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ISGAN Working Group 9 – Flexibility Markets
Task 4: Operational Planning

# Characterization of the Electric Energy System in view of Flexibility Usage

## Technical Report


ISGAN WG 9

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## Disclaimer

# List of Acronyms

## A

ACS  average cost of supply
aFRR  automatic frequency restoration reserve
AGC  Automatic gain control
AMI  Advanced Metering Infrastructure
APG  Austrian Power Grid AG (Austrian TSO)
ARR  average revenue realized
AS  Ancillary Services
AT&C  Aggregate Technical & Commercial Losses
AUFLS  Automatic under frequency-based load shedding scheme

## B

BRP  Balancing Responsible Party

## C

CAO  Control Area Operator
CEC  Citizen energy communities
CEP  Clean Energy Package
CERC  Central Electricity Regulatory Commission
CHP  Combined Heat and Power
$CO_2$  Carbon Dioxide

## D

DA  Day Ahead
DER  Distributed Energy Ressources
DG  Distribution Grid
DIN  *ger. "Deutsches Institut für Normung"* - German Institute for Standardisation
DISCOM  Distribution Companies
DNO  Distribution Network Operator
DR  Demand Response

## E

EEG  ger."Erneuerbare Energiegemeinschaften" - REC Renewable Energy Communities
EESL  Energy Efficiency Services Limited
EPEX  European Power Exchange
ESS  Energy Storage System, Energy Storage Systems
EU  European Union
EXAA  Energy Exchange Austria

## F

FCR  Frequency control reserve
FR  Flexible Resource

## G

GA  Global Adjustment
GBS  Gross budgetary support
GCT  Gate Closure Time
GDP  Gross domestic product
GOT  Gate Opening Time
GW  gigawatt(s)
$GW_{ac}$  gigawatts of AC power
GWp  gigawatt peak (of installed capacity)

## H

Hz  Hertz

## I

ICI  Industrial Conservation Initiative (in Canada)
ICT  information and communication technology
IEGC  Indian Electricity Grid Code
IESO  Independent Electricity System Operator
IGCC  Integrated Gasification Combined Cycle
IPDS  Integrated Power Development Scheme
ISGAN  International Smart Grid Action Network
ISO  Independent System Operator
IT  Information technology

## K

KEPCO  Korea Electric Power Corporation
KPX
Korean Power Exchange  11
kV  kilovolt

## L

LDC  Load Dispatch Center
LNG  Liquefied Natural Gas

## M

mFRR  manual frequency restoration reserve
MW  mega watt(s)

## N

N.A.  Not available
NDC  Nationally Determined Contributions
NEKP  *(eng: NECP)* national energy and climate plan
NERC  North American Electric Reliability Corporation
NLDC  National Load Dispatch Center
NSGM  National Smart Grid Mission (Organisation by the govt. of India)
NTC  Net Transfer Capacities
NWA  Non Wires Alternatives

## O

OPEX  Operational Expenditures

## P

PFC  Power Finance Corporation
POSOCO  Power System Operation Corporation (Indian TSO)
PPA  Power Purchase Agreement
PRAS  Primary Reserve Ancillary Service
PRD  Price Responsive Demand
PV  photovoltaic

## R

RAPDRP  Restructured Accelerated Power Development and Reforms Programme
RD  Redispatch
RE  Renewable Energy
REC  Renewable Energy Communities, Rural Electrification Corporation (India)
RLDC  Regional Load Dispatch Centres

## S

SCADA  Supervisory Control and Data Acquisition
SGU
significant grid users
SLDC
State Load Dispatch Centres
SO  System Operator
**SRAS**  Secondary Reserve Ancillary Service

## T

TFEU  Treaty on the Functioning of the European Union
TSO  Transmission System Operator
TWh  terawatt-hour

## U

UBA  ger. Umweltbundesamt- Austrian Environmental Agency

## V

VIU  Vertically integrated uitlity
VRE  Variable Renewable Energy

## W

WAM  with additional measures

# Abstract

In the framework of the IEA TCP International Smart Grids Action Network (ISGAN), Working Group 9 aims at identifying challenges and opportunities of flexibility markets related to operational planning. Therefore, this deliverable presents a comprehensive review of the current electricity systems of Austria, Canada, India, and Korea. A survey has been conducted that aims at laying the basis for a common understanding of international market designs and different flexibility services that are currently in use. To capture the whole picture, the topic of market design was split into three subtopics, covering general market design, flexibility market design, and flexibility services for system operators. Each of these topics is made accessible by several questions that have been answered by the respective countries, enabling the Working Group to understand presently used market designs and flexibility services. We find that the design of electricity markets differs significantly between European and non-European countries, thus presenting a wide range of challenges to the countries in question. Consequently, there are no general-purpose solutions for the successful implementation of flexibility markets related to operational planning. However, several common issues were identified and will be investigated in the further course of the work of Working Group 9 through stakeholder interviews from participating countries.

# Executive Summary

The purpose of this deliverable is to lay the foundation for a common understanding of international electricity market designs and different flexibility services that are currently in use. To create a country overview about market design and flexibility services, a survey among the participating partner countries has been conducted, focussing on three main aspects of the electricity system, namely general market design, flexibility market design, and flexibility services for system operators.

In terms of **general market design**, one important variable is the current status and future plans for the expanded use of renewable energies in the overall system. The countries' goals can be divided into two categories, i.e. 'net zero electricity' and 'climate neutrality'. In this sense, Austrian (and European) goals are quite ambitious, as the plan is to reach net zero electricity by 2030 and climate neutrality by 2040 (Europe: 2050). The same applies to Canada, targeting net zero electricity by 2035 and net zero energy by 2050. Korea plans to be carbon neutral by 2050, and India aims at reaching net zero energy by 2070. Increasing the share of renewable energy sources is considered against the backdrop of different stages of vertical integration and unbundling of the power systems in different countries. Unbundled utilities are established in Europe, whereas in most of Canadian provinces, vertically integrated utilities are in place. Furthermore, the responsibilities and ownership structure of the stakeholders in different countries differ significantly. Whereas the unbundled utilities in European countries lead to a strict separation of responsibilities and ownership of e.g., transmission grids, distribution grids and generation assets, in non-European countries often only one entity manages the whole electricity sector. As different forms of general market design decisions have different advantages and disadvantages, the current challenges and issues concerning the electricity system (e.g., higher share of RES) are highly dependent on the current market design choices. One problem that must be faced by all countries is the expansion of both high and low voltage grids. The general planning of both parts of electricity networks needs to take existing and future flexibility into account. Furthermore, a higher degree of TSO-DSO interaction and coordination is required in all countries with non-vertically integrated utilities in the future, and observability of lower voltage levels needs to be enhanced.

Understanding the characteristics of already participating and planned flexible resources is key for obtaining insights from international **flexibility markets**. In Europe, more and more small-scale assets, capable of providing flexibility, such as boilers, battery storage and heat pumps are being integrated into the flexibility markets. In Canada, different peak-shaving programmes are commonly available. In contrast, in Korea and in India, flexibility services are provided mainly by conventional power plants such as LNG and thermal generators. Nevertheless, conventional power plants provide most of the flexibility in the countries considered in this study. To foster market participants other than conventional power plants to supply flexibility, there are already some incentive mechanisms in place in Austria and Canada. Another important prerequisite for flexibility integration is the smart meter rollout. All countries participating in the survey intend to equip most of the network users with advanced metering infrastructure within the next years.

**Flexibility services for system operators** can be classified as flexibility services for TSOs, and flexibility services for DSOs. In Europe, TSO usage of flexibility services is mainly organized into markets for primary, secondary, and tertiary control. Furthermore, a growing number of countries is currently trying to include distributed assets into their redispatch processes. In non-European countries, the TSO usage of flexibility services is quite diverse.

Canadian TSOs place great emphasis on deploying generation and grid-scale batteries in order to handle operational and contingency needs. In India, besides primary, secondary and tertiary control, system inertia is used in combination with primary frequency response to control the immediate rate of change of frequency in the event of a sudden loss of connection.

For now, DSO engagement in flexibility services is limited in most EU countries. This should change in the future, as EU law aims to enable and incentivise DSOs to procure flexibility services. In Canada, distribution-located resources are commonly only used for peak shaving. In India DSOs currently do not use flexibility services. Nevertheless, some distribution grid applications for flexibility have been identified, in order to tackle challenges such as increasing penetration of decentralised generators and new consumers, and therefore increasingly frequent operation of these lower grid levels at their technical limits.

The report gives a comprehensive overview of the current electricity systems of Austria, Canada, India, and Korea. The conducted survey aims at laying the basis for a common understanding of international market designs and different flexibility services that are currently in use. To capture the whole picture, the task was split into three subtopics, covering general market design (Section 2.1), flexibility market design (Section 2.2), and flexibility services for system operators (Section 2.3). Each of these topics is illustrated by the responses of the respective countries. This enables us to understand the current state of market designs and flexibility services.

The insights gained from this country overview were used to create a questionnaire addressed at various stakeholders (TSOs, DSOs, aggregators, and consumer associations) in each country. The questionnaire as well as the evaluation of answers will be given in a follow-up report.

# Table of Content

# 1. Introduction

Energy systems around the world are experiencing a paradigm shift driven by the need for decarbonization and the rapid growth of decentralized renewable energy sources. A key element for the effective integration of renewables and decentralized energy sources into the power system is the use of flexibility from distributed resources, e.g. for market participation or the provision of grid services. The primary tasks of the DSOs, at least in Europe, are to ensure the long-term capability of the electricity system to meet reasonable demands for the distribution of electricity, for operating, maintaining and developing under economic conditions a secure, reliable and efficient electricity distribution system [1]. Preconditions for secure system operation as identified by [2] are:

- Availability of power to cover demand
- Adequate network and associated infrastructure
- Availability of resources to cover system imbalances in the operational hour
- System stability

In order to set out clear and objective requirements for TSOs, DSOs and Significant Grid Users, to contribute to non-discrimination, effective competition, and the efficient functioning of the internal electricity markets, and to ensure RES integration and system security, the EU drafted a Network Code for Operational Planning and Scheduling in 2013 [3]. This Network Code has been developed in response to the current development of ever more decentralized energy sources entering the market, which change the basis for long-term and operational planning needs. Furthermore, the planning principles of grid operators are also challenged by the increasing appearance of local flexibility markets, such as local energy communities. These can participate in flexibility markets that in turn can provide grid services to, e.g. facilitate the integration of variable renewables.

Task 4 of the current Working Programme of ISGAN Working Group 9 aims at answering the question of how system planners can adapt their strategies, and how they can take advantage of local flexibility markets. To do so, the first step is to provide a common base of knowledge concerning electricity market design in the participating countries. Therefore, the following chapters present a comprehensive review of the electricity systems in place today in Austria, Canada, India, and Korea. The conducted survey aims at laying the foundation for a common understanding of international market designs and different flexibility services that are currently in use. To capture the whole picture, the task was split into three subtopics, covering general market design (Section 2.1), flexibility market design (Section 2.2), and flexibility services for system operators (Section 2.3). Each of these topics is covered by several questions that have been answered by the respective countries, enabling us to better understand the market designs and flexibility services in use.

Based on the survey of the state of the art, the goal of this work is the identification of challenges and opportunities for using flexibility markets, as well as the associated changes in operational planning.

