Advel Application Note – AAN2009.1

DIN-rail systems in redundancy, current sharing and decoupling diodes

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1. Introduction

The use of redundant power supply systems is necessary for applications that require maximum reliability, and then typically for DCS, SCADA systems, PLC, ESD, F & G, BMD, security systems, fire detection, telecommunications ...

What happens when you put more power supplies in parallel? What features you should consider when choosing the power supplies for use in redundant systems?

2. Practical example

Consider to put two power supplies parallel: both have a regulated output at 24V (nominal voltage).

Now suppose that for some reason, the two output voltages are not identical: the first for example is 24.1V and the second is 23.9V (which is a very common event: it is very difficult that two power supplies are calibrated at exactly the same value of output voltage, because this can change over time due to internal component tolerances, that aging or heating can change their parameters). For simplicity, we consider that the cables are ideal (in reality it's not true, but for the moment it's not important).

The situation is shown in Figure 1.

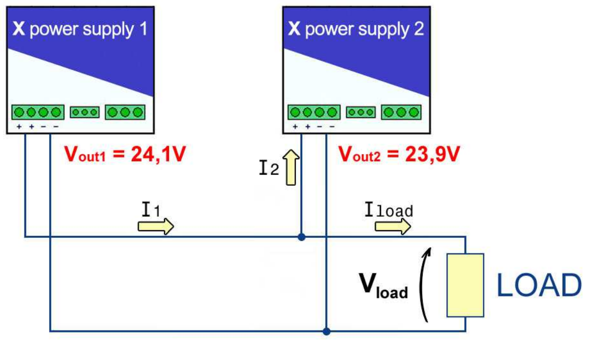

Figure1 *– Two power supplies in parallel, with output voltage not perfectly identical*

What happens in the case of Figure 1? It can be understood making a simple physical consideration: "*the current always flows from a high voltage to a lower voltage*". So in the example in Figure 1, where $V_{out1} > V_{out2}$, it happens that a part of current tends to flow towards the power supply n.2, which has the lowest output voltage, and then the power supply n.1 power entirely the load.

Remembering that we assumed the connection cables are ideal (so with no impedance, and then the voltage drop on the cables is equal to 0V), we have:

$$V_{load} = 24.1V$$
$$I_1 = I_{load} + I_2$$

In this case it's risky when one of two power supplies goes in fault. Suppose the worst case of failure with short circuit on the output of the power supply n.2: in this case power supply n.1 has a short circuit on it's output, then the V_{out1} goes to zero and the load is unpowered.

To prevent this situation it's necessary the use of decoupling diodes (Figure 2).

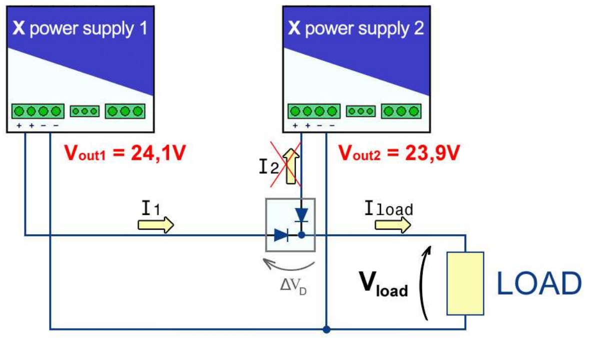

Figure2 *– Two power supplies in parallel, with output voltage not perfectly identical, but outputs decoupled by external diodes*

The decoupling diodes allow to realyze a **redundant** system: in case of failure of one of the n power supplies in parallel, assuming the worst case of short circuit on a power supply, the remaining power supplies continue to provide the service. With decoupling diodes the redundant system can be defined *fault tolerant*.

In this case, again assuming wiring ideal, we have:

$$V_{load} = 24.1V - \Delta V_D$$
$$I_1 = I_{load}$$
$$I_2 = 0$$

The presence of decoupling diodes makes the two power supply run in parallel safely.

