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Redundant Power Supplies in Mission-Critical Applications

Created by

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Abstract

There are many aspects to consider when designing a power supply that will specifically target the high-reliability applications. Power supply designers must take into account many key features of their design to ensure that the finished product is fit got purpose. One such method is to design with a certain amount of redundancy with your power supplies. This is where you increase the number of power supplies in a system to a point where your design will continue to function even in the event of a catastrophic failure of one or more of the power supplies.

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What is the Reliability of a Power Supply?

If we define the reliability of a power supply as the probability that it will continue to function within a certain operating period, then we start to understand the requirements that must go into a design in order to meet this criteria. The reliability will be directly impacted by the environment in which it must exist, but more importantly how the part has been designed to function within this environment.

Where are Redundant Power Systems Commonly Used?

Redundant power systems are commonly found in emergency, medical, security and communications systems, server rooms, and data centers. Deploying a redundant power solution is the most common way for these entities to increase system reliability. A redundant power system approach is much more cost effective than the alternative which is to over-engineer the power supply using high-grade components that are rated for a higher degree of thermal and electrical stress. Power supply engineers should note the cost and size penalties to either method of providing a high-reliability power source; however, a redundant system does provide greater ultimate reliability.

Redundancy vs. Reliability

In a system where one unit can support the load, and two units are used in parallel, the system is much more reliable than its component parts, since the system will still work even with one unit failed. Clearly, the probability of two units failing simultaneously is much less than that of one unit failing. This system would have a big size and cost penalty, (twice as big and twice as much) so normally an N+1 system is used, where N units can support the load, but N+1 units are used in parallel, "2+1" or "3+1" being the usual combinations.

Challenges of Designing a Robust Redundant System

While there are many challenges we pick out the top 4 items to discuss here. Many may also argue that only the first three are critical, but this will be application-dependent.

1. All N units must be rated to support full load.
2. Failure of any one component must not make the system fail.
3. If any component fails, this must be brought to the operator or system administrator's notice so that it can be replaced to ensure ongoing redundancy.
4. In some cases it may be a requirement to ensure that changing individual units must not make the system fail, referred to as "hot swap".

It does require some careful consideration to design the system to satisfy items 2 and 3. For example, the failure of components that do not effect system operation when all units are OK, but would effect operation if there was a fault (such as an isolating diode going short circuit, or a paralleling wire or connector going open circuit). This must be signaled as a problem and must be repaired. The circuitry necessary to arrange for all this (isolating diodes, signaling logic, hot plugging components, current sharing, etc.) has its own failure rate and degrades the overall system failure rate. In the following illustrations, this is ignored for simplicity, but in a real calculation, it must be taken into account. In many applications, the only way to detect such latent faults is to simulate a part failing by shutting it down remotely for a very short time. This circuitry will, of course, increase complexity and decrease reliability further still, as well as being dangerous. A system failure could be caused by the test circuit shutting the system down.

Availability

Availability is sometimes mentioned in this context, this is defined as:

$$\text{Availability} = \frac{\text{MTBF}}{\text{MTBF} + \text{MTTR}}$$

Where MTBF = Mean Time Between Failure

MTTR is the mean time to repair

For good, reliable systems, availability tends to be 0.99999…, where the mathematics get tedious and the number gets difficult to interpret. In such cases, unavailability is more meaningful, this being 1- Availability and is usually expressed in minutes/year (!).

