Heron Power Electronics
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OpenIBR (Inverter-Based Resources): Open-Source Grid-Forming Controls for Inverter-Based Resources and Loads

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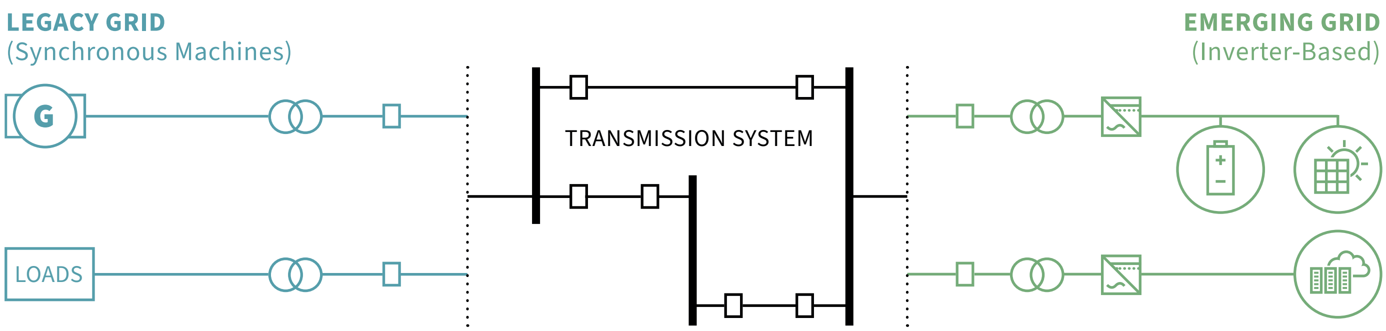
Toward Open, Interoperable Controls to Integrate Inverter-Based Resources and Loads

The electric grid is evolving faster than its control systems. Power-electronics connected renewable generation, battery storage, and data-centers dominate the interconnection queue and are rapidly displacing the synchronous machines that historically anchored voltage, frequency, and phase stability. To maintain a reliable power system through this evolution, inverter-based resources (IBRs) must provide predictable dynamic behavior and maintain compatibility with protection systems. Without a shift in paradigm, grids with high penetrations of renewables risk widespread instability and cascading outages, as underscored by the Brazil blackout of August 2023, and the Iberian Peninsula blackout of April 2025.

FIGURE 1 An Emerging, Inverter-Based Resource(IBR) Power Grid



To date, IBR controls have been defined by proprietary software with opaque, complex, and unpredictable behaviors. Proprietary software undermines trust between modeling and real-world behavior: every inverter behaves differently, forcing grid operators to rely on lengthy, bespoke studies to ensure system stability, slowing interconnection and creating uncertainty for developers. Software updates after commissioning bring systemic risk, with several reported incidents of unexpected power system side-effects of updates.

A complexity reset is needed to unlock the full potential of renewable generation and storage on the power system and to enable the ever-growing large-load deployments.

Navigating the Transition to an IBR-Dominated Power System

Today's inverters present challenges to power system engineers and operators. They complicate the source and large load interconnection process with more questions than answers:

- How to evaluate system stability without permitting latent vulnerabilities?
- How should inverter software OEM-specific model parameters be tuned?
- Will IBR facilities negatively interact with each other?
- How much IBR capacity can the system tolerate, and in what locations?
- How should protection be configured?
- Does inverter behavior in the field match that of the interconnection study?
- What's the impact of firmware updates?
- What are meaningful values to be captured in fault recordings?

Heron Power developed OpenIBR to address these challenges head-on. The library was designed with a specific focus to create simple, grid-forming, and transparent controls built around three pillars:

→ **Simple, intuitive behavior** allows planning engineers to predict and reason through plant response in grid events.
→ **Grid-forming controls** offer intuitive tuning parameters (impedance, inertia, damping), recreate the familiar voltage-behind-an-impedance characteristics native to a synchronous power system, and yield coherent fault currents interoperable with established protection systems.
→ **Transparent (open-source) implementation** can be inspected and third-party verified to match interconnection models to real-world behavior.

OpenIBR flips the script for IBR integration, putting planning engineers in the driver's seat. System planning can proceed independently of any specific project, focusing instead on achieving resource adequacy and reliability using a simple model of generic grid-forming plants. Hosting capacity can be mapped out along with values of inertia, damping, and impedance parameters required at each node. IBR plants can then be configured according to this plan, along with protection relays where necessary.

