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METHODOLOGY

Balancing Market Price Calculation

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Acronyms

AGC	Automatic Generation Control
ISP	Integrated Scheduling Process
TSO	Transmission System Operator
FRR	Frequency Restoration Reserve
HETSO	Hellenic Electricity Transmission System Operator
BMR	Balancing Market Rulebook
aFRR	Automatic Frequency Restoration Reserve (aFRR)
mFRR	Manual Frequency Restoration Reserve
CBMP_{aFRR}	Cross-Border aFRR Clearing Price
LMOL	Local Merit Order List

1 Introduction

1. This methodology is issued in accordance with paragraph 5 of Article 19.3 of the Balancing Market Regulation and describes the methodology for calculating clearing prices for manual frequency restoration reserve (mFRR) balancing energy, automatic frequency restoration reserve (aFRR) balancing energy, non-balancing energy, and the imbalance price.
2. This methodology is approved by a decision of the Regulatory Authority for Waste, Energy and Water (RAAEY), following a recommendation from the Hellenic Electricity Transmission System Operator (HETSO), in accordance with Article 18(4) of Law 4425/2016 and Article 1.2(6) of the Balancing Market Regulation.
3. In the event of discrepancies between the provisions of this methodology and the provisions of the Balancing Market Regulation, the provisions of the Balancing Market Regulation shall prevail.
4. This methodology forms an integral and single part of the Balancing Market Regulation (BMR) and shall be interpreted and applied in conjunction with its content.
5. The definitions contained in Article 1.3 of the BMR shall also apply to this methodology, unless otherwise expressly provided for.
6. If the calculation of clearing prices is rendered impossible, in particular due to an emergency situation, or to failure of the balancing market system or other electronic systems of the HETS Operator, the HETS Operator shall apply the procedure provided for in the 'Rules for settlement in case of suspension of market activities'.

2 Manual Frequency Restoration Reserve Clearing Price (mFRR)

The mFRR clearing price is defined as the price at which the balancing service entity is credited or debited for the activation of upward or downward mFRR energy offers within a single imbalance settlement period.

The calculation of the mFRR clearing price shall be calculated separately per direction in accordance with the provisions set out in this section.

The following shall be excluded when calculating the clearing prices of upward and downward mFRR:

- Upward and downward mFRR balancing energy offers activated for non-balancing purposes through the mFRR procedure;
- Upward and downward mFRR balancing energy offers submitted by balancing service entities for imbalance settlement periods, as defined in the 'Methodology for the Calculation of the Infeasible Market Schedule';
- Upward and downward mFRR balancing energy offers submitted by balancing service entities for the imbalance settlement periods that are activated for the purposes of mFRR test dispatch instructions.

2.1 Clearing price for upward mFRR energy

In the absence of congestion between the HETS bidding zones, the clearing price for upward mFRR energy (in €/MWh), $BEP_{z,t}^{up}$, for each imbalance settlement period, corresponds to the price at which balancing service providers are compensated for providing upward mFRR energy, and is equal to the maximum price steps of the upward mFRR energy offers that were activated to cover HETS Operator imbalances.

In the event that there is congestion between the HETS bidding zones, the clearing price for upward mFRR for each imbalance settlement period, t , for activation of upward balancing energy per bidding zone is equal to the maximum prices of the mFRR balancing energy offer steps that were activated to cover the imbalance in the specific bidding zone, z .

2.2 Clearing price for downward mFRR energy

In the absence of congestion between the HETS bidding zones, the clearing price for downward mFRR energy (in €/MWh), $BEP_{z,t}^{dn}$, for each imbalance settlement period, corresponds to the price at which balancing service providers are compensated for providing downward mFRR energy, and is equal to the minimum price steps of the downward mFRR energy offers that were activated to cover HETS Operator imbalances.

If there is congestion between the HETS Operator bidding zones, the clearing price for downward mFRR for each imbalance settlement period, t , for activation of downward mFRR balancing energy per each

bidding zone is equal to the minimum prices of the mFRR balancing energy offer steps that were activated to cover the imbalance of the specific bidding zone.

2.3 Example of mFRR clearing price calculation

The following example shows calculation of the clearing price of upward and downward mFRR energy. Assuming there is no congestion between HETS Operator bidding zones, the clearing price for upward mFRR energy, $BEP_{z,t}^{up}$, for each imbalance settlement period, t , is equal to the maximum prices of the steps of the upward mFRR balancing energy offers that were activated. Similarly, the clearing price of downward mFRR energy, $BEP_{z,t}^{dn}$, is equal to the minimum prices of the steps of the downward balancing energy offers that have been activated.

The following tables present the steps and corresponding offer prices submitted by the entities that were activated per direction during imbalance clearing period, t .

TABLE 1. STEPS OF UPWARD ACTIVATED OFFERS

Entity	SEG	Q _{SEG} (MWh)	P _{SEG} (€/MWh)
GBSE1	2	50	49
GBSE2	3	40	55
GBSE3	4	60	70

TABLE 2. STEPS OF DOWNWARD ACTIVATED OFFERS

Entity	SEG	Q _{SEG} (MWh)	P _{SEG} (€/MWh)
GBSE9	2	40	10
GBSE7	5	80	5
GBSE5	7	10	3

The maximum offer activated in the upward direction corresponds to the 4th step of entity GBSE3 and is equal to: $BEP_{z,t}^{up} = 70$ €/MWh. Regarding the downward direction, the minimum bid activated corresponds to the 7th step of entity GBSE5 and is equal to: $BEP_{z,t}^{dn} = 3$ €/MWh.

