Paris Session 2022

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TSO-DSO Cooperation
Control Centre Tools Requirements

Study Committee C2 – Power System Operation and Control

Tutorial / Workshop for CIGRE session 2021 Date, Time

Prepared by
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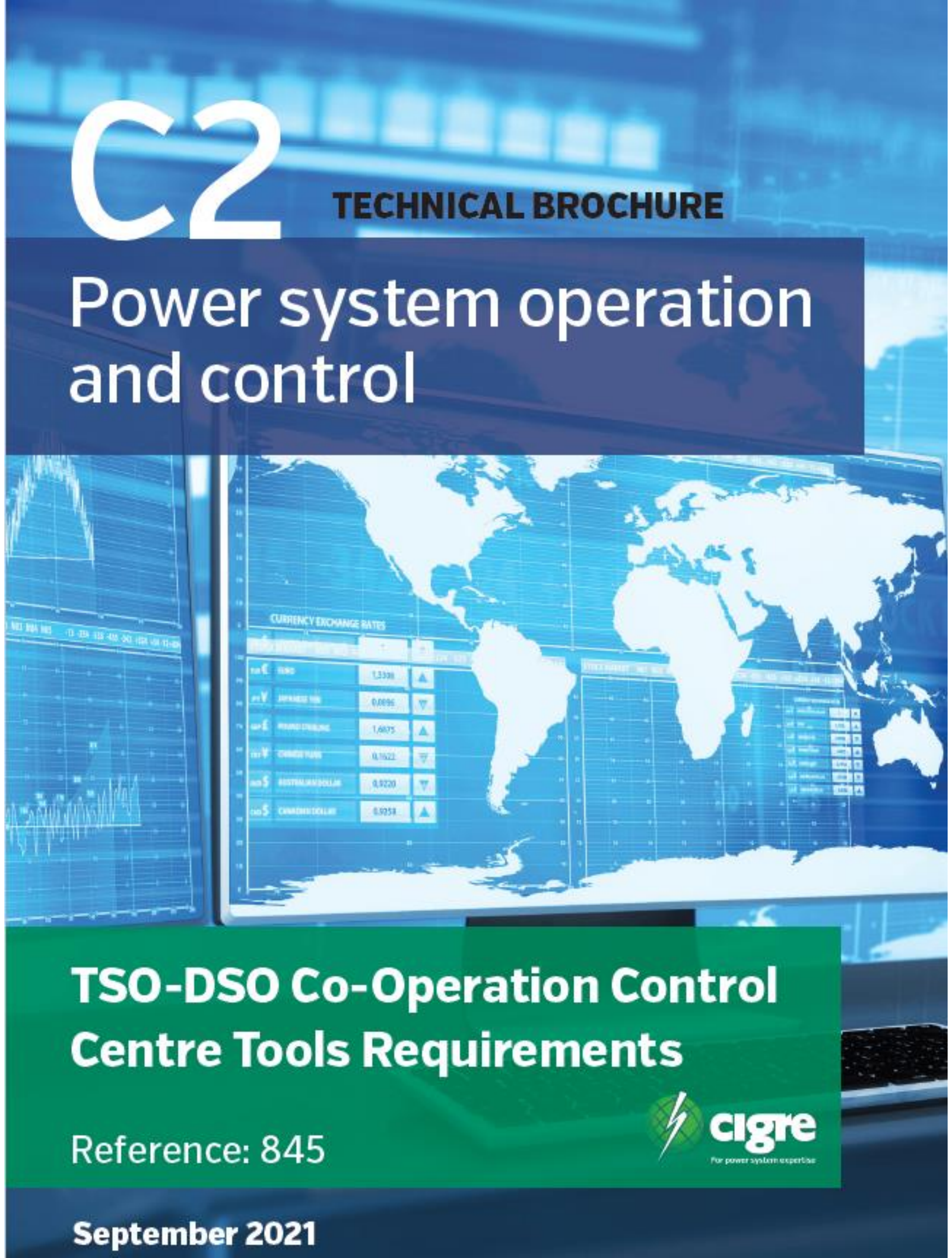
01 September 2022

SC C2 Tutorial

TSO-DSO Co-Operation – Control Centre Tools Requirements

- ✓Speakers – Michael Power and Tony Hearne (C6)
- ✓WG C2.40
- ✓Technical brochure 845 – published September 2021



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WG C2.40

TSO-DSO Co-Operation – Control Centre Tools Requirements

- ✓Convenor: Michael Power
- ✓Secretary: Jim Reilly
- ✓23 members from 12 countries

Aim of Technical Brochure

Identify the challenges for transmission and distribution system operators in managing networks with high penetrations of Distributed Energy Resources (DERs) and suggest tools that can be used in control centres to effectively address the challenges.

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Technical Brochure Outline

The technical brochure contains 5 chapters as follows:

Chapter 1 - Introduction

Chapter 2 - Operational Challenges

Chapter 3 - Data and Information Exchange

Chapter 4 - Tools (Six are discussed)

Chapter 5 - Conclusions and the future

Three appendices are also included.

Chapter 1 - Introduction

Chapter 1 - Introduction

Scene Setting / 1 of 2

The traditional electricity network has changed. These changes include but are not limited to:

- ✓Connection of vast numbers of DERs
- ✓Electrification of heat and transport
- ✓Consumers producing their own electricity
- ✓New technology is giving consumers more control over how they use electricity
- ✓Energy storage technology is rapidly improving and is growing accordingly
- ✓New rules, agreements and codes

Chapter 1 - Introduction

Scene Setting / 2 of 2

- ✓To effectively manage this changing landscape, in particular the high number of DERs, requires extensive TSO and DSO co-ordination including increased information and data exchange.

- ✓Importantly, it should always be remembered that the DSO never has full visibility of its network.

Chapter 2 – Operational Challenges

Chapter 2

Operational Challenges

Significant operational challenges include:

- ✓System balancing
- ✓Congestion and Constraint Management
- ✓Voltage Control
- ✓Controllability and Observability
- ✓Forecasting
- ✓Restoration and Blackstart

Chapter 2

Common TSO and DSO Tools and Approaches

Generic Requirements:

- A generic set of technical requirements for control centre tools for TSO-DSO co-operation are needed to effectively integrate DER services on the grid.

Assumptions and Pre-requisites:

- The TSO and DSO maintain separate electrical models of the networks under their respective control.
- The level and type of data exchange, real-time and off-line, as agreed between TSO and DSO are in place.
- The TSO and DSO each have sufficient observability of the networks under their respective control, to discharge their statutory functions.
- The TSO and DSO have some observability of each other’s network.

Chapter 2

Common TSO and DSO Tools and Approaches

TSO-DSO Required Interaction:

- Procurement and use by the DSO, of flexibility from distribution connected customers, singly or through Aggregators.
- Any material impacts of such DSO use of flexibility on TSO balancing and frequency management functions.
- Procurement and use by the TSO, of flexibility and/or System Services from customers connected to distribution level, singly or through Aggregators.
- Any material impacts, such as congestion, attributable to the TSO use of flexibility and/or System Services by the TSO, on DSO network operation functions require coordination between TSO and DSO.
- Application of agreed rule-sets to handle conflicts and priorities, where there are co-incident TSO and DSO requirements to use the same distribution connected resource(s).

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Chapter 2

Common TSO and DSO Tools and Approaches

High Level Tool Design Principles:

- Maintain Neutral Market facilitation by DSOs
- Maintain Transparent Market Operation by TSOs
- Allow maximum access to market parties considering the laws of physics and the technical nature of the offered products
- Comply with clear, transparent and Regulatory Authority (RA) approved rulesets to deal with conflicts, where they arise.

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Chapter 2

Common TSO and DSO Tools and Approaches

Vital elements of coordination include:

- The establishment of rules-sets and priorities for market access, where over-subscription arises
- The establishment of rules-sets and priorities for access to finite network capacity, where over-subscription arises
- The ability to anticipate or forecast and quickly identify and resolve any such conflicts

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Chapter 3 – Data and Information Exchange

Chapter 3

Data and Information Exchange

- ✓The coordination of the transmission and distribution systems, and especially the provision of ancillary services from distribution resources, requires close co-operation and exchange of information between all parties involved i.e., TSOs, DSOs, DER/Aggregators and market operators.

- ✓In many regions, TSOs have limited to no established interfaces with DSOs. Furthermore, increased distributed energy will require new information exchange that is not readily established today.

Chapter 3

Data Exchange Categories

The information exchange between TSO and DSO can be categorized in three main categories of data:

- Structural Data Exchange: Structural data include all the general and permanent information of the assets: characteristics, attributes, capabilities, etc. Structural data are necessary to prepare static and dynamic models of the facilities used to carry out static and dynamic security analysis.

