# DISTRIBUTED AND CENTRALIZED BYPASS ARCHITECTURES COMPARED

## Contents

## Executive Summary


When designing a power protection scheme for data centers, IT and facility managers must ask themselves whether a distributed or centralized backup strategy makes more sense. Unfortunately, there is no easy answer to that question. Companies must weigh each architectural advantages and disadvantages against their financial constraints, availability needs and management capabilities before deciding which one to employ.

This white paper explores the principle of centralized versus distributed bypass and will apply it equally to standalone monolithic and integrated-modular UPS architectures, especially trying to clarify the differences in two major areas:

- Reliability (in terms of comparative Mean Time Between Failure "MTBF") and hence availability
- Fault clearing capacity and short-circuit withstand rating

By following the suggestions in this white paper, data center operators can simplify their decision-making process by receiving an overview of weaknesses and capabilities of both system designs, whichever strategy they ultimately select.


### Distributed / Centralized System Description

In a distributed bypass architecture, each UPS module has its own internal static switch (Fig. 1), rated according to UPS size, and each UPS monitors its own output. 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. Here below a single line diagram is shown for clarity. On the contrary, in a centralized bypass system (Fig. 2), there is one large common static switch for the entire UPS system, 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 common static switch. Here below a single line diagram for a distributed parallel architecture is shown. The centralized bypass is an alternative to the distributed bypass.

Technically, the two solutions fulfill the same purpose (to guarantee power continuity for example) but have different architectures. Whilst it is true that distributed bypass solutions are the most common because of their flexibility of use and low initial cost, it is also true that, in the medium/large data center market, centralized bypass solutions could be preferable in terms of reliability, performance, footprint and sometimes cost; even more so in the case of large installations where the number and type of protections as well as system wiring have a big impact. It is therefore important to respond to the various requirements with flexible solutions, which are able to adapt to the growing demands of the market in terms of availability, capacity and performance requirements.

