VERTIV™ UNINTERRUPTIBLE POWER SUPPLIES:

Modular single-phase UPSs in applications requiring maximum availability

Abstract:

Modularity is an attractive concept, but sometimes not clearly defined or used in a generic manner. This paper addresses this modularity concept in the UPS market, especially in the single-phase UPS segment, and describes the advantages it can offer for critical loads at the edge or in distributed scenarios. The list of benefits is long, but especially important are a higher availability, flexibility for growth, lower TCO and more stable efficiency with each load change. These power protection benefits can be easily translated for the end user of the application with minimal data loss, better business continuity and easier disaster recovery in case of failure. These benefits are explained in several application cases described in the last section.

Introduction to modular UPSs

Modularity is a term frequently used in the industry but more recently in data center and UPS sectors. Basically, it refers to the capability to extend or growth power capacity, but when analysed in detail, it brings many points with it.

Up to now, traditional data centers were operated with UPS setup in parallel to increase capacity or obtain "N+1" redundancy. This has been the "monolithic" approach. However, in recent years, there has been a trend towards using smaller power modules to gradually build a larger UPS system when additional capacity is needed, or to achieve the ability for improved availability by using N+X configurations.

The reason for this change is that power consumption of IT loads is no longer constant and need to have the flexibility to grow, change or evolve as the market changes (as example, a small data center or some branch offices with changing of activities).

Let's start defining a "modular UPS". It can be defined as a group of power modules located in a single frame enclosure and working through a central control system that manages the operation of the entire system. Therefore, it means that a modular UPS should be scalable after installation, meaning the user can add power capacity to free slots or setup one of the power modules for redundant operation, or alternatively replace a failed power module without shutting down the load.

A modular UPS is sometimes confused with a capability for operation in parallel. Here it is important to consider the point about having a single frame enclosure for the entire system and a single controller. In reverse a power module from a modular UPS must be able to work in parallel, but not all monolithic UPSs being able to work in parallel can be considered modular. A modular UPS is not just two or more UPSs running in parallel. Similarly, in the case where a UPS has any type of component or subsystem duplicated, it does not mean that the UPS can be considered as modular.

In the data center industry, there are also many references about pre-fabricated modular systems. They should not be confused with the "modular UPS". These prefabricated modular systems are conceived as containerized solution typically including UPSs, cooling systems, power distributions and racks for IT equipment allocation. In these pre-fabricated modular systems, the ability for rapid deployment is one of the key performance factors, reducing the long process of project scope, planning, design, construction and commissioning of the data center.

Now that we have defined the concept for a modular UPS, we will try to navigate through the advantages that modular UPSs can bring to critical IT loads, especially the smallest ones found in 1ph systems. Even if modularity is used widely in larger 3ph UPS systems, the advantages in terms of flexibility, scalability, efficiency and fault tolerance are fully applicable into smaller UPS, up 20 kVA or 25kVA in the single-phase AC power range.

CASE NOTE: MARKET DRIVERS FOR MODULAR UPSs

- Flexibility and scalability
- Efficiency
- Serviceability & maintenance costs (TCO)
- Availability and fault tolerance

Why a modular UPS - market demands

According to several market researches by specialist companies, the market demands for a modular UPS can be summarized in the following points:

> Flexibility and scalability

> Improved energy efficiency

> Serviceability

> Better availability

Flexibility and scalability: the most evident advantage of a modular UPS system is the capability to adapt the power capacity gradually to the "hungry demands" of the load at that moment. Since a modular UPS is scalable after deployment, the IT manager can increase or decrease the power capacity while the UPS is in operation.

This concept is represented in the next figure. It shows a common frame work for the modular elements and several "bricks" of power or battery modules, so that they can be added or removed according to output power requirement. While we have talked about power modules, the same concept also applies for the battery modules, of course so that the achievable runtime can be also modified. As power in 3ph UPS increases, this capability to change runtimes may be done with battery banks instead of separate battery modules, due to larger capacity requirements.

