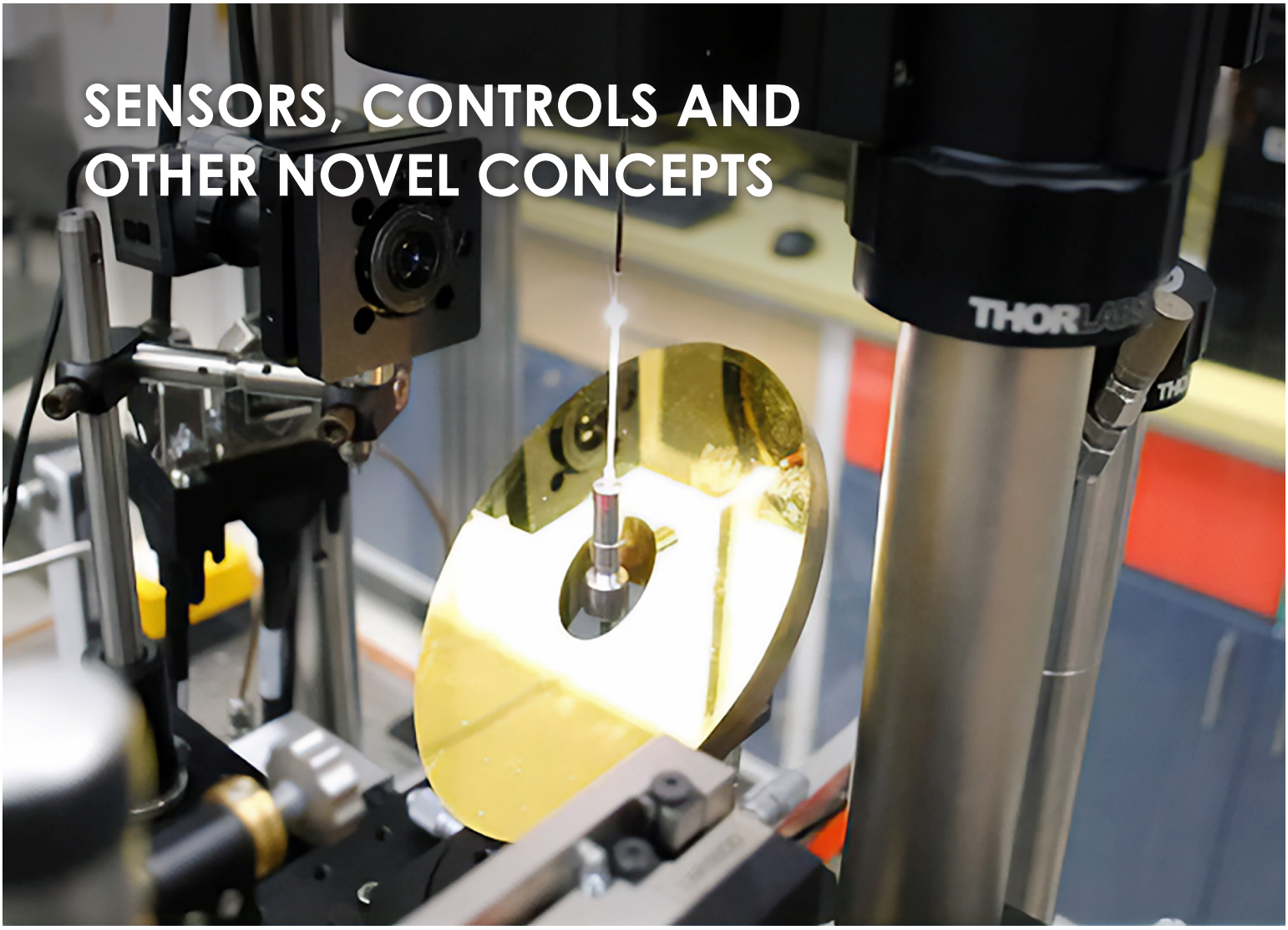
SENSORS, CONTROLS AND OTHER NOVEL CONCEPTS



Program 139, June 2024

NATIONAL ENERGY TECHNOLOGY LABORATORY

The Sensors, Controls and Other Novel Concepts technology program within the Hydrogen with Carbon Management research portfolio provides pivotal insights into optimizing plant performance, reliability and availability while utilizing and furthering technological megatrends, such as advanced manufacturing processes and Industry 4.0 principles.

