ENERGY SYSTEMS INTEGRATION FACILITY (ESIF):
WORLD-CLASS SYSTEMS INTEGRATION CAPABILITIES AND RESEARCH

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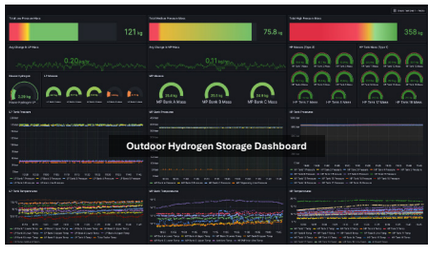


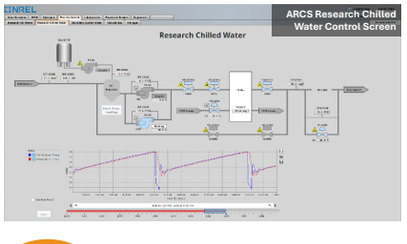
ESIF **ARCS** System

*The **Advanced Research Control Supervisor** (ARCS) is the main user interface used to control and monitor ESIF equipment and systems.*

- **50,000+** data points and sensors
- **11,500+** alarms configured
- **265+** screens, popups, and templates
- 4 redundant servers with **6 TB of RAM**

The ARCS features an **experiment recipe management system** to automatically configure and operate complex experiments that span multiple voltages, frequencies, test equipment, and renewable energy sources.

The ARCS supervises the **fire and gas detection** systems for critical facility **safety functions**. Further, the ARCS can interface with outside vendor equipment using a wide variety of **communications protocols**.



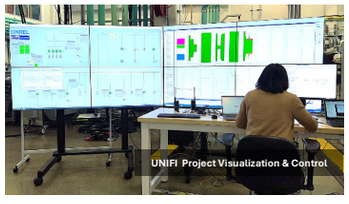
ESIF **RDNS** System

*The **Research Data Network System** (RDNS) provides **project-focused control, automation, visualization, and data storage** capabilities, enabling a **single pane of glass** for ESIF research projects.*

The RDNS provides **low latency** and **high data throughput** for **time-synchronized measurements** collected across the ESIF with **nanosecond resolution**. The capability includes **data visualization** through **Grafana dashboards** and responsive **human-machine interface (HMI) screens** as well as localized **time-series databases** for **storing and tagging research data.**

- **Signal sampling** and storage up to **50 kHz**
- **150+ Industrial Internet of Things protocols**
- **Software integration** with MATLAB and National Instruments
- Interfaces with **ARCS, ESIF High Performance Computing, Data Analysis and Visualization, Azure,** and **Amazon Web Services**

For the UNIFI project, RDNS provided HMI data visualization and storage from a distributed set of power measurement terminals.



*The ESIF consists of a **living network of diverse systems** designed, maintained, and advanced by the ESIF Research Operations group to enable cutting-edge energy integration research.*

ESIF **REDB** System

*The ESIF **Research Electrical Distribution Bus** (REDB) consists of electrical power networks that connect devices located across the facility through versatile, automatic circuit configuration.*

AC REDB	*DC REDB*
• **250-A** and **1600-A** buses	• **250-A** and **1600-A** buses
• **0 to 600-V** voltage range	• **0 to 1000-V** voltage range

The ESIF supports **megawatt-scale experiments** across **four AC and DC bus networks** that integrate a variety of **grid, solar PV, and battery simulators** with **inverters, loads,** and other emerging technologies. The REDB system supports research in **grid-forming validation, EV charging, microgrids**, **distributed energy resource management systems**, and **distribution power electronics conversion**.

The REDB system is closely integrated with the other ESIF research systems. The REDB enables **dynamic operation** of commercial **fuel cells** and **electrolyzers** from the hydrogen system. Operating the **250-kW combined heat and power gas microturbines** requires both the REDB and the thermal system. The ARCS system provides a means to control and monitor the connections between systems while the RDNS records electrical signals and captures system responses along the buses.

ESIF **Hydrogen** System

*The ESIF hydrogen system functions as **a highly adaptive, research-focused hydrogen hub**—capable of large-scale hydrogen production, drying, compression, storage, and delivery to laboratory end uses.*

A wide variety of research activities are supported by the hydrogen system, including bench-scale **cell membrane materials** development, **gas sensor** performance validation, commercial **fuel cell and electrolyzer** performance testing, light-duty and heavy-duty **hydrogen vehicle fueling**, and the production of other **renewable fuels** (e-fuels).

The hydrogen system provides:

- **1-MW electrolyzer** stack testing
- **18-kg/h** full-capacity **hydrogen production**
- **650 kg** of outdoor **hydrogen storage** up to **13,000 psi**

The recent Heavy-Duty Fueling Methods and Components project leveraged the advanced capabilities of the ESIF hydrogen system in a **cross-lab, multi-industry partner collaboration to reach new targets in fast-flow fueling** of heavy-duty hydrogen vehicles.

While validating specialized hydrogen fueling hardware, developing new fueling standards and protocols, and refining legacy fueling models, the researchers achieved an **80-kg fill in approximately 6.5 minutes**, with an **average fill** rate of **12.5 kg/min** and a **peak fill** rate of **23 kg/min**.

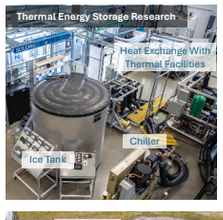
ESIF **Thermal** System

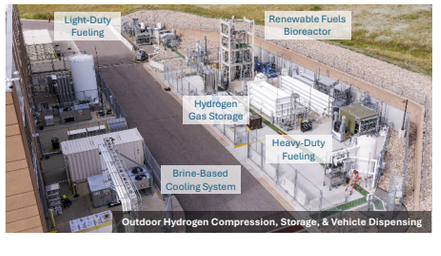
The ESIF research thermal system is a network of water-filled piping that branches throughout the facility to provide heating, chilling, and thermal management services to research projects and equipment.

Composed of **three circulating loops** conditioned with a research boiler, research chiller, and rooftop coolers, the thermal system is essential for **residential and commercial HVAC research**, low- and high-temperature **thermal energy storage** projects, **and providing cooling to ensure safe and stable operations** of all heat-producing research devices and processes across the facility.

Secondary Cooling Water	*Research Chilled Water*	*Research Hot Water*
• **600-GPM** pump	• **230-GPM** pump	• **115-GPM** pump
• **1800-kW** cooling capacity	• **700-kW** (200 ton) chiller	• **205-kW** (700 kBTU/h) boiler
• **70°F** nominal temperature	• **30°F–65°F** temperature range	• **100°F–180°F** temperature range

Researchers have used the chilled and hot water facilities with a **570-Wh ice storage tank** and a 105-kW (30-ton) chiller to **develop simulations for building energy costs**, accounting for different control modes, complex electricity rates from utilities, and on-site solar PV generation.





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