Key Messages
ISGAN Annex 6:
Power Transmission & Distribution Systems

Power systems around the world are faced with a wide range of challenges in order to realize the objective to integrate an increased amount of renewable energy sources in the modern electricity grids. The consequences affect the daily operation and long-term planning of transmission and distribution systems, and the network owners and operator's ability to ensure continuous, reliable and high quality of supply to the customers. The needs of each actor within the electrical supply chain provide drivers for revision of current practices and promotes future adaptions of functional components and systems, economic and regulatory areas.

In this document, we describe the **drivers for change** regarding *generation*, *demand*, and *grid*, the **resulting consequences** this has on *operation* and *planning* of the power transmission and distribution systems, and finally **the needs to ensure sustainability & security of supply** from the *technology*, *market* and *policy* perspectives.

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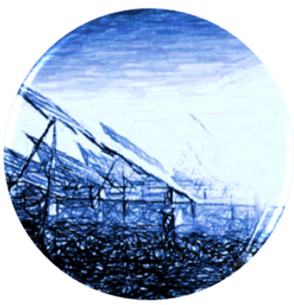
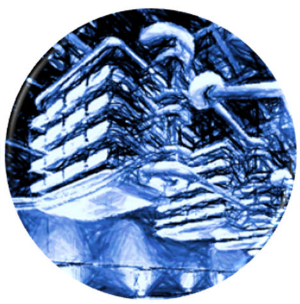


Drivers for Change

GENERATION

From: Large-scale, centralized, plannable & dispatchable synchronous generators
To: Small-scale, distributed, variable & weather dependent power electronic interfaced

The changes in generation mix is resulting in a true evolution of the power system.

The mode of electricity generation has been largely based on **bulk scale** thermal power plants which are **plannable** in the long-term horizon and **dispatchable** to meet operational needs. These plants are now being phased-out and replaced to a large extent by **smaller-scale distributed generation** in the form of **renewable** power plants with a lower degree of plannability and a higher level of **variability**.

The generation change is however not only concerning size of production units or the primary energy source, but also with physical connection to the grid. Historically, all generation has been done based on **synchronous generators** directly connected to the power system which all contribute to the inertia of the system. Newer types of generation are mainly connected to the system through a **power electronic interface**, effectively de-coupling any rotating mass of prime-movers from the power system.

DEMAND

New load devices and storage; Electrification of transport and production industry
Passive consumers ➔ Active & Flexible Prosumers

The changes in demand are on several levels, user behavior is evolving, and electricity usage is increasing.

New commercial demands are emerging, such as the electrification of the transport and production industry, leading to load growth especially in urban areas.

Users are transforming from being only **consumers to becoming prosumers** with their own distributed production and storages.

Advanced devices and digitalized solutions are increasing the customer awareness enabling **users to become active and flexible,** and the establishment of new markets and mechanisms are additionally influencing the user behavior.

GRID

Space restrictions, environmental constraints & public opposition
HVDC links & DC grids for better utilization of available space
Active distribution grids ➔ Interfaces between distribution and transmission grids

The changes in utilization is escalating the stress on the grid, which is becoming increasingly complex to develop.

Environmental aspects, public opposition, and other space restrictions are escalating **challenges of investing in new grid infrastructure**.

High voltage direct current (**HVDC**) transmission are of increased interest, in particular for DC grids connecting offshore wind power but also as an alternative to long AC transmissions for an increased utilization of available space.

Interfaces between distribution and transmission grids are becoming increasingly important, with the significant level of production integrated in distribution grids which are fast becoming active and exporting electricity to the system.

Resulting Consequences

OPERATION

Less predictable and more volatile power flows
Imbalances & increased (temporary) network congestions
Lower inertia and unforeseen dynamic behavior
Contradictory price signals and volatile prices

Increased challenges to maintain secure operation of power systems.

Volatile power flows, due to an increased amount of variable renewable electricity generation sensitive to abrupt shifts in weather conditions, leading to **imbalances** and temporary **network congestions** in both transmission and distribution grids.

Changed dynamic response and an **increased sensitivity to large disturbances**, due to the decreased level of directly connected synchronous machines which result in a system with **lower inertia**.

Contradictory price signals, due to coupling of national day-ahead markets (and, in the future, real time markets) subject to non-harmonized regulation.

