T&D europe

The European Association of the Electricity Transmission and Distribution Equipment and Services Industry

Digital Twins: Crucial for the Energy Transition

T&D Europe position paper

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Digital Twins are crucial for the success of the green energy transition

The energy sector is undergoing a significant transformation with decentralisation and multi-directional energy flows escalating the need for infrastructure upgrades. Electrification is raising electric energy demand and altering load profiles. The volatility of renewable energy generation requires greater flexibility and real-time balancing in the operation of network assets. In addition, enhancing energy efficiency to reduce peak demand is another key requirement.

Digitalisation will be a key enabler for the Europe's energy transition. The EU's Digital Strategy and Action Plan for the Digitalisation of the Energy Sector outlines a clear vision for the future electricity grid. Digital Twins will be crucial to this transition, connecting the physical and digital worlds to monitor, operate, coordinate investments, and drive the digitalisation of the energy system.

T&D Europe sees Digital Twins as a key element in facilitating the energy transition. Digital Twins have broad applications and offer numerous benefits depending on their specific applications. They enable grid transparency, grid efficiency, grid reliability, and improve asset and system availability. However, an effective Digital Twins ecosystem requires adherence to the specific framework conditions of the EU energy sector. In the following, T&D Europe presents its views and its recommendations on how to address the specific needs of the European energy sector.

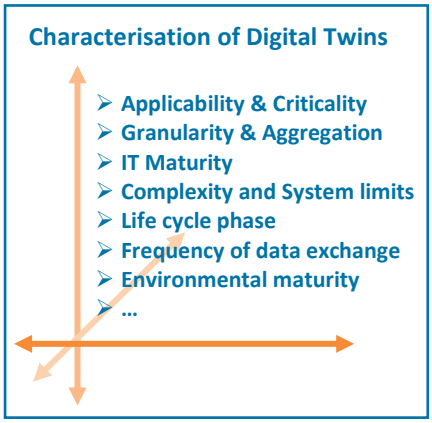
Digital Twins of the electricity grid

To develop the digital grid of the future, it is necessary to digitalise various aspects and stages of the electricity grid throughout its entire lifecycle: design, manufacturing, installation, commissioning, operation, maintenance, and end-of-life/disposal.

Elements of this digitalisation are already in place and will be integrated into future Digital Twins. Consequently, the future will be made up of an ecosystem of digital twins. An ecosystem that can scale effectively and maximise synergies across the entire energy sector and among all stakeholders.

T&D Europe defines Digital Twins as:

> *"Digital Twins are virtual replicas of physical assets, systems, processes, or software. They enable real-time monitoring, analysis, simulation, forecasting and control. In the context of electrical grids, Digital Twins represent the entire grid infrastructure, including substations, power plants, distribution networks, and software systems."*[1]



Digital Twins use data to enable the most efficient and cost-effective use of assets. They can represent single or multiple assets, as well as different aspects of a larger system, which together form an ecosystem. Interoperability of Digital Twins is essential to fully benefit from their implementation. For example, the Digital Twin of a substation must be able to communicate with the Digital Twins of various components, such as transformers, circuit breakers, and disconnectors. Digital Twins can also represent different stages of the lifecycle – planning, design, build, operation, maintenance, and recycling – across the entire electricity value chain, including transmission and distribution.

Furthermore, Digital Twins can vary in complexity. They range from static Digital Twins, with static properties such as catalogue data, to near real-time Digital Twins, where state and environment data enable grid state visibility and real-time contingency analysis. The most complex are intelligent Digital Twins, where AI and machine learning facilitates medium- and long-term planning as well as near real-time optimisation. The design and maturity of Digital Twins depend on the use case.