- Scheduled Data Exchange: Scheduled information represents the expected functioning of the different elements of the System in the future. Combined with structural data it enables the preparation of a scenario for expected situation of the system in a specific moment in the future to perform Security Analysis for that timeframe.

- Real Time Data Exchange: Real-time data exchanges for TSO include telemetry measurements or calculated (estimated) values for: active and reactive powers busbar voltages and frequency.

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Chapter 3

Structural Data Exchange

Structural data exchange between DSO and TSO is generally not yet systematically standardized or regulated globally. In Europe, DSOs with a connection point to a transmission system shall be entitled to receive the relevant structural, scheduled and real-time information from the relevant TSOs [SOGL 40(10)].

DSO structural data provision for TSO

✓Grid models (physics of network elements such as lines, transformers, busbars, switch bays, compensators, FACTS, etc.)

✓Grid topology, connectivity of grid elements.

✓Operational monitoring limits for the grid elements; PATL (Permanent Admissible Thermal Limit), TATL (Transitory Admissible Thermal Limit), tripping current, maximum and minimum acceptable voltages

TSO structural data provision for DSO

✓Structural data set of transmission grid to implement and maintain an observability area

✓Alternatively, a static grid equivalent model to enable DSO to perform security analysis calculations

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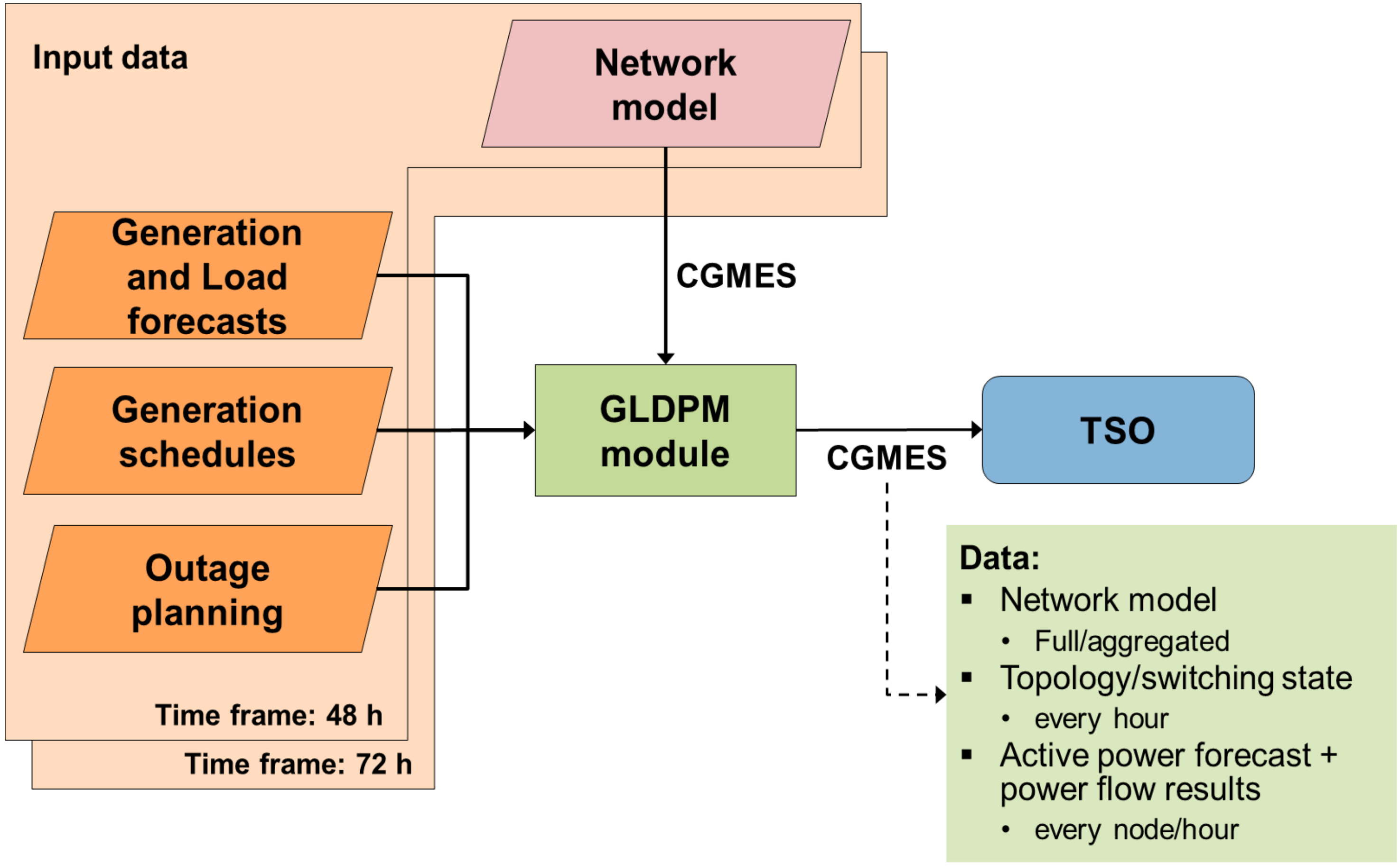
Chapter 3

GLDPM (Generation & Load Data Provisioning Methodology) with Data Sources



✓The TSO Initiative at European level (ENTSO-E) has also proposed a methodology for a process to facilitate the data exchange between DSO and TSO, so called GLDPM (Generation & Load Data Provisioning Methodology).

✓GLDPM sets out requirements with respect to the delivery of the generation and load data, to enable coordination and harmonization of capacity calculation and allocation in the long-term cross-zonal markets in Europe. To facilitate these aims the TSOs create a common grid model (based on CIM) on European level.

Chapter 3

Schedule Data Exchange

The coordinated exchange of schedule data from the DSO to the TSO shall enable the TSO and DSO to represent the forecast of its transmission system conditions in order to meet its operational needs. ISOs / RSCs again will use TSO schedule data to forecast active and reactive power flow and voltage profiles across TSO boundaries.

Possible DSO Schedule data for TSO

- ✓Forecast Generation and Load Flow at TSO/DSO Grid Connection points, aggregated forecast by each type of renewable and flexible generation (Wind, PV, Thermal)
- ✓Planned Outages including the outage of network assets but also the outage of the Significant Grid Users (SGU) connected to distribution system
- ✓Forecast operational topological situation at TSO/DSO interface and in the observability area. Network configuration in the high voltage network (110kV) with impact on the load flows in the transmission grid.

Possible TSO Schedule data for DSO

- ✓DSOs with a connection point to a transmission system shall be entitled to receive the relevant structural, scheduled and real-time information from the relevant TSOs. [SOGL 40(10)]
- ✓Planned Outages
- ✓Forecast Short Circuit Power
- ✓Forecast voltage level at TSO/DSO boundaries interface
- ✓Expected transit boundaries at TSO/DSO interface

