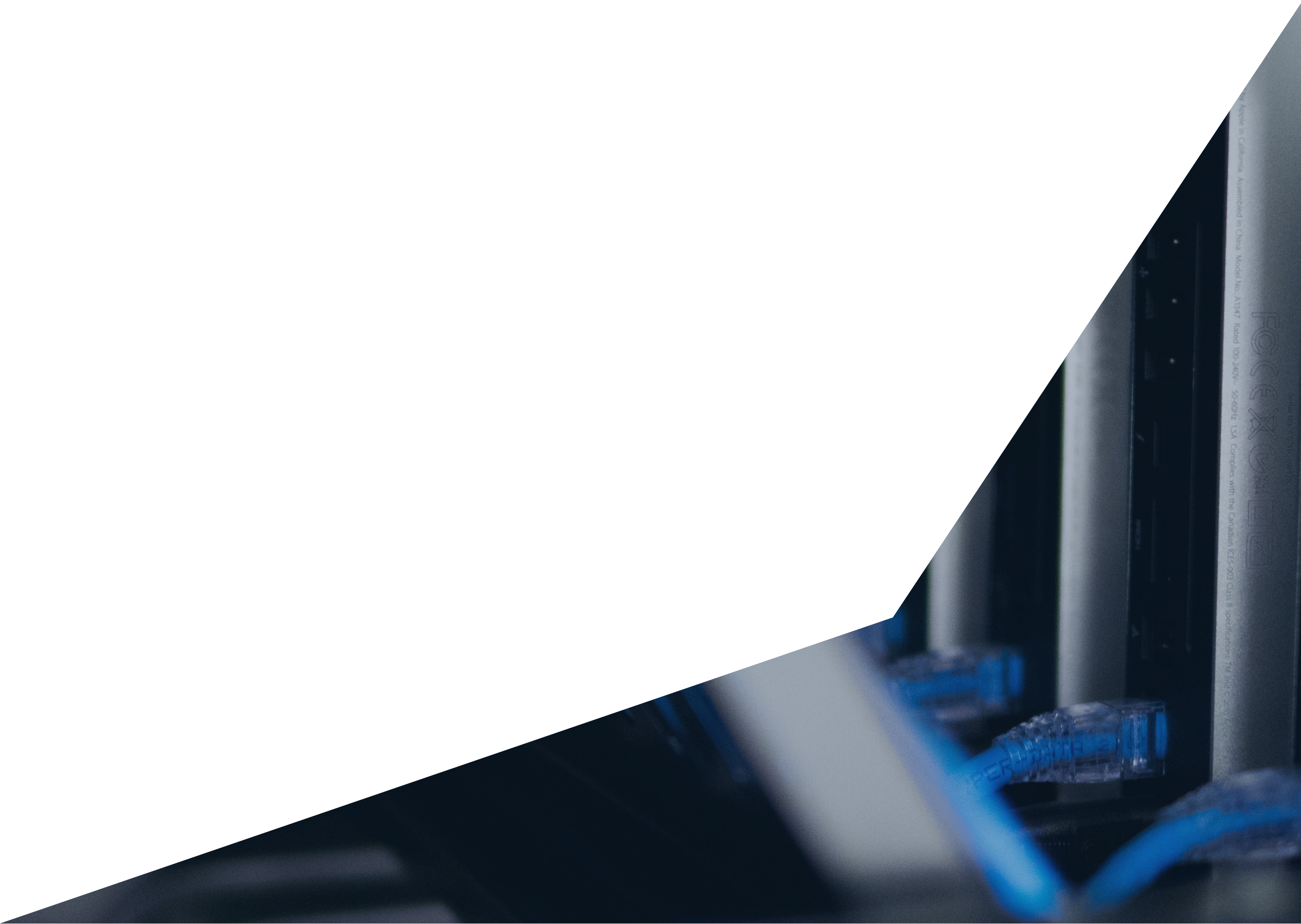
UPS DESIGN CONFIGURATIONS

WHITEPAPER



Uninterruptible Power Supplies (UPS) are installed for mitigating risks to critical infrastructure and to protect business continuity during a power outage. A system's reliability is largely dependent on its configuration, in order to reach a high level of reliability it is necessary to reduce the number of single points of failure, preferably to zero. Over the years UPS designers have come up with ways to harness maximum power capacity within a finite space. This is often achieved by scaling the number of UPS systems in a configuration to cope with the; load requirement, budget, existing infrastructure and risk tolerance.