OpenIBR can apply across many assets—including solar, storage, hybrid plants, and large electronic loads like data centers. Renewables firmed with batteries can balance and track load demand on a seconds-and-minutes time horizon. With grid-following controls, however, inverters struggle to compensate (in-fact can amplify) faster sub-cycle and sub-second disturbances. OpenIBR supports the grid across all timescales, providing effective harmonics damping, frequency stability, and even black-start functionality for system restoration. The benefits of OpenIBR apply to large power electronics loads as much as generators: using a small fraction of their backup batteries, a data center campus can behave like a grid-forming asset.

FIGURE 2 Power Electronics Providing Stability & Resilience

● Full Capability
● Partial Capability
● Harmful

		Harmonics Damping	Negative Sequence Contribution	Phase Voltage Balance	Blackstart Capability	System Strength	Frequency Damping	Inertia	Dispatchable	Firm
GRID-FOLLOWING	Solar					Harmful				Harmful
	Battery					Harmful	Partial Capability		Full Capability	Full Capability
	Data Center					Harmful				Harmful
GRID-FORMING (OpenIBR-enabled)	Solar w/ Energy Buffer	Full Capability	Full Capability	Full Capability	Full Capability	Full Capability	Full Capability	Full Capability		Harmful
	Battery	Full Capability	Full Capability	Full Capability	Full Capability	Full Capability	Full Capability	Full Capability	Full Capability	Full Capability
	Data Center	Full Capability	Full Capability	Full Capability	Full Capability	Full Capability	Full Capability	Full Capability	Full Capability	Full Capability
		Sub-Cycle Behaviors			Frequency Stability				Slow Dynamics	

◄ 0.1 MSEC 16 MSEC 2.0 SEC HRS/DAYS ►

→ **By extending grid-forming behavior across both generation and load, OpenIBR bridges the boundary between supply and demand**—turning power electronics from a source of instability into a foundation for resilience.

How OpenIBR Works

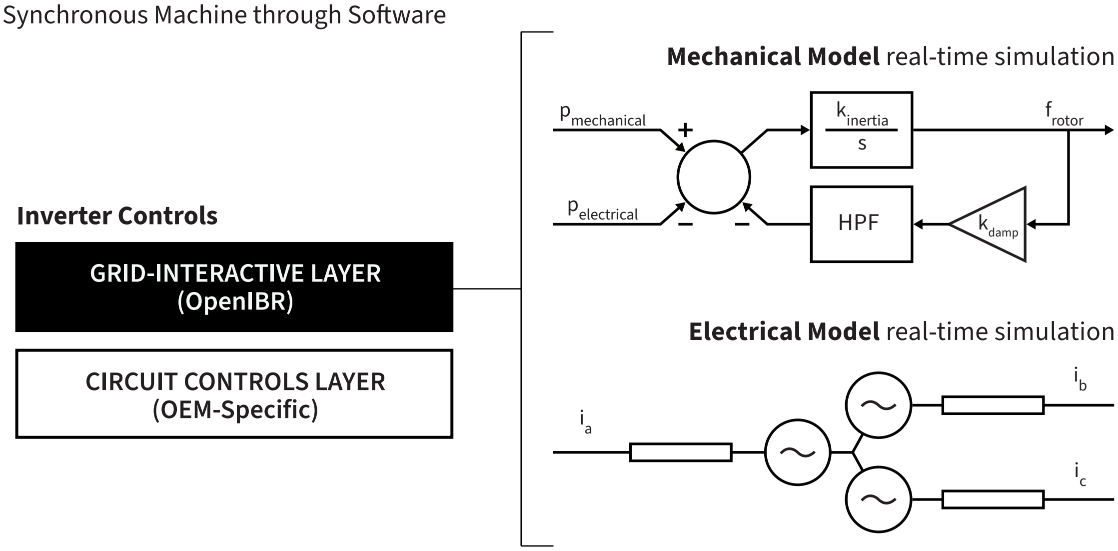
OpenIBR is a portable controls library available to any power electronics manufacturer that provides consistent grid-interactive behavior, regardless of the underlying power electronics topology.

At its core, OpenIBR is an open-source reference implementation of grid-forming Type C architecture (WECC REGFM_C1), a controls design emulating the behavior of a synchronous machine through software. Instead of tracking an external voltage reference, the inverter continuously solves a simplified machine model in real time to determine desired inverter current based on an internal voltage reference – emulating synchronous machine back-EMF. It employs a current limiting scheme specifically designed to maintain voltage source behavior during faults. This transforms the inverter from grid-following to a grid-forming device, one that naturally fits within the established stability and protection frameworks of the grid.