3 mFRR energy price for non-balancing purposes

The mFRR clearing price for out-of-balancing purposes is defined as the price at which the balancing service entity is credited or debited for the activation of upward or downward mFRR energy offers within a single imbalance settlement period for non-balancing purposes.

The following section shows the separate determination of the mFRR clearing price in cases where energy is activated for non-balancing purposes within the mFRR procedure and in cases where test dispatch instructions are issued.

3.1 Calculation of the non-balance settlement price for mFRR energy under the mFRR procedure

The clearing price credited or debited to each portion of a mFRR Energy Offer step, when activated during the mFRR procedure for non-balancing purposes, is equal to the offer price of the specific step. More specifically:

- α) For activation of an upward mFRR balancing energy offer submitted by balancing service entity e , that portion of the quantity of step s that was activated is credited or debited at the price of step s , $OPBE_{e,s,t}^{mFRR,up}$, for the entity in question.
- β) For activation of a downward mFRR balancing energy offer submitted by balancing service entity e , that portion of the quantity of step s that was activated is credited or debited at the price of step s , $OPBE_{e,s,t}^{mFRR,dn}$, for the entity in question.

Below is an example of the calculation of the mFRR clearing price for non-balancing purposes within the mFRR procedure. The tables below show, for each step s of the offers submitted by the entities that were activated to provide mFRR energy for non-balancing purposes during an imbalance settlement period t , the following: the quantities for each step, $QSEG_{e,s,t}$, the portion of each step that was activated, $QSEGact_{e,s,t}$, and the prices of the steps, $OPBE_{e,s,t}^{mFRR,up/dn}$.

In accordance with the above, the entity GBSE1 will be credited with the quantity of step 2 that was activated (30MWh), at a price of 60€/MWh, and for the quantity of step 3 that was activated (23MWh) with a price of 70€/MWh. Similarly, in accordance with the above, the entity GBSE2 will be charged with the quantity of step 2 that was activated (40MWh) at a price of 15€/MWh, and for the quantity of step 3 that was activated (37MWh) with a price of 10€/MWh.

TABLE 3. UPWARD ACTIVATED OFFER STEPS

Entity	Entities	$QSEG_{e,s,t}$ (MWh)	$QSEGact_{e,s,t}$ (MWh)	$OPBE_{e,s,t}^{mFRR,up}$ (€/MWh)
GBSE1	2	30	30	60
GBSE1	3	40	23	70

TABLE 4. DOWNWARD ACTIVATED OFFER STEPS

Entity	Entities	$QSEG_{e,s,t}$ (MWh)	$QSEGact_{e,s,t}$ (MWh)	$OPBE_{e,s,t}^{mFRR,dn}$ (€/MWh)
GBSE2	2	40	40	15
GBSE2	3	80	37	10

3.2 Calculation of mFRR clearing price for test instructions

The clearing price at which a balancing service entity is credited or debited for the energy activated during the issuance of mFRR test dispatch instructions corresponds to the mFRR clearing price of the relevant direction for the imbalance settlement period, as calculated in Section 2.

It is clarified that upward and downward mFRR balancing energy offers for the balancing service entities and for imbalance settlement periods that are activated for test dispatch instruction purposes are marked and excluded from the calculation of upward and downward mFRR clearing prices.

4 Automatic frequency restoration reserve clearing price (aFRR)

For automatic frequency restoration reserve (aFRR) energy clearing purposes, two **weighted aFRR clearing prices**, one for the upward and one for the downward direction, are calculated for each minute of the imbalance settlement period. For the calculation thereof, the **aFRR AGC cycle clearing price per each AGC cycle** is taken into account, determined separately for the cases in which the HETS Operator is either connected to or disconnected from the PICASSO Platform, in accordance with the provisions of this section.

The **aFRR clearing price** at which a balancing service entity is credited or debited for the activated aFRR energy is calculated separately for each Entity and for each direction, as it results from the comparison between the **weighted aFRR clearing price** and the price of the last activated step of the entity's aFRR energy offer in the corresponding direction.

4.1 Calculation of the clearing price for upward aFRR energy

The **weighted upward aFRR clearing price** in €/MWh, $SP_{WAE,i}^{aFRR,up}$ during one minute i of the imbalance balancing period t is calculated as follows:

$$SP_{WAE,i}^{aFRR,up} = \frac{\sum_{c \in i} (RE_c^{aFRR,up} \times MP_c^{aFRR,up})}{\sum_{c \in i} (RE_c^{aFRR,up})} \quad (1)$$

The **weighted downward aFRR clearing price** in €/MWh, $SP_{WAE,i}^{aFRR,dn}$ during one minute i of the imbalance balancing period t is calculated as follows:

$$SP_{WAE,i}^{aFRR,dn} = \frac{\sum_{c \in i} (RE_c^{aFRR,dn} \times MP_c^{aFRR,dn})}{\sum_{c \in i} (RE_c^{aFRR,dn})} \quad (2)$$

Where:

c	The AGC cycle.
$MP_c^{aFRR,up}$	The upward aFRR AGC cycle clearing price in €/MWh for the AGC cycle c .
$MP_c^{aFRR,dn}$	The downward aFRR AGC cycle clearing price in €/MWh for the AGC cycle c .
$RE_c^{aFRR,up}$	The required activation of upward aFRR balancing energy served locally in MWh for each AGC cycle c during minute i , with a positive value.
$RE_c^{aFRR,dn}$	The required activation of downward aFRR balancing energy served locally in MWh for each AGC cycle c during minute i , with a positive value.

