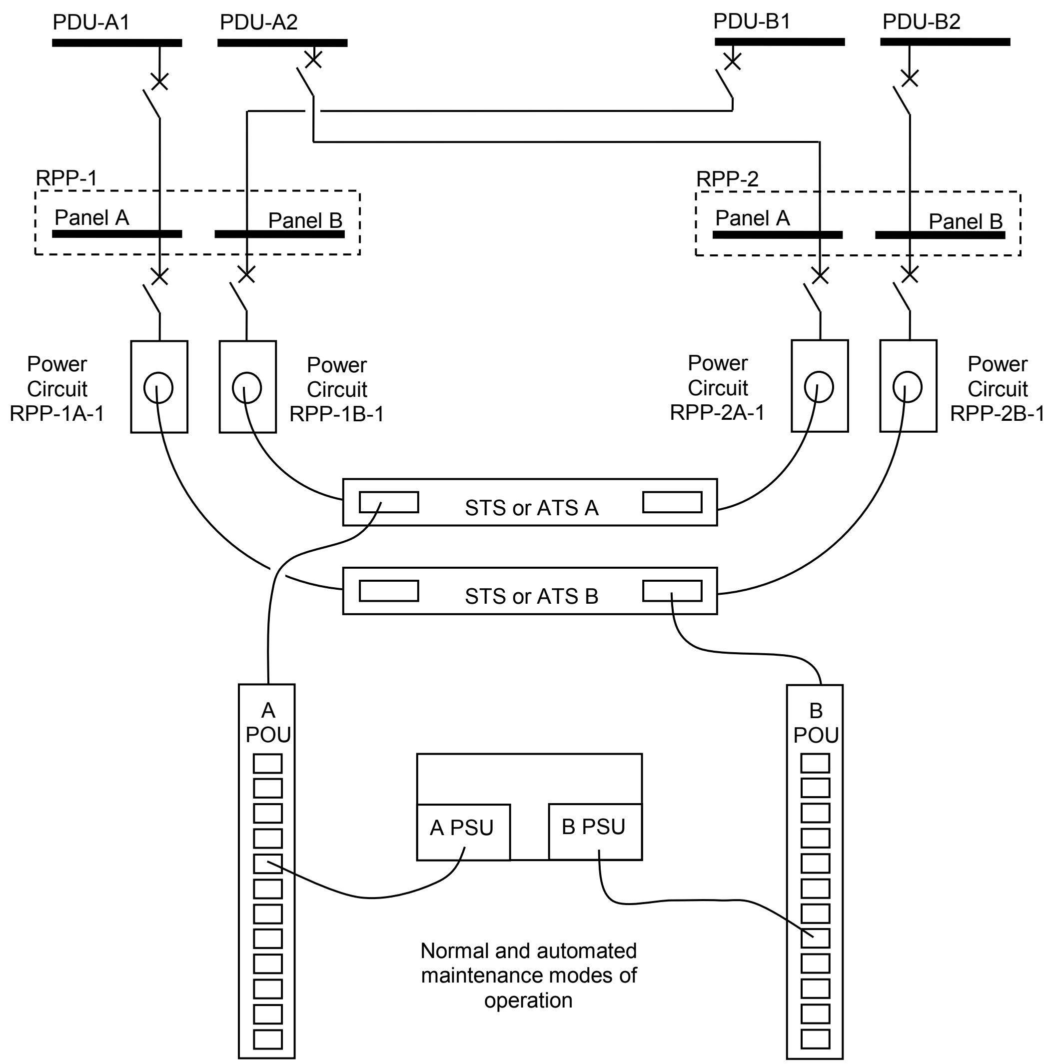
CAUTION: The MTBF data for the STS or ATS components should be provided by the manufacturer and analyzed by the designer prior to the use of rack mounted STS or ATS components in order to provide concurrent maintainability and fault tolerance between the UPS outputs and the POU within the cabinet. Inadvertent and non-predictable failures of rack mounted STS and ATS components have resulted in unplanned outages. When using this circuit mapping topology, it is recommended that the STS or ATS have a defined replacement cycle, which could be every 3 years or less, depending on the MTBF.

Figure 9-30 shows a method for circuiting a Class F4 data center's critical power systems.

The figures showing Class F3 and F4 represent one method available to implement the required level of redundancy. PDU and RPP manufacturers have options that enable other means to achieve the required level of redundancy, ensuring concurrent maintainability to the cabinet for Class F3 or fault tolerance to the cabinet for Class F4.

