2020 Workshop

Separating Nuclear Reactors from the Power Block with Heat Storage: A New Power Plant Design Paradigm

Web Workshop: 3 Sessions: 10:00 AM-1:00 PM Eastern; Wednesday July 29, Wednesday August 12 and Wednesday August 26

Nuclear plant design has followed fossil plant design with tight integration of the reactor and power block that includes the turbine generator. This workshop examines an alternative system design (Fig. 1), proposed by several reactor developers, that incorporates large-scale multi-gigawatt-hour heat storage between the reactor and power block. This change in plant design is driven by changes in electricity markets: (1) the addition of wind and solar that causes price volatility and (2) the goal of a low-carbon grid. The reactor, operating at base-load, is a heat production system that converts a cold heat-storage medium, such as salt, to a hot storage medium that is sent to a second tank. The reactor is decoupled from the production of electricity or heat to industry. The power cycle takes (1) hot salt or other storage fluid, (2) produces variable electricity for the grid with a peak output that may be several times the power output of the reactor and (3) sends cold salt or other fluid to the cold fluid storage tank. Heat can be sent to industry. If there is very-low-price electricity, electricity can be bought and converted to stored heat for later use.

The reactor inside its security boundary is decoupled from the power block and the gird by storage — avoiding the complications from directly coupling the reactor and the grid. With separation of reactor from power block, the nuclear reactor has the nuclear licensing, construction, and security costs. The power block and heat storage are designed, built and operated to normal industrial standards with an over-the-fence separation from the nuclear systems. Such an alternative system design has major implications for design, licensing, construction, security, operations and the business model—with large implications for revenue, capital costs and operating costs. This alternative system is applicable to multiple reactor types. The system design is used in some concentrated solar power (CSP) plants and is applicable to fossil-fuel plants with carbon capture and sequestration (CCS).

This is a joint Massachusetts Institute of Technology (MIT), Idaho National Laboratory (INL), Electric Power Research Institute (EPRI) workshop. Due to recent events, it will be held as a 3-part webinar on different days. The contacts are: Charles W Forsberg (cforsber@mit.edu), Piyush Sabharwall (piyush.sabharwall@inl.gov) and Andrew Sowder (asowder@epri.com).

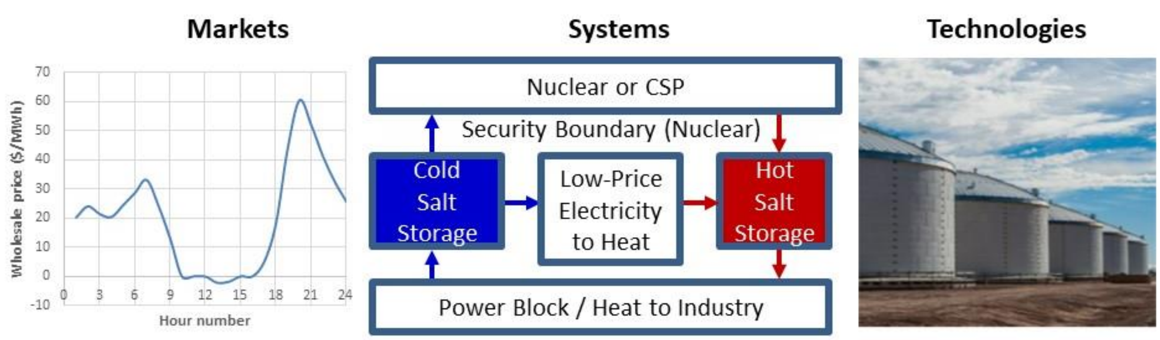

Fig. 1. Markets (Electricity Prices, California: 31 March 2020), System Design using Salt Storage, and Heat Storage (Solana Concentrated Solar Power Generation Storage, Nitrate storage, 4200 MWt)

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2020 Workshop Agenda

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Each session will include time for questions after each speaker and time after all of the talks for questions and general discussions among the participants. The presentations will be posted after each session before the next session to allow review of earlier sessions.

Session 1. Markets, Requirements and Systems Design (10:00-1:00 Eastern; July 29, 2020)

The energy market is changing because of (1) the goal of a low-carbon energy system and (2) the expansion of low-operating-cost wind and solar PV that collapse electricity prices at certain times. We examine the changes in markets and requirements and alternative nuclear system designs with large-scale heat storage to enable base-load nuclear plants to provide variable electricity to the grid and heat to industry. In the U.S., the industrial demand for heat is about twice the total electricity production; thus, there are two major markets for nuclear energy in the U.S. The addition of heat storage enables integration of electricity and heat markets because it partly decouples in time heat production versus heat and electricity to customers. Separate from these considerations, large-scale heat storage has massive implications for grid resilience because energy production is partly decoupled from the grid.

Session 2. Technologies for Heat Storage and Power Cycles (10:00-1:00 Eastern; Aug 12, 2020)

Work is underway in the nuclear and solar communities to develop heat storage systems from a few GWhs (hourly to daily storage) to 100 GWh (weekday/weekend storage) to match production with demand.[1] Research is ongoing for systems at different temperatures—suitable for LWRs or higher-temperature advanced reactors. Earlier workshops examined some of these systems. Much has happened since then as will be discussed in this session. The other half of the story are the power cycles that are now decoupled by storage from the reactor. There are the traditional cycles but also advanced power cycles designed for peak electricity production that are directly coupled to grid dispatch for very fast response to market needs.

Session 3. Economics, Business Strategies and Demonstration Strategies (10: 00-1:00 Eastern U.S. Time; Aug 26, 2020)

What are the economics? Is the base case nuclear with heat storage for variable electricity or is it nuclear co-generation with storage for variable electricity and industrial heat? What are the regulatory impacts of a system that has a 1000 MWe of base-load output that with heat storage a peak power of 2000 MWe and the ability to buy 1000 to 2000 MWe of electricity to convert to stored heat at times of low prices? What is the business model if industrial heat becomes a major product as well as electricity? What is the development and demonstration strategy? The same storage and power systems work with concentrated solar power (CSP) and fossil fuels with carbon capture and sequestration (CCS). Each of these communities has large incentives to develop similar storage/power systems to operate the heat generating technology at full capacity with variable electricity and heat to the market.

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[1]Heat Storage Coupled to Generation IV Reactors for Variable Electricity from Base-load Reactors: Workshop Proceedings, ANP-TR-185, MIT, INL/EXT-19-54909, INL (2019). https://www.osti.gov/biblio/1575201

[1]"Variable and Assured Peak Electricity from Base-Load Light-Water Reactors with Heat Storage and Auxiliary Combustible Fuels", *Nuclear Technology*, **205** (*3*), 377-396, (March 2019). https://doi.org/10.1080/00295450.2018.1518555