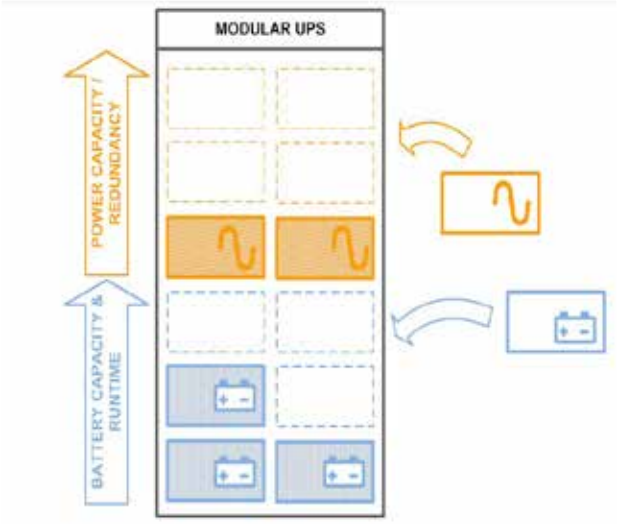

Figure 1: *Modularity on power capacity or runtime.*

This flexibility is very useful in those applications where the load is not defined in the early stage of the load life cycle (for example, when there are plans for continuous and progressive growth in capacity in the data center). Or a second case is when the UPS should reach different capacity levels depending on the location (for example, an international bank with multiple branch offices, that wish to use the same UPS globally and having the flexibility to match or expand the demands to each individual branch office). From an economic point of view, a modular UPS enables the user to "pay as you grow". Figure 2 shows how adding power modules progressively will help to adapt the power requirements to the IT load.

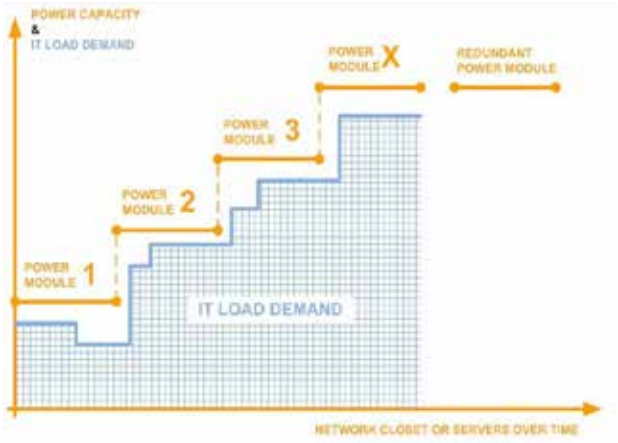

Figure 2: *Scalability and redundancy*

Underestimating the load capacity for future expansion can be a serious issue (complete system shutdown, need to reinstall, etc).

Moreover, the flexibility to grow in both power or runtime with the same UPS frame is a great advantage and increases flexibility. Even if the UPS may be sold as "modular", it may lack the flexibility to increase runtime without adding extra frames, minimizing the gains of a modular solution.

Improved energy efficiency: as with most electronic systems, the design is optimized for a range of operating conditions, so that when moving out of those settings, lower performance and efficiency is obtained.

In the case of UPSs, usually they are designed to achieve the highest efficiency at roughly 70-80% of the nominal load capacity, which are the recommended conditions and allow some margin for power expansion. Working at such load percentage, the UPS achieves its maximum efficiency and is reduced when the operating conditions change (for example, at 40%, 30%, 20% load etc.), while at a smaller load it is lower.

This can be the case if the UPS is designed for total or future power, while in the early stages of the data center, it may operate with a smaller load. Thus the efficiency will be lower and there will be sub-optimum operating conditions, or in a different way, with more energy waste being converted into heat-dissipation. Figure 3 shows this case with the efficiency of a centralized or modular UPS versus the IT load power demands.

