Increased power protection with parallel UPS configurations

Making the selection between Distributed Bypass and Centralized Bypass systems

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Executive summary

Organizations such as large data centers, banks and hospitals depend on reliable electricity to safeguard their critical data. A parallel UPS system continues to maintain power to the critical loads during commercial electrical power brownout, blackout, overvoltage, undervoltage, and out of tolerance frequency conditions.

Paralleling provides an excellent solution for matching an organization’s growth needs while extending the value of existing UPSs. This white paper discusses the main differences and typical concerns about Distributed Bypass and Centralized Bypass systems to help you determine the suitable solution for your organization.

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The need for parallel UPS systems

Uninterruptible Power Supplies (UPSs) provide continuous power to electronic systems to safeguard business-critical data. If the UPS needs to switch offline for some reason, it switches to an internal bypass path, and critical loads run off utility power until the UPS can be brought back online.

Parallel operation extends the normal operation of a UPS by offering increased capacity and/or redundant capability. The parallel system continues to maintain power to the critical loads during commercial electrical power brownout, blackout, overvoltage, undervoltage, and out of tolerance frequency conditions. The architecture of such a power protection system is designed to prevent the loss of valuable electronic information, minimize equipment downtime, and minimize the adverse effect on production equipment due to unexpected power problems.

Organizations such as large data centers, hospitals and banks are increasingly finding that using straight utility power is risky, even if used for short periods of time. Because the cost of downtime and the risk of losing data are too high, organizations deploy redundant UPS systems to ensure electrical supply even in cases when one UPS ceases to operate.

How paralleling technologies enhance the reliability of electricity

In paralleling, two or more UPSs are electrically and mechanically connected to form a unified system with one output — either for extra capacity or redundancy. In an N+1 redundant configuration, there would be at least one more UPS than needed to support the load. As a conjoined system, each UPS stands ready to take over the load from another UPS whenever necessary, without disrupting protected loads.

A redundant UPS configuration is designed to ensure that critical workloads remain protected even if one or more of the UPSs within that configuration becomes unavailable. Parallel redundant configurations, including N+1 and N+N architectures, are among the most common and effective varieties.

![Figure 1: A parallel Eaton 9395 UPS system. In this example, each UPS includes two power modules (UPM) and one static bypass.](image)

In the parallel redundant system, the electrical failure of any UPS power module (UPM) results only in the affected module isolating itself instantly, and not shutting down the entire system. The remaining UPMs continue to support the critical load, with conditioned power, and thus the mission reliability is enhanced.

The reliability benefit is due to the redundancy in the protected power. If the system operates as intended, it is extremely unlikely that the user would have to operate from the straight utility power. Any equipment failure is handled by the redundancy of the system, by isolation of the failed component, and the transfer to bypass is only used as the very last resort. In essence, mains bypass power would only be used due to UPS-external factors such as overload, over temperature or short-circuit. Routine maintenance of the UPS system should not require transfer to bypass.
**Understanding Distributed Bypass and Centralized Bypass systems**

There are typically two different types of parallel UPS systems: distributed bypass systems and centralized bypass systems.

In the distributed bypass system, each UPS has its own internal static switch, rated according to the UPS size. Each UPS monitors its own output, and if the UPS system needs to transfer to bypass, each static switch in each module turns on at the same time, and they share the load current amongst themselves. The distributed bypass system is shown in Figure 2.

![Figure 2](image)

*Figure 2 The distributed bypass system, with each UPS having its own static switch.*

In the centralized bypass system, there is one large common static switch (also known as System Bypass Module or SBM) for all paralleled UPSs, rated according to the size of the entire system. If the UPS system needs to transfer to bypass, the load current is then fed through the System Bypass Module. It should be noted that in this case the UPS units do not include internal static switches. These UPS units without internal bypass are sometimes referred to as Input-Output Modules, IOMs. The centralized bypass system is shown in Figure 3.
What are the effects on reliability - or are there any?

Reliability and availability are key components in any organization’s IT systems, and therefore UPS reliability is one of the most important design factors. Measures such as MTBF (Mean Time Between Failures), MTTR (Mean Time To Repair) and concurrent maintenance capabilities can be used to estimate the availability of a UPS installation. In addition, more sophisticated methods, such as Markov modeling, can be used to estimate the critical mission reliability of a fault tolerant system such as a redundant UPS.

