MIT/INL/Exelon Workshop

Heat Storage for Gen IV Reactors for Variable Electricity from Base-load Reactors

Changing Markets, Technology, Nuclear-Renewables Integration and
Synergisms with Solar Thermal Power Systems

Date: July 23-24, 2019
Bennion Student Union Building, Idaho State University, 1784 Science Center Drive, Idaho Falls, Idaho

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Website: https://art.inl.gov/SitePages/HeatStorageForGenIVRegistration.aspx

Description

The workshop will examine heat storage coupled to Generation-IV reactors (helium, sodium/lead and salt coolant) to enable variable electricity output while the reactor operates at base-load. The electricity market is changing because of (1) the large-scale addition of wind and solar and (2) the goal of a low-carbon electricity grid. The result is an electricity market where there are times of low and sometimes negative wholesale electricity prices and other times of high electricity prices. In such a market, a nuclear reactor that produces base-load electricity is at an economic disadvantage. Nuclear reactors have been designed primarily for base-load electricity production. That base-load market is disappearing. A new direction for GenIV reactor systems is required that addresses the changing market.

The goal of the workshop is to develop a strategic path forward to incorporate heat storage and assured peak generating capacity into GenIV reactors to enable them to be competitive in the changing electricity market. A workshop was previously held on heat storage for LWRs that emphasized heat storage systems associated with saturated steam cycles. This workshop addresses heat storage options associated with higher-temperature GenIV reactor systems that will have better heat-storage economics. Higher temperatures allow larger hot-to-cold temperature swings in storage with less heat-storage mass per unit of stored heat. Higher-temperature stored heat allows higher heat-to-electricity efficiency with less storage mass per unit of electricity. The workshop will address (1) the requirements for variable power based on market considerations, (2) the storage technology options for helium, sodium/lead and salt reactors and (3) what is the path forward? This includes heat storage in higher-temperature steam cycles, in the intermediate heat transfer loop and Brayton power cycles with heat storage and thermodynamic topping cycles.

The concentrated solar thermal power (CSP) community faces the same challenges—electricity price collapse from solar photovoltaic (PV) and wind. Thus, the workshop includes participants from the CSP community where market economics has resulted in new solar thermal power plants installing gigawatt-hour heat storage systems to maximize electricity generation at times of higher prices. There is a massive overlap between heat storage technologies and associated power cycles needed for Gen-IV reactors and advanced solar thermal power systems. Some proposed salt-cooled reactors plan to use the same salt storage systems used in CSP systems. Some of the advanced Brayton power cycles with heat storage being developed for GenIV reactors are directly applicable to the next generation of higher-temperature CSP systems. There are large incentives for cooperative programs going forward in time—from the research community to the commercial suppliers.

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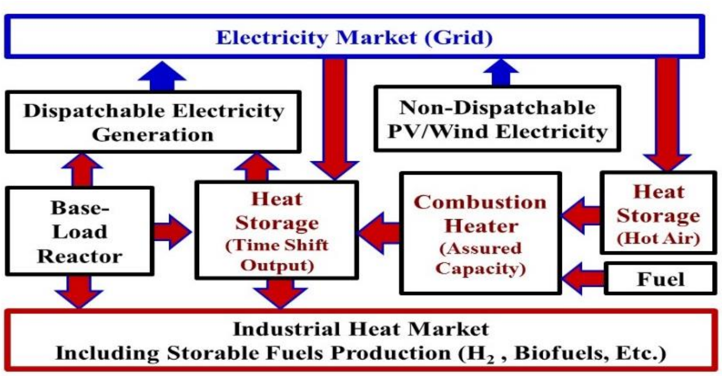
Added Resources

1. C. W. Forsberg, "Variable and Assured Peak Electricity from Base-Load Light-Water Reactors with Heat Storage and Auxiliary Combustible Fuels", *Nuclear Technology* March 2019. https://doi.org/10.1080/00295450.2018.1518555
2. C. Forsberg and P. Sabharwall, *Heat Storage Options for Sodium, Salt and Helium Cooled Reactors to Enable Variable Electricity to the Grid and Heat to Industry with Base-Load Operations*, ANP-TR-181, Center for Advanced Nuclear Energy, Massachusetts Institute of Technology, INL/EXT-18-51329, Idaho National Laboratory
3. M. Mehos et al., *Concentrated Solar Power Gen3 Demonstration Roadmap*, National Renewable Energy Laboratory, NREL/TP-5500-67464, January 2017. https://www.nrel.gov/docs/fy17osti/67464.pdf
4. The Future of Nuclear Energy in a Carbon Constrained World, Massachusetts Institute of Technology, https://energy.mit.edu/wp-content/uploads/2018/09/The-Future-of-Nuclear-Energy-in-a-Carbon-Constrained-World.pdf (MIT study)
5. C. Forsberg, K. Dawson, N. Sepulveda, and M. Corradini, *Implications of Carbon Constraints on (1) the Electricity Generating Mix for the United States, China, France and the United Kingdom and (1) Future Nuclear System Requirements*, MIT-ANP-TR-184 (March 2019)

Below are shown typical reactor coolant temperatures for GenIV reactors—what must couple to the heat storage system. The heat storage can be in the primary loop, secondary coolant loop, a separate loop isolated by a heat exchanger or the high-temperature steam cycle. These are nominal values of most proposed existing designs. There is significant work to increase the exit temperatures of high-temperature gas-cooled reactors (HTGR) to exceed 900°C and salt reactors to exceed 800°C. Both use the same fuel that is capable of much higher operating temperatures.

Coolant	Average Core Inlet Temperature (°C)	Average Core Exit Temperature (°C)	Average Temperature of Delivered Heat (°C)
Water	270	290	280
Sodium	450	550	500
Helium	350	750	550
Salt	600	700	650

There are many possible system configurations to include heat storage with a nuclear reactor. One system design is shown below that includes heat storage and assured peak electricity generation.



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