UPS Configurations

By: Daniel J. Skinner, Product Manager
Solidstate Controls, Inc.
Columbus, Ohio, USA

Abstract

Many of the problems experienced in data processing, communication and distributed control systems within the Process and Power Generation Industries are the result of problems with the power supply, such as temporary outages, momentary interruptions, surges, sags and electrical noise. A well designed Uninterruptible Power System (UPS) can be the solution to all of these potential problems. The methods by which one or more UPS units are utilized, not only dictate the cost of the UPS system but also the degree of load protection. This paper will discuss the various types of UPS configurations available, as well as the various levels of protection provided by these UPS configurations.

System Configurations

For over thirty years, Uninterruptible Power Supplies have been an important element in critical power protection schemes. Over this time many different system configurations have been developed to mitigate the risk of loss of utility power. The following is a presentation of four typical UPS configurations used in industrial applications and an evaluation of each of their capabilities.

A score between 1 and 5 has been assigned. A score of “5” indicates the highest degree of criteria capability, while a score of “1” indicates the lowest degree of criteria capability.

Evaluation Criteria:

Reliability – Evaluates a configuration’s capability to maintain conditioned power to the load for internal or external system faults.

Complexity – Looks at the complexity of the configuration and the potential for single point failures.

Maintainability – The system configuration must allow for concurrent maintenance of all power system components – supporting the load with part of the UPS system while other parts are being serviced.

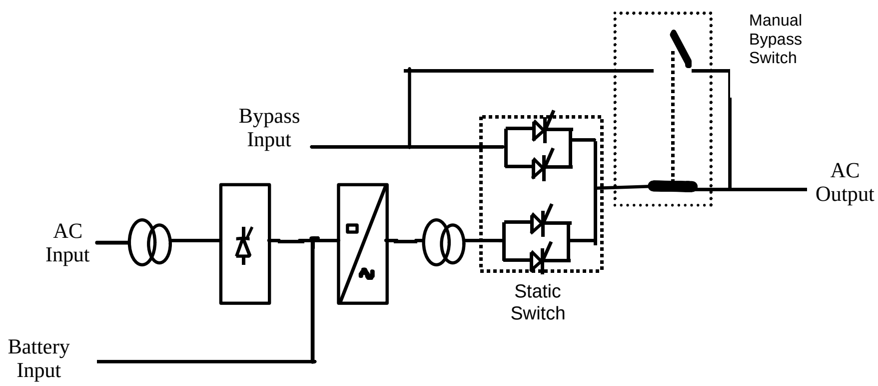
Functionality – The system configuration must be able to protect the critical load from a full range of power disturbances without transferring the critical load to external power sources, i.e. batteries or alternate power sources.

Cost – Evaluates the cost of the various system configurations as compared to the “Float” configuration. The “Float” configuration is utilized as it represents the lowest cost configuration. The “Float” configuration will be assigned a cost of 100%. The other configurations will then be given percentage multipliers against this value, i.e. 200% would represent a system cost that doubles that of a “Float” configuration.

Single Unit or "Float" Configuration

The single unit or "Float" configuration, Figure #1, is the most common configuration utilized in UPS applications because it contains the fewest number of major components. This system utilizes AC power (typically utility power) and converts it to DC through the rectifer/battery charger. The regulated DC power is supplied to both a bank of batteries and to the inverter. The inverter "inverts" the DC back into regulated, noise-free AC power and passes it along to the static switch. The static switch, under normal conditions, passes this AC power through to a manual switch and on to the load. If a failure in the inverter should occur, or a fault on the load should occur which overloads the inverter beyond its maximum capacity, the static switch will automatically transfer to the alternate (or bypass) position and feed the critical load from the alternate power source through the manual bypass switch. The manual bypass switch is a mechanical, make-before-break switch that is used to bypass the UPS for maintenance purposes. If AC power to the battery charger is lost, the batteries automatically begin supplying the required DC power to the inverter; there is no switching involved at this point.

Figure #1 – Single Unit or Float Configuration



<u>Criteria</u>	<u>Score</u>	<u>Comments</u>
Reliability	3	The technology utilized in the construction of "Float" configured UPS systems is for the most part mature. A negative most commonly associated with this configuration is the potential for a single point failure, i.e. a failure of the inverter results in the load being transferred to the alternate power source, which is generally not a clean, well regulated source of power, and whose reliability may be questionable. Additionally, a common output bus is provided, i.e. a failure along this path will result in the load power being interrupted.
Complexity	5	As compared to the other configurations, this configuration offers the simplest design and the least number of components. There is no dependence on other system components to function in conjunction with each other in order to properly power the load.
Maintainability	2	The load must be transferred to the alternate source power whenever a system component is being maintained. Leaving the critical load on the alternate source, which may not be very reliable.
Functionality	4	A well designed double conversion "float" system can cope with all power disturbances. Other UPS configurations, i.e. off-line, line interactive, etc. are not so well equipped to meet these conditions.
Cost	100%	This system configuration serves as the basis for the analysis. The configuration's simplicity and low component count attribute to a lower overall configuration cost.

