Isolated Redundant vs. Parallel Redundant Configuration

Reliability is the single most important factor when deciding on a UPS configuration, with redundant UPSs being the best way to increase reliability. By comparing the two most popular redundant configurations, isolated redundant and parallel redundant, fundamental differences are revealed that affect availability, maintainability and most importantly, the reliability of the configuration.

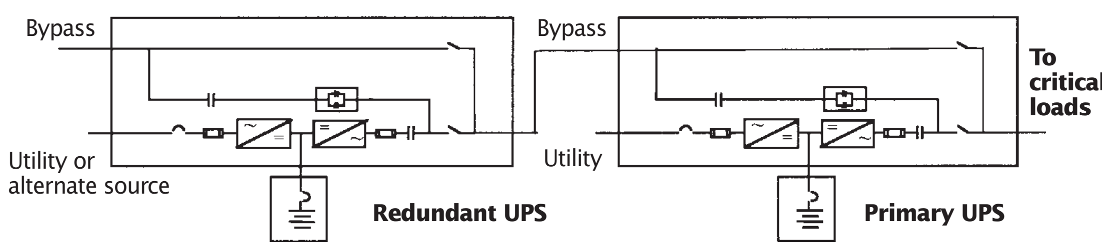
MGE can manufacture both parallel and isolated system configurations, designed for redundancy or capacity. MGE was the first manufacturer (and in many cases the only one) to design and promote the isolated redundant system. The isolated redundant system has many redeeming features but at the same time, MGE has installed more parallel systems due to customer preference.

Both configurations have specific features and benefits. Depending on the size, footprint, cable run, required maintenance, output distribution (centralized vs. distributed loads) or customer preference one configuration maybe more suitable for a specific application. The theory of operation for both configurations is based on two modules, using one module for capacity and the second module for redundancy.

Isolated Redundant Theory of Operation

Isolated redundant systems can use two like or different rated UPS modules connected in an isolated arrangement. The output of the redundant UPS output is fed directly into the bypass of the primary UPS. The primary UPS is configured to operate as an on-line reverse transfer system whereby in the event of a failure, the redundant UPS will assume the critical load.

The primary and redundant UPSs can consist of multiple modules (load segments) if the load capacity requires. Because the critical load is divided into separate, isolated segments, the failure of one segment will not affect the operation of the other load segments



Isolated Redundant Configuration

Normal Operation: Under normal operation the primary module is supplying the critical load power and the redundant module is in full operation feeding the bypass input of the primary module. As a result the critical load power will always be synchronized to the output of the redundant UPS allowing for a seamless in phase transfer.

Emergency Conditions: In emergency conditions, upon failure of utility power (blackout or brownout) both rectifiers / battery chargers will shut off and the inverters, using power from the storage batteries, will continue to power the critical load. When input power from utility or back-up generator is restored (prior to complete battery discharge), the rectifiers automatically start providing power to the inverters and simultaneously charge the battery banks. In the event that the input power outage extends long enough to discharge the battery bank of the primary UPS module, the critical load will be transferred to the “REDUNDANT MODULE” which has a fully charged battery bank.

Bypass: If the primary UPS module is shut down for any reason, the critical load power automatically transfers (via the internal static transfer switch) to the bypass. In isolated redundant systems, the bypass is being fed by the output of the redundant UPS module. This ensures that the load is still being fed with fully conditioned, uninterrupted power. Because the static transfer switch instantaneously switches between the primary and redundant UPS output, there is no interruption to the load power.

Maintenance Bypass/Test Mode: If the primary UPS module has to be shut down for maintenance or repair, the maintenance bypass completely isolates the primary UPS. Since the redundant UPS module is feeding the bypass input of the primary module, the critical power remains protected during maintenance. Likewise if the redundant module has to be shutdown, the load still remains protected by the primary UPS.

UPS Requirements for Isolated Redundant Configurations: The capability of a UPS to be connected in isolated redundant configuration is based on true pulse width modulation (PWM) switching technology utilized in the inverter. This advanced technology (employed in MGE UPSs) allows the module to supply a 100% step load change (0% to 100% of rated power instantaneously) while maintaining the output voltage regulation to within the allowed tolerance (maximum of +/- 3.5% - 4% output voltage transient with a crest factor of 3.5 for 16 milliseconds). This type of high output demand is not as well controlled with conventional step wave inverters, available on the market today. As a result, MGE is one of the few UPS vendor actively promoting the isolated redundant system.

