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How To Validate Current Sharing And Hot-Swap Behavior In CRPS Power Supplies

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Parallel CRPS power supplies are widely used to provide redundancy in high-density servers, but successful parallel operation requires more than verifying that both modules produce the correct output voltage. Differences in regulation, connector resistance, distribution impedance, temperature, and ORing behavior can create current imbalance and challenging transient conditions when a module is removed, inserted, or fails.

This article presents a practical approach to validating current sharing and hot-swap operation, including measurements of individual PSU current, bus-voltage behavior, load-step response, PSU removal and reinsertion, inrush behavior, PMBus telemetry, and degraded-state operation. The goal is to provide engineers with a repeatable test methodology for determining whether a parallel CRPS power subsystem remains stable and within electrical and thermal limits during normal operation and fault transitions.

Parallel Operation Is More Than Two PSUs On One Bus

Redundant CRPS architectures are common in servers because they allow a failed or serviceable power module to be removed without shutting down the system. A typical implementation may use two power supplies connected through a power distribution board, with ORing devices or ideal-diode circuitry preventing reverse current between modules.

From a system perspective, the architecture appears simple:

PSU A + PSU B → common dc bus → server load

But successful parallel operation depends on several interactions that are not obvious from the PSU wattage rating alone. Two modules with nominally identical output-voltage specifications will not necessarily deliver identical current. Small differences in output regulation, cable resistance, connector contact resistance, PCB resistance, temperature, and control-loop behavior can cause one module to carry more load than the other.

The engineering objective is therefore not perfect 50/50 current sharing. The objective is to confirm that:

- Current imbalance remains within acceptable limits
- Neither module exceeds its electrical or thermal capability
- The common bus remains stable
- A failed or removed PSU does not disturb the load
- A newly inserted module joins the bus safely
- Telemetry reflects the actual electrical behavior
- The system remains stable during simultaneous load and redundancy events

A useful validation plan should reproduce all of those conditions (Fig. 1).