For each AGC cycle, the required activation of aFRR balancing energy served locally is equal to the algebraic sum of aFRR demand and the most recent aFRR correction signal.

The **upward/downward aFRR clearing price per AGC cycle** is determined as follows:

- a. For each AGC cycle c during minute i , in which the HETS Operator remains connected to the PICASSO Platform, the upward and downward aFRR clearing prices per AGC cycle are identical and equal to the most recent cross-border aFRR clearing price ($CBMP_{aFRR}$) transmitted by the PICASSO Platform.
- b. For each AGC cycle c when the HETS Operator remains disconnected from the PICASSO platform, the upward aFRR clearing price of the AGC cycle equals the highest price of all upward aFRR balancing energy offers that were activated from the local aFRR merit order list, while the downward aFRR clearing price of the AGC cycle equals the lowest price of all downward aFRR balancing energy offers that were activated from the local aFRR merit order list.

The **aFRR clearing price** at which a balancing service entity e is credited or debited for each minute i of the imbalance settlement period t , $SP_{AE,i}^{aFRR,up/dn}$, is determined based on the direction of the activated aFRR energy as follows:

- a. For activation of upward aFRR energy, the price is determined as the maximum between, on the one hand, the weighted upward aFRR clearing price for the given minute i , and on the other, the price of step s of the upward aFRR energy offer submitted by the respective entity, which corresponds to the activated upward aFRR energy calculated for minute i , in accordance with the Activated Energy Methodology:

$$SP_{e,i}^{aFRR,up} = \max(SP_{WAE,i}^{aFRR,up}, OPBE_{e,s,i}^{aFRR,up}) \quad (3)$$

- b. For activation of downward aFRR energy, the price is determined as the minimum between, on the one hand, the weighted upward aFRR clearing price for the given minute i , and on the other, the price of step s of the downward aFRR energy offer submitted by the respective entity, which corresponds to the activated upward aFRR energy calculated for minute i , in accordance with the 'Activated Energy Calculation Methodology':

$$SP_{e,i}^{aFRR,dn} = \min(SP_{WAE,i}^{aFRR,dn}, OPBE_{e,s,i}^{aFRR,dn}) \quad (4)$$

Where:

$SP_{e,i}^{aFRR,up}$	The upward aFRR clearing price of entity e for the minute i , expressed in €/MWh
$SP_{e,i}^{aFRR,dn}$	The downward aFRR clearing price of entity e for the minute i , expressed in €/MWh
$SP_{WAE,i}^{aFRR,up}$	The weighted upward aFRR clearing price for minute i , expressed in €/MWh
$SP_{WAE,i}^{aFRR,dn}$	The weighted downward aFRR clearing price for minute i , expressed in €/MWh
$OPBE_{e,s,i}^{aFRR,up}$	The price of step s of the Balancing Energy Offer for upward aFRR of the Balancing Services Entity corresponding to the activated upward aFRR energy calculated for minute i , in accordance with the 'Activated Energy Calculation Methodology'
$OPBE_{e,s,i}^{aFRR,dn}$	The price of step s of the Balancing Energy Offer for upward aFRR of the Balancing

Services Entity corresponding to the activated downward aFRR energy calculated for minute i , in accordance with the ‘Activated Energy Calculation Methodology’.

4.2 Examples of aFRR Clearing Price Calculation

In the following examples, three scenarios are considered:

- Scenario I: The HETS Operator remains connected to the PICASSO Platform for all AGC cycles of minute i .
- Scenario II: The HETS Operator remains disconnected from the PICASSO Platform for all AGC cycles of minute i .
- Scenario III: The HETS Operator remains logged in to the PICASSO Platform for a certain period of time and disconnected for the rest of the time within minute i .

For example purposes, calculations are presented for two entities only, one per direction. Entity GBSE1 provides upward aFRR balancing energy, while entity GBSE2 provides downward aFRR balancing energy.

Each minute i consists of 15 AGC cycles of 4sec each.

Scenario I: Connection with the PICASSO Platform

Table 5 presents the required upward or downward activation of aFRR Balancing Energy, in MW, for each AGC cycle c during minute i , as well as the aFRR clearing price for the AGC cycle, which is consistent with the cross-border aFRR price in €/MWh.

TABLE 5. RESULTS OF THE AFRR PROCEDURE

AGC cycle	$RE_c^{aFRR,up}$ (MW)	$RE_c^{aFRR,dn}$ (MW)	$CBMP_{aFRR}$ (€/MWh)
C1	20		100
C2	20		120
C3	20		110
C4	50		50
C5		10	40
C6		10	10
C7		10	-5
C8		15	-100
C9	20		60
C10	50		80
C11	20		100
C12	50		150
C13		20	-200
C14		20	-220
C15		20	-70

According to the data in the above table, the required upward activation of aFRR balancing energy per minute is equal to 0.28 MWh and the required downward activation of aFRR balancing energy is equal to 0.12 MWh.

Activated aFRR balancing energy for the respective minute i per entity under consideration is presented in the following table, as arising from the ‘Activated Balancing Energy Calculation Methodology’.

TABLE 6. QUANTITY OF AFRR BALANCING ENERGY AWARDED PER ENTITY FOR THE MINUTE i

Entity	$ABE_{GBSE1,i}^{aFRR,up}$	$ABE_{GBSE2,i}^{aFRR,dn}$
GBSE1	0.15 MWh	
GBSE2		0.10 MWh

Presented below are the available steps of the upward aFRR balancing energy offer submitted by entity GBSE1 and, similarly, the available steps of the downward aFRR balancing energy offer submitted by entity GBSE2, as derived in accordance with the Technical Decision 'Rules for the Conversion of Balancing Energy Offers into Standardised Products' and included in the aFRR Local Merit Order List (LMOL).

