SIEMENS

Ingenuity for life

Siemens Electrical Digital Twin

A single source of truth to unlock the potential within a modern utility's data landscape

siemens.com/electrical-digital-twin

Prepare for a sustainable digital future

Enable interoperable data exchange and synchronization across your utility enterprise

There is only one physical power grid, but a typical utility can maintain many diverse grid models – each associated with a different enterprise domain, such as: planning, operations, asset management, GIS, outage management, and protection. But keeping this data synchronized is a big challenge. Every system works with its own data format, specific details, and has its own team to maintain the data – creating digital data silos.

Inconsistencies during data exchange across those systems – or worse, the lack of data exchange – can lead to dramatic consequences like model inaccuracies, suboptimal system performance, possible regulatory violations, and ultimately system-wide blackouts.

Even though utilities spend a lot of time and money to avoid data losses, the problem is only getting worse. Industry trends (such as distributed energy, renewables, and digitalization), are increasing grid connectivity and flooding the utility landscape with even more data that needs to be exchanged between systems. Regulations are demanding complex studies, cases, and analysis with increased dependency on data accuracy. The extensive growth of data collection and exponential need for data exchange poses emerging challenges but also valuable opportunities for utilities in the energy sector.

To thrive in this dynamic environment, utilities need to break down the barriers between traditionally silo'd systems, drive interoperable data exchange across their entire IT landscape, and prepare for a sustainable digital future.

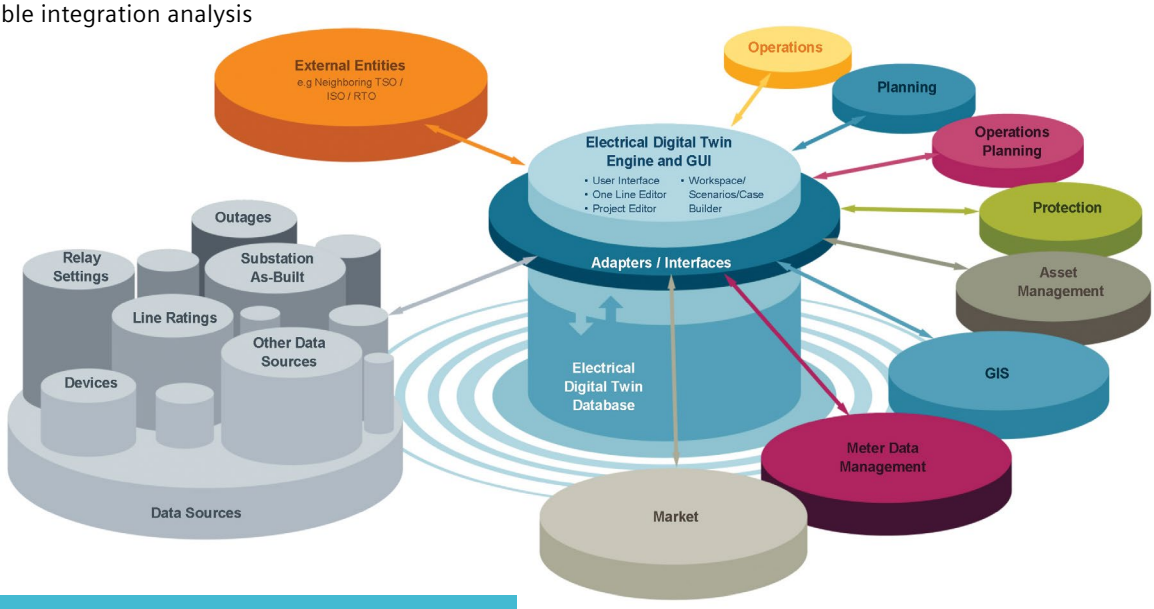
Siemens Electrical Digital Twin

The Siemens Electrical Digital Twin closely aligns real and virtual worlds by providing utilities with a single source of truth to model data across their IT landscape. Data is synchronized from various systems then standardized into one multi-user database via standards based adapters / interfaces. The common network model facilitates grid simulation across all domains relevant for reliable, efficient and secure electrical system planning, operation and maintenance.

The Siemens Electrical Digital Twin solution is vendor-neutral, highly customizable to specific needs and offers capabilities in the following areas:

- Transmission network model management across operations and planning
- Protection data management
- Streamlined renewable integration analysis using GIS data
- Automated operations planning case creation
- Data management for integrated T&D analysis
- Distribution planning model creation and synchronization with GIS, DMS, and MDM data

"With data at the core of the digital revolution, the Siemens Electrical Digital Twin is the digital data thread that weaves the modern utility together."



