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Flow-Based Market-Coupling in EMPS

User meeting 2025
Ole Martin Hansen



Technology for a better society

Presentation overview

1. FBMC in EMPS

- Introduction of Flow-Based Market-Coupling
- Overview
- Method
- New input and results

2. FBMC in LtmApi

Introduction - FBMC

- New capacity calculation method (CCM) for the day-ahead market - live in october 24
 - Replaced the Net Transmission Capacity (NTC) method
- Why?
 - More sophisticated method than the NTC
 - Better utilization of the grid
 - Increases the systems social welfare
 - Provides transparency of grid info
- How?
 - Physical limits in the grid
 - Based on available margin on Critical Network Elements (CNE) and Power Transfer Distribution Factors (PTDF) for the CNEs in relevant Bidding Zones
 - Describes how the change in Net Position of a bidding zone influence the flow on the CNEs

History - FBMC in EMPS

- More grid information available to producer
- **Vannfly 2020-2023:**
 - Knowledge building research project at SINTEF Energy
 - Main delivery: **prototype FBMC functionality in EMPS**
- Operationalisation of FBMC 2024
 - Main delivery: official **FBMC functionality in EMPS**

Overview - FBMC in EMPS

- EMPS simulation
- Released in LTM version 10.9
- Usage requirements:
- *Licenced functionality*
- *EMPS input file*



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Method: FBMC in EMPS

Objective: Minimise costs

Subject to:

$$\sum_{BZ} (\text{Net position}) = 0$$

NTC or FB constraints

- NTC constraints
 - Transmission corridors constrained by capacity limits
- *Economic power flow*
- FB constraints
 - CNEs constrained by RAM
 - Change in NP is described by PTDFs
- *Physical power flow*

Net position = sum of import/export in Bidding Zone

Consequence of new method

- FB constraints:
 - Change in structure requires building and solving a general *LP-problem*
- Solving general LP-problems is computationally demanding
- Additional EMPS results

