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Flow-Based capacity allocation add-on for the Balmorel model

Documentation and description of the Flow-Based add on developed for the Balmorel electricity market model

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Abbreviations

$CNTC$	Coordinated Net Transfer Capacity
Hub	Market region included in the Flow-Based add-on
CNE	Critical Network element
FB	Flow-Based
$PTDF$	Power Transfer Distribution Factor
RAM	Remaining Available Margin
Nex	Net export
TSO	Transmission System Operator
NTC	Net Transfer Capacity
P^+	Exported power flow
P^-	Imported power flow

The Flow-based capacity add-on

The Document provides an introduction into the Flow-based capacity allocation add-on for Balmorel model developed by Tallinn University of Technology in 2015. The FB capacity allocation model add-on consists of two major parts:

- Input data analyser and translator, designed to include input data from PSS/E output files
- The FB methodology implementation in the Balmorel model.

Background of Flow-Based capacity allocation methodology

The FB methodology is one of the two permissible methods of day-ahead and intra-day capacity allocation along with the CNTC method. So far, TSOs have mostly used the CNTC method to determine the transmission capacities. However, first implementations of the FB model have been successfully used in Central West Europe to determine the transmission capacities in the day-ahead market.

Testing indicates the FB capacity allocation model can provide improved utilization of the grid's capacity and thus is expected to be used by increasing number of TSOs. This creates the need for other European TSOs to prepare for possible implementation of the FB capacity allocation methodology. The add-on at hand aims to create the FB functionality in the Balmorel model, in which the FB capacity allocation has so far not been implemented. The Balmorel model is the main electricity market model used for TSOs in Estonia, Latvia and Lithuania. This makes developing the add-on a crucial for next steps in assessing the need to implement FB methodology for transmission capacity allocation in the Baltic countries.

Add-on mechanics in the model

The FB add on is implemented by two equations. The first one determines the value of $Nex_{Hub,T}$ for each of the simulated hours in the model. $Nex_{Hub,T}$ is a variable introduced in the FB model which holds the net exports of each of the FB hubs included in the FB model for each hour in the simulation. It is calculated for each of the FB hubs by summing all the outgoing power flows to

other hubs and subtracting incoming power flows by other hubs, as shown in equation 1. The value of the variable $Nex_{Hub,T}$ is then limited according to the PTDF matrix and critical element RAM values as is described in equation 2.

$$Nex_{Hub,T} = \sum (P^{+}_{Hub,T} - P^{-}_{Hub,T}) \tag{1}$$

$$PTDF_{Hub,CNE} \times Nex_{Hub,T} \leqslant RAM_{CNE} \tag{2}$$

When the FB add on is activated in the model, CNTC limits are automatically removed from between the Hubs which are represented in the FB add-on. The removal of the NTC restrictions and implementation of equations 1 and 2 are sufficient to implement the basic FB logic in the model.

Add-on implementation in the model

The FB logic introduced in the previous section and described by equations 1 and 2 has been written in GAMS code using Balmorel variables. Equations 3 and 4 describe the logic of equations 1 and 2 in GAMS code using variables in the Balmorel model.

QFBNEX(FBHUB,S,T)..

$$VFBNEX(FBHUB,S,T) = \sum_{IFBHUB} [VX\_T(FBHUB,IFBHUB,S,T) - VX\_T(IFBHUB,FBHUB,S,T)] \tag{3}$$

QFBLIM(FBLINE,S,T)..

$$FBPTDF\_VAR\_T(S,T,FBLINE,FBHUB) \times VFBNEX(FBHUB,S,T) \leqslant FBRAM(FBLINE) \tag{4}$$

In which $FBHUB$ is a subset of the Balmorel set RRR which represents the FB hubs in the model, and $IFBHUB$ is an alias set of $FBHUB$, which allows for flows between FB Hubs to sum up correctly. $VFBNEX$ is a new variable introduced to represent Nex. $FBPTD\_VAR\_T$ holds the PTDF matrix values for each hour, $FBRAM$ is a parameter containing the RAM limits. $FBLINE$ is a set of CNE in the model.

Third country exchange in the FB add-on

The developed add-on is compatible both $X3FX$ and $X3V$ third country simulation methodologies.

X3FX third country modelling

Third country modelling with the fixed X3FX power flows can be included in the FB add-on in three different ways. Firstly, it is possible to have the X3FX flows not be affecting the FB flows at all (the default way).