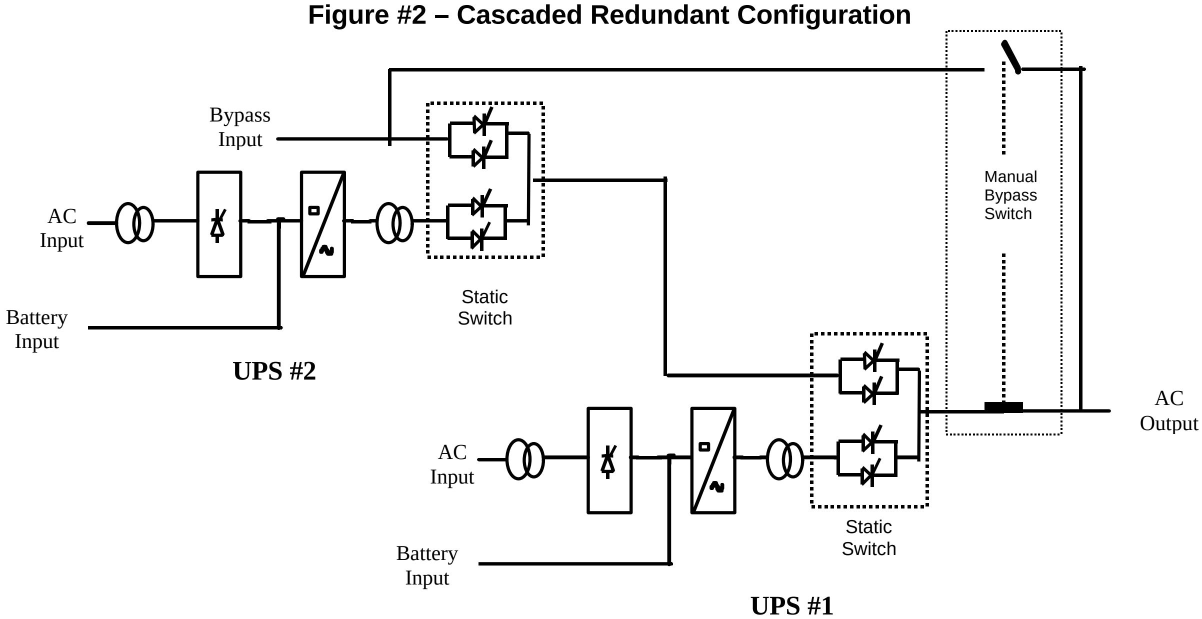
Cascaded Redundant Configuration

Utilizing two “Float” configured UPS systems, the Cascaded Redundant configuration is often lauded for its simplicity in providing a redundant configuration. Referring to Figure #2 – Cascaded Redundant Configuration, the normal system power flow to the critical load is through UPS #1. The DC voltage from either the rectifier/charger or battery supplies UPS #1 depending on the availability of the AC input. UPS #1 provides regulated, isolated AC power at its output, through the static switch, shown in the load position, and out to the critical load.

If UPS #1 should fail, or if the load current exceeds the UPS's full load rating, the static switch will, within 4 milliseconds maximum, transfer the critical load to the static switch bypass input (which is the output of UPS #2).

Under normal conditions, UPS #2 is idle but always on and ready to assume the critical load through the transfer of static switch (UPS #1). If UPS #2 should fail, its static switch will sense the loss of function and transfer the load to the system bypass source. The system bypass can supply through either a voltage conditioning (regulating) transformer or a non-regulating shielded isolation transformer.