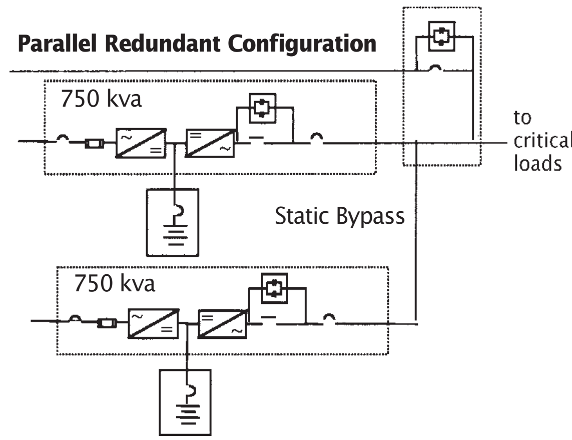
Not all isolated redundant systems are the same: When analyzing arguments against the isolated redundant configuration, it should be noted that other key vendors utilize dramatically different approaches to applying the configuration. One notable difference is the addition of complex switchgear, not found on MGE configurations, adding cabinets, cost and additional single points of failure. Such is not the case with MGE systems.

Isolated Redundant Design Principles and Requirements: To effectively implement an isolated redundant system the inverter must be capable of the following performance requirements:

- Superior dynamic response: +/- 5% output voltage deviation for 100% step load change and recovery to 1% voltage regulation in less than 16 millisecond (less than 1 cycle).
- Variable pulse, high frequency Pulse Width Modulation (PWM) inverter switching technology.
- Fast feedback response, which enable the inverter to react faster to load changes while maintaining voltage regulation.

Parallel Redundant Theory of Operation

Parallel redundant systems must consist of "like rated" UPS modules connected in a parallel arrangement usually connected through a separate static switch cabinet (SSC). The UPSs are also designed to operate as "on-line reverse transfer systems" in the following modes of operation:



Normal Operation: Each UPS module supports an equal share of the total load during normal, emergency, or recharge operations. In the event of a UPS module failure, the failed module automatically disconnects and isolates from the system load. As a parallel UPS(s) is also feeding the output power, there is no interruption to the critical load power should a single UPS fail. In a non-redundant parallel system (load power is greater than redundant UPS module power), the functioning UPS modules will support the critical load until the they are overloaded, at which point the system will transfer to bypass.

Emergency Conditions: Upon failure of the utility AC power source, the inverters obtain power from the batteries to supply the power to the critical load.

Bypass: The shared system static switch is used to transfer the load to the system bypass (typically fed from utility power) without interruption to the critical load. This is automatically accomplished by turning the inverters off. Automatic re-transfer or forward transfer of the load is accomplished by turning the inverters on.

Maintenance Bypass/Test Mode: A manual make-before-break maintenance bypass switch is provided to isolate the UPS system output and system static switch for maintenance. This allows each UPS module or the SSC to be tested or repaired without affecting load operation.

Comparing Isolated Redundant to Parallel Redundant

The theory of operation of both systems indicates that they both meet the basic requirements of operation and redundancy. However, there are notable differences between the two systems.

	Isolated Redundant	Parrallel Redundant
Number of Cabinets	Five cabinets minimum	Six cabinets minimum
Footprint	Smaller due to no Static Switch Cabinet	Larger due to extra SSC
Load Protected During Maintenance	Always	Must switch to utility during SSC maintenance
UPS Topology & Technology	Mix and match primary modules of any rating from any manufacturer	All modules must be like rated & from the same manufacturer
Required UPS Performance	100% step load change w/ 1% voltage regulation	Performance not critical
Reliability (MTBF)	498,000 hours	380,000 hours
Availability	0.9999919 %	0.9999768 %
Operating Efficiency	Typically maximized	Typically based on 50% load efficiency load efficiency or lower

Number of Cabinets and footprint: A MGE isolated redundant system uses two (2) UPS modules, two (2) battery banks (with circuit breakers) and maintenance bypass cabinet. A parallel system requires an additional system static switch cabinet. Since the isolated redundant system has no system Static Switch Cabinet (SSC), it has a smaller footprint.

Maintenance: In a parallel redundant system, the system static switch cabinet contains the system static switch, bypass circuit breaker and some control and monitoring printed circuit boards. The maintenance section of the theory of operation of the parallel system indicates that either module can be maintained without shutting down the load power. However, if maintenance is required on the SSC cabinet, the load power must be transferred to maintenance bypass. In some cases this is not acceptable since the load is not protected.

In the isolated redundant system the SSC does not exist. Therefore no maintenance is required. Each module could be maintained without transferring the load to bypass "raw" power.

Topology and Technology: As stated in the parallel theory of operation, both modules must be "like rated modules". Both modules must be of the same design, the same manufacturer, same rating, same technology and topology. The reason for that is both modules are sharing the load so they must be matched. In the isolated redundant system the UPS modules are isolated and they are not communicating. As a result, it is possible to use modules of different ratings, different technology and topology and from different manufacturers. Since both modules must be like rated and of the same design and manufacturer, future expansion may be difficult if the exact modules are not available. It also allows the liberty of switching manufacturers in favor of preferred technologies that may have come into existence. Because the isolated configuration does not require like rated modules, higher rated modules may also be added facilitating increased power requirements.

