Prospects for innovative power grid technologies

Launch event

19 June 2024

CONFIDENTIAL

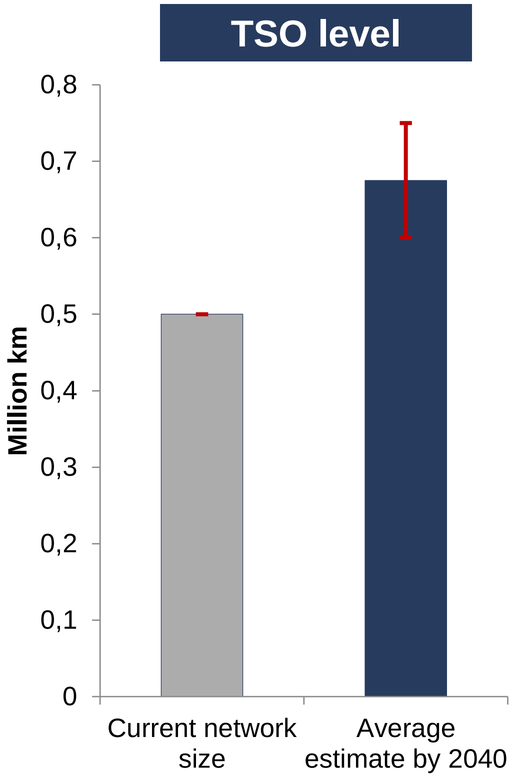
Context: A considerable expansion of electricity networks is required for the energy transition

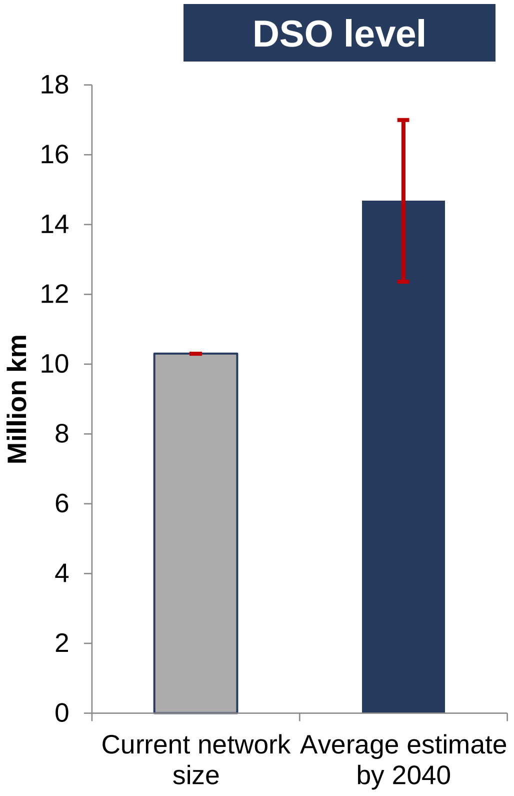
A significant expansion of the network is required for the energy transition in Europe, to integrate 2,000 GW[1] of renewables in 2040, compared to around 400 GW today:

- The total current size of the EU grid is **0.5 million km** at transmission level and **10.3 million km** at distribution level.
- By 2040, transmission grids might need to be expanded by **20-50%** to a total length of **0.6-0.8 million km**, and distribution by **20-65%** to a total length of **12.4-14.7 million km**, in the context of the energy transition – range based on an extensive review of prospective studies and CL analysis.

The required buildout needs to happen 3 to 20 times faster than past buildout rates, and the delivery capacity of TSOs and DSOs, and related supply chains might be under strain.

- In recent years, annual network built out in Europe has been approximately **500 km/year[2]** at the transmission level and **80,000 km/year[3]** at the distribution level.
- The buildout required by the energy transition might need to jump to **10 000 km/year** on average at transmission level, and **250,000 km/year** distribution level, a jump 20 and 3 times, respectively.