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Chapter 3

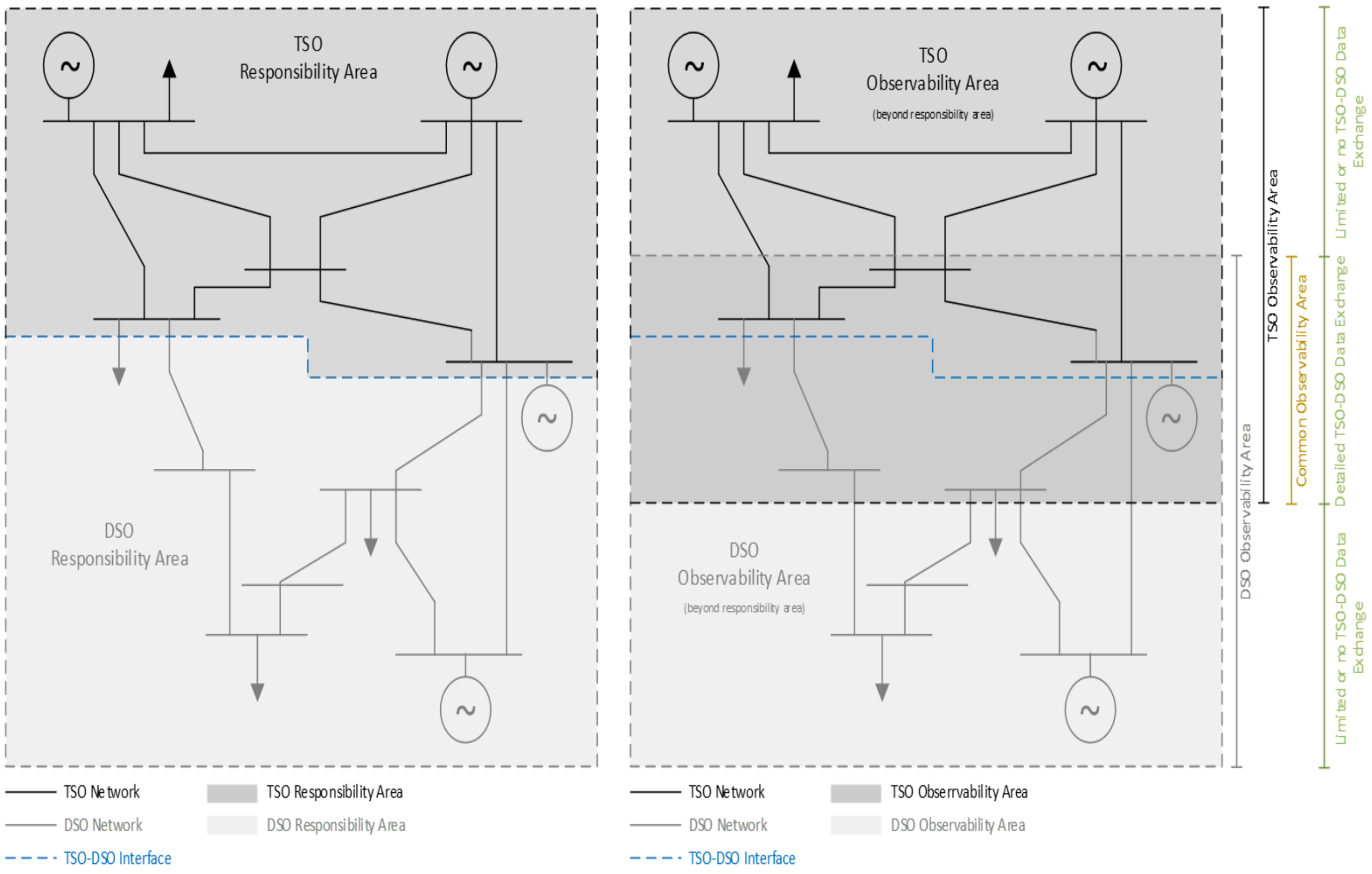
Real-time Data Exchange

- ✓In order to gain observability into neighbouring energy grids and to perform real time security analysis, real-time data exchange between neighbouring TSO and between TSO and DSO is required in addition to structural and scheduled data exchange.

- ✓The most common standard for real time data exchange, if mutually agreed between TSOs or DSOs, is ICCP (Inter Control Centre Protocol) or also TASE 2 (IEC 60870-6).

Chapter 3

Observability



Each system operator is responsible for its own grid, also called ‘responsibility area’. To operate this grid properly, it is important to also know what is happening in part of the surrounding grids. The responsibility area together with this part of surrounding grids that can affect the responsibility area is called the ‘observability area’.

This means that defining adequate observability areas for both TSOs and DSOs implies exchanging structural data with each other about their own networks. The concept is illustrated here and is based on a Portuguese example.

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Chapter 3

Co-ordination Architectures

DSO Centric

In the **first approach**, the control and monitoring of the DER connected to the distribution system is managed by the DSO.

TSO Centric

In a **second approach**, the activation of flexibilities of DER connected to distribution system is managed by the TSO. Due to the high number of DER that can be connected in distribution systems, the TSO can have several Geographical Control Centres (GCC) assuring a better coordination between local resources.

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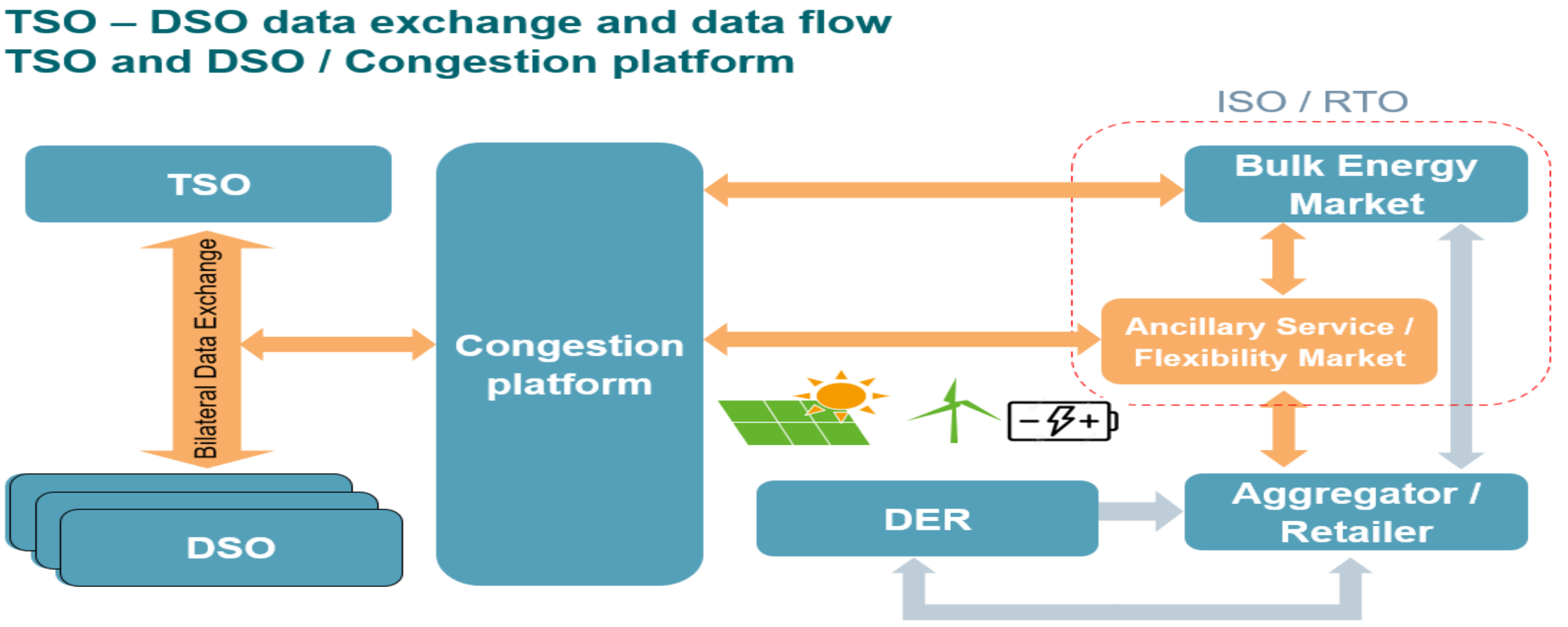
Chapter 3

Co-ordination Architectures - TSO / DSO Congestion Platform (GoPacs)

In a **third approach**, the activation of flexibilities of DER connected to distribution system is managed by TSO or DSO through a congestion platform. The congestion platform provides a collaborative approach in managing congestion and frequency balancing for the TSO and DSO.



Chapter 4 - Tools

Chapter 4

Introduction to Congestion and Constraint Management / 1 of 2

Transmission constraint and congestion concepts:

- ✓ The term “transmission constraint” may refer to an element of the transmission system that limits power flows.
- ✓ Transmission constraints are set at a specific level or limit in order to comply with reliability rules and standards established to ensure that the grid is operated in a safe and secure manner.
- ✓ Transmission constraints can be relieved by increasing the electrical rating of an element, increasing the operating limit, or adding new equipment that increases transmission capacity to deliver additional electricity.

https://www.energy.gov/sites/default/files/2014/02/f7/TransConstraintsCongestion-01-23-2014%20.pdf

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Chapter 4

Introduction to Congestion and Constraint Management 2 of 2

Transmission constraint and congestion concepts:

- ✓The term “congestion” refers to situations when transmission constraints limit transmission flows or throughput are below levels desired by market participants (e.g., to comply with reliability rules).
- ✓A high level of transmission system utilization alone does not necessarily mean congestion is occurring.
- ✓Congestion can only arise when there is a desire to increase throughput across a transmission path, but such higher utilization is thwarted by one or more constraints. Transmission congestion has costs.

https://www.energy.gov/sites/default/files/2014/02/f7/TransConstraintsCongestion-01-23-2014%20.pdf

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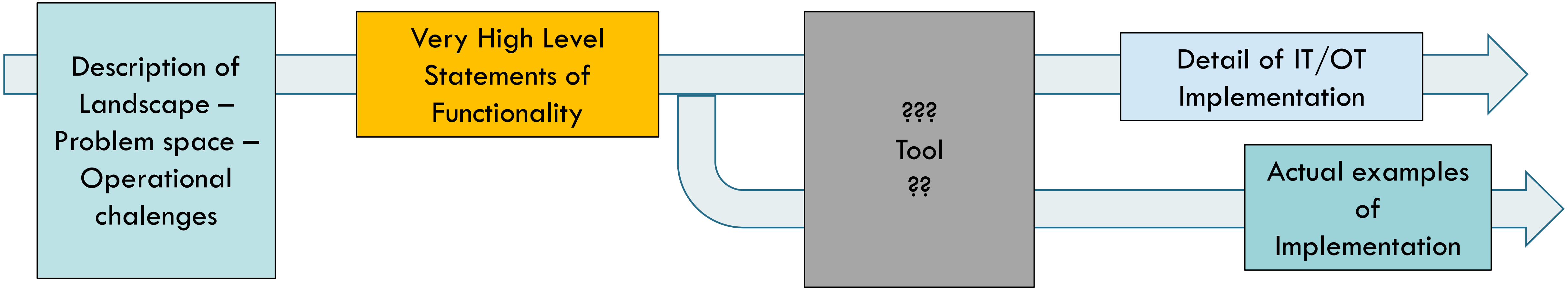
What is a Tool?

