Advel Application Note – AAN2008.2

Wiring many loads on a single power supply

Eng. Alessio Spinosi

1. Introduction

Using a single power supply for powering multiple devices presents a first problem: if the power supply fails, all devices powered by it turn off; this problem is around easily using a redundant power supply system (n +1 or n + n).

Much more difficult to get around is another problem: what happens when one device goes in short circuit? It's important to understand the implications of this problem, to take the necessary precautions.

2. Practical example

Let's consider a power supply 250W - 24V (I_{max} = 10A) with a LOAD, as in Figure 1.

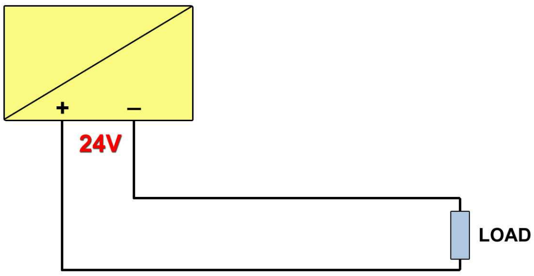

Figure1 *– A power supply with a load*

In this case, if the LOAD is short-circuited, the power supply of course tends to go to zero volts. Typically a good power supply can sustain a short circuit output: V_{out} will stay approximately at 0V, and I_{out} may be more than the I_{max} (typically 30-50%).

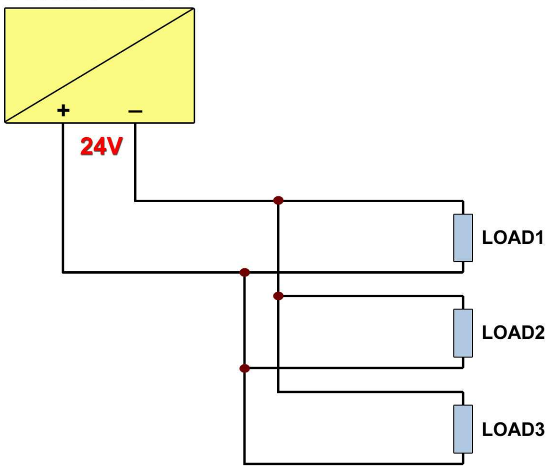

Figure2 *– A power supply with more individual LOADs*

Consider the same power supply 250W - 24V (I_{max} = 10A) with multiple loads, LOAD1, LOAD2, LOAD3, as shown in Figure 2.

In this case, if a LOAD is in short circuit (just one of the 3) the power supply of course tends to go to zero volts, so the remaining LOADs are not powered!

For this reason, it is a good idea to put protections in series with each one of the LOADs, for example a simple fuse or (better) a circuit breaker, properly sized (Figure 3). The type of breaker depends on the following factors, mainly:

- nominal load current,
- load (inrush current, ...)
- wiring impedance (length, size, ...)
- characteristics of the power supply.

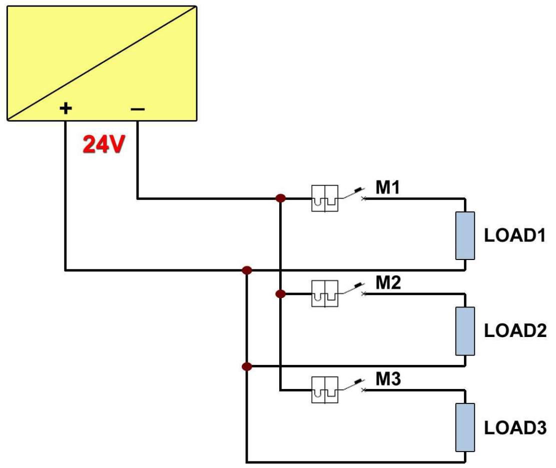

Figure3 *– A power supply with more individual loads and circuit breakers for each load.*

3. Brief qualitative considerations on the circuit breakers

Considering the example of Figure 3:

the "ideal" circuit breaker, in case of short circuit of one of LOADs, opens instantly, thus preventing the power supply voltage to drop to 0 volts, so preventing others LOAD remain unpowered.

Obviously the breakers don't open immediately, but need about 10-15msec to open in case of sudden overcoming of the threshold current.

There are several "operation curves" that define the type of circuit breaker (...); is not helpful now to get in the technical details of circuit breakers, so it wont be considered the "thermic" but only the "magnetic" circuit breaker characteristic.