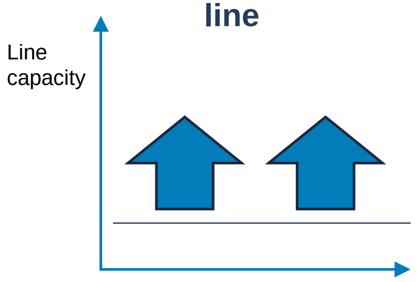


Source: CL analysis, [1] based on ENTSO-E Distributed Energy Scenario, [2] based on ENTSO-E inventory of transmission database, [3] 0.8% increase in the length of the distribution network in 2021-2022 according to Eurelectric (2024) Grids for Speed

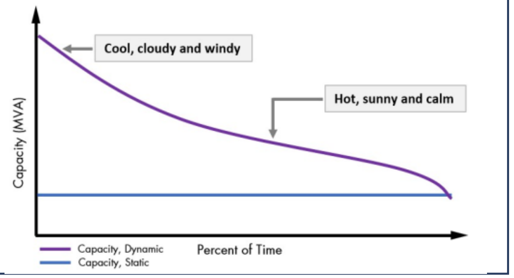
Opportunity: Innovative Grid Technologies (IGTs)[1] can support the required network buildout

Superpowers:

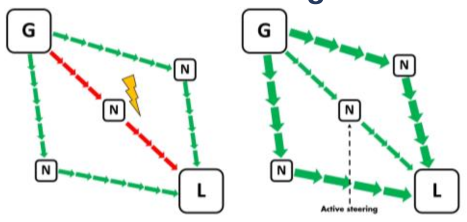
Capacity increase for a given line



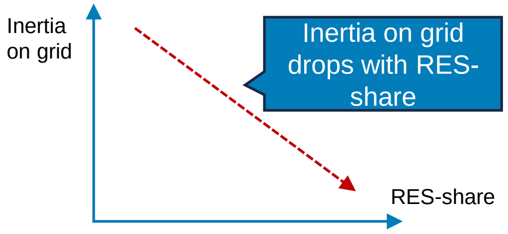
Better understanding of actual line limits



Dynamically controlling power flows on the grid



Better understanding of actual inertia limits/stability limits



Innovative Grid Technologies:

Advanced conductors **High Temperature Superconductor** **Storage as a transmission asset** (SATA)	**Dynamic line rating** (DLR)	**Advanced Power Flow Control** (APFC)	**Grid inertia measurements**

Digital Twin, Flexibility Management Systems

Note: [1] The US term "Grid Enhancing technologies" can also be use to describe technologies that "maximise the transmission of electricity across the existing system through a family of technologies that include sensors, power flow control devices, and analytical tools", according to the DoE (see US DoE (2022)). ***IGTs can hence also be referred as GETs+.***
this theoretical framework does not provide an exhaustive classification of IGTs, and of their effects. Other technologies and effects could potentially be considered.

Benefit 1: Reinforcing existing electricity infrastructure

Assuming a fast deployment, IGTs could increase overall network capacity btw. 20% to 40%, based on inputs from technology experts

- Current electricity infrastructure capacity stands at least at 550 GW in the EU[1]
- Case studies from actual application of IGTs demonstrate significantly **increased capacity figures**
- Overall, by assuming a fast deployment of several IGTs on the grid, based on discussions with technology experts, **a 20% to 40% overall capacity improvement (e.g. on the wider network) by 2040, seems realistic**, enabling from approximately 100GW to 200GW of additional capacity.