The implementation of a 50 to 600 V_{DC} power distribution from the output of the UPS can significantly simplify the concurrent maintainability and fault tolerance of the power distribution and circuit mapping from the UPS to the ITE. A Class F3 or F4 electrical distribution would consist of redundant double-ended overhead bus with each bus connected to both the "A" and "B" UPS system. This would enable the maintenance of any PDU or power circuit between the UPS and the ITE while maintaining fault tolerance on the circuits supporting the ITE. This is a significant benefit that 50 to 600 V_{DC} computer room power distribution offers.

Figure 9-31 shows a method for circuiting a Class F3 50 to 600 V_{DC} critical power system and Figure 9-32 shows a method for circuiting a Class F4 50 to 600 V_{DC} critical power system.



Each POU, STS, ATS, power circuit receptacle, and power circuit breaker sized to meet the total capacity requirements of the ITE load in the cabinet. STS or ATS with transfer times below PSU tolerances.

Figure 9-30
Class F4 Circuit Mapping

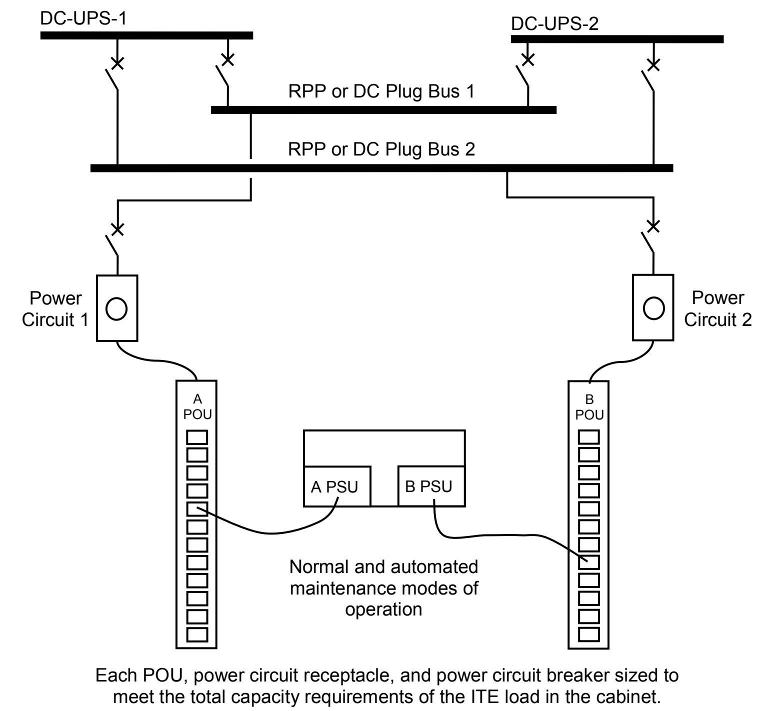


Figure 9-31
Class F3 50 to 600 V_{DC} Circuit Mapping

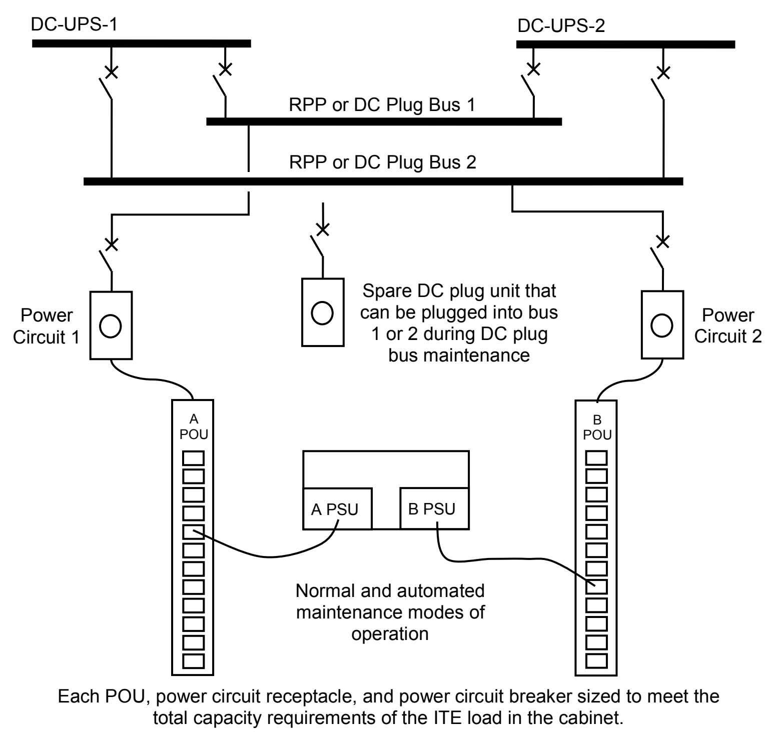


Figure 9-32
Class F4 50 to 600 V_{DC} Circuit Mapping

9.3.15.4.3 Power Cord Mapping

In addition to circuit mapping, it is important that the IT team understand how to implement power cord mapping based on the ITE being implemented. There are several power cord and redundant power supply configurations provided by ITE manufacturers, such as:

