Increased power protection with parallel UPS configurations

Making the selection between Centralized Bypass and Distributed 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 Centralized Bypass systems and Distributed Bypass systems to help you determine the suitable solution for your organization.

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The need for parallel UPS systems

Uninterruptible Power Systems (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, you would have at least one more UPS module 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: The Distributed Bypass system, with each UPS module having its own static switch.](image)

In the parallel redundant system, the electrical failure of any UPS 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 Centralized Bypass and Distributed Bypass systems

There are typically two different types of multimodule UPS systems: Centralized Bypass systems and Distributed Bypass systems.

In the Centralized Bypass system, there is one large common static switch (also known as System Bypass Module or SBM) for the whole UPS system, rated according to the size of the known final size of the system. If the UPS system needs to transfer to bypass, the load current is then fed through the System Bypass Module.

![Centralized Parallel Bypass System Diagram]

*Figure 2: The Centralized Parallel Bypass system (also known as SBM), with a common static switch for all UPS modules.*

In the Distributed Bypass system, each UPS module has its own internal static switch, rated according to the UPS size, just like in a single UPS. 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.
Figure 3: The Distributed Bypass system, with each UPS module having its own static switch.

The output of the system is normally supplied by Uninterruptible Power Modules (UPMs) contained in each UPS. Multiple UPMs are connected with their outputs in parallel (tied together) to provide a load level greater than the rating of one UPM, for redundancy, or both. The paralleled UPMs supply the output load with protected power as long as the load does not exceed the combined rating of the paralleled UPMs.

The power system is redundant as long as one of the UPMs can be disconnected from the output bus and the remaining UPMs can continue to supply power to the load without exceeding their ratings. When the load is being supplied by the UPMs, the system output bus is continuously monitored for an overvoltage or undervoltage condition. If an out of limits condition is detected, the paralleled UPSs transfer the load to bypass using the UPS static switches.

What are the effects on reliability - or are there any?

A MTBF (Mean Time Between Failures) ratio is often used to describe system reliability that is a key component in any organization’s IT systems. Reliability is a common concern towards the Distributed Bypass systems since a higher number of components results in a lower MTBF, thus lower reliability. MTBF alone does not necessarily serve the purpose for complex systems. 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. When considering UPS system availability, equally important are MTTR (Mean Time To Repair), concurrent maintenance capabilities and so on, although those are not discussed in this document.
When comparing a Centralized Bypass with a Distributed Bypass, one has to differentiate between two failure types; the static switch fails to open-circuit and cannot operate when it should, or it is short-circuited and remains conducting when it should be off. Let’s look at what happens in these cases to get the real picture.

- 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 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.

  If the system is fully loaded and not redundant, there is no difference to the Centralized Bypass system except a somewhat higher component count.

- In a less common problem case, the static switch is shorted. In a typical system with a shorted static switch, the faulty bypass line connects the system output to the incoming mains. As a result of this, the inverters need to shut down eventually and the whole system is on bypass. With the higher component count, this is a likely scenario.

  However, if the UPS system is properly designed and has a backfeed protection together with reliable shorted static switch detection, the backfeed protection device can be opened under this fault condition and the inverters can remain on-line to support the load.

  In a redundant Distributed Bypass system, each UPS can detect a shorted static switch independently and isolate it, thus leaving enough bypass capacity for the system to support the load if needed. Therefore, the effect of a higher component count has a minimal impact on the overall system reliability in practice.

How about operating multiple static switches simultaneously under fault conditions?

Another common concern is that a Distributed Bypass system cannot perform simultaneous switching of the static switches under fault conditions, and the switches may become unusable. 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 operates during fault situations, let’s look at two cases: a normal transfer to bypass and Emergency 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, via an external signal or due to certain faults 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 modules makes the decision to transfer and energizes its own static switch.

  At the same time, it transmits the transfer request for other units over the communication line. Other units receive this request and transfer as well. Processing the data to be sent over and received causes 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.

- 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 are not small and/or 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 and share the current among them.