Figure #2 – Cascaded Redundant Configuration



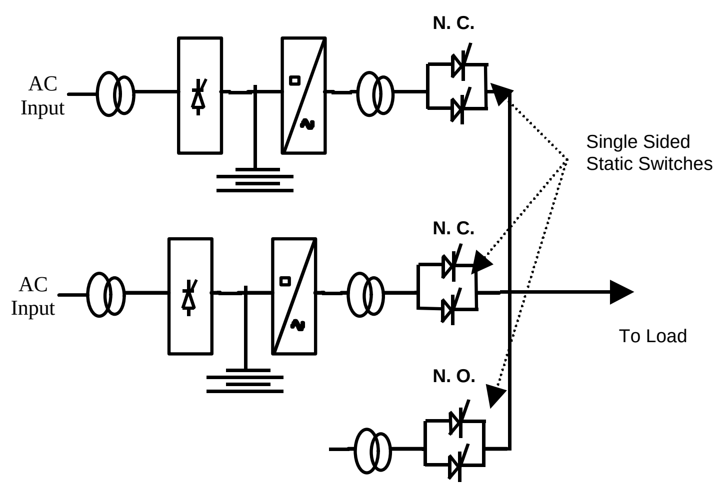
<u>**Criteria**</u>	<u>**Score**</u>	<u>**Comments**</u>
Reliability	4	Reduces the probability of the loss of power to the critical load associated with “Float” configurations by providing a protected power source if the primary UPS system fails. However, this configuration does not overcome the shortcoming of having a common output bus. A failure of this bus would result in dropping the critical load. The configuration’s reliance on the static transfer switch to function properly under a failure or fault condition is another area of concern. Another shortcoming associated with this configuration is that the alternate UPS system is constantly idling and that when it assumes the load it will be subjected to a large step load. Finally, as the load is not being supplied evenly between both systems there will be additional wear on the load bearing system.
Complexity	4	By far the simplest of the redundant UPS configurations as it utilizes two “Float” configured UPS systems to provide a basis for redundancy. Requires no additional system logic, outside of that provided in a “Float” configured system, to coordinate the function of the two systems.

Maintainability	5	System configuration allows for either UPS systems to be maintained while the critical load is being fed from a protected power source.
Functionality	4	A well-designed system is fully capable of protecting the critical load from typical power disturbances. This system configuration also offers the benefit being easily configured in the field from individual "Float" configured modules. This gives the customer the chance to "upgrade" their "Float" configurations in the future.
Cost	200%	Cost is negatively impacted by the addition of the second "Float" configured UPS system only.

Parallel Redundant Configuration

Parallel redundancy refers to the simultaneous operation of two or more UPS systems operating in parallel. Figure 3 – Parallel Redundant Configuration, illustrates two UPS systems operating in parallel. In this scheme both UPS systems are supplying approximately 50% of the combined AC load. The failure of either UPS system would result in the entire load being assumed by the healthy inverter. The failure of both UPS systems would result in the load being transferred to the alternate power source via the static transfer switch.

Figure #3 – Parallel Redundant Configuration



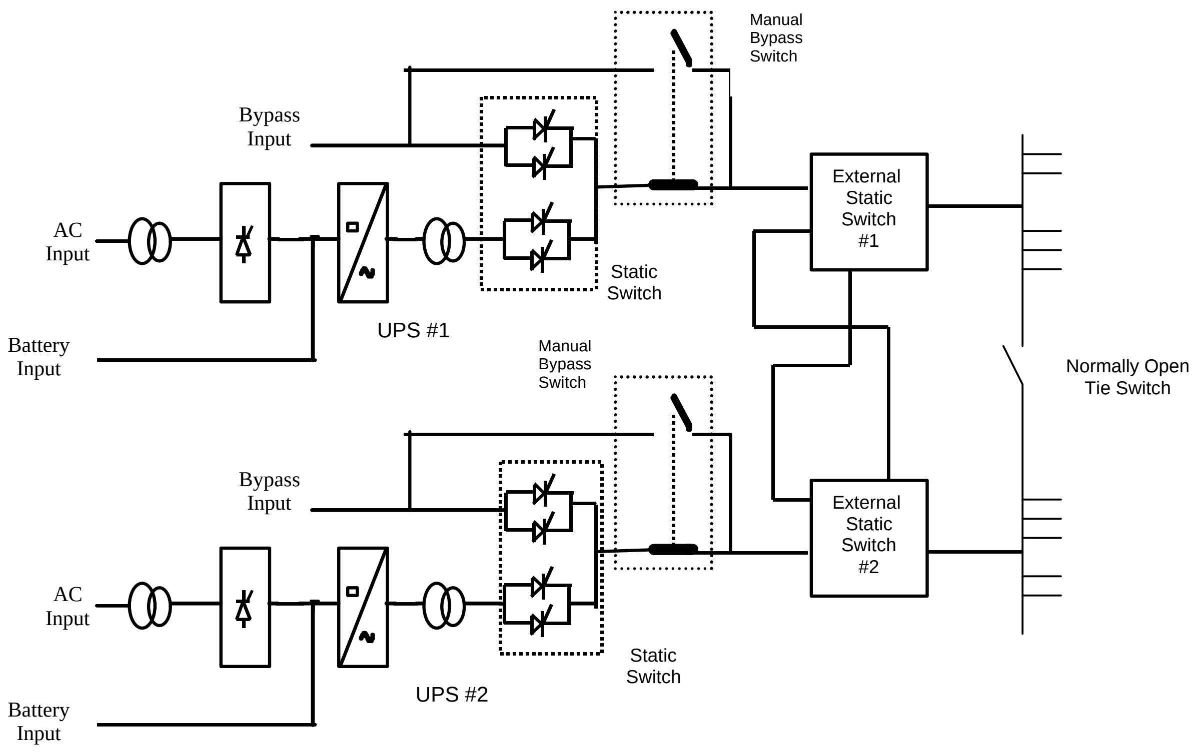
<u>**Criteria**</u>	<u>**Score**</u>	<u>**Comments**</u>
Reliability	3	Advantages of this configuration include features such as load sharing between UPS systems. This promotes equal wear and tear on both units and seamless transfers between the units under failure conditions. Additionally, the fault clearing capability of the overall system is higher because both units can provide short circuit current to the load side protective devices. A negative of this system configuration is a reliance on a single output bus. A failure on the output bus will result in a loss of power to the critical load(s).
Complexity	3	Utilizes a customized UPS "Float" configuration. Requires precise control over the power flow between the UPS modules to maintain a zero net power flow. If zero power flow is not maintained, system damage and/or failure of redundancy capability can occur. The additional system controls to achieve proper load sharing and to quickly detect and remove the faulty unit from the parallel output bus make this configuration a much more complex design.
Maintainability	5	System configuration allows for either UPS systems to be maintained while the critical load is being fed from a protected power source.