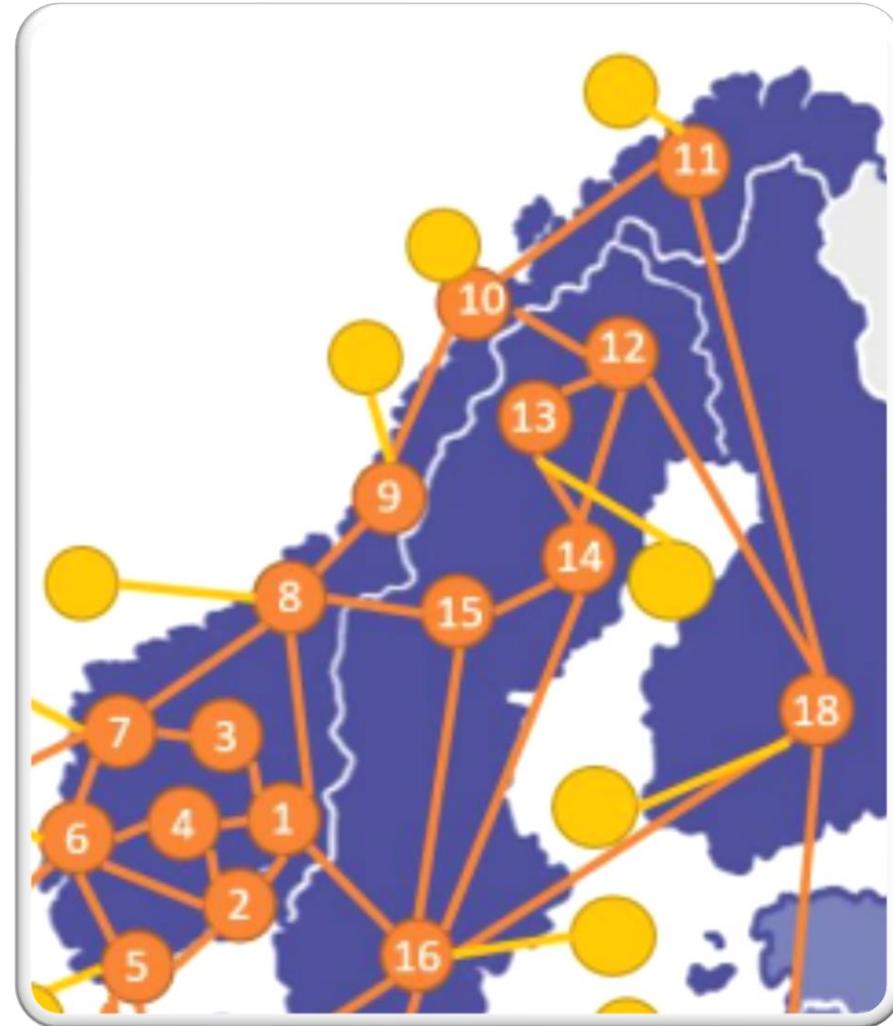
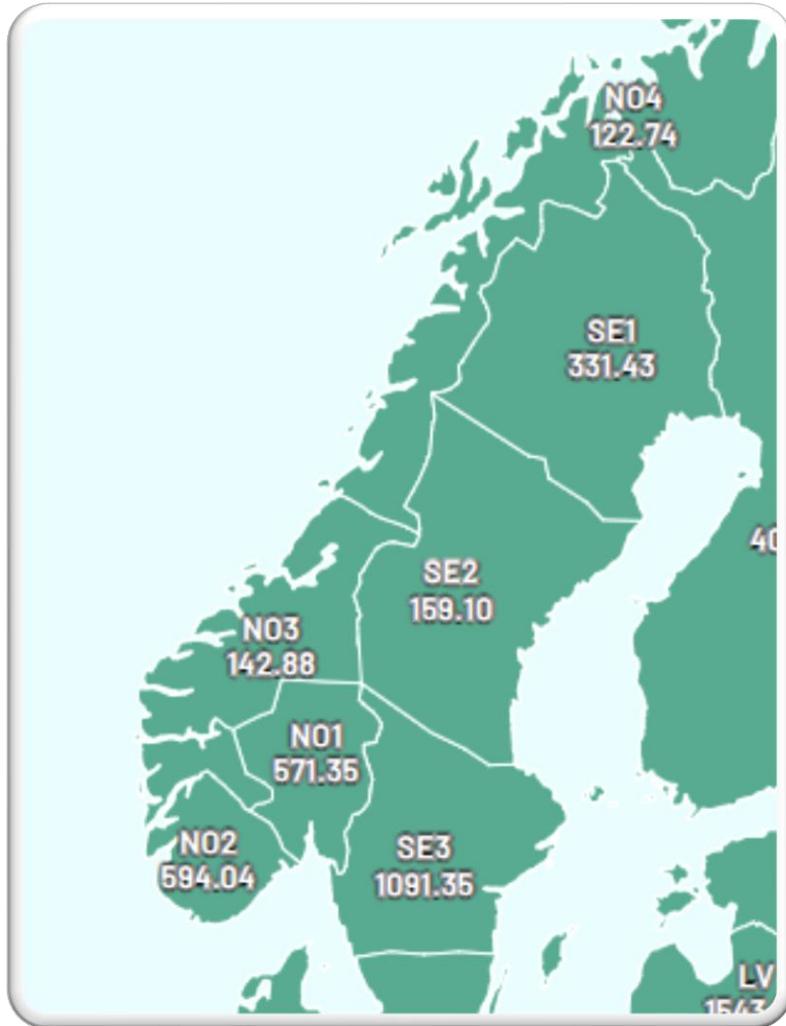
New data input

- FB parameters
 - PTDFs for all Bidding Zones (Flow distribution)
 - RAM for all CNEs (Flow constraint)
- Input can be provided by JAO publication tool*:
 - Data available on .json or .csv format
 - Hourly resolution



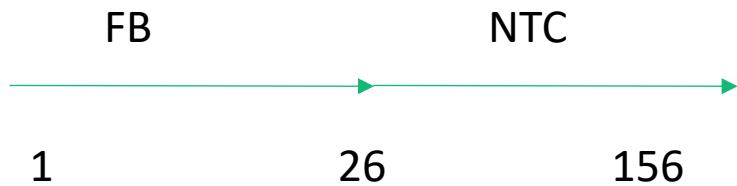
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AC grid, Bidding Zones and EMPS price areas



FBMC functionality options

1. Simulation speed up:
 1. Parallel processing
 2. Flexible use of FB and NTC constraints
 - FB constraints activated/deactivated for a defined periods
 3. Solver options: CPLEX and Coin