# 2. State of the art – Country profiles on market design and flexibility services

## 2.1. General market design

### Status and plans for renewable production

The following table compares the different statuses and plans for integrating renewables in the power systems of the considered countries. More details can be found in the appendix of this document.

**Table 1:** *Status and plans for renewable production by country*

<table>
<tr><th></th><th>Austria</th><th>Canada</th><th>India</th><th>Korea</th></tr>
<tr><td>Short-term goal</td><td>Net zero electricity by 2030</td><td>Net zero electricity by 2035</td><td><ul><li>An emission intensity target of 45% below 2005 levels by 2030</li><li>A target of achieving 50% cumulative electric power installed capacity from non-fossil fuel-based energy resources by 2030</li></ul></td><td>40% $CO_2$ reduction compared to 2018 levels by 2030</td></tr>
<tr><td>Long-term goal</td><td>Climate neutrality by 2040</td><td>Net-zero energy by 2050</td><td><ul><li>Net zero energy by 2070</li></ul></td><td><ul><li>40% of renewable energy capacity by 2034</li><li>Carbon neutrality by 2050</li></ul></td></tr>
<tr><td>Current electricity consumption</td><td>72,3 TWh (2021) [4]</td><td>569 TWh (2021) [5]</td><td>1282 TWh (2021) [7]</td><td>554 TWh (2021) [6]</td></tr>
<tr><td>Status of Wind</td><td>Installed capacity: 3,300 GW</td><td>13,6 GW total installed capacity of which 93% is connected to transmission grid, and 7% to distribution grid</td><td rowspan="2">More than 118 GW of installed capacity (wind and PV) as per September 2022</td><td>Planned installed capacity: 1,713 GW by the end of 2021</td></tr>
<tr><td>Status of PV</td><td>Installed capacity: 3,265 GWp as per 2022</td><td>Installed capacity: 2,9 GW total (67% centralized, 33% decentralized)</td><td>Installed capacity: 22 GWp as per 2021</td></tr>
<tr><td>Plan 2030 for renewable energy capacity</td><td>Planned increase of<ul><li>Wind power (167%; +10 TWh)</li><li>PV power (786%; +11 TWh), installed capacity by 2030.</li><li>Hydropower (13%; +5 TWh)</li></ul></td><td>-</td><td>-</td><td>33,8% of total renewable energy production</td></tr>
</table>

### What are the responsibilities of TSOs?

In Austria, the transmission system operator is responsible for **operating, maintaining** and **developing** the transmission system. In their role as Control Area Manager, the national TSO Austrian Power Grid (APG) is responsible **to ensure balanced power** in the associated control area to maintain a stable grid frequency. In India, TSOs do exist at central and state level. They are responsible to facilitate transfer of electric power within and across the regions and trans-national exchange of power considering reliability, economy and sustainability. Additionally, they are also responsible for facilitating competitive and efficient wholesale electricity markets and administer settlement systems.

**There are different stages of vertical integration and unbundling in Canada and Korea.**

**Vertically integrated utilities** are common in Canada (8 of 10 provinces), where one stakeholder is responsible for generation, transmission, system operation, distribution, and retail. Other than that, for instance in Korea, ownership of the transmission network, distribution network, and generator capacities is separated from operation. The operation is carried out by the Korean Power Exchange KPX, which is also operating the markets as well as carrying out the actual operation of the grid. In India, only DSOs are vertically integrated, whereas TSOs are unbundled.

**Unbundled utilities are in place in Austria as well as in the other European countries**, where networks are owned and operated by the same stakeholder and are unbundled from suppliers. Transmission system operators procure flexibility services for grid stability, e.g., for balancing or congestion management. Suppliers can trade their capacities at these markets for ancillary serves as well as power exchanges for conventional dispatch (Day-Ahead, Intraday). In those Canadian provinces (2 of 10) with electricity markets in place, owners of the transmission grid differ from the grid (and market) operators, contrary to Europe. In India, there is one TSO on the central/national level and several TSOs on state level. Carriage and content separation is implemented for TSOs in India, but not yet for DSOs. The national Indian TSO is reliable to facilitate the transmission of power with reliability, economy, and sustainability, facilitating competitive and efficient wholesale electricity markets and administering settlement systems.

### What are the responsibilities of DSOs?

The main responsibility of the DSO lies in the distribution of power from the transmission grid to end-users. In Austria, in Canadian provinces with non-VIU systems, as well as in Indian provinces with DSOs, their responsibilities are mostly local, and involve managing branch congestions, under- and over-voltages and network service restoration after local outages by reconfiguring the network.

**In Austria, distribution system operators are not allowed to own distributed (or any other) generation assets**. This holds true for all Member States of the European Union, which regulates DSOs' responsibilities in Directive (EU) 2019/944. A similar rule is in place in those **Canadian** provinces that operate non-VIU (unbundled) systems.

In some cases, municipally owned distribution system companies may exist in **VIU systems, such as in Canada.** These companies are supplied with electricity by the VIUs.

Korea is developing a concept for DSOs while clarifying the legal system, which describes the DSO **as an operator in charge of active control and dispatch of distributed generators connected to the distribution network**. This does not correspond to the European concept of a DSO, where the generators are still owned by other stakeholders and the general dispatch is done via power exchanges or TSO flexibility markets.

European DSOs would, however, also be entitled to operate flexibility markets, to solve voltage or congestion problems in the distribution grid. Until now, other measures to solve congestion and/or voltage problems such as changes in grid topology, have proven sufficient most cases, which is why DSO flexibility markets are not yet in operation in Europe. In Canada's Leamington, Ontario, local distribution company Essex Powerlines is involved in an ongoing flexibility market project. The project's goal is to utilise DERs over 100 kW to reduce distribution network congestions[1].

In India, DSOs have the same responsibilities as in Europe, which is maintaining safety and reliability of the system by managing branch congestions, avoiding under- and over-voltages, and network service restoration after local outages by reconfiguring the network. Not all DSOs have separated ownership of generation and distribution assets yet. In the near future, DSOs need to function as market facilitators, to support the participation of all types of potential market actors in a non-discriminatory and transparent way. In the future, the role of the DSO will be expanded by an additional set of responsibilities, which include distributed generation reliability coordination, transmission-distributed interface reliability coordination and energy transaction coordination.

**Table 2:** *Roles in the Power System in different countries*

| | Austria | Canada (VIU) | India | Korea |
|---|---|---|---|---|
| **Owner of transmission grid** | APG (TSO) | VIU | POSOCO (TSO) | KEPCO (Owner of grid and generator capacities) |
| **Owner of low-voltage grid** | Different DSOs | VIU or VIU-supported distribution system companies | DSOs | KEPCO |
| **Operation of transmission grid** | APG (TSO) | VIU | POSOCO (TSO) | KPX (Network operator) |
| **Operation of Low-Voltage grid** | Different DSOs | VIU | DSOs | KPX |
| **Ownership of generation assets** | Suppliers or other entities that are independent from System Operators | VIU, sometimes with independent power producer-owned VRE sites | In the transmission grid its separated from the TSO, partly DSOs | KEPCO |
| **Power supply** | Suppliers | VIU | | KPX |
| **Dispatch/Operation of power exchange** | Power exchanges (EPEX, EXAA) | VIU | | KPX |
| **Balancing of the grid** | CAO (TSO APG acting in its role as CAO) | VIU | | KPX |

[1] https://powershare.energy/

### For which assets and grid levels is observability in the distribution grid given?

Under VIU regimes, such as in **Canada**, DSOs and TSOs are the same stakeholder, hence no TSO-DSO interaction is required. In all other evaluated countries, interaction is rather limited. For instance, in Austria information exchange is carried out for the 110 kV grid level (highest DSO level) between the DSO and TSO by using '.csv' files.

In Canada, interaction is limited in that, effectively, distribution and transmission planning, and operations are mostly conducted separately; however, as DERs increase, there is a recognition of the need for change.

In India, there is currently also a lack of interaction between TSOs and DSOs. However, considering a continuous shift from fossil fuel to non-fossil fuel/renewable-based generation (mainly solar & wind) to facilitate accelerated development of a low-carbon energy system, an emerging need for collaboration/interaction between DSOs and TSOs is foreseen.

### What is the status of smart meter rollout and what are the experiences concerning enhancement of flexibility applications?

Smart meter rollout is a prerequisite for flexibility integration, but in many countries, it suffers from a delay. The foundation for the Europe-wide introduction of smart meters was laid with the Electricity Directive (Directive 2009/72/EC). This created the basis for the active participation of network users in the electricity market. Based on reports monitoring the status of smart meter rollout in the European Union, it was decided to extend the deadline for equipping at least 80% of network users until 2024 for those member states that started the systematic rollout of smart metering systems before July 2019.

Austria's goal is to reach a level of 95% before the end of 2024. However, this process is lagging behind its goal, with only approx. 31% reached in 2020.

Korea planned to supply 100% of Advanced Metering Infrastructure (AMI) to 22.5 million (low-voltage customers) by 2020. However, only 48% have been disseminated as per December 2021 due to a delay, and the initial deadline was reset to 2024.

In India, NSGM has been the key enabler in the deployment of AMI through Smart Grid Pilots all across India. As of September 2022, more than 5 million smart meters have been installed and another 5.7 million meters are under installation as reported by stakeholders.

In Canada, smart meters are already widely deployed to all customer types across Canada, although this rollout has taken place over the last 10 years, resulting in smart meters with different capabilities (i.e. old vs new). Generally, they are used for metering and, where DR is deployed, for measurement and verification (recognizing there may be limitations). Control of DR resources is typically achieved through other means, e.g. internet or wireless service connected to utility systems.

### Who needs to send schedules in advance?

In **Austria**, schedules of planned electricity injection and estimated consumption must be sent only by power plants with a capacity of 50 MW and above, and by significant grid users (SGU). Schedules comprise existing and new power generating facilities and demand facilities deemed significant by the TSO because of their impact on the transmission system in terms of security of supply, including provision of ancillary services. An open question is whether this will change in the future, and if whether smaller assets will also be obliged to send schedules. Currently, there is no level of accuracy required for scheduling.

In Canada, it is not required for operators of large loads to send their schedules in advance; however, in Ontario, scheduling may be used via participation in a day-ahead commitment process by large loads and/or aggregators to receive capacity payments or participate in the real-time market.

In Korea, all electricity, with some exceptions (e.g. PPAs), must be traded in power markets. In the DA market, dispatchable traditional generators with a capacity of more than 20 MW are bidding. There are no dispatchable DERs.

In India, the scheduling request shall be submitted by the power exchange to the National Load Dispatch Centre (NLDC). Generators shall ensure that bidding in the real time market is done by taking into account their ramping constraints to facilitate proper scheduling of trades. The individual transactions for state utilities and intra-state entities are scheduled by the respective State Load Dispatch Centers (SLDCs). Power exchanges send the detailed breakup of each point of injection and each point of drawl within the state to respective SLDCs.

### Who takes responsibility for deviations of the balancing responsible party?

In Austria, the responsibility of balancing the overall system lies with the TSO (APG) in their role as Control Area Manager, who balances the system through activating the balancing reserve. The costs for activation of the reserve are charged to the originators, which are the balancing responsible parties (BRP).