TABLE 7. UPWARD AFRR BALANCING ENERGY OFFER STEPS SUBMITTED BY GBSE1

Step (SEG)	Quantity (MW)	Quantity of energy per minute (MWh)	Step value (€/MWh)
2	30	0.50	70
3	40	0.67	90
4	70	1.17	120

TABLE 8. DOWNWARD AFRR BALANCING ENERGY OFFER STEPS SUBMITTED BY GBSE2

Step (SEG)	Quantity (MW)	Quantity of energy per minute (MWh)	Step value (€/MWh)
3	15	0.25	15
4	30	0.5	10

Based on the above, the second (2nd) step of the upward aFRR Balancing Energy Offer submitted by Entity GBSE1 corresponds to the activated upward aFRR energy calculated for minute i . Similarly, the last step of the downward aFRR Balancing Energy Offer submitted by Entity GBSE2 corresponds to the activated downward aFRR energy calculated for minute i is the third (3rd) step. Therefore, the values of the last steps activated are as follows:

- $OPBE_{GBSE1,s,t}^{aFRR,up} = 70 \text{ €/MWh}$
- $OPBE_{GBSE2,s,t}^{aFRR,dn} = 15 \text{ €/MWh}$

Provided that the HETS Operator remains connected to the PICASSO platform for all 15 AGC cycles of minute i , the aFRR clearing price for each AGC cycle c will coincide with the corresponding cross-border aFRR clearing price.

The weighted upward aFRR clearing price is calculated for the AGC cycles c_1, c_2, c_3, c_4 and $c_9, c_{10}, c_{11}, c_{12}$ that require activation of upward aFRR balancing energy. For calculation purposes, the corresponding aFRR clearing prices per AGC cycle are weighted against the required quantity of upward activated aFRR balancing energy, as follows:

$$SP_{WAE,i}^{aFRR,up} = \frac{\sum_{c1...15}(RE_c^{aFRR,up} \times CBMP_{aFRR})}{\sum_{c1...15}(RE_c^{aFRR,up})} = \frac{26,44}{0,28} = 95,2 \text{ €/MWh}$$

Accordingly, the aFRR clearing price at which entity GBSE1 is credited for the activation of its upward aFRR balancing energy offer is the maximum between the price of the offer step corresponding to the activated upward aFRR energy calculated for minute i , and the weighted upward aFRR clearing price calculated above, as follows:

$$SP_{e,i}^{aFRR,up} = \max(SP_{WAE,i}^{aFRR,up}; OPBE_{e,s,t}^{aFRR,up}) = \max(95,2; 70) = 95,2 \text{ €/MWh}$$

The weighted clearing price of downward aFRR is calculated for AGC cycles c_5, c_6, c_7, c_8 and c_{13}, c_{14}, c_{15} , during which downward activation of aFRR balancing energy is required. For calculation purposes, the corresponding AGC cycle aFRR clearing prices are weighted with regard to the required quantities of downward activated of aFRR balancing energy, as follows:

$$SP_{WAE,i}^{aFRR,dn} = \frac{\sum_{c1...15}(RE_c^{aFRR,dn} \times CBMP_{aFRR})}{\sum_{c1...15}(RE_c^{aFRR,dn})} = \frac{-12,06}{0,12} = -103,33 \text{ €/MWh}$$

Accordingly, the aFRR clearing price at which entity GBSE2 is credited or debited for the activation of its downward aFRR balancing energy offer is the minimum between the price of the offer step corresponding to the activated downward aFRR energy calculated for minute i , and the weighted downward aFRR clearing price calculated above, as follows:

$$SP_{e,i}^{aFRR,dn} = \min(SP_{WAE,i}^{aFRR,dn}; OPBE_{e,s,t}^{aFRR,dn}) = \min(-103,33; 15) = -103,33 \text{ €/MWh}$$

Scenario II: Full disconnection from the PICASSO Platform

If the HETS Operator remains disconnected from the PICASSO platform for all 15 AGC cycles of minute i , the AGC cycle aFRR clearing price will be calculated separately for the upward and downward directions. The upward aFRR clearing price per AGC cycle corresponds to the maximum price of all upward aFRR Balancing Energy Offers activated during AGC cycle c from the aFRR Local Merit Order List (LMOL), while the downward aFRR clearing price per AGC cycle corresponds to the minimum price of all downward aFRR Balancing Energy Offers activated during AGC cycle c from the LMOL, as presented in the following table.

TABLE 9. RESULTS OF THE AFRR PROCEDURE — SCENARIO II

AGC cycle	$RE_c^{aFRR,up}$ (MW)	$RE_c^{aFRR,dn}$ (MW)	$MP_c^{aFRR,up}$ (€/MWh)	$MP_c^{aFRR,dn}$ (€/MWh)

C1	20		80	
C2	20		100	
C3	20		70	
C4	50		90	
C5		10		15
C6		10		15
C7		10		10
C8		15		15
C9	20		70	
C10	50		90	
C11	20		80	
C12	50		90	
C13		20		10
C14		20		0
C15		20		0

Activated aFRR balancing energy and activated steps per the entity in question are identical to Scenario I (TABLE 6 to TABLE 8). Therefore, the values of the last steps activated are as follows:

- $OPBE_{GBSE1,s,t}^{aFRR,up} = 70 \text{ €/MWh}$
- $OPBE_{GBSE2,s,t}^{aFRR,dn} = 15 \text{ €/MWh}$