Secondly, its possible to take X3FX fixed flows into the FB Hubs into account when calculating *Nex* for each of the Hubs. To implement this option, the Hubs in which the X3FX flows should be taken into account when calculating *Nex*, should be added to the set $FBX3FXHUB$.

The last option is to simulate the X3FX flows to a FB Hub as another (unmodelled) FB Hub with fixed flows. This option is covered in the input data manipulation file *Datamine.xlsm*, as the X3FX flows are fixed and can be taken account before the modelling process. Using this method, the simulated Hub into which the X3FX flows are included, should also be added to the set $FBX3FXHUB$.

X3V third country modelling

Regions in X3V add-on can be taken into account in three ways. Firstly, its possible to have X3V regions in the model which do not affect FB flows at all and are not taken into account in any way in the FB add-on (the default option).

Secondly, it is possible to simulate an X3V hub as a common FB Hub. To implement this, a dummy region must be created in the model which will be included in the FB model. The X3V input data should be set for the dummy region, while $X3VQIM$ and $X3VQEX$ values should be sufficiently large to not be the limiting factors, as the flows will be limited by FB equation restrictions between the created dummy region and other FB Hubs. The created dummy region should have non-zero XKINI values defined with other relevant FB Hubs included in the model.

Thirdly, its possible to include the X3V third party flows into a simulated FB Hub without including the X3V third country to the FB model. To implement this, the X3V relevant X3V third region(s) from set $X3VPLACE0$ should be added to the subset $FBX3VHUB$ in the $FB\_DATA.inc$ input file.

List of input files

All the files included in the FB add on should be placed in folder \Model \base \addons \FlowBased.

Datamine.xlsm

Datamine.xlsm is the data translation tool designed to include PSS/E model output and produce the input files that will be included in the model. The functionality consist of three parts which can be accessed from the sheet “Import” by using the three buttons. *Import data* button reads the PSS/E output file and writes the relevant contents to the sheet “Table”. *Translate data* button transforms the relevant data into a PTDF matrix which will be shown in sheet “PTDF”. *Export data* button writes the output text files FB_Line.inc, FB_RAM.inc and FB_PTDF.inc

FB_Data.inc

FB_Data.inc is the main file handling data input. The input file FB_Data.inc should be included from Balmorel.gms. Within FB_Data.inc several other input files are automatically included and a portion of data manipulation is performed. In FB_Data.inc

FB_Line.inc

FB_Line.inc is included from the file FB_data.inc and contains the set FBLINE, which consists of all the critical network elements in the FB model used.

FB_PTDF.inc

FB_PTDF.inc is included from the file FB_data.inc and contains the PTDF matrix of the FB model used.

FB_RAM.inc

FB_RAM.inc is included from the file FB_data.inc and contains the RAM parameters of all critical network elements for the FB model used.

FB_Var.inc

The input file FB_Var.inc declares the necessary variables of the FB model. FB_Var.inc should be included straight from Balmorel.gms in the relevant section of the model.

FB_EQ.inc

FB_EQ.inc is responsible for the declaration of equations used in the FB add-on. It should be included from balmorel.gms in the equation declaration section of the model.

FB_Model.inc

FB_Model.inc contains the mathematical expressions of the equations used in the FB solution and should be included from balmorel.gms in the relevant part of the model.

FB_AddModel.inc

FB_AddModel.inc is responsible for adding the relevant equations to the BB3 model. It should be included from Balmorel.gms where the BB3 model is declared.

Using the add-on

For the add-on to function, it is necessary to add the option $*Setglobal FLOWBASED yes* to the balopt file. All the relevant input files should be in the add-on folder \Model \base \addons \FlowBased. The core file introducing new parameters, sets and including input files is *FB_DATA.inc*. The mentioned file also contains brief contents about the purpose of input data and files included.

Flow-Based add on testing

The implemented FB add-on has been tested under various market and model situations and has been found to be working as intended. Testing was performed with data provided by Capacity Allocating Service Company[2] for Central-Western Europe. A FB market calculation algorithm has been used for allocating flows between market regions in the Central-Western European system since the 5th May 2015. Parallel data is offered for countries included in the system, providing both FB data and NTC data for the same periods in time. This allows for testing runs between the FB and NTC method. The electricity market hubs involved in the tested FB model are France,

Germany, Holland and Belgium. Model runs both with NTC data and FB data are done and the results are compared with attention paid to interconnection utilization on an hourly basis.