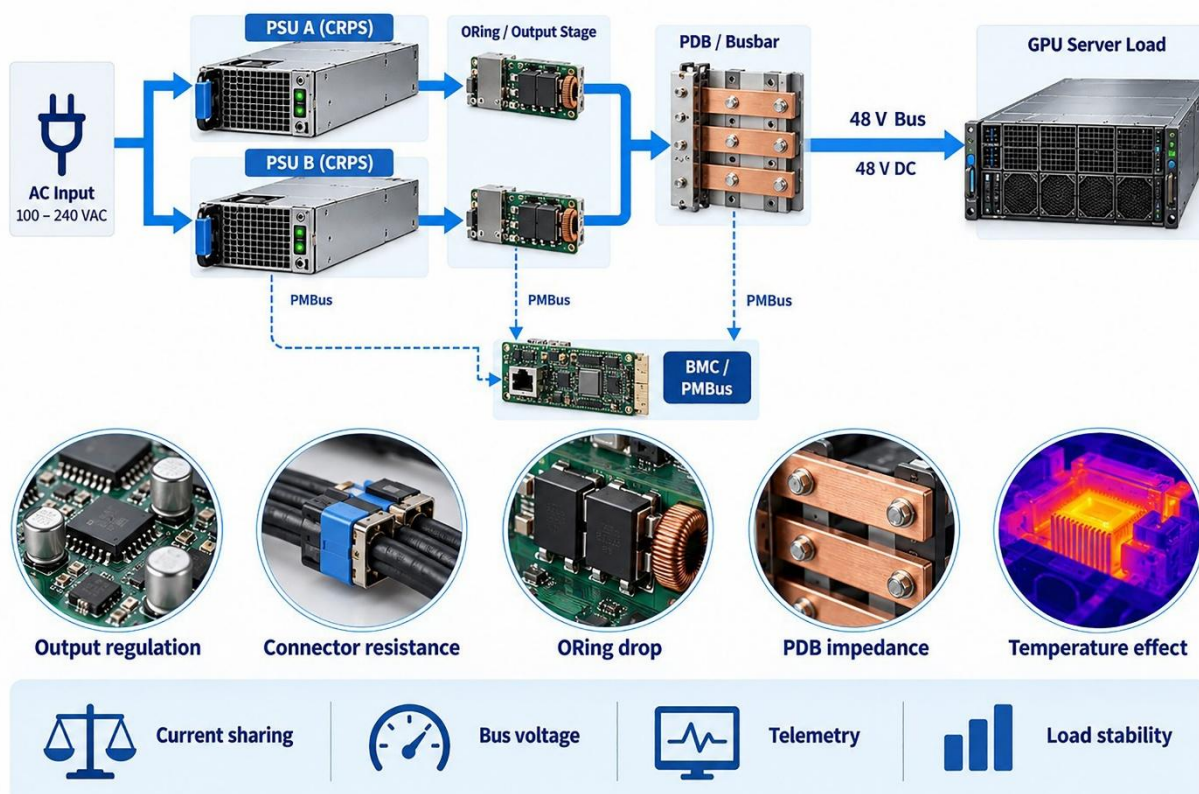


Fig. 1. Parallel CRPS current-sharing architecture showing the ORing stage, PDB/busbar, common load, and the principal electrical and thermal factors that can influence current sharing. In this example, two CRPS modules share a common load through the power-distribution path.

Why Current Sharing Is Never Perfect

Assume two PSUs are connected in parallel and both are intended to produce 48 V. The numerical power examples that follow are illustrative; use the platform ratings and protection limits for acceptance testing.

In an ideal system, a 2-kW load might be divided equally:

PSU A $\approx$ 1 kW

PSU B $\approx$ 1 kW

Real hardware is different. Suppose PSU A regulates slightly higher than PSU B. Even a small output-voltage difference can cause PSU A to source more current before the active current-sharing circuitry compensates.

The current distribution is also influenced by the resistance of each path. A simplified path can be represented as:

PSU output $\rightarrow$ ORing stage $\rightarrow$ connector $\rightarrow$ PDB $\rightarrow$ common bus

If PSU A sees a lower total path resistance than PSU B, it may naturally carry more current.

Sources of mismatch include:

- Connector contact resistance
- PCB copper resistance

- Busbar resistance
- Cable length
- Cable conductor tolerance
- ORing FET resistance
- Connector temperature
- PSU internal regulation tolerance

This is why current-sharing performance must be measured at the system level. Testing two PSUs individually on a bench does not reveal how they behave when connected through the actual PDB and interconnect path.

Start With A Controlled Current-Sharing Test

A useful baseline test begins with both PSUs active and a programmable load connected to the common bus. The load should be increased gradually across the expected operating range. For example: 10%, 25%, 50%, 75%, and 100% of the intended protected load.

At each point, record:

- PSU A output current
- PSU B output current
- Common-bus voltage
- PSU temperatures
- Connector temperatures
- PMBus-reported current
- PMBus-reported power

A simple sharing ratio can be calculated as

$$\text{Sharing ratio A} = I_A / (I_A + I_B)$$

If each PSU carries 50% of the total current, the ratio is 0.50. But there is little value in requiring exactly 0.50.

A practical engineering specification should instead define an acceptable sharing window based on the PSU design and system margin. The window should state both the steady-state imbalance and the allowed transient excursion, with measurement bandwidth and operating conditions defined.

For example, a platform might tolerate a meaningful but controlled imbalance as long as neither PSU, connector, PDB path, or thermal interface exceeds its validated limits. The pass/fail criterion should therefore be tied to the system design rather than an arbitrary ideal split.

Test Current Sharing Across Temperature

Current sharing should not be validated only at room temperature. Resistance changes with temperature. Connector contacts warm up. Copper resistance increases. Semiconductor characteristics change. PSU internal control loops may also behave differently.

