

by Dipl.-Wirt.-Ing. (FH) Thomas Wälker -  
(engineering/business management degree)

## Redundant power supplies and parallel operation of power supply units

### How to achieve the best price/performance ratio

The typical goal of connecting power supplies in parallel is to obtain a higher output rating or to maximize operational reliability through redundancy. This article sheds light on a number of aspects to be considered and explains how to achieve the best possible price/performance ratio.

The following points should be considered when connecting power supplies in parallel to increase power output or to configure a redundant electrical supply:

- Use only identical power supply units: Since different device types rarely have the same regulating characteristics, two devices will behave differently under both static and dynamic load conditions and will therefore, at best, share load unevenly when connected in parallel. In the worst case, resonance and component failure can occur.
- Do not mount devices on top of one another: If units are stacked, the bottom device will heat up the one above, which will reduce its life and increase the probability of failure. Always mount devices side-by-side.
- Adequately protect the device input: Inrush currents are additive when power supplies are switched on at the same time! It is important to select products with low inrush currents when several devices are connected in parallel.
- EMC (EN 61000-3-2): Harmonic emissions and power factor increase when power supplies are connected in parallel. Always use devices that perform significantly better than the specified maximum allowable values.
- Connect output leads together at a single distribution node

(Figure 1): Do not directly interconnect devices, even though the large double terminals on the PULS power supplies allows you to do this. The individual connecting terminals are not typically rated for the higher currents experienced during parallel operation and would be overloaded. For passive current sharing, all outputs should be connected together at a single distribution node using leads that have the same length and cross section, so that the operating point of the individual supplies does not shift as a result of different voltage drops across the leads. The individual supplies should have an adjustable output, which should be set as close to same value as possible.

- Pay attention to start-up performance: Switch-mode power supplies take a little time to reach steady state (typically between 0.3 and 1.5 seconds). Since this time range varies quite significantly, supplies connected in parallel may have

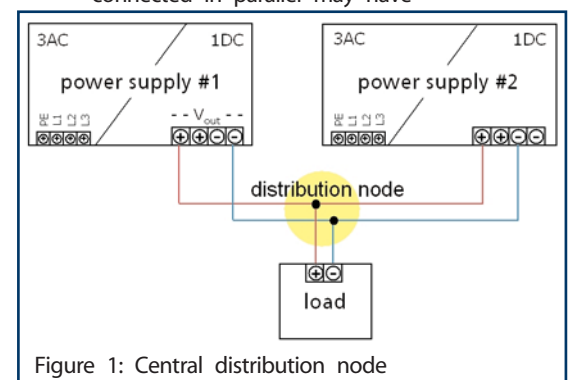


Figure 1: Central distribution node

start-up problems. A power supply that reaches steady state faster than its partner will be overloaded and could shut down before the second unit is able to assume its share of the load. This is why several start-up attempts are sometimes required for this type of configuration. Parallel supplies will start up on the first attempt if the start-up interval is shorter than the time it takes the units to shut down on overload. It is best not to use devices that are designed with hiccup current limiting.

- Behavior for load step changes/ dynamic behavior: Switch-mode power supplies have an internal auxiliary supply for their control circuits. On initial start-up, the line voltage charges up a capacitor that supplies the auxiliary voltage. As soon as the unit's power section is ready, it takes over and also supplies auxiliary power. If two devices operating in parallel are very lightly loaded, one unit's power section will shut down. This interrupts the auxiliary voltage, which must be brought back up the same way it was for start-up. If there is now a step-change in the load, there will be a delay before this unit is able to assume its share (typically around 500 ms), while the other device will temporarily go into current limit and cause the output voltage to reduce. Auxiliary power should therefore always be available for units that are to be connected in parallel, even under no-load conditions. This will ensure that all the power supplies instantly share current in the event of a step-change in load.
- Power back immunity: The power back immunity of a power supply determines the external voltage that may be connected to the device output without damaging it. If a

power supply does not have an adequate power back immunity rating, a supplementary external series diode must be used to protect its output from higher voltages resulting from parallel connection or other causes.