Therefore, thanks to its capability to grow in line with power requirements, it can operate in a modular UPS under more efficient conditions than in a non-modular UPS, because its capacity can continuously match the required power at that moment.

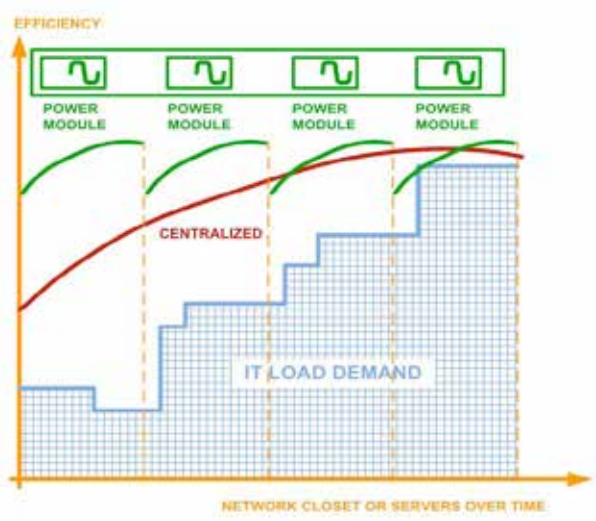

Figure 3: *Efficiency in a modular versus a centralized UPS system*

With a modular UPS, it can match more closely the load requirements as it changes, thus making continuous operation possible in terms of efficiency and heat dissipation.

Since electricity can be a significant part of the operating costs of any IT load (small server rack or network rack), it will lead to lower operating costs through energy savings by operating at higher efficiencies. Just consider the total cost during the lifecycle and consider the improvement on TCO.

Serviceability: the next key feature in a modular UPS is the serviceability. In a monolithic type UPS, in case of a repair or maintenance operation, it is required to change to maintenance bypass, with the risks associated of no backup (unless a more complex tier-level configuration is used). Access to each component must be secured.

However, in a modular UPS the concept is totally different, the sub-system of typically the inverter, rectifier and charger is assembled in a stand-alone "box" or separately handled element. And more importantly, this module is usually hot-swappable (1ph UPS), meaning that it can be inserted or extracted from the frame while the load is still powered from the other power modules. This ability to replace the power module without disruption makes the difference from the service providers point of view, as

- Replacement of the power module is faster than repairing or replacing the individual components
- Lower repairing costs (shorter work time)
- Reduced system downtime

This is linked to an established and qualified service staff on site for such maintenance, despite the fact that in several modular UPSs with smaller ratings, it may be also possible that a user with appropriate training may be willing to replace those modules (or insert a new one to upgrade the power capacity).

Better availability and fault tolerance: Availability is directly related to the previous point about serviceability. Availability is sometimes confused with reliability. This second refers to the probability of a system failure in several operating conditions, thus linked with the internal design, quantity and quality of components, design criteria for the stress levels, etc. It is also referred as MTBF or Mean Time Between Failures. However, for a user responsible of an IT load, it is more important to ensure availability or continuity in the operation of the complete system as required. It is typically measured in terms of "nines", so that for example, a five-9's means less than 5 minutes that the system is not operating

correctly over one year.

More importantly, availability is calculated with a combination of reliability (MTBF or "how good is the product") and repair time (MTTR or "how long takes the repair in case of failure"). Therefore, if we have a product with high reliability, and it is combined with features such as modular hot-swapability, this allows a higher availability of the protected load. This is key when it comes to modular UPS, as they are a step ahead to ensure continuity of the load operation.

Several experts advise that due to the high complexity of modular systems, the actual reliability (MTBF) of such UPS may be not so high. Without entering a deep technical discussion, reliability is not only related to the quantity of devices and complexity, but it also considers the design criteria for components stress, having a redundant design to avoid single failure, or having a centralized automatic or maintenance bypass to keep the critical load powered.