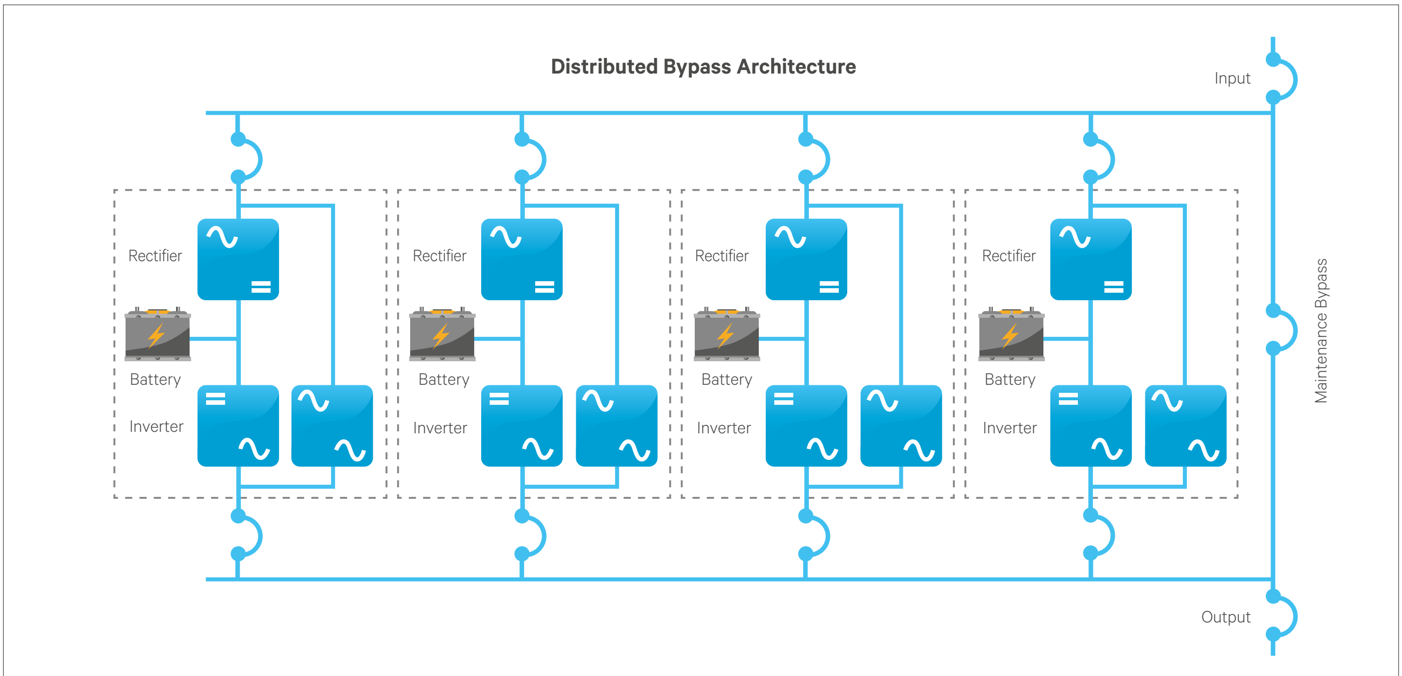



***Figure 1:*** Example of a distributed bypass architecture design.

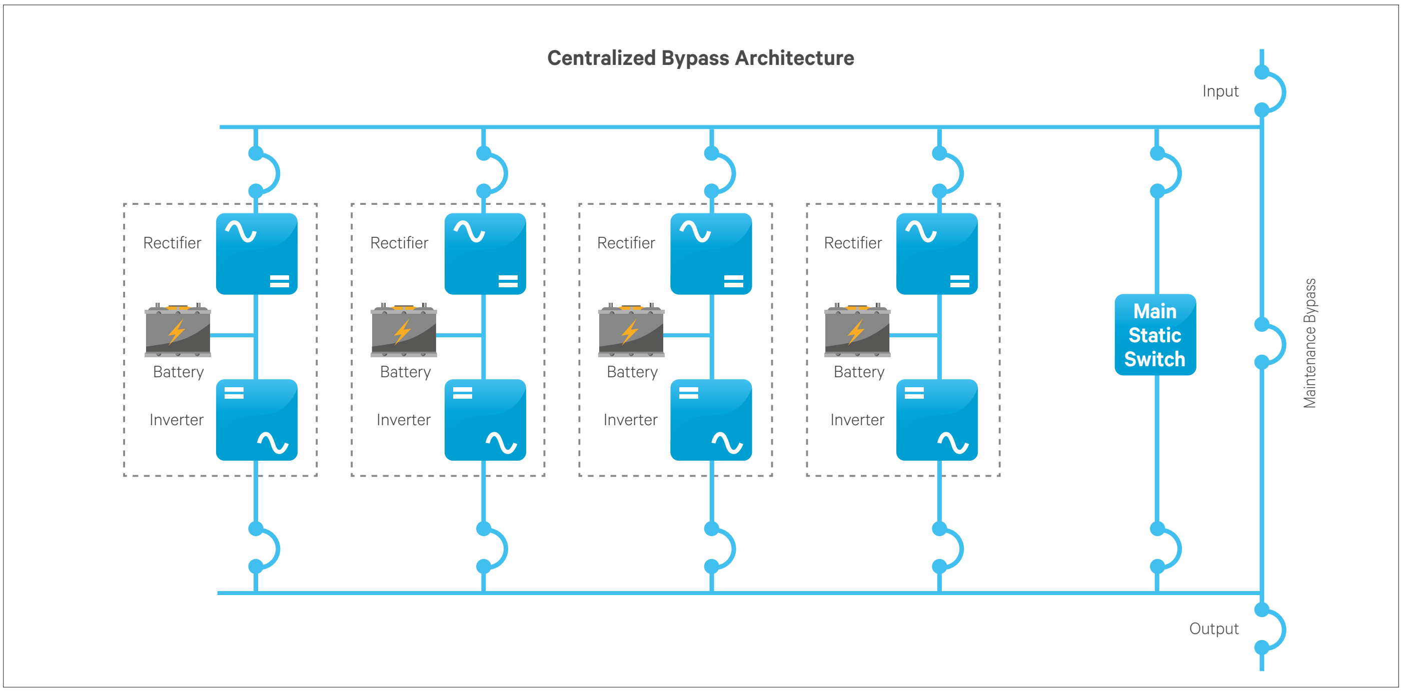



***Figure 2:*** Example of a centralized bypass architecture design.

## Centralized or Distributed?

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

In Table 1 below, some of the major points which need to be considered when evaluating the right setup for a parallel UPS system are listed.

