White paper: Optimising UPS system reliability using correct battery configurations

The successful design of any Uninterruptible Power Supply (UPS) system involves the minimisation of single points of failure, where possible.

During a mains supply interruption the entire protected network is dependent on the integrity of the UPS battery as a secondary source of energy. A potential single point of failure in a UPS system is often as a result of the design of its battery set. For example, if a UPS relies solely on a single string of batteries and any one battery cell in that string becomes faulty then the batteries may fail to support the load in the event of a mains power failure. To overcome this problem multiple strings of batteries connected in parallel should be used.

Different Types of Battery Configurations

To optimise the battery set to meet performance, reliability and cost criteria we must examine various types of battery configurations. Battery configurations are defined as 'single string' or 'parallel strings' of battery blocks, the relevance of which is described below.

Single Strings

A 'single string' comprises of a series of matching battery blocks connected 'end-to-end' to form the battery set. While this solution would normally provide the most cost effective solution it does introduce a potential single point of failure. A fault in any of the battery blocks connected in series could cause an overall open circuit of the set.

In a single string the positive terminal of the first block is connected to the negative terminal of the second battery set, the positive terminal of the second is connected to the negative of the third, and so on.

The overall voltage of the battery set is the sum of all the individual block voltages and must be arranged to match the float voltage setting of the UPS system.

The overall capacity of the battery set is unchanged with this arrangement, being the same as each individual block.

For example:
If 12 x 12Vdc 10Ah blocks are connected in series, the resulting battery is 144Vdc with a 10Ah capacity.

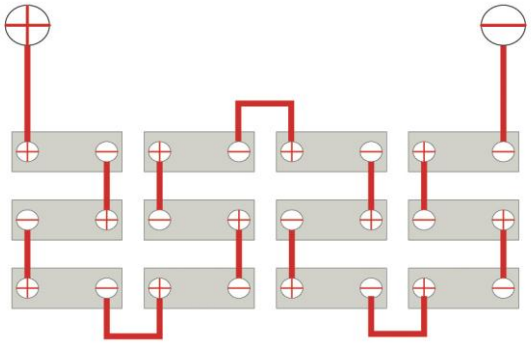

Figure 1: Serial Battery String

Parallel Strings

A 'parallel string' is a combination of two or more serial strings and each string must contain the same number of matching battery blocks. Battery strings are paralleled for two main reasons. The primary reason is to increase the capacity (Ah rating) of the battery set to meet the requirement of a longer battery back up time. The other reason is to increase the resilience of the battery set so that a single faulty battery block will not cause all of the batteries to be unavailable to the UPS system.

In a parallel string the positive terminal of the first battery string is connected to the positive terminal of the second battery string, the positive terminal of the second battery string is connected to the positive terminal of the third, and so on. Likewise, the negative terminal of the first battery string is connected to the negative terminal of the second battery string etc.

The overall voltage of the battery set is the same as the voltage of each string. The capacity of the battery set is the sum of the capacities of the individual strings.

For example:
If three strings of 12 x 12Vdc 10Ah batteries are connected in parallel, the resulting battery is 144Vdc with a 30Ah capacity.

It is unusual for more than six battery strings to be paralleled since circulating currents can become more prevalent as a result of impedance differences in the battery string.

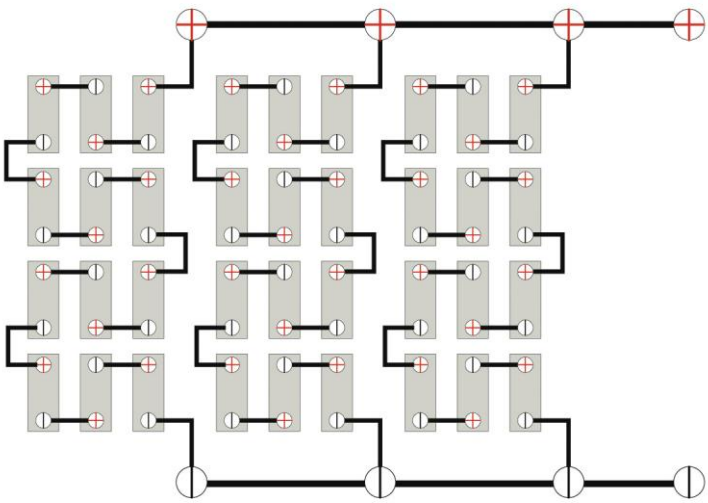

Figure 2: Parallel Battery Strings

Advanced Parallel Battery Strings for Parallel UPS Systems

Parallel strings are used to increase the capacity of a battery system and/or its resilience (by providing battery redundancy), and transition boxes are used to simplify wiring and to individually protect each string in the battery system.