Synchronized models and standardized data exchange across the entire utility IT landscape

Connecting real and virtual worlds

The Electrical Digital Twin solution technically consists of three parts: the engine, adapters / interfaces, and the user interface.

The engine refers to the core enabling technology, consisting of:

- Central multi-user database
- Data management functions (e.g. scenarios, variants, projects, etc.)
- Case builder
- Data synchronization
- Data validation
- Data exchange and communication

The adapters and interfaces are the connectors which enable data import and/or export data from other domains and systems. Adapters can work with both standards-based (such as CIM) and proprietary data. The Siemens solution provides a variety of off-the-shelf data connectors for both standard and proprietary formats.

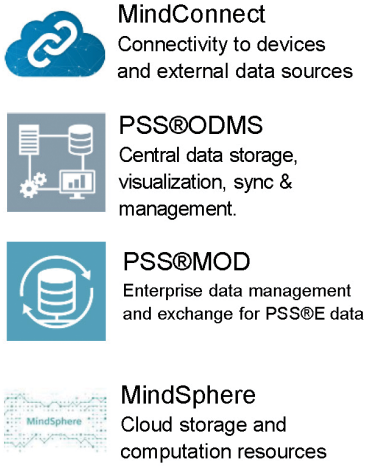
The user interface is the main graphical interaction with the EDT core, providing functionality such as graphical data visualization, maintenance, and user administration. It also enables multiple deployment options such as on-premise and cloud / hosted.

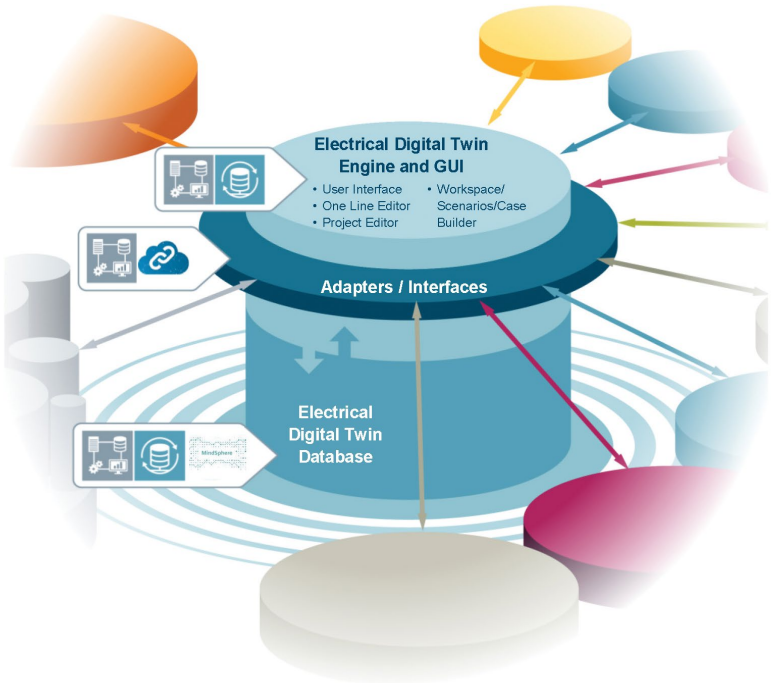
By connecting the three key parts of the Electrical Digital Twin solution, customers have the ability to automate model synchronization and standardize exchange across their enterprise, creating the perfect digital representation of their grid.

