The Nordic Capacity Calculation Methodology (CCM) project Stakeholder Forum

Clarion Hotel at Copenhagen Airport

12 December 2019

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Where do we come from and where are we now?

- Initial work on the Nordic FB methodology started as a voluntary and joint effort of all Nordic TSOs in 2012/13.
- With the CACM entering into force in 2015, the Nordic FB project was altered into the Nordic CCM project – being a CACM (and FCA) GL implementation project, addressing all the legal requirements

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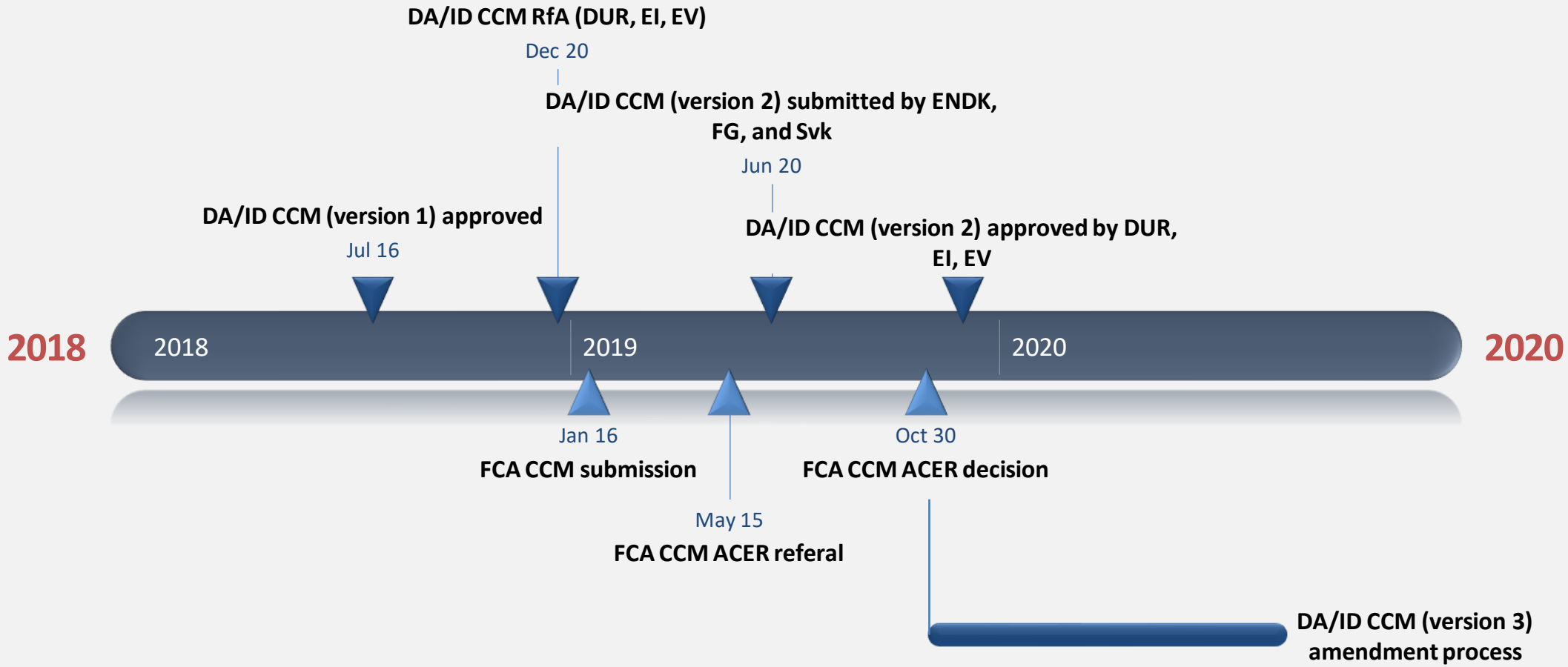
Where do we come from and where are we now?
- Nordic LT, DA, ID CCM development and approval -



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Where do we come from and where are we now? - FB simulations -

- Prototype tools and a prototype CGM have been developed in order to perform an impact assessment (presented in the supporting document that is published on the Nordic RSC website: link) and with the objective to run a weekly simulation process
  - ✓ FB capacity calculation and allocation simulations have been performed and are available on the Nordic RSC website for download (link)
    - 17 weeks in 2016
    - 11 weeks in 2017
  - ✓ The prototype-based CGM – and thereby the prototype simulation process - is error-prone
    - The CGM is built up from individual SCADA models created by each TSO, and merged centrally
    - The fact that the SCADA systems were upgraded or replaced at most TSOs stalled the prototype CGM process to a large extent in 2018/19
- The prototype simulation process facilitated a learning-by-doing, that is reflected in the IT specifications of the industrial tool that is currently being implemented
- The main focus is now on starting the simulations using the industrial tools and industrial CGMs, during the so-called internal and external parallel runs that are scheduled to start in 2020

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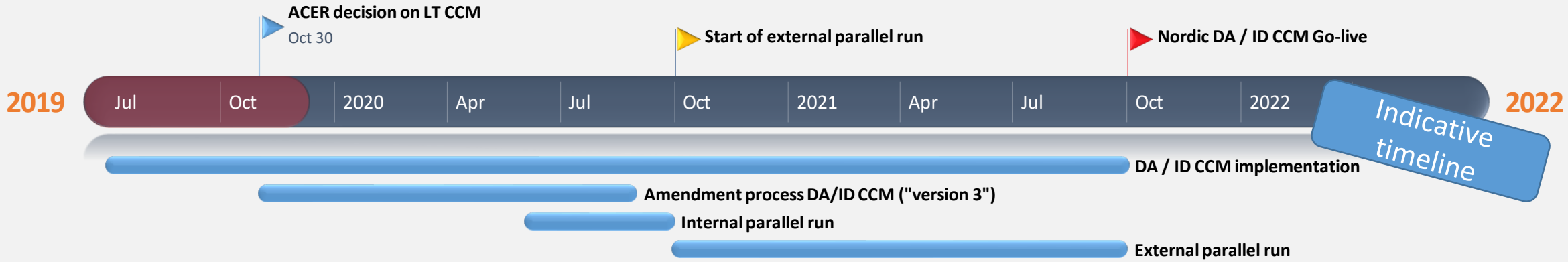
Where do we come from and where are we now?
- internal and external parallel run -



The internal and external parallel runs are expected to start in 2020

- Internal parallel run
  - ✓Testing of the tools and the CGMs available
  - ✓RSC and TSOs to perform the FB capacity calculation
  - ✓TSO to perform the FBMC simulations on an ex-post basis
  - ✓Readiness for the external parallel run

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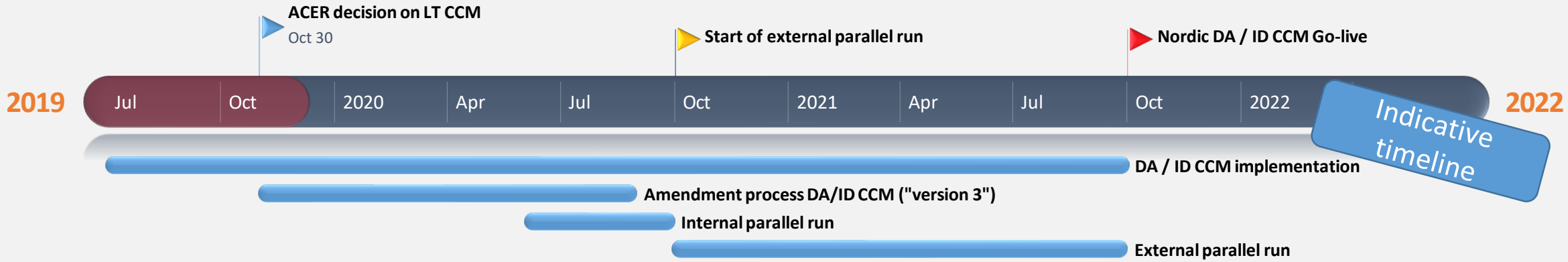
Where do we come from and where are we now?
- internal and external parallel run -



- External parallel run (at least for a one-year period)
  - ✓ RSC and TSOs to perform the FB capacity calculation on day-by-day basis (in addition to the operational NTC capacity calculation process)
  - ✓ NEMOs to perform the FBMC simulations on a day-by-day basis
    - Using Euphemia
    - Using the operational NTC-world order books
  - ✓ Share the results with the stakeholders
  - ✓ Monitor the KPIs / go-live criteria
  - ✓ Finetune where needed, and have more and more-developed IT modules installed along the run

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Recap of the FB methodology

1 Background

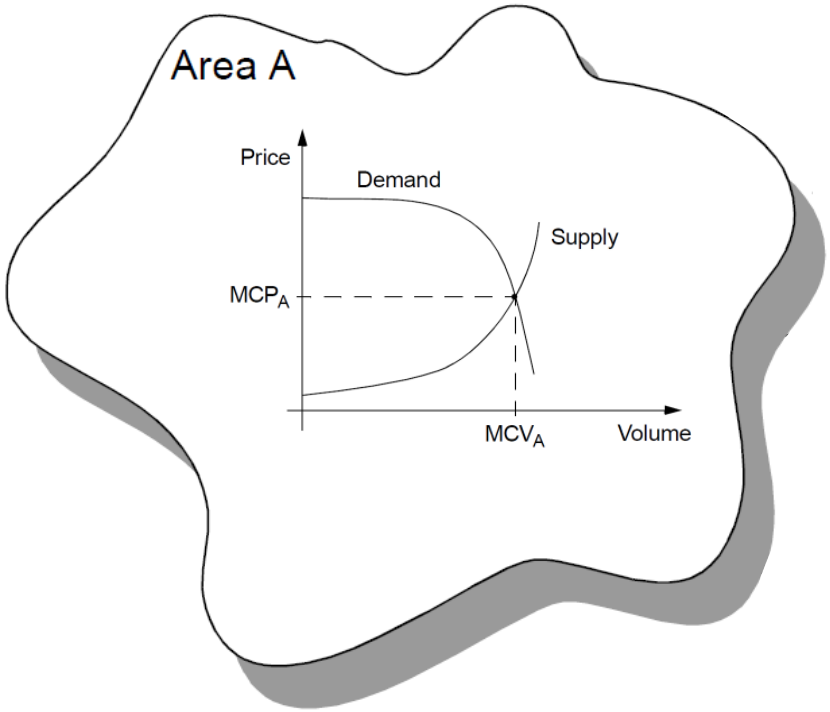
2 The status in Europe and the Nordics

3 Capacity calculation: FB and NTC

4 Example results

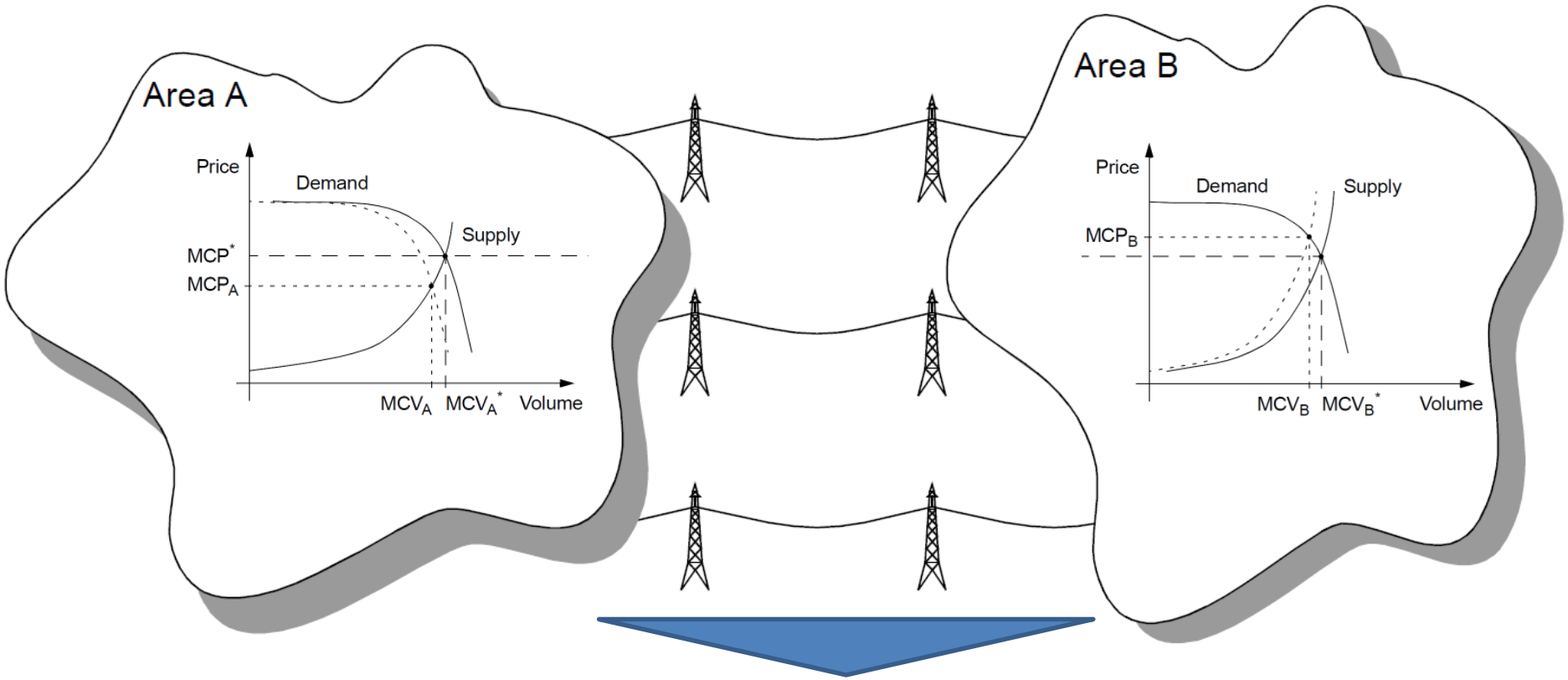
5 Questions

Market



Source: Electrical Power System Essentials (2nd edition), Pieter Schavemaker, Lou van der Sluis, Wiley, 2017.

Market coupling



Capacity calculation

Source: Electrical Power System Essentials (2nd edition), Pieter Schavemaker, Lou van der Sluis, Wiley, 2017.