In Korea, the responsibility of balancing the overall system lies with the operator of the transmission system, KPX. For the difference between the DA market and real-time operation, the opportunity cost is settled for the generator which supplied reserve power, and the cost is borne by the buyer (KEPCO).

In Canada, the ISO/TSO of the respective province is responsible for balancing within the province and can be considered the (sole) BRP.; Besides the ISO/TSO there is no BRP.

In India, the responsibility of balancing the overall system lies with POSOCO, the national grid operator. POSOCO balances the system through activation of the balancing reserve, and by price control through the Deviation Settlement Mechanism. The costs for this activation are charged to the originators, which are the balancing responsible parties and governed by the Deviation Settlement Mechanism Regulations, formulated by Central Electricity Regulatory Commission (CERC) at central or federal level in India.

### What are the major issues the electricity system faces?

Increase in electrification of heating and mobility as well as distributed generation has the potential to cause grid problems in lower grid levels in the future in all investigated countries. Problems observed in the countries reviewed in this report include the need for curtailment, rapid increases in demand due to increased demand for electricity, and the rate of grid expansion not being able to keep up with growing demand.

Korea for instance, faces a growing necessity for curtailment due to the increasing penetration of renewables. Decreasing system inertia requires demand for flexible resources, especially seasonal storages.

An increasing demand for power due to economic growth can lead to new challenges, as can be observed in in India. These include the necessity for grid reinforcement, and consequently require adequate planning methods.

In Korea, delays in the construction of grid infrastructure have caused delays in the connection of end-users to the grid. In Austria, efforts to reinforce the grid infrastructure are lagging behind, leading to a limitation of PV installation rate at low voltage levels in numerous branches of the distribution grid.

Generally, planning of both transmission and distribution systems needs to take advantage of existing and future flexibility. Furthermore, a higher degree of TSO-DSO interaction and coordination is required in Austria, the unbundled utilities in Canada, as well as India. But also in vertically integrated utilities, observability of distribution grid assets is lacking, and smart meter installations are being delayed.

Countries such as India, have put initiatives to improve reach and reliability of the last mile grid, and to leverage new technologies to enhance efficiency of existing infrastructure in place, for instance with the establishment of National Smart Grid Mission (NSGM).

Globally, increasing fuel supply uncertainty, such as for coal in the case of India, and natural gas in the case of Europe, enhances the need for the use of renewables and a highly flexible energy system.

However, increasing electrification will present large additional challenges to all types of electricity systems. Unlocking the potential stemming from DER, will require technical, market, and regulatory changes and upgrades.

This holds particularly true for Canada, given the different characteristics of utilities across the country. The various regimes in place enhance this challenge, as there is no universal solution. Differences include load compositions (e.g., some provinces use electricity for heating while others use natural gas) and VIU vs. market-based structures.

### What are other important characteristics of the general energy system design?

In Europe, the Treaty on the Functioning of the European Union (TFEU) lays out the legal basis for the liberalisation and harmonisation of the EU's internal energy markets. Therefore, starting in 1996, the EU gradually liberalised the energy market, aiming at the creation of one single integrated European electricity market. A key step in this process was, and still is, the unbundling of the European power sector. This means that generation, transmission, distribution, and retail activities are divided and run by independent stakeholders. As a result, suppliers can join a balancing responsible party (BRP) and trade electricity at the markets but must not be owners of the grid at the same time. Consumers can therefore choose their supplier independently, whereas the network operator is predetermined by their geographical location and cannot be chosen individually. Since this a European regulation, this of course also holds true for the case of Austria.

In India, all 36 LDCs are equitably responsible for maintaining grid parameters such as frequency, voltage, etc. Furthermore, they contribute to integrated decentralized power system operations. In recent times, the Indian power system has moved from a shortage situation to an adequacy scenario.

## 2.2. Flexibility market design

### Which flexibility resources are already in the market?

In Europe, more and more small-scale flexibilities, such as boilers, battery storage and heat pumps are being integrated into flexibility markets. In Austria, prequalification needs to be completed separately for each flexibility service provider and each type of asset. To incentivize peak shaving, grid fees for monthly peak consumption from medium voltage levels upwards are applicable. As a reaction to the 2022 energy crisis, a temporary demand-side-response electricity savings product is tested until March 2023 by Austrian TSO APG. This product supports the use of flexibility provided by consumers by reducing electricity consumption or shifting consumption outside peak hours to reduce prices, and in doing so benefit the system. All consumers who agree to provide flexibility of min. 2 MWh over a period of two hours during peak consumption times may participate.

In Canada, peak shaving programmes are commonly available to industrial customers who, through arrangements with their utility, can be requested to reduce their consumption during very high peak loads in return for monetary compensation. Time-of-use rates are available to customers in some provinces and serve to shift load away from peak periods. In Ontario, demand response resources can participate directly in the markets through a capacity auction or as dispatchable loads on the real-time market.

In contrast, in Korea and India mainly conventional power plants such as LNG and thermal generators provide flexibility services. In Korea energy storage systems (ESS) are used in the flexibility markets, but the amount is not significant.

### What is the primary flexibility solution?

In the analysed countries, conventional power plants provide most of the flexibility. A differentiation between renewable conventional power plants (such as pumped hydro, CHPs, ...) and other conventional power plants is necessary. In Austria, power plants providing flexibility include hydro, gas or CHPs, in Korea these are LNG, coal generation, and pumped storage, whereas in Canada, conventional hydro and/or natural gas in combination with interties between provinces and with the United States are used.

In Austria, for the special case of redispatch, mostly gas-fired power plants are used, and some large industry sites are also already providing balancing services.

### Are there mechanisms to incentivize market participants to supply flexibility?

Concerning the topic of incentives for flexibility provision, there is a lot of research going on in Europe, especially in Austria. For low voltage problems, discounted tariffs for interruptible loads (e.g., heat pumps) are in place. Furthermore, there are time-dependent tariffs that mostly rely on the day-ahead market price and allow consumers to adjust to the electricity price.

Suppliers, however, are quite restrictive and there currently is no option to contract two different suppliers, e.g., a flexible tariff for flexible and another tariff for non-flexible loads. Nonetheless, two tariffs and two meters are possible according to some suppliers. Concerning the industrial sector, Austrian industries may participate in the balancing markets.

In Canada, very large customers, i.e., those with over 500 kW peak demand, may be eligible to participate in the Industrial Conservation Initiative, which allows them to pay their share of

Global Adjustment (GA[2]) costs based on their load coincident with the top five 12-month system peaks. As already mentioned, in Canada, especially in Ontario, market participants have the possibilities to make use of price responsive demand mechanisms, the ICI, and direct participation at the capacity market.

To date, no mechanisms to incentivize market participants to supply flexibility exist in Korea and India.

### Are there any local flexibility markets in operation?

In Austria, two types of energy communities can be distinguished: First, renewable energy communities (REC) (ger.: Erneuerbare Energiegemeinschaften, EEG), and second, citizen energy communities (CEC) (ger.: Bürgerenergiegemeinschaften). On the one hand, renewable energy communities several parties such as households, municipalities, or commercial enterprises cooperate in order to share electricity. A PV system is mounted on one or several buildings within the energy community and the participants can profit from reduced grid tariffs, if they consume the electricity, produced within the community.The settlement is realized via the distribution grid operators. For the implementation of a renewable energy community, spatial proximity to the place of production is important.

Citizen energy communities on the other hand consist of a group of people or households seeking to benefit from joint electricity use. Spatial proximity to the place of electricity production is not mandatory in this model. This even allows for participants from different federal states to participate in a CEC.

Other forms of flexibility markets, such as direct marketing of renewables and minimization of balancing energy costs, as is the case in Germany, are not viable in Austria due to the subsidy and market design. As mentioned above, Canadian distribution company Essex Powerlines has an ongoing flexibility market project, which follows a goal of utilizing DERs over 100 kW to reduce distribution network congestions.

**In India and Korea, there are no local flexibility markets in operation at the time.**

### To which extent are the requirements for different flex applications harmonized?

Five different flexibility products exist in Europe: frequency control reserve (FCR), automatic frequency restoration reserve (aFRR), manual frequency restoration reserve (mFRR), replacement reserve (RR) and redispatch. In most European countries, there are different prequalification requirements, timelines (GOT, GCT) and baseline requirements for the different flexibility services. There are some discussions though, on harmonizing the prequalification processes for a common flexibility platform. In Austria there is no RR in place, since it is optional and not used in every European country.

In North America, grid reliability services are specified by NERC and its regional entities and their regional reliability coordinating council.

In Korea, except for the traditional generator used for balancing, the only flexible resource is an electrical storage system now. Therefore, there is no need for harmonized application.

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[2] GA covers the difference between payments for selected contracted or regulated generation (e.g., hydro, nuclear, and feed-in-tariff supported renewables) and conservation and related initiatives and that which would have been received from market revenues; it is applied to all customers in Ontario.

### Do flexibility concepts require schedules?

Austrian, and therefore european flexibility services are designed in such way that activation takes place almost in real time, leading to minimal lead-times. This, in return, requires no additional schedules. Some flexibility services, such as congestion management, could require reliable schedules though, depending on needed amounts and grid topology. The organizational, technical as well as legal requirements are currently under investigation.

The situation in India and Canada is similar to the current European situation, where flexibility services are always on standby and are activated as soon as the power system requires support.

### How is verification of the flexibility provision carried out?

In Austria, for verification of balancing products, the provider must make available the status of information concerning activation status, time-stamped measured values of frequency, operating point, and actual generation by means of online transmission for monitoring purposes.

In Korea, flexibility provision is confirmed through data acquired from SCADA systems that transmit relevant data every 2 seconds.

In Canada, the requirements differ by programme and region and are specified by the system operator. One option to verify the provision of flexibility by small scale assets (e.g., residential) are smart meter and/or internet-connected devices.

### Is a capacity calculation conducted for the distribution grid as input for the TSOs' flexibility activation?

In Europe, using a load flow calculation with forecasts is common. If required, a change of grid topology is sufficient in most cases to prevent problems in the DSO grid. So far, for the Austrian case, the available grid capacity is sufficient and flexibilities (such as balancing providing assets) are considered as worst-case options in the load flow calculations.

In contrast, no capacity calculation of flexible resources is conducted in Korea and India.

## 2.3. Flexibility services for system operators

### Status of TSO usage of flexibility services

TSOs may deploy a number of measures to tap into existing flexibilities in the electricity system. These include frequency control by increasing or decreasing load or generation in the area served by the TSO to maintain system stability, congestion management by reducing peak loads at specific nodes in the transmission grid, and others.

In Europe, there are organised markets for primary, secondary, and tertiary control. Furthermore, a growing number of countries tries to include distributed assets in their redispatch processes.

In non-European countries, the usage of flexibility services is quite diverse. In Canada, operational and contingency needs and other operational requirements (e.g., congestions) are handled by deploying generation and grid-scale batteries. In the special case of India, power systems are generally designed and operated so as to withstand a sudden loss/connection of generation units or loads without posing a threat to frequency stability. System inertia is used to control the immediate rate of change of frequency after an event. It is also used in combination with primary frequency response to limit the deviation in frequency before the frequency is restored to a steady state through secondary and tertiary reserves. Primary frequency response from thermal (210 MW and above), gas (50 MW and above), and hydro generating units (25 MW and above) is mandated in the Indian Electricity Grid Code (IEGC).

