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Power Transmission &
Distribution Systems

ICT aspects of TSO-DSO interaction

Data exchange and ICT requirements along organizational interaction between TSO and DSO

Discussion Paper

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About ISGAN Discussion Papers

ISGAN discussion papers are meant as input documents to the global discussion about smart grids. Each is a statement by the author(s) regarding a topic of international interest. They reflect works in progress in the development of smart grids in the different regions of the world. Their aim is not to communicate a final outcome or to advise decision-makers, but rather to lay the ground work for further research and analysis.

Disclaimer

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List of Acronyms

AS	Ancillary Services
CSG	China Southern Power Grid
DCC	Demand Connection
DER	Distributed Energy Resources
DSO	Distribution System Operator
EHV	Extra-High Voltage
EMS	Energy Management System
ER	Emergency and Restoration
FERC	Federal Energy Regulatory Commission
FSP	Flexibility Services Provider
HV	High Voltage
ICT	Information and Communication Technology
IEA	International Energy Agency
IOU	Investor-Owned Utilities
IT	Information Technology
LV	Low Voltage
mFRR	Manual Frequency Restoration Reserve
MV	Medium Voltage
NERC	North American Electric Reliability Corporation
OT	Operational Technology
PV	Photovoltaic
RfG	Requirements for Generators
RTO	Regional Transmission Organizations
SGAM	Smart Grid Architecture Model
SGCC	State Grid Corporation of China
TSO	Transmission System Operator

Abstract

Within ISGAN Annex 6, Task 5, a questionnaire focusing on Power Transmission & Distribution Systems was created and sent to the Annex 6 members. The main objective was to assess the current and future ICT interaction of distribution and transmission system operators to identify key challenges that deserve attention. Nine responses were collected and the results are shown in this document – some results are very similar in the countries, others show very diverse challenges.

Executive Summary

This discussion paper is part of task 5 within ISGAN Annex 6 which focuses on Power Transmission & Distribution Systems. The main objective is to assess the future data exchange and ICT requirements concerning the interaction of distribution and transmission networks, by identifying key challenges that deserve attention.

This report is based on a questionnaire regarding the ICT aspects of TSO-DSO interaction. The questionnaire contained questions regarding technical aspects (e.g. technical connection points between TSO and DSO in the countries), regulatory aspects, flexibility markets, drivers and barriers for TSO-DSO interaction as well as experiences from projects and lessons learned. The questionnaire was sent to the Annex partners and nine responses were collected. In particular Belgium, Germany, Italy, Finland, Sweden, United States, China, India and Austria have sent comprehensive answers.

Due to the integration of renewable energy sources, the interaction between TSOs and DSOs gets more and more important to handle the high volatility of generation and unexpected load growth in power grids. Additionally, new market mechanisms and the connected flexibilities require a closer interaction between TSOs and DSOs.

ICT aspects for TSO-DSO interaction have already been analyzed in several projects and activities around the world, allowing a common data platform for collecting metering data or calculating flexibility volumes to name but a few. Additionally, requirements for different TSO-DSO interaction schemes are analyzed in studies and projects. Hands-on experience from demonstration projects with focus on TSO-DSO interaction is still missing, but expected soon.

Besides a number of opportunities when having a high degree of interaction between different parties, several technical barriers and risks (e.g. congestions when activating flexibilities, highly-sophisticated mathematical models for calculating prices, IT-security issues) as well as organizational matters (e.g. resistance to well-established patterns, costs for building new infrastructure) have to be solved.

Infrastructure and operational costs will be a crucial factor in the future. Therefore, TSO-DSO schemes could only be profitable if costs for adaption of the current systems are less than the added benefits. Furthermore, the costs will depend on the defined requirements and frameworks und thus, too stringent requirements will result in high ICT development and deployment costs with decreased flexibility.

Table of Content

1. Introduction

This discussion paper is part of task 5 within IEA ISGAN Annex 6 on Power Transmission & Distribution. The main objective of this work is to investigate ICT aspects of Transmission System Operators and Distribution System Operators, based on a questionnaire and the response from different countries. Figure 1 positions this work in the ISGAN context.