In the Distributed Bypass system, each UPS will individually monitor its own output (the same as the system output), and transfer to bypass if 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 and are 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 one can understand from above, both bypass configurations are equally reliable when different fault scenarios within and outside the UPS system have been taken 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 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 Centralized and Distributed Bypass systems comes from the static bypass switch configuration for the UPS System.

- In the Centralized Bypass system (or in the SBM), the static bypass switch is rated to support the whole UPS system load, either momentarily or continuously.
- In the Distributed Bypass system, each UPS unit has its own UPS rated bypass switch and those are connected in parallel.

This different configuration will have effect to input and output switchgear configuration:

- 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 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. For more information, see Figure 2 above.
- 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 UPSs with parallel static switches.

As the Maintenance Bypass Switch (MBS) needs to be dimensioned for full system power, there is no difference on system design in this respect. The MBS will be part of the input and output switchgear.

Breakers for UPS units on input and output switchgears will be the same in both configurations, if UPS or Input Output Module (IOM)-UPS ratings are the same. In this case, UPS means the UPS unit used for a Distributed Bypass system including a static switch, and IOM-UPS means UPS unit used for a Centralized Bypass system without a static switch.
Typically, a single UPS or Distributed Bypass system has separate feeders for the rectifier and static switch of the UPS (for more information, see Figure 3). In a redundant Distributed Bypass system, anyhow, a common feeder for rectifier and static switch may be used without compromising the system reliability and to save installation costs.

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

When using a Distributed Bypass system, there is a need to consider that each UPS unit cabling or busbar connected from the input switchgear to the UPS static bypass and from the UPS output to the output switchgear must have equal length and impedances. This is needed to have an 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 more static switches.

The following illustration shows the basic principle of the wiring.

*Figure 4: Overview of the required parallel wiring principle and wiring length.*

Required parallel system wiring length must be equal to ensure approximately equal current sharing when in bypass mode. For a proper operation, the following must be true:

1A = 2A = 3A = 4A
1B = 2B = 3B = 4B

In order to save cabling costs, the following is also considered to be sufficient:

1A+1B=2A+2B=3A+3B=4A+4B

Any difference in wire length will result in decreased capacity of the UPS system while on bypass. For example, a 10% difference between the longest and the shortest wire lengths will result in a decrease in bypass capacity of 10%. This may disable transfer to inverter.
This is the main reason why distributed parallel systems are not an optimal choice to use up to 100% capacity, but for N+1 redundancy or up to 90% (as specified in Tier III classification). The Centralized Bypass system is more tolerant for cabling impedances between UPSs.

Distributed Bypass system will give more flexibility for system dimensioning as it could be expanded by similar rating UPSs in parallel to add redundancy or capacity. With Centralized Bypass (SBM) system, power rating is limited to SBM module rating, but it will allow using different IOM-UPS ratings in parallel.

**Centralized or Distributed? Choosing the parallel UPS system**

Large organizations need tailored configurations that meet the needs set 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 upgrading or changing from an existing setup.

In the table below, we have listed some of the pros and cons you can consider 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>
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</tr>
</thead>
<tbody>
<tr>
<td><strong>Advantages</strong></td>
<td><strong>Disadvantages</strong></td>
</tr>
<tr>
<td>• User controls the system from a central point.</td>
<td>• Dependence on the single static switch.</td>
</tr>
<tr>
<td>• Installation is not impacted by cable impedance/length.</td>
<td>• SBM adds cost and footprint.</td>
</tr>
<tr>
<td>• Less mechanical components and switching devices.</td>
<td>• Maintenance/service costs are slightly higher than with the Distributed Bypass system.</td>
</tr>
<tr>
<td>• Maintenance Bypass may be integrated into the System Bypass Module (SBM).</td>
<td>• Dependence on the single bypass breaker and motor operator if a single static switch is momentary.</td>
</tr>
</tbody>
</table>