> “
> *OpenIBR emulates the behavior of a synchronous machine through software, transforming the inverter from grid-following to a grid-forming device.*

The OpenIBR controller generates current references that OEM-specific high-bandwidth current control loops fulfill, according to each OEM’s proprietary converter design. The OpenIBR controller is therefore largely topology-agnostic and can be compiled into inverters with varied hardware architectures.

FIGURE 3 Simulating a Synchronous Machine through Software



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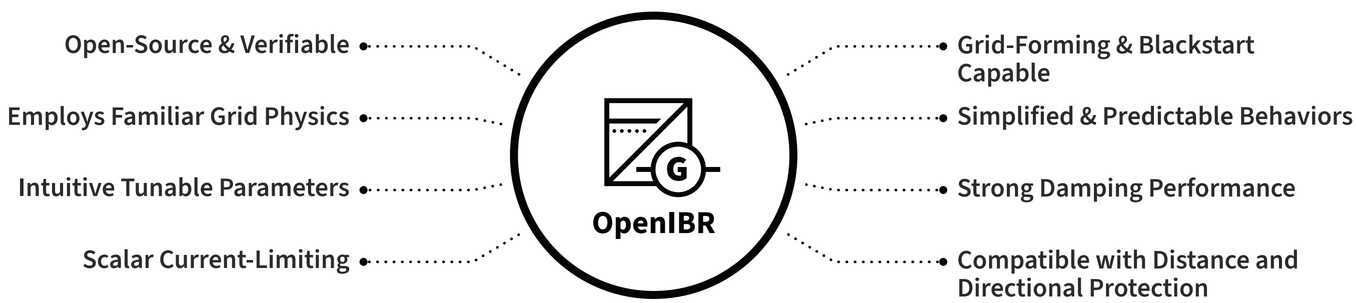
OpenIBR incorporates tuning parameters familiar to power systems engineers, allowing analytical and rule-of-thumb screening for stability and protection concerns. Parameters include the inertial constant (H), damping coefficient (D), stator impedance (X), and overload current capability (Ilimit). The electrical model generates elevated fault currents with signature dictated by the electrical path to the fault. RMS current limiting is applied gracefully with a scaling scheme designed to maintain symmetrical components (negative sequence currents) and preserve their relationships to the voltage frame-of-reference.

Unlike traditional machines, which are constrained by mass and friction, modern power electronics inverters can provide high levels of damping with little power loss. Through tunable parameters, OpenIBR allows planners to fine-tune stability response for different networks and continue to modify them as the network evolves.

FIGURE 4 OpenIBR (Inverter-Based Resource) Benefits



Why Open Source?

At times the biggest barrier to scaling inverter-based resources isn’t economic or technical but rather a gap in trust. Too often, interconnection models of grid-scale power converters don’t match their behavior in the field. Proprietary, non-linear software behaviors drive uncertainty for regulators, power system operators, utilities and developers as they assess how resources and loads respond to grid disruptions. This forces system operators into a conservative approach using extensive interconnection studies with numerous increasingly complex test cases that add delay and cost. Modeling itself becomes a bottleneck: detailed, bespoke studies are demanded precisely because confidence in current models is so low.

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> *Open source builds trust. Transparent, validated control models replace uncertainty with a common, reliable benchmark for grid-forming inverters.*

The intent of OpenIBR is not to mandate the control design of inverter-based resources, but to establish an open controls platform, proven to benefit the grid, that can be readily adopted by OEMs. The joint release of code, documentation, and validated models ensures simulation matches functionality in the field, building trust between developers, regulators, and system operators. The OpenIBR repository hosted on GitHub provides a complete, cross-platform toolkit for implementing and evaluating grid-forming control. Each component is designed for transparency, interoperability, and direct usability by developers, researchers, and system operators. The library includes:

- **Reference models** in Simulink for rapid design and testing
- **Embedded C code**, capable of being compiled directly into inverter / rectifier source code
- **Validated PSCAD models** for interconnection and stability studies
- **Comprehensive documentation and usage guides** to support evaluation, modification, and contributions from the broader community
- **Third-party assessment reports** for meeting IEEE2800.1 grid-forming requirements, and compatibility with transmission protective relays

OpenIBR builds on industry efforts with standards and generic models and complies with both IEEE 2800 and UNIFI specifications. By putting forward a concrete design with open models, Heron is providing a practical, working example that others can test, refine, and adopt—helping accelerate consensus and creating a trusted benchmark for grid-forming inverters and power electronics generation and load interconnections broadly. Open designs accelerate convergence: Heron’s goal is for OpenIBR to be a pragmatic path to harmonization.