#### Simple parallel circuit

If a power supply is said to be "parallel capable", it basically only means that two or more power supplies will not be damaged if connected in parallel (assuming compliance with the relevant manufacturers' specifications). The critical parameter is its power back immunity rating. A parallel capable designation does not define how power supplies will share load current or how they behave during start-up and load swings. When two standard units are connected in parallel and their output voltages matched as closely as possible, their high regulating accuracy usually results in the following when load is applied (see box and figure 2): Power supply number one supplies load current up to its current limit rating and power supply number two delivers the remaining load current. If the parallel connection is being used to satisfy redundancy requirements and the load is being fed from dif ferent

sources (e.g., AC line and battery), this mode of operation may be desirable to avoid using one of the sources (battery). If, however, the parallel connection is designed to deliver more power, the unequal sharing can have serious consequences. Both the reliability and the life of a power supply that operates continuously at current limit are reduced considerably. This leads to premature aging and causes premature failure of the overall system. Power supplies should therefore always share load equally. There are primarily two ways to achieve this objective:

Parallel connection featuring passive current sharing – devices with sloped output characteristic  
 Passive current sharing circuits are designed so that the output voltage is reduced slightly as output current increases. The output characteristic is considered sloped or soft (figure 3), and the output voltage drops by four to five percent, or one volt, between no load and full load. If, because of its load, the voltage of one device is lower than that of its partner, the second device has a greater current burden until it in turn has the lower voltage. How evenly the devices share current depends on how precisely the

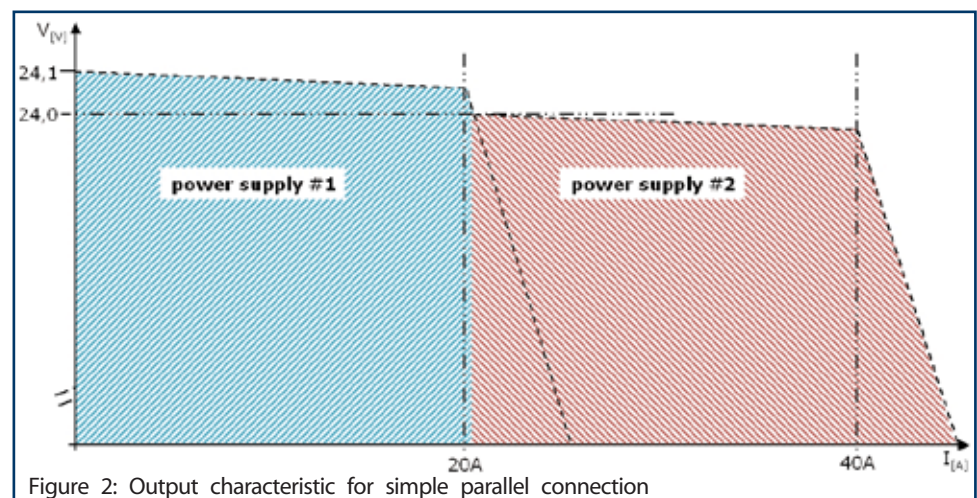


Figure 2: Output characteristic for simple parallel connection

Unequal load-current sharing (figure 2) occurs because in practice, no two devices will have the same output voltage. For example, output voltage on power supply no.1 may be 24.1 V, and on power supply no. 2 it may be 24.0 V. If the outputs of the two units are now connected in parallel, 24.1 V will also appear at the output of power supply no. 2. As a result, the voltage is higher than the setpoint. The regulator attempts to compensate and reduces the output current. Power supply no.1 delivers current to the load to the point where it reaches current limit and subsequently lowers the output voltage. At this point, the voltage at the output of power supply no. 2 finally falls below the setpoint and its regulator raises the output current level.

output voltages of all the power supplies are matched to one another. In addition, as stated above, all outputs must be tied together at a single distribution node. Soft output regulation by means of a sloped characteristic is acceptable for many applications. PULS has therefore chosen this economical, passive current-sharing method for most of its parallel-capable power supplies, and even offers it with a selectable output characteristic. In the "single use" (factory setting) position, the devices feature a stable "hard" regulation mode in which output voltage remains completely constant and is independent of load current. The "soft" characteristic is applied when the unit is switched to "parallel use"

operation. This cost-effective solution for single or parallel operation using one device reduces both the number of variants and inventory requirements. Examples from the PULS product family include the single-phase ML100 and the three-phase SL10.300. Parallel connection featuring active current sharing – utilize interconnected control loops to achieve load sharing.