### Status of DSO usage of flexibility services

DSOs may also deploy a number of measures to tap into existing flexibilities in the distribution system. These include e.g., variable grid tariffs, congestion management, voltage control, and others.

The European Electricity Directive, which is part of the "Clean Energy Package (CEP) for all Europeans" states, that "[…] member states shall provide the necessary regulatory framework to allow and provide incentives to distribution system operators to procure flexibility services, including congestion management in their areas […]" (Art. 32) [8].

Currently, in most European countries, DSOs barely activate any flexibilities for congestion management or voltage control. Austria provides the option of entering special grid connection contracts that allow the DSO to curtail some assets to an agreed power. In theory, there are interruptible tariffs, e.g. for heat pumps, to date these have been used only in rare occasions. The aforementioned options can be regularly used in a normal grid state. In case of emergency cases, the DSOs can separate parts of the grid from the power supply in order to prevent major supply losses.

In Canada, distribution-located resources are commonly only used for peak shaving, while in India, DSOs do not use flexibility services at all.

### What are the main flexibility resources available to DSOs and TSOs?

The following table gives an overview of the flexibility resources that can be used in different countries. No data was available for Korea at the time of compiling this report.

**Table 3:** *Flexibility resources that could be used by DSOs and TSOs in the considered countries*[3]

| | Austria | Canada | India |
|---|---|---|---|
| **Generators** | • Thermal power plants (natural gas, biogas, biomass, waste interactions)<br>• VREs (run-of-river power, photovoltaics, and wind power) | • Natural gas<br>• Dispatchable VREs | • Thermal<br>• Gas<br>• Hydro |
| **(Pumped) Storage power plants** | • Pumped hydro storages<br>• Hydro reservoirs | • Reservoir hydro | • Pumped hydro storages |
| **Import & Export** | • Marginal net transfer capacities that can be used for trading (NTC) all neighbouring countries; this amounted to 9,100 MW (export) and 8,855 MW (import) in 2020 | • Interties between provinces and with the United States | - |
| **Heat pumps and boilers** | • Households<br>• Commercial sector | • Largely untapped | - |
| **E-Mobility** | • Apart from field tests and pilot applications within research projects no actual usable potential | • Largely untapped | - |
| **Industry** | • Flexible self-generation plants<br>• Consumers with a large specific electricity consumption<br>• However, still a lot of unexploited potential remains | • Transmission connected industry loads, with/without cogeneration | - |
| **Commerce** | Sectors with high potential are:<br>• Air conditioning and ventilation<br>• Data centres<br>• Food refrigeration<br>• Wastewater treatment plants<br>• Water supply | • Largely untapped | - |
| **Hydrogen** | • Electrolysis (power-to-gas) | - | - |
| **Batteries** | • Home storage systems<br>• Large-scale batteries | • Utility-scale batteries | • Battery storage |

[3] There is no data available for Korea

| | | | |
|---|---|---|---|
| **Additional** | - | • Distribution-connected loads under exploration | • Entities capable of providing demand response (DISCOMs, Aggregators) |

### Which are/could be the main distribution grid applications for flexibility in your country?

The greatest challenge for distribution grid applications is posed by the increasing penetration of decentralised generators, new consumers in the distribution grid, and the associated stresses of operating of the grid at its technical limits. Regarding the use of flexibility in the distribution grid, the following findings and recommendations can be stated based on national and international experience:

1. A measurement-based recording of the real grid situation makes it possible to deviate from worst-case assumptions in grid planning. Through the continuous monitoring of real grid situations, both expanded reserves/capacities can be made usable, and critical grid areas can be pointed out and identified.
2. Grid topological measures (e.g. switching state, tap changers) are a very efficient solution in the high and medium voltage grid (e.g. temporary, or permanent ring closures). It is expected that this will be increasingly possible in the future, as more and more grid operators also fully integrate medium-voltage grids into their control systems. With a higher degree of automation and integration into control systems, switchovers in the grid can be carried out more easily. In the low-voltage grid, however, these measures are very difficult to implement, as these are operated as radial systems and the effort for automating is much higher.
3. The studies on innovative grid components, such as controllable local grid transformers and line controllers, show a great potential to increase the absorption capacity of low-voltage grids in a cost-efficient way. For this reason, they must be considered as alternatives in grid planning processes.
4. The coordinated operation of consumers (e.g. charging of electric vehicles) and generators (e.g. photovoltaics) alongside storage systems also shows great potential for avoiding generation or load peaks. Whether such measures can be used in grid planning depends on whether they also function reliably in practice, and how correct regulation is identified and implemented.
5. Measures defined in grid connection requirements or in grid codes (e.g. technical rules for generators in Austria) such as reactive power provision and voltage-controlled active line control are suitable measures for increasing the absorption capacity of existing grid infrastructure.
6. Measures covered by the grid tariff, such as interruptible supply (e.g., heat pump tariffs), continue to be a very suitable option for avoiding short-term bottlenecks. Interruptible supply allows load shifting in the event of capacity bottlenecks.
7. With the further development of grid control systems, the use of market-based flexibility analogous to existing products in the transmission grid may be possible on the high-voltage level. In the medium and low-voltage grid, market-based flexibility can only be used to for balancing services, as e.g., for redispatch capacity bottlenecks occur very locally and only a few grid users can be considered as potential providers.

# 3. Conclusions and next steps

To lay the foundation for a common understanding of international market designs and different flexibility services that are currently in use, a survey among the participating ISGAN Working Group 9 countries has been conducted. The aim was to create a country overview about market design and flexibility services, focussing on three main aspects of the electricity system: General market design, flexibility market design, and flexibility services for system operators.

Understanding the characteristics of already existing and planned flexible resources is key to obtaining insights from international **flexibility markets**.

In terms of general market design, we find that the responsibilities and ownership structure of the stakeholders in different countries differ significantly. Whereas the unbundled utilities in European countries lead to a strict separation of responsibilities and ownership of e.g., transmission grids, distribution grids and generation assets, in non-European countries often only one entity manages the whole electricity sector. As different forms of general market design decisions have different advantages and disadvantages, the challenges and issues concerning the electricity system are highly dependent on the current market design choices.

Increasing the share of renewable energy sources is planned in every participating country and therefore the problems that arise with this planned increase in volatile electricity sources must be tackled by all countries. Another problem that must be faced by all countries is the expansion of both high and low voltage grids.

In Europe and Canada more and more small-scale assets are integrated into the flexibility markets. In contrast, in Korea and in India, the provision of flexibility services is still conducted only by conventional power plants. In order to foster market participants other than conventional power plants to supply flexibility, Austria and Canada introduced incentivisation mechanisms.

The challenge of tackling increasing penetration of decentralised generators and new consumers, and therefore increasingly frequent operation of these lower grid levels at their technical limits is identified as a problem that has to be addressed by all of the participating countries. As for now, DSO engagement in flexibility services is limited in most EU countries. This should change in the future, as EU law aims to enable and incentivise DSOs to procure flexibility services. In Canada, distribution-located resources are commonly only used for peak shaving. In India DSOs currently do not use flexibility services. Nevertheless, some distribution grid applications for flexibility have already been identified.

To conclude we find that the design of European and non-European electricity markets, and consequently the issues that the countries face, differ significantly from each other. This leads to the suggestion that there will not be a general-purpose solution for the successful implementation of flexibility markets related to operational planning, but rather solutions on national levels – or even smaller sub-entities – to successfully overcome the hurdles in utilising flexibility.

Based on the country survey, Working Group 9's work will continue and conduct further research in the form of an detailed survey directed at different stakeholders from the participating countries. These include system operators, aggregators, regulators, and consumer associations. The aim of the survey is to extract knowledge and opinions on regarding the challenges and opportunities of flexibility markets related to operational planning from practitioners. Expected insights will revolve around the main barriers for increasing the use of local flexibility in the distribution systems, technologies and infrastructure that stakeholders are planning to use for measuring and verification, incentives for consumers and potentials to decrease costs for end consumers' flexibility provision, as well as regulatory barriers. The identified topics will be addressed in stakeholder interviews, to assess insights from international TSO and DSO perspectives. The findings will be analysed and presented in a separate report.

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# Appendix 1 - Detailed answers by country

## A 1. General market design

### A 1.1. Status and plans for renewable production

**Austria:**

- 100% electricity from renewable energy sources (national net balance) by 2030
- Carbon-neutral by 2040
- The potential associated with hydropower has already been largely realised. However, to reach these targets, an increase of 13% in hydropower (+5 TWh) by 2030 is planned.
- Planned increase of wind power plant (167%; +10 TWh) and PV power plant (786%; +11 TWh) capacity by 2030.
- The annual electricity generation from renewable energy is to be increased by 27 TWh by 2030 in total.

**Canada:**

- Net-zero electricity by 2035
- Net-zero energy by 2050
- Projections vary, but likely growth in hydro, PV, and wind
- Wind: 13.6 GW total, 93% transmission, 7% distribution connected
- PV: 2.9 GWac total, 67% centralized, 33% decentralized

**India:**

- India has total installed capacity of 405.77 GW and peak energy demand has increased to 203 GW in 2021-22 from 130 GW in 2011-12 (i.e., about 56.16% over the past decade). As of Aug 2022, more than 40.2% of India's installed electricity generation capacity is from Renewable Energy sources (RES). RE installed power has doubled in the past five years, enabling flexibility. India’s target is to achieve 500 GW RE installed capacity and sourcing 50% of energy requirement from renewables by 2030.
- As on 31.08.2022, the share of RES is 162.93 GW in which the solar installed capacity is 59.3 GW, which is 14.6% of the total installed capacity. India is leaping forward with faster adoption of renewables to achieve the RE target.

**Korea:**

- NDC update (’21.4): 40% reduction compared to 2018 by 2030 (4.17%/year)
- Carbon-neutral by 2050
- According to the 9th Long-Term Power Plan, the share of new and renewable energy generation in 2030 is 20.8%, and in 2034 is 26.3%.
- The share of new and renewable energy capacity in 2030 is 33.8%, and in 2034 is 40.9%. The new and renewable energy capacity in 2034 is below.

**Table A 1:** *Planned renewable energy capacity in Korea for 2034.*

| | PV | wind | hydroelectric | marine | bio | fuel cell | IGCC | Total |
|---|---|---|---|---|---|---|---|---|
| Rated capacity [MW] | 45,594 | 24,874 | 2,085 | 256 | 1,410 | 3,200 | 346 | 77,764 |

### A 1.2. What are the responsibilities of TSOs?

**Austria:**

The transmission system operators are responsible for **operating, maintaining** and **developing** the transmission system. In their role as Control Area Manager, the national TSO Austrian Power Grid (APG) is responsible **to ensure balanced power** in the associated control area to maintain a stable grid frequency. These short-term deviations are compensated for by power plants that supply FCR (frequency control reserve), aFRR (automatic frequency restoration reserve), and/or mFRR (manual frequency restoration reserve), and are activated by the TSO (in their role of the Control Area Manager). Moreover, bottlenecks arising from the outcome of the market, which does not consider transmission capacities within Austria and only to a limited amount cross-border, must be compensated for by additional use of mostly thermal power plants (coal or gas). These so-called "**redispatch**" measures are usually associated with high costs, which are to be avoided by grid expansion.