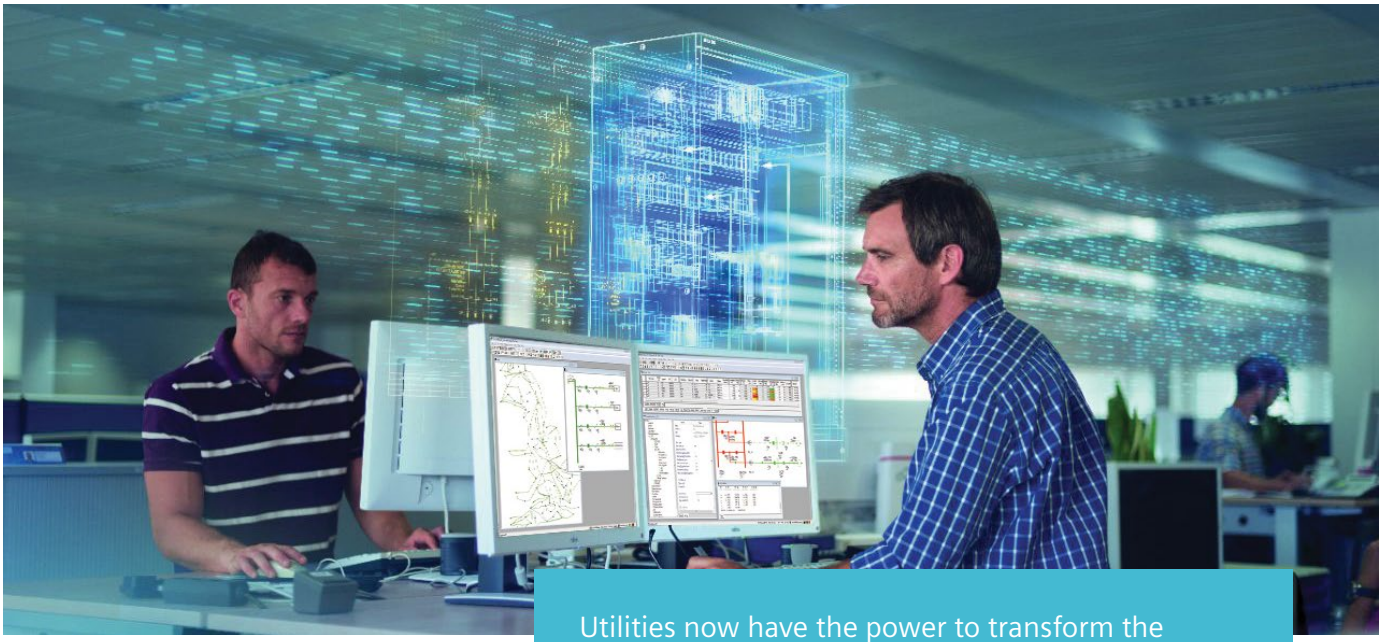
This Electrical Digital Twin is provided using one or more of the following Siemens portfolio elements – depending on the use case:

- MindSphere – Cloud storage and computation resources
- MindConnect – Connectivity to devices and external data sources
- PSS®ODMS – Centralized CIM-based network data management and storage
- PSS®MOD – Enterprise data management and exchange for PSS®E data

Siemens Electrical Digital Twin portfolio elements







Utilities now have the power to transform the wealth of data into into productive business results

Electrical Digital Twin Vision

Available today: Foundation	Future: Fully embedded Electrical Digital Twin
Portfolio: ▪ PSS®ODMS ▪ PSS®MOD	***Portfolio:*** ▪ PSS®ODMS ▪ MindSphere ▪ PSS®MOD ▪ MindConnect
Digital Twin Engine ▪ Central multi-user database ▪ Diagram editing and management ▪ Workspace / scenario management ▪ Case builder ▪ Data synchronization & validation	***Digital Twin Engine*** ▪ Increasing leverage of MindSphere and MindConnect to unlock: (1) massive computation power; (2) access to big data; and (3) new deployment approaches (cloud / hosted) ▪ Integration to rule-based and expert systems
Adapters ▪ Standards-based ▪ Custom / vendor-specific	***Adapters*** ▪ Increasingly standards-based → more 3rd party integration ▪ More off-the-shelf integration within Siemens software portfolio
GUI / Delivery ▪ Mainly on-premise with some remote access options	***GUI / Delivery*** ▪ Fully hosted / cloud ▪ On-premise (if needed) ▪ Digital software delivery and license management
Services ▪ Engineering, customization & delivery services ▪ Turnkey or in partnership with customer	***Services*** ▪ Increased automation around engineering services ▪ Business process and transformation services – to maximize your investment

Powerful applications and benefits

Transmission network model management across operations and planning

A transmission company exchanges data from both internal and external systems across their enterprise (e.g. planning, operations, operations planning, protection, etc.) to effectively plan and operate the grid. However, the input from these systems typically has its own data formats and team of experts to manually maintain each model. Inconsistencies in model data across these domains result in model inaccuracies, sub-optimal system performance, possible regulatory violations, excessive manual labor, and other additional resulting losses. Grid complexity is only complicating this challenge by influencing more studies, cases, complex model, etc. For optimal grid performance, utilities require a solution that can provide seamless / unified data exchange between internal and external utility domains.

