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High-Availability Power Systems, Part III: AC Distribution Options

SUMMARY

“High-Availability” power systems require Reliability, Functionality, Maintainability, and Fault Tolerance. The distribution of AC power between your UPS and load equipment will ultimately determine your Maintainability and Fault Tolerance.

The first two white papers in this series explained UPS Internal Topologies and UPS System Redundancy Options. See the end of this article for ways to obtain those earlier papers. This document will explore methods of distributing power from the UPS system to your critical load equipment.

Studies show that 80% of all power-related downtime is caused by disruptions between the UPS and the critical load. Failures can happen because of human error, equipment failures, load faults, short circuits and any number of peculiar events. Probability says that your equipment will eventually fail, and that human error will happen. Therefore it’s important to arrange your power distribution system to enable it to survive any single failure or blunder.

Some Definitions

Let’s begin by defining some standard industry terminology.

- **Panelboard.** The panelboard is an assembly typically containing 42 circuit breakers rated for 20 amps each. Panelboards are used to control power to single-phase devices, which operate at 120 VAC in the USA and at 220-240 VAC in Europe.
- **Power Distribution Unit.** Power Distribution Units (PDUs) combine an input isolation transformer, one or more panelboard assemblies and power monitoring equipment. Some include optional 3-phase subfeed breakers.

In the USA, the PDU transformer provides voltage stepdown (from 480 to 208 VAC) plus a separately derived neutral for optimal grounding. It provides a ground reference for the critical load and provides common-mode noise attenuation. It also minimizes the neutral-to-ground voltage,

reduces neutral current, reduces wiring costs (by enabling 3-wire instead of 4-wire connections between UPS and PDU) and allows for local voltage adjustment by the voltage-compensation taps.

In Europe, the PDU transformer isn't required for voltage stepdown, but it does have all the other advantages explained above.

- **Remote Distribution Cabinet.** The Remote Distribution Cabinet (RDC) contains 4 panelboard assemblies and power monitoring equipment in a small-footprint enclosure. A typical RDC is designed to fit the dimensions of a standard raised-floor tile (24 by 24 inches in the USA). The RDC does not contain an input isolation transformer, and typically receives power from a subfeed breaker in the PDU. RDCs can be configured as single input (all panelboards fed from the same source), dual input (fed from independent sources) or quad input.

The RDC is typically mounted at the end or in the middle of a row of server racks, as shown in Figure 1.

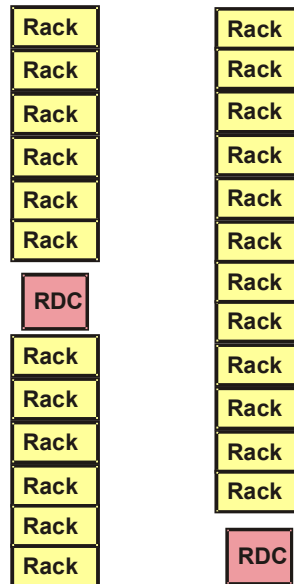


Figure 1. Typical RDC locations

- **Static Transfer Switch.** The Static Transfer Switch (STS) can transfer 3-phase loads between UPS sources within a quarter of an electrical cycle (4 milliseconds). These break-before-make transfers are quick enough to prevent disruption of the load. Transfers can be initiated by the operator (for scheduled maintenance) or by the STS itself (if a UPS source goes out of spec).
- **Point-of-Use Transfer Switch.** The Liebert SmartSwitch™ will transfer up to 60 amps of single-phase loads between different power sources. The SmartSwitch is typically dedicated to a specific server rack or cabinet, and can be mounted in the rack or under the raised floor. SmartSwitches typically supply power to plug strips inside the rack or cabinet. Unlike the STS, which uses Silicon Controlled Rectifiers (SCRs) as transfer devices, the SmartSwitch uses relays.

Armed with these tools, we can create power distribution solutions that give us optimum maintainability and fault tolerance.

Simplest Example: Servers with Dual Power Cords

The easiest system to design is one where all the servers have dual power cords and are completely functional on either cord. Each cabinet or rack must be supplied with two power feeds, one from each UPS system.

Power flow can be simple and direct, from the UPS through the PDU to the load equipment. For densely populated server farms, it is helpful to use Remote Distribution Cabinets between the PDUs and servers, to simplify the task of branch circuit wiring.

No transfer switches are required for redundancy or maintainability, but we do recommend Load Bus Synchronization (LBS) in case single-cord loads must be added later. See Figure 2.