2. Scenario dependent FB-parameters



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Input and output

- Input:
 - ptdf_constraints.h5
- Output:
 - fbmc_stats.txt
 - fbmc.h5

CNEC

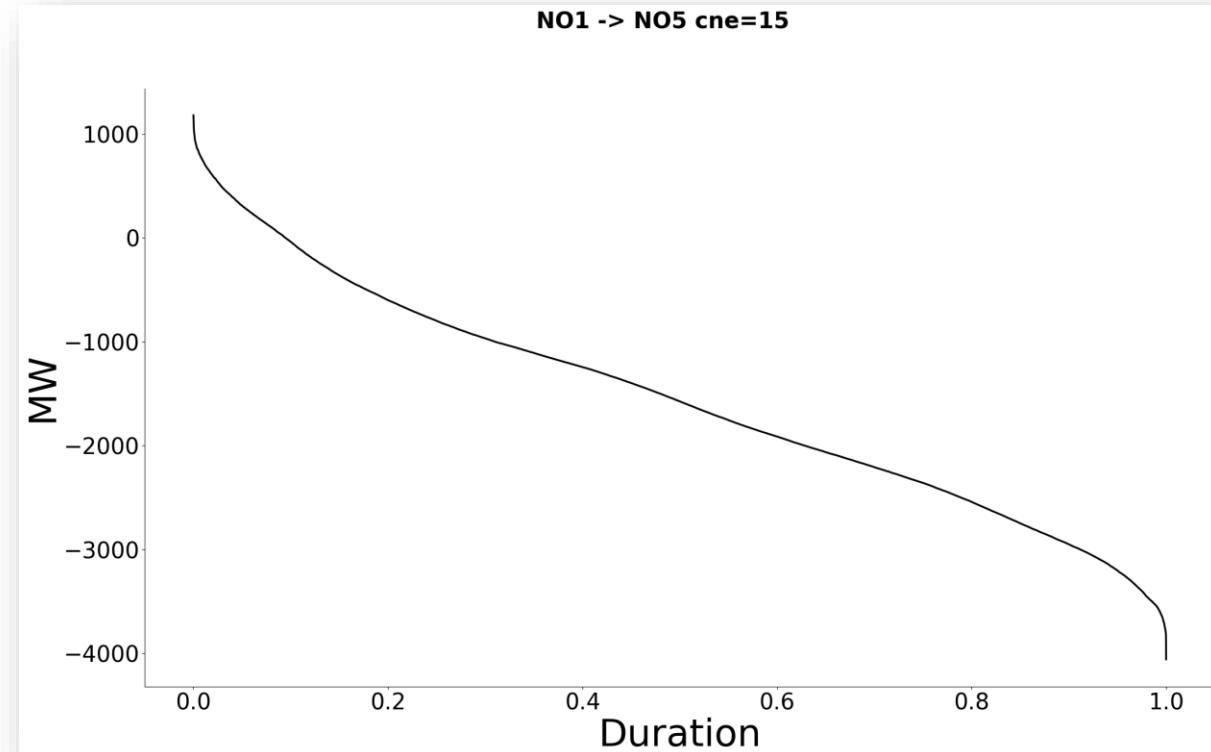
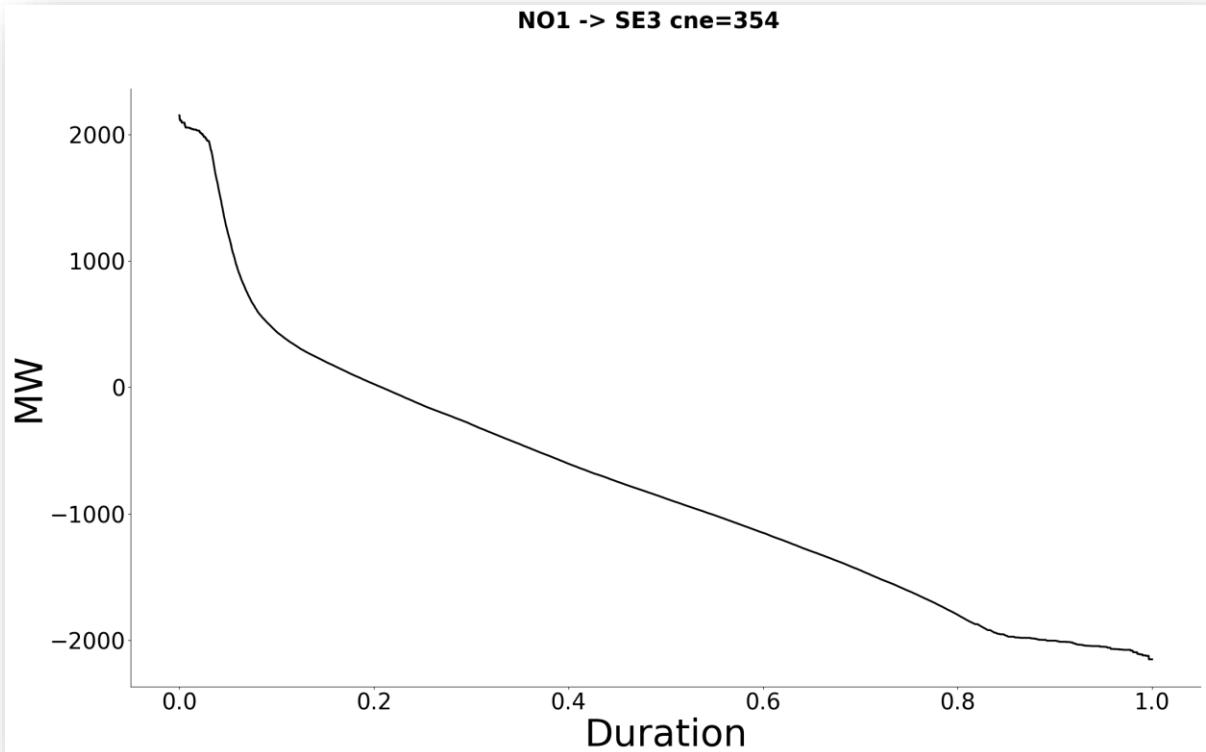
The screenshot shows the CNEC software interface. On the left, there is a file tree window titled "FBMC.h5" which contains "FBMC" and "dual values". Below the file tree is a list of icons. On the right, there is a table view titled "flow values at /FBMC/ [FBMC.h5 in D:\Dataset\NFE". The table has columns labeled 0, 1, and 2. The data starts with row 130, 0 = 82.12075. The table continues with 30 more rows of data. At the bottom of the table view, it says "dual values (1832, 2)" and "32-bit floating-point, 1413 x 30 x 52 x 56". A note at the bottom states "D = real/attribute to read/write".