- 2 power supplies, 1 to 3 cords each power supply, N+1 power supply configuration
- 3 power supplies, 1 to 3 cords each power supply, 2 power supplies in 2N configuration plus 1 non-redundant power supply configuration
- 3 power supplies, 1 to 3 cords each power supply, N+1 power supply configuration
- 4 power supplies, 1 to 3 cords each power supply, N+1 power supply configuration
- 4 power supplies, 1 to 3 cords each power supply, 2N power supply configuration
- 5 power supplies, 1 to 3 cords each power supply, 4 power supplies in 2N configuration plus 1 non-redundant power supply configuration
- 5 power supplies, 1 to 3 cords each power supply, N+1 power supply configuration
- 7 power supplies, 1 to 3 cords each power supply, 6 power supplies in 2N configuration plus 1 non-redundant power supply configuration
- 7 power supplies, 1 to 3 cords each power supply, N+1 power supply configuration
- 9 power supplies, 1 to 3 cords each power supply, 8 power supplies in 2N configuration plus 1 non-redundant power supply configuration
- 9 power supplies, 1 to 3 cords each power supply, N+1 power supply configuration

It is critical to fully understand how the power connections of the ITE with 3 or more power supplies have been configured within the ITE. If the power supplies are configured in a 2N+1 configuration, it is vital that it is specifically known which power supply is the "+1" non-redundant power supply and that it is connected to an STS with dual inputs. If the power supplies are configured in an N+1 configuration, then any one of the power supplies can be connected to an STS with dual inputs.

When power supply units have multiple input power connections, it is also important that the IT designer fully understand how the inputs are configured within each PSU and how they respond to all the failure modes. Some ITE have options to reconfigure how the input cords and power supply units are configured. It may be that all input cords to a PSU should be grouped to the same upstream distribution, or it may be required that the inputs to each PSU must be connected to separate upstream distributions in order for all the power supply units to perform as intended. As indicated, the IT designer must fully understand how multiple PSU inputs and multiple PSUs are configured for each ITE, and the network or system administrators must also fully understand the configuration before any changes are implemented within the ITE to alter the configuration.

Improper implementation of the power cord or power supply configuration with the redundant upstream power distribution can result in unplanned downtime because of human error, even if both the ITE and the power distribution have been designed as Class F3 or F4 systems.

9.3.16 Emergency Power Off (EPO) Systems

9.3.16.1 Introduction

A means of disconnecting the electrical supply, more commonly known as emergency power off (EPO), while not mandated by standards, is sometimes required by local codes. An EPO presents the greatest risk to electrical system availability in the data center as an EPO activation can be intentional, caused by sabotage, or accidental, via physical contact, mechanical failure, and human error during maintenance (such as the manipulation of the EPO system’s link to the fire suppression system). A failure of the electrical supply feeding the EPO circuit can cause catastrophic failure of the ITE power because EPO shuts down ITE power when its own power supply is lost.

Organization of an EPO system is illustrated in Figure 9-33.

9.3.16.2 Requirements

Local codes or insurance carriers often require EPO for the safety of firefighters, but they may allow some exceptions (such as when “orderly shutdown” is necessary). Additionally, some jurisdictions or codes may allow the EPO for the data center to be eliminated based on 24/7 occupancy of the facility or other considerations.

When a single point EPO for the data center or larger portion of the building is required and implemented, the EPO shall be supervised on a 24/7 basis.

NOTE: A single point EPO is typically an individual project requirement, negotiated at the time of the project’s development.

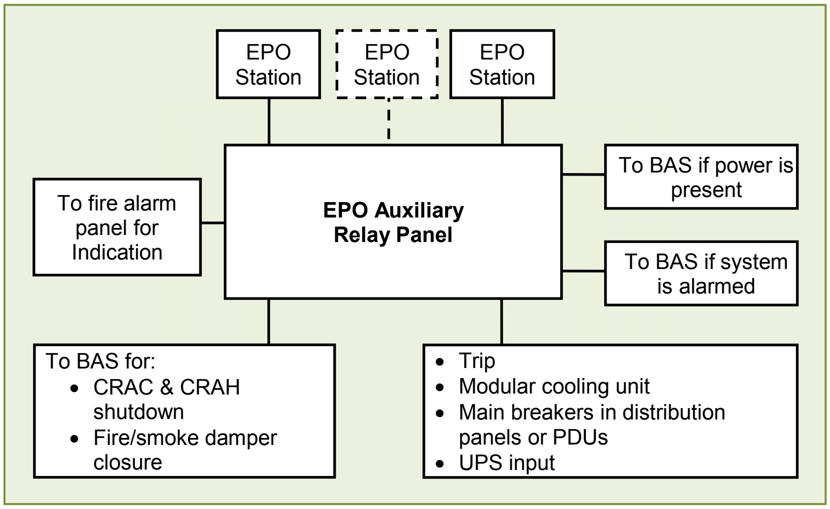


Figure 9-33
Example Organization of an EPO System

Where the back-up power supply to the EPO circuit is a battery, the charge shall be monitored and the battery able to be replaced without triggering the EPO.