Functionality	4	A well-designed system is fully capable of protecting the critical load from typical power disturbances.
Cost	215%	Cost is negatively impacted by the addition of the second UPS system as well as the control necessary to insure proper paralleling between the systems.

Cross Coupled Redundant Configuration

The cross-coupled redundant configuration, Figure 4, utilizes two “Float” configured UPS systems in conjunction with two stand alone STATIC bus transfer switches. In normal operation, both units are designed to carry 50% of the critical load, and have 50% reserve capability to support the load on the other bus in the event the UPS feeding the other load bus encounters an operational problem. This allows complete independence and total isolation of the two UPS units from each other, facilitates separate output load buses, and eliminates the possibilities of single point failures either due to faults on the load side or because of faults within the two units. The result is a configuration that allows both critical load buses to be automatically fed from either the dedicated bus unit or the second unit. The failure of UPS #1 would cause External Static Switch #1 to feed that system’s load from UPS #2. Similarly, the failure of UPS #2 would cause External Static Switch #2 to feed that systems load from UPS #1. Note, a common bypass feed, i.e. from the same bypass source, is necessary to insure that the output of the two systems will be synchronized, and to allow availability of unrestricted fault clearing power.

Figure 4 – Cross-Coupled Redundant Configuration



Criteria	Score	Comments
Reliability	4.5	Utilizes a standard “Float” configured UPS systems in conjunction with stand alone static bus transfer switches. This system configuration (dual bus output) eliminates the potential for single point failures associated with single output bus failures that the other three configurations are susceptible too.
Complexity	4	From a complexity standpoint this system ranks slightly below a cascaded redundant configuration and slightly above parallel redundant configuration. The addition of two extra static switches makes this configuration slightly more complex than a cascaded systems and the elimination of paralleling control makes it less complex than the parallel configuration. The logic and circuitry behind this configuration are mature.
Maintainability	5	System configuration allows for either UPS systems to be maintained while the critical load is being fed from a protected power source.
Functionality	4	A well-designed system is fully capable of protecting the critical load from typical power disturbances.
Cost	225%	Cost is negatively impacted by the addition of the second UPS system and the addition of the second set of static bus transfer switches.

Conclusions

What conclusions can be drawn from this analysis? Figure 5 – Evaluation Criteria Summary, indicates a clear difference between the “Float” configuration and each of the three redundant system configurations. This is understandable, as the redundant configurations are each designed to mitigate the problems associated with the “Float” configuration. However, this analysis shows little or no difference between the three redundant configurations, i.e. there is no “better” redundant configuration. Various system manufacturers specialize in different redundant configurations, adopting a particular configuration as their “standard” design. Therefore, there is always the potential for asking five different manufacturing sources for the “best” redundant configuration and getting five different responses. Adoption of configurations that the manufacturer of the system is familiar with and/or specializes in lends itself to reductions in manufacturing variations, lower cost and increased system reliability. Adoption of configurations that are outside the expertise or specialization of the manufacturer lends itself to increased manufacturing variation, increased cost and the potential for decreased system reliability. Ask the manufacture for input on which configuration they prefer and why, adopt criteria for analyzing the manufacturers recommendations (Reliability/Simplicity, Fault Tolerance, Maintainability and Functionality) against your own application needs. The only real error that can be made in the selection of a configuration is to not understand the associated benefits/risks associated with that configuration.

Figure #5 – Evaluation Criteria Summary

	Float	**Cascade Redundant**	**Parallel Redundant**	**Cross-Coupled Redundant**
Reliability	3	3	4	4.5
Complexity	5	4	3	4
Maintainability	2	5	5	5
Functionality	4	4	4	4
Cost	100%	200%	215%	225%
Totals	**14**	**16**	**16**	**17.5**

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