The Siemens Electrical Digital Twin enables:

- Automated synchronization of models across planning and operations
- Easily exchange network model data within your own company and across other utilities / entities
- Central “single source of truth” database grid data

Benefits:

- >90% time savings in grid model creation and maintenance
- Improved accuracy in transmission planning and operations models leading to more profitable and efficient system operation
- IT integration cost reduction
- Eliminate duplicate modeling effort
- Provides sustainable and future-proof way to manage data within your enterprise
- Unlocked potential for future click-of-a-button studies such as predictive maintenance, economic / investment analysis, etc.

Protection data management

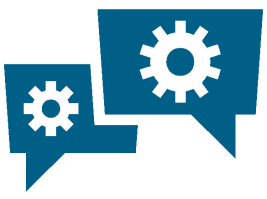
System operators, planners and protection engineers face an ever-increasing landscape of challenges around power system protection. These challenges include the growth of digital technology, increased number of protection system data points (i.e. digital relays, substations, etc.), and pressure to maximize grid reliability. Protection data, used and house in separate systems needs to be synchronized manually with field data causing inaccuracies in data models and cases.

The Siemens Electrical Digital Twin enables:

- Synchronized data exchange across systems and devices
- Scalable data collection / storage
- Automated protection setting calculation

Benefits:

- Reduced errors in protection models, enabling system operation closer to limits and improving reliability
- Decreased effort to keep protection models synchronized
- Save time and improve reliability via automatic / adaptive protection setting
- Improved safety
- Enables sustainable and future-proof way to manage data within your enterprise



45% *of electricity industry profits are at stake from digital transformation (through value addition and migration) over the next decade.*

Source: World Economic Forum / Accenture research

Maximize renewable energy integration with seamless transmission and distribution analysis

Streamlined renewable integration analysis using GIS data

The grid is becoming increasingly inter-connected at the distribution level, including the growing integration of distributed energy resources (especially renewable prosumers). Power distribution planners are experiencing more interconnection requests causing longer queues and additional manual efforts to perform studies. Despite the growing complexity, utilities are obligated to maintain reliability and resilience. In order to easily understand the impacts of distributed energy resources (DERs) on the grid, utilities need to streamline interconnection application processes and create digital network analysis models from existing GIS network data.

The Siemens Electrical Digital Twin enables:

- Streamlined processes to build cases for interconnection studies
- Automated analysis / simulation / screening of interconnection studies
- Ability to leverage data from existing GIS systems for creating a digital twin of power distribution network for planning studies

Benefits:

- Reduced data maintenance, IT Integration and modeling costs, effort, and complexity
- Automated DER interconnection assessment process and maximized DER return on investment (ROI)
- Optimized design / approval process
- Simplified regulatory requirement compliances through integrated tool landscape

Automated operations planning case creation

Due to these grid changes, government bodies are increasing regulations and standards around grid stability and data format consistency. This growing landscape has increased the volume of operations planning studies and cases utilities need to run in order to operate. In order to achieve their tasks, operations planners need to prepare different "what-if" cases which can then be studied using grid simulation software. Building these cases can be a time-consuming and error-prone manual task that involves fusing information from various formats and sources (outage schedules, generation forecasts, load forecasts, interchange schedules, state estimator snapshots, etc.). Utilities need a solution that provides effortless, automated, repeatable, and accurate production of solved forecast cases according to government expectations.

The Siemens Electrical Digital Twin enables:

- Automatic case creation
- Automatically synchronized case data with other systems (e.g. planning, generation / load forecast, outage schedule, etc.)

Benefits:

- Reduced time required to build forecast cases and perform studies
- Improved accuracy in case creation
- Easy to integrate data from other systems (outage schedules, load profiles, dispatch, topology, etc.)
- Regulatory support (e.g. CGMES (EU), NERC-TOP-002 (NA))

Data management and integrated T&D analysis

The proliferation of Distributed Energy Resources at the distribution level has changed the very fundamentals of power system planning and operations. Power flows are becoming increasingly bidirectional causing inter-dependencies between the T&D levels, a more complex recovery process after disturbances, grid reliability concerns, and the need for optimal supply. Power utilities are now required by regulation and/or internal processes to perform integrated T&D analysis to address these challenges.

The Siemens Electrical Digital Twin enables:

- Integrated T&D network analysis, enabled by common / synchronized data model across T&D
- Evaluate effects of transmission system on distribution system and vice versa
- Model & data exchange across planning and operations at both T&D levels
- Protection coordination across T&D

Benefits:

- Optimized grid utilization
- Delivered synergies in T&D System design and operation that enable optimized investment planning
- Improved transmission reliability by considering the short circuit contributions from the distribution networks

Distribution planning model creation and synchronization with GIS, ADMS, and MDM data

With the grid becoming increasingly connected at the distribution level - utilities are pressured to optimize system performance, ensure grid reliability and stability, and meet emerging regulatory requirements in regard to distribution planning.