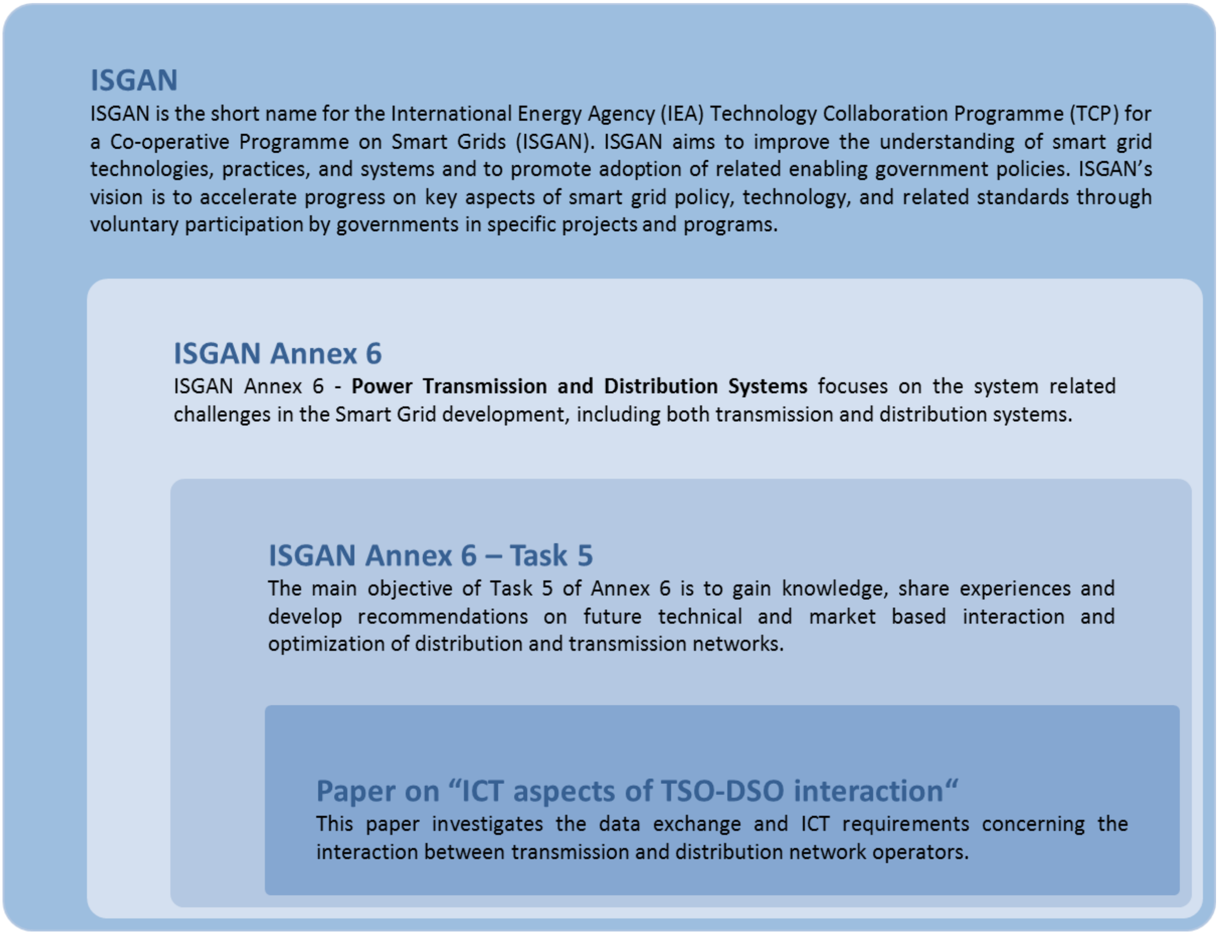

Figure 1: Position of this paper in ISGAN context

For the investigation, a questionnaire was created and sent to all Annex 6 members to gather input on ICT requirements for TSO-DSO interaction. The answers were used as input for this document, in particular to create a best practice analysis.

In total, nine countries submitted their completed questionnaire, namely Belgium, United States, China, Germany, Italy, Finland, India, Sweden and Austria (see Figure 2).

In Chapters 1 and 2, a short introduction is given, followed by the contents of the questionnaire in Chapter 3 and the results in Chapter 4. At the end, a conclusion showing the most important results is presented.

