SINGLE, SERIES AND PARALLEL REDUNDANT UPS´S

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***Abstract* – Nowadays, many types of operations can be assigned to three phase UPS, with the objective of providing clients with more reliable systems. A large variety of combinations between rated power, number of units, load distribution, redundancy and other specifications that may be explored to answer the present and future demands of users is available in this paper.**

***Keywords* - parallel, redundant, series, single, UPS, MTBF.**

I. INTRODUCTION

The aim of this paper is to introduce and explain the Single, Series Redundant and Parallel Redundant configurations, their particularities, and where and why to apply them. The objective is to make the reader capable of differing them and the most appropriate for each client needs. These three options are part of product line of CP Eletrônica S.A.

II. SINGLE OPERATION

A. What is it?

This sort of operation is implemented with only one "UPS" supplying critical load. The figure 1 exemplifies this operation; it is possible to observe a unit and its components (rectifier, batteries and inverter) without a static transfer switch.

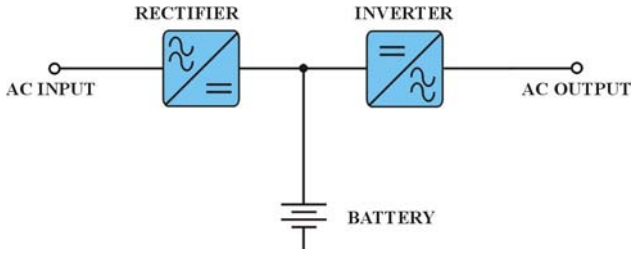

Fig. 1. Components of an UPS.

The above configuration is the basis of the UPS and its MTBF (mean time between failures) shown below is based on data collected from installed units:

$$MTBF_1 = 50.000\ h$$

III. STATIC TRANSFER SWITCH (STS) FOR SINGLE OPERATION

A. What is it?

The STS is an electro-electronic device that manages the unit output, switching between the UPS inverter and an alternative power supply, aiming at rated power supply continuity. Its usage is associated to unit maintenance, overload, output short-circuits, over temperature or to the occurrence of possible failure. The system is as shown in Figure 2.

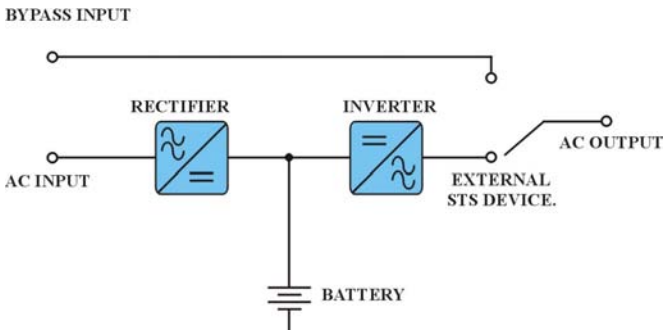

Fig. 2. UPS with Static Transfer Switch.

The Static Transfer Switch is very simple; it is based on thyristors and/or contactors and is highly reliable, contributing to the increase of the UPS's global MTBF. Devices such as this one have high $MTBF_3$, reaching from 500.000 to 800.000 hours.

The bypass may be the utility power, an engine-generator system or even a reserve UPS. In the case of a reserve UPS, there is the Series Redundant Configuration.

It is important to highlight that the use of a static transfer switch demands that its MTBF and the utility power MTBF are considered for the calculation of the UPS's global MTBF.

In Brazil, the official MTBF for utility power is the one presented below:

$$MTBF = 625\ h$$

The MTBF of a Single UPS with STS shown below is obtained based on the data collected from the installed unit:

$$MTBF_2 = 372.000h$$

IV. SERIES REDUNDANT CONFIGURATION

A. What is it?

As seen in Figure 3, in the Series Redundant configuration there are at least two UPS, of the same rated power. There is a main UPS, that feeds the load, and its bypass is connected to the reserve UPS. The second unit also includes STS, which may be a reserve unit or the utility power.

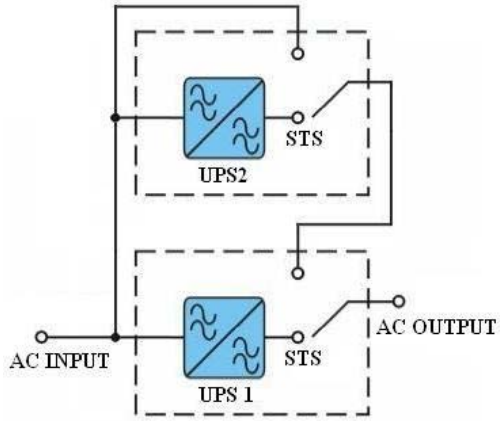

Fig. 3. Two UPS in Series Redundant Configuration.