Volatile prices, due to inaccurate forecasts with significant differences between actual and forecasted power flows.

Unpredictable system behavior due to digitalization of devices and control signals outside the energy sector (e.g. Smart Home, electric vehicle charging).

New type of incidents resulting from malicious or undesired ICT behavior, e.g. failures in the communication infrastructure or Cyber-attacks.

PLANNING

Aging grid infrastructure ➔ challenging maintenance planning & increased risk for outages
Increased uncertainties of long-term scenarios ➔ increasing risk for stranded investments and/or opportunity costs for not investing

Increased challenges to maintain reliable long-term planning of power systems.

Maintenance planning is increasingly challenging to conduct, due to the increased the need for maintenance and refurbishing of an aging grid infrastructure further leading to an **increased risk for outages**.

Risk for stranded investments, as well as opportunity costs for not investing, is increasing due to the growing **uncertainties in long-term future scenarios**, regarding e.g. the location of small-scale generation and storage as well as of demand developments.

Shorter investment horizons and lifetime with digitalized equipment, increasing the need to more frequent reinvestments.

Needs to ensure sustainability & security of supply

TECHNOLOGY

Services for dynamic response & secure grid utilization
Exploit distributed resources & sector coupling for services and flexibility
Improved forecasting techniques & information sharing between grid operators
Maintain information & cyber security

Digitalized solutions are enablers to change the operation and planning of power systems, providing possibilities to implement advanced technical solutions.

Support the power system, providing services for enhance dynamic response (e.g. inertia, fast frequency reserves) and increased secure utilization of the grid.

Exploit distributed resources (e.g. generation, storage, controllable loads) to provide services and flexibility to the power system.

Utilize sector coupling to support the supply of flexibility of the interconnected energy system through broadening of available time constants.

Improved information sharing between grid operators and aggregators to provide grid operators with an overview of their possible courses of action and their effects.

Improved forecasting techniques to support the development of reliable scenarios, due to the increased uncertainty of demand and generation.

Maintain data security in the digitalized power system, including secure handling and exchange of information (user, business, and market sensitive).

Prevent and mitigate cyber-attacks on interconnected assets (e.g. regarding advanced monitoring, control and protection devices).

MARKET

Shifting gate closure towards real time
Sufficient reserves & harmonized procurement and activation
Clear price signals for new services
Market availability for an enlarged number of participants
Integration of local and central market solutions

Exploration of innovative market solutions provide the means of utilizing flexibilities and other services.

Shifting gate closure towards real time to decrease the uncertainty of available volatile production and reserves.

Sufficient amount of reserves available for the system, with efficient and harmonized procurement and activation.

Clear price signals for new services (system services, ancillary services, flexibility services, etc.), and availability of markets for an enlarged number of participants to increase competition to the benefit of consumers, energy communities as well as the system as a whole.

Local and central markets integration to support local- and system-level needs.

POLICY

Regulation of ownership
Socio-economic and environmental aspects
Definition of new roles and actors
Interaction and cooperation between transmission and distribution systems
Regulate how local and system level needs are considered
Advances in planning and operational procedures
Regulate data security also for small actors and devices
Governance process for long-term risk management

Advances in policies and regulations are needed to follow and to guide the technological and market developments, with regulatory sandboxes providing test opportunities.

Regulation of ownership (especially for storages) to incentivize novel solutions.

Socio-economic and environmental aspects to have increased impact to incentivize alternative grid expansion investments.

Responsibilities and **definition of new roles and actors**, e.g. aggregator services, are entering the market to make sure that grid requirements considered by all participants.

Structured interaction and **cooperation between transmission and distribution system operators**, considering the increased amount of resources located in the distribution grids which provide services to the system.

Regulate how **local- and system-level needs** are considered, and how (flexibility) services are activated, for secure operation and planning of distribution and transmission grids.

Regulate data security also for small actors and devices, in particular if these can cause large disturbances by common cause failures.

Advances in planning and operational procedures, to: facilitate improved TSO-DSO interaction, consider probabilistic methods for secure grid utilization, promote efficiency, and include environmental impact assessment.

Establish a **governance process for long-term risk management** and foster a closer collaboration between the power and communication critical infrastructures.

ISGAN
INTERNATIONAL SMART GRID ACTION NETWORK