1. Much debate about this!
2. Eventual conclusion:



Chapter 4

Tool #1 – Congestion Management

The first tool outlined is a Congestion Platform where the DSO receives proposed flexibility activations from the Flexibility Service Providers (FSP) and runs power flow analysis to determine if congestion is predicted, based on the proposed activations. Where the DSO congestion platform identifies that the proposed flexibility activations will create congestion, then it must apply an agreed set of rules to ensure that a reduced set of activations is presented back to the FSP.

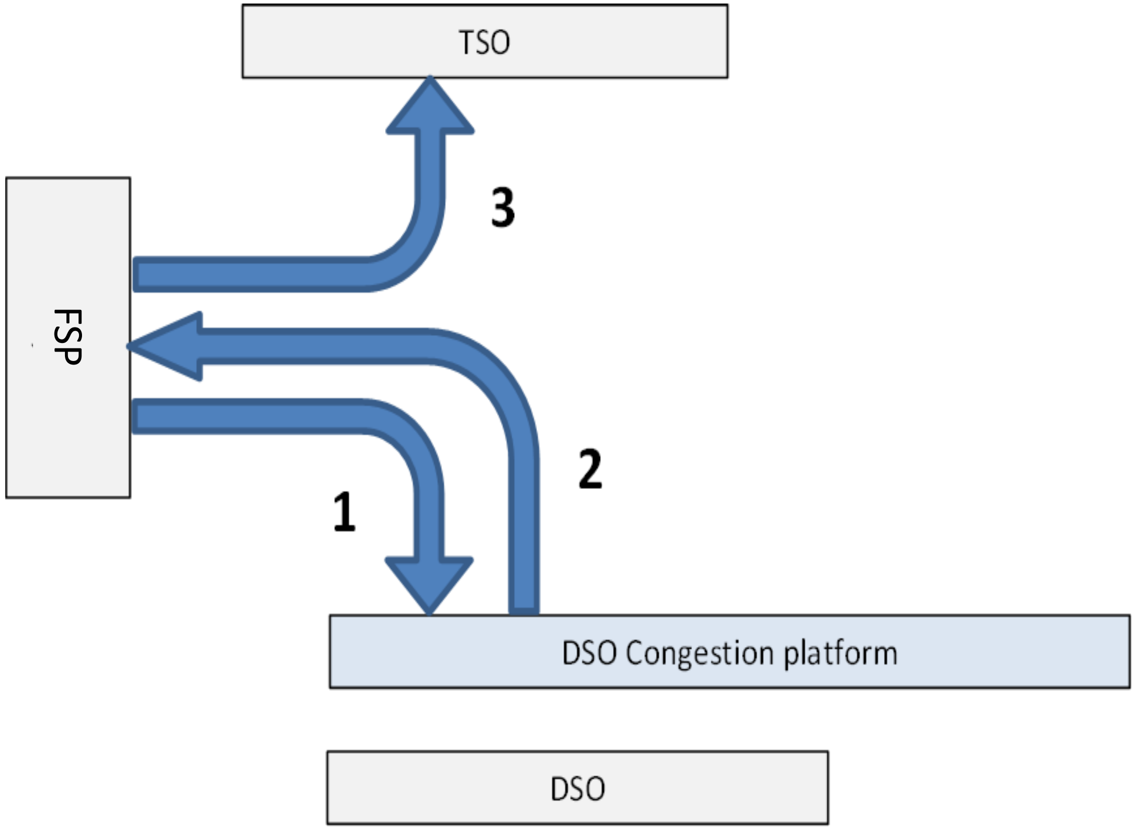
Chapter 4

Tool #1 – Congestion Management

Three variants on coordination tools for Congestion Management are proposed.

1. An Iterative Approach
2. A Capacities (or Traffic Lights) Broadcast approach
3. Automated Approach

Congestion Management Tool: Iterative Approach



In step 1, the proposed flexibility activations are made visible to the DSO. Using a Congestion Management Platform studies are conducted to determine and quantify any congestions attributable to the activations.

In step 2, for a given period of time ahead, the DSO would either return the proposed activations as permitted or, where necessary, would apply a rule-set and advise a reduced set of activations.

In step 3, the FSP would then enter the “net” bids to the market.

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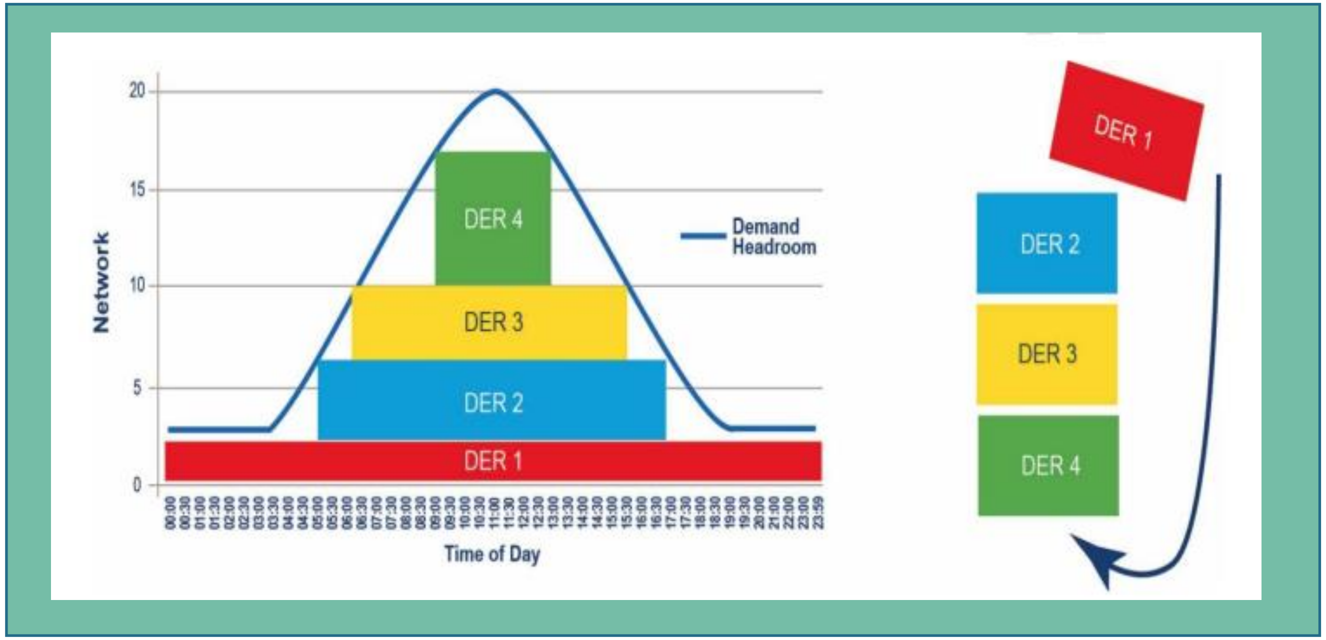
Congestion Management Tool: Iterative Approach Example

Step 2: For a given period of time ahead, the DSO would either return the proposed activations as permitted or, where necessary, would apply a **rule-set…**

- Last in First Out (LIFO)
- Cost
- Equal Distribution
- Round Robin
- Etc.



