Impact of Increasing Share of Renewables on the Deployment of Generation IV Nuclear Systems

Economic Modeling Working Group (EMWG)

The growing penetration of variable renewables (primarily wind and solar PV) is incentivized by policy driven subsidies and sometimes supported by priority dispatch rules; while the overall electricity demand is flattening in many OECD countries. This could result to periods where the residual electricity demand can be lower than the capacity of the baseload nuclear power plants. In a liberalized electricity market this can lead to instances of negative electricity prices for dispatchable power generation, including nuclear. Hence, when revenues are derived primarily from wholesale markets, it may not be in a utility's interest to invest in a new nuclear reactor if it expects that it will be operating at a relatively low capacity factor in order to meet flexibility needs of the power systems. Flexible nuclear operations would therefore be limited to grid requirements in terms of frequency regulation and safety specific needs. Increasing penetration of renewables on the grid can also affect reliability of the power supply, and has in many cases required increased installed capacity of fast responding generators such as GHG-emitting open cycle gas turbines.

From a technical standpoint, the most commonly used method to adjust nuclear production at the plant level is to conduct load-following with ramp rates up to 5%/min. This method is in addition to grid requirements for primary and secondary frequency regulation up to +/- 5 to 7% of the rated power throughout the fuel cycle. In some countries, existing LWR can already operate in load-following mode (e.g., EDF nuclear fleet in France, where a change in the operation of the reactors as a consequence of the increasing penetration of renewables + flat demand). It is likely that the role of intermittent renewables will have increased to a significant level when Gen IV reactors are ready for deployment; requiring Gen IV reactors to also be flexible to meet the variable demand from the grid and to provide frequency regulation. Requirements for flexible operation of the advanced reactors are already now being proposed by the utilities. System developers of the Gen IV systems may have to design the Gen IV reactors taking into consideration the flexible operation requirement and associated thermal cycling and fatigue, reactivity management and fuel optimization at the design stage.

Large-scale energy storage and co-generation (for instance, hydrogen and heat) applications coupled with Gen IV energy systems could allow for flexible dispatch, while ensuring overall high capacity utilization; provided that the reactor controls and balance-of-plant and co-generation plants are designed for dynamic balancing of thermal and electrical outputs. Hybrid energy systems, consisting of coupled nuclear and renewable generators with adequate energy storage and co-generation applications could, thus, meet the flexible demand from the grid while operating the power generators to full capacity to ensure an overall economically viable operation.

Policy- and market-driven challenges could be more formidable compared to technical challenges of designing the reactors for flexible operation. Existing market designs do not always value reliability aspects of supply, nor the external costs of CO2 emissions from fossil plants. Significant policy changes will be required to recognize and value reliability of nuclear generation as part of a resilient and reliable power grid. Various policies on electricity pricing and contractual arrangements such as power-purchase agreements, strike-price, reliability payment, zero-emission credits and capacity payments have been proposed and have faced challenges. Carbon policies are also hampered in some part of the word by other policy interventions such as renewable targets. Policies to sustain existing nuclear capacity and incentivizing new investments will be required for deploying flexible Gen IV reactors with a high penetration of renewable resources in the electricity market. Such policy decisions will have to be made by the relevant authorities on the integration of renewables with nuclear such that the power is affordable to the consumer. This complex issue has to be addressed at a much higher level of policy and energy system planning (state-level). Also reactor designers could respond to changed market circumstances by offering affordable, flexible designs with a shortened construction time. Regulators could anticipate on licensing of novel designs in a predictable way, limiting investment risks.

The Economic Modeling Working Group worked collaboratively with the Senior Industry Advisory Panel to write a position paper intended to inform the Policy Group's strategic reflection on the deployment of Generation IV reactors in the future energy markets with significant penetration of renewable resources. An abridged version of the position paper will be presented at the GIF Symposium to be held in Paris on October 16-17, 2018.