Capacity calculation
From complexity to simplicity

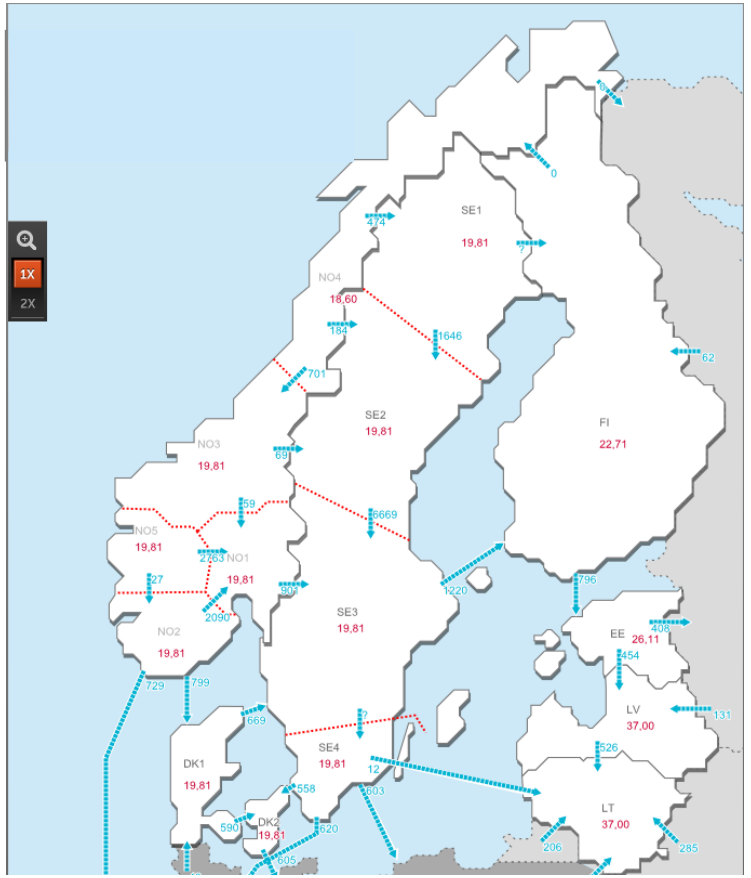
The physical world

Complexity → Simplicity

Detailed grid model	Flow Based (FB)	Net Transmission Capacity (NTC)

Capacity calculation is the process of translating the complex physical grid into a simplified form that can be understood and applied by the power exchange

The commercial world



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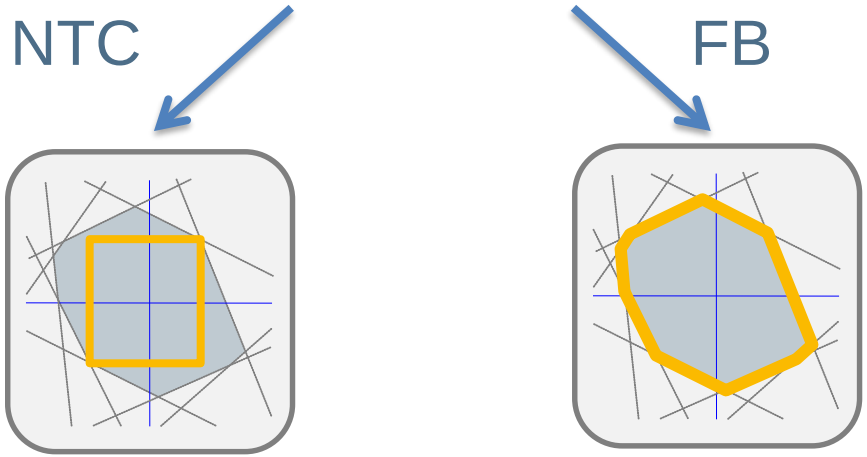
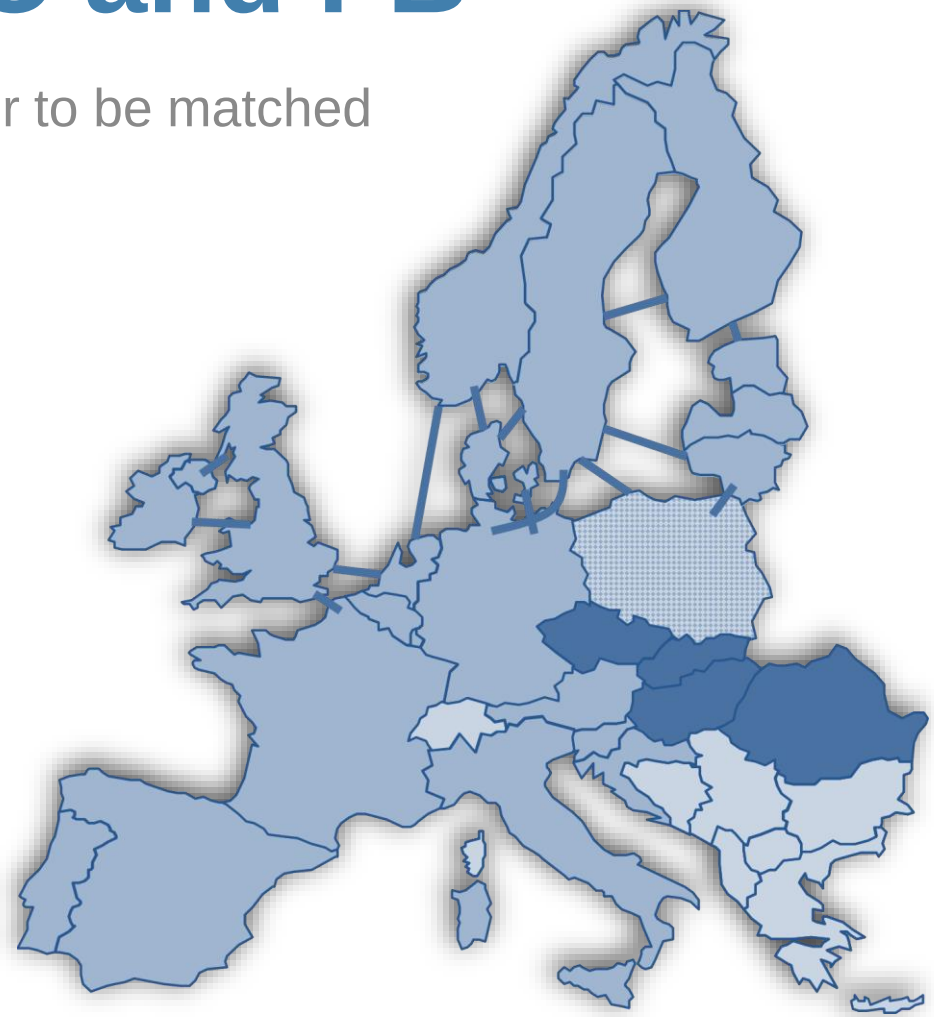
Market coupling: NTC and FB

- All the bids of the bidding areas are brought together in order to be matched by a centralized algorithm
- Objective function: Maximize social welfare
- Control variables: Net positions
- Subject to: ∑ net positions = 0
  Grid constraints





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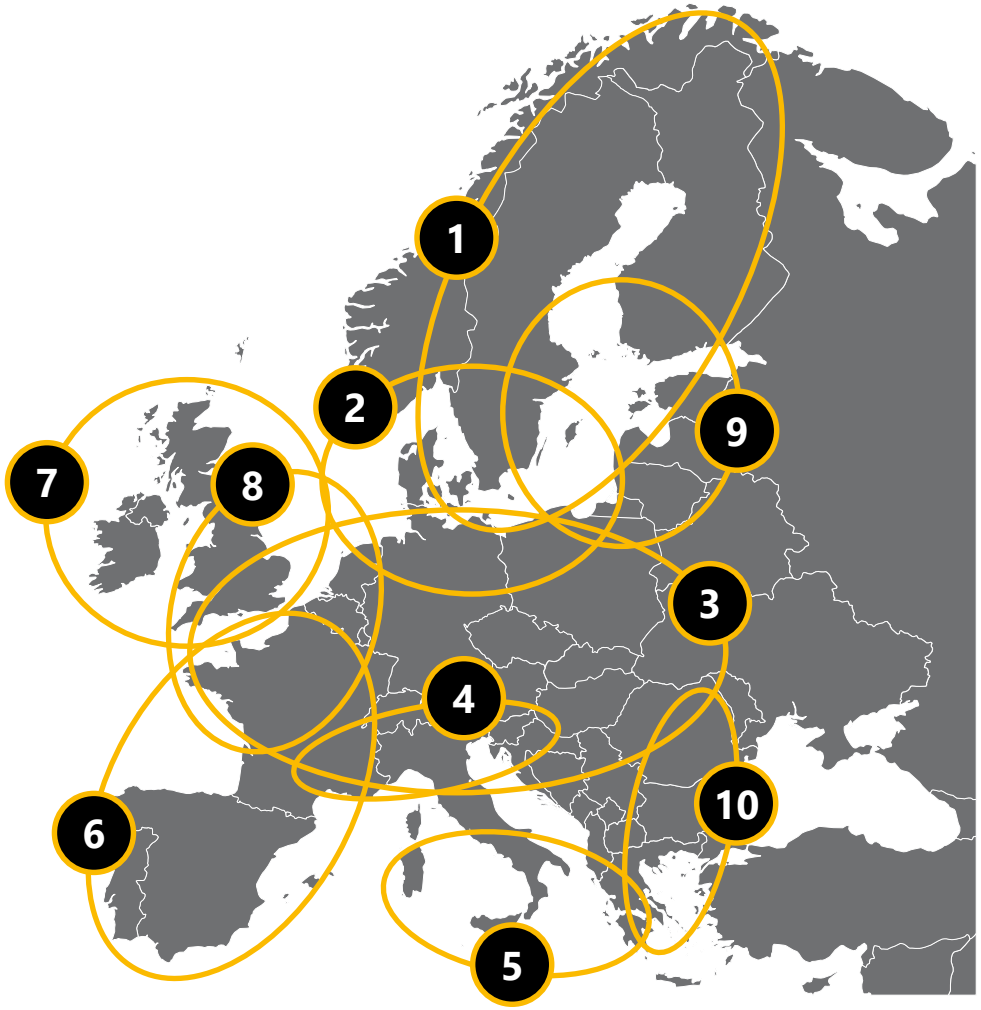
Capacity Calculation Regions

1. Nordic
2. Hansa
3. Core
4. Italy North
5. Greece-Italy (GRIT)
6. South-West Europe (SWE)
7. Ireland and United Kingdom (IU)
8. Channel
9. Baltic
10. South-East Europe (SEE)



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Guideline on Capacity Allocation and Congestion Management (CACM GL)

L 197/24 EN Official Journal of the European Union 25.7.2015

COMMISSION REGULATION (EU) 2015/1222

of 24 July 2015

establishing a guideline on capacity allocation and congestion management

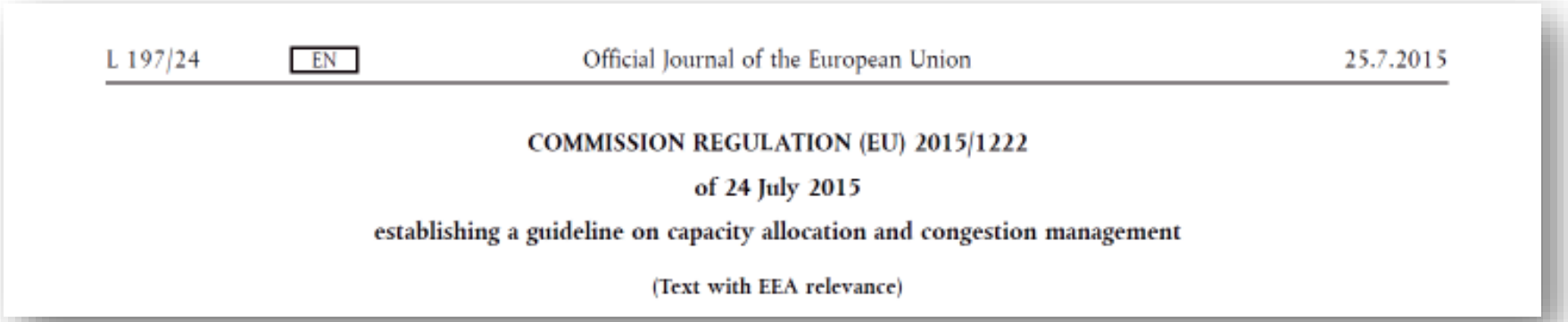
(Text with EEA relevance)

- Article 20.2:
  '*No later than 10 months after the approval of the proposal for a capacity calculation region in accordance with Article 15(1), all TSOs in each capacity calculation region shall submit a proposal for a common coordinated capacity calculation methodology within the respective region.'*

- The ACER decision on the TSO's proposal for the determination of Capacity Calculation Regions dates November 17, 2016

Source: http://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32015R1222&from=EN

Guideline on Capacity Allocation and Congestion Management (CACM GL)



L 197/24 EN Official Journal of the European Union 25.7.2015

COMMISSION REGULATION (EU) 2015/1222

of 24 July 2015

establishing a guideline on capacity allocation and congestion management

(Text with EEA relevance)

'There are two permissible approaches when calculating cross-zonal capacity: flow-based or based on coordinated net transmission capacity. The flow-based approach should be used as a primary approach for day-ahead and intraday capacity calculation where cross-zonal capacity between bidding zones is highly interdependent.'

…

'The coordinated net transmission capacity approach should only be applied in regions where cross-zonal capacity is less interdependent and it can be shown that the flow-based approach would not bring added value.'