Briefly, we can consider that:

- a curve B circuit breaker opens in about 10msec if the current exceeds about 3 times the Inom;
- a curve C circuit breaker opens in about 10msec if the current exceeds about 6 times the Inom;
- a curve D circuit breaker opens in about 10msec if the current exceeds about 10 times the Inom.

4. Power supply requirements

Suppose in our example to choose a 10A circuit breaker curve C (the most used): it opens in about 10-15ms if the threshold of 60A is passed.
The first question is: if LOAD1 is short-circuited, does its magnetic **M1** (10A, Curve C) opens in time to prevent the output voltage going to zero?
<u>First of all it's necessary the power supply is able to provide 60A, otherwise the circuit breaker will not open.</u>

So in such a system it is essential the power supply is able to provide an Icc-pk (short circuit current peak), above the threshold of intervention of the circuit breaker.

The second question is: how much current is "requested" by the short circuit?
Applying the Ohm's Law: if LOAD1 goes in short, the short-circuit current required is:

$$I_{1\ c.c.} = \frac{voltage\ applied\ to\ the\ \ faulty\ circuit}{faulted\ circuit\ impedance}$$

Assuming that LOAD1 goes in <u>net</u> short circuit (worst case), the impedance of the faulty circuit depends on the resistance of the cable. For example, a 10m long cable, section 4mmq, has a resistance of $50m\Omega$, and the current required by the short circuit is equal to:

$$I_{1\ c.c.} = \frac{24V}{50m\Omega} = 480A$$

(we can define it **Icc-wc**, or short-circuit current in the worst case)

So the second requirement is that the power supply is able to provide a current Icc-wc (short-circuit current in the worst case) for 10-15msec before Vout drops to 0V.

5. The power supplies SPS manufactured by Advel

Consider the power supply **SPS251DZ1** output 24V (Imax = 10A) manufactured by Advel.

In Figure 4 is showed the evolution of the output current after giving a short circuit on the output terminals.

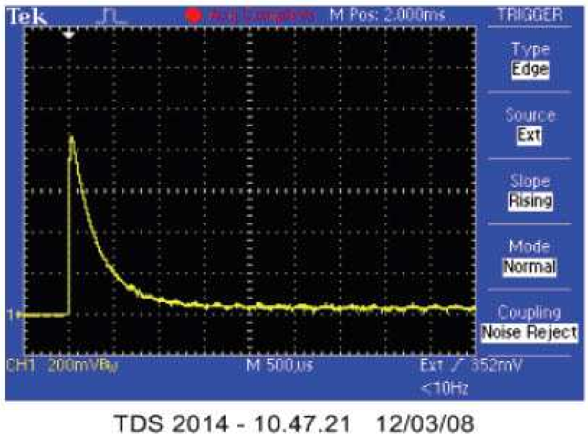

Figure4 *– Curve of Iout after a short circuit on the output terminals of a power supply SPS251DZ1 (Advel).*

Figure 4 shows that the power supply SPS251DZ1 can provide a peak current of 430A, which then decays to about 15A, after few msec (largely satisfying the new Machinery Directive EN60204-1).
In this extreme case, the circuit breaker certainly opens, but the Vout does not remain at 24V for 10-15ms (so the first is respected but not the second requirement, according to the initial example) therefore if LOAD1 goes in short circuit, M1 opens but for a moment LOAD2 and LOAD3 remain unpowered.
The short circuit currents are typically hundreds of amps, in practical cases. It's the kind of short circuit, as well as the cable (length, size) that define the value of Icc-pk.
If the Icc-pk was "only" equal to 60A (that is 6 times the Inom) **SPS251DZ1** without doubt would be capable to support the 24VDC for 15msec, time necessary for the circuit breaker to open, <u>but how can we hope that the short circuit is such that it requires only 60A</u>?

6. Suggestion

To protect securely against all types of short circuit, it would be better that the LOADs were provided of special Hold-up circuits inside (or externally wired, as in Figure 5).

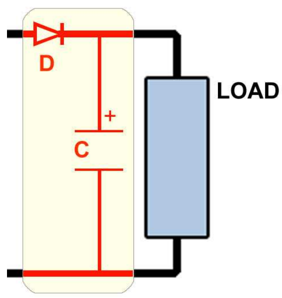

Figure5 *– Hold-up circuit on the input of each LOAD.*

With this simple circuit, in case of lack of the input voltage of the LOADs (that is the output voltage of the power supply), the electrolytic capacitor **C** (accordingly sized in function of the current and of the minimum operating voltage of the LOAD) takes the LOAD powered on for 15msec. The second requirement defined in paragraph 4 (difficult to pretend by the power supply), might therefore be overlooked. However, the costs of implementation of this system are often prohibitive, especially for several loads.