This chapter will concentrate on the static bypass behavior and reliability of a parallel UPS system. When comparing a centralized bypass with a distributed bypass system, the two most common failure types of the static bypass should be examined; a static switch thyristor might fail to open-circuit and cannot operate when it should, or it is short-circuited and remains conducting when it should be off. Let’s examine the system reliability in these two failure modes.

Static switch open-circuit failure:

In a centralized bypass system, if the static switch has an open-circuit failure, the only static switch in a system simply fails to operate when needed, thus making the bypass unavailable.

In a redundant distributed bypass system, when one of the static switches fails to operate, the rest of the switches are still functioning and can support the load when needed. Therefore, the system has enhanced reliability against this type of fault as the system is not dependent on the operation of a single static switch.

However, if the distributed bypass system does not have redundancy and is fully loaded, a static switch open-circuit failure will lead to unavailable bypass, similarly to the centralized bypass system.

Figure 3: The centralized bypass system with IOMs (UPS 1, UPS 2 and UPS 3) in grey and the SBM module in blue.
Static switch short-circuit failure:
The short-circuit failure is a less common failure mode of the static switch. If a thyristor in the static switch suffers a short-circuit failure, the faulty bypass line connects the system output to the incoming mains. This creates a safety hazard as it enables feeding power back to the utility from the UPS system. Therefore backfeed protection is a mandatory safety feature of a UPS installation. During a short-circuit failure of the static switch, the backfeed protection device can be opened and the inverters can remain on-line to support the load.

Backfeed disconnect devices together with backfeed detection is implemented internally in all Eaton 3ph UPS equipment as standard. Therefore in a redundant distributed bypass system, each static bypass can detect the short-circuit failure and isolate it independently, thus leaving enough bypass capacity to support the load for the system if needed.

In a centralized bypass system the SBM unit also includes an internal backfeed disconnect device as standard. Therefore static switch short-circuit failure in an SBM can be isolated and the load is protected in double-conversion. However, the static bypass will be unavailable until maintenance work is carried out.

How about operating multiple static switches simultaneously under fault conditions?
A common concern regarding distributed bypass systems is the operation of the multiple static switches under fault conditions. The worry is that the system could not perform simultaneous transfer to the static bypass under fault conditions, and the static bypasses might become unavailable. This has even led to some experts having doubts about using a distributed bypass system in their designs for datacenters. To understand how the distributed bypass system operates during fault situations, let’s look at two cases: normal transfer to bypass and emergency transfer to bypass.

Distributed bypass system - Normal transfer to bypass
A normal (or planned) transfer takes place when the user commands the UPS system to bypass from the front panel of the UPS or via an external signal. The transfer to bypass occurs also due to certain fault situations such as overload, overheating or similar. Whatever the reason, the system has detected a need to transfer to bypass. In this case, one of the UPSs makes the decision to transfer and energizes its static switch.

At the same time, the UPS transmits the transfer request for other units over the communication line. Other units receive this request and transfer to bypass as well. Processing the data to be sent and received causes only minor delays, maximum around 2 milliseconds, in static switch turn-on times.

This delay is negligibly small since during the normal transfer to bypass the inverters are still able to support the load. The current levels in system output are on moderate levels, thus not risking the power devices in static switches.

Distributed bypass system - Emergency transfer to bypass
Emergency transfer to bypass (ETB) occurs when the inverters are not capable to maintain the system output voltage within normal limits. Most critical situation would be when there is a short circuit in the UPS system output side. In this case, the inverters are feeding as much current to the fault as they can to maintain output voltage and will possibly reach their current limit used to protect the power components.

If the downstream protective devices between the UPS and fault aren’t sized small enough or aren’t fast enough, the UPS system output voltage will drop and become out of limits. Hence ETB occurs immediately resulting in a high level of fault current through the bypass to clear the fault. For such a case, it is very important that all static switches turn on simultaneously to share the high current among them.
In the Distributed Bypass system, each UPS will individually monitor its own output, as well as the system output, and transfer to bypass if they are out of limits. Each unit will detect the fault in output independently.

The detection of proper output voltage is fast, and the need for ETB is detected approximately at the same time in all units. They will turn on their static switches independently without the delays of any communication lines. The possible delays between the units are the result of running the program loops for output voltage detection. The resulting delay is fractions of a millisecond. Thus they enable simultaneous transfer to properly share the fault current between static switches.

It is important to understand how a UPS system operates under different fault conditions. As described above, both bypass configurations are equally reliable since different fault scenarios within and outside the UPS system have been taken into account in product design. A UPS system with proper fault detections and backfeed protection devices can operate static switches simultaneously or isolate the faulty static switch allowing the inverters to operate normally. In Eaton UPSs and SBM, the backfeed protection comes built-in as standard and the UPS internal static bypass and the SBM system bypass both utilize same fault detection methods to enable highest critical mission reliability.