Chapter 4

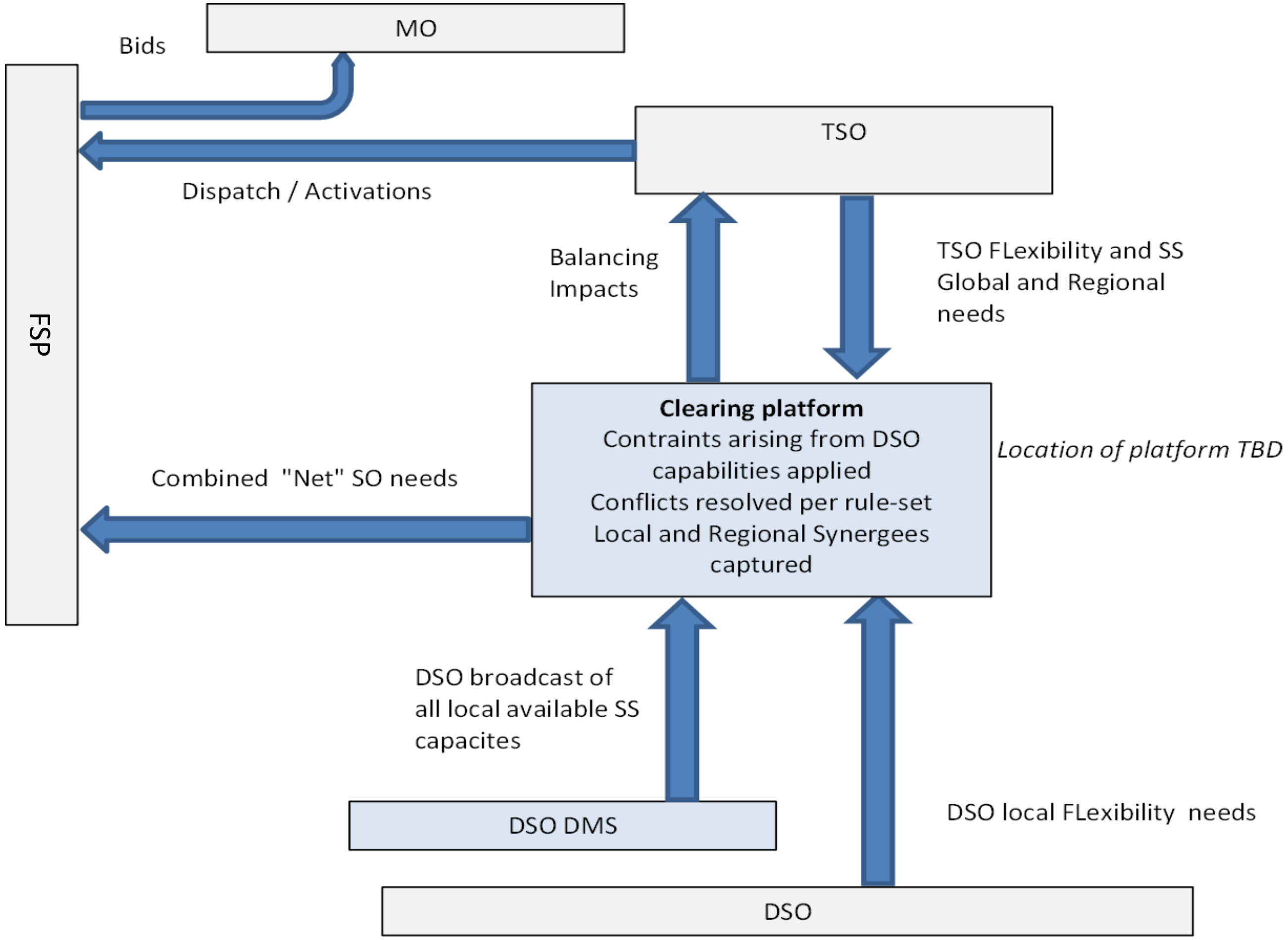
Tool #2 – Capacities Approach

The second tool is a Clearing Platform for Network Constraints on the Transmission/Distribution Networks.

It receives global and regional flexibility needs from the TSO and local flexibility needs from the DSO.

Within the clearing platform any network constraints specified by the TSO and DSO are applied and a “net” set of flexibility requirements is relayed to the FSP, taking into account conflicts between competing TSO and DSO requirements and synergies between local, regional and global requirements.

Congestion Management Tool: Capacities Approach



The DSO, potentially using its distribution management system (DMS) – or an advanced Distribution Energy Management System (DERMS), effectively broadcasts a set of available locational "capacities" or "headroom". Similar to the DSO congestion platform, this is achieved through power flow analysis and is required over various timelines.

The locational "capacities" are passed into a "Clearing Platform", which receives:

- Global and regional flexibility needs from the TSO.

- Local flexibility needs from the DSO.

Within this engine:

- Any network constraints arising from application of all the requirements are applied.

- Conflicts between competing requirements are resolved per pre-agreed rule-sets.

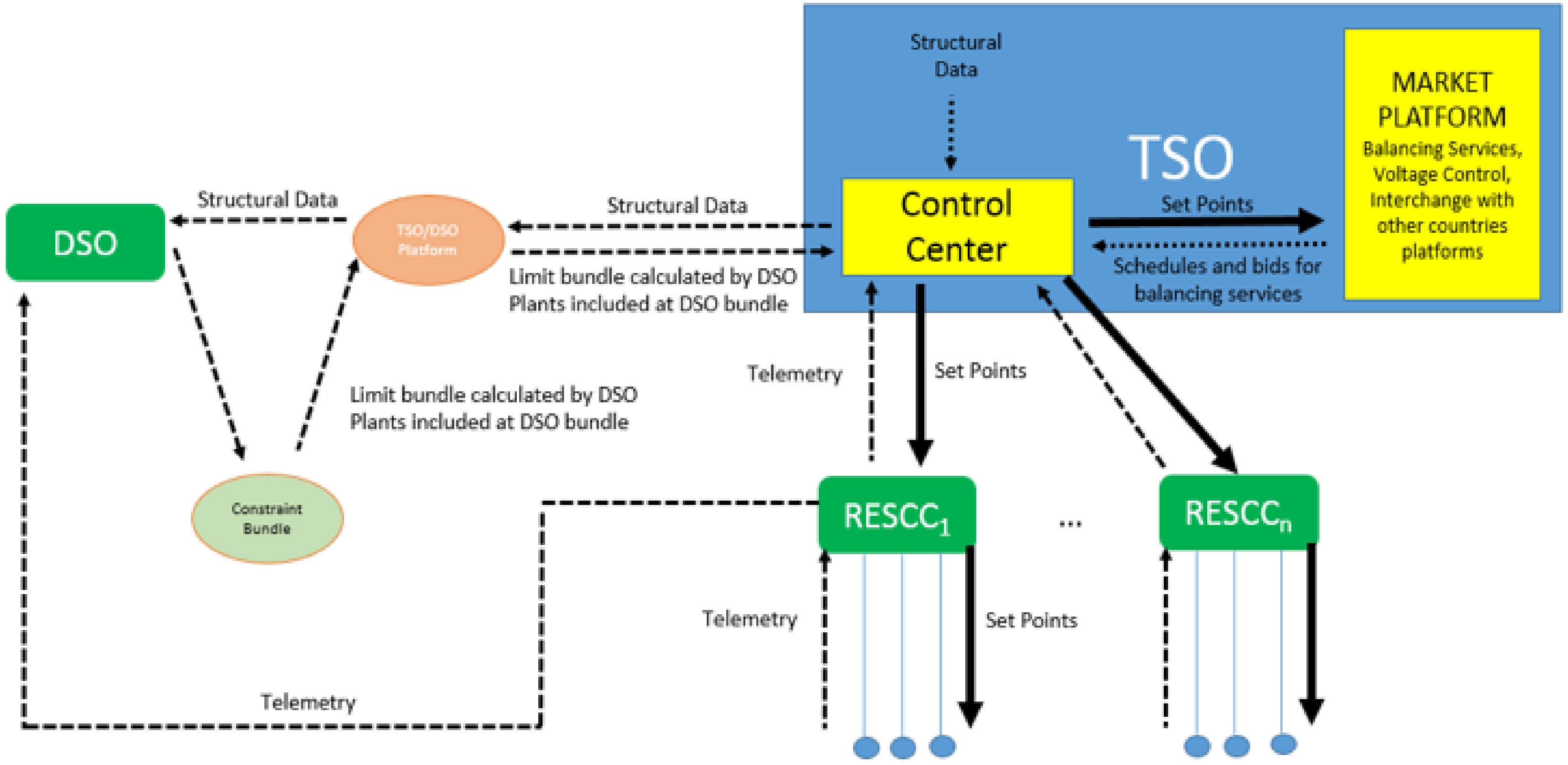
- Synergies between local, regional and global requirements are captured.

- Balancing impacts identified are relayed to the TSO.

The result is a "net" set of flexibility requirements which is relayed to the FSP. This approach has the advantage of avoiding iterations and is computationally appealing.