**Canada:**

Varies by province/territory. 8 of 10 provinces have a vertically integrated utility[4]. Other two provinces have independent system operators, which are responsible for market operation (incl. dispatch) of the power system and planning; these are separate from the transmission "wires-owners", which build and maintain their systems.

**India:**

Power system operation is a complex process and transmission system operations are more crucial as it is more multifaceted in the context of achieving overall economic efficiency, reliability, security, capability of dispatching economic generation, co-ordination with underlying utility etc. As electricity is a concurrent subject in India, TSOs do exist at central and state level too whereas DSOs are under the ambit of respective States. Carriage and content separation in India is not implemented for Distribution sector as yet but is on the cards for some time now. The transmission system operators are responsible for operating & maintaining the integrated National Grid. The national TSO - Power System Operation Corporation Limited (POSOCO) is responsible to ensure Integrated Operation of the Indian Power System to facilitate transfer of electric power within and across the regions and trans-national exchange of power with reliability, economy and sustainability. Additionally, they are also responsible for facilitating competitive and efficient wholesale electricity markets and administer settlement systems, promoting innovation and adoption of latest technology with cyber security.

**Korea:**

According to the structure of the electric power industry in Korea, there is no TSO, and it is composed of KEPCO (Korea electric power corporation), which owns the transmission and distribution network, and KPX, which operates the transmission system (ISO).

The duties of KPX as a system operator are as follows.

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[4] The traditional definition of a "vertically integrated" utility is one that owns all levels of the supply chain: generation, transmission and distribution.

KPX operates the necessary bulk power system to transmit the generated electricity to the load centers. The power system mainly consists of generators, transmission lines and substations, and distribution lines. To prevent overload and to maintain the system voltage at appropriate levels, KPX manages the transmission network operational planning in advance by analysing the power flow. In preparation for failures of power facilities or outages, KPX establishes contingency plans for reliable system operation by performing fault analysis, power flow calculation, stability analysis, and outage schedule adjustment. Together, they guarantee the secure operation of the transmission network. In case major transmission lines connected to a large generation complex experience a failure, all generating units in the complex may stop operating. In preparation for this scenario, appropriate countermeasures are established through stability analysis. By installing a control circuit that can immediately separate the faulty unit from the system, other generating units can sustain normal operating conditions.

KPX monitors and analyses the operations of all power facilities particularly those located in the metropolitan areas to secure the reliability of power supply.

- Formulating power restoration plans and countermeasures in case of faults in facilities
- Developing and applying restoration scenarios in case of changes in the power system
- Educating and training KPX staff and personnel of member companies
- Developing and applying innovative technologies

### A 1.3. What are the responsibilities of DSOs?

**Austria:**

In general, DSOs operate distribution grids ranging from 0.4kV to 110kV. The latter are connected to the TSOs' 220/380kV grids. The majority of the end-consumers are provided with electricity from the 230V/400V grids (low voltage grids; Niederspannungsnetz). DSOs have an obligation to publish general terms and conditions, and to enter into agreements with end users and producers, under these terms and conditions, while providing for their connection to the grid. Such general terms and conditions are subject to prior approval by the E-Control Commission (national regulator). The electricity laws of the Austrian federal states allow for the existence of area monopolies for electricity distribution grids. Therefore, a concession for this type of grid is only granted as long as no other distribution grid exists. The implementing laws of the federal states have to ensure that the distribution grid operator has the exclusive right to connect all end users and generators in the area covered by its concession.

**Canada:**

Varies by province/territory. 8 of 10 provinces have a vertically integrated utility (VIU), though in some cases towns/cities may be served by a municipally-owned distribution system company supplied by VIU. In market (non-VIU) systems, local distribution companies own and operate their distribution systems; however, they are often not permitted to own DG.

**India:**

Traditionally, the distribution system delivers power from the transmission grid to customers. Utility distribution companies/DSOs are responsible for maintaining safety and reliability of the system. India has vast distribution network which have grown as on need basis without any scientific study in most of the States/DSOs.

DSOs responsibilities are mostly local, such as managing branch congestions, under- and over-voltages and network service restoration after local outages by reconfiguring the network or, in the cases of longer interruptions. The local nature of distribution network problems requires finding feasible solutions within an enclosed geographical area. To do so, DSOs in near future, need to foster as market facilitators, to support the participation of all types of potential market actors in a non-discriminatory and transparent way.

DSOs evolving role will be required to coordinate the operation of distributed resources and micro-grids to maintain safety and reliability. So, in addition to the functions performed by the traditional distribution operator, the DSO role will be expanded by a new set of minimal responsibilities:

- Distributed generation reliability coordination
- Transmission-Distribution interface reliability coordination
- Energy transaction coordination

**Korea:**

KO does not have DSOs like those in the Europe and consists of ISO(KPX) and DNO(KEPCO).

However, DSO system is being introduced to establish a system for managing and supervising distributed power system in the region with the expansion of the distributed generators.

We plan to clarify the legal system, such as the Act on distribution network operation, and enact operating rules.

The concept and role of DSO in Korea are as follows.

| | |
|---|---|
| concept | An operator in charge of active control and dispatch of distributed generators connected to the distribution network |
| roles | - Efficient operating distribution network with ICT-based auto control & remote management<br>- Autonomous establishment and implementation of optimal dispatch schedules, operating plan of the distribution network in the region |

### A 1.4. For which assets and grid levels is observability in the distribution grid given?

**Austria:**

Observability is only given for the 110 kV grid or higher. There are no major congestions in the distribution grid so far. Research is performed on how the energy system will evolve in the future with volatile generation and increasing electrification as key drivers of change.

**Canada:**

In market (non-VIU) systems, system operator visibility is generally limited to the transmission system and transmission-connected assets.

**India:**

Traditionally most of the DSOs have limited observability up to 11KV/33KV feeders. (Limited to Voltage Level and current flow etc.). However, the Indian power sector is amidst a paradigm shift as it transitions towards a more distributed, consumer-centric, digitally enabled ecosystem by installing Smart prepaid meters for all consumers.

**Korea:**

Observability is only given for the 22.9kV grid or higher because SCADA(Supervisory Control and Data Acquisition) is currently installed above 22.9kV.

### A 1.5. To which extent is there a cooperation/interaction between TSO and DSO? What information is exchanged between TSO and DSO?

**Austria:**

Information exchange between DSO and TSO is conducted using the .csv file format in the observability area of the 110 kV grid.

**Canada:** In market (non-VIU) systems, TSO-DSO interaction is limited.

**India:**

Power system planning at large depends on the electricity industry structure of the country, their policy, law and regulations, economic growth, industry and business development, energy/load requirement, GDP, geographical locations, natural resources, planning and design criteria, planning standards, market, cross border policy with neighbouring countries, etc.

In small power system, planning can be done based on experiences and other conventional methodologies while in growing and highly mesh interconnected large grid, optimal planning necessitates the automation techniques with scientific approach that can provide set of good combination on which planners can further use other optimization and feasibility tools to extract the best candidates of transmission lines.

As distribution load forecasting is done on micro level /area by area to assess the area wise load, the uncertainties are always there in forecasting the accurate demand. Further, the non-availability of authentic data of existing system is also a big hinderance in actual demand prediction. Currently, there is lack of cooperation/interaction between TSO and DSO in India. However, considering continuous shift from fossil fuel to non-fossil fuel/renewable based generation (mainly solar & wind) to facilitate accelerated development of low carbon energy system, there will be an emerging need of collaboration/interaction between DSOs and TSOs. Further as Regulators are responsible for evaluation of the performance of Distribution company/DSOs, they have to take appropriate actions to push the distribution company/DSOs to take up the necessary network planning and co-ordination with TSOs for providing 24x7 reliable supply to all consumers.

**Korea:**

KO do not have DSO.

### A 1.6. What is the status of the smart meter rollout and what are the experiences concerning enhancement of flexibility applications?

**Austria:**

Smart meter rollout is a prerequisite for flexibility integration (but not yet for observability). The goal is to reach 95% before the end of 2024. However, this process is already delayed, with approx. 31% reached in 2020.

**Canada:**

Smart meters are widely deployed to all customer types across Canada although this roll-out has taken place over the last 10 years resulting in smart meters with different capabilities (i.e. old vs new). Generally, they are used for metering and, where DR is deployed, may be used for measurement and verification (recognizing there may be limitations). Control of DR resources typically achieved through other means, e.g., internet or wireless service connected to utility systems.

**India:**

Smart Meter is an essential part of Smart Grid and NSGM has been the key enabler in the deployment of Smart Metering/Advanced Metering Infrastructure (AMI) through Smart Grid Pilots all across India. As of Sep 2022, more than 5 million Smart Meters have been installed

in India and about 5.7 million meters are under installation as reported by stakeholders (REC, PFC, EESL, Utilities etc.) at NSGM (https://www.nsgm.gov.in/en/state-wise-map)
The increasing participation of RE in the Grid is necessitating flexibility of different nature (Power, Energy, Transfer Capacity and Voltage) in the Grid.
The adoption of Smart Grid technologies can facilitate flexible grid operation to accommodate intermittent and unpredictable renewable generation as well as consumer engagement thru Demand Response program for grid support functions. This adoption can be accelerated when all stakeholders of the ecosystem i.e. utilities, manufactures, standard making bodies and regulators have congruity of goal and strive to meet larger objective of reliable Clean power with Consumer Choice.

**Korea:**

The buyer (KEPCO) has been in the AMI distribution projects since 2010, and previously planned to supply 100% of AMI to 22.5 million (low-voltage customers) by 2020. However, only 48% had been disseminated as of Dec 2021 due to the delay, and the target of 100% by 2024 was reset.

### A 1.7. Who needs to send schedules in advance?

**Austria:**

At the moment, schedules (of planned electricity consumption) have to be only sent for plants larger than 50 MW and for significant grid users (SGU). Such comprise existing and new power generating facilities and demand facilities deemed significant by the TSO because of their impact on the transmission system in terms of the security of supply, including provision of ancillary services.

An open question is whether this will change in the future, and if smaller assets will also be obliged to send schedules. Currently, there's no "accuracy" for the fulfilment of the schedule.

**Canada:**

Cannot say with certainty, but generally it is not required for large loads to send their schedules in advance; however, scheduling may be used in some instances to secure day-ahead prices. (Large loads in Canada tend to be industrial, which are generally flat.)

**India:**

The Scheduling request of Collective Transaction in Real Time Market shall be submitted by the Power Exchange(s), to the National Load Dispatch Centre (NLDC).
Generators shall ensure that bidding in the Real Time Market is done taking into account their ramping constraints to facilitate proper scheduling of trades.
NLDC shall send the details (Scheduling Request of Collective Transaction in Real Time Market) to the concerned Regional Load Despatch Centers (RLDCs) after receipt of the same from the Power Exchange(s) accommodating them in their schedules.
Concerned RLDCs shall accommodate the Schedule of Collective Transactions in Real Time Market in the schedules of the respective Regional Entity's and inter-Regional Schedules.
RLDCs shall schedule the Collective Transaction at the periphery of the respective Regional Entities. RLDCs shall incorporate all buyers within a State (clubbed together as one group) and all sellers within a State (clubbed together as another group), in the schedules of the Collective Transactions in Real Time Market. The individual transactions for State Utilities/intra-State Entities shall be scheduled by the respective State Load Dispatch Centres (SLDCs). Power Exchange(s) shall send the detailed breakup of each point of injection and each point of drawl within the State to respective SLDCs.