The features highlighted in the previous sections explain the continuous interest in modular UPS, a segment that has grown steadily in the last years, and a wider range of products. This is especially true in the segment of single phase UPSs, where these features of scalability, availability and efficiency are particularly valuable - in applications like small cabinets or server rooms, edge micro data centers, or CCTV control rooms. Finally, the price will always be decision criteria, as due to the higher system complexity, this type of modular UPS is slightly more expensive than the similar monolithic ones

Modularity brings a new approach

The points highlighted in the previous sections show the advantages of the modular UPS. Anyway, the major point is that modular UPS means a new concept to achieve maximum availability for the load and your data.

How to avoid a fault system and cause downtime? Typically, this is done using high reliability UPSs (MTBF), adding the right protection devices, some oversizing or using higher class tier configuration with some redundancy, for example.

Unfortunately, errors can happen due to several reasons (serious perturbance, human intervention, storms, etc.) so in these cases it is important having the right approach for this type of faults and disaster recovery. What will be your response and fault tolerance?

In case of using a monolithic UPS, even if it works with a certain redundancy, it would require an intervention from the service personnel, evaluation, repairing, having the right spares on inventory, etc. From a practical point of view, it may be a longer MTTR.

When using an approach with a modular UPS, several of the previous points can be addressed more easily. For example, the modular UPS may have parallel modules or easily be reconfigured to work with a N+1 or even N+2 to ensure continuity in power delivery.

In case of services, interventions on a modular UPS should be faster and easier, due to the nature of the modular design, simplified lists of spare parts, hot-swapability of the modules, and lower risks trough the repairing activity (it should be easier and with a more standardized concept). Finally, a modular UPS will have a design with no "single point of failure", so that in case of an internal failure in the components (for example the control module), a redundant element will be removed from operation.

All these concepts help to reduce the MTTR in a modular UPS, and it is well known that availability is related to achieve high reliability (MTBF) with a low repair time (MTTR). From this perspective, a well-designed modular UPS provides a tremendous improvement on availability versus a non-modular solution. That's is a major advantage that summarizes the ideas explained along this white paper. And from the users point of view, higher availability means better data protection, improved business continuity and load protection.

Several application cases with small modular UPSs

Now let's see several application cases in selected market segments where the advantages of a modular UPS may be more attractive. Despite the broad product offering of several UPS suppliers, it will focus on single phase UPS. There are products in the EMEA market from 1 kVA up to 25 kVA approximately. This segment is especially interesting as there are many applications where flexibility, availability, efficiency and serviceability are of primary importance.

Application case 1: Branch offices in banking

The first case can be the consideration of branch offices in banking (or even in healthcare in small medical care centers). Let's think of a corporate bank with multiple offices spread around a country or at continental level, having different performance requirements depending on the quantity of employees working there, loads protected, ATMs, security systems, etc.

Continuous access to information (accounts, stock markets, etc), maximum security (CCTV & access) or customer service (ATMs) are of paramount importance, so business continuity is a must.

Thus, we can summarize the demands on a single-phase UPS up to 20 kVA, e. g. we wish for a high output power factor (more loads can be connected), rack mounting (full integration into a rack), or high efficiency (less energy consumption and billing).

In this scenario interesting features from a modular UPS are scalability (increasing power capacity by more medical or IT equipment is added on each location), the superior availability (no interruptions) due to redundant design and hot-swapability in the worst case of a failure. Finally, the higher efficiency, always at an optimum point according to the power increase, will also be appreciated because of the energy billing when considering multiple offices.

APPLICATION CASE: Branch offices in banking and medical care

- Flexibility (pay per growth)
- Efficiency (savings)
- Serviceability & maintenance costs (TCO)
- Availability and fault tolerance

Application case 2: Transportation and railways

The next case relates to transportation and railways. Managing such a complex and widespread infrastructure with thousands of passengers every day, will require a lot of attention to maintain the continuity of operations due to the economic impact.

