AN004

Parallel and Series Connection of Power Supplies

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1 Parallel Use of Switching Mode Power Supplies (SMPS)

Modern applications may require the use of several SMPS in parallel configurations.
SMPS can be used in parallel configuration for 2 main reasons:

1) For **increasing the available power** to the load (*paralleling for power* - abbreviated "**PP**") by using the same type of power supply
2) For creating **redundant systems** (*paralleling for redundancy* - abbreviated "**PR**")

PP can be used in those applications where:
   a) there is an increase of load exceeding the nominal power of the installed units
   b) the load needs exceed the power available by 1 standard unit and there is no bigger unit rated for satisfying the needs

PR may be used in those applications where the load loss is unacceptable by the failure of 1 or more units powering a critical load.

1.1 Paralleling for Power (PP)

In theory **PP** can be used with any kind of power supply of same type, but the practical results may be unsatisfying. Many suppliers define their units as **PP** compliant, independently of the used technology. This is not always true.

The main problem related to PP is the correct ***current sharing*** between the various SMPS. Ideally, for a perfect current share the various SMPS have to present identical output impedances and also closest possible output voltage set-up. This is not guaranteed in time due to normal dispersion of the output parameters and ageing/ temperature factors. Besides, during transitory regimes (e.g. start-up, overload, short circuit, etc.) the behavior of the system may become unstable.

Unbalanced currents may lead to **premature aging** of the most stressed units with negative consequence on the system reliability.

In order to achieve the best current sharing the SMPS may use various techniques as:

1) dedicated **load share bus (LSB)**. This solution uses a communication bus between the units and it is mostly present in the high end, high power products. This solution is present in our NPS2400 units.
2) specific **regulation algorithms** (**SRA**). This solution, relatively cheap, does not need any communication bus and achieves a good natural current balancing between the various units. This solution is present in most of the NEXTYS SMPS, as NPSM121/241/481 and NPST501/721/961.
3) external **active redundancy module** (**ARM** - as OR20 or OR50 by NEXTYS). In this case the ARM has also a role in balancing the output impedance of the 2 feeding SMPS. Any SMPS could be used in this configuration, but a test is recommended.

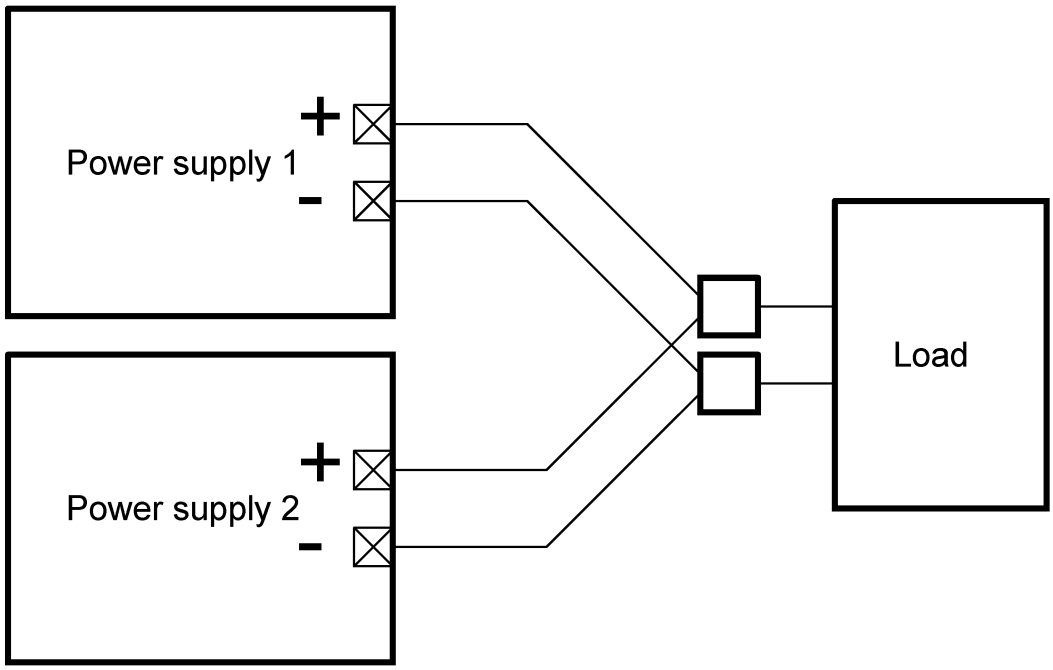

Figure 1: recommended connection for **PP** operation

As basic rules for **PP** operation (Figure 1):

