Appendix 1

Methodology for the Calculation of Linear Trajectories

Table of Contents

1. Introduction

This document presents a detailed description of the process of calculating the starting points of the linear trajectories of the annual growth of transmission capacity for the purposes of cross-zonal electricity trading, in order to achieve the CEP 70% target by 31 December 2015;

Owing to a much less complicated process of calculating starting points of linear trajectories for asynchronous interconnectors, the calculations for the Sweden-Poland and Lithuania-Poland border are described in the main document. This document covers a description of the methodology for synchronous interconnectors.

2. Methodology for the calculation of linear trajectory starting points for synchronous interconnectors

According to Article 15(2) of Regulation 2019/943, the starting point of the trajectory is the **capacity allocated** at the border or on a critical network element either:

- **the average in the calendar year before adoption of the action plan**

or

- **the average during the three calendar years before adoption of the action plan**,

whichever is higher.

The application of the Action Plan is assumed to start on 1 January 2020, and its adoption date falls at the end of 2019. Thus the basis for the calculation of the starting point is the average capacity allocated in 2018 and the average capacity allocated in 2016-2018.

The ACER Recommendation shows in Section 4.2 that a uniform and consistent monitoring approach should be taken to monitor the minimum levels of the margin available for cross-zonal trade (MACZT) and should consist in MACZT monitoring at the level of critical network elements and critical network elements associated with a contingency used in capacity calculation (CNE/CNEC) in all coordination areas, i.e. areas with different methods of calculating and allocating cross-zonal capacity and with different levels of coordination of those processes. Having regard to the provisions of the ACER Recommendation, the linear trajectories and their starting points have been calculated for each CNE/CNEC in accordance with the list of CNEs/CNECs defined by TSOs for synchronous interconnectors in the Polish bidding zone.

The process of calculating trajectory starting points is described in the steps below (Sections 2.1-2.5).

2.1. Assignment of reference grid models to individual hours of the analysed period

The calculation period (2016-2018) was divided into 7 timeframes. In each timeframe, a relevant ENTSO-E reference grid model was used. Table 1 contains a summary of the grid models used and the periods of their application.

Table 1. ENTSO-E reference grid models

season (s)	ENTSO-E reference grid model	application period
winter 2016	20160120_1030_RE3_UX2.uct	1.01.2016 – 31.03.2016
summer 2016	20160720_1030_RE3_UX3.uct	1.04.2016 – 31.10.2016
winter 2017	20170118_1030_RE3_UX5.uct	1.11.2016 – 31.03.2017
summer 2017	20170719_1030_RE3_UX0.uct	1.04.2017 – 31.10.2017
winter 2018	20180117_1030_RE3_UX3.uct	1.11.2017 – 31.03.2018
summer 2018	20180718_1030_RE3_UX4.uct	1.04.2018 – 31.10.2018
winter 2019	20190116_1030_RE3_UX2.uct	1.11.2018 – 31.12.2018

Source: PSE S.A.

According to the above table, if hour h belongs to a given application period defined in the right-hand column, zonal Power Transfer Distribution Factors (zonal PTDFs) are calculated on the basis of the model specified in the middle column. The assignment of a season to an hour is represented by $s(h)$.

2.2. Calculation of the value of zonal Power Transfer Distribution Factors for CNEs and CNECs

The values of seasonal zonal power transfer distribution factors (PTDFs) in N-0 and N-1 state[1], i.e. for CNE and CNEC elements respectively, are calculated on the basis of nodal PTDFs and the Generation Shift Key (GSK) matrix:

$$U_{i,z,s(h)} = \sum_{n} H_{i,n,s(h)} \cdot K_{n,z,s(h)}$$

where:

- $U_{i,z,s(h)}$ – represents the zone-to-slack PTDF reflecting the impact of the net position of a zone z on flow on a CNE/CNEC i in hour h
- $H_{i,n,s(h)}$ – represents the nodal PTDF reflecting the impact of change in generation in a node n on flow on a CNE/CNEC i in hour h
- $K_{n,z,s(h)}$ – represents the generation shift key (GSK) reflecting the impact of change in generation in a node n on a change of the net position of a zone z in hour h
- $s(h)$ – represents the season assigned to hour h (see Table 1 in Section 2.1)
- n – grid node

[1]N-1 state or situation means the situation in the transmission system in which one contingency from the contingency list occurred. N-0 state means the state of the transmission system where it is operating without contingencies.