7. Conclusions

In the case of single power supply that powers multiple loads, it's necessary to insert in the input of each LOAD a fast protection, for instance an circuit breaker (not just a fuse), which opens in case of sudden short circuit of a LOAD. However, in this case it is unreasonable to require that the power supply can provide for a time of 15ms (intervention time of a circuit breaker) the current required by the short ($I_{cc\text{-}pk}$), basically because this depends on the type of short (in the worst-case of net short, $I_{cc\text{-}pk}$ would be in the hundreds Amperes).

A strategy for these systems is to use more power supplies of medium/small power for small groups of LOADs (Figure 6a), rather than using few big power supplies for large groups of LOADs (Figure 6b), even if the cost plant grows slightly.

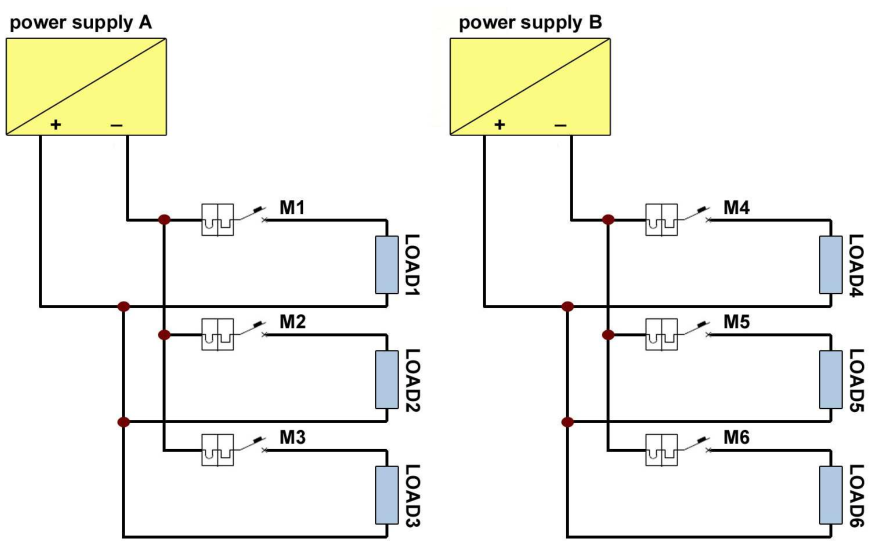

Figure6b *– Two power supplies give power to 3 LOADs each: in case of failure (short) on a LOAD, you can have only a disservice on the power of that small group*

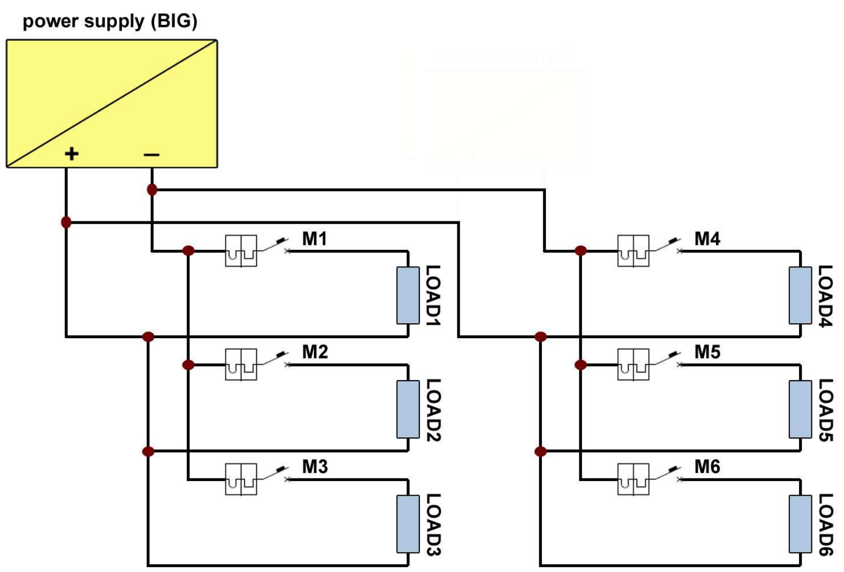

Figure6b *– Single power supply for 6 loads: in case of failure (short) on a load, you may be a disservice to all other loads.*

»ADVEL«
ELETTRONICA INDUSTRIALE
HEADQUARTER: Via Miglioli 13, Segrate 20090 MI (Italy)
Technical DPT: Eng. A.Spinosi, tec@advel.it