This continuity means having multiple sub-systems running, like ticketing, passenger access and CCTV, traffic control, station signalling, internal communication, parking, etc., which is truly a complex system where a failure on energy supply for any of the elements will probably affect to the global system.

While it may not be possible to use a single centralized solution for power protection, it requires the use of multiple UPSs with different rating adapted to each location or sub-system. A key element for maintaining this infrastructure can be, for example, the signalling and control systems.

Such systems will probably require a UPS with a high output power factor (more loads connected for the same VA rating), operation under extreme operating temperature conditions, capability to withstand multiple harmonics and interference from electrical environment, etc.

Again, guaranteeing maximum availability due to the use of a reliable hot-swappable modular UPS system combined with a remote diagnosis and maintenance system such as Vertiv LIFE), redundant operation, and flexibility to adapt the power capacity to the loads demands, are key elements to guarantee the maximum service level and continuity for such a critical system.

APPLICATION CASE:

Transportation and railways

- Flexibility (pay per growth)
- Efficiency
- Serviceability & maintenance costs
- Availability and fault tolerance

Application case 3: Edge and small server rooms

The third case is about micro data centers used for edge applications, IoT aggregation or content delivery networks.

These applications will typically require several racks (1-5 racks) that integrate the server and network equipment for that application.

Here again, features such as high efficiency, high output power factor, small size or integration capability in a rack are required. The advantage of a higher efficiency lies in the savings in both billing as well as heat dissipation in the UPS, thus contributing even more to the reduction of energy billing.

For those that need to be a step ahead, a modular UPS product will provide benefits in terms of higher availability (minimum downtime in case of failure and recovery) as well as the chance to progressively increase power capacity as more devices or subscribers are connected. Adding more servers or devices connected to the network will not cause any problem thanks to the flexibility to increase the power rating.

APPLICATION CASE: Small server rooms and network closets

- Flexibility (pay per growth)
- Efficiency
- Serviceability & maintenance costs
- Availability and fault tolerance

Vertiv has several UPS products with this modular approach. In the case of single phase UPS - Vertiv offers the Liebert® APS which ranges from 5 kVA up to 20 kVA.

It is a high-performance on-line double conversion UPS, with power modules of 5kVA / 4.5kW. It provides great flexibility and scalability thanks to the 16 bays that allows multiple configurations in terms of power, auxiliary battery charger or runtimes. It works in both on-line or ECO mode to achieve extremely high efficiencies (up to 98% in ECO mode) and is an Energy Star® qualified product. Also noteworthy is the removable LCD display for user interface, specifically convenient when embedding the UPS into a rack.

Figure 4: *Vertiv Liebert APS 5 – 20 kVA single phase modular UPS*

Maximum availability is ensured thanks to a highly reliable design, hot-swappable power and battery modules, dual control module that allows continuous operation in case of a failure, long life batteries, an integrated bypass or compatibility with Vertiv LIFE service for remote diagnostics and maintenance systems.

In summary, a complete set of top performance features for demanding applications that require the maximum from a modular UPS.

Conclusions

This paper has described the modular UPSs and their advantages, especially for single phase UPSs. It has started with a description of the multiple similar (but not the same) ideas about what a modular UPS is, and then shared the reasons for the market demands of this type of modular UPS, according to external market research.

Then this paper analysed the key concepts behind a modular UPS, and its advantages versus a monolithic solution. Vertiv has both UPS technologies in the single-phase UPS segment, so each product family (Liebert® GXT5™ or Liebert® APS) can be used according to convenience.

Finally, to show the positive impact of modular UPS technology, several applications cases have been addressed. They show the strong benefits in terms of availability, operation in optimum efficiency conditions and energy savings, as well as flexibility in scaling as the demand for performance grows.

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MKA4L0UKwp-USP-mod Rev.1-02/2019 (1220)