Source: http://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32015R1222&from=EN

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Capacity Calculation Regions

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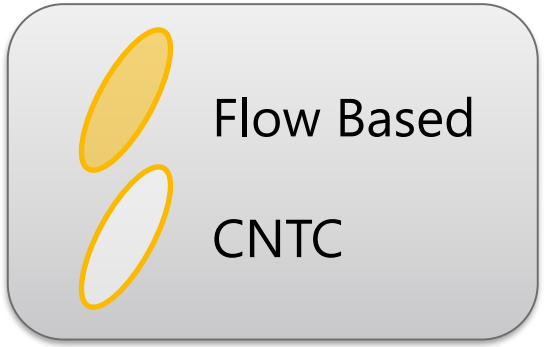

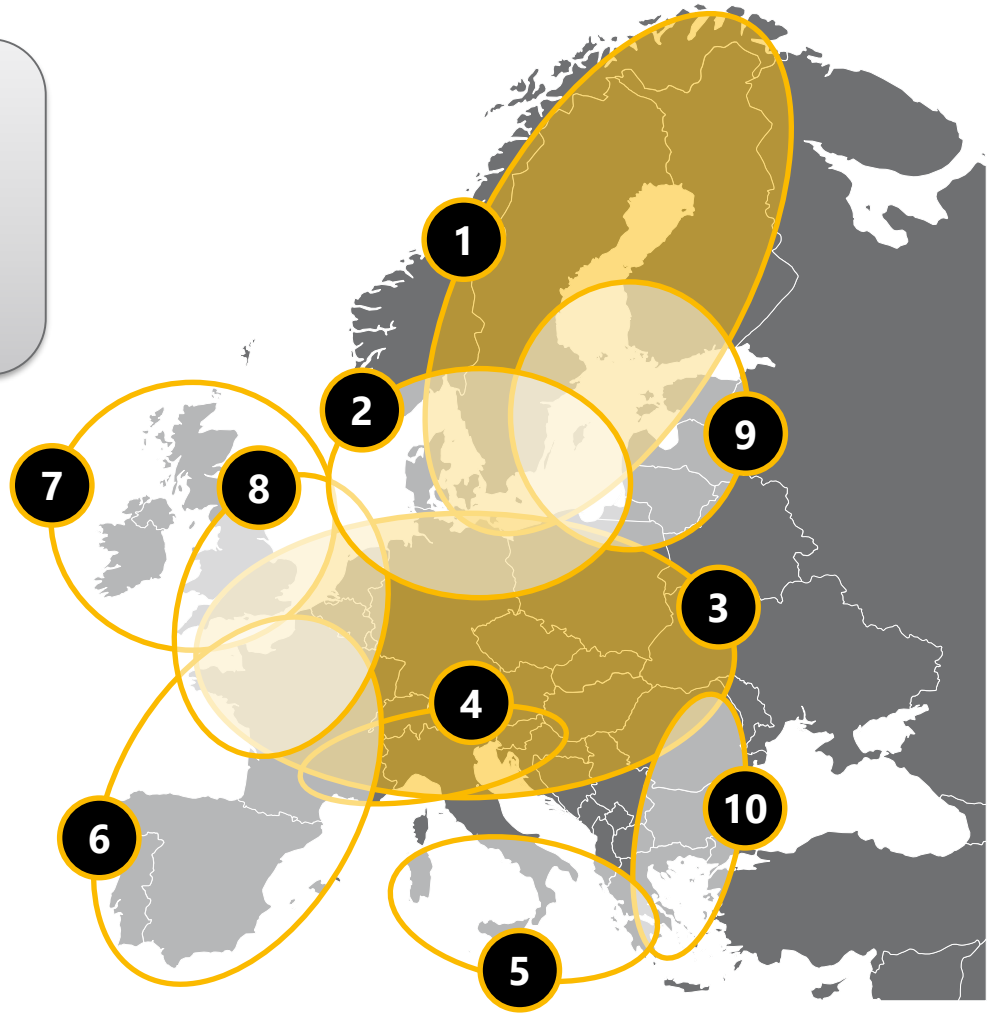

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Recap of the FB methodology

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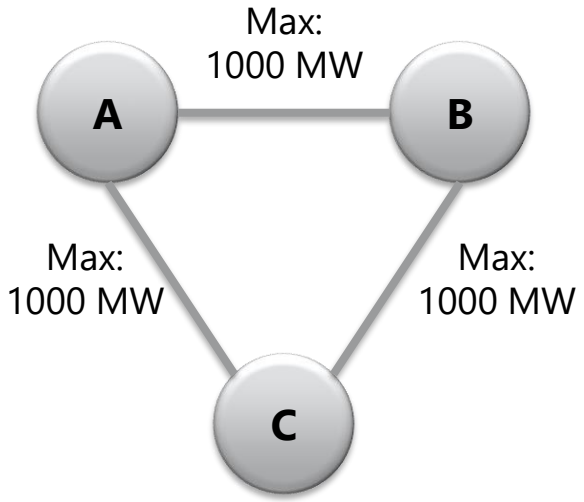
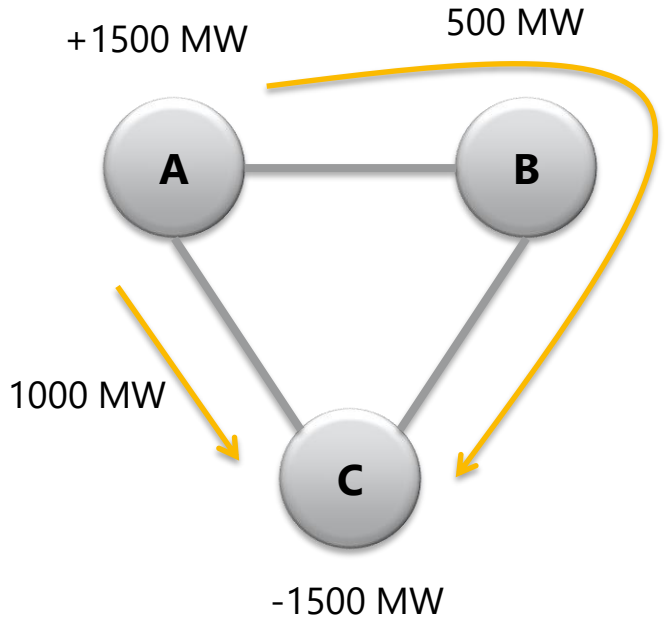
An example three-node network

- Let's consider a three-node network
  - Equal impedances
  - Max flow on the branches: 1000 MW



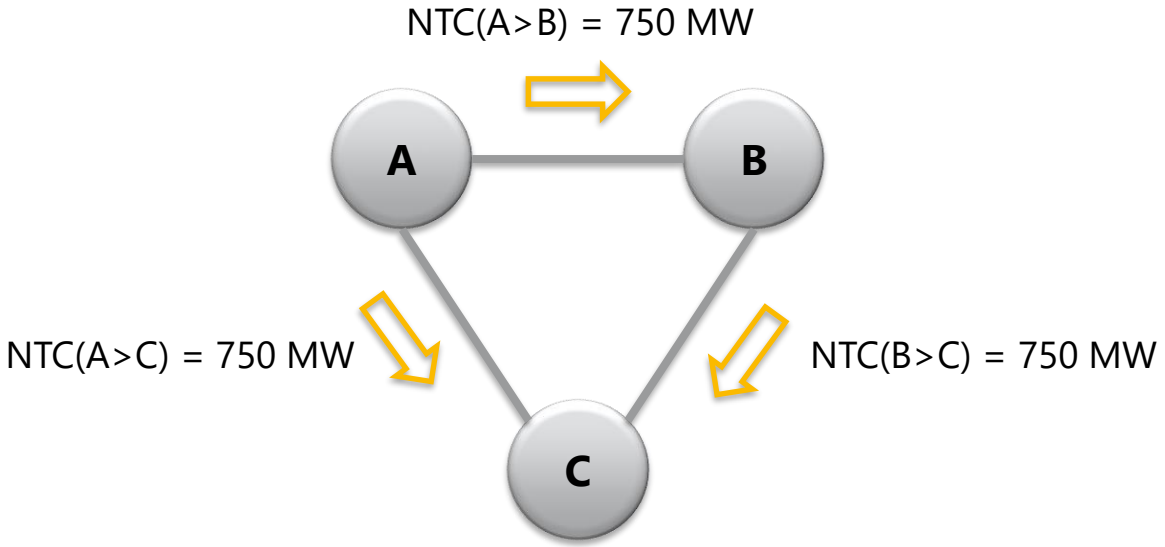
- The maximum export from A to another bidding area amounts 1500 MW:



An example three-node network: NTCs

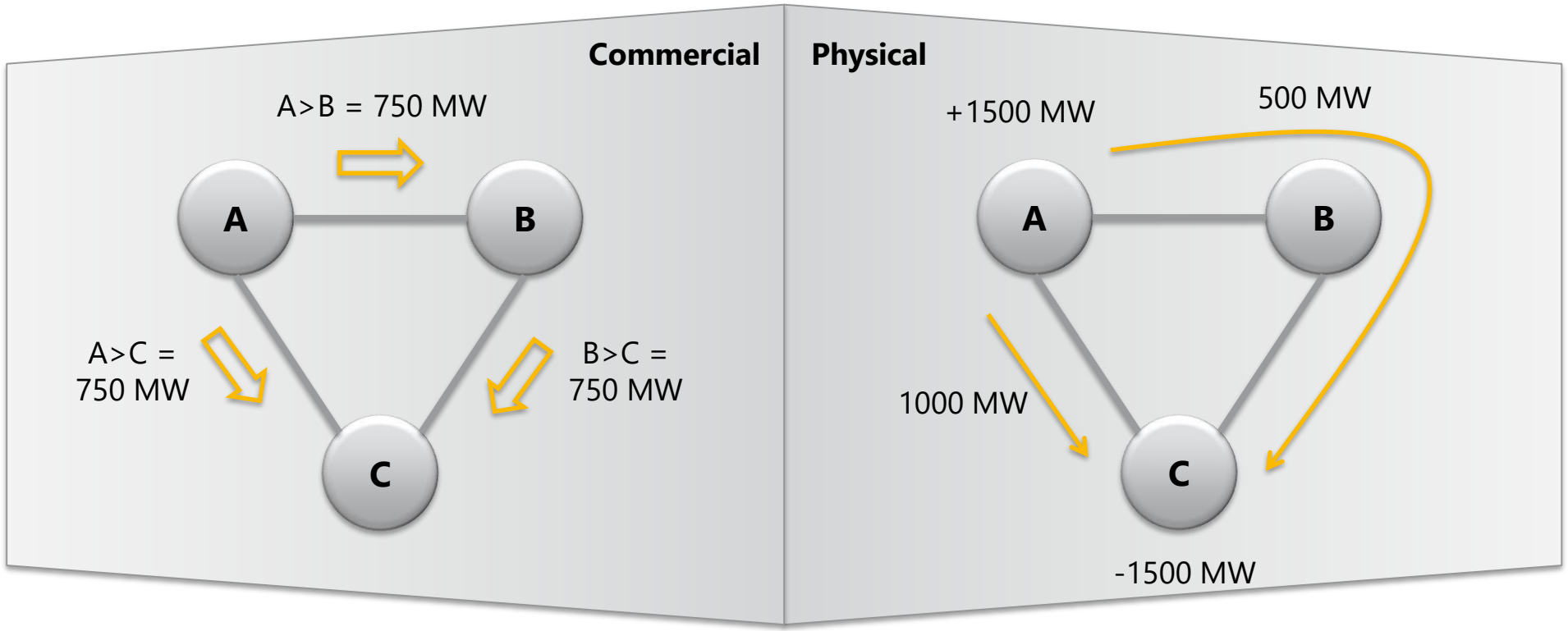
- NTCs are determined by the TSOs to facilitate the market while safeguarding the grid
  - A NTC limits a commercial exchange between two bidding areas
  - NTCs are simultaneously feasible

- Given the maximum export of bidding area A, the TSO needs to split the 1500 MW export capability into two bilateral exchanges, for example:
  - NTC(A>B) = 750 MW
  - NTC(A>C) = 750 MW
- There are in principle an infinite number of NTC solutions; it is a choice which one to select



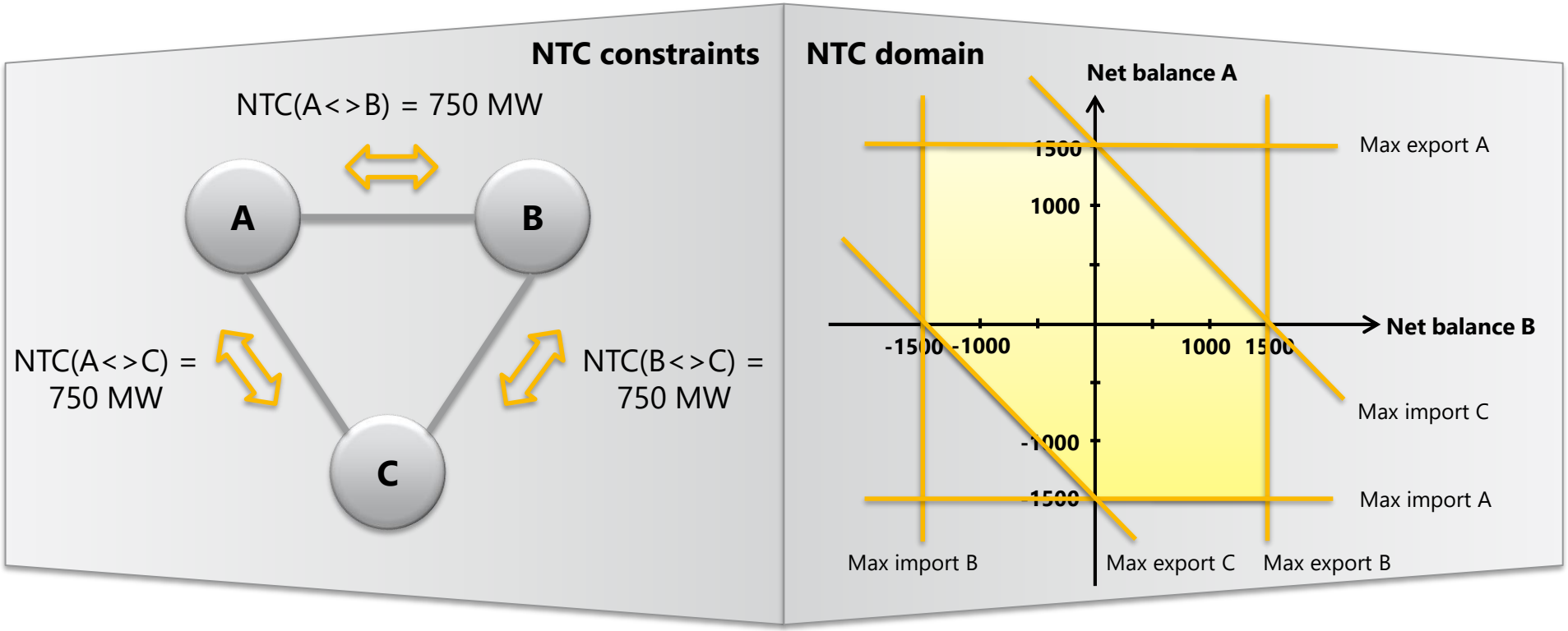
An example three-node network: NTCs and physical flows