B. What for:

This configuration is the most reliable among all configurations, which have STS. It is used to increase the system's reliability through the first unit bypass attributes increase, changing the utility power, its low MTBF and its low quality, for a reserve UPS and its higher reliability.

In the case of maintenance, protections or failure in the first unit, the load is totally transferred to the second unit. In the event of overload, short-circuit or simultaneous failures in both units the load will be supplied by the utility power, being therefore, subject to its disturbances.

Thus, by means of the calculations presented in [1][2], we come to the following number for this topology, considering a 48-hour figure for the MTTR (Mean Time to Repair – valid for all calculations in this paper). The MTBF below describes the final product of such redundancy:

(1)

$$MTBF = \frac{1}{\left[\frac{1}{\left(MTBF_1 + MTBF_2 + \frac{MTBF_1.MTBF_2}{MTTR}\right)} + \frac{1}{MTBF_3}\right]}$$

MTBF= 499.356 h

V. PARALLEL REDUNDANT CONFIGURATION

A. What is it?

In this operation there are two or more UPS feeding the load, together and in a shared way. Its outputs are connected directly to a common bus and then to the load. Figure 4 and Figure 5 show this operation, and give an example of the usage of two and three units.

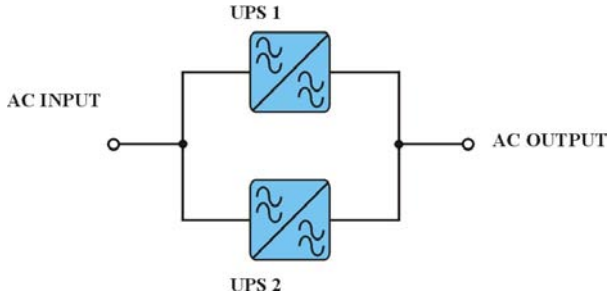

Fig. 4. Two UPS in Parallel Redundant Configuration.

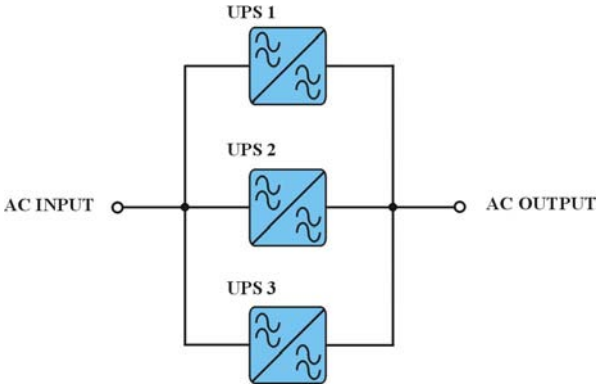

Fig. 5. Three UPS in Parallel Redundant Configuration.

B. What for:

The use of two or more UPS in a parallel configuration increases the system reliability and allows for future expansions. The basic premise for this reliability increase is that at least one unit (the reserve one) may be disconnected from the bus and the other(s) may continue feeding critical load. Once this condition is fulfilled, it will be possible to allow maintenance or unit failure without any damage to the load.

However, the MTBF increase is not linear. That because it is the result of the capacity that the UPS combinations in parallel have to supply load. It is known as the success probability of the cluster in relation to the load. It is necessary to always bear in mind the number of units needed to feed the nominal load and the number of units that can be disconnected from the bus without having an overload condition, and provided that there is some protection.

For instance, a load of 13kVA is supplied by three units of 10kVA. In case one it is withdrawn from the bus, the two resting ones will continue to operate normally. However, when a second one is disconnected, the remaining one will be overloaded, and may disconnect the load.

The MTBF analysis for parallelism (N+1) and (N+2), following this paper, will exemplify these cases. The increase in a reserve unit, from (N+1) to (N+2), will have a meaningful reliability result.

C. N+1 Configuration

In this configuration, there are ***N*** necessary units, one reserve unit, that is, any unit can be out of the load bus, and

the others will be able to supply the critical load. Below is the MTBF for associating up to six units:

TABLE I
Parallel MTBF (N+1), in hours

Number of UPS´s	Hours
2	285388h
3	107709h
4	60844h
5	41152h
6	30856h

It is important to highlight the number of hours decrease due to the units increase. The explanation to this decrease is the lower percentage of "reserve" in the bus. While there is a reserve of 50% for two units, for six there is only 16.7%. It is noticeable that from 5 units on, there is a lower MTBF than in a single unit.

Besides that, these figures are valid for units of the same rated power, for its participation must be proportional. That does not mean that units with different rated power cannot be connected in parallel, but their configurations will affect the system's MTBF.

D. N+2 Configuration

In this configuration, there are ***N*** necessary units and ***2*** reserve units, where any two units can be disconnected from the bus without any disturbance of the load power.