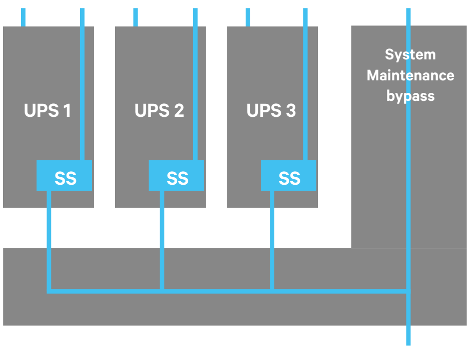
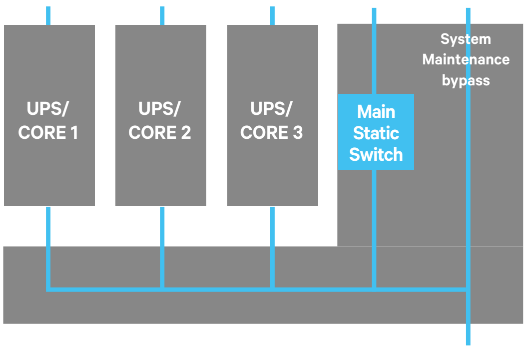
| Distributed bypass | Centralized bypass |
|---|---|
|   |   |
| System scalability – fuzzy growth plans | Robust design / higher fault clearing capacity |
| Lower up-front cost | System scalability – clear growth plans |
| Typically smaller footprint | Higher system reliability for large system installations |
| Easier installation and deployment (simple switchgear) | Higher up-front cost |
| More complex system management (no single point of control) | Typically larger footprint |
| Typically applied for small/medium business space (power module up to 200 kVA) | More complex installation and deployment (possibility to integrate MSS into switchgear) |
| | Possibility to monitor and control the system from a central point |
| | Typically used for large enterprise space (multiple power module above 200 kVA) |

***Table 1:*** *Considerations about distributed and centralized parallel system configurations.*

Here below some of the major arguments of the above comparison which need to be cited separately:

- **Invest-as-you-Grow** (minimized capital expenditure) – the restriction being that in a centralized bypass architecture the static switch (rated for the maximum load) had to be purchased 'up-front' even if the load was forecast to grow over time; while distributed bypass architectures help save on Capex by adding UPS incrementally each time the load increases, instead of making large upfront investments in centralized configurations with more capacity than they initially need. However, the customer will still need to install the full supporting upstream infrastructure regardless of the planned load growth.
- **Single-point-of-failure** (SPoF) – the idea being that you may have a centralized system, which may have N+1 modular redundancy but only a single N rated single static-switch, compared to a distributed system which has N+1 bypass redundancy as well as UPS module redundancy.

