ETC Briefing – Power Systems Transformation

Innovative Grid Technologies:
a fast-track to cheaper, resilient grids

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Around the world, grids will need to grow and modernise. As the world electrifies, both rapidly growing electricity demand, as well as rising wind and solar generation, will require large scale investment in both transmission and distribution grids. **Innovative Grid Technologies (IGTs) can offer a vital solution for optimising grid build.** IGTs, which can be either software solutions (such as dynamic line rating) or hardware solutions (such as advanced conductors), optimise use of existing infrastructure by maximising the network capacity and reducing losses, lowering investment needs, speeding connection queues, and accelerating renewable integration. To scale, they require coordinated action across the value chain to reform regulation, align incentives, and ease supply chain bottlenecks.

1. The world needs to massively expand and invest in grids

Upgrading global grids is one of the defining challenges of the energy transition. Overall, the Energy Transitions Commission estimates that the total global grid length must grow by around 2 times from today to 2050, growing from around 82 million km of grid in 2025 to around 150 million km in 2050, with growth across all regions.[1] To put this in perspective, 150 million km is around 1.1x the distance from the Earth to the sun. The challenge is fundamentally different around the world. In countries such as India, this simply represents a continuation of the pace of grid built out seen in the last decade. In Western Europe and the US, the increase will be a step change after a period of relatively slow investment.

These expansion needs are matched by a similar order of needs of investment. Total global investment in grids needs to grow from around $370 billion in 2024 to ~$900 billion per annum in the 2030s and 2040s. About 55% of the total is required in the distribution network and 45% in transmission. This is not just about adding more copper wires – it involves replacing aging grid assets and modernising grid infrastructure and capabilities, such as enabling two-ways flows.

2. IGTs can reduce grid investments by up to 35%

IGTs are both software and hardware solutions that can optimise the use of existing grid infrastructure by maximising network capacity and reducing losses. Commercially ready IGTs include hardware solutions such as advanced conductors, voltage upgrades, and “storage as transmission assets” which can boost network capacity by 40% to 400%. On the software side, technologies like flexible AC transmission systems, dynamic line rating (DLR), volt-var management, dynamic voltage control and grid inertia and flexibility measurements can increase network capacity by around 30% through real-time visibility and response.[2] Advances in artificial intelligence are now making these tools more powerful, improving automation, precision and integration into grid operations. Emerging applications include self-healing grid systems that automatically detect and isolate faults.[3]

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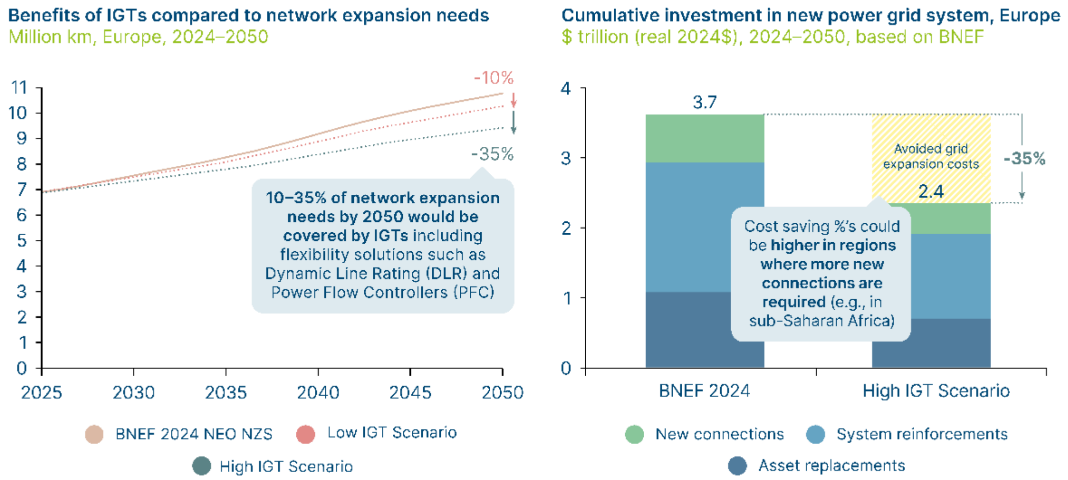
[1] IEA (2023), Electricity Grids and Secure Energy Transitions; BNEF (2024), NEO grids.
[2] IEA (2023), Electricity Grids and Secure Energy Transitions; BNEF (2024), NEO grids;
[3] Alam et al (2025), Artificial intelligence integrated grid systems: Technologies, potential frameworks, challenges and research directions

The IGT opportunity is significant. In Europe, deplying IGTs could unlock a 20–40% improvement of grid capacity by 2040; even at a conservative 10–20% improvement, this equates to gaining 4–8 years of new grid build. Maximum deployment of IGTs could reduce cumulative European network investment needs by $1.3 trillion (35%) between now and 2050.[4] There is even greater potential in fast-growing regions such as Sub-Saharan Africa to achieve a higher proportion savings on new grid investment. In the US, IGTs could increase grid capacity by 20–100 GW and defer $5–35 billion in transmission and distribution costs over the next five years.[5]

Innovative grid technologies could significantly reduce grid build and investment



NOTE: We have assumed that IGTs impact all three investment categories: IGTs lower new connection needs by maximising existing and new infrastructure use (though some remote renewables still need connections, new connections leveraging IGTs will require fewer upgrades in future); IGTs delay system replacements by extending grid asset life; and IGTs reduce reinforcement requirements by improving line capacity and utilisation.