**Korea:**

KPX operates the power market where sellers, power generating companies, and the single buyer (KEPCO) participate. All electricity, with the exception of some (ex. PPA), must be traded in power market. In the DA market, dispatchable traditional generators with a capacity of more than 20MW are bidding. There is no dispatchable DERs.

### A 1.8. Who takes the responsibility for deviations of the balancing responsible party?

**Austria:**

The responsibility of balancing the overall system lies with the TSO APG in their role as Control Area Manager, who balances the system through activation of the balancing reserve. The costs for this activation are charged to the originators, which are the balancing responsible parties.

**Canada:**

In Canada, we do not have balancing responsible parties, per se; however, the ISO/TSO of the province is responsible for balancing within that province and could perhaps be considered as the (sole) BRP.

**India:**

In the modern power systems, imbalances could be attributed to the factors such as, Forced/unplanned outage (Generation loss or load loss), Load forecast error, Forecast error of RES (Wind & Solar) generation, Extreme Weather Conditions/Abnormal Event and Difference between scheduled and actual generation.

Deviation of the frequency from the nominal value is a consequence of the above imbalances. This implies that in a given time block, the interchange schedule would never match the demand or supply perfectly – it would either be 'over-scheduled' or 'under scheduled'. Thus, the deviation of actual interchange from the interchange schedule are inevitable in a power system.

The responsibility of balancing the overall system lies with the POSOCO in their role as National Grid Operator, who balances the system through activation of the balancing reserve and price control by way of Deviation Settlement Mechanism.

The costs for this activation are charged to the originators, which are the balancing responsible parties and governed by the Deviation Settlement Mechanism Regulations, formulated by Central Electricity Regulatory Commission (CERC) at Central /federal level in India

**Korea:**

The responsibility of balancing the overall system lies with the ISO, KPX. Adjust the output of all the generators so that the generation cost is minimized throughout the changing demands. For the difference between the DA market and real-time operation, the opportunity cost is settled for the generator that supplied reserve power, and the cost is paid by the buyer (KEPCO)

### A 1.9. What are the major issues the electricity system faces?

**Austria:**

- **Security of supply:** Lack of (seasonal) storages/flexibility
- **Prevention of bottlenecks:** Higher transmission capacities/grid reinforcement or smart positioning of storages and usage of flexibilities is required due to higher volatility/production peaks caused by wind/solar.
- **Electrification of heating and mobility** could cause grid problems in the DSO grid: Limit grid entrances (maximum power) or adjust grid tariffs, to incentivise reducing power peaks.

- **Responsibilities of the DSO**: The European Electricity Directive (EU) 2019/944 states that the DSOs should be encouraged/incentivized to procure flexibility services, including congestion management in their areas, in order to improve efficiencies in the operation and development of the distribution system. DSOs barely activate any flexibilities for congestion management or voltage control. (Grid connection contracts that are only given under the condition that some assets can be curtailed to an agreed power. Interruptible tariffs are available for i.e., heat pumps. In emergency cases parts of the grid can be separated from the power supply.)
- **Lack of DSO-TSO interaction:** Possible future (high) concurrency factors when activating aggregated flexibility by the TSO. The DSO needs to have the possibility to constrain the TSO's flexibility activation. Load flow calculation with forecasts is done, if required, and a change of grid topology is sufficient in the DSO grid. Information exchange via .csv files between DSO and TSO in the observability area of the 110kV grid node. So far, the available capacity is sufficient, and flexibilities are considered as a worst-case scenario in the load flow calculations. However, new capacity calculation methods are required in the future.
- **Lacking observability in the distribution grid**: Capacity calculation and flexibility integration requires sufficient information from the flexible assets in the distribution grid, as well as the integration of transmission of live data into the DSOs' control system. Observability is only given for the 110 kV grid or higher.
- **Impact of local energy communities/flexibility markets** on the grid unknown: With an increasing share of distributed generation, an incentive for local consumption is to participate in local energy communities. At the moment, there is little knowledge on how the design of local energy communities effects the grid, therefore it is subject to change and lacks plannability for consumers.
- **Flexibility is not considered in DSOs' long-term planning:** Presently, DSOs are known to have a set-and-forget planning policy (planning of distribution grids based on worst-case scenarios and therefore oversizing the grids). With an increasing amount of distributed generation and consumption peaks from EVs, HPs etc., this could become uneconomical.
- How could DSOs include potential flexibility from the beginning of the planning process?

**<u>Canada:</u>**

- Planning for net-zero electricity 2035 and net-zero energy 2050. Achieving net-zero electricity is easier for some provinces (especially those with significant hydro resources) than others; however, upgrading systems required to accommodate electrification needed for 2050 will present large challenges to all systems (it is estimated that electrification will increase demand by 50% plus). In addition, the uncertainty related to when and where electrification efforts across sectors will occur.
- Capturing the potential from DER, which will require technical, market, and regulatory changes/upgrades. Given the different characteristics of utilities across Canada, this is a particular challenge as there is no one-size-fits-all solution. Differences include load compositions (e.g., some provinces are electricity heated vs currently natural gas in others) and VIU vs market-based structures.
- Planning of both transmission and distribution systems to take advantage of flexibility, in addition to operation coordination of such events.
- Climate change related impacts to resiliency
- Customer integration and supporting their new assets/systems (e.g. DG hosting capacity limits, electrified loads resulting in larger demands)

**India:**

- Efficient and reliable power infrastructure is one of the most important requisites for sustainable and inclusive economic growth in the country. As the GDP of a country grow, so will the demand for power.
- The two largest challenges facing the Indian power sector are fuel supply uncertainty and deteriorating distribution companies (discoms) finances.
- Considering dominance of coal in India's fuel mix, coal shortages can severely impede investments in the generation segment. Importing coal is not a viable long term option.
- Govt. of India has taken several initiatives for strengthening existing distribution system and financial turnaround of the DISCOMs/Utilities. These initiative aims to enhance reach and reliability of last mile grid and leveraging newer technologies to enhance efficiency of existing infrastructure. The journey started with establishment of IT infrastructure as part of RAPDRP & IPDS and has been enhanced with establishment of National Smart Grid Mission (NSGM).
- Government of India has launched a "Revamped Distribution Sector Scheme: A Reforms based Results linked scheme" in July 2021 with an outlay of ₹3,03,758 Crores and GBS of ₹97,631 Crores with the objective of improving quality and reliability of power supply to consumers through a financial sustainable and operationally efficient distribution sector. The Scheme aims to reduce the AT&C losses of pan-India level of 12-15% and ACS-ARR gap to zero by 2024-25 (**https://recIndia.nic.in/revamped-distribution-sector-scheme**).

**Korea:**

- The growing penetration of renewables is causing the frequency and size of Curtailment. In addition, as the system inertia decreases, the demand for flexible resources is increasing, but in the current situation where there is no AS market, the only solution is ESS.
- The problem of delays for grid connection is emerging due to the lack of grid assets. This happens because of the relatively long construction period compared to distributed resources and the problem of the acceptance of residents.

### A 1.10. Other important characteristics of the general energy system design?

**Austria:**

Network operation and energy trading are unbundled since 2003. Suppliers can join a balancing responsible party (BRP) and trade electricity at the markets but must not be owners of the grid at the same time. Consumers can therefore choose their supplier location independently, but the network operator is predetermined by their geographical location.

**India:**

In Indian power system, frequency is collectively controlled and democratically stabilized. All the 36 LDCs at state/UT levels with 6 LDCs at regional and national level are equitably responsible for maintaining grid parameters such as frequency, voltage etc. and contribute in integrated decentralized Indian power system operations.

Indian power system has moved from shortage situation to adequacy scenario in recent times. It has been observed, world-over, that during clean energy transition and especially during pandemic times, there have been certain bumps in the journey in terms of energy security, resource adequacy, market design, costs of compliance to standards and grid codes, market prices, ramping reserves, storage etc.

## A 2. Flexibility market design

### A 2.1. Which flexibility resources are already in the market?

**Austria:**

**Balancing reserve market participation**: In the research project Flex+[5], a boiler pool has been already prequalified for the balancing energy market in Austria, and the prequalification of battery storages and heat pumps has been discussed with the responsible TSO. Currently, the prequalification needs to be done separately for every manufacturer and every kind of device. In the project iWPP-Flex[6], the use of heat pump flexibility in the day-ahead electricity market and the tertiary control energy market was evaluated as economically positive for Austria, but only under the condition that the costs for ICT integration are low. The Austrian TSO APG is working on a common platform, where flexibility from distributed assets should be able to be offered at different markets.[7]

**Minimisation of imbalance settlement costs:** Further application possibilities are being investigated within the framework of various research projects. In the project EcoGrid EU[8], a dynamic, innovative 5-minute market was simulated, and the extent to which heat pumps and boilers respond dynamically to it was tested. It was shown that highly dynamic price fluctuations are difficult to control, especially if there is short-term feedback between price and flexibility (e.g. if the TSO specifies dynamic prices for the balancing energy costs for the next minutes). As the results show, ideally - at least in the first development step - the existing markets should be used for the integration of prosumer flexibility.

Industry: Larger industry sites are already participating at the balancing markets

**Canada:**

**VIU:** On the load side, peak shaving programs are commonly available to industry. Some provinces may also have similar programs for residential and commercial customers.

**Market-based systems**

- Market dispatch is conducted in 5-minute intervals
- Double-sided (supply and demand bids)
- Ontario: Demand response (DR) resources can participate directly in the markets through IESO's capacity auction or as dispatchable loads on the real-time market. Large customers (wholesale) may also be price responsive and reacting to energy costs (i.e., price responsive demand, PRD), though these are not formally recognized in a market mechanism as in some other regions. Very large customers, i.e., those with over 500 kW peak demand, may be eligible to participate in the Industrial Conservation Initiative (ICI), which allows them to pay their share of Global Adjustment (GA) costs based on their load coincident with the top five 12-month system peaks. GA covers the difference between payments for selected contracted or regulated generation (e.g., hydro, nuclear, and feed-in-tariff supported renewables) and conservation and related

[5] https://www.flexplus.at/news/deliverables/
[6] https://energieforschung.at/projekt/intelligentes-waermepumpen-pooling-als-virtueller-baustein-in-smart-grids-zur-flexibilisierung-des-energieeinsatzes/
[7] https://www.apg.at/projekte/stromausgleich-oesterreich/
[8] http://www.eu-ecogrid.net/

initiatives and that which would have been received from market revenues; it is applied to all customers in Ontario.

**India:**

Traditional system components either have limited flexibility to suppress extensive system variation, or their role is limited due to lack of proper regulatory provisions and inefficient market design. Large-scale integration of renewable energy (RE) resources (e.g., solar, wind) imposes additional variability and uncertainty to the existing system and thus enhances flexibility need. There are various solutions to the problem. Revamping system operation protocol with existing resources, retrofitting current power-generating assets, network expansion, etc. can provide flexible service. Investing in a new type of resources like energy storage and Demand Response (DR) however, needs aggressive policy interventions and market mechanisms.