3. Power suplies in parallel

There are three types of parallel systems:

- power supplies "simply" in parallel,

- power supplies in parallel with passive current sharing,
- power supplies in parallel with active current sharing.

In short: if the purpose is only the redundancy, the use of two power supplies “simply” in parallel could be a sufficient solution in this case: <u>both power supplies must be able to withstand safely the full load</u>.

However, in reference to the example in Figure 2, only one of two power works and therefore heats up, and that it reduces the average life of the system.
Without making unnecessary calculations, we can say that the average lifetime (or MTBF) of a device is inversely proportional to the square of the working temperature inside the device. Then, given a system of two power supplies in parallel, is more reliable a system in which the two power supplies equally share the current load, rather than a system where only one of two power supply works (the concept is extended for more than two power supplies in parallel, of course).
Hence the importance of load sharing between power supplies in parallel.

4. Power supplies in parallel with passive current sharing

In this type of power supplies, the control circuits of V_{out} are designed so that the output voltage is reduced slightly with increasing current. It will result in a smooth curve of the output voltage, which falls in function of the load and that of course becomes very steep when the current exceeds the maximum current $I_{out,max}$.
This type of power supplies, easy to realize and therefore favored by the vast majority of power supplies manufacturers on the market, has some drawbacks:

- the V_{load} is no longer well stabilized, and in fact it depends on the load. In a 24V system it can go down up to 1V due to the passive current sharing behavior, which must be added to the drop cables (not always negligible) and the voltage drop on external decoupling diodes (typically 0.4 ÷ 0.7V depending on load current).
- The current sharing is not perfectly equal between the power supplies in parallel.

5. Power supplies in parallel with active current sharing

In this type of power supplies, the control circuits are designed to ensure that each power supply provides the same current in all conditions. The result will be a fair current sharing between the power supplies in parallel, immune to any differences in the calibration of power supplies or to wiring not well done (Figure 5, below). Of course, this type of control can lead to an extracost in this type of power supply.

6. Advel power supplies

Advel power supplies have many advantages compared to many other power supplies on the market.
Figure 3 shows the same redundant system originally defined, but built with power supplies series **DZ1** manufactured by Advel, which have <u>internal</u> decoupling diode and <u>active</u> current sharing device.

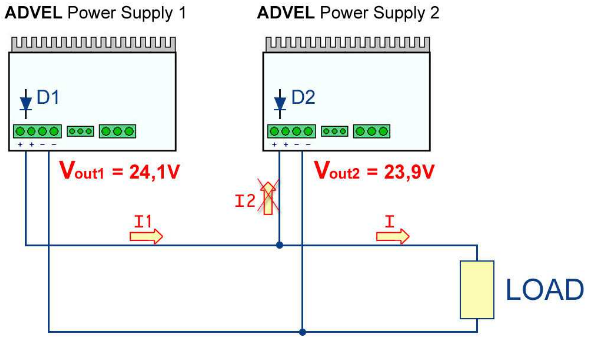

Figure3 *– Two power supplies in parallel (DZ1 Advel series), with output voltage not perfectly identical, but outputs decoupled with internal diodes*

The Advel choice of placing the decoupling diode <u>inside</u> the power supply, has several advantages:

- ease of wiring;
- compensation of decoupling diode voltage drop ΔV_D, through the internal feedback control of V_{out};
- it is easier to calibrate the power supplies in parallel to the same V_{out}, thus obtaining a good sharing of the load current. Conversely, if the diodes were external, it would be very difficult to calibrate the power supplies at the same V_{out} precisely cause of the great variability of the voltage drop on diodes (depending on temperature and load current).

The **DZ1** power supplies manufactured by Advel must be interconnected via a cable, said **CS** (Current Sharing) to enable the <u>active</u> load sharing between power supplies in parallel, however, the lack of such interconnection does not affect their operation: the power supply will work just in passive current sharing mode.