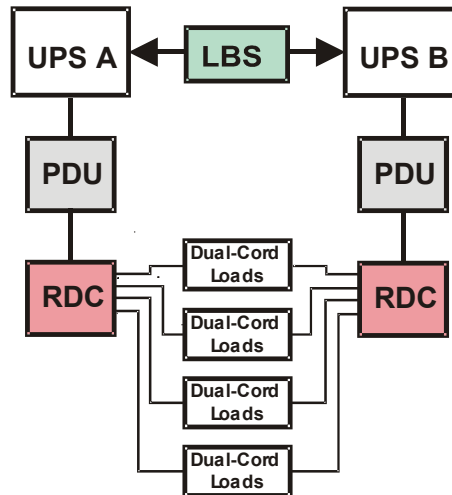


Figure 2. Distributed-Redundant System, all dual-corded loads

This configuration can achieve continuous availability of conditioned power. Redundancy extends down to the inputs of every load device. Either UPS system (and its associated PDU and RDC) can be completely de-energized for maintenance without affecting the critical load.

Single-Cord Loads with Static Transfer Switch

The pendulum is swinging back toward single-corded loads. The current wave of one-rack-unit-high (1-U) servers is single-corded, since there isn't room inside the case for redundant power supplies. As a result, the power system designer must take other steps to ensure maintainability and fault tolerance.

Pictured below is an example of a system using a Static Transfer Switch (STS) to add redundancy. The STS is fed by two PDU transformers. The output of the STS is fed to various Remote Distribution Cabinets (RDCs), which provide power to the individual racks or cabinets. The LBS unit keeps the output of the two UPS systems in sync so loads can be transferred seamlessly between them.

When it's time to service UPS A and PDU A, the STS can be manually transferred to UPS B and its PDU. Then UPS A and its PDU can be completely de-energized for maintenance. The process can then be reversed to service UPS B. In addition, the STS will automatically transfer between UPS systems should one of them fail. The drawback to this configuration is that redundancy stops at the input of the STS; everything downstream of the STS is a single point of failure.

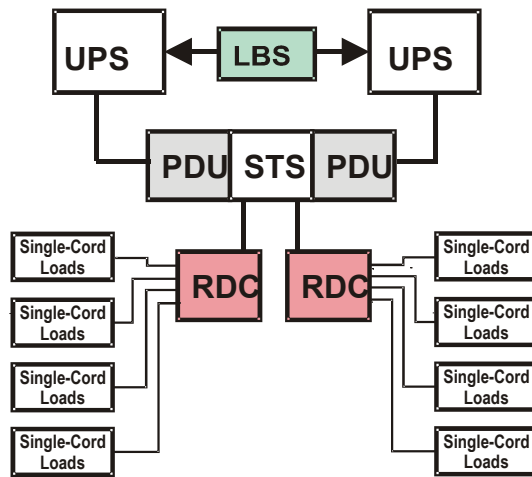


Figure 3. Single-cord loads with STS

Single-Cord Loads with Point-of-Use Transfer Switches

One method of bringing redundancy closer to the load equipment is to provide SmartSwitches dedicated to individual cabinets. These can be mounted under the raised floor or in the rack with the load equipment. Figure 4, below, illustrates how this can be achieved.

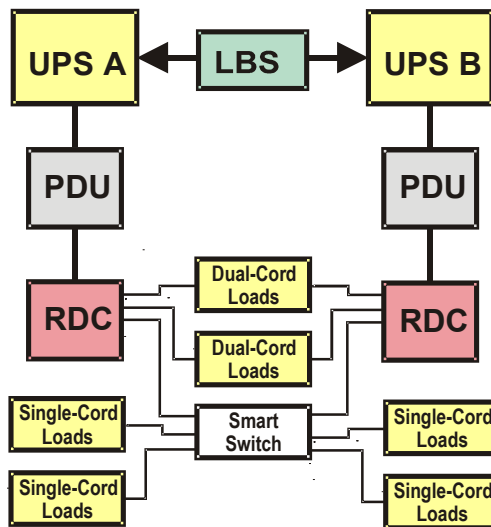


Figure 4. Mixed loads with point-of-use transfer switches

As you can see, the SmartSwitches enable single-cord and dual-cord equipment to co-exist in the same cabinet. Both types of equipment will have redundancy up to their input terminals, for maximum maintainability and fault tolerance.