- The following commercial exchanges are feasible given the NTCs:
  - A>C = 750 MW
  - A>B = 750 MW
  - B>C = 750 MW



An example three-node network: NTC domain

- The NTCs in the three-node system define the NTC domain:
  the import/export positions that the market is allowed to reach under the market coupling while not jeopardizing the grid security



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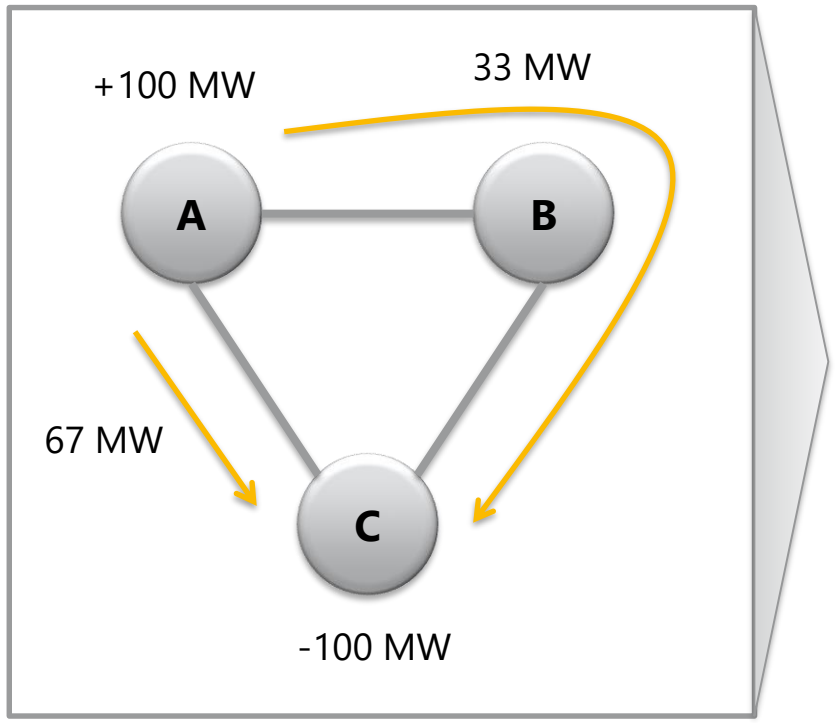
An example three-node network: FB constraints

- FB constraints are a kind of simplified grid model, reflecting the impact of import/export positions on the flows on the grid

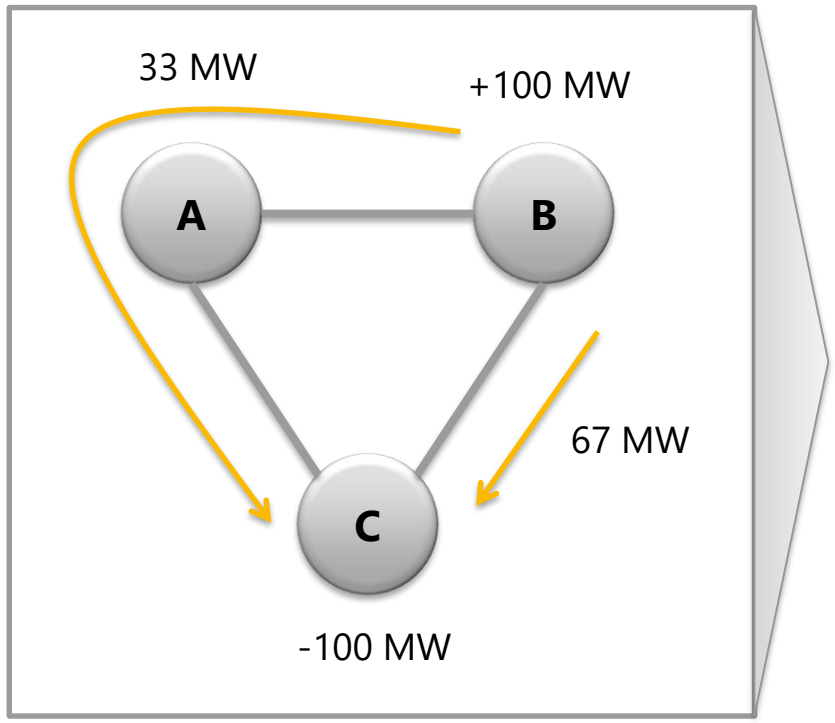


FB constraints ('grid model'):

	Margins	PTDF factors		
Line	**Maximum flow**	**Influence from area A**	**Influence from area B**	**Influence from area C**
A>B	1000 MW	33 %		
B>C	1000 MW	33 %		
A>C	1000 MW	67 %		

An example three-node network: FB constraints

- FB constraints are a kind of simplified grid model, reflecting the impact of import/export positions on the flows on the grid



FB constraints ('grid model'):

	Margins	PTDF factors		
Line	**Maximum flow**	**Influence from area A**	**Influence from area B**	**Influence from area C**
A>B	1000 MW	33 %	- 33 %	
B>C	1000 MW	33 %	67 %	
A>C	1000 MW	67 %	33 %	

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An example three-node network: FB constraints

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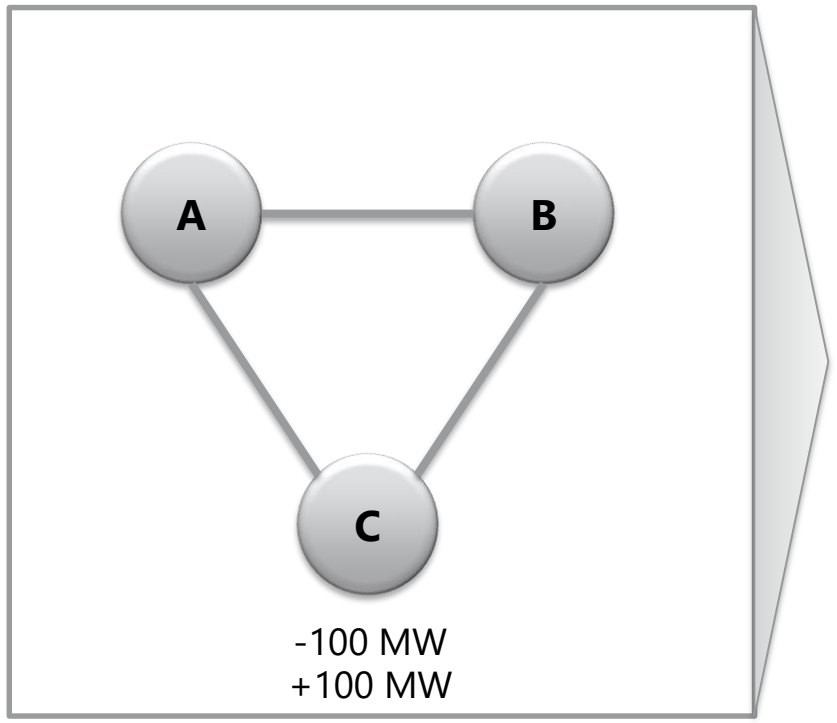
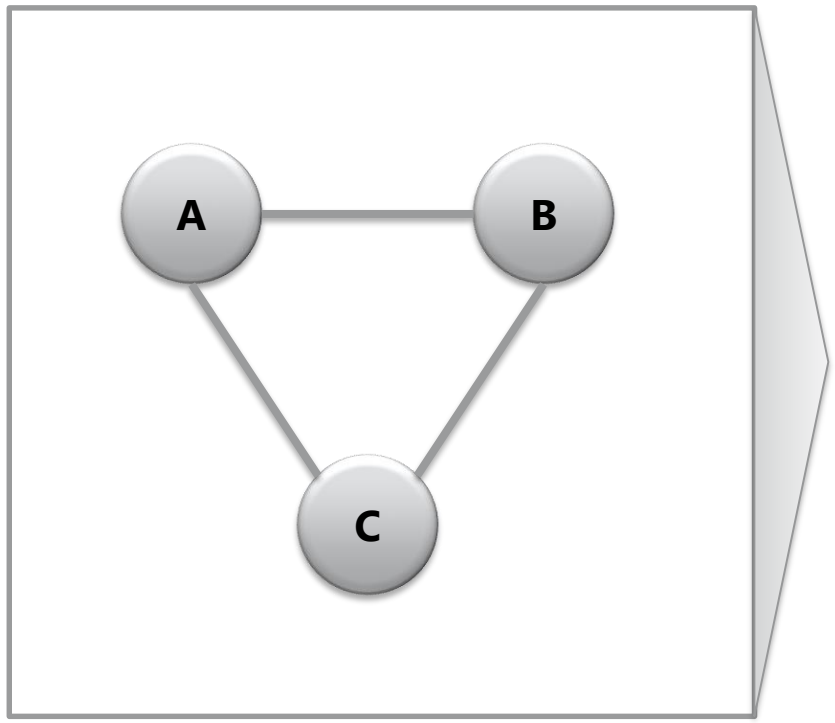


FB constraints ('grid model'):

	Margins	PTDF factors		
Line	**Maximum flow**	**Influence from area A**	**Influence from area B**	**Influence from area C**
A>B	1000 MW	33 %	- 33 %	0
B>C	1000 MW	33 %	67 %	0
A>C	1000 MW	67 %	33 %	0

An example three-node network: FB constraints

- FB constraints are a kind of simplified grid model, reflecting the impact of import/export positions on the flows on the grid



FB constraints ('grid model'):

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A>B	1000 MW	33 %	- 33 %	0
B>C	1000 MW	33 %	67 %	0
A>C	1000 MW	67 %	33 %	0
B>A	1000 MW	-33 %	33 %	0
C>B	1000 MW	- 33 %	- 67 %	0
C>A	1000 MW	- 67 %	- 33 %	0

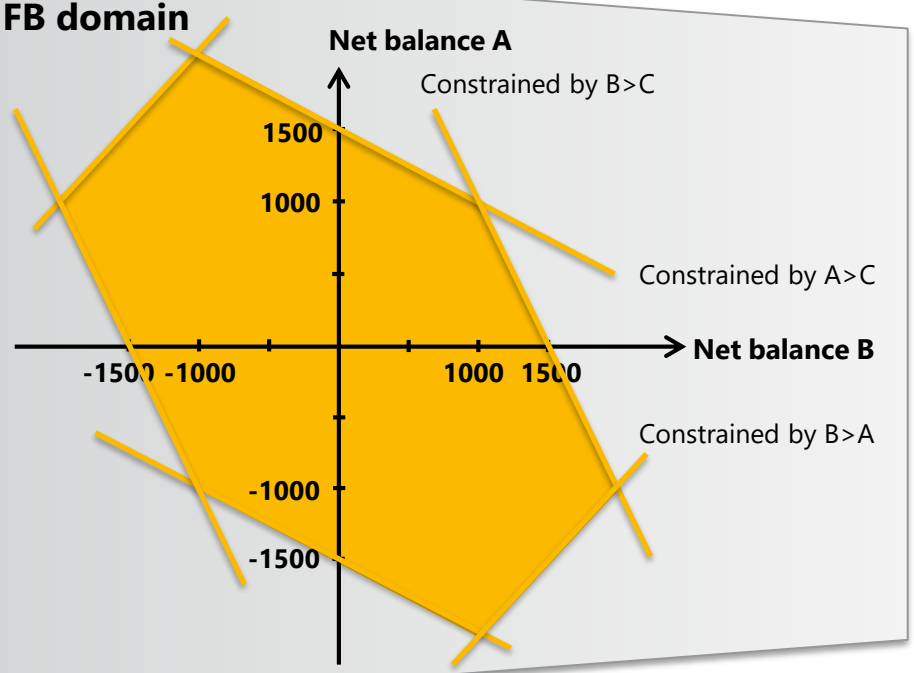
An example three-node network: FB domain

- The FB constraints in the three-node system define the FB domain: the import/export positions that the market is allowed to reach under the market coupling while not jeopardizing the grid security

FB constraints

Line	Maximum flow	Influence from area A	Influence from area B	Influence from area C
A>B	1000 MW	33 %	- 33 %	0
B>C	1000 MW	33 %	67 %	0
A>C	1000 MW	67 %	33 %	0
B>A	1000 MW	- 33 %	33 %	0
C>B	1000 MW	- 33 %	- 67 %	0
C>A	1000 MW	- 67 %	- 33 %	0