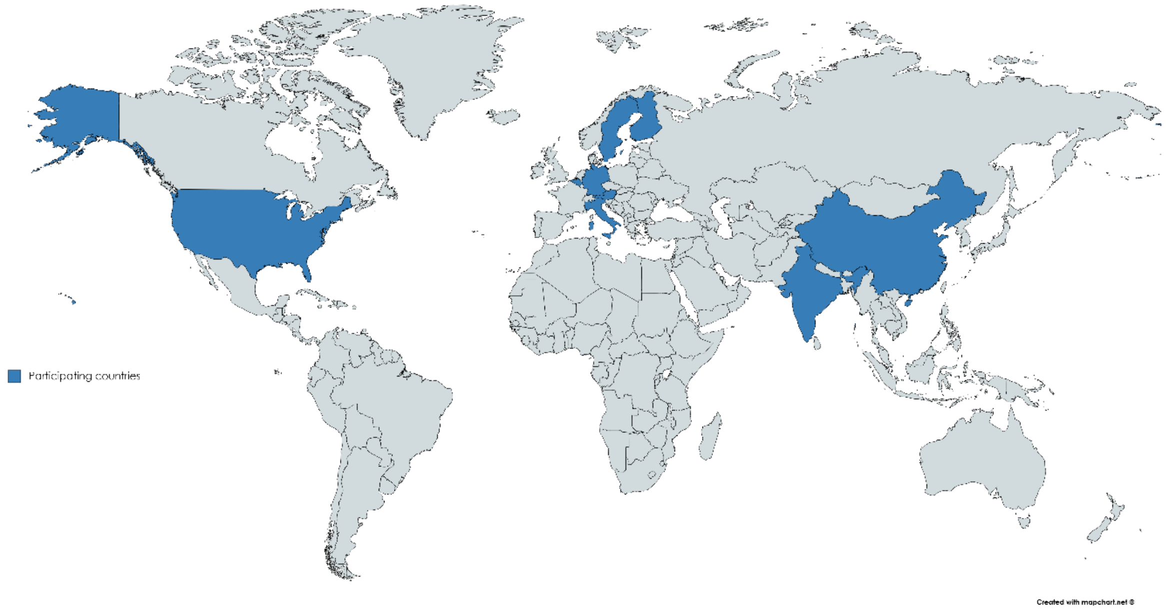

Figure 2: Countries which provided input through the questionnaire

2. Why do we need TSO-DSO interaction?

Due to the increasing number of renewable distributed energy sources (DER), mainly connected at the distribution grid, a higher need for flexibility services for network operators (TSOs and DSOs) and other parties is arising. This flexibility is needed to counteract the high volatility of energy sources such as wind or PV, controlling the frequency and/or voltage of the grid on one hand as well as providing congestion management on the other hand.

Ever more flexible resources connected to the distribution grid are providing ancillary services (AS) to support the transmission network operation. This might lead to problems if also the DSOs want to make use of the same flexibilities to solve local problems. Taking this trend into account, an increased interaction between TSO and DSO is unalterable [1] [2] [3] [4] [5].

3. Questionnaire

The questionnaire consisted of thirteen questions covering technical details of TSO-DSO interaction, the main drivers for implementation of (changes in) TSO-DSO interaction, current experiences, and others. The questions in the questionnaire were as follows:

1. What technical connection points between TSO and DSO are operated in your country?
2. What are the main TSO-DSO interaction schemes operated in your country? On what technical rules/regulations are they based?
3. How many TSOs and DSOs exist in your country?
4. Are flexibility markets operated in your country where TSO and DSO are present?
5. What are the main drivers for implementation of changes in TSO-DSO interaction (such as more volatility, flexibility handling, changing market mechanisms, etc.)?
6. What are the main barriers?
7. Are you aware of or partner in best practice projects with relevant ICT aspects for TSO-DSO interaction? What are these projects and what are the main goals/findings?
8. What benefits do you expect from ICT-based TSO-DSO interaction?
9. What would you formulate as lessons learned so far from previous activities?
10. Future expectations: What changes in ICT requirements do you expect?
11. Is SGAM (Smart Grid Architecture Model) modelling relevant for TSO-DSO interfaces?
12. Is ICT for TSO-DSO interaction (technical interfaces, data exchange platforms, etc.) a substantial cost factor?
13. Additional comments you might have?

4. Results

In the following sub-sections, the results are presented in detail. Some of the questions and the related answers have been condensed. Table 1 gives an overview about the number of TSOs and DSOs in European countries, participating in this survey.

Table 1: Number of TSOs and DSO in the participating European countries.

Country	Number of TSOs	Number of DSOs
Germany	4	900
Belgium	1	19
Italy	1	152[1]
Sweden	1	199[2]
Finland	1	76
Austria	1	122

The North American power grid is divided into the Western, Eastern, and Texas interconnections. At the bulk power level, the US power system is made up of a total of 66 balancing authorities and 345 transmission owners. At the distribution level, entities that trade electricity on both the wholesale and retail markets can include municipal organizations, cooperatives, and investor-owned and wholesale power marketers. As of 2016, the following entities were delivering electricity to customers across the U.S.: 809 cooperatives, 11 behind-the-meter companies, 8 federal entities, 173 IOUs, 829 municipal utilities, 18 municipal marketing authorities, 108 political subdivisions, 254 power marketers, 18 state utilities, 16 transmission entities, and 35 wholesale power marketers[3].

For China, two major companies are representing both TSOs and DSOs of different regions of the mainland: State Grid Corporation of China (SGCC) and China Southern Power Grid (CSG).

The Indian TSOs are POSOCO and POWERGRID and other state transmission companies, whereas the DSO role is played by state owned distribution companies.

4.1. Technical connection points between TSO and DSO

The European power grid is a three-phase alternating current grid operated at a frequency of 50 Hertz at all voltage levels. In general, four different voltage levels can be distinguished:

- Extra-High Voltage (EHV)
- High Voltage (HV)
- Medium Voltage (MV)
- Low Voltage (LV)

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[1] Source: https://www.terna.it/en-gb/sistemaelettrico/impresedistributrici.aspx
[2] 4 regional DSOs directly connected to the network owned by the TSO, about 195 local DSOs
[3] See https://elecidc12c.eia.doe.gov/2017%20EIA-861%20Instructions.pdf for the code names and descriptions

Most of the European Transmission Grid is in the Extra-High Voltage domain, operated mostly at 380 kV, whereas other voltage levels are also in use (e.g. 220 kV but declining). In general, possible technical connection points between TSO and DSO occur between the transmission and the distribution level at primary substations for all participating countries, in particular between EHV and HV (e.g. Germany: 380 kV/110 kV).