It is a highly reliable configuration, for it presents a higher flexibility for the system operation success. The same observations made for the previous cases are valid; they explain the highest MTBF concerning the N+1 and the decrease in hours due to the increase of units.

TABLE II
Parallel MTBF (N+2), in hours

Number of UPS´s	Hours
3	1628927h
4	468837h
5	215575h
6	123710h

VI. STATIC TRANSFER SWITCH (STS) FOR PARALLEL REDUNDANT CONFIGURATION

A. What is it?

As in the Single configuration mode, the use of a bypass through a STS may increase the system's reliability. However, in the case of a Parallel Redundant Configuration, an STS device external to the units must be used. Its function is to connect either the bus consisting of the UPS outputs or bypass source to the load. Figures 6 and 7 exemplify this case for two or three units in parallel and with the utility power as a *bypass*.

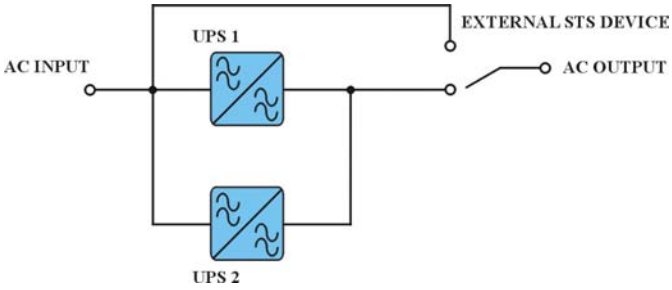

Fig. 6. Two UPS in Parallel Redundant Configuration, with External STS

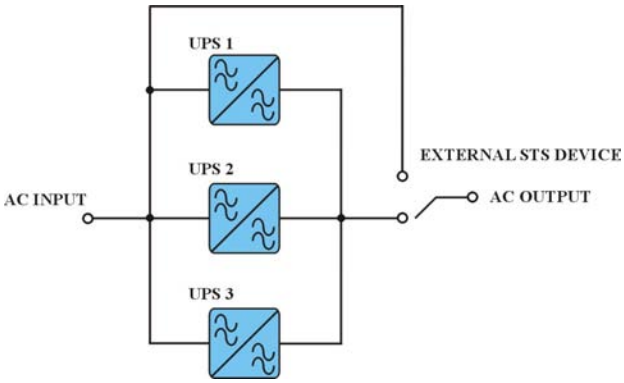

Fig. 7. Three UPS in Parallel Redundant Configuration, with external STS.

The following tables present the MTBF calculation for the N+1 and N+2 configurations, considering that the *bypass* is supplied by the utility power itself:

TABLE III
Parallel MTBF (N+1), in hours, with external STS

Number of UPS´s	Hours
2	444469h
3	375671h
4	315322h
5	268006h
6	232120h

TABLE IV
Parallel MTBF (N+2), in hours, with external STS

Number of UPS´s	Hours
3	489288h
4	464659h
5	429041h
6	388150h

It is important to highlight the function of the external STS in the configuration (N+1), which represents a system reliability increase.

However, in the N+2 case, there was a decrease in the reliability in the cases of three and four units, for these associations present a MTBF higher than the one of the STS itself. This must be reminded when the client requests a highly reliable system. The N+2 configuration with three units, without STS, presents an MTBF of 186 years!

VII. COMPARING THE CONFIGURATIONS

A system with two units, including STS will be considered.

TABLE V
Comparison between Series and Parallel Redundancy

Configuration			
Topic	**Parallel**	**Series**	**Best**
Global MTBF	444469h	499356h	Series
MTTR	Low	Low	Tie
Price	2 UPS + External STS	2 UPS	Series
Installation	More Complex and Slow	Simple and Faster	Series
Load Sharing	Yes	No	Parallel
Strength to Overload	Higher Shared Between the Units	Subjected to the Rated Power of Each Unit	Parallel
Load Transfer in Case of Failure	Yes	Yes	Tie
Maintenance	Yes	Demands Only one of the Units in the Bypass	Tie
Possibility to Increase Rated Power	Yes	No	Parallel
Model and/or rated power Flexibility	No	Yes	Series
Efficiency	Below the Nominal Rated Power	Nominal, but one Unit with no Load	Parallel

VIII. CONCLUSION

This paper was written to demonstrate the properties and main differences between the Single, Series Redundant and Parallel Redundant UPS configurations. Numerical results of MTBF were presented of each one. Comparative between Series and Parallel mode was presented too, supplying to the user subsidies to choose the best economical and technical configuration, leading in account the system reliability, the investment to be made in the installation and the system expansion already installed.

REFERENCES

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[2] E.E. Lewis, “Introduction to Reliability Engineering”, John Wiley & Sons Inc., 1987.
[3] M. Suri, A. Pedra, “UPS Reliability and System Configuration”, *Power Quality*, September 1992.