The weighted upward aFRR clearing price is calculated for the AGC cycles c_1, c_2, c_3, c_4 and $c_9, c_{10}, c_{11}, c_{12}$ that require activation of upward aFRR balancing energy. For calculation purposes, the corresponding aFRR clearing prices per AGC cycle are weighted against the required quantities of upward activated aFRR balancing energy (TABLE 9), as follows:

$$SP_{WAE,i}^{aFRR,up} = \frac{\sum_{c1...15}(RE_c^{aFRR,up} \times MP_c^{aFRR,up})}{\sum_{c1...15}(RE_c^{aFRR,up})} = \frac{23,89}{0,28} = 86 \text{ €/MWh}$$

The aFRR clearing price at which entity GBSE1 is credited for the activation of its upward aFRR balancing energy offer is the maximum between the price of the offer step corresponding to the activated upward aFRR energy calculated for minute i , and the weighted upward aFRR clearing price calculated above, as follows:

$$SP_{e,i}^{aFRR,up} = \max(SP_{WAE,i}^{aFRR,up}; OPBE_{e,s,t}^{aFRR,up}) = \max(86; 70) = 86 \text{ €/MWh}$$

The weighted clearing price of downward aFRR is calculated for AGC cycles c_5, c_6, c_7, c_8 and c_{13}, c_{14}, c_{15} , during which downward activation of aFRR balancing energy is required. For calculation purposes, the corresponding aFRR clearing prices per AGC cycle are weighted against the required quantities of downward activated aFRR balancing energy (TABLE 9), as follows:

$$SP_{WAE,i}^{aFRR,dn} = \frac{\sum_{c1...15}(RE_c^{aFRR,dn} \times MP_c^{aFRR,dn})}{\sum_{c1...15}(RE_c^{aFRR,dn})} = \frac{0,92}{0,12} = 7,86 \text{ €/MWh}$$

The aFRR clearing price at which entity GBSE2 is credited for the activation of its downward aFRR balancing energy offer is the minimum between the price of the offer step corresponding to the activated upward aFRR energy calculated for minute i , and the weighted downward aFRR clearing price calculated above, as follows:

$$SP_{e,i}^{aFRR,dn} = \min(SP_{WAE,i}^{aFRR,dn}; OPBE_{e,s,t}^{aFRR,dn}) = \min(7,86 ; 15) = 7,86 \text{ €/MWh}$$

Scenario III: Partial disconnection from the PICASSO Platform

In this scenario, it is assumed that the Administrator remains connected to the PICASSO Platform for AGC cycles $c_1 - c_{10}$, and $c_{12} - c_{14}$, while disconnecting ARP cycles c_{11} and c_{15} . The required upward and downward activation of aFRR balancing energy, in MWh, for each AGC cycle c during minute i remains as in TABLE 5.

For each of the AGC cycles $c_1 - c_{10}$, and $c_{12} - c_{14}$ that the HETS Operator remains connected to the PICASSO Platform, The clearing price for upward and downward aFRR per AGC cycle coincides with the cross-border aFRR clearing price, $CBMP_{aFRR}$, in accordance with Scenario I.

For AGC cycles c_{11} and c_{15} , during which the HETS Operator remains disconnected from the PICASSO Platform, the upward/downward aFRR clearing price per AGC cycle corresponds to the maximum/minimum price of all upward/downward aFRR Balancing Energy Offers activated from the Local Merit Order List (LMOL), in accordance with Scenario II.

The following table shows the results of the resolution of the aFRR procedure per AGC cycle. In the column 'Connected to PICASSO' the indication '1' corresponds to connection to the platform and '0' indicates disconnection from the platform.

TABLE 10. RESULTS OF THE AFRR PROCEDURE — SCENARIO III

AGC cycle	$RE_c^{aFRR,up}$ (MW)	$RE_c^{aFRR,dn}$ (MW)	Connection with PICASSO	$CBMP_{aFRR}$ (€/MWh)	$MP_c^{aFRR,up}$ (€/MWh)	$MP_c^{aFRR,dn}$ (€/MWh)
c_1	20		1	100		
c_2	20		1	120		
c_3	20		1	110		
c_4	50		1	50		
c_5		10	1	40		
c_6		10	1	10		
c_7		10	1	-5		
c_8		15	1	-100		
c_9	20		1	60		
c_{10}	50		1	80		
c_{11}	20		0		70	
c_{12}	50		1	150		
c_{13}		20	1	-200		

c₁₄		20	1	-220		
c₁₅		20	0			0

For AGC cycles $c_1 - c_4$ & $c_9 - c_{12}$, when an upward activation of aFRR balancing energy is required, the corresponding AGC cycle aFRR clearing prices are weighted with regard to the required amounts of upward activated aFRR balancing energy for the above cycles (**TABLE 10**).

$$SP_{WAE,i}^{up} = \frac{\sum_{c1,2,3,4,9,10,12}(RE_c^{aFRR,up} \times CBMP_{aFRR}) + \sum_{c11}(RE_c^{aFRR,up} \times MP_c^{aFRR,up})}{\sum_{c1,2,3,4,9,10,11,12}(RE_c^{aFRR,up})} = 92,8 \text{ €/MWh}$$

Accordingly, the aFRR clearing price at which entity GBSE1 is credited for the activation of its upward aFRR balancing energy offer is the maximum between the price of the offer step corresponding to the activated downward aFRR energy calculated for minute i , and the weighted upward aFRR clearing price calculated above, as follows:

$$SP_{e,i}^{up} = \max(SP_{WAE,i}^{up}; OPBE_{e,s,t}^{aFRR,up}) = \max(92,8; 70) = 92,8 \text{ €/MWh}$$