	0	1	2
325	-64.58032	-511.7817	528.94116
326	-21.120747	-208.0869	187.27475
327	-545.8595	654.0702	711.61664
328	373.0	-263.71713	-373.0
329	-765.5762	25.391672	23.47774
330	-506.15814	641.2557	716.34186
331	638.80817	344.58368	91.3034
332	-21.962534	-200.33765	182.5048
333	-114.137794	-64.068825	-3.4961455
334	15.337131	154.88913	63.032795
335	-1282.0	1282.0	1282.0
336	-734.81494	136.87865	571.8713
337	683.3791	419.7872	113.506355
338	445.93112	-51.483097	-207.84602
339	-734.81494	136.87865	571.8713
340	-541.0138	420.9685	881.4049
341	0.0	0.0	0.0



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Example new results – physical flow on CNE(C)



Related projects - FBMC

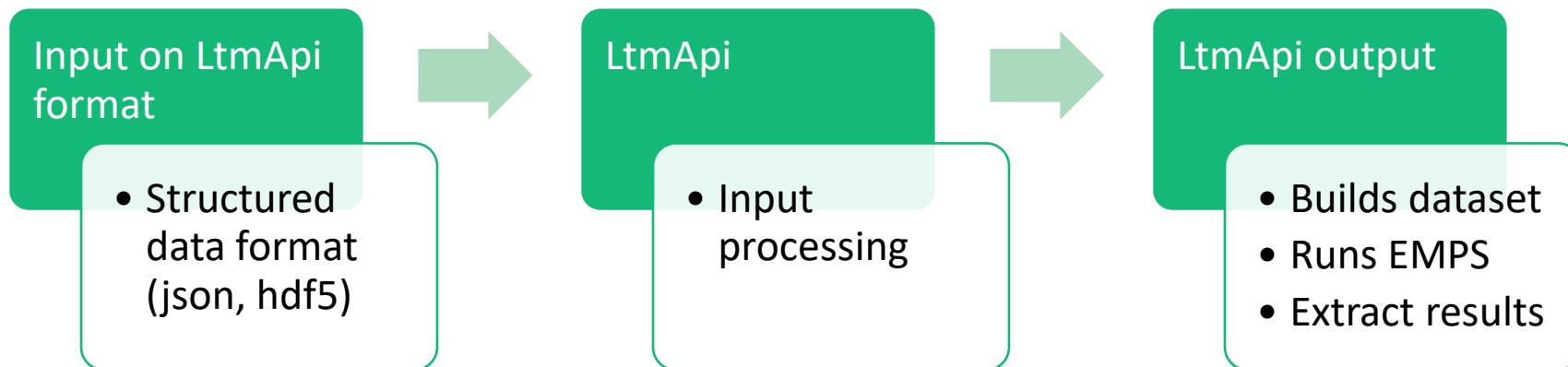
- Småstein – FB-parameters calculator based on EMPS results and open grid information
 - Input to EMPS
- NordenStein – project proposal

Summary

- FBMC functionality is available in EMPS
- Requires new input data
- Produces new results
- Increased simulation time (dependent on LP-solver, parallel processing, FB activation period, degree of details in dataset, etc...)