9.3.16.3 Recommendations

When not required by code, the owner must carefully balance the needs of business continuity with personnel and building safety. When an EPO system is to be installed, a number of features can be included to make it more reliable, including:

- Delay to EPO activation after button push
- EPO override switch (keyed or non-keyed)
- EPO activation countdown timer
- Multiple stage systems

  NOTE: EPO systems used in data centers should be three-state systems, with *off*, *test*, and *armed* modes of operations.
- EPO activation stations requiring multiple steps to operate them such as lift-hold-and-pull or the simultaneous operation of two buttons (when not prohibited by ADA and similar accessibility regulations).
- EPO activation stations that include a pre-alarm function, in which an audible and visual alarm is activated when the EPO button cover is lifted. This allows someone who has accidentally lifted a cover to know that there is a danger of activating the EPO system.
- EPO activations that allow a time delay, deactivation of a smaller areas of the data center, or centralized as part of an integrated electrical system.

  NOTE: All of these techniques should be reviewed and approved by the local AHJ prior to implementation.
- Multiple disconnecting means to de-energize ITE and cooling equipment.

Decisions during installation can also affect reliability. Recommendations that should be followed include:

- In an N+N system, power to the EPO circuit should emanate from more than one UPS, to minimize risk of power failure to the EPO.
- Security cameras should be installed at EPO stations so that the face of the operator of the EPO can be clearly seen.
- EPO systems should be capable of being isolated from the fire alarm system so that when the fire alarm system is undergoing routine maintenance, the EPO is not accidentally activated.
- Do not specify or disconnect onboard, device-specific EPO buttons, if present, from UPS modules, UPS control cabinets, PDUs, static switches, and any other factory-installed EPO button. If the EPOs cannot be safely removed, the covers should be tied down to prevent accidental activation. These EPOs are not required if the room they reside in has one since they disconnect only one system or device as opposed to all of the room's equipment.

List continues on the next page

- Activation of an EPO circuit should also remove power to dedicated HVAC systems serving the room and should cause all required fire or smoke dampers to close unless a hazard/risk assessment determines, and the AHJ agrees, that cessation of air movement would pose a greater hazard than continuous ventilation.
- The disconnecting means may be permitted to be located in a secure area outside of the computer room, but this should be reviewed and approved by the local AHJ prior to implementation. Consideration should also be given to security risks if the EPO is not in a controlled access space.

Additionally, unless required by code or the local AHJ, EPO systems should not be installed:

- In UPS, chiller, and battery rooms
- Near light switches, phones, or any other device that is routinely touched

9.3.17 Fault Current Protection and Fault Discrimination

9.3.17.1 Introduction

As a result of reducing electrical loss, the power circuit impedance in data center electrical systems have become lower, leading to greater fault currents flowing towards a short circuit, particularly at locations where multiple circuits converge. Components such as static switches, PDU's, and rack power busway are at particular risk. If the component is not rated for the possible inrush current a major short circuit can cause the component to fail or even explode.

In a correctly designed system, a fault on a circuit should only result in a disconnection of the first fuse or breaker upstream of the fault. This is called fault discrimination, and is difficult to achieve for the entire system

9.3.17.2 Recommendations

Fault current protection and fault discrimination must be considered in the design from early conception, using software tools. It may be necessary to reconsider the concept to achieve compliance.

9.4 Mechanical Equipment Support

9.4.1 Introduction

Mechanical systems are as vital in the data center as the UPS systems that serve the ITE. The ability to have little or no interruption to the cooling services while maintaining temperature and humidity within a relatively narrow band is vital for the operation of most high-performance computing systems.

There have been several instances of thermal runaway where the heating of the data center could not be stunted in time to prevent the ITE from shutting down on a high temperature condition.

Some computing systems consume so much power and operate at such a high-power density (as viewed in W/m^2, W/ft^2, kW/cabinet, or kW/floor tile) that an interruption of cooling medium for only one minute can result in ITE shutting down. In this light, ITE requires uninterruptible power and nearly uninterruptible cooling.

There are two considerations for the electrical system when it supports the mechanical system—the restart of the cooling system (viewed in its entirety from the cooling plant to the ventilation systems) and the diversity of the electrical paths to the mechanical systems that matches the redundancy of the given mechanical components being served.