Similar to the European grid, different voltage levels are distinguished in the United States but in contrast to Europe, the highest voltage level goes up to 765 kV (compared to 380 kV) used as transmission network. Below this voltage domain, there is a sub-transmission system supplying the distribution substations.

4.2. TSO-DSO Interaction schemes

Table 2 gives an overview about the interaction schemes between TSOs and DSOs in the different countries and the regulatory background.

Table 2: TSO-DSO Interaction schemes within the countries.

Country	TSO-DSO interaction schemes
Germany	**Electro-technical interaction** The DSOs are obliged to support the TSO in its system security tasks: The TSO can issue high level commands to the DSO (e.g. load shedding or curtailing of generation). The details are defined in the German *Transmission Code 2007*. The right to issue this transmission code by the TSOs is laid down in the *German Energy Industry Act* EnWG §§12-13. Examples are congestion management by feed-in management of wind turbines (so called EISMAN) or balancing of reactive power at HV/MV grid connection points (but the latter is rarely used in Germany). **Business processes** • Market Clearing: The DSO calculates for every balancing group manager how much energy it has consumed/produced every 15 minutes and forwards this information to the TSO on a daily base. (*Stromnetzzugangsverordnung*) • Trading renewable energy: The DSO measures or calculates how much energy any feed-in subsidized renewable energy resource did produce every 15 minutes and forwards this information to the TSO on a daily base. (*Erneuerbare-Energien-Gesetze*, Act for renewable Energies) **ICT interactions for operational and planning purposes** The TSO may, by law, determine the rules of the exchange of information (EnWG §12.4). **Operational requirements for ICT** In Germany the information flows between TSO and DSO are often referred to as *Energieinformationsnetz* (energy information network). If the TSO needs (smart) meter data for operation or planning (e.g. forecasting of wind for planning the necessary amount of balancing energy) the DSO must provide this data. (Smart Meters Operation Act (*Messstellenbetriebsgesetz*) §§ 66,67).

	Static information In the German Transmission code 2007 it is stated that “As a minimum requirement, information must be provided on the first mesh of the horizontally and vertically adjoining networks to the respective TSO for purposes of operational planning and system management.” In the case of necessary adjustments of electricity feed-in and extractions the TSO has to inform DSOs and electricity traders affected in advance, whenever possible, immediately when the actions are performed and subsequently when the process has ended. From February, the TSOs call for a CIM-based link to support the forecasting of electricity production or loads from "significant" prosumers in distribution **Communication Technology** For the cascade and most other communication between TSO and DSO black-fall resistant telephone is recommended in the grid code. In addition, especially for broadcasting, e-mail is used (a solution not working in case of a blackout). In some cases, TASE.2 and IEC protocols are used The details of the TSO-DSO interaction will be formulated in VDE-AR-N 4141-1 which is the German specification of the European network codes Requirements for Generators (RfG), Demand Connection (DCC) and Emergency and Restoration (ER). The Praxis-Leitfaden für unterstützende Maßnahmen von Stromnetzbetreibern (Practical Guide for Supporting measures of electricity network operators) gives detailed information how to organize the cascade and other measures for a secure and reliable power system. It emphasizes the interactions between TSOs and DSOs.
Belgium	The regions are responsible for distributing and transmitting electricity locally via networks with a nominal voltage of 70 kV or less. There is a distinction between operating systems with a voltage of 30, 36, and 70 kV and those with a lower voltage. This means that distribution systems (with a voltage lower than 30 kV) operate alongside the following networks: • the local transmission system (in Wallonia); • the regional transmission system (Brussels-Capital region); • plaatselijk vervoernet (in Flanders). These systems have a voltage of 30, 36, and 70 kV and link up with the federal transmission system operated by Elia. The three regions are responsible for renewable energies (excluding federally governed North Sea wind farms) and the rational use of energy. The basic legislation for each region is the following: • Flanders: Energy Decree of 8 May 2009; • Wallonia: Decree of 12 April 2001; • Brussels-Capital: Ordinance of 19 July 2001.
Italy	The TSO is retrieving services for balancing and congestion management in transmission, whereas the DSO has no active role in ancillary services (just operates the distribution), according to specific directives of the Italian regulator (AEEGSI – Italian Regulator Authority for Electricity Gas and Water).
Finland	In Finland, the interaction between TSO and DSO is mainly in balancing and congestion management, regulated in the Electricity market law 588/2013.