Chapter 4

TSO Constraint management tool - scheme for interchange communication



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Chapter 4

Tool #3 - Voltage Support

- ✓The third tool is a Voltage Support tool which provides optimal coordination of reactive power exchanges between the TSO and DSO, using the capabilities of the distribution system to support the voltage on the transmission system.
- ✓This is achieved via four executable steps which achieve optimal reactive power or voltage set points at the boundary points between the transmission and distribution networks, known as Points of Interconnection (PoI).

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Chapter 4

Tool #3 - Voltage Support

The main objective of a joint tool for voltage control and reactive power management is the optimal coordination of the reactive power exchanges between the TSO and DSO, using the capabilities of the distribution system to support voltage control in transmission systems. From this, the following general requirements for such a tool are:

- ✓ Reactive power capability assessments of the DSO and TSO networks.
- ✓ Coordination between the DSO and TSO considering constraints and sources on the system.
- ✓ Applicability across real-time and operational planning time horizons.
- ✓ Optimal control of reactive power source (RPS) in power systems.
- ✓ Knowledge and exchange of all required information to control the voltage in different parts of the system optimally.
- ✓ Focus on global system benefits, not individual owner/operator interests.

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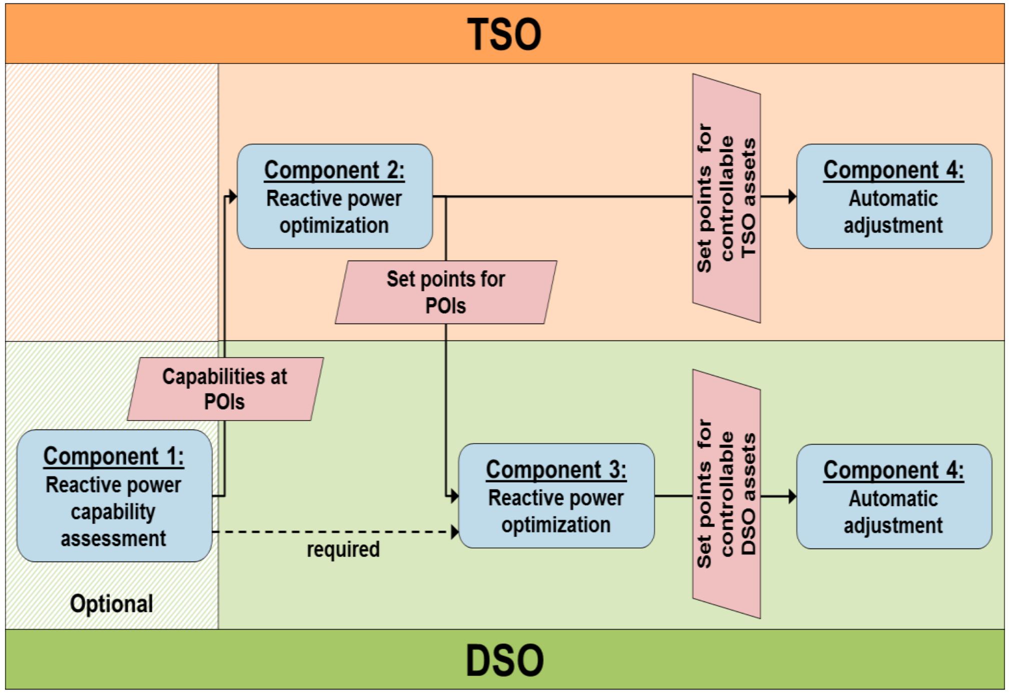
Voltage Support Tool

Tool objective: Deliver the optimal coordination of reactive power exchanges between the TSO and DSO, using the capabilities of the distribution system to support voltage control in transmission systems.



In step 1, The evaluation of the available capabilities to provide reactive power at the POIs is based on two assessments:

-A reactive power capability assessment of the Reactive Power Source (RPS) connected to the DSO network.

-The maximum capability of the local network to accommodate additional reactive power before thermal or voltage issues arise.

In step 2, it is necessary for the TSO to calculate the optimum control modes (voltage control, reactive power control, power factor control) and set points for both the TSO connected reactive power sources and the POIs to the DSO network.

In step 3, the DSO runs power flow analysis to determine the set points for the control variables which are then input into component 4.

In step 4, the required control modes and set points will be sent by the voltage control tool directly to the RPS.

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Chapter 4

Tool #4 - DERMS

- ✓The fourth tool is DERMS (DER Management Systems) which an application platform using technologies and operational concepts to aggregate, integrate and manage distributed energy resources (DER) and controllable loads in distribution and transmission systems to enable the provision of flexibility services.

- ✓DERMS can help utilities integrate DER with operations at all levels of management. These emerging systems are expected to play a vital role supporting TSO and DSO interaction for the management of Inverter Based Resources (IBR) including storage system and controllable loads.

Chapter 4

Tool #4 - DERMS

DERMS Core Functions

- ✓Aggregation
- ✓DER device information
- ✓Registration, grouping, DER monitoring and status
- ✓Dynamic grouping
- ✓DERMS operation and control
- ✓Dispatch, estimation

Chapter 4

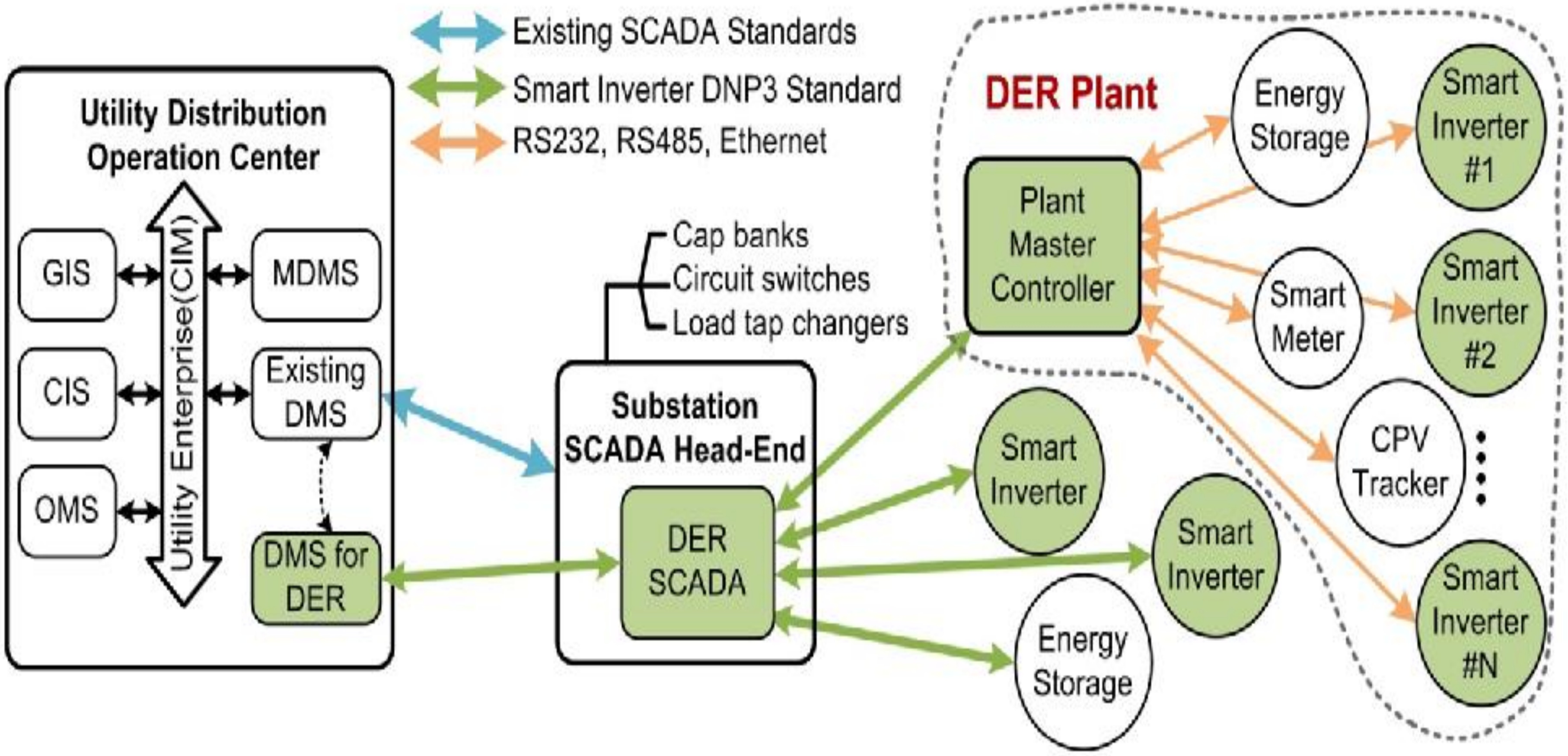
Tool #4 - DERMS

System Services Provided by DERMS

- ✓Basic energy and capacity
- ✓Frequency response, support, and control
- ✓Ramping services – both up and down
- ✓Fast Frequency Response to make up for lower inertial response
- ✓Sustainable post contingency Primary Frequency Response
- ✓Load-balancing Secondary Frequency Response (AGC)
- ✓Voltage regulation, support and control
- ✓Maintaining/setting voltage profile for optimizing transmission system operation
- ✓Black start capabilities in support of power system restoration

Chapter 4

Tool #4 - Example DMS-DERMS Architecture



Chapter 4

Tool #5 - Restoration

- ✓ The fifth tool addressed is for restoration. For distribution systems with a high degree of IBR penetration, the traditional methods of restoration may no longer be sufficient. System operators will have to embrace alternative methodologies.

