

Power: Centralized or Distributed?

by: Robert Marchetti, Senior Product Manager
Vicor Corporation

The decision to use a centralized or a distributed power system is a fundamental design decision made at the beginning of the system design process. In the past, the centralized system, usually a custom design constructed of discrete components, was often chosen because it was less expensive. With the availability of modular, high-density and low-cost DC-DC converters, however, distributed power systems have become more attractive solutions. The photo to the right shows a comparison between a power supply implemented in discrete components and one with modular components.

Requirements for quick time-to-market, fault tolerance and high reliability are often mandated in markets served by embedded real-time systems. These issues are also among those particularly relevant in making the decision to employ a centralized or a distributed power system.

A centralized power supply contains the entire power supply — from the front end through the DC-DC conversion stages — in one housing. It converts the line voltage to the number of DC voltages

needed in the system and buses each voltage to the appropriate load. These systems, in general, work well when the power requirements, once defined, are not likely to change.

Distributed power systems are characterized by a front end box that converts the incoming AC to a single intermediate bus voltage, which is distributed to DC-DC con-

blocks used to create power solutions to meet individual user needs. They come in thousands of combinations of input voltage, output voltage and power level. They provide designers with proven, sophisticated electronic modules that, when combined with complementing modules (such as AC input modules), create a power system with stable, highly regulated output.

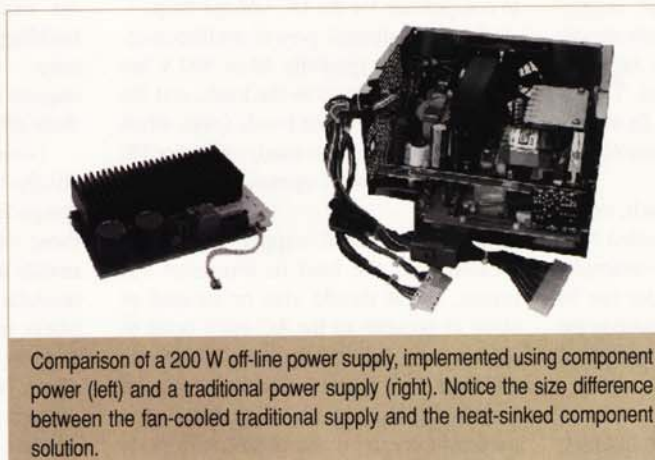
Although modular power components can be configured as centralized or distributed power systems, centralized systems will be considered here to be made of discrete components and distributed systems of modular components to avoid confusion.

Centralized Versus Distributed

Any design is a complex trade-off of many factors. A number of design issues are explored below, specifically

comparing the centralized and distributed power architectures.

Time-to-Market: The centralized power system designed using discrete components typically has a development cycle requiring six to nine months to design,



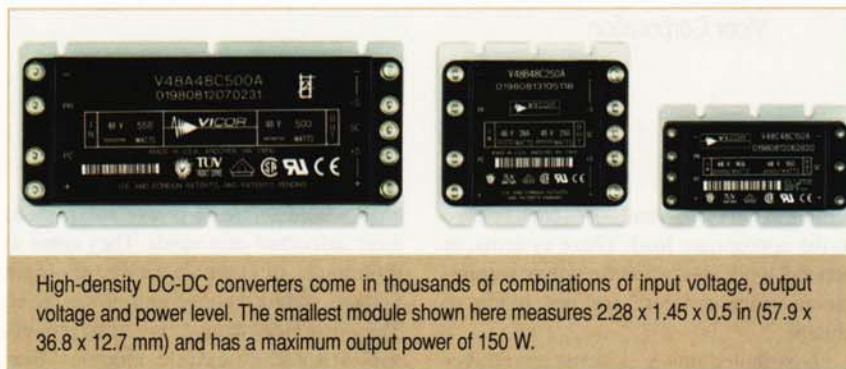
Comparison of a 200 W off-line power supply, implemented using component power (left) and a traditional power supply (right). Notice the size difference between the fan-cooled traditional supply and the heat-sinked component solution.

verter modules throughout the system. The basic architecture rectifies and filters the AC main voltage close to the point at which the AC enters the box and provides DC-DC conversion close to the point of load.