As per Indian electricity grid code, ancillary services are services necessary to support power system or grid operation in maintaining power quality, reliability, and security of the grid. Ancillary services may include scheduling and dispatch, frequency regulation, voltage control, generation reserves etc. General classification of ancillary services is:

- Frequency Controlled Ancillary Services
- Network Controlled Ancillary Services

**Frequency controlled ancillary services:** These are used to maintain frequency within the desired range by balancing load and generation in real time. Three levels of control are generally used to achieve frequency controlled ancillary services:

a) Primary frequency control requires response period of 5-10 seconds,
b) Secondary response requires response period of 10 sec-10 minutes
c) Tertiary frequency control requires response period of 10-30 minutes.

**Network controlled ancillary services:** These are required to maintain network parameters within permissible range. They are further classified as:

a) Power flow control ancillary services: These are used to control the flow on interconnectors within the limits.
b) Voltage controlled Ancillary services: These are used to maintain system voltage within desired range, three levels of control are required for voltage controlled ancillary services – they are primary, secondary and tertiary voltage control.
c) System restart ancillary services: These help in restarting system post blackout situations. These are required to backup capacity of system and capacity required to return to normal operation after major or partial blackout. So, system restart ancillary services are the services reserved for contingency situations – in which there has been a whole or partial system blackout and the electrical system must be restarted.

**Korea:**

KPX is supplying operating reserve through conventional power plants such as LNG and thermal generators. ESS (Energy Storage System) is also providing flexibility, but the amount is not significant.

**A 2.2. What is the primary flexibility solution?**

**Austria:**

Conventional power plants, such as hydro, gas or CHPs are currently the main providers flexibility services to the TSO. For redispatch, mostly gas-fired power plants are used, and some large industry sites are also already providing balancing services.

**Canada:**

Generation – conventional hydro (where available), otherwise natural gas.

**India:**

Primary Reserve Ancillary Service (PRAS) means the Ancillary Service which immediately comes into service through governor action of the generator or through any other resource in the event of sudden change in frequency.

The primary frequency response is the first stage of the automated frequency control in a power system which restricts/limits the overall frequency deviation after a disturbance, bringing it to a nadir/zenith point.

Once the system frequency deviates from a predefined band, the primary frequency response would typically start within a few seconds from the start of the frequency event. The speed of response depends on the resource mix which is in operation at a point in time. The primary frequency response of a system is measured in MW/Hz.

**SRAS Provider:** A generating station or an entity having energy storage resource or an entity capable of providing demand response, on standalone or aggregated basis, shall be eligible as an Secondary Reserve Ancillary Service (SRAS) provider, if:

- Bi-directional communication system with RLDC;
- AGC-enabled, in case of a generating station;
- Can provide minimum response of 1 MW;
- has metering and SCADA telemetry in place for monitoring and measurement of energy delivered;
- Capable of responding to SRAS signal within 30 seconds and providing the entire SRAS within 15 minutes and sustaining at least for the next 30 minutes.

**Korea:**

Conventional power plants, such as LNG, coal generation and pumped storage are the main flexibility solution.

### A 2.3. Are there mechanisms to incentivize market participants to supply flexibility during system operation?

**Austria:**

**Local voltage problems:** There are **discounted tariffs for interruptible loads** (e.g., heat pumps) that are typically switched at fixed times or interrupt power purchases in the event of grid problems. Currently these do not consider current market prices or customer self-interest/comfort limits.

**Day-ahead market oriented prices:** On the other hand, there are **time-dependent tariffs** with flexible, often monthly prices, which allow consumption to be adjusted to the electricity price and thus create an incentive to reduce load during peak load periods and consume during periods of high production. For example, aWATTar is a pioneer in Austria for flexible tariffs and offers an hourly tariff based on hourly spot prices to customers with smart meters. However, there is no compensation for balancing energy and no marketing on an intraday basis yet. Moreover, suppliers are quite restrictive and there is currently no option to take two different suppliers and for instance a flexible tariff for the flexibility and another tariff for non-flexible loads. Two tariffs and two meters are possible according to some suppliers.

**Canada:**

Yes, in one province. See above questions on flex. Resources (price responsive demand, ICI, capacity market)

**India:**

- SRAS Provider shall be paid from the Deviation and Ancillary Service Pool Account, at the rate of their energy charge or compensation charge, as declared by the SRAS Provider, as the case may be, for the SRAS-Up MW quantum despatched for every 15 minutes time block.
- SRAS Provider shall pay back to the Deviation and Ancillary Service Pool Account, at the rate of their energy charge or compensation charge, as the case may be, for the SRAS-Down MW quantum despatched for every 15 minutes time block,
- Average of SRAS-Up and SRAS-Down MW data shall be calculated for every 15 minutes time block in MWh for every SRAS Provider by the Nodal Agency (POSOCO) using the archived SCADA data at the Nodal Agency and reconciled with the data received at control centre of the SRAS Provider and shall be used for payment of energy charge or compensation charge, as the case may be, to the SRAS Provider as per CERC Regulation.
- SRAS Provider shall be eligible for incentive based on performance. Performance of the SRAS Provider shall be measured by the Nodal Agency by comparing the actual response against the secondary control signals for SRAS-Up and SRAS-Down sent every 4 seconds to the control centre of the SRAS Provider measured using 5-minute average data.

**Korea:**

As of now, mechanisms to incentivize market participants to supply flexibility are not set up. However, in case of ancillary services, KPX is planning to establish a new reserve capacity value settlement amount to compensate the generator that has actually supplied the operating reserve.

### A 2.4. Are there any local flexibility markets in operation?

**Austria:**

In renewable energy communities (dt.: Erneuerbare Energiegemeinschaften, EEG) several members (e.g. households, municipalities or commercial enterprises) join together to share electricity. A PV system is mounted on one or several buildings and the participants can use and the self-produced electricity.

For the implementation of a renewable energy community, spatial proximity to the place of electricity production is important. Citizen energy communities (dt.: Bürgerenergiegemeinschaften) are a group of people or households seeking to benefit from joint electricity use. Spatial proximity to the place of electricity production is not mandatory in this model though. This allows, for instance even participants from different federal states. Certain flexibility markets, such as EEG direct marketing of PV and minimisation of balancing energy costs, as is the case in Germany, are not possible in Austria due to the subsidy and market design compared to other markets.

**Canada:**

No. Local energy communities do not exist in Canada. However, there is a pilot project run by the IESO, York Region NWA to capture flexibility from distribution resources for application to TSO/DSO systems.

**India:**

No local flexibility markets are in operation.

**Korea:**

No local flexibility markets are in operation. Currently, improving system flexibility is mainly discussed to utilize distributed energy resources.

### A 2.5. To which extent are the requirements for different flex applications harmonized?

**Austria:**

There are different prequalification requirements, timelines (GOT, GCT) and baseline requirements for the different flexibility services (FCR, aFRR, mFRR and redispatch). There are some discussions though, if the prequalification should be harmonized for a common flexibility platform.

**Canada:**

Operational and contingency reserve needs may be specified by the North American Electric Reliability Corporation (NERC) and their regional reliability coordinating council.

**India:**

No data

**Korea:**

Except for the traditional generator used for balancing, the only flexible resource is FR ESS now. Therefore, there is no need for harmonized application.

(KEPCO has installed ESS for frequency regulation since 2015 to prevent a sudden frequency drop due to a system failure of a large generator.)

### A 2.6. Do the flexibility concepts require schedules?

**Austria:**

Due to the short lead-times of FCR, aFRR and mFRR activation, no additional schedules must be sent. It is still in discussion whether every asset that wants to provide redispatch (including smaller assets that are not obliged to send schedules today) will be obliged to send schedules in the future.

**Canada:**

- Load flexibility does not require schedules: they are either dispatched by the operator, or self-dispatch.
- In the Ontario market, there is a day-ahead unit commitment process tied to the real-time market. In other VIU systems, typical supply unit commitment and dispatch processes are used.

**India:**

No, these services are always on standby and they kick in as and when required to support power system or grid operation in maintaining power quality, reliability and security of the grid. These services include- scheduling and dispatch, frequency regulation, voltage control, generation reserves etc

### A 2.7. How is the verification of the flex provision carried out?

**Austria:**

For balancing, the provider must make available the current status information concerning the activation status for the designated generation units to the TSO. In addition, the provider must transmit time-stamped measured values of frequency, operating point and actual generation of its pool by means of online transmission for monitoring purposes. Finally, the provider must also record and archive these values for the individual technical units in the pool itself and make them available to the TSO upon request. Further specifications can be found in the prequalification requirements.

In the project Industry4Redispatch (I4RD)[9], the verification process for redispatch is currently discussed. Preliminary results show that it will be necessary for all units that want to provide redispatch, to send schedules in advance to verify the provision.

**Korea:**

It is being confirmed through data acquired from SCADA system. (every 2 seconds)

**Canada:**

- The exact requirements differ by program and region and are specified by the system operator or utility.
- Small load verification (e.g., residential) may rely on smart meter and/or internet-connected devices.
- Aside, we have heard anecdotally that, in some cases, the penalties for not responding to load flexibility dispatches (DR events) was not high enough to encourage response to such calls.

### A 2.8. Is a capacity calculation conducted for the distribution grid as input for the TSOs flexibility activation?

**Austria:**

A load flow calculation with forecasts is performed. If required, a change of grid topology is sufficient in the DSO grid. So far, the available capacity is sufficient, and flexibilities are considered as a worst-case scenario in the load flow calculations. Maybe new capacity calculation methods are required in the future.

**Korea:**

A capacity calculation of flexible resources is not conducted.

[9] https://projekte.ffg.at/projekt/4151540

**Canada:**

Unknown. There is one TSO-DSO coordination pilot[10], ongoing that uses local shadow pricing.

**India:**

No

## A 3. Flexibility services for system operators:

### A 3.1. Status of TSO usage of flexibility services (e.g., frequency control by increasing or decreasing load or generation in the area served by a TSO to maintain system stability, congestion management by reducing peak loads at specific nodes in the transmission grid, …)

**Austria:**

In Austria, there are organised markets for primary, secondary, and tertiary control. A concept for redispatch provision from distributed assets is currently under discussion.

**Canada:**

System operators (VIU, ISO) commonly deploys generation and grid-scale batteries to meet operational and contingency reserve needs and other operational requirements (e.g., congestion)

**India:**

Power systems are designed and operated so as to withstand the sudden loss/connection of an identified quantum of generation/loads without posing a threat to frequency stability. The system inertia helps in controlling the immediate rate of change of frequency post an event. Inertial response and primary frequency response helps to limit the deviation in frequency before frequency is restored to steady state through despatch of secondary (automatic) and tertiary reserves (manual).

In case of inadequate inertial and primary response the frequency would continue to decline and could potentially lead to the loss of load through the triggering of automatic under frequency based load shedding scheme (AUFLS). Primary frequency response from thermal (210 MW and above), gas (50 MW and above), and hydro generating units (25 MW and above) is mandated in Indian Electricity Grid Code (IEGC)

### A 3.2. Status of DSO usage of flexibility services (e.g., variable grid tariffs, congestion management, voltage control, …)

**Austria:**

DSOs barely activate any flexibilities for congestion management or voltage control. Possibilities are:

[10] https://www.ieso.ca/en/Sector-Participants/Engagement-Initiatives/Engagements/IESO-York-Region-Non-Wires-Alternatives-Demonstration-Project

- Grid connection contracts that are only given under the condition, that some assets can be curtailed to an agreed power
- Interruptible tariffs for e.g. heat pumps
- In emergency cases parts of the grid can be separated from the power supply

In general, grid topology measures are always used first.

