Spotlight on Smart and Strong Electric Power Infrastructure
Best practice shared from the ISGAN Annex 6 case book

Introduction

The introduction in the generation mix of a continuously increasing share of generation from renewable energy sources (RES), the geographical spread of generation when increasing the amount of distributed production, as well as changing patterns of demand from new types of load such as electric vehicles, will create new challenges for the electric power transmission and distribution (T&D) systems.

Many different approaches are possible to meet these challenges and the regulators have a key role in supporting the development towards clean sustainable solutions.

Different countries have different challenges, will use different solutions to those challenges, and have reached different maturity in the implementation of those solutions. Smart grid solutions are also found across the entire electrical system, from the high voltage transmission grid, through the distribution grid and finally on consumer level. It is therefore no generic solution or size that fits all for the solution towards the smart and strong grid. At the same time there are generic solutions and findings from experiences that can be adapted by other countries to make local implementation faster and more efficient.

ISGAN (International Smart Grid Action Network) Annex 6: Power T&D Systems has therefore in 2015 published a T&D Case Book called "*Spotlight on Smart and Strong Power T&D Infrastructure*" where the member community has contributed with specific projects to illustrate applications, solutions and technology from different countries and from different levels in the electrical system (http://www.iea-isgan.org/index.php?r=home&c=5/378).

Figure 1 The ISGAN Annex 6 T&D Case Book

This paper is based on the T&D Case Book, an article based on the same published at the India Smart Grid Week 2015, and other work done by ISGAN Annex 6: Power T&D Systems.

To provide the real-time flexibility needed to efficiently handle the new operating conditions of the power grid and at the same time secure stability, security of supply and quality of service, the T&D system has to become smarter and stronger. This requires different types of improvements throughout the system.

Controllable devices based on power electronics

Smart transmission technologies are traditionally based on power electronics. With power electronics it is possible to build controllable transmission systems such as flexible AC transmission systems (FACTS) and high voltage direct current (HVDC). These technologies are continousely being developed towards even higher controllability with the introduction of new generation of power semiconductors. The most recent HVDC technology VSC-HVDC allows long underground subsea or underground cables and also offers new system services.

The Irish transmission system operator (TSO), Eirgrid, shares a case in the case book where they have improved the security of supply in their network by providing additional capacity. This was done by building the East-West Interconnector (EWIC), using the latest semiconductor technology, a voltage source converter (VSC)-HVDC based link, which connects the electricity transmission grids of Ireland and Great Britain. The interconnector has a capacity of 500 MW (equivalent to approximately 10% of the Irish peak demand) and also provides a range of smart solutions including:

- ancillary services such as
    - frequency response;
    - reactive power provision
- black start' capability for both Ireland and Great Britain.

The project is instrumental for Ireland to reach its renewable electricity targets but also greatly contributes to lowering the electricity price for consumers.

The Swedish TSO is building a link (South West Link) also using the VSC-HVDC technology to increase the reliability and improve security of supply to the south of Sweden. Increasing the capacity to the southern part of Sweden became especially important after the decommissioning of a nuclear power plant which led to increased capacity limitations related to voltage instability. The link is thus important for developing the network to allow the increased penetration of renewable energy as planned. The transmission system was basically using exsisting right-of-way for overhead lines and underground cables in virgin land. This was only possible by using the new VSC Technology.

Both the Swedish and the Irish systems represents new technology with higher performance but also a technology risk. There were no particular regulatory incentives to stimulate the use of new technology. Such regulation could be needed to share the risk with new technology.

Increased system knowledge and supervision

Another element to reach a strong and smart grid is to increase knowledge and supervision of system behavior and wide area implementation of information and communication technology (ICT) for monitoring, protection, control, automation and visualization.

New regulation providing penalties for outages and improved statistics of grid reliability has stimulated the use of more advanced monitoring, measurement and control systems for the grid. Smart solutions will generally increase the utilization of existing assets and this is generally not rewarded in current regulatory regimes that mainly are focusing on penalties than rewards.

Both the United States and Italy share cases where wide area management systems (WAMS) and phase measurement units (PMUs) are integrated into their networks.

The project presented in the U.S. case provides grid operators and reliability coordinators with more frequent and time-synchronized system information. Better system visibility will help system operators avoid large-scale regional outages, better utilize existing system capacity, and enable greater utilization of intermittent renewable generation resources. The synchrophasor-based controls will use wide-area synchronized measurements to determine voltage stability risks and will initiate corrective actions in less than one second. Also real-time analytical applications are in use in the control centre together with operational displays. Another important benefit of the project is that the collected data is used to validate the system models leading to more accurate models, which is essential for reliable and economical grid planning and operation.