IGT	Capacity increase achieved / Case study example
Advanced power flow control	**5%** increase in overall network capacity
Advanced conductors	**100%** increase in capacity of a line
Storage as a transmission asset	**40%** increase in capacity of a line
Dynamic Line Rating	**30%** increase in capacity of a line
Grid Inertia Measurement	Reduced RES curtailment thanks to +30% higher assumed inertia
High temperature superconductors	**400% to 1000%** increase in capacity of a line[2]

20%-40% capacity improvement of overall network would be achievable

Note: [1] EU peak demand (see for instance ENTSO-E (2018) Electricity in Europe 2017), [2] compared to conventional lines

Benefit 2: Faster deployment of grid capacity at system level

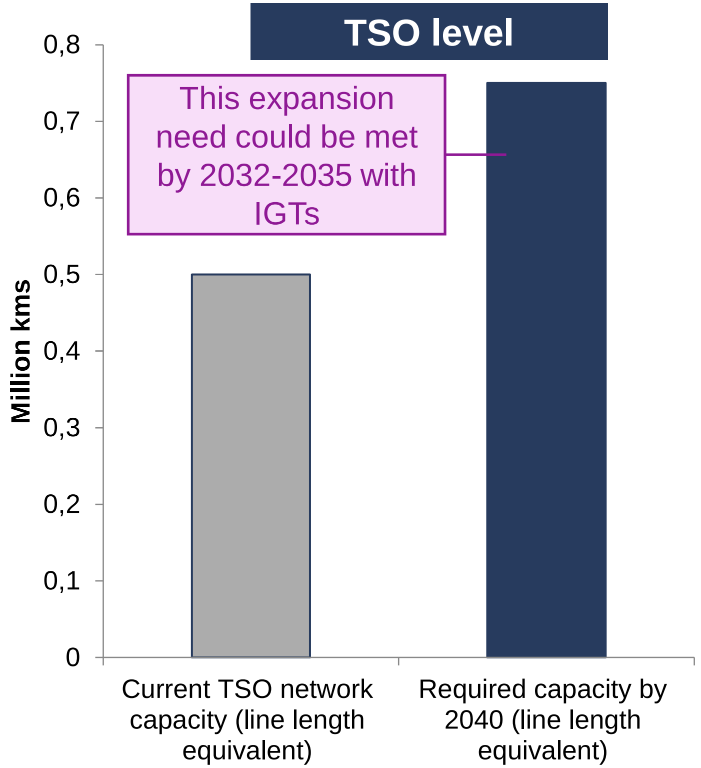
A conservative 10-20%[1] increase in network capacity through IGTs would already yield major benefits

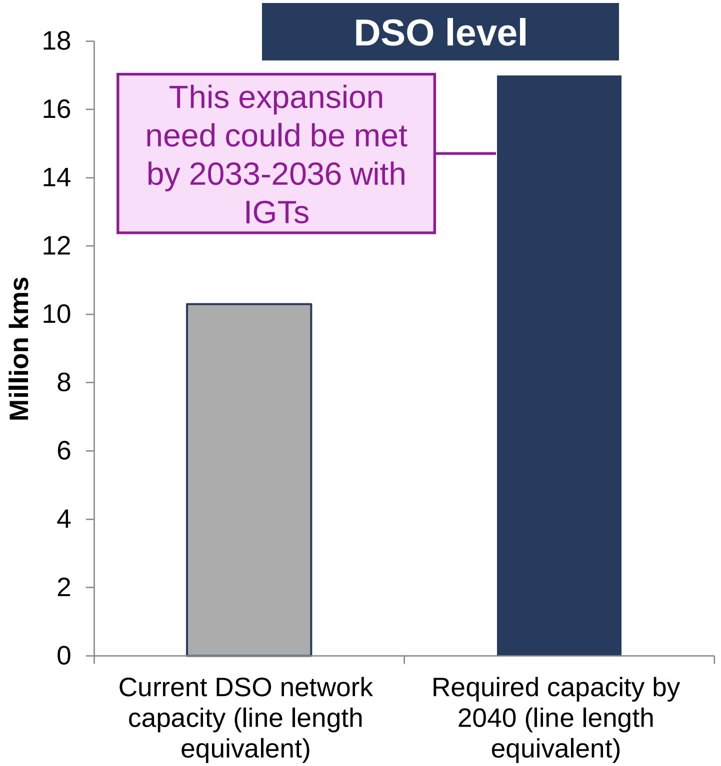
IGTs – in combination with conventional grid expansion - can support adding the required capacity faster.