- ✓ To this end, a restoration support tool (RST) for use by control room operators is proposed. The RST can be used effectively as a bridge between the TSO and DSO, facilitating the cooperation that is critical for efficient restoration in times of grid separation.

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Chapter 4

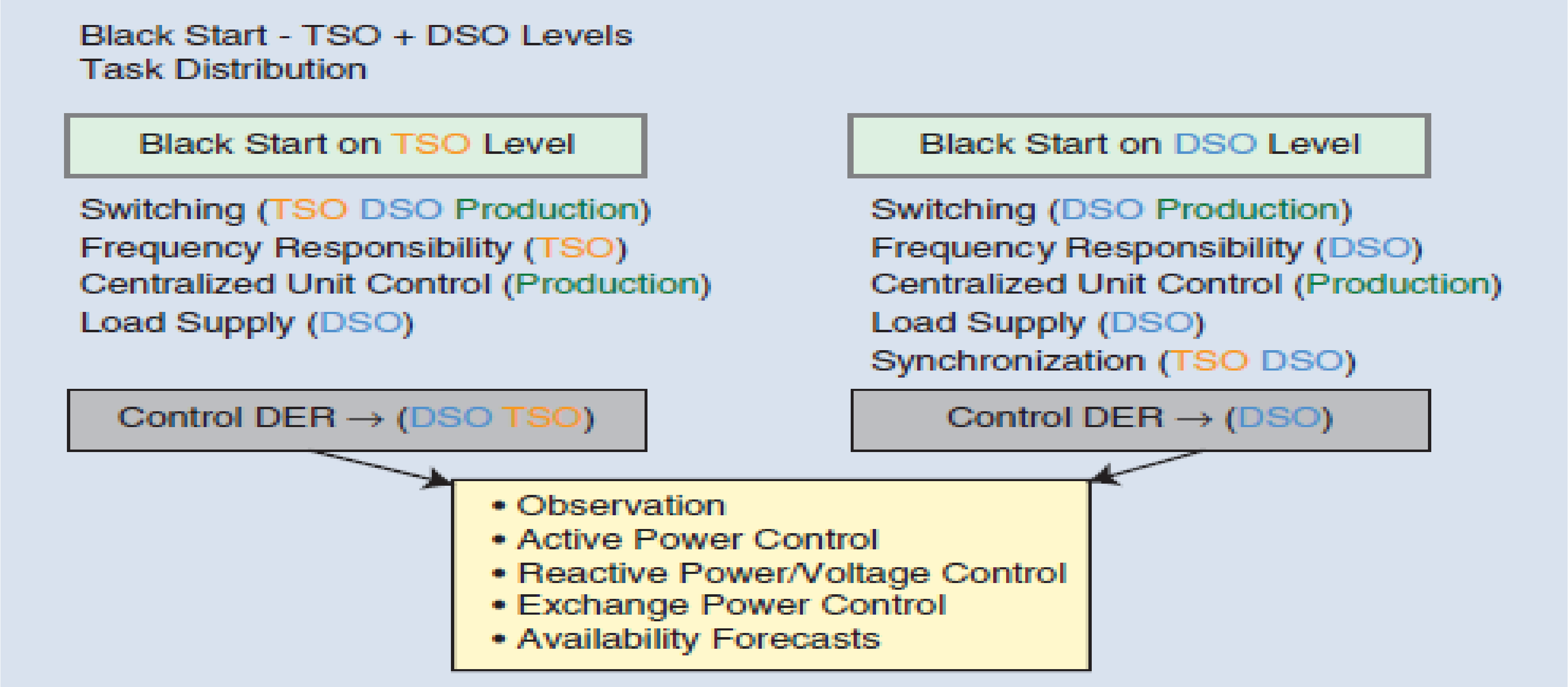
Tool #5 - Restoration

For a system that has high degree of DER penetration, the TSO and DSO must consider the following factors for restoration:

- ✓The observability of distributed generators
- ✓Interaction among ISO/RTOs, TSOs, and DSOs
- ✓Command and control structure of the network
- ✓The regulatory framework

Chapter 4

Tool #5 - The task distribution for black start at TSO and DSO levels



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Chapter 4

Tool #5 - Restoration Support Tool (RST)

One such restoration support tool (**RST**) for use by control room operators in training and real-time system restoration would have the following features:

- ✓Estimation of maximum tolerable load pickup
- ✓Estimation of maximum tolerable DG reconnection
- ✓Estimation of maximum tolerable conventional unit resynchronization
- ✓Contingency analysis
- ✓Security controlled switching
- ✓Flexibility assessment

Chapter 4

Tool #6 - Joint Tool for Power Flow, Voltage Control and Active and Reactive Power Management

- ✓ The sixth and final topic is a joint tool for power flow and voltage control and active and reactive power management at points of interconnection for the optimal coordination of the active and reactive power exchanges between the TSO and DSO.

- ✓ The focus of the tool is to explore the capabilities of the distribution grid to alleviate network congestion and to improve overall security support and voltage control on transmission systems.

- ✓ Additionally, the TSO might support the DSO to alleviate congestion and to support voltage control in distribution systems.

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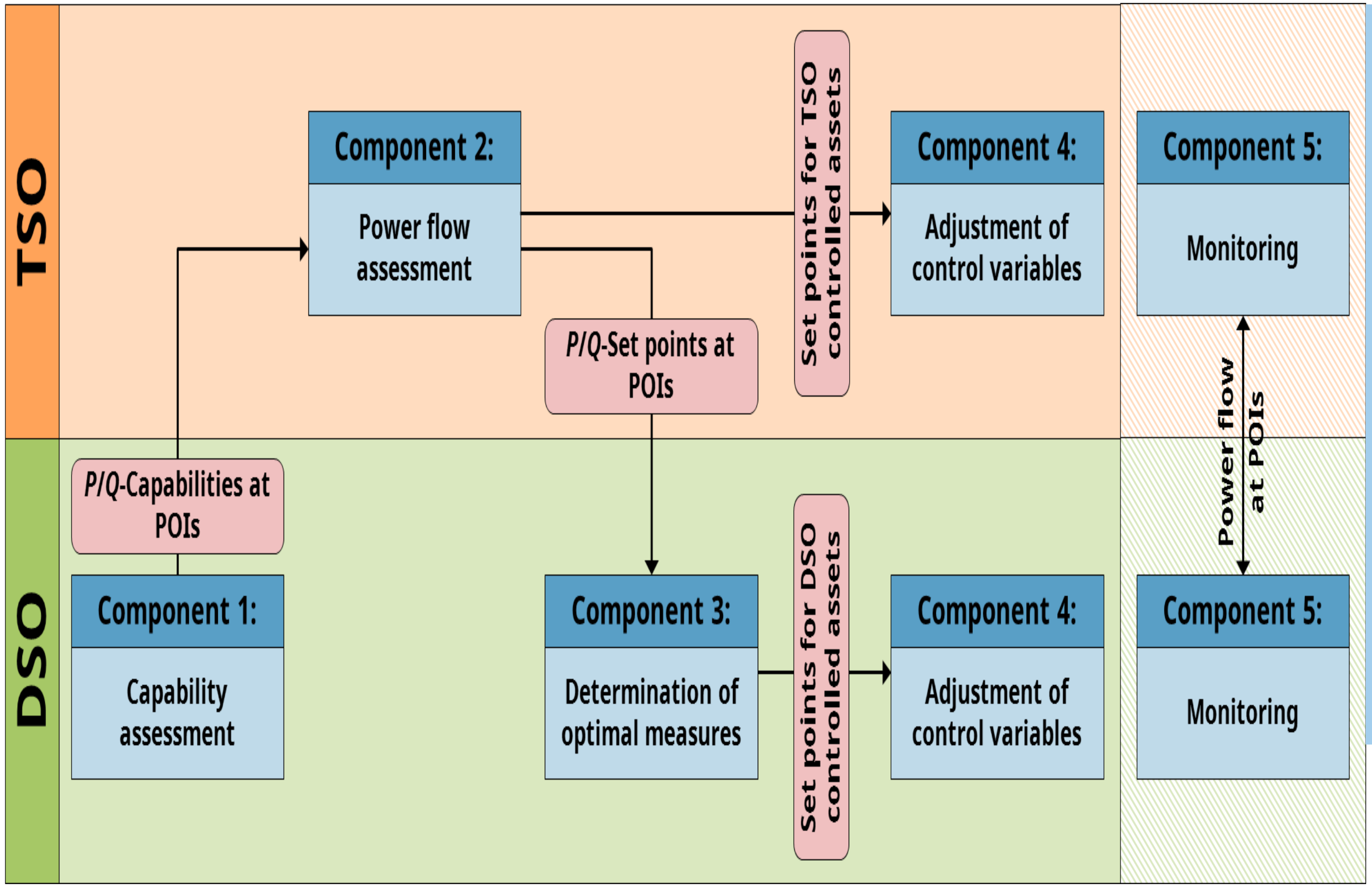
Chapter 4