For maximum resilience each UPS module in a parallel UPS system should have its own set of separately fused paralleled strings of batteries. This configuration is typically used for mission critical applications where cost and space is of secondary consideration. However, with large, high powered parallel UPS systems this could be prohibitively expensive and take up too much space within the UPS/computer room. Such space pressures can be partially overcome with careful design of the battery systems by, for example, using more individual strings of lower capacity battery blocks to achieve the required total battery capacity. It is invariably cheaper however, to have a single string of large batteries than multiple strings of smaller batteries.

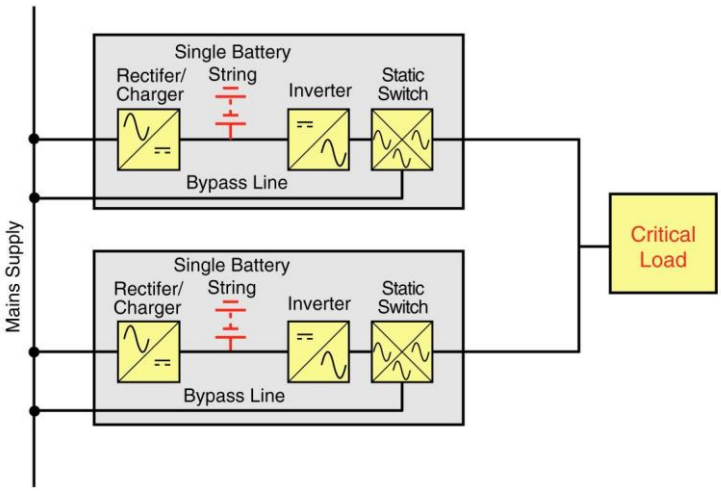

Figure 3: Parallel UPS System with One Battery String

Figure 3 shows a two-module parallel UPS system where each UPS module has a single string of batteries. In such a configuration, if any one battery cell becomes open circuit in either of the battery strings only one UPS module will be able to operate in the event of a mains power supply failure. In a parallel capacity UPS system this may result in the overloading of the UPS module with healthy batteries, potentially resulting in a load loss.

However, in a parallel redundant UPS system the latter battery failure will result in a reduction of battery autonomy, but the critical load will be maintained without interruption, albeit UPS redundancy will be lost.

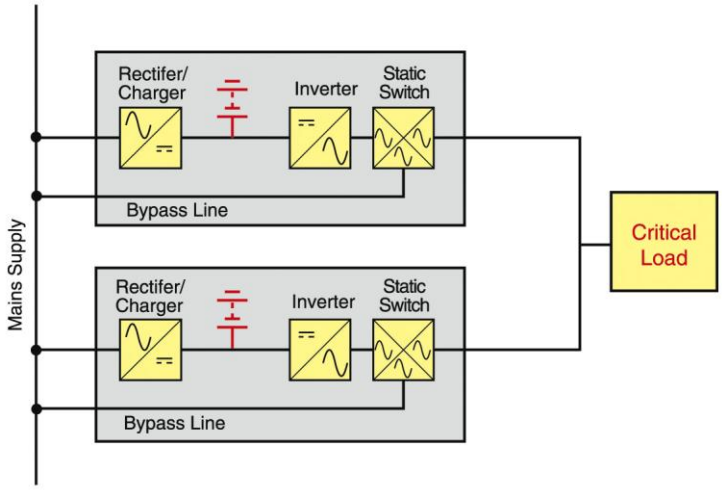

Figure 4: Parallel UPS System with Dual Battery Strings

Figure 4 shows the same two-module parallel UPS system but this time each UPS module has two strings of batteries connected in parallel. If any one battery cell in such a configuration becomes open-circuit then both UPS modules will continue to operate. As both UPS modules equally share the load the UPS module with only one healthy battery string will discharge its good batteries quicker than the other UPS module, but with appropriately rated batteries the required battery autonomy can be maintained. In addition, in parallel redundant configuration UPS redundancy is not lost.

Common Battery Configuration for Parallel UPS Systems:
Both of the systems shown in Figure 3 and Figure 4 have batteries that are configured as separate batteries, i.e. each UPS module has its own set of batteries and no other UPS module in the system has access to these batteries. It is possible to configure the same batteries as common batteries i.e. all of the batteries are physically connected to all of the UPS modules in the system. Common batteries are normally selected when cost and space are at a premium.

Common battery configurations utilising multiple strings overcome the problems presented by open-circuit cells, as discussed in the earlier paragraphs, but unless great care is taken with the common battery's dc distribution system, such a battery configuration can present a single point of failure (e.g. a short circuit on the dc bus of one of the UPS modules may cause all of the battery fuses in the system to fail).

An example of a common battery system designed to connect all of the system batteries to all of the UPS modules in a parallel configuration is shown in Figure 5. Figure 5 shows the dc distribution system for a six-module parallel UPS system with four strings of batteries configured as a common battery. For illustrative purposes the UPS dc input protection has been rated at 250A and the battery string protection has been rated at 630A. In a practical application the actual rating of the protection would depend upon the power rating and quantity of UPS modules and batteries.

