Solar grid integration

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Power grids are the foundation of energy systems, playing a key role in the energy transition by enabling the use of renewable energy sources (RES). To meet the growing demand for renewable energy, the world may need to integrate RES into power grids--but there are hurdles to overcome.

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With the push to decarbonize economies, the installed capacity of renewable energy is expected to show significant growth to 2050. The transition to RES, coupled with economic growth, will cause electricity demand to soar--increasing by 40 percent from 2020 to 2030, and doubling by 2050.1Global Energy Perspective 2023, McKinsey, November 2023.

Utilities confront two significant challenges when integrating RES into electric grids. First, they face network inadequacy, with a lack of physical capacity to accommodate supply and demand in locations with the best resources. Second, as the share of RES increases, the lack of real-time network management at low voltages could lead to network instability, which may affect high reliability standards and cause voltage instabilities, frequency inconsistency, and harmonic distortion of the power system.

Grids were not originally set up for such a fast-paced energy system; their tools and processes were developed in a slower, less volatile world. In this article, we examine the challenges that grid operators are facing across planning, connection, and operations, and explore coordinated solutions to benefit from the rapidly increasing need for RES.

Almost 1,000 gigawatts (GW) of solar projects are waiting for connection across Europe and the United States (which is close to four times the amount of new solar capacity installed globally in 2022). In addition, 500 GW of wind installed capacity is waiting to be put into the grid (five times the amount built in 2022).1"A power grid long enough to reach the sun is key to the climate fight," BloombergNEF, March 8, 2023.

Similarly, in the United States, the average time spent waiting for connection has almost doubled since 2015, and now exceeds three years.3"Queued up 2022," Lawrence Berkeley National Laboratory, April 2023.

First, we have noticed that network inadequacy is a challenge for many operators (see sidebar "Network inadequacy"). At present, there is not enough physical grid capacity to accommodate supply and demand connections. This is primarily due to difficulties in optimizing grid capacity (currently designed for centralized, mainly fossil fuel generation) and inefficient grid planning, leading to less new RES capacity being built than needed.

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Grid operators face multiple challenges along the value chain that can potentially put them at risk of being underprepared for the energy transition. However, they have numerous avenues available to help them better plan, connect, and operate.

The tools and processes available at present for grid planning are not up to the task of optimizing current capacity and planning for the setup of efficient new capacity. Complex power flow models are not able to handle the long time frames, nor the uncertainties of today"s system regarding demand (absolute growth and profile effect) and supply (availability, location, and dispatchability) growth trends and could affect the future regulatory landscape.

Planners can draw on flexible and modular data architecture and AI-driven, stochastic optimization of investment plans, as these can assist in optimizing existing grid capacity and the buildout of new capacity using integrated grid planning.

Such models combine macrogrid trends and microgrid dynamics to evaluate many options, helping to build confidence under uncertainty. This allows for better planning, enabling the modeling of a full year quantifying unpredictability of events such as asset failures and voltage fluctuations, which additionally can serve as a robust fact base for regulators and operators and provide valuable insights for informed decision making.

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