<table>
<thead>
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<th>Distributed Bypass Paralleling</th>
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</thead>
<tbody>
<tr>
<td><strong>Advantages</strong></td>
<td><strong>Disadvantages</strong></td>
</tr>
<tr>
<td>• No need for System Bypass Module: saves footprint and up-front cost.</td>
<td>• Multiple static switches must operate in unison. For example, all of them must turn on at the same instant, and all of them must turn off at the same instant.</td>
</tr>
<tr>
<td>• No dependence on a single static switch and/or a bypass breaker.</td>
<td>• Installation must include consideration of the bypass wiring impedance (+/- 10%).</td>
</tr>
<tr>
<td>• Tie cabinet contains no intelligence: it is simple, reliable, and vendor-independent.</td>
<td>• All ISBMs (therefore systems) must be identical. No paralleling of mismatched units can be made.</td>
</tr>
<tr>
<td>• Better scalability.</td>
<td></td>
</tr>
</tbody>
</table>

When it comes to the cost of the systems, when comparing simple 2-module Distributed and Centralized systems, the Distributed system will be less expensive. However, as the paralleled UPM system size increases, the difference in overall UPS system cost, including the switchgear and installation, gets closer to each other.

In Eaton’s solution, the HotSync® paralleling technology is shared by both systems. Whereas most parallel technologies on the market can meet the needs for synchronization, load-sharing and selective tripping, a great deal of control wiring is usually required between modules and sometimes between modules and the bypass cabinet. In essence, the failure of any of these “loops” will result in the parallel system transferring to bypass, and this is exactly the result that customers are attempting to avoid with
their purchase of a parallel redundant UPS. With Eaton’s HotSync® paralleling technology, the above-mentioned problems are eliminated.

An architecture based on a HotSync® load share algorithm provides connectivity and operational mode control, and accomplishes multiple UPS synchronization and load sharing without dependence inter-module wiring networks. The Distributed Bypass system consists of two to six UPS units each with a Controller Area Network (CAN) card (for paralleling the UPSs), and a customer-supplied tie cabinet or load distribution panel to act as a tie point. A peer-to-peer architecture operates the parallel system without the need for a master load share or master synchronization controls, since each inverter using the HotSync load share algorithm is capable of regulating its own output and to load share independently based on its own measurements.

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 energy consumption and environmental impact.

Concluding thoughts
Organizations go for 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, defense, industrial, commercial, government and healthcare facilities.

In modern systems, there is no single point of failure. Using a peer-to-peer architecture, each UPS module operates independently without an external master controller or inter-module control wiring. Both Centralized Bypass (SBM) and Distributed Bypass systems have the benefit of enhancing the reliability of power, and therefore the availability of the datacenter itself. This occurs in two ways: (1) UPS system redundancy, and (2) the ability to perform concurrent maintenance on any UPS or SBM while the total system continues to provide conditioned, battery-backed power.

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. During UPS system design, the two most important words the engineers will ask are: “What if…” to eliminate any single point of failure. Contrary to the common belief about Distributed Bypass systems, Eaton’s solution is able to offer the same standard of reliability as the Centralized Bypass system since the UPS design is done properly and various fault conditions are duly considered.

About Eaton
Eaton Corporation is a diversified power management company with 2010 sales of $13.7 billion. Celebrating its 100th anniversary in 2011, Eaton is a global technology leader in electrical components and systems for power quality, distribution and control; hydraulics components, systems and services for industrial and mobile equipment; aerospace fuel, hydraulics and pneumatic systems for commercial and military use; and truck and automotive drivetrain and powertrain systems for performance, fuel economy and safety. Eaton has approximately 70,000 employees and sells products to customers in more than 150 countries. For more information, visit www.eaton.com.

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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.

**Downloads on demand**

Download Eaton white papers to learn more about technology topics or explain them to customers and contacts. HotSync®, maintenance bypass, paralleling, UPS topologies, energy management and more are demystified in free white papers from our online library: [http://www.eaton.com/pq/whitepapers](http://www.eaton.com/pq/whitepapers).

Read more about the System Bypass Module (SBM) from *Eaton 9395 SBM datasheet*, available in [http://www.eaton.com/powerquality](http://www.eaton.com/powerquality).