Similarly, for AGC cycles $c_5 - c_8$ & $c_{13} - c_{15}$, where downward activation of aFRR balancing energy is required, the corresponding AGC cycle aFRR clearing prices are weighted with regard to the required amounts of downward activated aFRR balancing energy for the above cycles (**TABLE 10**).

$$SP_{WAE,i}^{dn} = \frac{\sum_{c5,6,7,8,13,14}(RE_c^{aFRR,dn} \times CBMP_{aFRR}) + \sum_{c15}(RE_c^{aFRR,dn} \times MP_c^{aFRR,dn})}{\sum_{c5,6,7,8,13,14,15}(RE_c^{aFRR,dn})} = -90 \text{ €/MWh}$$

Accordingly, the aFRR clearing price at which entity GBSE2 is credited for the activation of its downward aFRR balancing energy offer is the minimum between the price of the offer step corresponding to the activated upward aFRR energy calculated for minute i , and the weighted downward aFRR clearing price calculated above, as follows:

$$SP_{e,i}^{dn} = \min(SP_{WAE,i}^{dn}; OPBE_{e,s,t}^{aFRR,dn}) = \min(-90; 10) = -90 \text{ €/MWh}$$

5 Imbalance Price

The Imbalance Price is the price at which the Contracting Parties with Balancing Responsibility are credited or debited for their respective imbalances within an imbalance settlement period.

Calculation of the imbalance price is based on the maximum/minimum price approach in accordance with ACER Decision 18/2020.

5.1 Calculation of the imbalance price with system deviation within the range [-25MW to +25MW]

When system imbalances are very small, there is no need for the imbalance price to provide an incentive for Balance Responsible Parties to address these, since this may create an abrupt reversal in the direction of the system imbalance. For this reason, and in order to avoid large fluctuations in the imbalance price when the system imbalance is close to zero, a range is defined within which the imbalance price is equal to the value of the avoided activation of balancing energy. Therefore, in the case where the system imbalance, SI_t , as calculated in accordance with Article 19.5 of the Balancing Market Rulebook, falls within the range [-25MW to +25MW], the imbalance price is equal to the value of the avoided balancing energy activation $VOAA_t$, and is calculated as the average of the following:

- α) the lowest price of the upward balancing energy offer for either mFRR or aFRR, which is available for local activation for the specific imbalance settlement period, and
- β) the highest price of the downward balancing energy offer for either mFRR or aFRR which is available for local activation for the specific imbalance settlement period.

5.2 Calculation of the imbalance price with system deviation outside the range [-25MW to +25MW]

On the PICASSO Platform, the cross-border aFRR clearing prices arise having taken into account balancing energy activations made to meet the overall needs of the aFRR within each uncongested area. In the event that the direction of the HETS Operator aFRR differs from the direction of the corresponding total aFRR needs for the uncongested area, the cross-border aFRR clearing prices result from activations in the opposite direction to the activation direction required in the Greek System. To address the case where the total need for aFRR and mFRR is in the opposite direction from the need of the HETS Operator, and therefore the maximum/minimum price approach cannot provide appropriate incentives, a lower limit is added to the imbalance price when the system imbalance is negative, and an upper limit is added when the system imbalance is positive. These limits are equal to the value of the avoided activation of aFRR Balancing Energy in the corresponding direction.

In the case where the system imbalance, SI_t , is less than -25MW or greater than +25MW, IP_t the imbalance price is calculated as follows:

$$IP_t = \begin{cases} \max\{MP_{WAE,t}^{aFRR}, BEP_{mFRR,t}^{up}, VOAA_t^{up}, VOAA_t^{dn}\}, \text{όταν } SI_t < -25MW \\ \min\{MP_{WAE,t}^{aFRR}, BEP_{mFRR,t}^{dn}, VOAA_t^{up}, VOAA_t^{dn}\}, \text{όταν } SI_t > 25MW \end{cases} \quad (5)$$

Where:

$MP_{WAE,t}^{aFRR}$	The weighted average of aFRR clearing prices per AGC cycle for imbalance settlement period t , in accordance with the provisions of this section.
$BEP_{mFRR,t}^{up}$	The clearing price of upward mFRR balancing energy in €/MWh for the imbalance settlement period t , in accordance with the provisions of Section 2.1.
$BEP_{mFRR,t}^{dn}$	The clearing price of downward mFRR balancing energy in €/MWh for the imbalance settlement period t , in accordance with the provisions of Section 2.2.
$VOAA_t^{up}$	The value of avoided balancing energy activation in the upward direction, which is equal to the lower value of the upward balancing energy offer for either mFRR or aFRR in the corresponding LMOL for imbalance settlement period t .
$VOAA_t^{dn}$	The value of avoided balancing energy activation in the downward direction, which is equal to the highest value of upward balancing energy offer for either mFRR or aFRR in the corresponding LMOL for imbalance settlement period t .

For calculation of the weighted average of the aFRR clearing prices per AGC cycle for the Imbalance Settlement Period t , the following cases can be distinguished, according to whether there is a connection to the PICASSO Platform or not.