In traditional chiller plants (not including slaved DX units to a given air handler), the compressor restart time for the chiller can lead to thermal runaway in the data center during a power failure. This is caused by the ITE loads still operating under UPS power while the chillers, powered by the generator system, undergo a complete and protracted restart cycle following a power interruption.

Battery run time for UPS power systems that are supporting continuous cooling system needs to be coordinated with generator start and transfer time. Similarly, critical house and control systems need to consider any reboot or transfer time ahead of any mechanical equipment restarting.

While the restart control sequence is the purview of the mechanical designer, careful consideration needs to be paid to the following as soon as possible after an outage or retransfer from generator to normal power:

- Keeping chilled water moving in the system
- Keeping the ventilation systems operating
- Reestablishing the cooling plant (regardless of its design).

Generally speaking, a Class F4 mechanical system does not have the same topology as a Class F4 electrical system. Since the Class F4 mechanical system must meet the performance definitions defined for Class F4, the electrical system that supports the mechanical system must map to the normal, failure, and maintenance modes of operation for the mechanical system.

In many ways, the circuiting of the mechanical system is similar to circuiting of multicorded equipment loads in the computer rooms; multiple power paths must be used to ensure that a given piece of equipment survives a failure or is still on line during maintenance. Since Class F1 and Class F2 systems do not offer load supply redundancy, these Classes are not offered as solutions. The circuiting pathway for support of mechanical loads for a Class F3 facility is illustrated in Figure 9-34.

An example of a power distribution system supporting a Class F4 mechanical system is illustrated in Figure 9-35.

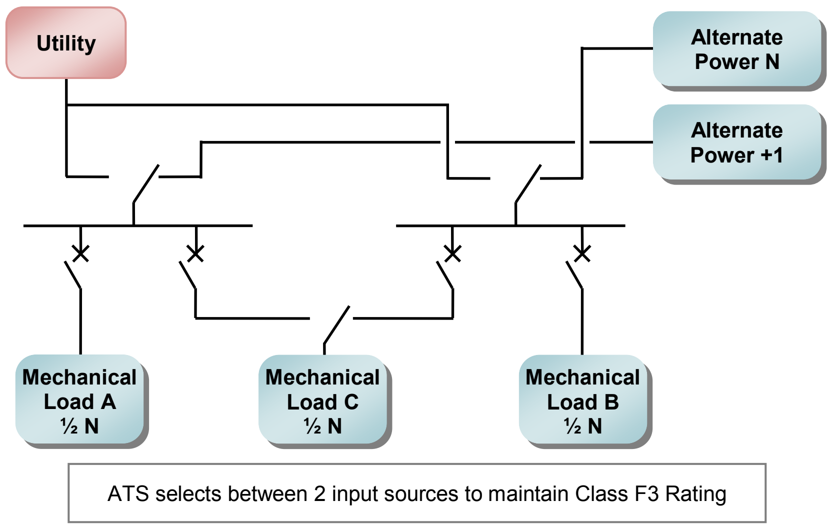


Figure 9-34
Sample Power Circuits for a Class F3 Mechanical System

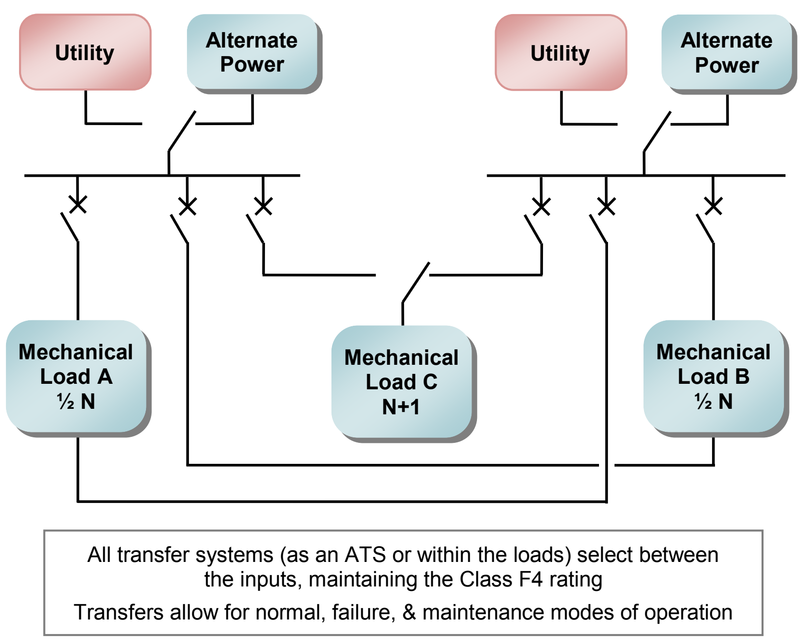


Figure 9-35
Sample Power Circuits for a Class F4 Mechanical System

9.4.2 Requirements

Temperature controls shall be maintained during normal, maintenance and failure modes of operations. Where redundant temperature and cooling plant controls are provided, redundant circuits shall be provided commensurate with the diversity of the control system.