## 1. Focus on Reliability

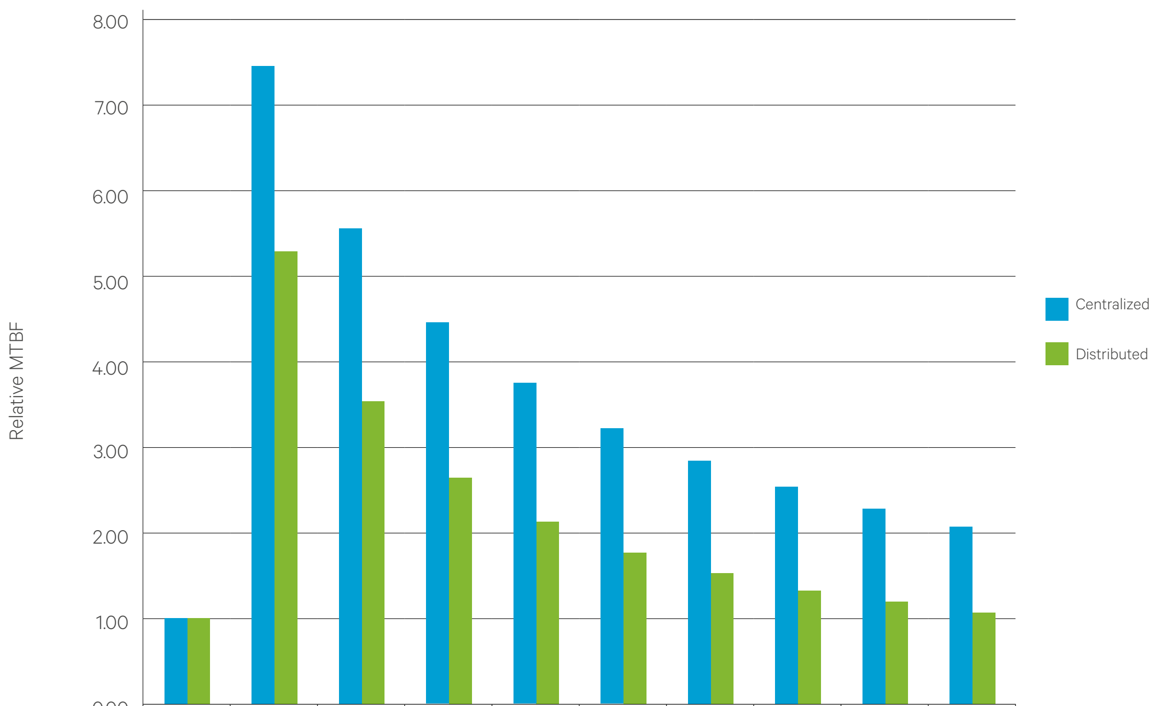
Typically many manufacturers of critical power equipment, such as UPS, publish 'reliability' data for their products in the form of an MTBF. Allied with an estimate of the Mean Down Time (MDT) or Mean Time To Repair (MTTR), which should include an element of 'travel time' and 'spares logistics' which both reflect the anticipated reaction time of the service organization to respond to a site emergency, a simple calculation can produce the commonly used metric of 'reliability' – that of availability.

Only a small number of manufacturers produce MTBF data from actual field measurements and, when they do, the absolute number is based on cumulative field service hours run compared to the number of failures of the output bus voltage. Taking the cumulative hours run, rather than the hours run between failures on an individual single module/system, can give a distorted view of an individual system MTBF as it shares multiple failures over a diverse group of individually isolated systems.

### 1.1 So, Does This Mean That Such MTBF Calculations Are of No Use?

Not necessarily: if used with care and when the input data is based on the same set of underlying assumptions, the concept of 'comparative' system reliability is useful.

The results should be used in comparison and should not be used to state or infer absolute MTBFs. In other words, a system 'A' which has a calculated MTBF of 5,000,000




| | N | 1+1 | 2+1 | 3+1 | 4+1 | 5+1 | 6+1 | 7+1 | 8+1 | 9+1 |
|---|---|---|---|---|---|---|---|---|---|---|
| Centralized | 1.00 | 7.46 | 5.68 | 4.59 | 3.85 | 3.31 | 2.91 | 2.59 | 2.34 | 2.13 |
| Distributed | 1.00 | 5.44 | 3.62 | 2.72 | 2.17 | 1.81 | 1.55 | 1.36 | 1.21 | 1.09 |

Modular Redundancy

***Figure 3:*** *Relative MTBF for centralized and distributed bypass architecture.*

hours can be regarded as twice as likely to fail (at any time) compared to a system 'B' of MTBF 10,000,000 hours – whilst we should ignore the 'lower' absolute number of 5,000,000 hours (571 years) which may appear to be more than 'sufficient' for the application.

On the power output side, each machine would be connected to the output switchboard through isolators to a common busbar. It is possible (and therefore has to be taken into account) that a failure in one UPS module (for example a short circuit at the output) could adversely affect the remaining module(s) – negating the 'independence' of their combined reliability.

