ACER
European Union Agency for the Cooperation of Energy Regulators

Annex IV – Methodological description of the modelling analysis conducted by ACER

(1) The modelling analysis consists of calculating a node-to-node power transfer distribution factor ('PTDF') matrix which constitutes a matrix mapping the power distribution factor:

(i). For a selected set of lines which constitute critical network elements with contingencies ('CNECs') which are located in Spain and in Italy:

a. The "base case" (i.e. no contingency or outage of another line) is also considered to be a CNEC for the purpose of this modelling analysis;

b. The contingency (or outage) is only taking place on a line in the same country as where the line constituting the critical network element ('CNE') is located.[1]

(ii). Given an exchange between two nodes constituting a 2-combination of selected nodes:

a. Either the exchange takes place between a node located in France and a node located in Italy;

b. Or the exchange takes place between a node located in France and a node located in Spain.

(iii). Given two sets of input data representing the state of the CE SA by representative common grid models at two different period of time t:

a. During the winter (state of the CE SA by representative common grid model on 15 January 2019 at 10:30 as generated by Convergence in two day-ahead on 13 January 2019 at 19:16);

b. During the summer (state of the CE SA by representative common grid model on 16 July 2019 at 10:30 as generated by Convergence in two day-ahead on 14 July 2019 at 21:02).

(2) All the matrices are generated for all the CNECs located in both Italy and Spain. On the other hand, a separate matrix will be generated for the set of 2-combination of nodes located in France and Italy and for the set of 2-combination of nodes located in France and Spain as well as for the two different periods of time t. Therefore, there will be four node-to-node PTDF matrices generated:

[1] Combining a line in Italy with an outage (a contingency) of a line in Spain (and vice-versa) is very similar to the base case scenario (i.e. without any outage/contingency).

- A node-to-node PTDF matrix for all the selected CNECs (rows of the matrix) in relation to an exchange taking place between a node located in France and a node located in Italy (columns of the matrix) given the state of the CE SA in winter on 15 January 2019 at 10:30;

- A node-to-node PTDF matrix for all the selected CNECs (rows of the matrix) in relation to an exchange taking place between a node located in France and a node located in Spain (columns of the matrix) given the state of the CE SA in winter on 15 January 2019 at 10:30;

- A node-to-node PTDF matrix for all the selected CNECs (rows of the matrix) in relation to an exchange taking place between a node located in France and a node located in Italy (columns of the matrix) given the state of the CE SA in summer on 16 July 2019 at 10:30;

- A node-to-node PTDF matrix for all the selected CNECs (rows of the matrix) in relation to an exchange taking place between a node located in France and a node located in Spain (columns of the matrix) given the state of the CE SA in summer on 16 July 2019 at 10:30.

(3) As regards the selection of lines (CNECs), ACER (i) only considered all the lines located in Italy and Spain operating at nominal voltage higher than or equal to 380 kV included in the common grid models and (ii) calculated, for each of these lines, the Line Outage Distribution Factors ('LODFs'). LODFs represent the sensitivity of the active power flow due to the topology changes (outages). They determine which outages are critical for the selected line. The selection criterion was to keep, for each line (i.e. in the base case, without contingency), only outages leading to an absolute value of the LODF greater than or equal to 5%.

- LODFs are a function of the nodal PTDFs. The LODF matrix has a row for each critical network element and a column for each contingency. An element $LODF_{l,k}$ gives the change in power flow through line *l* in case of an outage of line k.

- The nodal PTDF matrix describes the linear relation between the net power injections into the grid and the active power through the lines. The nodal PTDF matrix has a row for each line in the network and a column for each node. An element $PTDF_{l,k}$ gives the change in power flow through line *l* caused by an additional injection of 1 MW at node *k* and a withdrawal of the same amount at the reference node.[2]

- LODF values are calculated separately for Italy and Spain as well as for the two different periods of time (winter and summer). The only input necessary to calculate these LODF values are the topology of the network (i.e. which lines are connected to which nodes) and the electrical reactance of the lines expressed in

[2] This reference node may be chosen arbitrarily in the network as the resulting DC load flow does not depend on this selection. Only one node in the network is given this role of reference node. This comes from the constraint, based on Kirchhoff's law, for which the sum of all injections and withdrawals across the whole network has to be zero.

Ω (ohms). More precisely, the exogenous variables necessary for the calculation which are extracted from the common grid model are the following: [3]

- For the nodes: (i) Node (code); (ii) Node type code; and (iii) Voltage.
- For the lines: (i) Node 1 (code); (ii) Node 2 (code); and (iii) Reactance X (Ω).