FIGURE 5 Building on Industry Harmonization Efforts

IEEE 2800 & UNIFI Spec — Design agnostic requirements → **WECC Generic Models** — Behavior approximations → **OpenIBR** — Fully equivalent model & implementation

Benefits Across the Grid Ecosystem

By providing a transparent, validated, and interoperable foundation for inverter behavior, OpenIBR works to resolve long-standing bottlenecks and accelerate the safe integration of inverter-based resources and large loads.

"By replacing black-box uncertainty with transparent, validated control, OpenIBR drives benefits across the grid ecosystem: faster interconnection, stronger reliability, and more predictable performance.

- **For developers and investors of renewable energy and storage projects,** OpenIBR streamlines the path to interconnection. As open, validated models gain adoption, costly and bespoke studies based on proprietary black-box models will be replaced by streamlined templates already compatible with system operator requirements. This lowers study costs, reduces approval timelines, and creates more predictable outcomes, strengthening project bankability and investor confidence.
- **For data center builders,** adopting OpenIBR ensures large-load datacenters are grid-supporting assets. Just seconds of energy storage on a data center DC bus is enough to both absorb GPU power ripple and provide grid-forming support. Such facilities can ride through disturbances, maintain critical IT operations, and respond rapidly to grid needs: extended voltage and frequency ride-through (in line with emerging ride-through expectations), inertial and primary frequency response, voltage controls, harmonics damping, and real-time power support. OpenIBR can enable streamlined interconnection for data center developers and unlock predictable, grid-strengthening behavior for system operators.
- **For regulators and policymakers,** OpenIBR offers a trusted tool for interconnection oversight. Transparent models that match deployed firmware reduce uncertainty, streamline planning, and enable consistent, harmonized requirements across jurisdictions. This in turn supports national goals for reliability and resilience, ensuring that deployment of renewables, storage, and data centers strengthens rather than undermines grid stability.
- **For utilities and system operators,** OpenIBR delivers predictable grid behavior, easing both real-time operations and long-term planning. Standardized, parametric behavior across vendors and sites yields calibrate-able, predictable performance. Grid-forming functionality improves frequency and voltage response, raising hosting capacity in weak-grid areas, and avoiding the investment and maintenance costs of synchronous condensers and other capex- and opex-intensive T&D or project-level upgrades. Together, these capabilities help utilities clear interconnection backlogs, maintain reliability, and manage their networks with greater confidence and efficiency and lower costs.

→ **For the grid modeling community**—power system operators, consultants, and researchers—OpenIBR eliminates black-box burdens and provides consistent, cross-platform reference materials, allowing grid engineers to deeply understand the behavior of transparent control algorithms. Instead of hunt and peck validation of opaque, OEM-specific behavior, they can plan their systems with confidence, specify inverter settings up front, modify them as needed over time, and ensure consistent, interoperable performance across projects. This frees engineers to focus on higher-level forward-looking system design and risk mitigation.

Path to Adoption

The value of OpenIBR depends on broad engagement and practical use. Heron invites collaboration and adoption across the industry in several ways:

- **Validation and feedback:** We welcome system operators, consultants, and researchers to test OpenIBR models in their platforms of choice and contribute improvements.
- **Integration into project studies:** We urge developers to request OpenIBR in new resource interconnection studies, helping to shorten approval times and standardize expectations.
- **Incorporation into interconnection guidelines:** We propose regulators and system operators adopt OpenIBR or equivalent open models as a referenced requirement for inverter performance, ensuring consistent, transparent evaluation across regions.
- **AI-campus pilots:** We will work with data center developers and power equipment vendors to demonstrate OpenIBR's disturbance support, enhanced ride-through for IT loads, and real-time power support on representative topologies.

By working together to validate, adopt, and refine OpenIBR, stakeholders can ensure that inverter-based resources and large loads integrate seamlessly into the grid. The payoff is not just faster approvals or reduced costs—it is a more resilient, reliable system that can keep pace with electrification for the benefit of all.