Although there is a spectrum of design configurations, there are five principle UPS arrangements often referred to as; 'Capacity' (N), 'Isolated Redundant', 'Parallel Redundant' (N+1), 'Distributed Redundant' (N+N) and 'System plus System' (2N) or (2N+1). Making it difficult to identify where some configurations lie within the spectrum, manufacturers and designers worldwide have often given alternative names to configurations which may include; "power parallel", "A+B", "hot standby", "standalone", "catcher systems" and "hot sync" to name a few.

This whitepaper explores each configuration behind the five principal UPS arrangements, explaining the suitable applications and advantages and limitations of each.

WHAT DOES 'N' STAND FOR?

N' is used within the configuration formula to represent the amount of output power needed to support a critical load. For example, if the critical load requirement was 400kW then N must represent a 400kW uninterruptible power supply capacity.

LOAD AND CAPACITY

With more than one type of load and a number of ways to describe capacity, more often than not there are differing opinions of what 'N' should be.

Load Variations

- Average load
- Peak load
- Full load
- Continuous load
- Day 1 load vs future load

Capacity Definitions

- Planned capacity
- Installed capacity
- Available capacity
- Future capacity
- Seasonal capacity

With the above variations, when discussing load and capacity there is usually a disconnect between what is trying to be communicated and what is understood. As the cost of N+1 increases with an enlarged capacity and the cost of 2N multiplies, it is important to fully understand what is meant by each term.

WHAT IS "REDUNDANCY?"

Redundancy is a term often used to describe the state of being no longer needed or useful. However, when used in the context of UPS and critical power backup, redundancy refers to the duplication of critical components or systems, with the intention of increasing reliability as a whole to support business continuity.

CAPACITY "N"

A capacity or 'N' system is the most common type of UPS installation and the minimum requirement to provide power protection to the critical load. Also referred to as 'power parallel', It comprises a single standalone UPS module or a paralleled set of modules with a matched capacity to the critical load projection. One small single phase UPS system in a home office is an 'N' configuration. Likewise, two 400kW UPS units in parallel supporting an 800kW load would also be 'N'. This is because as with having one UPS system to support the total load, two UPS systems with a maximum capacity of half the load, running in parallel provides the same critical load capacity. 'N' is, therefore, the amount of capacity required to support a given load, hence the name 'capacity' is given for a standalone UPS configuration. This can simply be illustrated by saying if five UPS systems were installed and all five were being relied upon to support the critical load then this would be described as 'N' due to there being no redundancy in the configuration.

With no redundancy, 'N' UPS configurations put the critical load at risk whenever maintenance is carried out. Alleviating such risks, an external maintenance bypass, connected directly to the UPS output panel, may be considered to allow safe shutdown of the UPS system for maintenance. An 'N' configuration is often used for small home offices or a small bank of computers in situations where the business is not particularly concerned about the overall stability of the buildings electrical infrastructure.

Limitations

- Numerous single points of failure.
- No system redundancy means the load is not protected in the event of a UPS failure.

ISOLATED REDUNDANT

May also be referred to as an 'N+1' system; however, it is significantly different from a parallel redundant 'N+1' configuration due to the load not being equally shared. In this configuration there is a 'master' or 'primary' UPS system which carries 100% of the critical load, the 'slave' or isolation system, therefore, carries the redundancy and is completely unloaded. In this instance the systems do not have to be of the same capacity, type, or from the same manufacturer and a separate input for the static bypass circuit is required for the primary UPS.