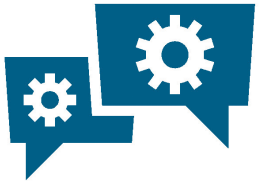
To combat grid complexity, utilities have started to manually interface their distribution grid models with data from Geographic Information Systems (GIS), Advanced Distribution Management Systems (ADMS), and Meter Data Management Systems (MDM). In order to save time and increase accuracy, an automated and integrated is needed for interfacing with external information systems.

The Siemens Electrical Digital Twin enables:

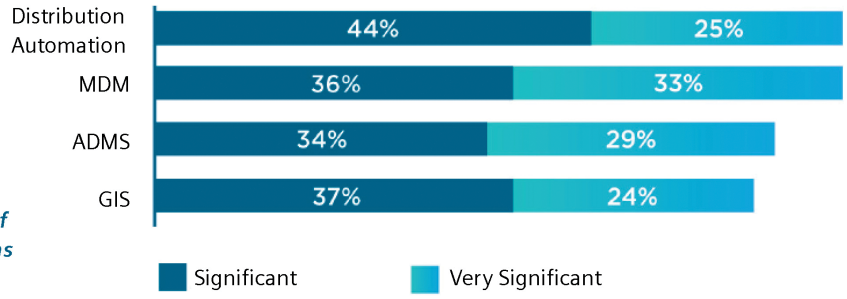
- Automated generation of distribution planning model from GIS
- Automated synchronization of planning data with ADMS data
- High-accuracy load forecast data (e.g. from MDM) for planning studies
- Automated creation of cases for distribution planning studies

Benefits:

- >90% time savings in grid model creation and maintenance
- Improved accuracy in distribution planning models leading to more profitable and efficient system operation
- Faster fault recovery for a more reliable grid



Utilities rate the importance of digitalized technology solutions for enabling DER integration



Case studies

Transmission network model management at Fingrid – Finland

Fingrid is Finland's transmission system operator, responsible for the operations and planning of more than 14,000 kilometers of 400, 220 and 110 kilovolt transmission lines and more than 100 substations.

In the past, planning for future grid investments at Fingrid took 80 percent of effort on data collection and verification, and 20 percent on actual analysis. With most of the time utilized for manually collecting the data, incorporating the missing parts, and finally combining the data successfully.

"To every grid operator hesitant to introduce a digital twin, I say: Don't wait any longer"

– Jussi Jyrinsalo, Senior Vice President, Fingrid

In recent years, the rise of decentralized, renewable energy input made it harder to maintain the balance of the entire grid. Business requirements are changing as aging and inadaptable tools are no longer sufficient, especially when more and more traditional power plants are replaced with wind and solar.

In 2016, they partnered with Siemens to introduce the digital grid model – ELVIS – that supports their asset and operation management as well as infrastructure investment planning. The single source of truth model is linked to asset management data, as well as past and real-time measurements and is combined with economic studies that forecast future energy consumption. This Electrical Digital Twin model is used to develop several investment scenarios taking different policy frameworks into account.

The Electrical Digital Twin continues to enable Fingrid to save time and money that was originally spent to manually maintain a model. The data collection and verification process now takes no more than 20 percent of the time, while 80 percent remains for the crucial analysis task. In summary, the single source of truth has improved overall accuracy and consistency of network models and provides a foundation for efficient digitalization of current and future business processes.

Transmission network model management at American Electric Power (AEP) – United States

AEP Transmission, a division of American Electric Power, owns and operates the largest transmission network in the nation, with more than 40,000 miles of lines serving more than 5.4 million customers across 11 states. It manages operations, engineering, and planning network models, each of which involves preparation and input of data from multiple internal and external systems.

Over the past two decades, model sizes and complexity increased significantly and model coordination was a mounting challenge. Regulatory reliability and compliance mandates were increasing; and the industry as a whole was dealing with an aging infrastructure.

"By designing and deploying a standards-based network model management solution, AEP can leverage emerging industry technologies around data management and data analytics"

– Eric Hatter, T-Nexus Program Manager, AEP

Within AEP Transmission, organizational and technology limitations were becoming more evident. The basic transmission network models for planning, operations, and protection were maintained by different business units within the company, and coordinating models between the business units was a largely manual process.