What all Digital Twins have in common is that their benefits are greater when they are implemented within a digital ecosystem. A digital ecosystem refers to an

[1] Digital Twin Consortium: https://www.digitaltwinconsortium.org/initiatives/the-definition-of-a-digital-twin/

interconnected network of sectors, processes, and technologies that interact and collaborate through digital channels, such as communication paths or platforms. When embedded in such an ecosystem, Digital Twins **share and continuously enrich data throughout their lifecycle.**

Digital Twins' Potential for the Electricity Grid

Digital Twins offer a wide range of benefits to the electricity sector. Depending on the use case, they can help plan network expansion and assets operation more cost-effectively, optimise maintenance times, reduce outages, and increase revenues. They also improve the reliability and resilience of the grid against extreme weather events and other grid disturbances. Most importantly, digital twins enable **smart grid functionalities**[2] across the life cycle, such as:

- Continuous monitoring and forecasting of asset and grid status at all grid levels
- Dynamic balancing of generation and load, considering available hosting capacity, improved consumption estimation and better forecast renewable generation
- Aligned system operation across all grid levels
- Predictive system management that leverages the operational limits of assets

These smart functionalities enable various use cases, for example:

- **Grid Optimisation**: Enhancing grid utilisation by identifying components overload and optimising energy load balancing
- **Scenario Simulation**: Testing measures to various scenarios such as increased demand or extreme weather events to ensure grid resilience
- **Asset Performance Management**: Monitoring and optimising the performance of grid assets to improve reliability and efficiency
- **Real-time Monitoring**: Providing real-time insights into grid operations for proactive decision-making

Digital Twins provide real-time data to monitor and enable control functions throughout the entire lifecycle of the network. They link this information with asset lifecycle data. By using a standardised approach, they can provide data access for all grid applications and

[2] More about future grid functionalities:
full study: 2023-03-13_ZVEI_Stromnetze_2030_final_Anpassungen_ZVEI.pdf,
management summary: Study_Power_Grids_2030__EN_Management_Summary.pdf (zvei.org)

enable cross-sector information exchange. **Digital Twins have the potential to scale exponentially, supported by a conducive regulatory framework and integrated digital ecosystem.** They should be designed to accommodate future growth and adapt to changes in grid infrastructure. Fundamentally, they must be designed to be scalable and flexible at their core.

Specifics of Digital Twins in the Electricity Grid

Digital Twins in the electricity grid must consider specific framework conditions due to the unique characteristics of this highly regulated sector.

Historical Evolution: The electricity grid has developed over the last 120[3] years and continues to evolve, integrating new assets into an existing, highly interconnected system. This requires Digital Twins to accommodate a broad mix of technologies and (digital) maturity levels.

Regulatory Framework: The **regulatory environment** plays a crucial role by setting the **monetarisation conditions**. It establishes the framework for investment, depreciation, and cost itemisation, which are essential for viable business cases of Digital Twins:

- **Reliability and Security**: The reliability and security of electricity supply are the key values for grid operators and heavily influence their actions and decisions. Digital Twins must align with these core values to be effective.
- **Shifting Sector Boundaries**: Traditionally, the **boundaries of the electricity sector** have been clearly understood and defined both technically and from a regulatory standpoint. However, this is evolving. With targeted sector coupling and increased electrification, the grid must now provide new functionalities and also consider the needs of other sectors, such as mobility, buildings, and industry.

[3] Tennet: https://www.tennet.eu/de/blog/die-geschichte-des-leitungsbaus-im-land-der-leitungspioniere

Key elements to enable Digital Twins

Today's technologies can be leveraged to create an ecosystem of Digital Twins. However, the electricity sector must accelerate the adoption and integration of these technologies to fully enable Digital Twin implementation.

Digital Twins bridge the real and the physical worlds. Consequently, the framework conditions of both realms – encompassing both software and physical elements - must be considered when developing a Digital Twin.

Digital and physical enabling technologies for Digital Twin implementation

Digital world - requirements	Digital world – current state
• **User-friendly interfaces**: ➢ Dashboards and 3D visualisation for displaying grid behaviour and performance in an accessible way. • **Robust Computing systems**: ➢ Include cloud infrastructure and edge computing solutions. • **Data management and analytics**: ➢ Comprehensive systems for data storage, cleansing, preprocessing, and fusion, capable of handling large amount of data through techniques such as advanced analytics, machine learning, and artificial intelligence. • **Advanced algorithms:** ➢ Facilitate utilisation of AI in energy sector to enhance the grid performance based on real-time data and insights from physical assets. • **Standardised data models**: ➢ Implement a Single Source of Truth Concept (SSOT)[4] to ensure consistency and accuracy of data.	The digitalisation of the electricity grid is currently partial. The transmission network exhibits higher digital maturity, which facilitates the implementation of Digital Twins and provides more value. This represents the initial phase in creating a well-connected digital ecosystem for the grid, establishing a solid foundation for complete integration and optimisation. Several projects, both completed and ongoing, have been funded to enhance secure and ubiquitous interoperability. However, digital maturity in the distribution network is lagging, partly due to its greater complexity.