FB domain



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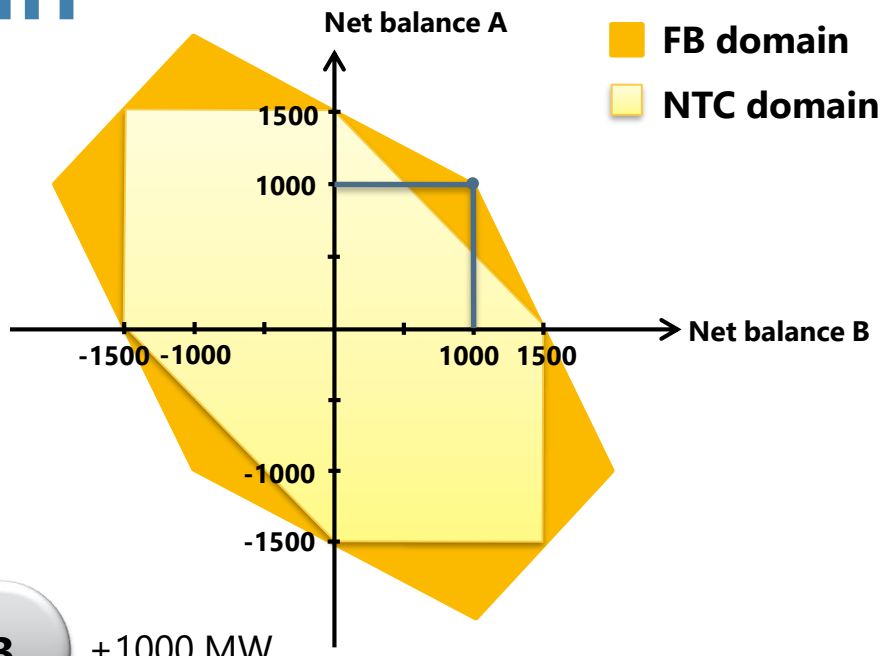
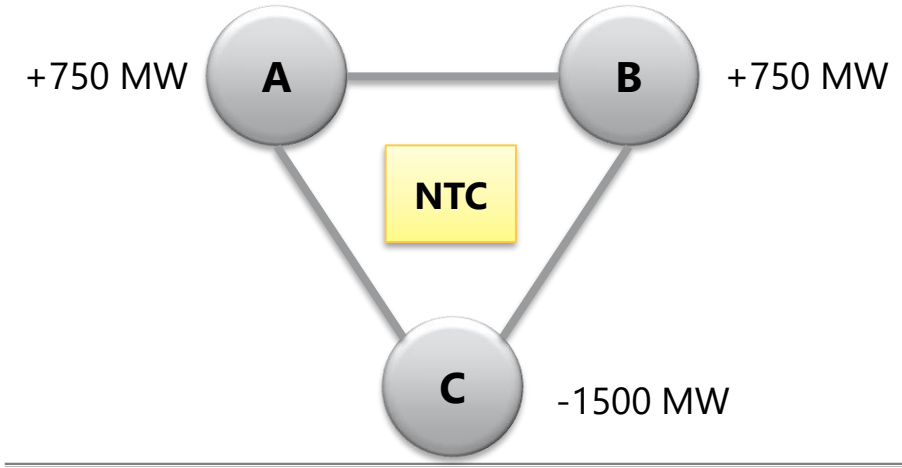
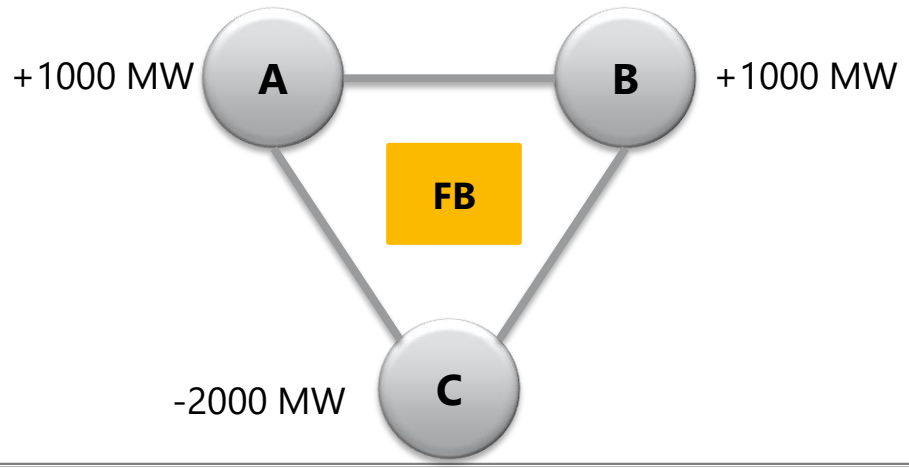
An example three-node network: NTC vs FB domain

- In FB capacity split is not a choice of the TSO, but is market driven (at the time of allocation)
- In principle, FB offers more trading opportunities with the same level of security of supply
- Example:
  - NTC: North-South exchange limited to 1500 MW
  - FB: North-South exchange possible of 2000 MW







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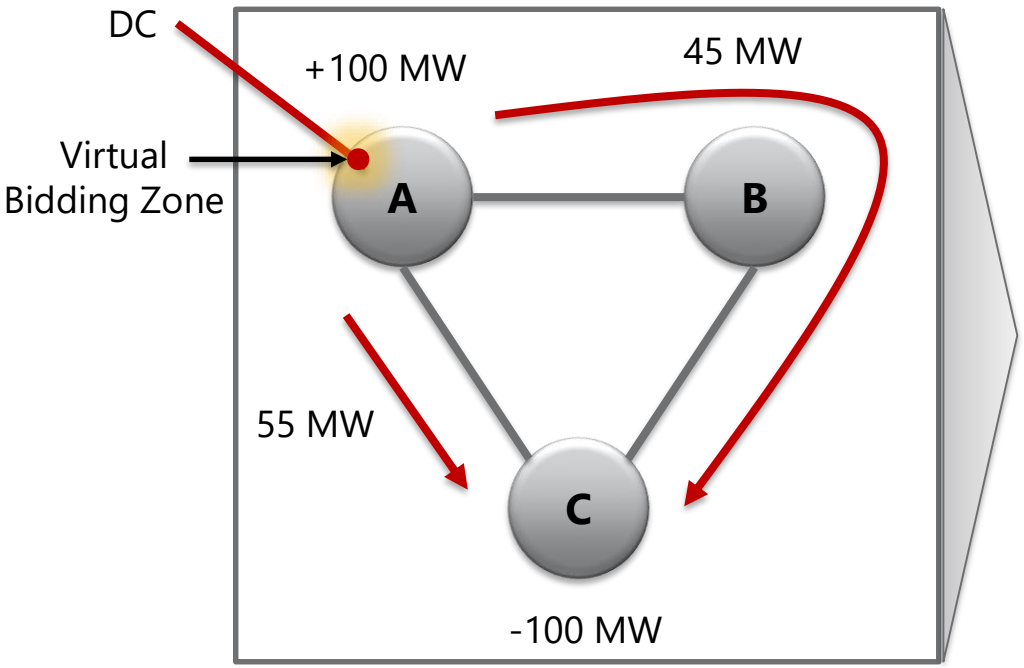
Advantages of the FB approach

- In FB capacity split is not a choice of the TSO, but is market driven (at the time of allocation)
  - More efficient and flexible use of the grid
- FB offers more trading opportunities with the same level of security of supply
  - More price convergence / smaller price differences
  - Higher social welfare
  - Income redistribution: Less congestion income and more producer and consumer surplus
- FB offers the possibility to have the DC cables efficiently embedded in the allocation mechanism, by providing a fair competition for the use of the scarce AC capacity
- Flow-based market coupling provides an efficient allocation mechanism in which all exchanges that are subject to the allocation mechanism compete with one another for the use of the scarce capacity

An example three-node network: DC links - Advanced Hybrid Coupling

- Advanced Hybrid Coupling is applied on all DC links and AC connections to other CCRs
  - In this way, they compete for the scarce capacity in the AC grid like any other commercial exchange
  - This introduces virtual bidding zones at the converter stations of the DC links in the Nordic area



	Margins	PTDF factors			
Line	**Maximum flow**	**Influence from area A**	**Influence from area B**	**Influence from area C**	**Influence from virtual BZ**
A>B	1000 MW	33 %	…	…	45%
B>C	1000 MW	33 %	…	…	45%
A>C	1000 MW	67 %	…	…	55%
B>A	1000 MW	…	…	…	…
C>B	1000 MW	…	…	…	…
C>A	1000 MW	…	…	…	…

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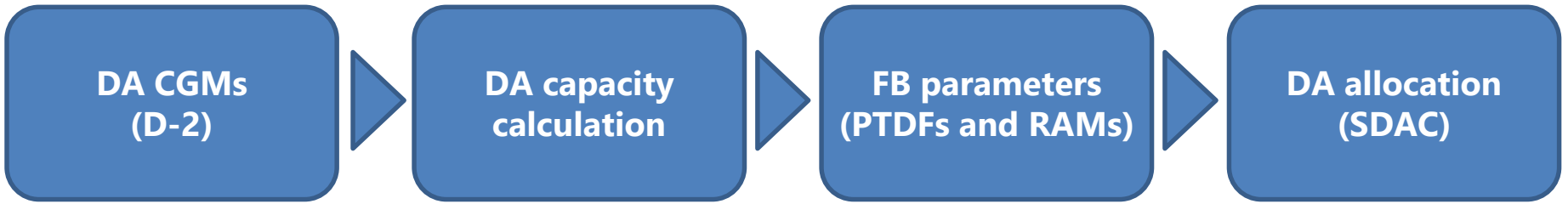
Nordic DA CCM in a nutshell



Nordic DA CCM in a nutshell

- Advanced Hybrid Coupling is applied on all DC links and AC connections to other CCRs
- Number of Bidding Zones: 27
  - Nordic bidding zones: 12
  - Virtual bidding zones: 15
- Two synchronous areas
  - DK1 is part of the continental European synchronous system
- Number of presolved FB constraints
  - Around 85
- In order to maximize socio-economic welfare, the FB market coupling could result in “non-intuitive” flows on some borders: flows from a high-price to a low-price area

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Recap of the FB methodology

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2 The status in Europe and the Nordics

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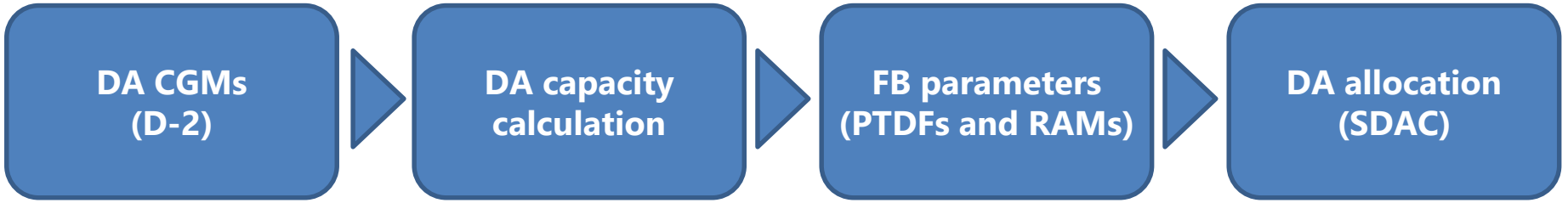
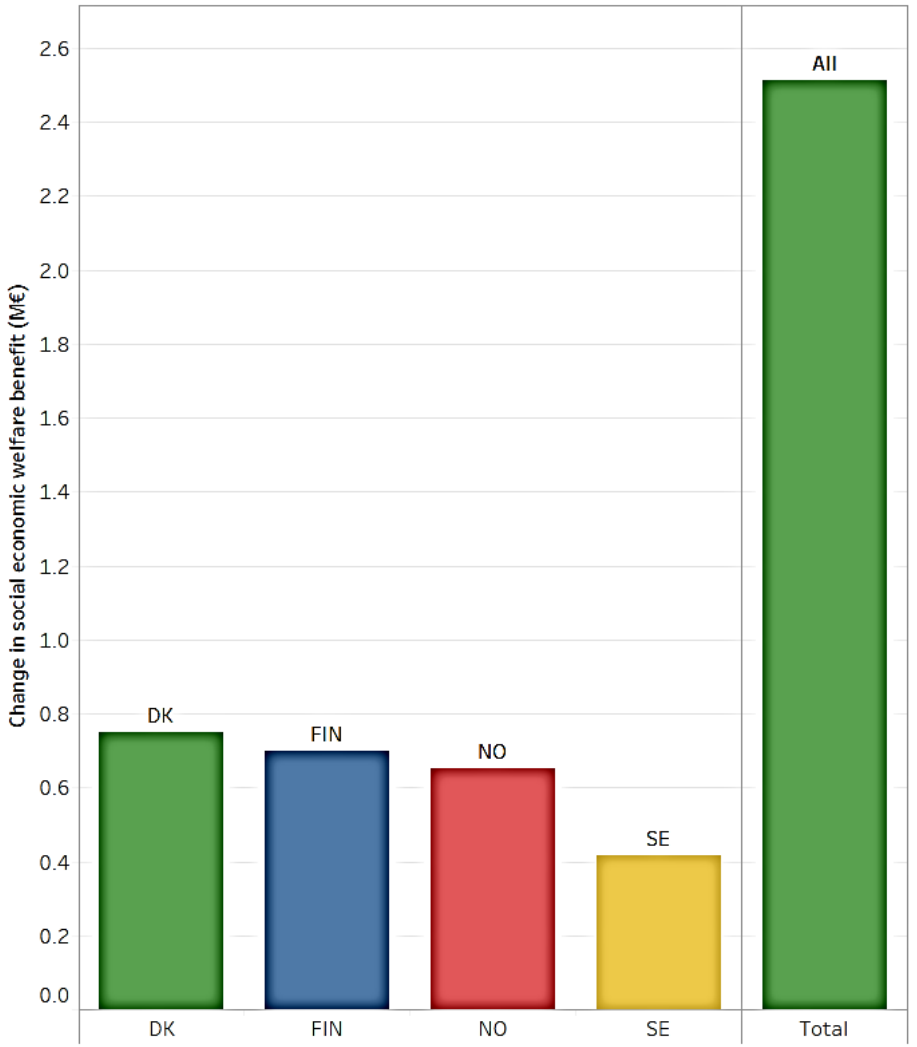
FB simulations: setup



- FB simulations are being performed by the project, based on
  - Prototype CGMs
  - Prototype tooling to perform the DA FB capacity calculation
  - The so-called NEMO's Simulation Facility to simulate the SDAC using the FB constraints and actual historical order books
- With the implementation ongoing at the Nordic RSC, gradually, elements in this process will be replaced by more robust data and IT modules

FB simulations: socioeconomic welfare gains

- The following results are for weeks 1-6 and 8-12, 2017 and compare the market outcomes with FB and with historical NTCs.
- The graphs show the difference between the day-ahead socioeconomic welfare (SEW) with FB and with historical NTCs
- Day-ahead SEW = producer surplus + consumer surplus + congestion income
- Structural congestions such as West Coast corridor and export limitations in Norway dealt with in a more efficient way with flowbased:
  - No need to limit capacities ex ante.
  - Instead: full capacities + critical network elements given to the market => capacity allocated in the market in a more efficient way.



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Week 1: 4 January, 03.00: A windy night
Example of the West-Coast Corridor

FB

NTC

- A lot of wind to be exported from DK/GE to the Nordics
- With NTC, ex-ante limitations on DK1->SE3 and DK2->SE4 due to West Coast corridor
- With FB, capacity allocation in the market considers directly the West Coast corridor without need for limitations.
- Note that the limitations GE->SE4 are due to limitations on the German side.