By considering a **10% to 20%[1] increase** in the capacity of the existing grid assets achieved by 2030, and by considering **that similar improvements is applied to all new grid assets built in the future**, we see that:

- **Transmission grids** expansion can be accelerated **by 5 to 8 years**
- **Distribution grids** expansion can be accelerated **by 4 to 7 years**

Comparison of current network size and size required by 2040 in the EU (upper range)





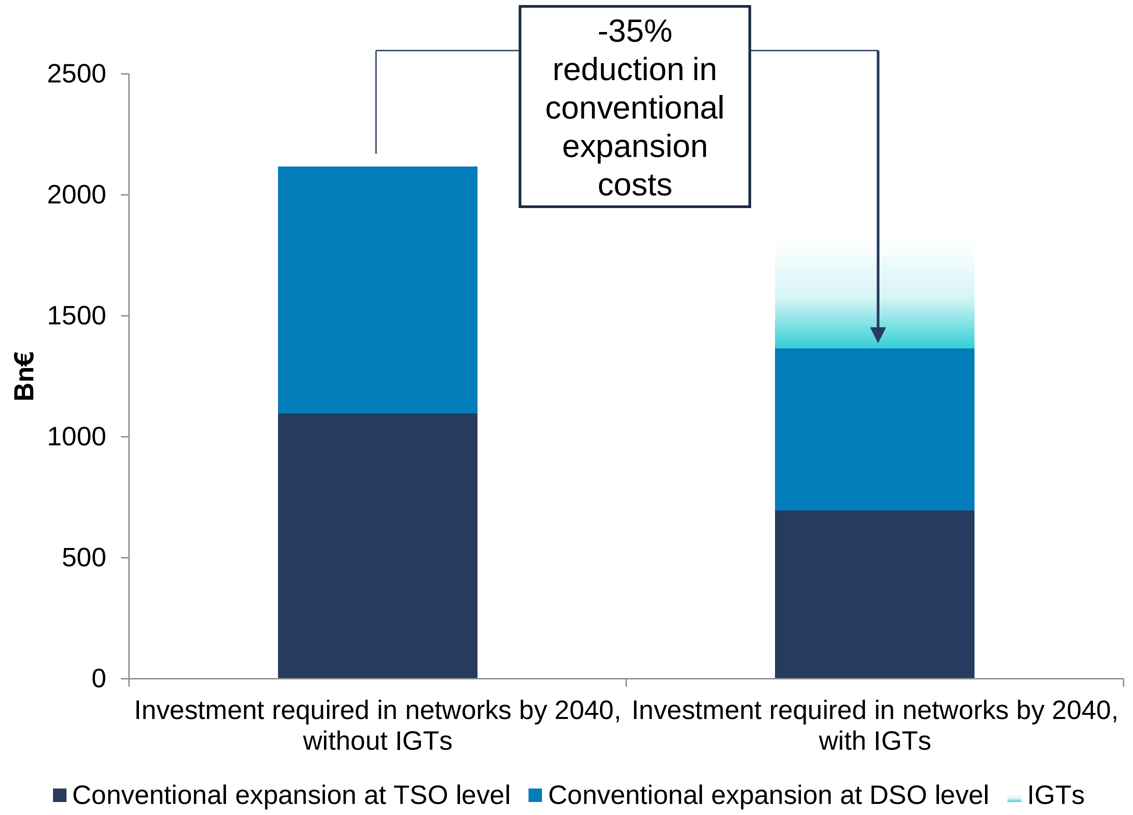
Note: *[1]* To avoid overstating capabilities or underestimating unforeseen challenges, a conservative 10% to 20% (halved) overall increase is used in the rest of the study. *[2]* The upper range of network expansion need is considered here to avoid overstating IGTs capabilities