The component power modules shown in the photo on p. 68 are the basic building

breadboard, troubleshoot, lay out, prototype, debug and obtain agency approvals. As we have seen, changes can invalidate a discrete design, resulting in significant delays while the changes are made or the system redesigned.

With a wide variety of standard or custom inputs and outputs already designed, proven and readily available, prototype development time can be reduced dramatically with designs using component power modules. A modular design also simplifies the agency approval process because most modules have already earned approvals such as UL, VDE, CSA, CE and TUV.



High-density DC-DC converters come in thousands of combinations of input voltage, output voltage and power level. The smallest module shown here measures 2.28 x 1.45 x 0.5 in (57.9 x 36.8 x 12.7 mm) and has a maximum output power of 150 W.

Fault Tolerance: A power supply failure can cripple an entire system. Redundancy is one approach to increasing the reliability of a supply. Implementing power supply redundancy in a centralized discrete design is costly because it requires two supplies, each capable of driving the load. This is referred to as 2 N redundancy. In such a case, a 600 W load would need two 600 W supplies.

A more cost-effective approach, easily implemented with modules, is called N+1 redundancy. A 600 W supply, for example, consisting of three 200 W modules can be designed with an extra module, allowing the supply to produce 600 W as long as three of the four modules are functioning.

Reliability / Distribution of Thermal Load:

Thermal management can be a special challenge in a centralized architecture, where excess heat could amount to hundreds of watts all in one concentrated area. Large heat sinks and fans are often needed to keep the power supply from becoming overheated. System hotspots are a source of reduced reliability.

A distributed approach spreads the heat throughout the system, greatly reducing or eliminating the need for heat sinks or high-velocity air flow. With temperature more evenly maintained throughout the system, reliability specifications are easier to meet.

Cabling: A centralized power supply should be located near the point of load, especially with circuit voltages becoming smaller, current levels in the power distribution network are increasing — often exceeding hundreds of amperes. The conductors necessary to transmit these levels of current without significant voltage drops are large, unwieldy and expensive.

Losses due to I²R can cause a significant loss of efficiency, localized heat in the wire and problems with the ability of the supply to compensate for the DC voltage drop.

In a distributed power architecture, higher voltages typically 48 or 300 V are used to deliver power to the loads, and the resulting lower current levels (even when smaller cable sizes are used) minimize I²R losses throughout the system.

Noise: The central supply should be located near the load to minimize I²R losses, and it should also be located as close as possible to the AC entry point to reduce noise radiated from the unshielded AC lines. This is often a difficult trade-off with the input cables requiring shielding to minimize common and differential mode currents that produce noise.

Distributed systems are not immune to these problems, but they are, by definition, close to the AC entry point and close to the point of load. In addition, each converter needs to cope only with its local environment. Typically, the level of problems associated with noise are proportional to

the power rating of the power supply or converter.

Regulation and Transient Response: In a centralized power architecture, accurate voltage regulation to loads at varying conductor lengths from the supply can be very difficult and expensive to accomplish effectively. Long conductor paths add inductance, which slows transient response to rapidly varying loads.

Shorter conductor paths in distributed power architectures greatly reduce inductance and improve transient response. With DC-DC converters located close to the load, output voltage regulation is much simpler.

Flexibility for Expansion, Changes and Upgrades:

A centralized power system is very inflexible; if expansion, changes or upgrades are made, it is often necessary to restart the design process.

A distributed architecture is fundamentally more flexible and can easily accommodate changes and upgrades to the system. Increased power requirements can often be met by replacing an existing converter with another converter in an identical package with a higher power rating.

New Design Rules

Modular power components — which are analogous to the proven software building blocks reused in embedded systems — are complex devices, and designers require a specific knowledge base to use them effectively.

Nevertheless, power architects with relatively little experience will find modular design far easier than discrete design, and those with many years of experience can readily apply their extensive knowledge to modular designs. The major module suppliers provide applications engineering support to help users through the design effort. Telephone consultation, applications manuals and on-site visits by experienced applications engineers are available to facilitate an engineer's design experience with component power. ▀

Vicor Corporation
25 Frontage Rd.
Andover, MA 01810
(978)470-2900
[www.vicr.com].