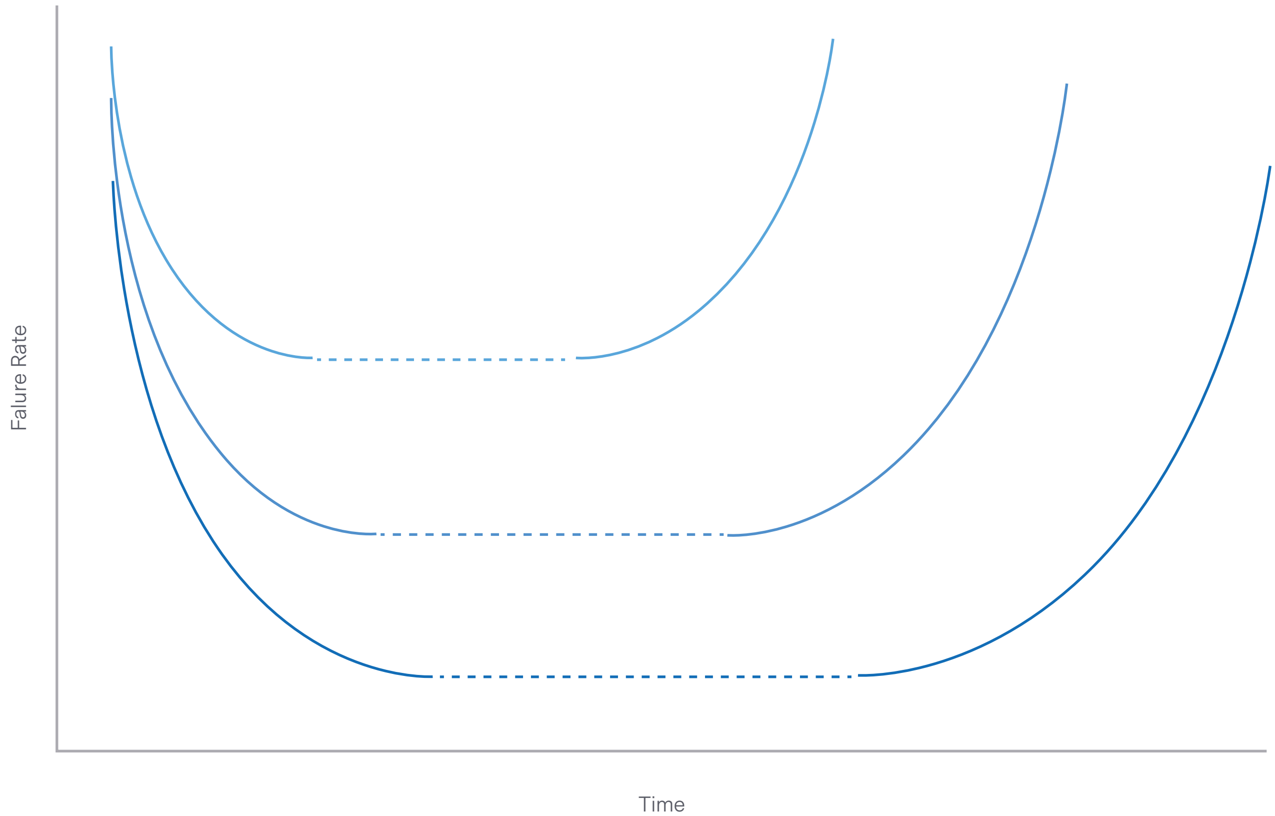
What is interesting to consider is that when using redundancy to improve availability, the service calls to repair system failures get much less frequent, but the service calls to repair part failures get more frequent. Since the object of the exercise is to maintain system availability, this is a small price to pay, but the costs of system failure should be weighed against the cost of service maintenance.

Reduce Costs while Simultaneously Improving System Availability

In some cases it is possible to either reduce costs or improve system availability further by partitioning (i.e., have different load-groups fed by different power-supply-groups). This is a subject in itself, but as an illustration the level of redundancy in a typical telephone exchange is as follows:

- Each system is powered by 1+1 redundant dc/dc inverters.
- Each system is duplicated in 1+! redundancy.
- Each bay and its supplies are partitioned.
- The power cables and connections are 1+1 redundant.
- There is a battery backup system for the dc supply, feeding independent, duplicated busbars.
- The AC/DC supplies feeding a bay and charging the batteries are 1+1 redundant.
- There is a diesel generator system to back up the ac supply (the mains).

Factors Effecting Reliability



Any kind of stress will have a direct impact on the failure rate of a power supply. The types of stress can typically involve:

- Thermal (temperature)
- Temperature rise (due to current)
- Environmental (vibration)
- Voltage

Any of the stresses above will act as accelerators to bringing components and effectively the power supply closer to its end of life wear out time. For example, a 10°C rise in component case temperature will reduce it's reliability by 50%. From an environmental point of view, a transistor with a failure rate of 1 in a ground benign (GB) application will increase to 320 for the same resistor being used in a cannon launch (CL) application as per MIL 217F transistor database. The same transistor with an operating voltage stress will drop from 1 (for 100% voltage rating) down to 0.54 if the voltage stress is reduce by 20%. For Generic failures rates of components choosing a Ceramic capacitor over a tantalum capacitor will reduce its failure rate by a factor of 5.

Summary and Conclusion

In order to increase the reliability of a system, the designer has two clear choices. Either choose more expensive components, or design with redundancy in mind. If the latter is chosen, then the considerations outlined above must be implemented or the result will simply be an over -designed, over-complex and under-performing system. More importantly, if a single fault condition occurs, there is a likelihood of the entire system shutting down.

About the Author

Shane holds a bachelor of engineering (honors) from Cork Institute of Technology. He was also awarded the title of chartered engineer by the Institute of Engineers of Ireland in 2002, and was elected to be Fellow in 2012. He currently holds the role of director of Innovation Engineering at Advanced Energy Industries, Inc.

Prior to joining Advanced Energy Industries, Inc., Shane joined the Excelsys Technologies team in early 2006, and he held the role of director of Applications Engineering. Prior to joining Excelsys, Technologies he held a number of senior engineering positions at Artesyn Technologies and also at EMC. He has considerable power supply design engineering experience and engineering team leadership experience in product development, NPI and customer program management.