A) Full connection to the PICASSO Platform

To account for the cost of covering the total aFRR needs of the HETS Operator during the imbalance settlement period, aFRR demand (as calculated and submitted by the HETS Operator to the PICASSO Platform for each AGC cycle) is taken into account when calculating the imbalance price. Through connection to the PICASSO Platform, the aFRR needs of the HETS Operator can be met through the exchange of aFRR Balancing Energy, that is, by activating offers from the aFRR Local Merit Order List (LMOL) of other TSOs. Furthermore, the direction of total aFRR needs for the uncongested area of the PICASSO Platform may not coincide with the direction of the aFRR needs of the HETS Operator in every AGC cycle. Accordingly, calculating the imbalance price involves taking into account the aFRR clearing prices per AGC cycle for all AGC cycles within the imbalance settlement period, regardless of direction, for the congested area.

For an imbalance settlement period t , during which the HETS Operator remains fully connected to the PICASSO Platform (that is, for all 225 AGC cycles c of the period), the weighted average of aFRR clearing prices per AGC cycle, $MP_{WAE,t}^{aFRR}$, is calculated as follows:

$$MP_{WAE,t}^{aFRR} = \frac{\sum_{c \in t} (abs(SD_c^{aFRR}) \times MP_c^{aFRR})}{\sum_{c \in t} (abs(SD_c^{aFRR}))} \quad (6)$$

Where:

c	The AGC cycle.
MP_c^{aFRR}	The cross-border aFRR clearing price in €/MWh, as submitted by the PICASSO Platform for each PICASSO cycle preceding the AGC cycle c within the imbalance settlement period t .
SD_c^{aFRR}	The demand for aFRR in MWh that has been met for each execution cycle of the aFRR process preceding AGC cycle c within the imbalance settlement period t . The need for aFRR is calculated and submitted by the HETS Administrator to the PICASSO Platform for each AGC cycle.

B) Disconnection from the PICASSO Platform

In the event of disconnection from the PICASSO Platform, as the aFRR needs of the HETS Operator are then met exclusively through local aFRR balancing energy offers, only the aFRR clearing prices per AGC cycle corresponding to cycles with aFRR needs in a single direction (upward or downward) are taken into account in the calculation of the imbalance price, depending on the direction of the system imbalance for the specific imbalance settlement period. In this manner, appropriate incentives are offered to Balance Responsible Contracting Parties to limit system imbalance.

For a settlement period t , during which the HETS Operator remains fully disconnected from the PICASSO Platform (that is, for all 225 AGC cycles c of the period), the weighted average of aFRR clearing prices per AGC cycle, $MP_{WAE,t}$, is calculated as follows:

- If the system imbalance, SI_t is less than -25MW:

$$MP_{WAE,t}^{aFRR} = \frac{\sum_{c \in t} (SD_c^{aFRR,up} \times MP_c^{aFRR,up})}{\sum_{c \in t} SD_c^{aFRR,up}} \quad (7)$$

Where:

- c The AGC cycle.
- $MP_c^{aFRR,up}$ The upward aFRR clearing price for the AGC cycle in €/MWh, which corresponds to the maximum price of all upward aFRR balancing energy offers activated from the aFRR LMOL, for each AGC cycle c .
- $SD_c^{aFRR,up}$ The upward demand for aFRR in MWh met for each AGC cycle c , with a positive value.

b. If the system imbalance SI_t is greater than 25MW:

$$MP_{WAE,t}^{aFRR} = \frac{\sum_{c \in t} (SD_c^{aFRR,dn} \times MP_c^{aFRR,dn})}{\sum_{c \in t} SD_c^{aFRR,dn}} \quad (8)$$

Where:

- c Each AGC cycle within a imbalance settlement period t .
- $MP_c^{aFRR,dn}$ The downward aFRR clearing price for the AGC cycle in €/MWh, which corresponds to the minimum price of all downward aFRR balancing energy offers activated from the aFRR LMOL, for each AGC cycle c .
- $SD_c^{aFRR,dn}$ The downward demand for aFRR in MWh met for each AGC cycle c , with a positive value.

The need for aFRR is calculated by the HETS Administrator for each AGC cycle and submitted to the PICASSO Platform.

C) Partial disconnection from the PICASSO Platform

In cases where, during a single imbalance settlement period, the HETS Operator remains connected to the PICASSO Platform for part of the time and disconnected for the remaining time, the weighted average of aFRR clearing prices per AGC cycle is calculated based on:

- the equations (6) and (7) for system imbalances of less than -25 MW, and
- equations (6) and (8) for system imbalances greater than 25 MW.

The above values are weighted in relation to the respective time intervals.

5.3 Examples of imbalance value calculations

For the purposes of the examples, the following are taken into account:

- System imbalance, SI_t , is considered to be less than -25MW.
- The upward mFRR clearing price, $BEP_{mFRR,t}^{up}$ for the specific imbalance settlement period is equal to €40/MWh.
- The value of avoided balancing energy activation in the upward direction, $VOAA_t^{up}$, for the specific imbalance clearing period is equal to 20 €/MWh and in the downward direction, $VOAA_t^{dn}$, is equal to 25 €/MWh.

Each imbalance settlement period consists of 225 AGC cycles of 4sec each. However, for the sake of better understanding and ease of reading the results, data is presented for 20 AGC cycles only. Therefore, in the three scenarios examined, in order to meet the upward need for mFRR and aFRR Balancing Energy during the Imbalance Settlement Period t , the following apply:

- Scenario I: The Operator remains connected to the PICASSO Platform for the 20 AGC cycles.
- Scenario II: The Operator remains disconnected from the PICASSO Platform for the 20 AGC cycles.
- Scenario III: The Operator remains logged in to the PICASSO Platform for 18 AGC cycles and disconnected for 2 AGC cycles within an imbalance settlement period t .