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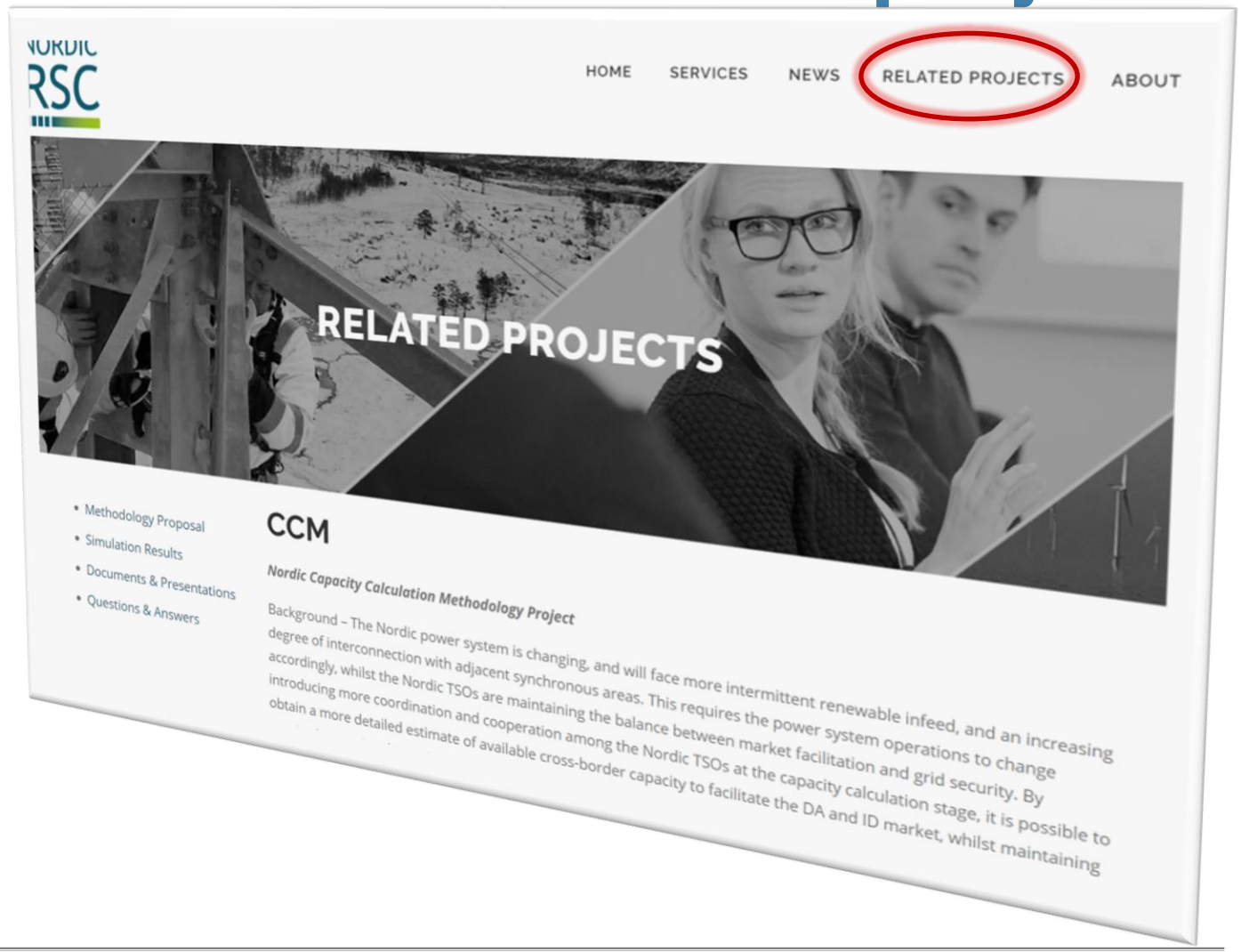
Recap of the FB methodology

More information on the Nordic CCM project?

- Please refer to the website of the Nordic RSC
- https://nordic-rsc.net/related-projects/
- Or contact us by email: ccm@nordic-rsc.net



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Questions?

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Nordic RSC

NorCap implementation timeline

2019.12.12

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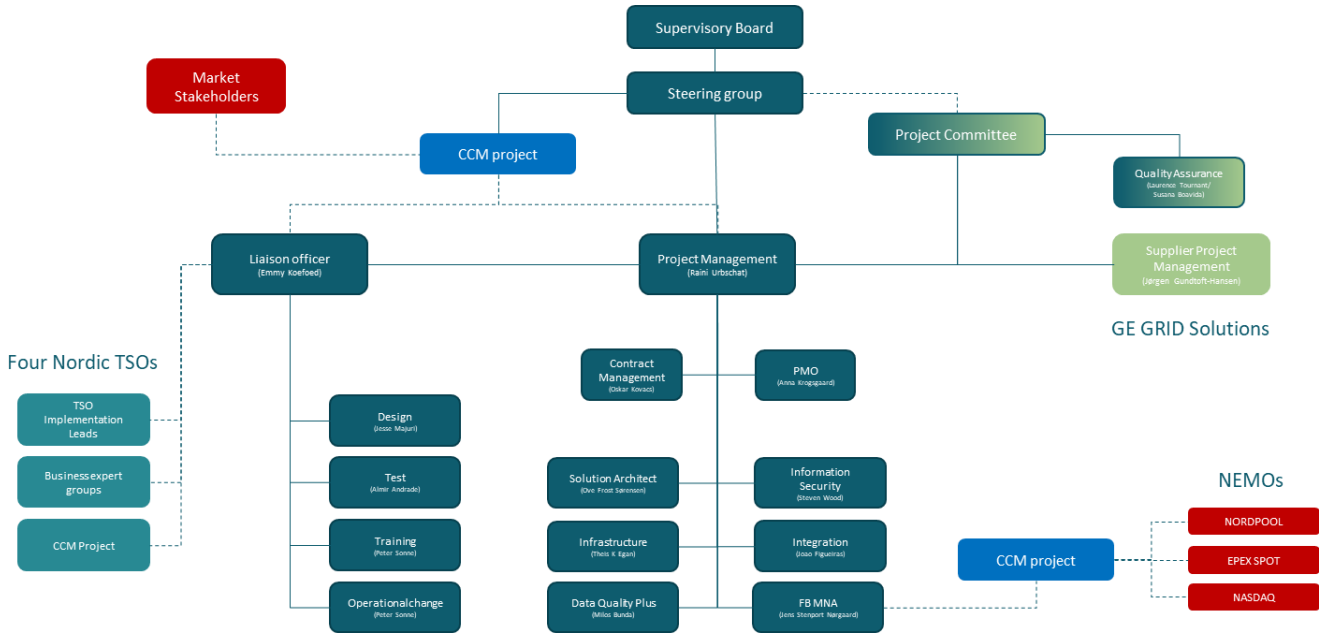
Presentation

1. Short introduction
2. NorCap implementation project (Scope)
3. Stepwise implementation
4. Implementation timeline
5. Questions

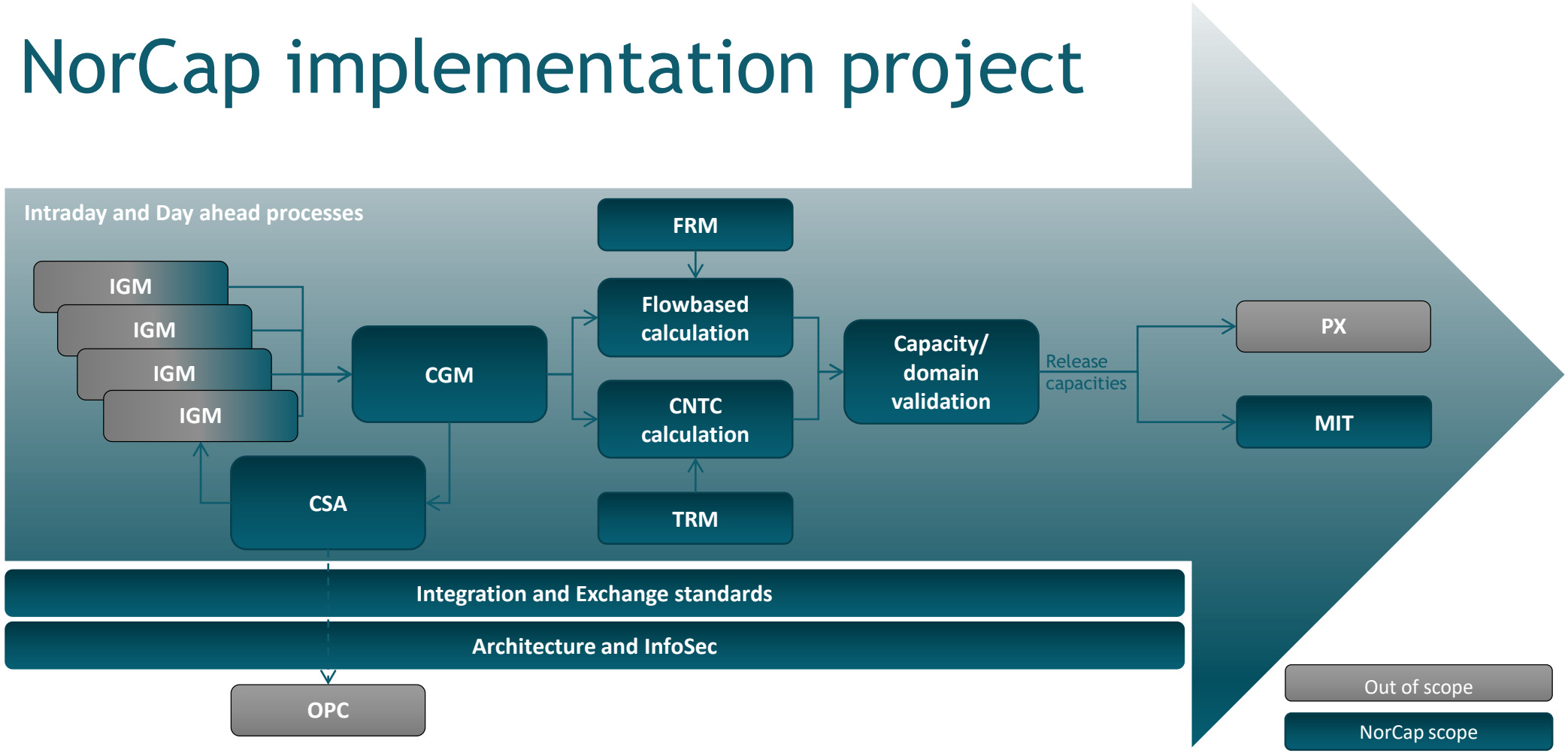
Short introduction

For those of you who don't know me:
My name is Raini Urbschat

- Employed by Nordic RSC to support the transition to operation
- Procurement lead to support the procurement of the NorCap IT application
- Project Manager of the NorCap implementation project
- I'm trying to keep track of this organization within Nordic RSC ☺ →



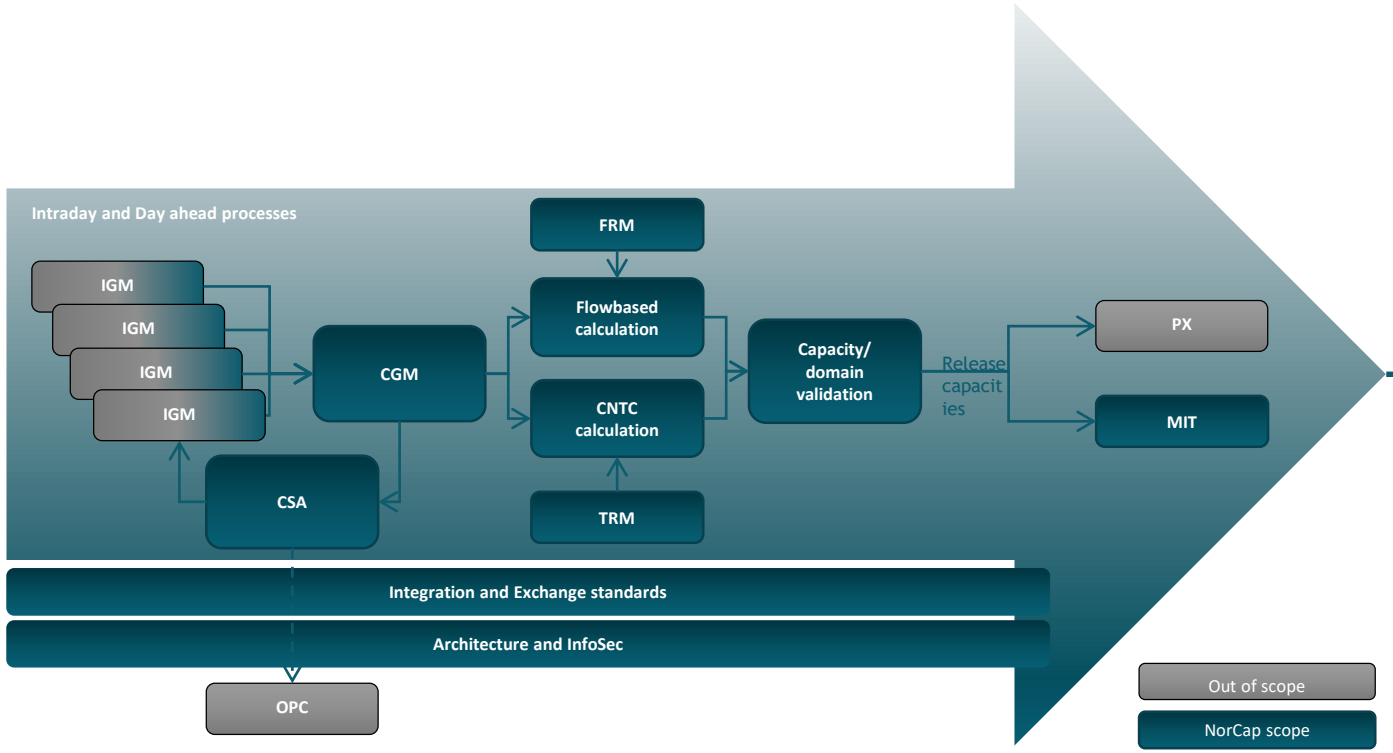
NorCap implementation project



IGM = Individual Grid Model
CGM = Common Grid Model
CSA = Coordinated Security Analysis