Sweden	The forthcoming changes regarding the exchange of measurement values and other data between TSO and DSO are currently being implemented (due to the new guidelines according to the EU's common network codes).
United States	U.S. electricity markets have both wholesale and retail components, and different entities set the rules that govern reliability and commerce among consumers, electric utilities, public utilities, traders, and other participants. The Federal Energy Regulatory Commission (FERC) has jurisdiction over wholesale electricity markets and monitors compliance with the rules that provide oversight of the competitive outcomes of markets, setting rules and regulations for entities that are approved to trade electricity on FERC markets. FERC established open-access tariffs through Orders 888 and 889. As a result, in portions of the US, independent system operators (ISOs) were created to promote trading of electricity bilaterally or through power pool agreements. FERC Order 2000 promoted the establishment of regional transmission organizations (RTOs), which are coalitions formed by electric utilities to operate the transmission system. In addition, FERC gave the North American Electric Reliability Corporation (NERC) a mandate to provide regulations and standards that maintain and ensure the power grid’s reliability in all the NERC regions (FERC 2016). States and localities throughout the U.S. have their own regulatory structures under which electric utilities can provide three functions: generation, transmission, and distribution. The different types of utilities are: • Investor-owned utilities (IOUs), which are generally for-profit corporations subject to regulation of electricity rates and services by the states in which they operate. • Municipal utilities and rural electric cooperatives, which are regulated by retail customers they serve, and public utility districts, which are forms of customer-owned utilities in which elected officials establish electricity rates.
China	Based on the principle of unified dispatching and hierarchical management on grid operation to ensure the safety, quality, and economic operation of the power grid, interactions are conducted through steps concerning optimal real-time operations, such as data exchanges on generation and consumption planning, operation modes, etc. Technical rules are based on DL/T5003-2005 Power system dispatching automation design technical regulations, released by the People's Republic of China National Development and Reform Commission.
India	Grid code by CERC, Deviation settlement mechanism, regulation for ancillary services operations are some of the schemes operated in India. Further details are available in Mission Innovation country report (**www.nsgm.gov.in**).
Austria	Although the TSO and DSOs are responsible for the planning and operation of their own grids, there already is quite some interaction between them, for network planning as well as operation. In terms of network planning, the TSO and DSOs coordinate network expansion activities, taking into account the evolution of the grid loading at the DSO level. During network operation, examples of the coordination between the TSO and the DSOs are the setting of the tap of the transformer between the transmission and distribution grid, agreed ranges for the reactive power flows over the points of connection between TSO and the DSOs. Also in case of faults and for maintenance, the DSO in some cases supports the TSO line loading via switching measures at the DSO level.

	This interaction between TSO and DSOs does not have high requirements in terms of ICT infrastructure or data exchange. It is sufficient to have frequent interaction and in some urgent cases, the dispatch centers of the involved network operators coordinate their actions.

4.3. Flexibility markets for TSO and DSO

Figure 3 shows an overview about the participating countries and the availability of flexibility markets (green: flexibility market operated, yellow: flexibility market planned or in development).

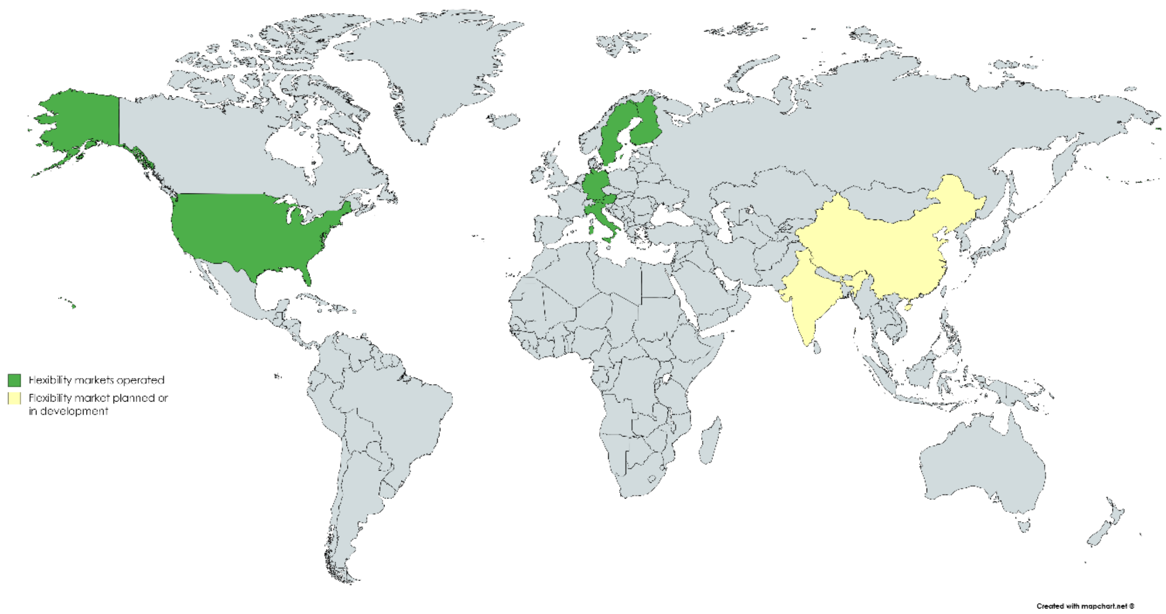

Figure 3: Flexibility markets operated in participating countries.