Tool #6 - Component workflow & interaction



✓In the first component, the DSO assesses its capabilities to provide active and reactive power at the POIs to the TSO based on a capability assessment of the connected active / reactive power sources (APS/RPS). The resulting available capabilities are reported to the TSO.

✓The second component represents a power flow assessment by the TSO. The TSO calculates the optimal set points for the POIs prioritizing its own control objectives, while considering the predetermined capabilities of the DSO. In this process, the optimal set points for the power flow at the POIs are determined. The computed set points for the POIs are sent to the DSO as target values (flexibility activation).

✓In the third component, the DSO determines the optimal measures to fulfill the set points defined by the TSO or to match them as far as possible.

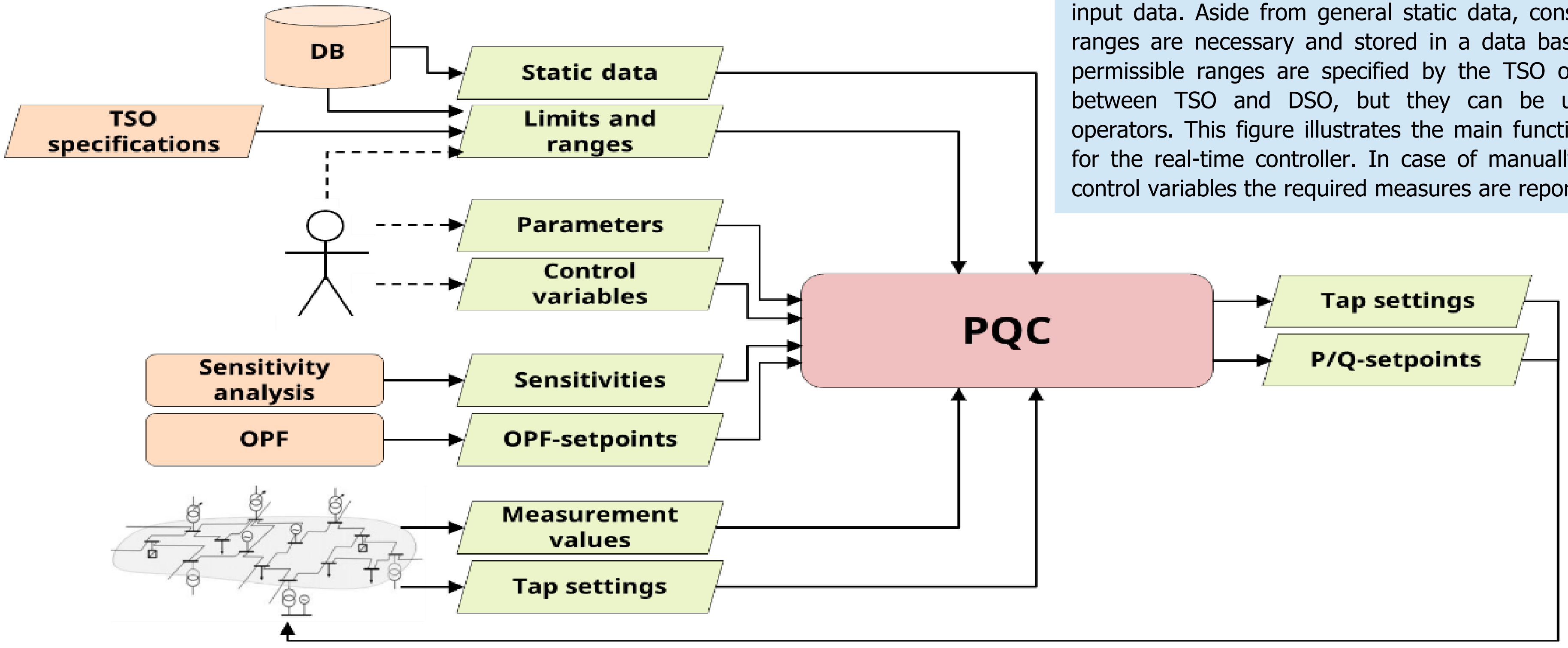
✓In the fourth component, the controllable assets of the TSO and DSO are controlled to achieve the identified set points.

✓In the fifth component the change of the power flow is monitored by both the TSO and the DSO.

Chapter 4

Tool #6 - Overview of the real-time controller (PQC)

In addition to OPF set points, the real-time controller requires additional input data. Aside from general static data, constraints and permissible ranges are necessary and stored in a data base. The constraints and permissible ranges are specified by the TSO or in a joint agreement between TSO and DSO, but they can be updated online by the operators. This figure illustrates the main functions and the input data for the real-time controller. In case of manually adjustable/executable control variables the required measures are reported to the operator.



Chapter 5 – Conclusions and the Future

Chapter 5

Conclusions and the Future – 1 of 2

- ✓ Although progress has been made on standardization of data exchanges using CIM / CGMES based models and IEC Standards for Communication, there is a further need for standardized data exchange at all levels. The industry is still far away from full participation of small to large market players due to lack of plug and play standards.
- ✓ Many EMS and dispatching tool functions will need alterations to their existing functionality to allow for new asset classes that represent a distributed aggregation across a wider area. This is more of a change to a tool, than a new tool in and of itself. Tools such as dynamic stability assessment will require updated forecasts of DER locations, net injections and models. That would normally come from a merger between the EMS / SCADA snapshots and the stability tool's own DB.

Chapter 5

Conclusions and the Future – 2 of 2

- ✓Market Management Systems will also need alteration to represent aggregations and handle the coordination process with the DSOs to pre-clear market bids.
- ✓The overall effect on control rooms needs to be considered. Does this mean additional operators and control desks will have to be provided? Additional operator training may be required which will lead to, for example, modified DTSs for both the TSO and DSO.
- ✓Will control rooms soon be dispatching load to match generation?

Chapter 5

Comments of UFLS

- ✓ The well-established purpose of Under Frequency Load Shedding schemes, as part of system defence, is to trip distribution demand feeders, to prevent total system collapse. However, as DER penetrates more into such feeders, it becomes a very real possibility that at the time of an UF (or LF) event, the feeder in question could be exporting and acting as a generator feeder. In that event, shedding such a feeder would act to exacerbate, rather than help the situation.
- ✓ This is recognised in many of the European Network Codes. Some stipulate that from 2022, relays in such schemes must have a power flow direction detection facility, such that they could be configured to block tripping in the event described above.
- ✓ This will bring with it, additional challenges for both the DSO and TSO. It means that it will be difficult for the TSO, to know with certainty, how much load is available for disconnection.

Additional Comments 1 of 2

State Estimation (not in TB)

- ✓DSE (Distribution State Estimation), also known as DSSE (Distribution System State Estimation) is extremely difficult to implement due to issues such as data availability and the number of devices which are not monitored.
- ✓KEPCO have implemented an ADMS where DSE (Distribution State Estimation) and DGE (DER Generation Estimation) are the main goals of their distribution network analysis (Electra No. 320, February 2022, pp 28-33)
- ✓Interfacing the TSO's state estimator with multiple DSOs' state estimator will be challenging

Additional Comments 2 of 2

Power Flow Controllers (not in TB)

- ✓PFCs, at both transmission and distribution voltage levels, can ease system congestion.
- ✓Traditionally settings for PFCs has been done on an individual basis.
- ✓With the widespread adoption of PFCs, the calculation and coordination of settings especially with the TSO and DSO involved, will be challenging (see C2 session paper C2-10873)

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Thank you

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