In the distribution network, flexibility is used for voltage regulation and to avoid bottlenecks. DIN EN 50160 defines the requirements for voltage maintenance in the distribution network. Therein, 10-minute intervals are used as typical periods to define the voltage quality. Critical network situations may also necessitate the use of longer time intervals.

**Canada:**

Use of distribution located resources is commonly only used for peak shaving (for economic or operational reasons).

**India:**

DSOs/ Distribution Company's do not use flexibility services as of now.

### A 3.3. What are the main flexibility resources that could be used by DSOs and TSOs in your country?

**Austria:**

**Generators:** In the analysis of the flexibility potential of generators, a distinction is made between thermal power plants (natural gas, biogas, biomass, waste incineration) and variable renewable generators (run-of-river power, photovoltaics, and wind power; Variable renewable generation, VRG) as well as (pumped) storage (see point below). While many flexibility options are only in their infancy, generators have historically taken a central role in providing the necessary system flexibility and will continue to play an important role in the future. The expected use of generators in the future provision of flexibility (i.e., 2030) was determined using energy market modelling.

(Pumped) storage power plants currently (2020) provide the greatest potential (positive and negative potential aggregated) and are treated separately below due to their storage character.

Among the pure producers in 2020, the greatest negative flexibility potential was in run-of-river and cascading hydropower, followed by wind power. At the same time, natural gas provided the greatest positive potential, which can also be used as negative flexibility.

Due to the planned shift to more renewable energies, the highest potentials in 2030 lies with volatile producers such as photovoltaics and wind power, although these are normally only available as negative flexibility via curtailment and when the corresponding resources are available. The potential of controllable producers, on the other hand, will decrease by 2030 due to the planned reduction of fossil fuels.

**(Pumped) Storage Power Plants:** In addition to import and export, storage hydropower is already a dominant flexibility option today. First, however, a distinction must be made between pure storage hydropower plants without pumps and pumped storage power plants. Austria operates both types of plants, which can provide flexibility through demand-based generation. In the future, an increase in installed capacity and storage capacity is expected.

According to the UBA-WAM/NEKP scenario an increase in the turbine capacity of (pumped) storage power plants from currently (2020) 8.8 GW to 10.8 GW (2030) is planned, as well as an increase in the pumping capacity from 4.2 GW to 5.5 GW.

**Import & Export:** Both today and in the future, cross-border electricity flows represent one of the most important flexibility options for balancing differences in generation and consumption. The prerequisite for cross-border electricity trading is the existence of a corresponding grid infrastructure. Transmission grid capacities with generators, consumers and storages located in other market areas can in principle be used as a flexibility option for the various markets or operations. The marginal net transfer capacities that can be used for trading (NTC) to all neighboring countries amounted to 9,100 MW (export) and 8,855 MW (import) in 2020.

To ensure a safe grid operation, they are significantly smaller than the thermal transmission capacity of the cross-border lines - but even these represent a theoretically available potential. The actual usable potential corresponds to 80% of the technical one since the n-1 security is considered. It should be mentioned here that the potential is subject to technical network and system restrictions (e.g. ring flows, consideration of capacities already allocated, simultaneity), which reduce the availability of cross-border capacities. Likewise, the existence of cross-border transport capacities does not mean that the required flexibility can be made available in the neighboring electricity markets at the specific point in time.

**Heat Pumps and Boilers:** Due to the efficient coupling of the heat and electricity sectors, heat pumps and electric boilers play an increasingly important role in providing flexibility, both in the household and commercial sectors. Especially for heat pumps, a large flexibility potential can be achieved through the different thermal storage options available (heating storage, hot water storage, and buildings). Activations are possible several times a day for several hours (depending on the season and building structure). For both heat pumps and boilers, a strong increase in technical potential is expected by 2030; for heat pumps by more than five times and for boilers by more than seven times. Heat pumps are already participating in the electricity market in some cases; with boilers, this is currently only the case within the framework of research projects.

**E-Mobility:** Apart from field tests and pilot applications within the framework of research projects, there is still no developed technical and thus no actual usable potential of flexibility of electric vehicles in 2020. The technical potential of flexibility is significant in 2030, but there are still technical challenges to exploit the flexibility. With the increased options of providing positive and negative flexibility through "vehicle-to-grid" services and "smart charging" in the future, the battery-electric mobility sector will also play a growing role in providing flexibility.

However, it must be noted that the flexibility potential of electric vehicles can only be used in pools and the used flexibility potential usually has to be recharged shortly after the flexibility use or the recharge will take place on the same day.

**Industry:** The potential of flexibility provision from industrial consumers results mainly from flexible self-generation plants and, to a large extent, also from consumers with large specific electricity consumption. In 2020, industry still offers a lot of unexploited potential, which is why this sector can play an important role in the provision of flexibility in the future.

However, a constraint regarding its calculability and reliability is that the production behavior of industrial companies, depending on the sector, only follows defined patterns to a limited extent. It is also heavily dependent on the economic situation and thus on capacity utilization. While the technical potential will remain almost the same until 2030 due to the long lifespan of industrial process plants, barriers must be removed in this period to be able to exploit the usable potential. For the modelling, only those potentials were explicitly selected that enable load shifting for at least one hour without risking a loss of production.

**Commerce:** Commercial sectors with high potential for providing flexibility are air conditioning and ventilation, data centers, food refrigeration, wastewater treatment plants, and water supply. The greatest potential in terms of power in the commercial sector is air conditioning and ventilation, but this is also the area with the greatest restrictions in terms of the duration and frequency of the calls (max. 1 h, max. 1x/day). The greatest increase in technical potential is expected in data centers. The greatest challenge in the commercial sector are the high-quality requirements for the applications. Here, automatic control must ensure that the requirements of the systems are always fulfilled. Therefore, in all sectors, the actual utilization of the potential already available is not expected until 2030.

**Hydrogen:** The production of hydrogen through electrolysis (power-to-gas) offers the electricity system both the flexibility to balance short-term load and generation fluctuations and to shift energy seasonally, since hydrogen, unlike electricity, can be stored over a longer time.

A seasonally focused generation of hydrogen would mean significantly increased installed capacities and investment costs. At the moment, there are no large-scale power-to-gas applications and infrastructure in Austria. For the year 2030, it is assumed that hydrogen will play a larger role in the electricity system. Therefore, the Austrian NEKP (National Energy and Climate Plan) mentions an electricity consumption for hydrogen production (conversion input) of 1.18 TWh[11].

**Batteries:** In general, we distinguish between home storage systems and large-scale batteries. The development of flexibility supply in this sector depends very much on future economic incentives, but the provision would be technically feasible. In particular, the provision of system services, such as frequency control reserve and possibly faster balancing reserve products in the future, can be attractive for large batteries. Due to the current regulatory framework, large-scale use of battery storage to support the distribution grid is unlikely by 2030. However, they could very well be used in individual niche applications for temporary grid support.

**<u>Canada:</u>**

- Generation: reservoir hydro, natural gas, dispatchable VREs
- Storage: reservoir hydro, utility-scale batteries. (Canada also has 2 or 3 operational pumped hydro storage facilities)
- Loads: transmission-connected industry loads, distribution-connected loads

**<u>India:</u>**

- Generating station (Thermal/Gas/Hydro)
- Entities having energy storage resources (Battery storage/Pumped Hydro storage)
- Entities capable of providing demand response (DISCOMs/Aggregators)

**<u>Korea:</u>**

[11] Source: Umweltbundesamt, 2019. *WAM NEKP Scenario.*

No Data.

### A 3.4. Which are/could be the main distribution grid applications for flexibility in your country?

**Austria:**

The greatest challenge for distribution grid applications identified in Austria is the increasing penetration of decentralized generators and new consumers in the distribution grid, and the associated, increasing operation of this grid level at the technical limits. Regarding the use of flexibility in the distribution grid, the following findings and recommendations can be stated based on national and international experience:

1. A measurement-based recording of the real grid situation makes it possible to deviate from worst-case assumptions in grid planning. Through the continuous monitoring of the real grid situations, both expanded reserves/capacities can be made usable and critical grid areas can be pointed out and identified. For the low-voltage grid, the effort for this monitoring is significantly higher due to the greater line lengths, number of resources, customers, and nodes.
2. Grid topological measures (e.g., switching state, tap changers) are a very efficient solution in the high and medium voltage grid (e.g., temporary, or permanent ring closures). It is expected that this will be increasingly possible in the future, as more and more grid operators also fully integrate the medium-voltage grids into their control systems. With a higher degree of automation and integration into control systems, switchovers in the grid can be carried out more easily. In the low-voltage grid, however, these measures are very difficult to implement, as these are operated as radial systems and the effort for the automating is much higher.
3. The studies on innovative grid components, such as controllable local grid transformers and line controllers, show a great potential to increase the absorption capacity of low-voltage grids in a cost-efficient way. For this reason, they must be considered as alternatives in grid planning processes.
4. The coordinated operation of consumers (e.g., charging of electric vehicles) and generators (e.g., PV) together with storage systems also has great potential for avoiding generation or load peaks. Whether such measures can be used in grid planning depends on whether they also function reliably in practice and how correct regulation is identified and implemented.
5. Measures defined in grid connection requirements or in grid codes (e.g., technical rules for generators in Austria) such as reactive power provision and voltage-controlled active line control are suitable measures for increasing the absorption capacity of existing grid infrastructure. The implementation of a 70 % curtailment (e.g., Germany) should be considered or discussed in Austria. The power is limited to 70%, but this only entails a small energy loss of max. 3%.
6. Measures covered by the grid tariff, such as interruptible supply (e.g., heat pump tariff), continue to be a very suitable option for avoiding short-term bottlenecks. Interruptible supply allows load shifting in the event of capacity bottlenecks.
7. With the further development of grid control systems, the use of market-based flexibility analogous to existing products in the transmission grid may be possible on the high-voltage level. In the medium and low-voltage grid, market-based flexibility can only be used to a very limited extent, as capacity bottlenecks occur very locally and only a few grid users can be considered as potential flexibility providers.

In general, it must be noted that the economic evaluation of the solutions in the low-voltage grid is very sensitive to the assumptions regarding the running costs (OPEX) of the solutions. The actual operational costs will only become known with the experience gained from a wider deployment of the solutions. Therefore, in network planning, very conservative OPEX assumptions are made for new technologies (i.e. more towards the upper end of the possible costs). In any case, the solutions must be simple and very robust (keyword maintenance effort).

**Canada:**

- As non-wires alternatives for differing distribution system capital investments to accommodate growth and electrification.
- Increasing prosumer participation and DER
- Maintaining/increasing reliability and resiliency
- Support economic adoption of electrified loads like heat pumps and electric vehicles

**India:**

N.A.

**Korea:**

There is no Ancillary Service market in Korea. However, at the end of next year, ancillary service market in 15 minute granularity will be established so that reserves can be traded as products in the market.