Cooling water pumps may require uninterrupted power. If the decision is made to support motors and pumps without interruption, they shall have a dedicated UPS suitable for the high inrush currents characteristic of such loads. Motors and pumps shall not share the same bus as ITE loads. (See Sections 9.1.6.5 and 9.1.6.6).

9.4.3 Recommendations

9.4.3.1 General Considerations

Having mechanical system controls on UPS power may provide faster cooling system restart times; however, this would need to be verified with the mechanical system vendor as it can be dependent on the manufacturer/model of system implemented. If the chiller is on unprotected power but the chiller controls are backed by UPS, upon loss of utility power, the chiller controls might lock out the chiller and remain in failed state. This constraint may not be factory or field adjustable.

Chiller and cooling systems often require substantial restart time, and these systems will take some time to return to full operation. This demands a few considerations:

- While the cooling systems are restarting, the UPS systems are still providing power to the load. Heat generated by the ITE loads operating on that UPS power will build in the data center spaces. Cooling plant restart times are often much longer than the time it may take for heat to rise sufficiently in the room to a point where ITE will shut down.
- The diversity of the electrical systems serving the mechanical plant must address maintenance and failure modes of operation to ensure that the cooling system restart time does not cause ITE loads to fail because of overheating.
- Substantial cooling water may exist in the cooling water piping system to help bridge the time or capacity gap for the cooling plant restart. In this light, keep cooling and condenser water pump running at all times.
- Some heat transfer may take place by simple ventilation, so keeping the fan system running can mitigate some of the heat rise in the room.
- For cooling plant restart, the following sequence of load additions to active service are recommended (all loads on alternate power):
  - Ventilation
  - Pumps
  - Chillers and cooling plant
- For higher power densities, there may be only a couple of minutes or dozens of seconds before the room heat “runs away” to a point where, even if cooling is restored, ITE may drop out or be damaged because of temperature. In this case, some of the mechanical support loads must be maintained on a 24/7 basis and may require UPS power in support of the IT mission. For high-density loads, some pumps and fans will require power from a dedicated UPS.
- Prudent design calls for the ability, first, to determine the rate of heat gain in the data center versus the restart time in failure or maintenance modes of operation and, second, to ensure that the electrical system offers sufficient capacity and diversity to prevent thermal run away in the facility.
- For fast chiller restart the chiller controls (but not the pumps) should be on UPS.

9.4.3.2 Chillers and Central Cooling Plant

Chiller and cooling plants have particular challenges to overcome for high-availability applications. Chillers, towers, and pumps tend to be single input type of machines with only a single feeder serving them. For open-circuit cooling systems utilizing cooling towers, chillers are sometimes paired with a cooling tower and pumps while in other cases, they work independently from each other. Whichever the case, the chiller input power must be coordinated with the mechanical plant’s chiller redundancy scheme. For some high-availability sites, heat exchangers and thermal storage systems are employed and must be considered in the circuiting of the cooling plant.

In all events, the pumping and other supporting systems, such as controls, must also be energized and maintained during normal, maintenance and failure modes of operation. Dual input to the chillers, cooling towers, and associated cooling equipment via automatic or manual transfer systems may be required.

For high-density computing environments, it is essential that some form of cooling be maintained during the generator start and mechanical cooling plant restart cycles. Some form of cooling equipment may have to be placed on UPS power in order to maintain temperature and humidity control in the data center.

9.4.3.3 Pumps

Pumping systems for data centers come in numerous forms—chilled water primary and secondary, condenser water, make up water, well water, and booster pumps. Most of these systems are configured as parallel redundant systems, operating on an N + x basis (where x can be an integer or a percentage, depending upon the design criteria). Occasionally, a 2N system might be seen as well. Pumping systems typically operate much like paralleled generators or UPS modules might, sometimes equally sharing the load and sometimes not, depending on the drive and control configuration. Therefore, each pump for a given system needs to be powered independently of its partners. The circuit mapping also needs to follow the Class requirements and maintenance and failure modes for the equipment.

For high-density computing environments, it is essential that water flow be maintained, possibly requiring that some water flow systems be placed on dedicated UPS power.