[4] Single Source of Truth as a consistent and trusted data foundation: As the volume of available data continues to grow, it becomes increasingly important to link data and ensure that different systems use the same data foundation. Currently, it is common for different software systems to operate independently without the ability to link and utilize each other's data. This leads to inefficiencies and a lack of comparability in analyses. A Single Source of Truth (SSoT) ensures a universally valid data repository, which is a fundamental requirement for the application of Digital Twins.

• **Integration APIs and data standardisation**: ➢ Facilitate system integration and synchronisation through seamless data exchange. • **Mature platforms and data spaces**: ➢ Ensure data accessibility across sectors and among stakeholders. • **Robust security protocols**: ➢ Employ encryption techniques, access controls, monitoring mechanisms, and reliable communication channels to protect data integrity, prevent unauthorised access, and ensure the privacy of sensitive information.	
Physical world - requirements	**Physical world – current state**
• **Systemwide rollout of measuring and communication devices**: ➢ Include gateways, IoT devices and sensors deployed in substations, transformers, and power line equipment. • **Remote controllable assets** • **Mature communications network**: ➢ Both wired and wireless networks, with connectivity to all required assets, including Gigabit grid and 5G. • **High performance computing systems** • **Scalable Infrastructure**: ➢ Systems and networks designed to scale with increasing data volumes.	The majority of the existing system, particularly on Distribution MV/LV, lacks digital connectivity.

(Reference: The Digital Twin in the Network and Electricity Industry by VDE ETG – May 2023 https://www.vde.com/resource/blob/2293228/3e50b3417c8777c85e9e33cb3e1e9ebc/vde-st-a4-digital-twin-12-2023-final-data.pdf

T&D Europe Recommendations

Without the appropriate regulatory framework, the real and the digital world cannot be connected. Digital Twins are crucial to generate the synergies between the individual elements. To facilitate the development and deployment of interconnected Digital Twins throughout the lifecycle and value chain of the electricity grid, policymakers and implementing stakeholders should focus on the following topics. While some of these have already been recognised by stakeholders, T&D Europe strongly reinforces the importance of the following recommendations:

1. Build out and upgrade hardware to leverage Digital Twins

A digital layer must be added to the existing grid infrastructure:

- Rollout measuring and communication devices like gateways, IoT sensors across substations and power lines especially in low and medium voltage grids.
- Establish mature wired/wireless networks, connect assets, and implement high-performance scalable computing systems.

2. Enhance data availability, quality and interoperability

Digital Twins depend on high-quality, near real-time data from various sources. To achieve this, T&D Europe recommends:

- **Clear data ownership and governance framework**: Establish clear responsibilities and permissions for data access and use to avoid ambiguities.
- **Comprehensive data interconnectivity and consolidation**: Integrate data sources to eliminate data silos and prevent data inconsistencies, ensuring a seamless flow of information.
- **Data quality assurance**: Ensure the data is accurate, consistent, and reliable to support effective Digital Twin operations.
- **Connectivity and latency management**: Establishing reliable connections and minimise data transmission delays to maintain real-time functionality.
- **Flexible and scalable IT infrastructure**: Develop infrastructure capable of accommodating growing data volumes, computing demands, and additional functionalities.
- **Data Integration Platforms**: Implement robust systems for integrating diverse data sources and formats into a unified environment. Data spaces for example can achieve this by enabling collaborative insights, ensuring data sovereignty, and enhancing ecosystem connectivity, thereby revolutionising how organisations interact with and benefit from their data.

- **Single Source of Truth (SSOT) concept**: Adopt SSOT principles to ensure a reliable and efficient development process, preventing uncontrolled data redundancies and inconsistencies when integrating and interconnecting data.