Reliability: While some manufacturers claim over 1,000,000 hours Mean Time Between Failure (MTBF) using self derived calculations, MGE uses the industry standard MIL-HDBK-217D formula for MTBF. This standard is based on failure rates of electronic components observed in the field over many years. Under these calculations the highest MTBF, or most reliable configuration is isolated redundant with a MTBF of 498,000 hours versus 380,000 hours with a shared parallel system.

Availability: The availability of a UPS system is a function of the MTBF and the Mean Time To Repair (MTTR). The MTTR is based on the complexity of the UPS system and typically ranges from _ hour to 24 hours. Availability = MTBF / (MTBF+MTTR). Non availability (1-availability) indicates the percentage of down time over a certain period. The down time over five years on a parallel redundant system is over one hour versus an isolated redundant system with 0.35 hours of down time – the lowest of any configuration available. Keep in mind that with a properly maintained system, down time does not indicate that the power will be "down", but rather how long the load may be running on utility power, unprotected during the five year period. Furthermore, abiding by a strict maintenance and inspection schedule can practically eliminate the time an isolated redundant configuration has to run on "unprotected" power.

Operating efficiency: In parallel redundant systems each of the UPS modules share an equal portion of the load. This causes the modules to operate at less than 50% of their respective capacities during normal operation, far below optimum operating efficiency. In an isolated configuration, The primary module(s) assumes the load. As fewer modules power the load, the primary UPS(s) operates far closer to its optimal efficiency. The redundant module has minimal losses during normal operation.

The efficiency differential between the two configurations can easily be as high as 4%, with the isolated configuration saving up to tens of thousands of dollars per year in utility and air conditioning costs.

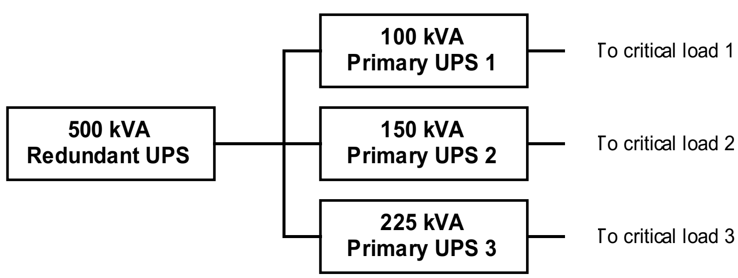
Configuration	Reliability (MTBF hours)	Availability	Non-availability	Downtime In five years
Single module w/o static bypass	27,440	.9997813	.0002187	9.58 hours
Single Module w/ static bypass	250,000	.9999760	.0000240	1.05 hours
Shared-parallel-for-capacity (2 modules)	185,000	.9999567	.0000433	1.90 hours
Conventional-parallel-for-capacity (2 modules)	135,210	.9999408	.0000591	2.59 hours
Shared parallel-redundant (2 modules)	380,000	.9999789	.0000210	0.92 hours
Conventional parallel-redundant (2 modules)	345,000	.9999768	.0000231	1.01 hours
Sync-Tie via shared paralleling (4 modules)	190,000	.9999368	.0000631	2.76 hours
Sync-Tie via conventional paralleling (4 modules)	172,500	.9999304	.0000695	3.05 hours
ISOLATED REDUNDANT	498,000	.9999919	.0000080	0.35 hours

Advantages of Isolated Redundant UPS Systems

From a reliability, availability and maintainability standpoint, the isolated redundant system proves to be a superior configuration. Features that make isolated redundant the superior configuration include:

- No initial investment: An isolated redundant system does not require a system cabinet since there is no current sharing between the UPS modules. Removing the system cabinet reduces the initial investment and the overall footprint of the system.
- No single point of failure: The classical parallel configuration uses the "system cabinet" as a tie point that connects all UPS modules and bypass power to the critical load. This tie point is considered a single point failure since any failure in the system cabinet will cause load power interruption. In the isolated redundant configuration all outputs are isolated and the single tie point is eliminated.
- Multi level redundancy: Isolated redundant systems have three levels of redundancy. Level one is the primary module with its internal bypass, level two is the isolated (redundant) module with its internal bypass, and level three is the system bypass (utility power).
- Smaller load bank requirements: Testing the maximum performance capacity of an isolated system requires a load bank half or less the size as would be required with most parallel systems.
- Modules can be in separate rooms: The only connections required to junction an isolated are the output cables of the UPSs and utility cable. This allows the UPSs to be located in different rooms.
- Protection against operator errors: No single operator induced error can leave the load unprotected.
- UPS power available during maintenance
- Higher operating efficiencies
- Lower operating costs
- Flexible site planning
- Fewer components
- Lower system cost
- Maximum overall system reliability / lowest MTBF
- Flexible product choice (mix & match)
- No risk of discontinued products
- Smaller footprint
- Improves reliability of existing single module sites

Retrofitting for Reliability



***Improving the reliability of existing sites*:** An MGE redundant UPS can be easily added to existing sites to improve the reliability of single module configurations. The existing primary UPSs need not be MGE UPSs.