1) Consider that the **available system power** is not the **sum of the system units powers**, but **maximum 80% of it**. There is no perfect current share!
2) Use always **identical units**, possibly from same batch
3) Avoid the use of units that have the **current limitation based on hiccup, fold back or latch modes.** Prefer **CC (Constant Current) mode** SMPS.
4) If present, set the current limitation mode in **CC (Constant Current) mode**.
5) Try to **limit the number of units** (normally <4)
6) Place the units in such manner to assure as much as possible the **same operating temperature** for each
7) Before making the parallel connection wiring: set-up **all output voltages** at low load on each (about 10% of the nominal rating) with the same value, **closest possible** (< +/- 20mV)
8) Use **same wiring length and thickness** from each unit towards the load. The leads should converge at the load, not at the power supplies. This improves the symmetry. DO NOT DAISY CHAIN THE OUTPUTS!
9) **Control the current sharing after 30 min. of operation** and **adjust the output voltages** again in order to balance the currents

1.2 Paralleling for Redundancy (PR)

Redundancy is requested when powering a critical load.
The idea behind a redundant supply concept is to safeguard the entire system supply in the event of a power supply failure, i.e. the maximum total current needs to remain available in any situation. This means that the total current has to be provided by several power supplies.
In addition to these power supplies, at least one more power supply needs to be used as a back-up device in order for the total current to be kept available in the event of a power supply failure (n+1 redundancy). The greater the number of additional power supplies used, the greater the fault tolerance (n + m redundancy; m = the number of additional power supplies).
To achieve a reliable form of redundancy, the outputs of all the power supplies connected in parallel must be isolated by means of ORing (redundancy) circuitry (diodes or MOSFETs). If one of the devices should fail, this prevents a short circuit from occurring for the other units and stops a fault current from flowing back into the defective power supply unit.
The redundancy circuitry can be hosted by the SMPS itself or by an external redundancy module (ORing), as OR20 and OR50 by NEXTYS.

As a **quite unique feature** most of the NEXTYS SMPS models provide a "**P**" version (includes internal ORing circuitry) which allows the building of a **PR** system without the need of external modules/ parts, **decreasing dramatically the cost and size of the PR systems.**

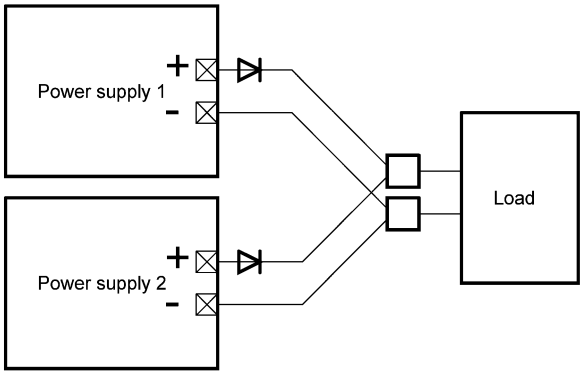

Figure 2: PR connection with ORing diodes (may be integrated in the power supply)

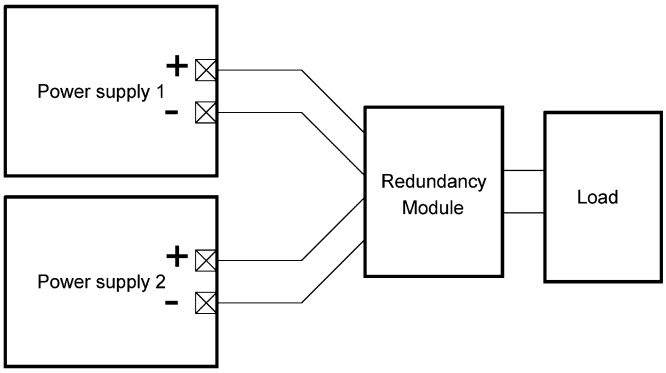

Figure 3: PR connection with external ORing module

As basic rules for **PR** implementation (Figures 2, 3):

1) Define the "**m" parameter from "n+m"** in order to achieve the requested redundancy
2) Pay attention to the **ORing rating for current and voltage**, assuming that at one moment one SMPS may take all load.
3) Use always **identical units**, possibly from same batch
4) By correct output voltage trimming try to balance **the current share** on all units in order to keep them all "hot". The use of all units as suppliers to the load increase the life time of the system.
5) Place the units in such manner to assure as much as possible the **same operating temperature** for each
6) Use **same wiring length and thickness** from each unit towards the load. The leads should converge at the load, not at the power supplies. This improves the symmetry.

2 Series Connection of Power Supplies

Various applications may require the use of several SMPS with **series connection (SC)** of their output.
SMPS can be used in series configuration mainly for achieving a **level of voltage or power** not available with a single standard unit.