Configuration of the static bypass switch for load support

The main difference between the distributed and centralized bypass systems is the static bypass switch configuration for the UPS system. This affects the input and output switchgear configurations as well as the bypass cabling requirements.

- In the distributed bypass system, each UPS has its own bypass switch rated for the UPS power. These bypass switches are connected in parallel.
- In the centralized bypass system the system static switch in the SBM is rated to support the entire UPS system load.

Input and output switchgear configuration

With distributed bypass system, there is a need for multiple UPS rated breakers on input switchgear and switches on output switchgear to feed and isolate the UPSs with parallel static switches.

With the centralized bypass system, there is a need for an additional full system power breaker on input switchgear and an additional full system power switch on output switchgear to feed and isolate the static switch. Also, there is a need for multiple UPS rated breakers on input switchgear and switches on output switchgear to feed and isolate UPS modules. The breakers and switches have been drawn in Figure 3.

However, the Maintenance Bypass Switch (MBS) does not differ in these two configurations, as it always needs to be dimensioned for full system power. The MBS will be part of the input and output switchgear. Also the breakers for UPS or IOM units on input and output switchgears will be the same in both configurations.

Typically a UPS has separate feeders for the rectifier and static switch, as shown in Figure 2. In a redundant distributed bypass system, however, a common feeder for rectifier and static switch may be used without compromising the system reliability and to save installation costs.

Table 1 Differences in input and output switchgear configuration.

<table>
<thead>
<tr>
<th>Input Switchgear Breakers</th>
<th>Centralized Bypass</th>
<th>Distributed Bypass</th>
</tr>
</thead>
<tbody>
<tr>
<td>Maintenance Bypass Switch</td>
<td>1 pc Fully Rated</td>
<td>1 pc Fully Rated</td>
</tr>
<tr>
<td>Static Switch</td>
<td>1 pc Fully Rated</td>
<td>1-6 pcs UPS Rated</td>
</tr>
<tr>
<td>UPS units</td>
<td>1-5 pcs IOM Rated</td>
<td>1-6 pcs UPS Rated</td>
</tr>
<tr>
<td>Centralized Bypass</td>
<td>Distributed Bypass</td>
<td></td>
</tr>
<tr>
<td>-------------------</td>
<td>--------------------</td>
<td></td>
</tr>
<tr>
<td><strong>Output Switchgear Switches</strong></td>
<td><strong>Distributed Bypass</strong></td>
<td></td>
</tr>
<tr>
<td>Maintenance Bypass Switch</td>
<td>1 (+1) pc Fully Rated</td>
<td></td>
</tr>
<tr>
<td>Static Switch</td>
<td>1 pc Fully Rated</td>
<td></td>
</tr>
<tr>
<td>UPS units</td>
<td>1-5 pcs IOM Rated</td>
<td></td>
</tr>
</tbody>
</table>

**Bypass cabling requirements**

When using a distributed bypass system, there is a need to consider that each UPS unit cabling connected between the input switchgear to the UPS static bypass, and connected between the UPS output to the output switchgear must have equal length and impedances. This is needed in order to have equal load sharing between UPS static switches when the system is on bypass. If these impedances are not equal, it will cause unbalanced load between the static switches and may lead to an overload of one or several static switches. Figure 4 shows the basic principle of the wiring.

![Figure 4: Overview of the required parallel wiring principle and wiring length.](image)

The cabling requirements are the main reason why distributed parallel systems are typically used for N+1 redundancy or up to maximum 90% capacity (as specified in Tier III classification). Dimensioning the distributed parallel system for close to 100% capacity is not an optimal solution due to the difficulty to match the bypass cabling to enable full bypass capacity. The centralized bypass system is more tolerant for cabling impedances between UPSs.

However, the distributed bypass system will offer more flexibility for system dimensioning as it can be expanded by similar rating UPSs in parallel to add redundancy or capacity. With centralized bypass system, the power rating is limited to the power rating of the SBM module. On the other hand, the distributed bypass system allows using different IOM ratings in parallel since the static switch dimensioning is not an issue.
Centralized or Distributed? Choosing the parallel UPS system

Large organizations need tailored configurations that meet the set requirements for availability and manageability. The choice of the configuration is also affected by the existing situation, whether the customer is getting a new UPS system or is upgrading or changing an existing setup.