The program's controls research centers around artificial and distributed intelligence for process control and decision-making networks. The ability to monitor key energy system parameters and align results in real time with self-organizing information networks will enable decision-makers to improve operational efficiency during challenging transient conditions, and increase system availability and environmental controls.

Advanced manufacturing techniques are enabling sensors to be embedded into turbine blades capable of operation in extreme environments and outfitted with condition-based monitoring algorithms. NETL develops, tests and matures novel sensor and control technologies that are operable in next-generation energy systems, including hybrid plants incorporating components such as hydrogen-powered turbines and fuel cells, renewables and energy storage applications.

These sensors enable responsiveness to varying conditions in real time, maintaining high efficiencies and reducing emissions. This research will aid in achieving DOE goals that include net-zero carbon emissions in the energy sector by 2035 and a decarbonized wider economy by 2050.

This program is advancing and integrating technologies across the following primary platforms research areas:

HARSH ENVIRONMENT SENSORS — Harsh environment sensors research efforts enable and enhance carbon management technologies ranging from hydrogen production and power generation to carbon storage. This research optimizes sensor arrays, enabling the optimization of parameters such as temperature, pressure, fluid composition and material condition. Researchers explore various advanced manufacturing techniques, such as 3D printing, to assess the feasibility of embedding sensors equipped with condition-based monitoring algorithms. These sensors are designed to function in extreme environments and monitor components from pipes and tubing to turbine blades, with the aim of predicting maintenance requirements and reducing plant downtime. As a result, they have revolutionized equipment inspection and repair across a wide range of systems. These advancements in remote inspection are enhancing performance, reliability and the economic outlook for future energy infrastructure. NETL has developed, optimized and tested a deployable miniaturized laser-induced breakdown spectroscopy (LIBS) system for subterranean chemical sensing that resulted in a patent and an R&D 100 Award. Optical fiber sensor work developed as part of this program was incorporated into the Transformer Watchman technology suite, which enables measurement of temperature, several dissolved gases and acoustic signals for partial discharge and arc fault detection in aging transformers. This work won an R&D 100 Award in 2023.

ADVANCED CONTROLS AND CYBERPHYSICAL SYSTEMS — Controls research at NETL enables increased energy system complexity and optimized performance. Optimized controls will reduce emissions while ensuring safe and efficient performance. Smart control systems enable an optimal balance between operational performance and reliability. Advanced controls will also manage complex interactions of hybrid power systems (featuring renewable generation, energy storage, carbon management, etc.) and other subsystems. One significant capability at NETL is the Hybrid Performance (HYPER) cyber-physical platform, which combines virtual numerical models with physical hardware to implement advanced controls and designs. HYPER serves as a test bed for novel control strategies and cybersecurity concepts that will help improve the optimization of next-generation power plants.

OTHER NOVEL CONCEPTS — Emerging technologies support energy applications that will prove essential to an equitable clean energy future. Next-generation technologies such as quantum sensors and direct power extraction will move towards technology maturation and then transition to the marketplace. Artificial intelligence and machine learning tools will be used to discover and select materials for harsh environment sensing. These same tools can be used to predict novel sensor performance, lowering testing and validation costs.

BENEFITS OF SENSORS, CONTROLS, AND OTHER NOVEL CONCEPTS RESEARCH

- Digitized and optimized hybrid power plants facilitate carbon emission reductions.
- Advanced data analytics, such as machine learning algorithms, facilitate optimization of energy system control and operations.
- Advanced manufacturing techniques enable cost-effectively creating and embedding sensors in energy infrastructure.
- Next-generation sensing techniques enable more data gathering and accuracy.

NETL is a U.S. Department of Energy (DOE) national laboratory dedicated to advancing the nation's energy future by creating innovative solutions that strengthen the security, affordability and reliability of energy systems and natural resources. With laboratories and computational capabilities at research facilities in Albany, Oregon; Morgantown, West Virginia; and Pittsburgh, Pennsylvania, NETL addresses energy challenges through implementing DOE programs across the nation and advancing energy technologies related to fossil fuels. By fostering collaborations and conducting world-class research, NETL strives to strengthen national energy security through energy technology development.

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