In theory any 2 or more power supplies can be connected in series, independently of their output voltages. Some attention has to be paid anyhow.

Remarks:

1) The **highest available current** in the system is the one of the **lowest current rated unit**
2) The total **available power** is the **product** between the **sum of the voltages** and **the highest available current. There is no derating as for PP systems.**
3) Units with **various input sources/output voltages/ power** can be connected in series
4) The **current limitation** of the system will follow the **one of the unit with lowest current threshold**

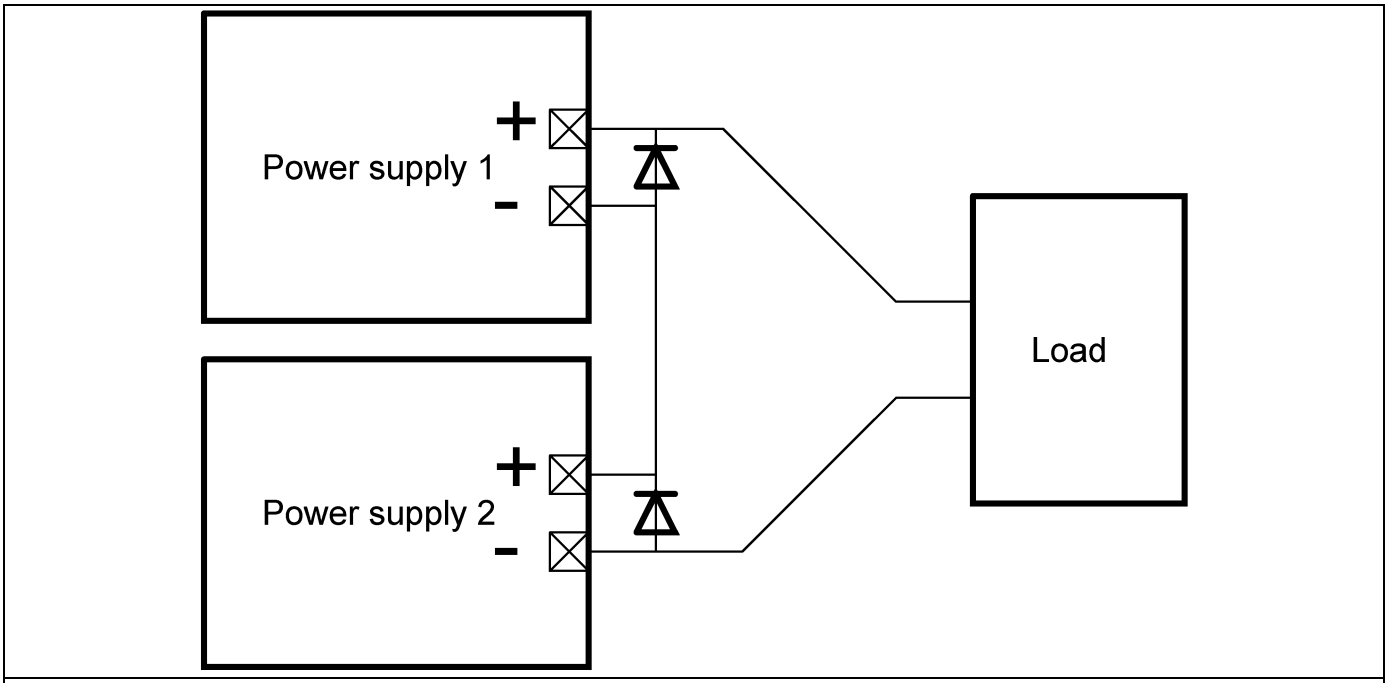

Figure 4: recommended connection for **SC** operation

As basic rules for **SC** implementation (Figure 4):

1) Try to use **identical units**, possibly supplied from **same source**
2) Pay attention to the **load needed current** in order to not overload any of the system units
3) Units may have **different start-up times**. In order to avoid reverse voltage on their outputs due to the earlier start of some units in the system an **anti-parallel diode (rated to the maximum voltage of the system and to with a peak surge current at least equal to the nominal current**) has to be connected to each output
4) Pay attention to the **safety rules** in relation to the **system voltage** if it exceeds dangerous levels (> 60 Vdc)
5) Use **correctly rated wiring that should connect in DAISY chain** the units towards the load.
6) Avoid using **too many units** (> 4) in series.

3 Final Considerations

Although widely used, it is recommended to avoid the **PP** configuration. We prefer the **SC** instead, which gives better stability and use of the SMPS.
PR configuration is useful in many critical applications and we strongly recommend the system designers to consider it, by using adequate rating and redundancy connection (by internal ORing or by external redundancy module).