An initiative was launched in 2015 with two primary goals: to better coordinate network model information across several business functional domains, and to centralize management of that information. In early 2017, AEP Transmission partnered with Siemens PTI to help provide and facilitate the transition to an Electrical Digital Twin Solution - part of AEP's greater T-Nexus Network Model Management Improvement Program.

The new solution is built upon the industry-approved Common Information Model (CIM) open standard, which allows AEP Transmission to efficiently maintain, analyze and exchange network data across multiple domains, and produce short-term and long-term cases.

As a result, AEP transmission will:

- Greatly reduce the time and costs associated with manual model coordination efforts, both internally as well as with external entities
- Establish the infrastructure and data governance foundation to support AEP's strategy of capital investment in transmission improvements and expansion
- Provide a model alignment solution that will help drive the implementation of advanced technologies, such as predictive asset health analytics, synchrophasors, etc.

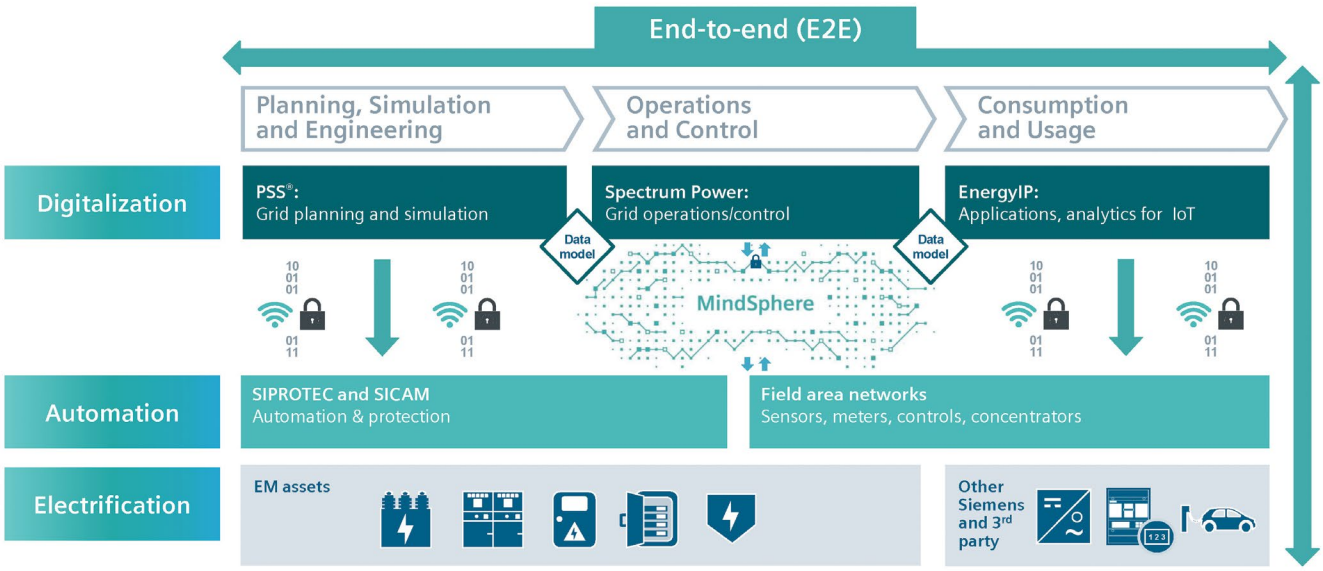
Siemens commitment to you

More than just technology... a partnership

In this new digital world, Siemens views data as the heart of everything. As the industry is constantly shifting, we are dedicated to investing in a solution that evolves ahead of the challenges. That's why it is our vision to work collaboratively with our customers in building Electrical Digital Twins to achieve operational efficiencies and excellence previously unheard of.

The Electrical Digital Twin is a central part of Siemens' global strategy – backed by the highest level of company management in terms of visibility, support, and R&D investments. Partnering with Siemens brings another uniquely valuable aspect: the ability to connect the dots across the entire digital energy landscape. Specifically, Siemens has products and solutions active across the entire domain, providing the deep subject matter expertise (breadth and depth) to not just weave the digital data thread, but also understand the technical implications of complete system and the decisions made within it.

We understand the data and are active players in all of different utility domains / systems. We know what the data is used for, what is good data, what is bad data, what the implications are for designing the digital twin solution one way vs. another way. To Siemens – it's not just data, its knowledge.



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