Benefit 3: Reduction in required investments

By investing in IGTs in parallel to conventional grid buildout, gross cost savings of 700 Bn€ in conventional expansion might be achieved by 2040

- The required investments in electricity networks, if IGTs are not deployed at scale, might amount to approximately **1000 Bn€[1] in the transmission network** and **1000 Bn€[2] in the distribution network** in Europe by 2040.
- Installing IGTs (with the assumptions described in the previous page) could reduce the need for network buildout by approximately 35% by 2040, and hence achieve overall **gross savings of 700 Bn€ in conventional expansion costs.** However, this figure doesn't take into account the costs of IGT deployment themselves.
- Nonetheless, these **gross benefits** may be **significantly higher than the costs of deploying the said IGTs** – for instance, the US DoE indicates that IGT can indeed achieve an increase in capacity at a lower cost than conventional reinforcements[3].

Gross benefits of IGT deployment - Saved investments in network expansion



Note: [1] CL estimate, based on the projected cost of onshore network buildout per km of new lines in Germany, Italy and Spain, and the need for network buildout presented in this study [2] 67Bn€/year for EU27+NO according to Eurelectric (2024) Grids for Speed, [3] For instance, for APFC and DLR, see: DoE (2022) Grid-Enhancing Technologies: A Case Study on Ratepayer Impact

Despite these substantial benefits IGTs could provide to the energy transition, their deployment is currently hindered by several barriers

Barriers for IGT deployment

1 Lack of incentives to opt for non-CAPEX intensive solutions	▪ **Incentive to opt for CAPEX solutions rather than OPEX solutions due to a difference in the regulatory treatment between OPEX and CAPEX.**
2 Insufficient output incentives and incentives for innovation	▪ **Lack of incentives for network operators to use overall cheaper solutions** ▪ **Lack of incentives for innovations that may cost-efficiently increase output**
3 Investment doctrine and methodologies of network operators	▪ The investment doctrine of T/DSOs might include **bias towards predetermined solutions to fix the issues identified, rather than adopting a technology-neutral approach to answer system needs**.
4 Death-by-pilot risk	▪ **IGT adoption is hindered by long processes for network companies to trial and then adopt new innovative solutions**.
5 Funding schemes' eligibility issues	▪ **Some of the potentially available funding schemes cannot easily be accessed by IGTs yet, due to eligibility issue of IGTs.**

Sources: Compass Lexecon

Regulatory solutions exist to remove these barriers, and have already been implemented in some European countries

Barriers for IGT deployment	Examples of best practices and solutions
1 Lack of incentives to opt for non-CAPEX intensive solutions	▪ TOTEX regulation ▪ Introduction possibility of OPEX increase for network operators
2 Insufficient output incentives and incentives for innovation	▪ Output-based remuneration, decoupled from CAPEX/OPEX spent
3 Investment doctrine and methodologies of network operators	▪ NOVA principle: grid optimisation has priority over grid reinforcement, which has priority over grid expansion ▪ Technology-neutral planning approach, e.g. with CBAs
4 Death-by-pilot risk	▪ Lump-sum innovation Funding / WACC premiums ▪ Regulatory sandboxes ▪ Transfer of best-practices and standards
5 Funding schemes eligibility issues	▪ Widen eligibility of national and EU-financing schemes to IGTs

Thank you for your attention!

Key insights

Context of grid expansion needs

20 to 50%
increase in TSO network length required by 2040

20 to 65%
increase in DSO network length required by 2040

3 to 20x
Increase in buildout speed compared to past

IGT Benefit 1: Reinforcing existing electricity infrastructure

20% to 40%
increase in overall capacity achievable with IGTs based on expert discussions

IGT Benefit 2 Faster deployment of grid capacity at system level

5 to 8 years
Acceleration of TSO grid expansion by 2040

4 to 7 years
acceleration of DSO grid expansion by 2040

IGT Benefit 3 Reduction in required investments

-35%
Reduction in conventional expansion costs by 2040

700 Bn€
gross cost savings of conventional expansion