One advantage of this approach is its flexibility. The system designer can plan the wiring as if all the loads are dual-corded, and bring dual power feeds to each cabinet. Dual-cord loads can drop right in, when they're available. Individual cabinets requiring single-cord loads and a SmartSwitch can be outfitted as they're identified, during buildout. This approach will require the LBS functionality, to keep the outputs of the UPS systems in sync.

Ultra-High-Availability Solutions

Some customers prefer to use RDCs in dual-input configurations, with a different STS feeding each input. For these applications, the STSs should be set to use different UPS systems as their preferred

sources. This will avoid situations where 100% of the load is on one UPS and 0% on the other, effectively negating the advantages of redundancy.

The RDCs are normally configured with two panelboards facing forward and two facing the back aisle. In the dual-input configuration, the front panelboards will be fed by STS A while the rear panelboards are fed by STS B. This enables a single RDC to provide both the A and B power feeds to its row of cabinets.

This configuration has somewhat higher hardware cost than some others, because of the extra PDU transformers and the additional Static Transfer Switch. However, the entire power system is completely maintainable, down to the input terminals of the load equipment and the SmartSwitches. Please refer to Figure 5, below.

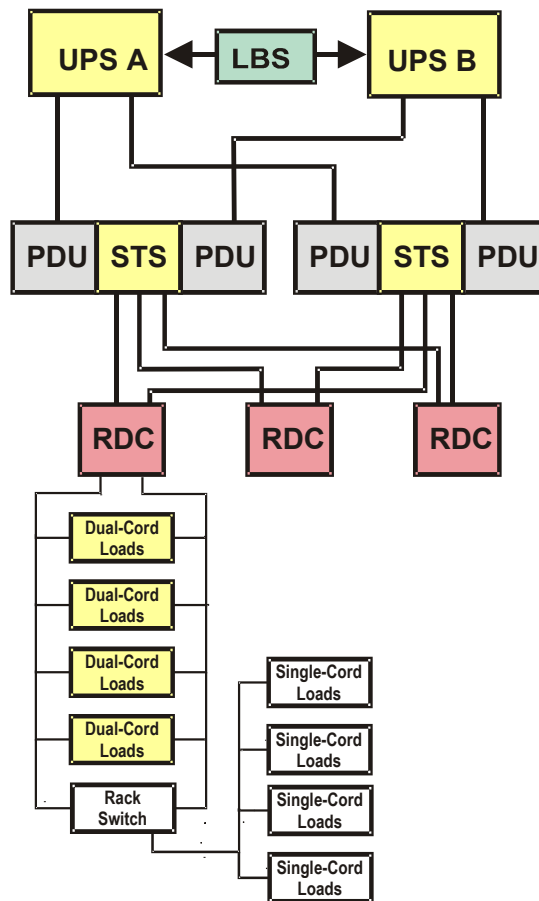


Figure 5. Dual-input RDCs in High-Availability configuration

STS Application Note

For purposes of this paper, the Static Transfer Switch is always shown on the output of a pair of PDU transformers. It is also possible to apply the STS on the input of a single PDU transformer, which is a lower-cost approach. However, this “primary-side” application has performance issues.

The key issue is that PDU transformers have an inrush of magnetizing current whenever they start up. This inrush current can be up to 8 times the amount of steady-state load current. If the voltage coming into the transformer dips briefly (enough to cause the STS to transfer to the other UPS), the transformer may need to re-magnetize as soon as the STS finishes the transfer. For a large UPS system, this might not be an issue. But if several STSs transfer from one UPS to the other at the same time, the inrush current could become an issue.

Grounding Note

When using two PDU transformers to feed an STS, the neutrals of the two transformers are intentionally connected together at *one point* and a neutral-to-ground bond is made. This ensures that the STS can make transfers without causing a ground potential shift or causing neutral current to flow on the ground circuits (possibly causing ground fault protection systems to activate).

Most sites will have multiple Power Distribution Units, each with one or two PDU transformers. Each PDU will have a neutral-to-ground bond, and the PDU ground will be solidly connected to the building ground system. That ensures that each PDU provides a clean neutral and ground reference point for its connected equipment.

Conclusion

Each of the system configurations described in this paper has its own advantages and disadvantages. Consult your power system design engineer for the configuration with the best price/performance ratio for your facility.

For copies of the first two white papers, contact Liebert at 800.877.9222 (USA and Canada only) or 614.888.0246. Alternatively, visit the Liebert website, <http://www.Liebert.com> and look under “Support” for the list of white papers for 3-Phase Power.