Improved understanding of power grid performance leads to possibilities to optimize the capital investment. It is also expected that the synchrophasor data will lead to large-scale outage avoidance and early detection of equipment problems.

In Italy, functions have been developed for oscillatory stability analysis, network separation detection, load shedding intervention evaluation and line thermal estimation. Real-time plots and charts of system quantities such as phase angle differences, and the output of monitoring functions such as oscillation identification, allow operators to better track system stress and dynamic phenomena, and evaluate the possible impact of switching actions. Cooperation with other countries of the same synchronous area, in the form of real time PMU data exchange, has proven being particularly useful.

Another possibility to improve the network operation based on increased information is the "Situational Awareness System" that is being implemented in South Africa.

The idea with situational awarenesss is to combine the electrical interconnected power system with environmental conditions and by doing so being able to more accurately anticipate future problems to enable effective mitigation actions. Grid situational awareness provides real time support for decision making based on real-time event management, forecasting, power stability and management through dynamic system sources.

France presents a case based on an industrial pilot project that aims to design, build, test and operate two fully digital smart substations. The project includes experimentation of a new technological package including new advanced control functionalities.

The intention with the project is to enable the electrical power equipment to work closer to their physical limits. And it will assess the benefits provided by solutions such as a lower environmental impact, better integration of the renewable energy sources, improved transmission capacities, and optimal use of the existing assets.

The new technique can offer a more cost efficient way of utilize the grid. Interoperability standards are required for this development and incentives from regulators can speed up this process.

Control in the Distribution Network

Solutions could be implemented at all different levels of the energy system.

The Austrian case presents solutions for low or medium voltage networks. The main goal of the Austrian project is to find an efficient way for the integration of renewable electricity production with regard to optimized investment by maximizing the utilization of the existing asset base.

The main challenge of integrating distributed energy resources (DER) in rural distribution networks, as pointed out in the case book, is to keep the voltage within the specified limits, which the project aims at doing through the use of smart planning, smart monitoring and smart control. The project demonstrated that different voltage control concepts made it possible to increase the possibility for integrating more renewables significantly.

Customer interaction

There is also a new role for customers when time-dependent electricity prices, local generation, as well as grid-side energy storage, all become increasingly feasible.

The second Italian case describes their experience of introducing time-of-use tariffs and the effects of such tariffs on electricity consumption by residential customers in Italy. The long-term goal is to induce the Italian customers to adjust their consumption according to the abundance or scarcity of electricity leading to a smoother load profile. This will for example lead to less need of reinforcements in the network due to a reduction of the load during peak hours.

The results show that, even if there was a limited shift of consumption from peak hours to off-peak hours in the period following the introduction of the mandatory ToU tariff, the change in the behaviour of the users is not negligible.

An holistic approach to achieve a cost effective transition

A holistic view across system planning, investment, and operation is needed to create a power grid capable of integrating the actions of all actors — including new market players — while maximizing the benefits and limiting costs.

Smarter and stronger grids will require investment at all levels of the grid. Priority investment should be targeted where the deployment of new technologies will immediately improve system operation and promote clean energy deployment. This calls for the introduction of both power electronics and ICT technologies to increase grid flexibility and to provide knowledge and control capabilities of system behaviour. Furthermore, as they are at the centre of power systems, interaction and coordination between grid operators at all levels and across regions should be enhanced to minimize cost and secure system stability.

Important issues for policy makers to focus on

The collective learning has resulted in some key issues that the policy makers should focus on:

1. The adoption of interoperability standards to accelerate technology deployment and innovation

a. Local or national standards should be aligned with internationally developed "future proof" standards in order to drive both deployment of available technologies and ongoing innovation.
b. Technical and financial know-how is a key element for making the policy and interoperability decisions. Policy education has to be provided and international expertise exchange should be leveraged to advance international cooperation.