9.4.3.4 Air Handling Systems

Air handling systems typically possess a higher degree of diversity than any other mechanical load in the data center. For example, 10 air handlers might be required for the load, and 13 are installed. This can be due to air distribution, the designer's preference, or the room's physical organization or dimensions. Serving that from two or three mechanical load buses poses a challenge without the use of manual or automatic transfer systems for individual or groups of air handlers. Similar to chillers and pumps, the air handler diversity and the N + x basis (where x can be an integer factor or a percentage factor depending upon the design criteria) must be known. Then the electrical system circuiting should be overlaid to support them.

For high-density computing environments, it is essential that air circulation be maintained, possibly requiring that some air handling systems be placed on UPS power.

9.4.3.5 Humidification

Humidification can occur either locally or centrally in a data center, depending on the mechanical designer's technique. If the humidity control is local to the air handler, the power for the humidity system may be integral to the air handler. Note that humidification and dehumidification can be very energy intensive, which means that each unit having its own control can be very wasteful. Additionally, there is the potential for units to "fight" each other (i.e., one unit is adding humidity which triggers another unit to reduce humidity), which is extremely wasteful. Thus, current best practice is to have a more centralized control of humidity either at a room, module, or entire data center level. The air handler's circuiting will accommodate it pursuant to the Class' requirements. If the humidification is not powered by the air handler, a separate circuit for the humidifier is needed and the same set of circuiting requirements for the given Class. The same can be said for humidification or dehumidification systems that are independent of the air handlers that are mounted either in the data center itself or in the air supply ductwork.

9.5 Uninterruptible Power Supply (UPS) Systems

9.5.1 Introduction

NOTE: UPS systems are also discussed in Section 9.3.8 as part of the distribution system.

Using an analogy in which the electrical distribution system can be considered the arteries of the critical power system, the UPS systems are the heart—the nexus of power conversion and continuity. While there are several methods and designs for achieving a topology that will meet a given Class goal, the sizing and considerations of the UPS power plant itself has several common issues. This section will address the varying technologies, design applications, and other considerations for the UPS plant. These include:

- Sizing and application
- Technology
- Paralleling and controls
- Batteries and stored energy systems.

Appropriate selection of the UPS topology depends on the criticality of the applications supported by the data center. It is acknowledged that every business demands different levels of criticality and that the topology chosen has substantial impact on cost, space, complexity of operation, cost of operation, and expected lifespan.

9.5.2 Sizing and Application

9.5.2.1 Application

UPS and critical power system applications are focused on delivering quality power, whether originating from an electric utility or from internal energy storage, on an assured, 24/7 basis. While there are several issues related to loading and topology, the primary concern of UPS system design for Class F3 and F4 systems is the maintenance of critical power services while accommodating known failures or allowing for safe and logical preventive maintenance. There are several points to consider when selecting equipment or employing UPS systems and critical power components into a cohesive critical power system.

Similarly, system bypasses, whether they be static or external/maintenance, must offer a safe and clear method for rolling load on and off the UPS module or system. System designs should be arranged so that a failure in a single module or system is not allowed to propagate to adjacent or paralleled systems. Failure compartmentalization should also be used for other portions of the critical power system.

The main design and application considerations for UPS and critical power systems are:

- Automatic, single-step response to a failure
- Failures limited to the system that failed
- UPS power plant maps correctly to the critical power distribution system
- Stored energy system able to carry the critical load during all input power failures

9.5.2.1.1 Automatic, Single-Step Response to a Failure

System failures should be automatically corrected without risking the load. Failure response should allow the UPS system to settle into a steady state as expeditiously as possible. The response to a fault may transfer the load from the UPS module or system to another UPS system or to an unconditioned bypass source. Regardless, the UPS system has its highest chance of maintaining the critical power load's continuity with a single transfer or operation, also known as the "one step save." If the UPS system requires several steps to arrive at a revised steady state, it may fail in the transition process, resulting in a critical power load loss.

Failures should be limited to the system or portion of the critical power chain that experienced the failure. For example, a failure of a single module in a multiple module, paralleled system should limit the failure to the module that failed. In the case of a distributed system, the interconnection of the systems should not allow a failure to cause a failure in the supporting systems. This only speaks for system changes of state and not the normal, customary, and predicated load transfer to the other UPS systems that are expected based on the Class or system constitution.

There is a word of caution for some of the UPS plant designs that seek to establish a "ring" bus to share redundancy for multiple UPS power plant outputs or in the distribution system. Power quality, especially switching transients, resonance, or "ringing", need to be carefully examined to ensure that the UPS waveform is not corrupted by the failure mode operation of any portion of the system.

9.5.2.1.2 UPS Power Plant Maps Correctly to the Critical Power Distribution System

There are several instances when the N count of the UPS systems may not agree with the N count of distinct critical power distribution channels downstream of the UPS plants. ITE loads are typically dual-corded with many systems being more-than-two-corded. This brings up the phenomenon where the UPS plants' pathways do not directly map to the number of pathways of the downstream power distribution system. An easy plant-to-distribution map is a 2N system with a PDU capacity matching the UPS system (not considering the idiosyncrasies of the individual PDU setups).