CNTC = Coordinated NTC
FRM = Flow Reliability Margins
TRM = Transfer Reliability Margins

PX = Power Exchanges
MIT = Market Information Tool
OPC = Outage Planning Coordination



Out of scope

NorCap scope

Stepwise implementation of the NorCap IT Application

Proof of Concept

- CGM
- Flowbase

Intermediate release

- CGM

Allowing us to work more structured with Data Quality Improvement

Major Release 1

- CGM
- Flowbase
- Domain Validation

(Minimal Viable Product)

Major Release 2

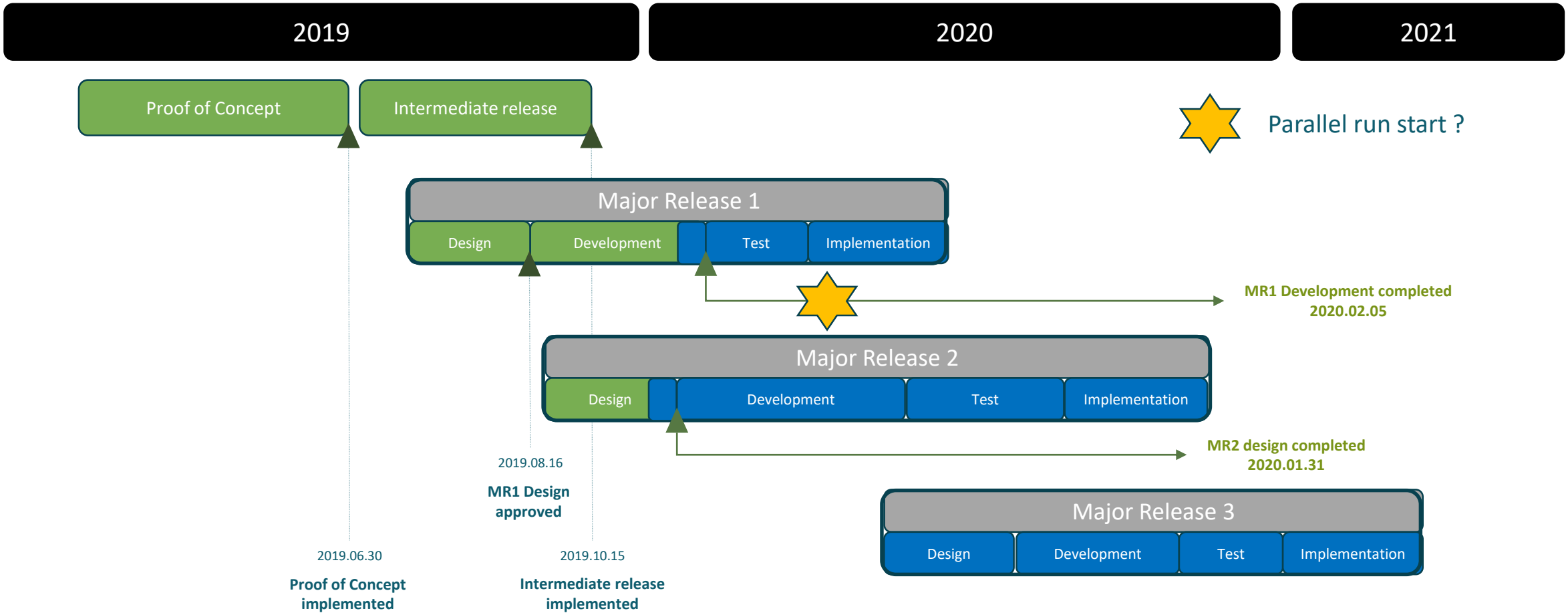
- CGM
- Flowbase
- Domain Validation
- PX integration
- MIT

(First version of NorCap)

Major Release 3

- FRM
- CSA
- CNTC
- TRM

Implementation timeline (working assumption)



Timeline risks

- The number of stakeholders involved
- Implementation of CGMES is still ongoing
- Flowbased methodology is new
- New IT development methods are used

NORDIC RSC

Any questions

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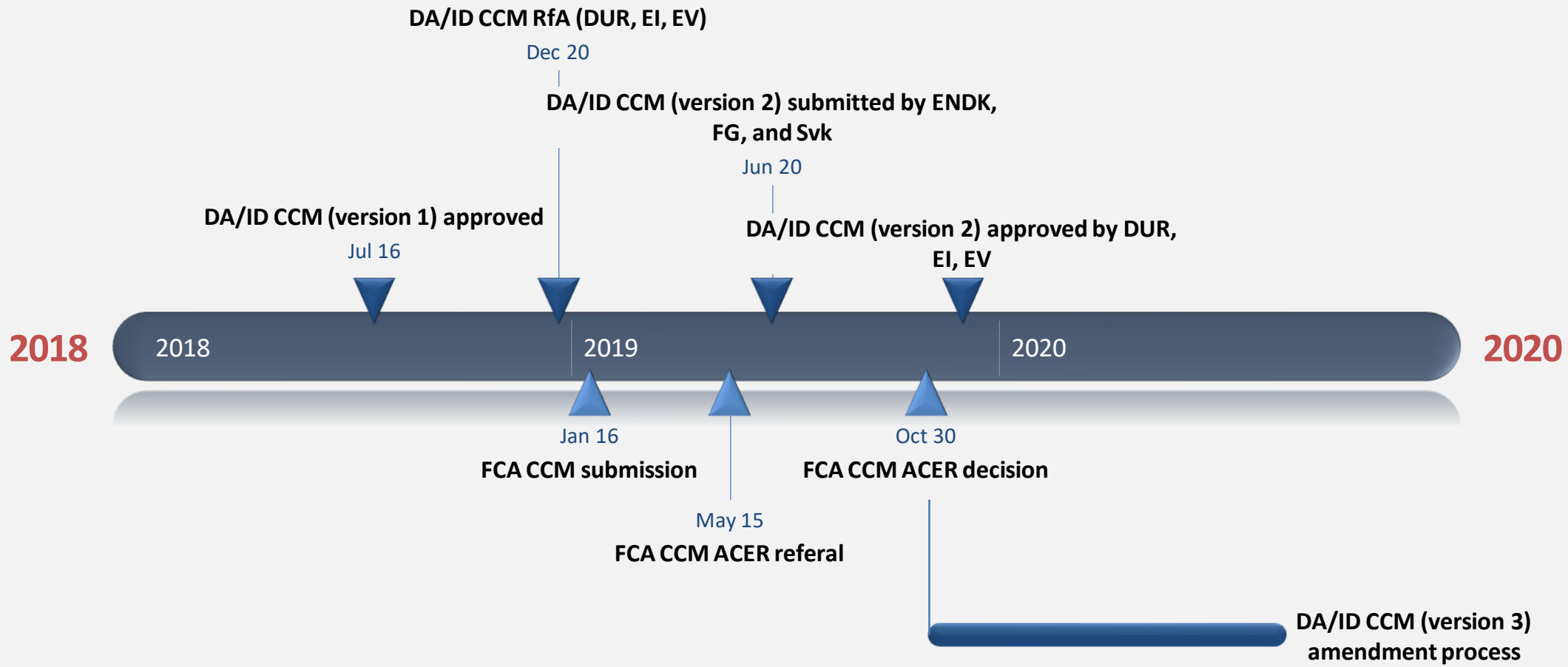
Nordic LT, DA, ID CCM development and approval



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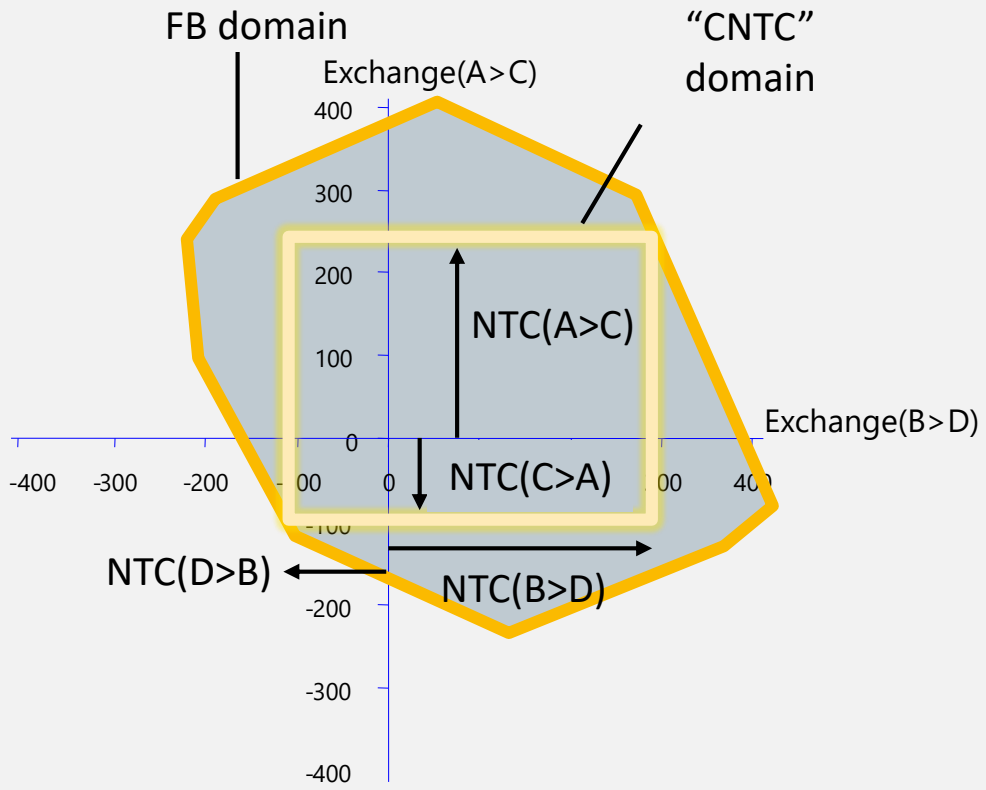
Original Nordic TSO LT CCM proposal: CNTC

- In the FCA GL, the CNTC methodology is the default capacity calculation approach
- The Nordic TSOs proposed a CNTC LT capacity calculation methodology, where
  - ✓ A linearized security domain (i.e. FB domain is assessed) first, and
  - ✓ A CNTC domain is extracted from that
- As there are many CNTC domains that can be extracted from the FB domain, the CNTC extraction is based on an optimization



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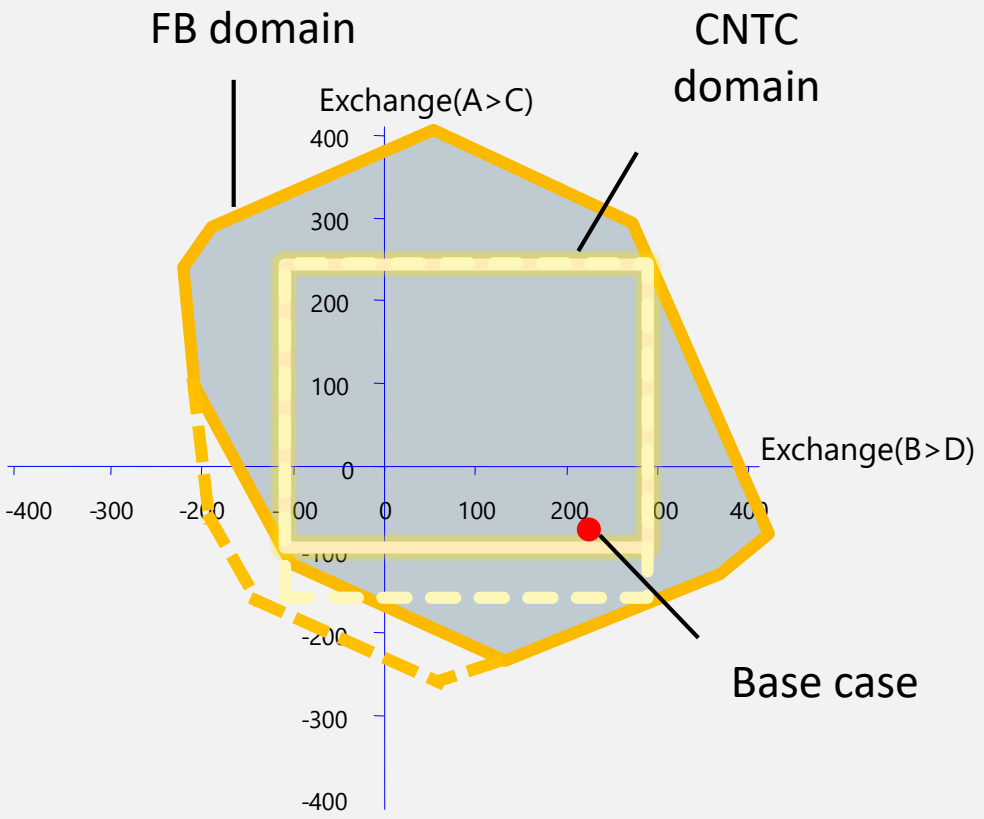
Original Nordic TSO LT CCM proposal: CNTC

- CNTC characteristics
  - ✓ CNTC is a “limited / not-so-detailed” way to represent grid limitations
  - ✓ All CNTC capacities are simultaneously feasible
- Due to these characteristics, the fear is that the CNTC domain, that is extracted from a FB domain, is too restrictive (compared to today’s values)
- Therefore, relaxation of the FB domain is considered for the CNTC extraction
  - ✓ This comes at a price: the CNTC domain “sticks” out of the FB domain and may cause an operational risk.