2. Implement stable financial support regimes and clear regulations
    a. Governments and regulators should share the risk in investment decisions with stable financial support regimes for new technology and business model deployment.
    b. Transparent and well communicated cost-benefit analyses are crucial for clear regulations and stable financial support regimes and increase public acceptance.
3. Support simplification of permitting procedures regarding implementation of necessary grid infrastructure
4. Roles and regulations must be developed in parallel with changing markets and actors
    a. The cooperation of utilities should be encouraged to align procedures, implemented technologies, standards and long term planning.
    b. The necessary information exchange between Smart Grid actors has to be identified and assured in order to manage the system in the most efficient way and to secure system stability.

ISGAN

ISGAN, International Smart Grid Action Network, is a mechanism for international cooperation with a vision to *"accelerate progress on key aspects of smart grid policy, technology, and investment through voluntary participation by governments and their designees in specific projects and programs."* It is a multilateral government-to-government collaboration to advance the development and deployment of smarter electric grid technologies, practices, and systems.

ISGAN has to date 25 members: 24 countries from five continents and the European Union.

Figure 2 The ISGAN members

ISGAN aims to improve the understanding of smart grid technologies, practices, and systems and to promote adoption of related enabling government policies. ISGAN activities center on those aspects of the smart grid where governments have regulatory authority, expertise, convening power, or other leverage, focusing on five principal areas:

Policy, Standards and Regulation
Effective policies and efficient regulation are critical to the development and deployment of Smart Grid technologies, practices and systems. Sharing information on policies and regulations developed by a country and associated lessons learned; harmonizing specific policies regarding developing and implementing smart grid inter-operability standards; and developing toolkits for policymakers for policy implementation at the national, sub-national and local levels may accelerate overall progress on smart grids.

Finance and Business Models
Implementing Smart Grid technologies will likely require new business models and financing mechanisms beyond simple rate recovery. Thus, an objective is to share information and experiences on novel government and private-sector models to support deployment of smart grid systems.

Technology and Systems Development
Cooperative research, development and demonstration of pre-competitive Smart Grid technologies using consistent methodologies and testing protocols will advance the state-of-the-art of the industry and allow for more rapid deployment of Smart Grids. Activities may include cataloguing existing RD&D efforts and coordinating laboratory or test bed networks.

User and Consumer Engagement
The full benefits offered by smart grids will be achievable only with the involvement of stakeholders along the full spectrum of the electricity system, from power generation through power transmission and distribution, and ultimately to end-use by consumers. This area involves understanding how best to engage these many stakeholders to educate them on the purpose, benefits, and use of smart grids.

Workforce Skills and Knowledge
Implementation of new Smart Grid technologies and approaches to energy and information will require training not only of utility and power industry personnel directly involved with electricity production, transmission, and distribution, but also regulatory staff, information technology and cyber security specialists, and others who will need deep understanding of this complex and potentially transformational suite of technologies, practices, and systems.

The International Smart Grid Action Network (ISGAN) was launched at the first Clean Energy Ministerial (CEM), a meeting of government ministers and stakeholders from 23 countries and the European Union which was held in Washington, D.C in July 2010. In April 2011, ISGAN was formally established as the technology Collaboration Programme within the International Energy Agency (IEA) for a Co-operative Programme on Smart Grids (ISGAN), operating under the IEA Framework for International Energy Technology Co-operation. Membership in ISGAN is voluntary.

ISGAN is managed by its Executive Committee, which meets twice a year, and supported by a Secretariat at the Korea Smart Grid Institute. Within the ISGAN, a Chair and three Vice Chairs serve the ISGAN in a close collaboration with the Secretariat.

Further information can be found at the ISGAN website (http://www.iea-isgan.org/).

Additional reading

ISGAN Insights Publications can be downloaded at http://www.iea-isgan.org/index.php?r=home&c=5/378.

Some of the available materials are listed below.

Published discussion papers by ISGAN Annex 6: Power T&D Systems

TSO-DSO Interaction - An Overview of current interaction between transmission and distribution system operators and an assessment of their cooperation in Smart Grids.

FLEXIBLE POWER DELIVERY SYSTEMS - An Overview of Policies and Regulations and Expansion Planning and Market Analysis for the United States and Europe

Smarter & Stronger Power Transmission -Review of feasible technologies for enhanced capacity and flexibility

Case Books

Spotlight on Smart and Strong Power T&D Infrastructure

Spotlight on Advanced Metering Infrastructure

Spotlight on Demand Side Management

Other

Smart Grid Project Catalogue part 1

Smart Grid Project Catalogue part 2

The Role of Smart Grids in Integrating Renewable Energy

Smart Grid Drivers and Technologies by Country, Economies and Continents