The control loops on devices involved in active current sharing are tied together through a balancing circuit. As a result, the control loops themselves ensure that each power supply shares current equally under all conditions. The output characteristic does not need to be sloped since the output voltage is absolutely constant across

the entire load profile. Furthermore, in contrast to passive current sharing, active current sharing is unaffected by voltage tolerances and the way the outputs are connected together. However, this method is more costly, in terms of both design and installation, since the devices now need to precisely measure current and require extra current regulators, as well as additional external terminations and wiring. The PULS family of products includes the SL40.301, a three-phase, 40-amp power supply that features active current sharing (figure 4). When connected in parallel, the control loops of these power supplies are interconnected by means of control wiring.

## Continuously operating a power supply at maximum load significantly reduces its reliability and shortens its life

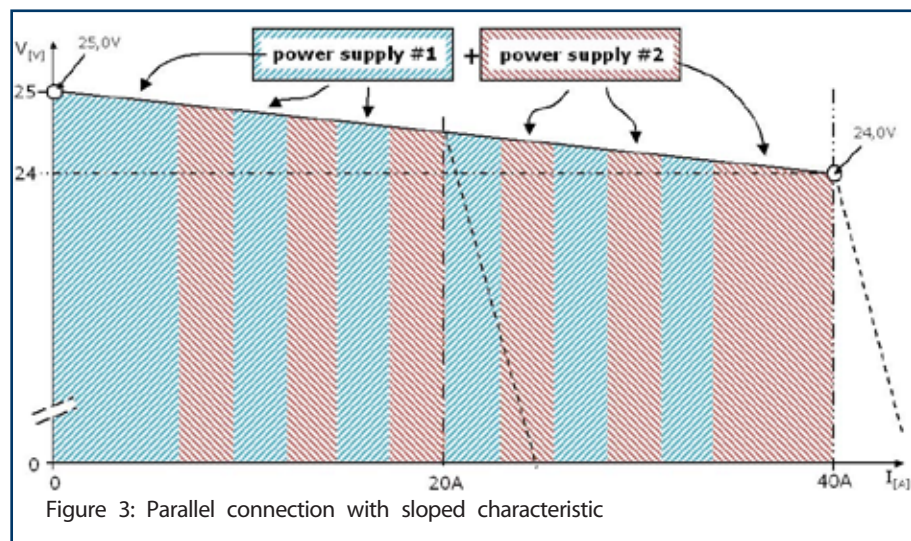


Figure 3: Parallel connection with sloped characteristic

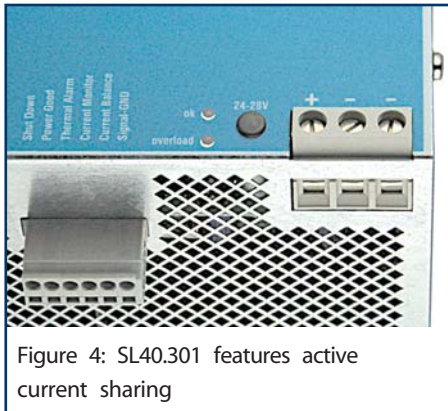


Figure 4: SL40.301 features active current sharing

**Redundant power supplies**

Redundant power supplies are used to ensure maximum reliability. In this configuration, one additional power supply operates in parallel, so that if a unit fails, the remainder can safely supply the entire load. This type of redundancy is called "n+ redundancy". Of course, it is also possible to use more than one parallel unit; i.e., M power supplies, in order to achieve even greater reliability. This configuration is described as "N+M redundancy". But in addition to just straightforward paralleling, failsafe power supply designs need to consider the following:

- Operating below current limit: The design must ensure that none of the devices operate at maximum load or current limit, so that they do not overheat and age or fail prematurely.
- Decoupling: Under worst-case conditions, a unit may fail in a shorted state and could act as a current sink for all the other devices. The power supplies must therefore be decoupled from one another. This can be achieved by means of an external decoupling diode, such as the PULS MLY02.100, or it may already be

integrated into the power supply as in the PULS redundant power supplies type SLR2.100, SLR5.100 and SLR10.100.