In the event of a power failure or for maintenance purposes, the load is transferred from the primary UPS system to the static bypass and the isolation system accepts the full load. This configuration allows a UPS system to be added to a current 'N' configuration and achieve a level of redundancy for a previously non-redundant configuration. Although this configuration is more reliable than 'N', the component life of the primary unit will be short in comparison to that of the isolation unit, and thus the mean time between failures (MTBF) of the whole system is reduced.

An alternative way of achieving an isolated redundant, or N+1, configuration is by using a static transfer switch (STS) to allow an instantaneous transfer of power sources. Power Control has previously achieved an N+1 configuration by installing a 2MW 'power parallel' (N) comprised of four 400kVA units into five data rooms using this as the primary source and a maintenance set of four 500kVA units supplying the B side of the static switches for all the data rooms. This provides N+1 for each data room but means only one set of UPS can be lost before losing any redundancy.

Advantages

- A mix of UPS manufacturers and models can be used in the same system.
- UPS units can be added to an 'N' design prospectively to provide redundancy.
- Cheaper than a parallel redundant configuration.
- Better reliability than a standalone 'N' configuration.

Limitations

- Reduced MTBF for the component life of the primary unit will be shorter than that of the isolated unit.
- If the primary UPS fails, the isolation UPS is subject to the entire load, which up until this point had been idle. This could result in the isolation UPS malfunctioning and result in a loss of power to the load.
- Complex and costly switchgear if isolation UPS systems are required to support multiple primary UPS.
- Higher losses, lower efficiencies and a worse regulation of the output.
- A single load bus per system means there is a single point of failure.
- A higher operating cost as a result of the secondary UPS running at 0% load.

PARALLEL REDUNDANT (N+1)

As it is not advised to consistently run a UPS at over 50% load capacity, a parallel redundant, or 'N+1', configuration consists of one UPS ('N') sharing the critical load evenly with another UPS system ('+1'). Both UPS systems are either part of a common output bus meaning they are synchronised with one another or they have a function embedded within the module itself. The number of UPS systems that can be paralleled into a common bus is often left to the discretion of the UPS manufacturer.

Running off a common parallel bypass switch, in normal operation five of the six parallel switches will be closed. Both output switches from the pair of UPS systems are closed and the load switch (common point after UPS output) is also closed with only the bypass open. In a mains failure, the relevant switches will open supporting the load through the UPS systems.

During maintenance or in the event of a UPS failing, one system can be taken offline while the remaining system is required to immediately support the load of the offline UPS system, temporarily giving that UPS system 100% load.

Although this configuration is more expensive initially than a capacity system, the user should be cognisant to the fact that the total cost of ownership (TCO) and efficiency of the backup are increased.

With the system overload capacity being doubled, the mean time between failures (MTBF) is greatly increased. This is due to each UPS system only being subjected to half the load compared to a capacity configuration.

Another benefit of parallel redundancy configuration is the increased fault clearing capabilities of the system and thereby ensuring that short circuits are cleared twice as effectively without having to transfer to bypass. This avoids unnecessary switching or tripping of supply switchgear. For example, in a two block parallel redundant configuration, single phase fault clearing is increased from 2.5 to 5.6 (approx.) and in three phase fault clearing capability is increased from 2.1 to 4.2 (approx.).

Advantages

- In the event of a UPS failure, the remaining units will automatically resume full load, enabling the damaged unit to be isolated and repaired.
- The paralleling of the inverters increases the fault clearing capability of the system.
- The system overload capacity is doubled.
- Allows for ease of maintenance.
- A parallel system with a common battery allows for cross feed capability.
- Scalable if the power requirements change.
- The design configuration is simple and therefore is cost effective.