A useful test sequence is

1. Start with both PSUs at room temperature
2. Apply a representative sustained load
3. Allow the system to reach thermal equilibrium

4. Record the current split
5. Increase inlet temperature or reduce airflow within the qualified operating range
6. Repeat the measurements

If one PSU gradually takes a larger share as temperature rises, engineers should determine whether the cause is PSU control behavior, higher resistance in one path, connector heating, PDB imbalance or airflow asymmetry.

Thermal images can be especially useful here because current imbalance often appears as unequal heating before it becomes an electrical limit violation (Fig. 2).

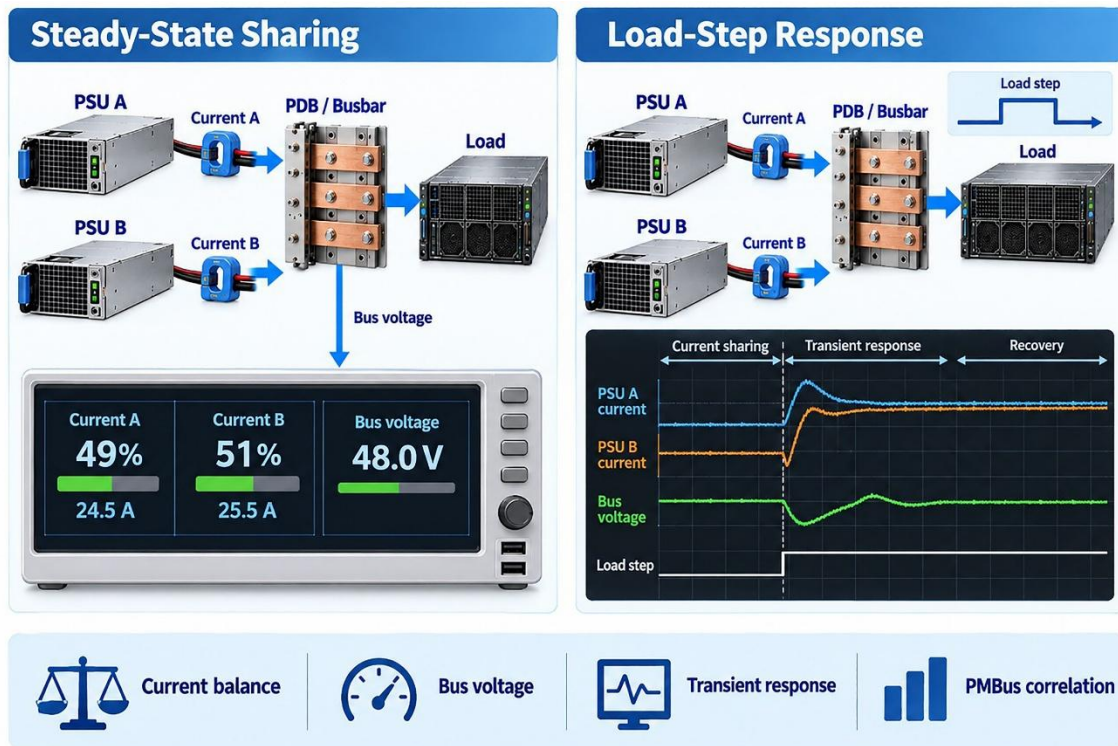


Fig. 2. Static and dynamic current-sharing measurement. Example measurement setup showing steady-state current sharing and the response of PSU A current, PSU B current, and common-bus voltage during a controlled load step. Verify load balance at steady state and response during load-step transients.

Dynamic Load Sharing Matters More Than Static Sharing

Static current sharing is only the first test. GPU and AI server loads are dynamic. Rapid changes in processor or accelerator activity can produce load steps that force the PSUs to redistribute current quickly. A realistic validation setup should therefore include a programmable electronic load or target system capable of producing controlled load transitions.