3. Comprehensive deployment of Digital Twins in interconnected grids

For Digital Twins to be effectively deployed and to communicate across sectors, grid areas, voltage levels, and lifecycle stages, T&D Europe recommends:

- **Developing a data ecosystem**: Create an interconnected network that integrates various actors, technologies, and services to support Digital Twin deployment.
- **Facilitating key information transfer**: Ensure the seamless transfer of information across grid areas and voltage levels. This supports a holistic and comprehensive understanding, planning, and efficient management of the network. Effective data exchange within the Digital Twins of the electricity sector is crucial.
- **Integrating lifecycle data**: Collect and integrate data from all stages of the lifecycle to maximise the asset value and reliability. Policy makers should encourage the use of data collection technologies, for instances, the use of IoT devices.
- **Cross-sector data exchange**: Future data exchange between the energy sector and other sectors requires a cross-sector data ecosystem. To achieve this, standardisation of APIs across all sectors is necessary.

4. Security and Privacy Concerns, and regulatory and compliance considerations

Digital Twins manage critical energy infrastructure data, which requires robust cybersecurity measures to counteract cyber threats. Additionally, addressing privacy concerns around the collection, storage, and sharing of grid data is critical for maintaining stakeholder trust. T&D Europe recommends the following:

- **Implement robust cybersecurity measures**: Ensure comprehensive protection of sensitive data and prevent unauthorised access to both Digital Twins data and associated infrastructure.
- **Establish a clear data access framework**: Define and regulate who has access to the data, the conditions under which data can be shared, and the responsibilities for data management.
- **Address privacy concerns**: Using techniques such as anonymisation or pseudonymisation to safeguard sensitive data, preserving privacy while maintaining its analytical value. For instance, an identity management

framework can help securely manage and protect identities, enhancing the overall privacy and security.

- **Conduct regular security assessments**: Perform periodic security evaluations and audits to identify and address potential vulnerabilities in the system.

5. Support technical expertise and a motivated mindset

To implement Digital Twins on a large scale, it is crucial to foster both digital and technical expertise. The following measures are recommended to achieve this:

- **Encourage workforce upskilling**: Invest in training programs to enhance skills in areas such as power systems engineering, software, AI, data analytics, grid optimisation, and cyber/physical security.
- **Facilitate digital transition acceptance**: Apply change management principles to address the organisational acceptance of digital transformation, driving both cultural and operational change.
- **Promote awareness and prioritisation**: Increase awareness of the energy sectors' digital needs and prioritise initiatives, such as integrating Internet of Things (IoT) devices, to enable real-time monitoring and control of energy assets, thereby improving efficiency and reliability.

6. Harmonised approach towards implementation across the EU and its Member States

To ensure the successful implementation of the Digital Twin strategies across Europe, a consistent approach among the Member States is essential. T&D Europe recommends:

- **Monitor progress with Smart Grid Indicators (SGIs)**: Track the advancement of Digital Twin implementation across the Member States using SGIs.
- **Develop a regulatory monetarisation scheme**: Establish a suitable regulatory monetarisation framework that includes innovation incentives and compensation for investments to support and encourage Digital Twin adoption.

Conclusion

Digital twins are pivotal to the energy transition, fundamentally transforming the energy sector and enabling the smart grid functionalities essential for meeting the 2040 decarbonisation targets. By interactively leveraging real-time data and AI algorithms, Digital Twins enhance grid transparency, controllability, forecasting, and operational capabilities and efficiency across all voltage levels and stages of the grid's lifecycle. They also facilitate effective communication between system operators and the various energy sector stakeholders, promoting cross-sector synergies.

Effective data transfer within the Digital Twin ecosystem is crucial to unlock its full benefits. Digital Twins play instrumental in economically expanding and strengthening the grid capacity while securing grid stability.

The recommendations proposed by T&D Europe aim to accelerate the rollout of Digital Twins, targeting scalability and speed. T&D Europe highlights the necessity for build out and upgrade hardware, improved data availability, quality, and interoperability, alongside the need for technical expertise and digitally motivated mindset of the stakeholders. It is essential to cultivate an environment that encourages innovation and entrepreneurship, facilitates data access and sharing, and upholds fair competition, intellectual property rights, security, and privacy. Moreover, this environment must guarantee secure and reliable investments, providing the remuneration underpin and accelerate the energy transition.

To achieve this, Digital Twins integrate various technology layers, from sensors and grid devices to software applications, by merging their data to create smart functionalities and enhance grid intelligence with innovative data products. The Digital Twin ecosystem thus evolves into a dynamic platform for new smart businesses, driving development and innovation across the entire energy sector.