Limitations

- UPS systems must be the same model and capacity and from the same manufacturer.
- Higher initial spend compared to an isolated redundant system.
- If the critical load is more than the capacity of one UPS, then the load will be unprotected during maintenance.

DISTRIBUTED REDUNDANT (N+N OR 2N)

Commonly used in large data centres, a distributed redundant configuration or 'N+N' system is similar to a parallel redundant configuration but the UPS units are completely separate with separate input and output feeders and two supplies out. Each UPS is capable of carrying the entire critical load and supports its own independent distribution system with no power connections between each one. Multiple power distribution units (PDUs) are used for distributing the electrical power between the critical load and independent UPS units. All downstream loads can be switched to one of the UPS units allowing the others to be taken offline for maintenance or load reconfiguration.

Also referred to as an 'A+B' configuration, a distributed redundant design is scalable for larger applications and the end user can specify a conventional parallel redundant UPS for each side, 'A' and 'B'. It is similar to a 2N system in the sense that each rack will have two supplies to it but increases the load on each N supply as if a power stream is lost. The load from that UPS is now spread across two or more power streams.

If for example, the load was 1MW, a typical 2N system would require 2MW of UPS capacity and associated infrastructure (switchgear etc.). This could be split into three 500kW UPSs (A+B+C) resulting in the maximum load on each UPS being 66% instead of the classic 50%. Typically, this would have a lower operating cost as the units would be operating higher up the efficiency curve, and as a lower overall KW (-25%) infrastructure is required, the capital cost could be lower too.

With two independent distribution systems the critical load equipment is always available so there is less risk for the electrical independence of the distributed redundant system, ensuring the load fault on one UPS will not propagate to the other. This means that the critical load will still be supported by the unaffected UPS.

Advantages

- Fewer UPS units required than in a 'system plus system' (2N) configuration making it a cheaper option.
- Maintenance to the UPS and corresponding equipment can be carried out without transferring the load to bypass mode.
- Concurrent maintenance of all components can be carried out.

Limitations

- The complex configuration in large data centres makes it challenging to keep all systems evenly loaded.
- The system is reliant upon correct operation of STS equipment, which means there is a single point of failure.
- During normal operation, UPSs run at less than full load leading to UPS efficiencies.

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SYSTEM PLUS SYSTEM CONFIGURATION

'2N', '2(N+1)', '(N+1) + (N+1)' and '2N+2' are all configuration formula variations of a system plus system design. Offering resilience and ensuring availability in the event of a whole system failure, it now becomes possible to create UPS systems that may never require the load to be transferred to the utility power source. Comparably with a distributed redundant configuration, each UPS supports its own independent distribution system without communicating with one another.

With a '2N' system plus system configuration there is two times the capacity required for operation and so it is possible to alleviate all potential single points of failure. Although the standby systems components do not actively participate within the systems normal operation, they are either tested or cycled to ensure they remain functional if/when needed.

This configuration is the most reliable but also the most expensive. It is often used in large multi-megawatt data centres and some collocation centres as it provides complete redundancy between sides 'A' & 'B' making it easier to keep the UPS system evenly loaded. Depending on the engineer or owners vision, the system can either be simple, complex or anything in between.

Advantages

- No single points of failure due to there being two separate power paths.
- In some designs of this type, redundancy still exists.
- Maintenance can be carried out without transferring to load bypass mode.
- Somewhat easier to keep systems evenly loaded than in a distributed redundant configuration.

Limitations

- Most expensive design configuration due to the number of redundant units.

CONCLUSION

There are many variables affecting the availability or uptime of a system, for example; human error, reliability of components, maintenance schedules and recovery time. The impact that each of these variables has on the overall availability is determined by the configuration chosen.

When choosing which design configuration is best suited to the successful operation of a facilities equipment, the advantages and limitations, as well as the suitability of size and scale should be considered. By thoroughly understanding the facilities budget, load requirement and capacity requirement, an informed decision can be made.

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