In the United States, flexibility markets as part of energy markets are operated. Flexibility can be provided through demand response and self-commitment and dispatch schedules in return for uplift payments.

The only real flexibility market in Germany for TSOs is the market for *balancing power*[4]. The balancing power is solely used for frequency control. The products are primary control, secondary control, and minutes reserve[5]. In addition, congestion management in the transmission grid is done by countertrading at the spot market. The DSO is forbidden to trade, sell, or buy energy. However, congestion management is an important issue in a distribution grid with a high amount of renewable generation. It is planned to allow for the *smart grid traffic light concept*: In the amber phase the DSO can buy or sell energy to omit congestions. The situation in Austria is very similar to the German one in terms of balancing power provision.

[4] www.regelleistung.net
[5] Cf. Transmission Code 2007

In Belgium, the DSO-connected flexibilities can participate to the *balancing market* on one hand and on the *strategic reserve market* on the other hand. Therefore, a DSO-FSP (Flexibility Services Provider) contract is necessarily.

In Italy, two flexibility markets are operated, both by the TSO with no presence of the DSOs.

Sweden and Finland are part of Nordic electricity market area which is an example of regional energy market.

In China and India, flexibility markets are not available yet but some pilots were started in some regions or are under development, respectively.

4.4. Main drivers and barriers for implementation of changes in interaction

The main drivers for implementation of changes in TSO-DSO interaction have been very consistent within all participants, in particular the steadily increasing number of renewable (volatile and weather-dependent) energy sources on one hand as well as changing market mechanisms and connected flexibility on the other hand.

4.4.1. Renewable energy sources

In Germany renewable energy sources are expected to account for 40 to 45 percent of electricity generation in 2025 and as much as 80 percent by 2050. The main part will be connected to the distribution grid, concentrated in rural areas with wind turbines in the north and east and PV in the south. Consequently, the renewables must contribute to provide ancillary services.

A similar situation is seen in Italy, Finland and Austria – an increase of photovoltaic power plants and wind power plants resulting in a higher volatility of generation patterns and prices together with steady reduction of conventional power plants.

In Sweden, additionally to the increase of volatile generation, new customer demands (e.g. data sites and electrification of transport) were named, resulting in an unexpected load growth in some urban areas.

4.4.2. Market mechanisms and connected flexibility

Germany is expecting changing market mechanisms: In the future, market trading will be standard whereas risk-free tariffs are expected to be exceptional. Additionally, experts expect a change of the behavior of industrial and private customers in a way that they will be more flexible, altering the simultaneity factors which can lead to congestions.

In Belgium, the TSO and the DSOs have created a joint datahub for flexibility, allowing cooperation in collective metering data and calculation of delivered energy volumes as well as transmission of these volumes (at aggregated level) to market players such as suppliers and Flexibility Service Providers (FSP).

China has named several drivers for changes in the interaction between TSO and DSO:

- The proportion of China's coal and electricity has remained high, causing serious pollution in the electricity production process and serious carbon emissions. The issue of carbon emissions has so far been unsolved even with the current technology to achieve zero pollution.
- Renewable energy has not developed as expected. According to the recently released "Thirteenth Five-Year Plan for Power Development (2016-2020)", the total installed capacity of wind power and solar power reached 173 million kW by the end of 2015, accounting for 11.3 % of the installed capacity of power generation in the

country, but the proportion of generating capacity is only about 4 %. The consumption of clean energy suffers heavy resistance.

- The monopoly has brought about problems such as the inefficient operation of assets, the transfer of benefits, and the like, resulting in strong investment motives for power generation enterprises or power grid enterprises because investment can increase assets and increase control power.
- The current power grid enterprises have assumed the responsibilities of some government departments, such as cross-subsidization and universal services. This has led to the electricity bill charged by the power grid becoming a muddling account, allowing the power grid enterprises to bear a huge public pressure.
- If the government holds the power of examination, approval, and pricing of power infrastructure investment, it will inevitably lead to the control of captives. Interest-driven power companies have all kinds of means to lobby regulators and influence regulators

Although there are many initiatives to improve the exchange of information between TSO and DSO, still some barriers exist which should be surmounted, in particular they can be summed up in the following categories:

4.4.3. Legal aspects

Missing adaptions and immature development of regulation pose barriers to the adoption of processes which are technically already possible (e.g. traffic light concept in Germany, limitations set for prioritized data traffic over mobile network in Finland).

4.4.4. Technical barriers and risks

Technical barriers that have been identified are:

- Resulting local congestion when activating flexibility for balancing purposes, which would require e.g. a dynamic congestion risk indicator.
- Flawed market mechanisms or mathematical difficulties in determining the most economic and efficient price to deliver of electricity to customers.
- Necessity to accurately measure/meter flexibility at delivery points behind existing access points.