For example:

1 kW → 2.5 kW → 1 kW

or

30% load → 80% load

The important measurements are common-bus voltage deviation, PSU A current response, PSU B current response, settling time, overshoot, undershoot and current-sharing recovery.

An oscilloscope with suitable differential voltage probes and current probes is far more useful here than relying only on slow telemetry. PMBus data is valuable for system monitoring, but it may not capture the fastest transient behavior. Electrical measurements and digital telemetry should be treated as complementary tools.

The Hardest Event Is Often The Loss Of One PSU

One of the most important tests is the sudden loss of one power module while the server remains under load. Before failure, the load may be divided between two PSUs. After failure, the surviving PSU must rapidly assume the required current.

For example, before failure:

PSU A = 100 A

PSU B = 100 A

After PSU A is lost:

PSU B → approximately 200 A

The transition may occur much faster than firmware-level power management can respond. The electrical power path therefore has to survive the immediate transition on its own.

Engineers should monitor common-bus voltage, surviving PSU current, failed PSU current, ORing-stage behavior, load voltage, fault signals, PSU power-good signals and PMBus fault reporting.

A properly designed system should avoid excessive voltage droop, bus interruption, reverse current into the failed PSU, oscillation and protection trips in the surviving PSU. Only after the electrical system remains stable can the baseboard management controller (BMC) or other controller reduce the workload if required.

Test Both Electrical Failure And Physical Removal

There are at least two different redundancy events worth testing.

One is ac input loss. To perform this test, remove ac power from PSU A while the module remains physically installed. This tests input-loss detection, ORing isolation, current transfer, fault reporting and surviving PSU response

Another event is hot-swap removal. For this test, physically remove PSU A from the system while the server remains powered. This additionally tests connector sequencing, presence detection, mechanical contact behavior, signal disconnection order, and bus disturbance during removal.

The two events should not automatically be assumed to produce identical behavior. Physical removal can introduce additional contact transitions and signal timing effects that do not occur when ac input is simply removed.

Reinsertion Can Be More Difficult Than Removal

Removing a failed PSU is only half of the hot-swap problem. A replacement module must eventually be inserted into a live system. During insertion, the new PSU may encounter a live dc bus. Without proper control, the event can produce inrush current, contact arcing, bus-voltage disturbance, ORing-device stress, or current-sharing instability.

A typical sequence may involve mechanical insertion, presence detection, standby power availability, control communication, output qualification, controlled connection to the common bus, and current-sharing ramp. The

exact sequence depends on the architecture, but the principle is the same: The new module should not simply slam onto the live bus at full current. Engineers should observe current and voltage during reinsertion with an oscilloscope.

Particular attention should be paid to peak insertion current, bus-voltage disturbance, time before the new PSU begins sourcing current, current ramp rate and final sharing ratio (Fig. 3).