- Fault indication and alarm signals: Power supplies used in a redundant operation scheme must be monitored for failure to ensure that a problem can be rectified quickly. Fault indications and/or alarm signals are therefore necessary.
- An LED mounted on the device is one way to achieve this, or for greater flexibility, a dry relay contact that serves as a ready signal can be provided.
- PULS redundant power supplies and modules are equipped with these feature.
- Operating on different phases: The best redundant power supply design would be useless if all devices were connected to a single phase that could subsequently fail. It is therefore advisable to distribute the individual power supplies in a sin-

gle-phase redundant power supply scheme evenly across three phases (figure 5 ). The power supply ratings are chosen so that the remaining devices are able to supply the total connected load in the event of a phase failure. In the case of three-phase power supplies, individual units must be rated for continuous operation on two phases and to deliver the current needed to maintain operation.

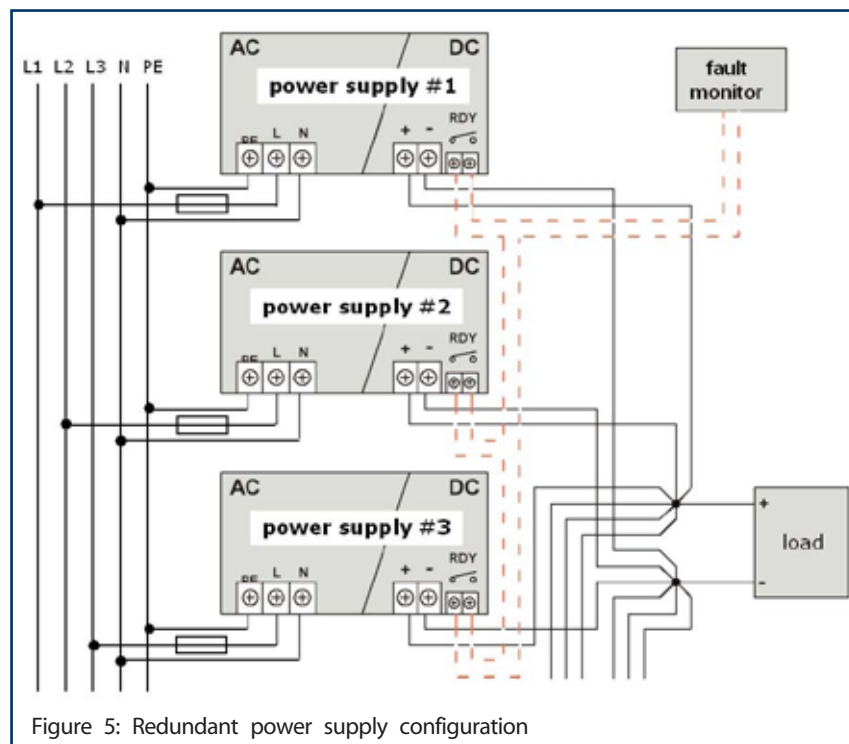


Figure 5: Redundant power supply configuration

**Conclusion:**

The basic requirement of parallel-capable power supplies is simply that they not be damaged when operating in parallel.

The objective of true parallel operation is to ensure equal loading through either passive or active current sharing. Over and above that, it is to optimize the behavior of the individual parallel-connected power supplies during start-up, or during step load changes and AC supply failures. Redundant operation goes one step further and maximizes reliability and availability. Power supply fault monitoring and

signalling is provided. Decoupling minimizes the risk of the entire power supply system and ensures that at least one additional power supply is continuously available to operate in parallel.

The design must not only consider power supply faults, but also complete failure of one of the supply phases. In order to address all the different requirements cost-effectively, the PULS product family includes inexpensive power supplies with passive or active current-sharing capability for individual or parallel operation, special redundant power supplies

with integrated decoupling, alarm and indicating features, as well as special decoupling and redundancy modules for designing redundant circuits using non-redundant capable power supplies.



Product brochures describing both our parallel-capable power supplies featuring passive or active current sharing and other power supplies are available on request or on our website.