In the case of a distributed bypass, each module has an internal automatic bypass which avoids the need to have a common centralized bypass.

Even if the centralized bypass architecture might be seen as a common point of failure, it's indeed the preferable solution for large system installations since a distributed bypass design would produce one common point of failure in every module resulting in multiple SPoFs.

For example, if we consider large system installations, the positive impact is higher with a fewer number of modules in parallel, as can be seen in Fig. 3.

For large multi-module systems, a centralized bypass architecture is preferable because it is considered most reliable, thus, the only conclusion that can be reached is that, despite the apparent attractiveness of multi-module redundancy of bypasses for large system installations, the reliability aspect is in favor of a single centralized bypass.

## 2. Focus on Withstand Rating (Short-Circuit Capacity) of The Bypass

When a short-circuit occurs downstream the UPS, (in a section of the load itself or in a part of the fixed distribution wiring) the voltage collapses to near zero and the source current rises and flows to the fault. The rate of rise and peak value of the fault current depends upon the sub-transient reactance (output or 'forward transfer' impedance) of the source. The reaction of the UPS to the collapse in voltage is to transfer the output bus to the bypass so as to utilize the short-circuit clearing capacity of the grid transformer and clear the fault (by opening the appropriate circuit breaker or blowing the closest fuse to the faulty branch circuit) within the typical hold-up time required by the rest of the (healthy) load (e.g. 10 - 20 ms).

There is an important precaution that has to be taken into account in the distributed bypass design (Fig. 4), as the slightest difference in impedance of each parallel path will cause any short-circuit current to flow in a highly unbalanced fashion and will usually cause overload damage and cascade failure.