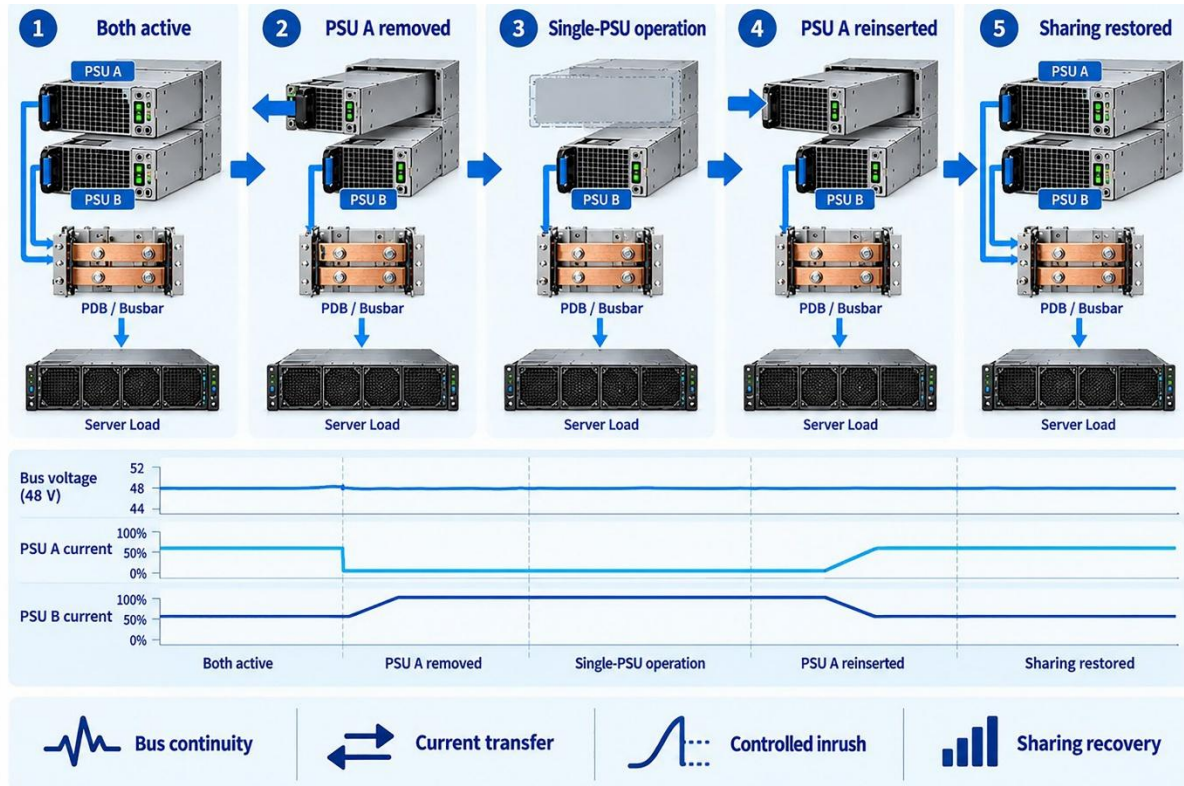


Fig. 3. Hot-swap removal and reinsertion sequence. Hot-swap sequence showing normal parallel operation, PSU removal, single-PSU operation, reinsertion, and recovery of current sharing. Observe bus continuity, takeover by the surviving PSU, and recovery of current sharing.

ORing Behavior Needs To Be Validated

Parallel power supplies require isolation between modules. Traditional diode ORing provides simple isolation but introduces conduction loss. Modern systems often use MOSFET-based ideal-diode or ORing controllers to reduce loss. Whatever method is used, it must prevent one PSU from feeding current backward into another module.

During testing, engineers should intentionally create conditions that challenge the ORing stage:

- Remove ac from one PSU
- Disable one module
- Insert a module with output initially below the bus voltage
- Apply load steps during module transition

Reverse current should remain within the limits defined by the design. The ORing devices should also be thermally evaluated because they carry the full load current of their respective paths. At multi-kilowatt power levels, even low milliohm resistance can produce meaningful heat.

PMBus Telemetry Should Be Compared With Real Measurements

PMBus can provide valuable information such as output current, output voltage, output power, input power, temperature, warning status, and fault status. But telemetry should be validated against actual electrical measurements. During characterization, compare PMBus current vs. current probe measurement and PMBus voltage vs. calibrated DMM or oscilloscope measurement.

The goal is not only to verify absolute accuracy. Engineers should also verify update rate, delay during fault events, behavior when communication is lost, whether telemetry freezes during failure, whether fault registers latch correctly, and whether replacement modules are detected correctly.

For a BMC-controlled server, inaccurate or delayed telemetry can result in incorrect power-management decisions.