4.4.5. Organizational issues

Some organizational barriers that have been identified are:

- Changes to distribution planning processes that can slow down procurement process.
- Resistance to changes on well-established patterns.
- Fragmentation and need of changes in mentality of DSOs.
- Competition between TSO and DSO regarding owner of data processes and platforms.
- New business model opportunities.
- Costs for building new transmission lines and connections.
- Lack of capital investment in enabling technologies.

4.5. Expected benefits and requirements for TSO-DSO interaction

The expected benefits of TSO-DSO interaction can be mainly divided into three groups: increased use of flexibility in the grid, enabling market participation and optimized grid operation. The main arguments are listed in the following:

- Efficient and scalable operation and calculation of flexibility data and activation management.
- Integration of distributed energy resources into wholesale electricity market by providing communication interfaces for sending and receiving market signals.
- Long-term efficient operation of power plants increases the amount of electricity generated and increases the utilization of assets (e.g. in Asia and developing countries, operating efficiencies have increased from 70 % to 75 %, reaching up 80 % of industrialized countries such as North America and Europe).
- Extend monitoring and automation to the grid through smart devices and networks and optimize grid operations by using real-time grid data with finer granularity. As a result, the TSO-DSO level network management can react faster on load changes or erroneous conditions and the two-way communication will enable more flexible resource sharing between TSOs and DSOs.
- Investment in grid infrastructure enables power distribution equipment generating electricity more stable and resumes more quickly. Furthermore, the grid can be operated more efficient.
- Maintenance of reliable and secure power systems by providing them the ability to disconnect (island) resources to avoid voltage fluctuations or disruptions in services.

To achieve the stated chances above, further activities and requirements are necessary. In particular, one of the first steps should be the harmonization and standardization of ICT requirement and interfaces to help TSOs and DSOs to choose and develop suitable ICT technologies and service implementations in the future. Furthermore, practical guidance for the analysis of large amounts of data, produced by an increasing number of measuring and monitoring devices, should be established and data and service platform implemented.

Additionally, in several areas, technical and organizational improvements are necessary to enable DER development (e.g., communication costs and network strategies, quality of service, availability, response time to market signals, cyber security) and get the ability to control DER for managing load and generation and ensure high quality and flexibility of these resources.

4.6. Smart Grid Architecture Model (SGAM)

Most of the participants at least know the Smart Grid Architecture Model (SGAM), some of them already used it. The SGAM model is a good framework for modeling interaction, data content, and requirements in well-defined layers but is not usable for analysis of the models. Thus, other tools are necessary (e.g. for cost-benefit analysis, determine quality of solutions).

Another benefit of using the Smart Grid Architecture Model is the potential to describe interactions between TSO and DSO for relevant use cases in detail and to provide tools for the standardization of ICT interfaces.

4.7. ICT for TSO-DSO interaction as cost factor

In general, it can be stated that the costs for implementing TSO-DSO interaction can become a substantial factor, depending on the degree of standardization and interoperability between ICT systems of the TSOs and DSOs as well as which customer segment is considered (industrial sector as most expensive in terms of customer total costs versus the residential sector being the cheapest).

Although the implementation of TSO-DSO interaction entails costs, the benefits are reflected in various aspects, through the provision of telecommunication services and information services generated by internet services, by enhancing the safety, robustness, and reliability of power systems as well as the reduction of grid operation costs, to name but a few.

4.8. Best practice projects and activities

Table 3 shows some best practice projects and activities from the responding partners. It cannot be questioned that there are already some activities regarding ICT aspects for TSO-DSO interaction. On the other hand, further collaboration between TSO, DSO and other market players are desirable.

Table 3: Best practice projects and activities

Country	Best practice projects and activities
Belgium	ELIA (TSO) participated in establishing a Flexibility Datahub in cooperation with DSOs allowing the collection of metering data from both TSO and DSO connected delivery point for mFRR services, the calculation of delivered energy using baseline calculation based on the metering data and transmission of aggregated flexibility volumes to suppliers and FSPs for bilateral settlement purposes.
Germany	The German industry association of energy suppliers (BDEW) coordinates project groups consisting of TSOs, DSOs and other market participants regarding market and data communication. It publishes roadmaps, technical papers, and is in close contact with the German regulator. The participants of the project groups are also active in a lot of research projects.
Italy	Within the European research project *SmartNet* (work package 3, led by VTT), ICT requirements and implications of different TSO-DSO coordination schemes (aimed at extending flexibility market to distribution networks) are investigated.
United States	Coordination between the transmission and the distribution portion of the power system has been subject of pilot studies and theoretical and foundational analyses. The *Pecan Street Smart Grid* pilot is an ongoing residential project that begun in 2010 in Austin, Texas. Relevant ICT aspects of this pilot are the technologies that have been implemented in the participating homes. These technologies include energy management systems (EMS), distributed solar photovoltaic energy, plug-in electric vehicles, smart meters, distributed energy storage, smart appliances, in-home displays, and programmable communication thermostats. Studies comparing this pilot to other existing smart grid projects have shown that electricity consumption in the pilot households was lower than that of the average American household. The studies also acknowledged that participating households were more interested in, and prone to use smart grid technologies, and preferred technologies that automatically shift their energies use because this