The testing process has been successful. No drastic increase in model solving time has been detected. The add-on successfully ignores all the NTC restrictions between the hubs while enforcing new dynamic FB restrictions based on the PTDF and RAM input values. An example comparing allowed NTC power flows along with FB restrictions is shown in figure 1.

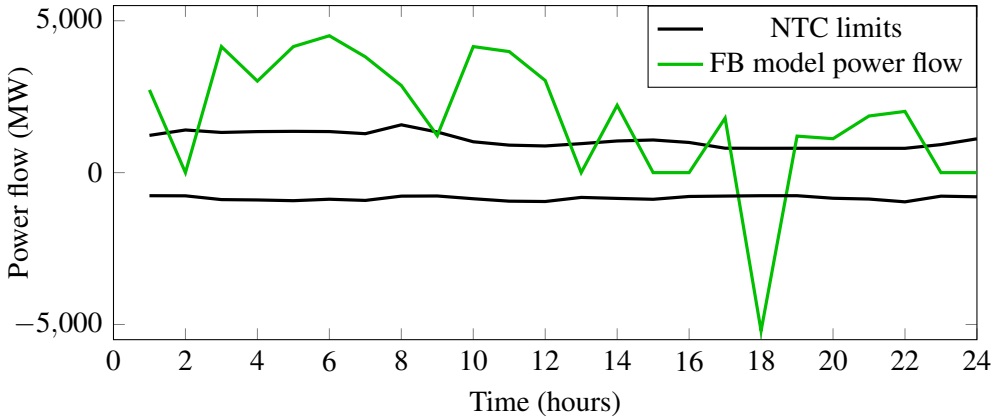

Figure 1: Comparison of power flows in NTC and FB models

It can be observed that the flows in the FB model go beyond the ones in the NTC limits, allowing for greatly improved efficiency of network utilization. Figure 2 depicts the net exports of two FB Hubs in a simulation and their respective Nex limitations derived from PTDF and RAM parameters.

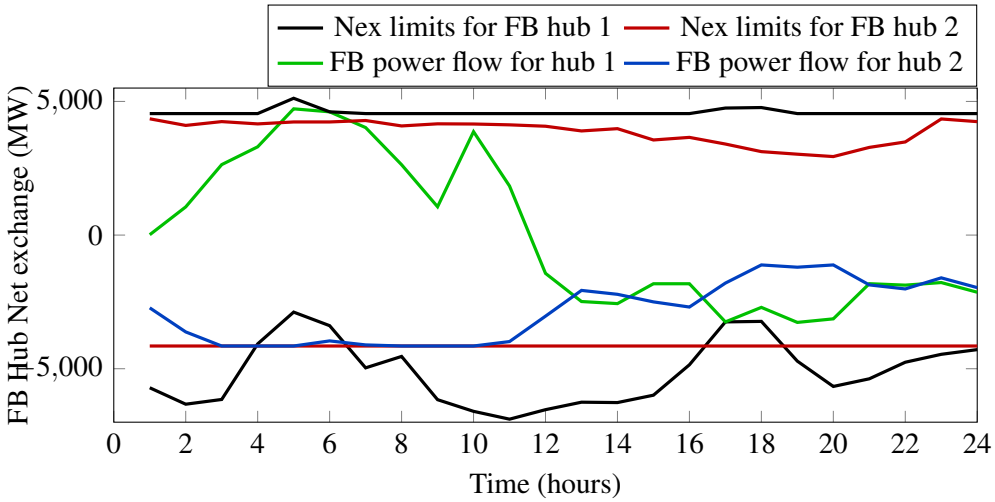

Figure 2: Nex and Nex limits in FB simulation

Figure 2 indicates that the net exchanges stay within feasible boundaries for both Hubs in the simulation. For hub 2, the FB net exchange limitations have been limiting flows in 6 of the simulated hours and for hub 1 the limitations have activated in 2 simulated hours.

Conclusion

After developing and testing the new FB framework in the Balmorel model, it has been concluded that FB logic is compatible with the Balmorel environment and works well in harmony with the equations already present in the model. Thus, the add-on development process has been successful.

Bibliography

[1] Retrieved from *http://balmorel.com/* dated on 15 Dec 2015

[2] Retrieved from *http://http://www.casc.eu/en/* dated on 17 Dec 2015