Add A Combined Fault And Load-Step Test

A system that passes individual tests can still fail when multiple events occur together. One useful stress case is:

High load → sudden PSU loss → additional transient load

This can represent a difficult real-world condition where a GPU workload changes at nearly the same time one PSU becomes unavailable. The test can reveal whether:

- The surviving PSU has enough transient margin
- The bus capacitance is sufficient
- The PDB remains stable
- Protection thresholds are coordinated correctly
- Power capping activates quickly enough

Engineers should also test the reverse sequence:

PSU failure → degraded operation → large workload transition

The goal is to confirm that the redundancy design works during realistic combinations of events, not only under isolated laboratory conditions.

Thermal Measurements Should Follow The Current

Electrical pass/fail results alone are not enough. During high-load current-sharing tests, measure temperature at PSU output connector, ORing devices, PDB input, busbar, cable termination, high-current connector and surviving PSU after failure.

Suppose two PSUs appear to share current acceptably, but one connector operates 20°C hotter than the other. That may indicate higher contact resistance, unequal airflow, poor termination or localized current concentration.

Thermal behavior can reveal problems that may not yet appear as voltage faults. The surviving PSU path is especially important. A system might survive a PSU failure electrically for several minutes but exceed a thermal limit during prolonged degraded operation. So degraded-state validation should include enough time for temperatures to stabilize.

A Practical Bench-Test Setup

A useful test station can include two CRPS modules, production-representative PDB, production connectors and cables, programmable ac source or independent ac feeds, programmable electronic load, oscilloscope,

differential voltage probe, dc current probes, digital multimeters, thermal camera, temperature probes and PMBus interface or system BMC.

The setup should reproduce the real power path as closely as possible. Using unusually short laboratory cables or bypassing production connectors can make the system appear better than the final product. For this reason, prototype validation should eventually move from simplified bench hardware to production-representative mechanical and electrical assemblies.

Example Validation Sequence

A repeatable validation flow might look like this:

Test 1—Static Current Sharing

- Sweep load from low to maximum expected operating load.
- Record current distribution and temperatures.

Test 2—Dynamic Load Steps

- Apply controlled load transitions.
- Measure bus voltage and individual PSU current response.

Test 3—AC Loss

- Remove input power from PSU A.
- Verify current transfer to PSU B.

Test 4—Hot-Swap Removal

- Physically remove PSU A during operation.
- Confirm uninterrupted load power.

Test 5—Hot-Swap Insertion

- Insert PSU A into the live system.
- Measure inrush and bus disturbance.

Test 6—Recovery Of Current Sharing

- Confirm the new PSU ramps into parallel operation without oscillation or excessive overshoot.

Test 7—Degraded-State Sustained Load

- Operate on one PSU long enough to reach thermal equilibrium.

Test 8—Degraded-State Load Step

- Apply a load transient with only one PSU active.

Test 9—PMBus Validation

- Compare reported telemetry with external instruments.

Test 10—Thermal Validation

- Repeat critical tests at elevated inlet temperature and worst-case airflow.

See Fig. 4.