Nodal PTDF matrixes (H) are calculated on the basis of grid model parameters calculated on the basis of reference grid models (see Table 1 in Section 2.1). Matrix H consists of PTDFs for N-0 and N-1 states, so that successive lines of the matrix correspond to the power flow on the individual CNEs/CNECs for which trajectory starting points are calculated. GSKs (K) represent the impact of generation in a given grid node on a change of the net position of the zone in which it is situated. The keys are calculated on the basis of determined value of operating points of generation units in the reference grid model (only sums of non-negative generation values of generation units connected to the network node concerned are taken into account – the value calculated this way, characterising the node, is designated as $p_{n,s(h)}$).

$$K_{n,z,s(h)} = \begin{cases} \frac{p_{n,s(h)}}{\sum_{m \in z} p_{m,s(h)}} & \text{for } n \in z \\ 0 & \text{for } n \notin z \end{cases}$$

where:

- $K_{n,z,s(h)}$ – represents the generation shift key (GSK) reflecting the impact of change in generation in a node n on a change of the net position of a zone z in hour h
- $p_{n,s(h)}$ - represents the value of the non-negative generation at node n belonging to the zone z from the network reference model assigned to the season s and hour h (see table 1 in point 2.1)
- $\sum_{m \in z} p_{m,s(h)}$ - represents the sum of non-negative generations in nodes belonging to the zone z
- n and m – node number designations

2.3. Calculation of hourly values of flows allocated for CNECs

A market (allocated) flow on a given CNE/CNEC depends on the hourly configuration (vector) of zonal net positions and seasonal zonal power transfer distribution factor (PTDF) matrixes in N-0 and N-1 states.

$$f_{i,h} = \sum_{z} U_{i,z,s(h)} \cdot \eta_{z,h}$$

where:

- $f_{i,h}$ – market flow (allocated capacity) on a given CNE/CNEC element i in hour h expressed in MW
- $U_{i,z,s(h)}$ – represents the *zone-to-slack* PTDF reflecting the impact of the net position of zone z on flow on a CNE/CNEC i in hour h
- $\eta_{z,h}$ – represents the net position of zone z in hour h
- $s(h)$ – represents the season assigned to hour h (see Table 1 in Section 2.1)

2.4. Calculation of hourly flows allocated for CNECs expressed in percentage of the maximum capacity of a CNE

The market flow (allocated capacity) on a given CNE/CNEC expressed in percentage of the maximum capacity of a CNE is a basis for the calculation of trajectory starting points. The maximum capacity $F_{\max i}$ has been calculated for each CNE in each hour h on the basis of load characteristics of individual lines and transformers which are CNEs and historical ambient temperatures for those CNEs for the 2016-2018 period.

$$f_{i,h}^{\%} = \frac{f_{i,h}}{F_{\max i,h}}$$

where:

- $f_{i,h}^{\%}$ – market flow (allocated capacity) on a given CNE/CNEC element i in hour h expressed in percentage of maximum capacity of CNE element
- $f_{i,h}$ – market flow (allocated capacity) on a given CNE/CNEC element i in hour h expressed in MW
- $F_{\max i,h}$ – represents maximum transmission capacity of CNE element for the CNE/CNEC i in hour h

It should be noted that a market flow on a given CNE/CNEC in a given hour h may have a positive value – flow in the direction consistent with the CNE definition (e.g. from node A to node B for the A-B CNE definition) or negative value – flow in the direction opposite to the CNE definition (from node B to node A for the A-B CNE definition).

2.5. Calculation of average flows allocated for CNECs representing trajectory starting points

Trajectory starting points defined according to the ACER Regulation as $MACZT_{min}$ are calculated for each CNEC as the greater of the two averages in specific timeframes:

- calendar year 2018
- calendar years 2016-2018

and separately for (i) the direction consistent with the CNE definition

$$MACZT_{min,i}^{\%+} = max\left(\frac{1}{n_{h18}^{+}}\sum_{h\in N_{h18}^{+}} f_{i,h}^{\%+}; \frac{1}{n_{h1618}^{+}}\sum_{h\in N_{h1618}^{+}} f_{i,h}^{\%+}\right)$$

and (ii) separately for the direction opposite to the CNE definition

$$MACZT_{min,i}^{\%-} = \left|min\left(\frac{1}{n_{h18}^{-}}\sum_{h\in N_{h18}^{-}} f_{i,h}^{\%-}; \frac{1}{n_{h1618}^{-}}\sum_{h\in N_{h1618}^{-}} f_{i,h}^{\%-}\right)\right|$$

where:

- N_{h18}^{+}, N_{h18}^{-} – the set of hours in 2018, when a positive or negative market flow was calculated respectively on a given CNE/CNEC
- n_{h18}^{+}, n_{h18}^{-} – number of elements in sets, respectively, in N_{h18}^{+}, N_{h18}^{-}
- $N_{h1618}^{+}, N_{h1618}^{-}$ – the set of hours in 2016-2018, when a positive or negative market flow was calculated respectively on a given CNE/CNEC
- $n_{h1618}^{+}, n_{h1618}^{-}$ – number of elements in sets, respectively, in $N_{h1618}^{+}, N_{h1618}^{-}$
- $f_{i,h}^{\%+}, f_{i,h}^{\%-}$ – market flow (allocated capacity) on a given CNE/CNEC in hour h expressed in percentage of the maximum capacity of a CNE, positive or negative, respectively

3. Linear trajectory pattern

The trajectory end point for each CNE/CNEC *i* is the target value applicable from 1 January 2026 in both directions, i.e.

$$MACZT^{\%,sgn}_{2026,i} = 70\%,$$

where sgn means a flow direction consistent with the CNE definition (+) or opposite (-).

The linear trajectory was calculated between points $MACZT^{\%,sgn}_{min,i}$ and $MACZT^{\%,sgn}_{2026,i} = 70\%$, in which the successive $MACZT^{\%,sgn}_{y,i}$ values are determined for each critical element *i* both for the consistent direction and the opposite direction for each year $y \in \{2020, 2021, \dots, 2025\}$, and represent linear interpolation between the values of $MACZT^{\%,sgn}_{min,i}$ and $MACZT^{\%,sgn}_{2026,i}$.

$$MACZT^{\%,sgn}_{y,i} = MACZT^{\%,sgn}_{min,i} + \left(MACZT^{\%,sgn}_{2026,i} - MACZT^{\%,sgn}_{min,i}\right) \div 6 \times (y - 2020)$$

Where a new CNE/CNEC is added to the list of CNEs/CNECs in accordance with the definition on Section 1.1 (c) of the Action Plan, i.e. an element commissioned in 2019-2025, a trajectory in which $MACZT^{\%,sgn}_{min,i} = 0$, and the trajectory pattern is as shown in Table 2 for both directions (direct and opposite).

Table 2. Linear trajectory pattern for new critical elements commissioned in 2019-2025.

Year of commissioning of CNE/CNEC	% of CNE capacity in both directions						
	2020	2021	2022	2023	2024	2025	from Jan 2026
2019	0	12	23	35	47	58	70
2020	0	12	23	35	47	58	70
2021	-	0	14	28	42	56	70
2022	-	-	0	18	35	53	70
2023	-	-	-	0	23	47	70
2024	-	-	-	-	0	35	70
2025	-	-	-	-	-	0	70

Source: PSE S.A.

4. Impact of linear trajectories on the level of offered cross-zonal capacity

Article 16 (8) of Regulation 2019/943 introduces the notion of minimum levels of available capacity for cross-zonal trade expressed in percentage of capacity for a given border or a critical network element, calculated respecting operational security limits. As a consequence, starting points of linear trajectories and their pattern in different years are also calculated in capacity percentage for a given border or critical network elements, calculated respecting operational security limits. It should be noted that the TSO uses dynamic monitoring of the load capacity of transmission elements, i.e. reflecting their actual capacity depending on the ambient temperature. Consequently, for a given point of the trajectory (in a given year) expressed in capacity percentage, different levels of capacity offered may arise, expressed in MW, depending on the ambient temperature.

Article 16(4), first sentence, of Regulation 2019/943 provides that: “The maximum level of capacity of the interconnections and the transmission networks affected by cross-border capacity shall be made available to market participants complying with the safety standards of secure network operation.” This means that, where possible from the point of view of network operation security, the TSO will offer cross zonal capacity volumes greater than those resulting from the linear trajectories adopted here.

In addition, it should be pointed out that planned and unplanned outages of transmission system elements affect the capacity level that can be securely offered on the market. In particular cases, for example where outages of transmission system elements are required in order to carry out necessary construction, maintenance or upgrade works, the transmission system operates in an incomplete network configuration. A situation may then arise where for selected network elements (CNEs/CNECs), the required values of minimum capacity cannot be achieved respecting operational security limits. The above is of a lasting nature, which means that situations may arise where it is not possible to meet the levels resulting from the CEP 70% target, both in the course of implementation of the Action Plan and after its implementation. The only, theoretically possible, solution is a significant strengthening of the transmission network, going beyond economically justified needs of network users who bear the cost of such network development. For this reason, outages of transmission system elements that affect the capability to offer minimum capacity while ensuring network operation security will be taken into account at the stage of capacity calculation and will be monitored by the Regulator for compliance with the minimum capacity requirement.