SOURCE: Systemiq analysis for the ETC; CurrENT (2024), *Prospects for innovative power grid technologies*; BNEF (2024), *New Energy Outlook.*

Examples of IGT deployment:

- **Dynamic Line Rating** is already deployed in UK, US, Belgium, France, and Norway. It Increases line capacity by 10–45% depending on external conditions. Its effectiveness is particularly high in temperate regions.[6]
- **Advanced conductors** can double the power capacity which can be carried by lines of pylons. As a mature market technology, it is already cost-effectively installed at scale: 20,000 km in Europe and 175,000 km worldwide.
- **Super conducting materials** could increase line capacity by 4–10 times, but commercial availability is expected only by around 2030 and may be expensive even when deployed at large scale.[7]

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[4] CurrENT (2024), Prospects for innovative power grid technologies.
[5] US DOE (2024), Pathways to Commercial Liftoff: Innovative Grid Deployment.
[6] National Grid (2022), National Grid trials new technology which allows more renewable power to flow through existing power lines; US DOE (2017), Improving Efficiency with Dynamic Line Ratings
[7] Systemiq analysis for the ETC; CurrENT (2024), Prospects for Innovative Power Grid Technologies; BNEF (2023), New Energy Outlook Grids

3. IGTs can grow to be a $100 billion USD market

IGTs are an attractively sized market – a high-level estimate of market value is conservatively at $100 billion[8], using digital grid investment share of total grid investments as a proxy. In reality this has a fair chance of being higher due to hardware making up the majority of total grid investments to date and projected to continue at 85%[9].

4. Value chain stakeholder action needed to push for change in regulatory and policy incentives

Despite their potential, IGTs are not yet being scaled. There is growing focus on transmission-level solutions, but distribution-level options that alleviate local network constraints remain underutilised[10]. Scaling IGTs will require coordination fo the value chain to:

- **Reform grid regulation:** Regulators should ensure that innovative grid solutions are valued equally to conventional grid build. This includes:
    - A shift away from mandates that encourage grid operators to minimise operational expenses, while allowing capital investments to "pass through" on a regulated rate of return for the grid operator; a shift away from regulation that links revenues only to keeping costs low, and not to increasing overall output, which discourages innovation and risk-taking.[11]
    - Establishing preliminary deployment mechanisms, such as the use of regulatory sandboxes, to accelerate validation. Several jurisdictions are experimenting with adjacent mechanisms to support innovative solutions, (E.g, in the UK, the US through the FERC, and Australia).[12]
    - Ensure IGTs are part of regulated business plans, to understand holistic benefits.
- **Early low-regret deployment,** through partnerships and commercial demos between grid operators and technology providers, and then rapidly moving to system-wide adoption. Software-based IGTs should be prioritised in the near-term to deliver immediate gains, gather real-world data and better understand grid constraints.
- **System operator integration**, by improving integration between system operators and transmission owners. This involves interoperable data models and shared digital platforms[13] that allow information from different grid systems to be shared and interpreted consistently, enabling IGTs to deliver coordinated, system-wide

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[8] Estimated using digital share of total grid spend as a proxy for IGT spend, and projected future grid annual spend from BNEF and IEA
[9] BNEF (2024): Readying the Global Power Grid for Net Zero
[10] Examples include Switched Source's dynamic feeder reconfiguration and FischerBlock's local voltage and frequency stability technologies.
[11] E.g. Performance could be defined as grid capacity utilization, grid congestion reduction, or SAIDI improvement.
[12] This includes Ofgem's Strategic Innovation Fund in the UK, the United States Federal Energy Regulatory Commission's proposed shared-savings incentives for grid-enhancing technologies, and the Australian Energy Regulator's regulatory sandbox framework.
[13] Schneider Electric (2022) Grid to Prosumer: A Practical Guide for Digital Energy Transition.

optimisation[14]. Dispatch rules and control platforms should be able to absorb and act on new data (e.g. from DLR, which provides real-time visibility of transmission line capacity based on temperature, wind speed and conductor conditions).

- **Adoption of AI and data capabilities on the grid**: Grid capabilities should be upgraded to leverage new digital tools for real-time system monitoring and balancing, using cloud-based data platforms and digital twins that combine information from IoT devices, smart meters and sensors[15]. AI enhances grid visibility and automation by enabling self-diagnosis and self-healing, allowing automatic detection and localisation of faults, rapid isolation and re-routing of power to minimise outages and accelerate system recovery.

5. Areas for further dialogue

The recommendations outlined in this piece are a starting point. Delivering on them will require collaboration across regulators, transmission operators, technology providers and policymakers. To that end, we invite discussion on a set of open questions that remain critical to unlocking progress:

1) How to make near term progress given long regulatory timescales?
2) What changes to the cost-recovery frameworks would incentivise operators to prioritise innovative solutions alongside conventional grid build?
3) What partnerships between utilities, technology providers, and government could accelerate system-wide adoption?

[14] For example, Europe's transmission operators use a common grid data model to exchange information on network conditions, as well as real-time limits fed into dispatch and secure, API-based data sharing to ensure system-wide value
[15] Schneider Electric (2021) GOPaaS White Paper: Grid Operations Platform as a Service