In the table below are listed some of the pros and cons that can be considered when evaluating the right setup for a parallel UPS system.

Table 2 Pros and cons of the two paralleling UPS system configurations.

<table>
<thead>
<tr>
<th>Central Bypass Paralleling</th>
<th>Disadvantages</th>
</tr>
</thead>
<tbody>
<tr>
<td>• User controls the system from a central point.</td>
<td>• Dependence on a single static switch.</td>
</tr>
<tr>
<td>• Installation is not impacted by cable impedance or length.</td>
<td>• Dependence on a single bypass breaker.</td>
</tr>
<tr>
<td>• Less mechanical components and switching devices.</td>
<td>• Dependence on a single motor operator if a single static switch is momentary.</td>
</tr>
<tr>
<td>• Maintenance Bypass may be integrated into the System Bypass Module (SBM).</td>
<td>• SBM unit adds cost and footprint.</td>
</tr>
<tr>
<td></td>
<td>• Maintenance and service costs are slightly higher.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Distributed Bypass Paralleling</th>
<th>Disadvantages</th>
</tr>
</thead>
<tbody>
<tr>
<td>• No need for SBM: savings in footprint and up-front cost.</td>
<td>• Multiple static switches must operate in unison. For example, all of them must turn on and off at the same instant.</td>
</tr>
<tr>
<td>• No dependence on a single static switch or bypass breaker.</td>
<td>• Installation must include consideration of the bypass wiring impedance (+/- 10%).</td>
</tr>
<tr>
<td>• Tie cabinet doesn’t contain any intelligence: it is simple, reliable, and vendor-independent.</td>
<td>• All UPSs must be identical. Not possible to parallel units with mismatched ratings.</td>
</tr>
<tr>
<td>• Better scalability.</td>
<td></td>
</tr>
</tbody>
</table>

When comparing the cost of the systems, the distributed bypass system will be less expensive since SBM unit is not needed. The cost difference is greatest with the smallest parallel systems. However, as the size of the parallel system increases, the difference in overall system cost, including the switchgear and installation, decreases.

Eaton solutions use unique Powerware Hot Sync paralleling technology in both distributed and centralized parallel systems. Most paralleling technologies on the market can meet the needs for synchronization, load-sharing and selective tripping by requiring control wiring and load share signals between UPSs and the bypass cabinet. A failure in the communication will result in the parallel system transferring to bypass, which is exactly what customers want to avoid when purchasing a parallel redundant UPS.

With Eaton’s patented Powerware Hot Sync paralleling technology, the above-mentioned problems are eliminated. Hot Sync technology is based on a load share algorithm that accomplishes the synchronization and load sharing of multiple parallel UPSs independently of any communication between the UPS units. In fact, using the Hot Sync load share algorithm, each inverter in the UPS system is able to regulate its own output and to load share independently based in its own output measurement data.

Both systems can use Eaton’s Energy Advanced Architecture (EAA) to save energy and therefore the operating costs of the IT system. The two complementary proprietary technologies, Variable Module Management System (VMMS) and Energy Saver System (ESS), maximize UPS efficiency and significantly reduce the energy consumption and environmental impact.
Concluding thoughts

Organizations obtain parallel UPS systems to prevent the loss of valuable electronic information, minimize equipment downtime, and minimize the adverse effect of power outages on production equipment. Already in the 1970s, extensive UPS installations were made in various military, industrial, commercial, government and healthcare facilities.

In modern systems, the requirement for no single point of failure is essential. Using Eaton’s Hot Sync technology, each UPS module operates independently without an external master controller or inter-module control wiring. When choosing Eaton’s parallel UPS system, you can be sure that your critical load is protected by the most reliable system on the market.

Whether distributed or centralized bypass system is optimal for each installation is dependent on the entire solution, and needs to be considered specifically for each UPS project. In fact, both paralleling methods have their pros and cons, but most importantly both are solutions that guarantee reliable protection for critical loads. Enhancing the reliability of the UPS system, and therefore the availability of the datacenter itself, has two main reasons: the UPS system redundancy and the ability to perform concurrent maintenance on any UPS or SBM while the system continues to provide conditioned, battery-backed power.

About Eaton

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The staff at Eaton is committed to creating and maintaining powerful customer relationships built on a foundation of excellence. Decades of experience in paralleling large UPS systems are incorporated in the reliable product offering and customer-based tailoring.

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Learn more about Eaton’s offering towards data centers at www.eaton.eu/datacenters.