	requires minimal effort from them. Another example of efforts by a number of organizations, including CAISO and California electric utilities, is the *More than Smart* project. This consortium has developed a framework for assessing what will be needed to accommodate growth in distributed energy resources in wholesale markets. Findings suggest that DER can be accommodated in market by developing theoretical and economic rules on different time frames, from long term to medium term, during which changes to the current market structures and operations can be undertaken to increase the coordination between transmission and distribution.
China	In the last five-year plan, several national key R&D plans are concerning ICT implementation for TSO-DSO, but majorly about distribution upgrading. Some relevant projects are Research and Application of Intermittent Energy Consumption and Optimization Technology in Active Distribution Network, Research on the Key Technologies of Intelligent Distribution Network Optimal Dispatch, Intelligent distribution network new measurement, communication, protection technology research and development, etc.
India	UI charges project was implemented for better grid control in India, based on ICT aspects and the same is now subsumed under the so-called Deviation Settlement mechanism.
Austria	Taking into account an ever-increasing amount of volatile generation, it is expected that more flexibility will be needed in future to ensure stable grid operation. Part of this flexibility will be found at the distribution level. The HybridVPP4DSO[6] project has investigated how distribution connected flexibility can be used to support distribution network operation, while providing balancing services to the TSO. The project also provides an IT-security concept as a response to the IT-security requirements for potential future implementations.

Coordination between the TSO and DSO already exists in Sweden. However, the discussions around best practice for ICT meeting future demands could be improved. Finland replied to the questionnaire regarding best practice with the recommendation that future solutions require closer collaboration between planners and builder from both perspectives, the communication side as well as the energy side. Identification of real communication requirements for TSO-DSO interaction in different TSO-DSO coordination schemes is a challenging task. It requires the analysis of multiple factors (latency, reliability, security, communication technology) in business, function, information, network, and system component levels. The evolution of ICT technology is fast and versatile, so finding an optimal solution for energy systems is harder especially at the edge of the grid.

[6] http://www.hybridvpp4dso.eu/front_content.php?changelang=10

4.9. Lessons learned from previous activities

Based on the experience of previous activities regarding the ICT aspects of TSO-DSO interaction, one of the most relevant learnings is that a close and intensive cooperation between TSO, DSO, market participants, and regulators is of paramount importance. Furthermore, the mutual understanding of needs and concerns of different parties is crucial when undertaking cooperation.

Nevertheless, actions from the regulator will be necessary to deploy new approaches in the field. The technical solutions go hand in hand with regulation.

Infrastructure investment costs need to be streamlined and reduced to enhance the adoption of smart grid technologies. Complex TSO-DSO schemes could only be profitable if costs for adaptation of the current system are less than the added benefits. Furthermore, the costs will depend on the defined requirements and frameworks. Too stringent requirements will result in very high ICT deployment costs with decreased flexibility. Especially requirements for security and latency have a significant impact on suitable communication technologies. Smart Grid communication networks involve discussions and co-planning between OT (Operations Technology) departments and IT (Information Technology).

On the customer side, economic incentives and opportunities are needed to change how customers perceive and adopt these technologies.

(Funded) research projects can be a good way for working together (industries, research institution, universities, operators, etc.) on important aspects and for developing possible solutions.

5. Conclusion

This document presents the results of a questionnaire regarding ICT aspects in TSO-DSO interaction. The questionnaire was sent to the Annex 6 partners and other international experts. Inputs from nine partners were collected. It contained 13 questions regarding technical aspects (e.g. technical connection points between TSO and DSO), regulatory aspects, flexibility markets, drivers and barriers for TSO-DSO interaction as well as experiences from projects and lessons learned.

Due to the integration of renewable energy sources, the interaction between TSOs and DSOs gets more and more important to handle the high volatility of generation and unexpected load growth in power grids. Additionally, new market mechanisms and the connected flexibilities require a closer interaction between TSOs and DSOs.

ICT aspects for TSO-DSO interaction have been already analyzed in several projects and activities around the world, allowing a common data platform for collecting metering data or calculating flexibility volumes to name but a few. Additionally, requirements for different TSO-DSO interaction schemes are analyzed in studies and projects. Hands-on experience from demonstration projects with focus on TSO-DSO interaction is still missing, but expected soon.

Besides a number of opportunities when having a high degree of interaction between different parties, several technical barriers and risks (e.g. congestions when activating flexibilities, highly-sophisticated mathematical models for calculating prices, IT-security issues) as well as organizational matters (e.g. resistance to well-established patterns, costs for building new infrastructure) have to be solved.

Infrastructure and operational costs will be a crucial factor in the future. Therefore, TSO-DSO schemes could only be profitable if costs for adaption of the current systems are less than the added benefits. Furthermore, the costs will depend on the defined requirements and frameworks und thus, too stringent requirements will result in high ICT development and deployment costs with decreased flexibility.

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