7. The importance of wiring

The wiring between power supplies in parallel, if not well done, may compromise the sharing of power between the two (or more) power supplies in parallel, because the voltage drop on the wires is not always negligible.
This is well described in Figure 4.

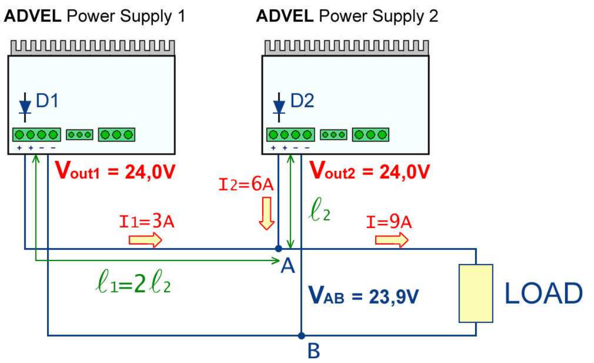

Figure4 *– Two power supplies (Advel) in parallel with output voltages exactly identical, but wiring is not well done*

In the example in Figure 4, the two power supplies are both calibrated at V_{out} = 24.0V, however, they have been put in parallel using wires of different lengths. The voltage drop on each wire is inversely proportional to the length of the wire, and consequently the currents are different.

In the example in Figure 4, the cable ℓ_1 is twice long the cable ℓ_2 and therefore we have:

$$I_2 = 2 \cdot I_1$$

Also note that the voltage of the load is lower than 24V, due to the voltage drop on the cables (supposed 0.1V in this example).

It is obvious that to have a good current sharing, power supplies must be made in parallel using cables of equal length ("star" wiring), as well as being perfectly calibrated.

Of course, the active current sharing allows a fair sharing of the load current between the power supplies in parallel, regardless of the wiring, as showed in Figure 5: the three power supplies equally split the load current.

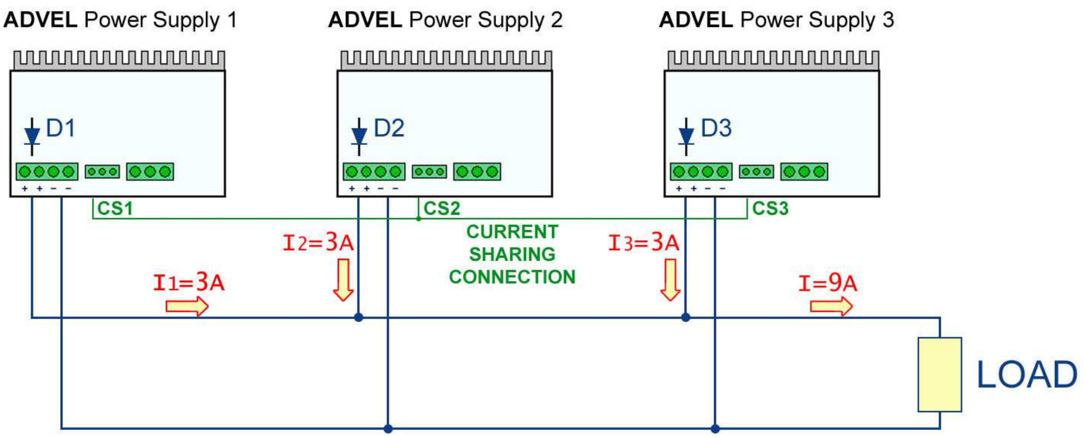

Figura5 *–Three power supplies (Advel) in parallel, with CS interconnection, to enable the active current sharing*

8. Conclusions

Have been shown the benefits, in a system of parallel or redundant power supplies, of calibration of the output voltages of power supplies, of decoupling diodes, of wiring.

The power supplies **DZ1** manufactured by Advel are designed to achieve maximum benefit in terms of:

- accuracy and ease of wiring (thanks to the internal decoupling diodes),
- reliability of the system (due to active current sharing).

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