It can be seen that a short circuit on the dc busbars within any of the UPS modules will not affect any of the other UPS modules or any of the battery protective devices. It can also be seen that a short circuit within any of the battery strings will not affect any of the other battery protective devices or any of the UPS modules.

The only single point of failure of this system are the dc busbars themselves, but as these are solid copper bars protected and enclosed within a busbar chamber it is highly unlikely that a short circuit will be presented here. It is still, however, a single point of failure within the overall system and if such a single point of failure is considered unacceptable to the UPS user the batteries must be configured as separate batteries.

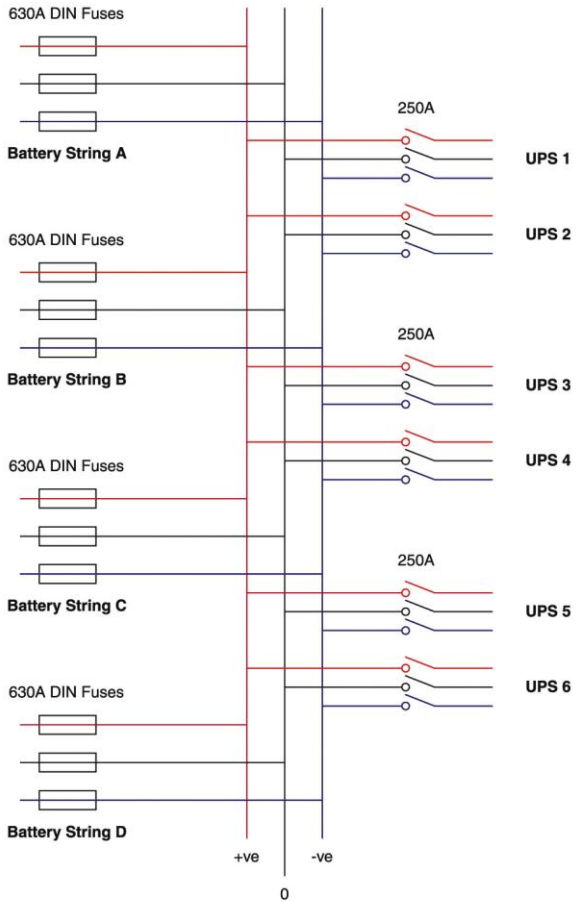

Figure 5: DC Distribution system for a common battery

Relevance of Transition boxes for parallel UPS Systems

Transition boxes are used to provide protection and isolation for each battery string of a UPS system. In addition to providing space for the correct termination of battery cables they also contain suitable fuses to protect the individual battery strings and associated cabling.

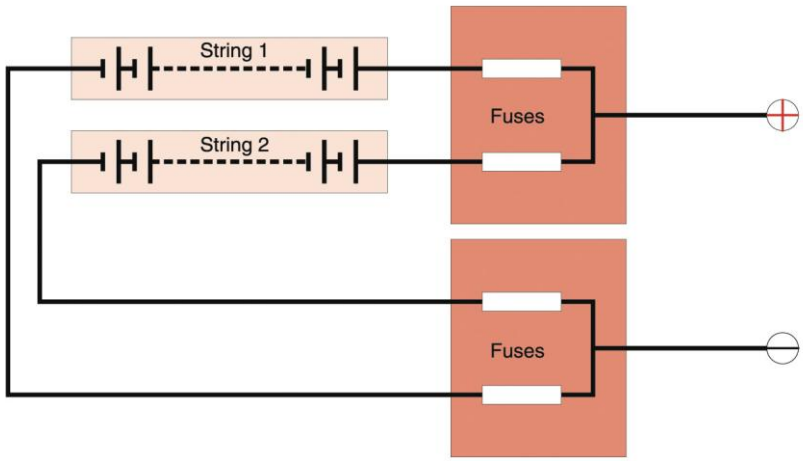

Figure 6: Fused transition boxes for two battery strings

When two or more parallel battery strings need to be connected to the same UPS system, it is common to use transition boxes. Fused transition boxes allow individual battery strings and cables to be protected and also enable an individual battery string to be safely isolated for maintenance or repair without completely disconnecting the UPS equipment.

It is important to keep the lengths of cables within each battery string approximately the same to ensure that the impedance (and hence the current share) of each battery string is approximately the same.

Optimum battery configuration for advanced parallel UPS Systems

The optimum battery configuration for a parallel UPS system will vary depending upon the site facilities (stand-by generator, available space etc.), the load requirements and how critical the load is. A good UPS supplier will be able to discuss all of the options available to allow the UPS user to make an informed decision on the configuration that best suits its requirement and budget.

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