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Original Nordic TSO LT CCM proposal: CNTC

For example: Sum of weighting factor*NTC

Maximize $f(TTC)$

Subject to

$$g_j\left(\sum_n TTC^n * PTDF_j^n\right) \leq h_j(RAM_j) \qquad \forall j \in \{All\ CNEs\}$$

To include „relaxation“, and to allow the CNTC domain to stick out of the FB domain

Where:

f = a function defining the weight for each border in the optimization

g_j = a function defining the weight of each trade in the total flow on CNE j

h_j = a function defining the scaling of CNEs in non-relevant market directions

TTC^n = maximum allowed power exchange on bidding zone border n

TTC = a vector of maximum allowed power exchanges for all borders

$PTDF_j^n$ = zone-to-zone PTDF for bidding zone border n

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ACER's decision on the Nordic LT CCM: FB

- On May 15, Nordic NRAs referred the LT CCM to ACER
  - ✓ NRAs have a different interpretation of "what constitutes a CNTC and what constitutes a FB methodology"
- ACER amended the LT CCM, and iterated with TSOs and NRAs in weekly conference calls
- ACER decided on October 30 (Decision 16/2019) to approve the Nordic LT CCM (see embedded documents FYI)
- ACER decided on a FB Nordic LT CCM:

> (35) According to the CACM Regulation, the CNTC approach was never meant to be applied in a meshed transmission network, because it is extremely difficult efficiently to define simultaneously feasible NTC values for highly interdependent borders as is the case for the Nordic CCR. Therefore, the Nordic CCR should ideally apply a flow-based approach

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ACER's decision on the Nordic LT CCM: FB some highlights

Original Nordic TSO proposal

- CNTC
  A linearized security domain (i.e. FB domain is assessed) first, and a CNTC domain is extracted from that
- Optimization-based CNTC extraction
- Dynamic constraints as CNEs (as so-called PTCs: Power Transfer Corridors)
  This means that the dynamic analysis can be performed by the TSO
- Advanced hybrid coupling is part of the CCM
- Publication of data as in the Nordic DA/ID CCM

ACER decision

- FB
  FB with ATC extraction as intermediate solution until a FB LT allocation is supported by the service provider (the terminology CNTC is not used)
- Optimization-based CNTC extraction (**unchanged**)
- Dynamic constraints as allocation constraints
  This means that the dynamic analysis can be performed by the TSO
- Advanced hybrid coupling is part of the CCM (**unchanged**)
- Publication of data has been extended and aligned to that of the ACER decision on the Core DA/ID CCM

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ACER's decision on the Nordic LT CCM: FB some highlights

Amendment of the LT CCM / actions required within 18 months after implementation of the methodology

- Amend the CCM by including the **method for assessing the economic efficiency of including internal network elements** (combined with the relevant contingencies) in the long-term capacity calculation.
- Amend the CCM - in case the concerned Nordic TSOs cannot find and implement a more efficient solution than the applied **combined dynamic constraint -** by:
  (a) the technical and legal justification for the need to continue using the combined dynamic constraint indicating the underlying operational security limits and why they cannot be transformed efficiently into maximum flow on specific CNECs;
  (b) a detailed methodology to calculate the values of the combined dynamic constraints.
- Amend the CCM by **further harmonizing the generation shift key methodology**.
- Amend the CCM by including the description and definition of the functions used in the **ATC extraction**.

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Amendment process of the DA/ID CCM

- The “Version 2” DA/ID CCM - being the amended DA/ID CCM following the RfA from DUR, EI, and EV – has been approved by the three NRAs

- The Nordic TSOs are in the process of amending the DA/ID CCM (“Version 3”), **in line with the LT CCM**
- This amended DA/ID CCM is to replace fully the earlier two versions
- The public consultation of this amended DA/ID CCM is expected to start in January 2020

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Amendment process of the DA/ID CCM
Some highlights

- FB ID, with ATC extraction as intermediate solution until a FB ID allocation is supported by the service provider
- Publication of data as proposed by ACER for the LT CCM
- Dynamic constraints as allocation constraints
- 18 months after DA/ID CCM implementation, amend the CCM by including the method for assessing the economic efficiency of including internal network elements
- Economic efficiency test and operational security test for the application RAs will be removed in the light of the previous bullet, and the Regulation 943/2019

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MIT, Background

CACM, Art. 20

> 9. The TSOs of each capacity calculation region applying the flow-based approach shall establish and make available a tool which enables market participants to evaluate the interaction between cross-zonal capacities and cross-zonal exchanges between bidding zones.

- The interpretation of this has been discussed in previous stakeholder meetings
- Capacity data will be made available on a web platform, available at the start of ||-run
- The platform will support three means of accessing data;
  1. Through web browser
  2. Through download of excel file(s)
  3. Through Application Programmable Interface (API) – “machine-to-machine”

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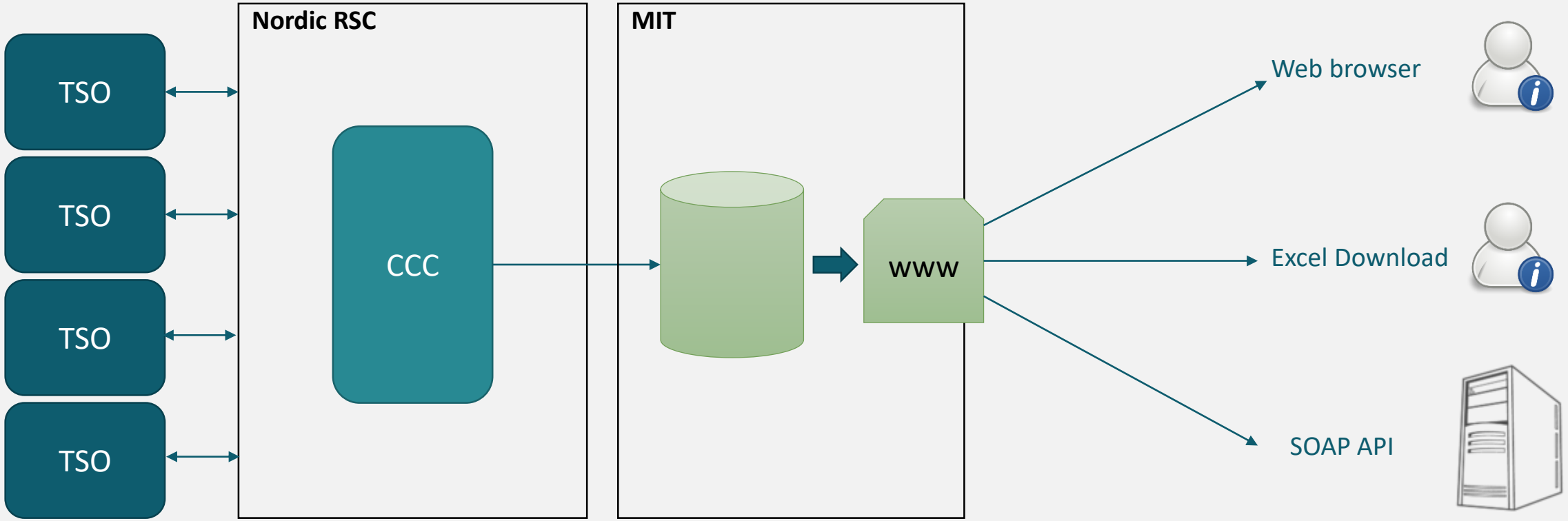
MIT, Conceptual view



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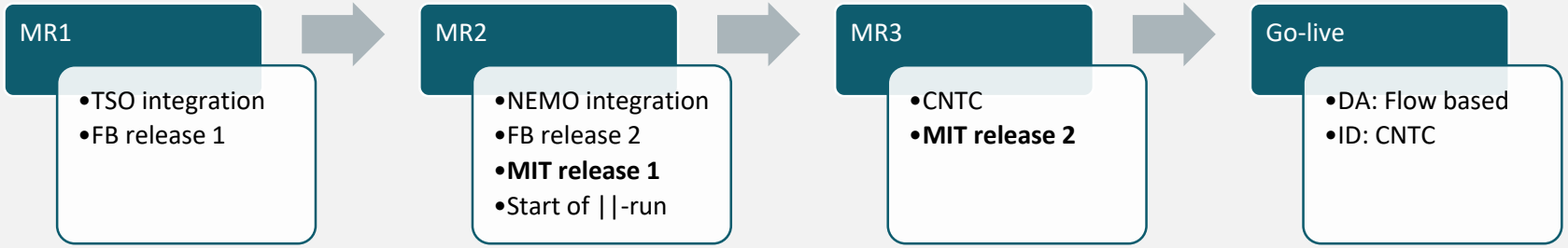
MIT Development

- MIT will be released in phases (as similiar to the entirety of the implementation)
- R1 will not contain any CNTC calculations (or presenting FB domain as ATC)
- Release 2 (R2) will make available both CNTC representation of DA FB domain, as well as starting ID CNTC domain
- Future discussion will be held on what to be published on ”Nordic MIT” and on ”European Transparency Platform”



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MIT, Interactive graphical view (conceptual)

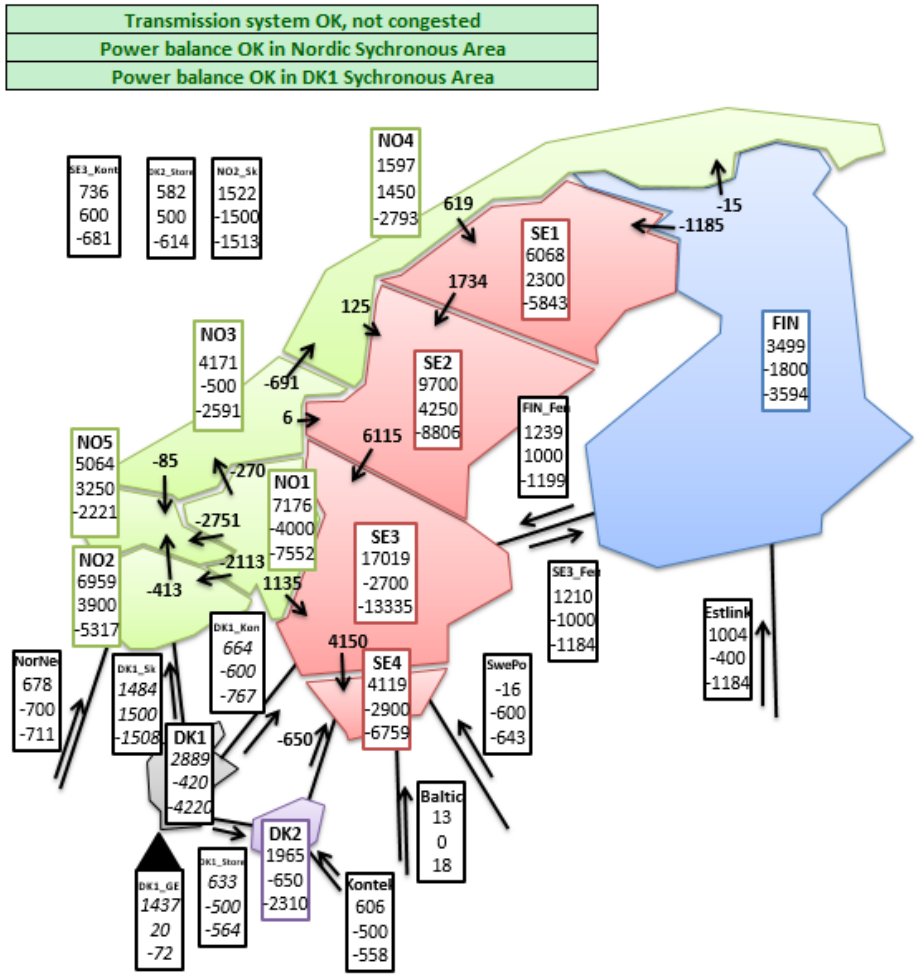
EDD
2019-10-05

MTU
03:00 - 04:00

Market Time Frame
D-2

Interactive

Test custom NPs:			
Bidding zone	Min NP	NP	NP
NO1	-7552	-4000	7176
NO2	-5317	3900	6959
NO3	-2591	-500	4171
NO4	-2793	1450	1597
NO5	-2221	3250	5064
SE1	-5843	2300	6068
SE2	-8806	4250	9700
SE3	#####	-2700	17019
SE4	-6759	-2900	4119
DK2	-2310	-650	1965
FIN	-3594	-1800	3499
DK1	*-4220*	*-420*	*2889*
DK1_KontiSkan	*-767*	*-600*	*664*
SE3_KontiSkan	-681	600	736
DK1_Skagerrak	*-1508*	*1500*	*1484*
NO2_Skagerrak	-1513	-1500	1522
DK1_Storebælt	*-564*	*-500*	*633*
DK2_Storebælt	-614	500	582
DK2_Kontek	-558	-500	606
FIN_Estlink	-996	-400	1004
FIN_FennoSkan	-1199	1000	1239
SE3_FennoSkan	-1184	-1000	1210
NO2_NorNed	-711	-700	678
SE4_Baltic Cable	18	0	13
SE4_SwePol Link	-643	-600	-16
DK1_GE	*-72*	*20*	*1437*
Power Bal. Nordic Synch. Area		0	
Power Bal. DK1 Synch. Area		0	
Congested?		No	



Also, an interactive data view is developed, where changes in net positions are shown as changes in RAM

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MIT Data, General Domain information

Information	MR1	MR2	MR3
Base case net positions		✓*	
Min/max possible net positions		✓	
FB domain transformed into CNTC parameters			✓
Min/Max bilateral exchange		✓	
GSK strategies used for each BZ		✓	
Allocation Constraints, with constraining TSO		✓	
Indication of whether results stem from fallback (or extrapolation)		✓	

* Will be published ex-post, with a delay of 7 days

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MIT Data, CNEC data per MTU (FB Domain)

Information	Description	MR1	MR2
Sending TSO	The TSO that has submitted the constraint		✓
CNEC Name	The name of the constraint		✓*
CNE Name	The name of the critical network element that is monitored		✓*
Contingency Name	The name of the contingency that is studied (if any)		✓*
From/To BZ	The bidding zones of each terminal of the critical network element		✓
RAM (MW)	Remaining Available Margin		✓
RAM (% of Fmax)	Remaining Available Margin as percentage of Maximum admissible flow		✓
FRM (MW)	Flow Reliablity Margin		✓
Fref (MW)	Reference flow in base case CGM		✓**
Fref' (MW)	Linearized reference flow, adjusted to zero net positions		✓
FAV (MW)	Final Adjustment Value (operator adjustment)		✓
RA (MW)	The increased amount of capacity given from remedial action(s)		✓
Fmax (MW)	Maximum admissible physical flow		✓
F_AAC (MW)	Flow on element, due to already allocated capacity in a previous timeframe		✓
PTDF for each BZ	Power Transfer Distribution Factors		✓

* Will only be published for Energinet & Fingrid data, due to security laws in Sweden & Norway

** Will be published ex-post, with a delay of 7 days

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