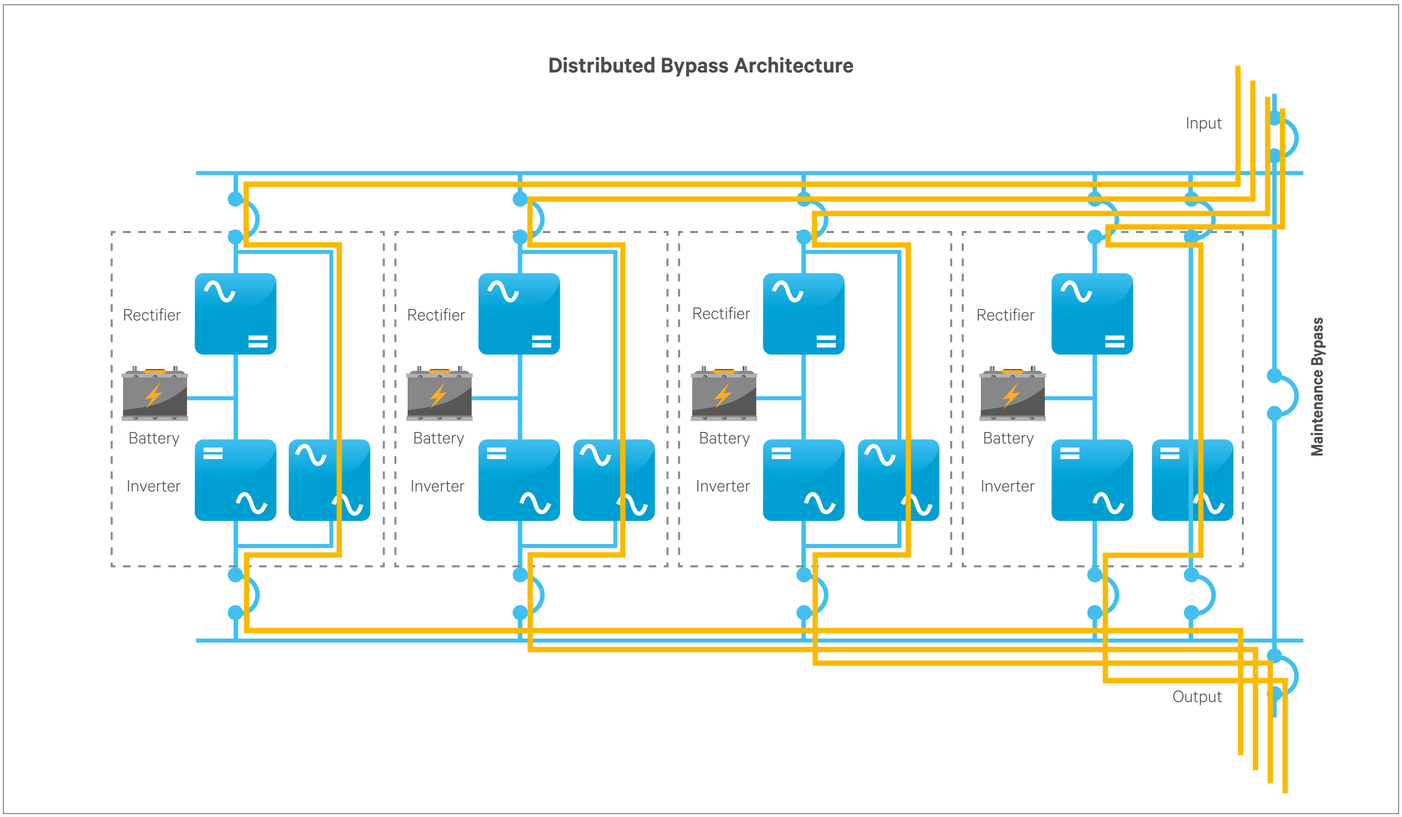



***Figure 4:*** Example of the current path over a distributed bypass architecture design.

Ensuring that the cable lengths are closely matched will largely mitigate the problem but systems with long cable run differences between modules must be carefully treated. Once the path impedance is matched, we have a situation where the withstand rating of the individual bypass static switches will each take a share of the transformer sub-transient current. In fact, as UPS bypass static switches are in N+1 redundant array, then they will, in theory at least, have a higher withstand than the alternative central bypass.

**3. Vertiv™ Distributed and Centralized Designs**

When choosing Vertiv UPS systems the user may select between different UPS architectures (monolithic or modular scalable) all compatible with both bypass system designs (centralized or distributed).

Considering T-free modular UPS architectures:

- Liebert® Trinergy™ Cube up to 3 MW in a single unit offers a centralized bypass solution up to 5000 A rating as standard with the centralized bypass located in the I/O box.

| | Liebert Trinergy Cube |
|---|---|
| Distributed static bypass | ✘ |
| Centralized static bypass | ✔ |

Considering T-free monolithic UPS architectures:

- Liebert® EXL S1 up to 1200 kW in a single unit offers asstandard a distributed bypass solution with the bypass static switch fitted in each single unit. There is also the possibility to configure the system for a centralized bypass architecture, enabling the UPS with inhibited bypass to be connected in parallel with an external central piece of equipment up to 5000 A rating (MSS) to address higher availability or short-circuit withstand capacity requirements.

| | Liebert EXL S1 |
|---|---|
| Distributed parallel | ✔ |
| Centralized parallel | ✔ |

**Conclusion**

Going for a distributed or centralized backup strategy is a decision that IT and Facility Managers must take when designing a power protection scheme for their data center. However, there is no single answer to that question as architecture advantages and disadvantages together with financial constraints or management capabilities must be taken into consideration and evaluated by companies before deciding which way to go. The answer to the five simple questions below might help taking the right decision:

- What are the scalability plans expected in the near future?
- Which strategy makes better financial sense?
- Which bypass architecture will better meet my availability requirements?
- What are the impacts on system reliability?
- Which is the most fault tolerant solution for my data center?

Where large multi-module arrays are planned in high power UPS systems, the provision of a centralized bypass is preferable to a distributed architecture for both maximizing the system MTBF and safeguarding the operation during short-circuit withstand scenarios. This is particularly specific to modular UPS systems where partial load is expected and modules are switched off to match the UPS capacity to the load.

Choosing Vertiv UPS systems, IT and Facility Managers can find all the answers to the above questions by selecting the backup strategy which makes more sense for each specific scenario, in order to ensure that the critical load is always protected by the most reliable solution without compromises in terms of availability, capacity and efficiency.

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