For distributed systems, the failure modes of the individual critical power circuits need to be mapped upstream to the PDUs, then the PDUs need to be mapped against the critical power distribution systems or switchboards, and then the critical power distribution switchboards need to be compared against the UPS plants to which they are connected. While this is a straight forward exercise for normal operations, the failure and maintenance modes of operations need to be examined for loading and change of state operations as well to ensure that the critical power is maintained at all times under all modes of operations.

9.5.2.1.3 Stored Energy System Able to Carry the Critical Load During All Input Power Failures

Since an alternate source of power is an integral part of the data center's design, a utility power failure should result in the generator starting and the facility being transferred to the generator or that alternate source of power. The ability to carry vital ITE loads and critical support loads during the power resumption on the generator or maintaining services during the retransfer from generator to utility is necessary for any data center design.

With the advent of the high-density computing environment, the maintenance of cooling systems and the room environment is as vital to maintaining the IT processes as the UPS systems' stored energy systems.

The stored energy systems for the UPS modules and systems will be discussed in detail in Section 9.5.5. Every UPS power system must have some form of stored energy to bridge the transfer to the alternate source of power and the retransfer to utility and normal operating conditions or for any situation where the input power falls outside of the system's tolerances. For single corded loads, subcycle static transfer switches may be employed where the ITE loads themselves do not offer redundancy. In many cases, the ITE loads themselves will arbitrate which power input is most appropriate for its use.

For certain computing environments, UPS power may be derived from batteries, flywheels, or another stored energy system that provides the ability for a power or cooling system to maintain or restart loads before an impact to the computing environment. In some cases, this might mean that the chilled water pumping systems or chiller water storage system must be on UPS power. In other cases, the ventilation system must be maintained on the UPS power system.

In any event, these collateral, nontechnology loads must be added to the ITE loads to arrive at the proper UPS plant size for the facility.

9.5.2.2 System Sizing

System sizing is linked to the Class, system design, and topology chosen by the designer. The UPS system design should be based on kilowatts (kW) with consideration given to kilovolt-amperes (kVA) and the resulting power factor. The system kW must consider derating factors such as:

- Altitude
- Run time at a given load level
- Operating temperature of the electrical room or the location of the systems and equipment

The critical power system sizing is based on fully meeting the critical power load with the fewest modules or pathways available during maintenance or failure modes of operation (fairly assuming that the normal mode of operation always has more systems or pathways than failure or maintenance modes of operation).

The UPS power system capacity is always determined at the output of the UPS system. PDU or transformer losses related to generating ITE utilization voltage are to be considered part of the ITE load and are not to be included in the power capacity calculations. This method considers all UPS module and system losses but it does not penalize critical power distribution systems that may not employ PDUs or transformers or any further voltage conversion below the UPS systems. When determining power density (rendered in W/area), the output kW rating of the UPS power system is to be utilized for the calculation.

9.5.2.2.1 Loading Levels

As for many power systems, there is a fine balance between an overloaded and an under loaded electrical system. While the issues of overloading are clear (e.g., heating, breaker tripping, and reduction of Class), under loading may lead to system instability or, for some older systems, an inability to operate.

While this is not a big issue for a single module system, this can be a huge issue for large-scale paralleled or distributed-redundant systems where load is being shared equally among several, equal components. Loading levels must be considered for normal, maintenance and failure modes of operation. The fact is that for higher Class rated systems, there are often many systems sharing a modest critical power load sometime during the lifespan of the facility.

Overloading factors are noted below in the next section, and it is recommended that a given UPS system be operated at no less than 20% and no more than the safety factor discussed below under normal, maintenance and failure modes of operation.

Critical power system loading is load growth versus the Class. For example, a Class F4 system, when it passes a certain loading level, may revert to a Class F3 level. This occurs because power modules that were formerly used for redundancy may now be required for capacity (i.e., to serve a larger critical power load).

9.5.2.2.2 Safety Factors

It is impractical to load any electrical system to its full capacity. While some manufacturers have purported or proven 100% system rating and a resulting 0% safety factor when weighed against the critical power load kW rating, best practice is to always apply a safety factor in system design. This addresses unanticipated load fluctuations, inrush currents, and code-required continuous-duty system ratings.

A load factor of 90% is recommended with a 95% maximum, leaving a design of 10% to 5% safety factor. This does not include the continuous-duty rating demanded by the applicable code (e.g., *NEC*). For most designs, the code-mandated safety factor required for continuous load could also be used as the design safety factor.