- The total number of possible CNECs were:
  - Under the winter scenario: 99.856 Spanish CNECs and 113.569 Italian CNECs (i.e. a total of 213.425 for both Spain and Italy);
  - Under the summer scenario: 99.856 Spanish CNECs and 114.244 Italian CNECs (i.e. a total of 214.100 for both Spain and Italy).
- There were only 20.482 CNECs under the winter scenario and 12.137 CNECs under the summer scenario with a LODF larger than 5%.
- Based on these selected CNECs, nodal PTDFs for French, Italian and Spanish nodes were then calculated in order to generate node-to-node PTDF matrices.

(4) As regards the selection of the nodes, ACER only considered all the PU (or PV) nodes (i.e. nodes with a constant active power generation and a constant voltage, generally representing generation units) located in France, Italy and Spain operating at nominal voltage higher than or equal to 380 kV as included in common grid model:

- Under the winter scenario: there are 67 selected nodes in France, 46 selected nodes in Italy and 73 selected nodes in Spain, leading to:
  - 3.082 combination for the exchange between a node located in France and a node located in Italy;[4]
  - 4.891 combination for the exchange between a node located in France and a node located in Spain.[5]
- Under the summer scenario: there are 56 selected nodes in France, 42 selected nodes in Italy and 69 selected nodes in Spain, leading to:
  - 2.352 combination for the exchange between a node located in France and a node located in Italy;[6]
  - 3.864 combination for the exchange between a node located in France and a node located in Spain.[7]

[3] See UCTE data exchange format for load flow and three phase short circuit studies, pp. 7-8.
[4] 3.082 = 67 * 46
[5] 4.891 = 67 * 73
[6] 2.352 = 56 * 42
[7] 3.864 = 56 * 69

- Using an exchange between two cross-border nodes which are both generation units reflects the idea of using remedial actions (countertrading or redispatching) where the production at one node is increased and the production at the other node is decreased.

(5) As regards the calculation of the node-to-node PTDF matrices, this calculation takes place in two steps:

- First step: for each scenario (winter and summer), a nodal PTDF matrix is created for the selected nodes of each country:
    - Under the winter scenario:
        - the nodal PTDF matrix of France consists of 20.482 rows (the selected CNECs for both Italy and Spain) and 67 columns (the selected nodes for France);
        - the nodal PTDF matrix of Italy consists of 20.482 rows (the selected CNECs for both Italy and Spain) and 46 columns (the selected nodes for Italy);
        - the nodal PTDF matrix of Spain consists of 20.482 rows (the selected CNECs for both Italy and Spain) and 73 columns (the selected nodes for Spain).
    - Under the summer scenario:
        - the nodal PTDF matrix of France consists of 12.137 rows (the selected CNECs for both Italy and Spain) and 56 columns (the selected nodes for France);
        - the nodal PTDF matrix of Italy consists of 12.137 rows (the selected CNECs for both Italy and Spain) and 42 columns (the selected nodes for Italy);
        - the nodal PTDF matrix of Spain consists of 12.137 rows (the selected CNECs for both Italy and Spain) and 69 columns (the selected nodes for Spain).
    - The only input necessary to calculate these nodal PTDF matrices are the topology of the network (i.e. which lines are connected to which nodes) and the electrical reactance of the lines expressed in Ω (ohms). More precisely, the exogenous variables necessary for the calculation which are extracted from the common grid model are the following: [8]
        - For the nodes: (i) Node (code); (ii) Node type code; and (iii) Voltage.

[8] See UCTE data exchange format for load flow and three phase short circuit studies, pp. 7-8.

- For the lines: (i) Node 1 (code); (ii) Node 2 (code); and (iii) Reactance X (Ω).

- Second step:
  - For each scenario (winter and summer), the node-to-node PTDF matrix is calculated by subtracting:
    - the nodal PTDF matrix of France from the nodal PTDF matrix of Italy;
    - the nodal PTDF matrix of France from the nodal PTDF matrix of Spain.
  - This results in four nodal-to-nodal PTDF matrices:
    - Under the winter scenario:
      - a matrix consisting of 20.482 rows (the selected CNECs for both Italy and Spain) and 3.082 columns (the exchange between a node located in France and a node located in Italy);
      - a matrix consisting of 20.482 rows (the selected CNECs for both Italy and Spain) and 4.891 columns (the exchange between a node located in France and a node located in Spain).
    - Under the summer scenario:
      - a matrix consisting of 12.137 rows (the selected CNECs for both Italy and Spain) and 2.352 columns (the exchange between a node located in France and a node located in Italy);
      - a matrix consisting of 12.137 rows (the selected CNECs for both Italy and Spain) and 3.864 columns (the exchange between a node located in France and a node located in Spain).
  - Subtracting two nodal PTDF matrices enables to illustrate the impact of a bilateral exchange between two nodes. As a balanced exchange between the two nodes is assumed, it does not lead to a change (withdrawal) at the reference node and, therefore, its dependency/location is cancelled out in the node-to-node PTDF matrix.