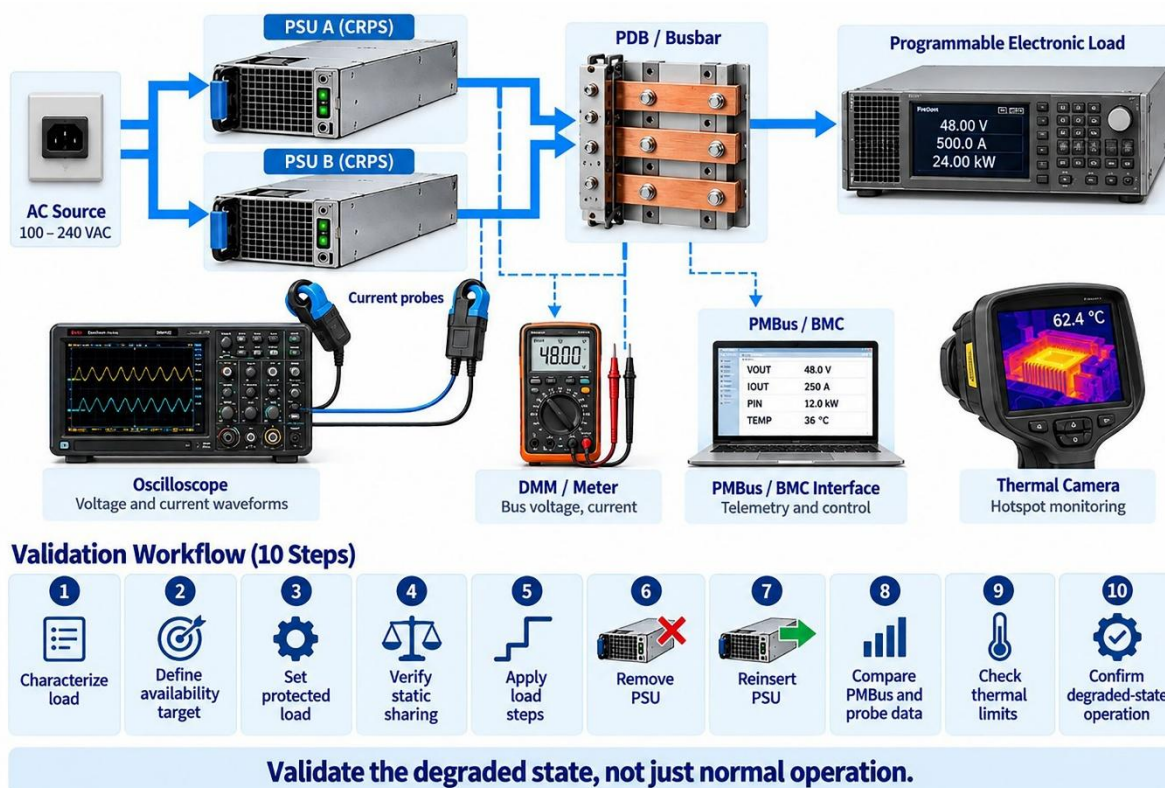


Fig. 4. Parallel CRPS validation test bench and workflow. A practical setup for verifying sharing, hot-swap behavior, telemetry, and thermal limits. This representative validation setup uses two CRPS modules, PDB/busbar, programmable load, oscilloscope and current probes, PMBus/BMC telemetry, and thermal measurement.

Define Pass/Fail Criteria Before Testing

One common mistake is performing extensive testing without defining what constitutes success. Before validation begins, establish limits for:

- Maximum current imbalance
- Maximum bus-voltage deviation
- Minimum load voltage
- Maximum connector temperature
- Maximum PSU temperature
- Maximum insertion current
- Maximum recovery time
- Acceptable telemetry error
- Permitted degraded-state load

The exact numbers depend on the PSU, PDB, connectors, server platform, and reliability requirements. The important principle is that the criteria should be defined in advance. This avoids deciding after the test whether an unexpected result is “probably acceptable”.

Validate The System, Not Just The CRPS Module

A redundant power module can meet its individual specifications while the complete server power subsystem still has problems. Current sharing is influenced by everything between the two PSU outputs and the load.

Hot-swap behavior depends on electrical, mechanical, and control sequencing. Fault recovery depends on both hardware response and management logic. That is why CRPS validation should ultimately be performed as a system-level exercise.

The question is not simply, "does each PSU work?" It is, "do the PSUs, PDB, ORing stage, interconnects, telemetry, and control system continue working together during the transitions that redundancy is supposed to protect against?"

For parallel CRPS architectures, that distinction is what separates installed redundancy from validated redundancy.

About The Author



Steven Zhang is product manager at [Powernexu](#), where he focuses on server power supplies and power-delivery requirements for high-density computing systems. His work covers CRPS power supplies, redundant power architectures, current-sharing and hot-swap validation, PMBus telemetry, and power integration for AI and GPU server platforms.

For more on current sharing in power supply design, see How2Power's [Design Guide](#), and keyword search "current sharing". Also locate the "Design area" category and select "[Power Protection](#)".