FBMC in the LtmApi

- LtmApi allows for building, running and extracting results using python





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EMPS input

Price
Areas

Hydro power

Market description

....

Busbars

Reservoirs

Hydro
plants

Aggregated
hydro
power

...

Market
steps

Loads

....

....

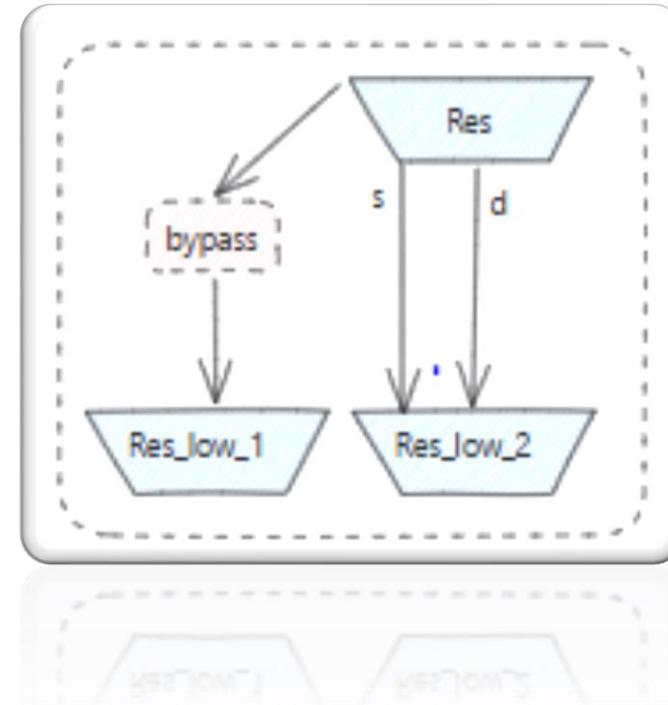
Api objects



LtmApi - input

- LtmApiModel description on structure data format (json)
 - Objects (Plants, Reservoirs, Batteries, DC-lines, Market_steps, Loads, Bidding Zones etc.)

```
{  
    "reservoirs": [  
        {"name": "UpperReservoir", [...]},  
        {"name": "LowerReservoir1", [...]},  
        {"name": "LowerReservoir2", [...]}  
    ],  
    "plants": [  
        {"name": "HydroPlant1", [...]}  
    ],  
    "bypasses": [  
        {"name": "Bypass1", [...]}  
    ],  
    "spills": [  
        {"name": "Spill1", [...]}  
    ]  
}
```



FBMC in LtmApi – additional input

Api objects

Bidding Zones

```
{  
    "#comment": "tev and battery",  
    "name": "N2",  
    "is_fbmc": true  
},  
{  
    "#comment": "otra",  
    "name": "N3",  
    "is_fbmc": true  
},  
{  
    "#comment": "HVDC numedal",  
    "name": "N1_hvdc",  
    "is_fbmc": true  
},  
{  
    "#comment": "HVDC tev",  
    "name": "N2_hvdc",  
    "is_fbmc": true  
},  
{  
    "#comment": "HVDC numedal"  
}
```

CNEs

```
{  
    "name": "N1-N2",  
    "cneName": "Test1",  
    "biddingZoneFrom": "N1",  
    "biddingZoneTo": "N2",  
    "active": {  
        "name": "",  
        "timestamps": [  
            "2025-02-13T00:00:00Z"  
        ]  
    },  
    "scenarios": [  
        [1]  
    ],  
    "ram": {  
        "name": "",  
        "timestamps": [  
            "2025-02-13T00:00:00Z"  
        ]  
    }  
}
```

- API can build CNE objects from JAO input!

Summary 2

- LtmApi for FBMC functionality is available
 - JAO API format support (json)
 - LtmApi FBMC input objects (Bidding Zones and CNEs)
- LtmApi extraction of FBMC output – *still in progress*
 - Physical flow on CNEs
 - Results summary



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Sintef dataset - 2030

FBMC input fra
uke 1 2023

57 areas

- 11 NO, 4 SE, 2 DK, FI
1, + UK and northern Europe

~1200 hydro
modules

3 hour time
resolution

52 weeks

30 scenarios

AC-grid:
NO,SE,DK2,FI

MASKENETT
2030