Scenario I: Connection with the PICASSO Platform

In this scenario, the HETS Operator remains connected to the PICASSO Platform for all 20 AGC cycles under review, in which case the AGC cycle aFRR clearing price is identical to the cross-border aFRR clearing price ($CBMP_{aFRR}$), as defined in Section 4.1. Indicative data are presented in the following table.

TABLE 11. RESULTS OF THE aFRR PROCEDURE - SCENARIO I

AGC cycle	SD_{oc}^{aFRR} (MW)	$CBMP_{aFRR}$ (€/MWh)
C ₁	20	70
C ₂	50	100
C ₃	30	110
C ₄	60	120
C ₅	80	230
C ₆	-20	30
C ₇	-60	50
C ₈	-50	20
C ₉	-50	10
C ₁₀	-80	5
C ₁₁	-20	-10
C ₁₁	-10	-20
C ₁₃	10	200
C ₁₄	20	230
C ₁₅	30	170
C ₁₆	20	150

C17	50	120
C18	100	260
C19	100	200
C20	100	150

The weighted average value of AGC cycle aFRR clearing prices are $MP_{WAE,t}$, calculated in accordance with equation (6) shown in Section 5.2 and the table above as follows:

$$MP_{WAE,t}^{aFRR} = \frac{\sum_{c1...c20} (abs(SD_c^{aFRR}) \times CBMP_{aFRR})}{\sum_{c1...c20} (abs(SD_c^{aFRR}))} = 127,19 \text{ €/MWh}$$

The imbalance price, IP_t , is then calculated in accordance with Section 5.2 as follows:

$$IP_t = \max (MP_{WAE,t}^{aFRR}; BEP_{mFRR,t}^{up}; VOAA_t^{up}; VOAA_t^{dn})$$

$$= \max (127,19; 40; 20; 25) = 127,19 \text{ €/MWh}$$

Scenario II: Full disconnection from the PICASSO Platform

In this scenario, the HETS Operator remains disconnected from the PICASSO Platform for all 20 AGC cycles under consideration. Accordingly, the upward aFRR clearing price per AGC cycle corresponds to the maximum price of all upward aFRR balancing energy offers activated from the aFRR LMOL, for each AGC cycle c within the period under review, in accordance with the provisions of Section 4.1. Indicative data are presented in the following table.

TABLE 12. RESULTS OF THE AFRR PROCEDURE - SCENARIO II

AGC cycle	SD_c^{aFRR} (MW)	$MP_c^{aFRR,up}$ (€/MWh)
C1	20	70
C2	50	100
C3	30	110
C4	60	140
C5	80	250
C6	-20	20
C7	-60	20
C8	-50	10
C9	-50	10
C10	-80	-5
C11	-20	-50
C11	-10	-60
C13	10	220
C14	20	240
C15	30	170
C16	20	150
C17	50	120
C18	100	300
C19	100	290
C20	100	230

The weighted average value of aFRR clearing prices for the AGC cycle, $MP_{WAE,t}$, in accordance with equation (7) shown in Section 5.2 and the results of the above table, is calculated as follows:

$$MP_{WAE,t}^{aFRR} = \frac{\sum_{c1...c20} (abs(SD_c^{aFRR,up}) \times MP_c^{aFRR,up})}{\sum_{c1...c20} (abs(SD_c^{aFRR,up}))} = 147,71 \text{ €/MWh}$$

The imbalance price is calculated in accordance with equation (5) shown in Section 5.2 and taking into account the weighted average clearing price of the AGC cycle aFRR clearing prices calculated above, as follows:

$$\begin{aligned} IP_t &= \max (MP_{WAE,t}^{aFRR}; BEP_{mFRR,t}^{up}; VOAA_t^{up}; VOAA_t^{dn}) \\ &= \max (147,71; 40; 20; 25) = 147,71 \text{ €/MWh} \end{aligned}$$

Scenario III: Partial connection to the PICASSO Platform

In this scenario, the HETS Operator remains connected to the PICASSO platform for 18 AGC cycles (c_1 up to and including c_{18}), that is, for period Δt_1 which is equal to 72 secs and corresponds to 90% of the total duration of the period under consideration, and remains disconnected from the PICASSO platform for 2 AGC cycles (c_{19} to c_{20}), that is, for period Δt_2 which is equal to 8 secs and corresponds to 10% of the total duration of the period under consideration.

TABLE 13. RESULTS OF THE AFRR PROCEDURE - SCENARIO III

AGC cycle	SD_{oc}^{aFRR} (MW)	$CBMP_{aFRR}$ (€/MWh)	$MP_c^{aFRR,up}$ (€/MWh)
C ₁	20	70	-
C ₂	50	100	-
C ₃	30	110	-
C ₄	60	120	-
C ₅	80	230	-
C ₆	-20	30	-
C ₇	-60	50	-
C ₈	-50	20	-
C ₉	-50	10	-
C ₁₀	-80	5	-
C ₁₁	-20	-10	-
C ₁₁	-10	-20	-
C ₁₃	10	200	-
C ₁₄	20	230	-
C ₁₅	30	170	-
C ₁₆	20	150	-
C ₁₇	50	120	-
C ₁₈	100	260	-
C ₁₉	100	-	290
C ₂₀	100	-	230

Initially, the weighted average value of the AGC cycle aFRR clearing prices, for the period Δt_1 during which

the HETS Operator remains connected to the PICASSO platform, is calculated in accordance with equation (5) of Section 5.2 and the results of the above table, as follows:

$$MP_{WAE,\Delta t_1}^{aFRR} = \frac{\sum_{c1\dots c18}(abs(SD_c^{aFRR}) \times CBMP_{aFRR})}{\sum_{c1\dots c18}(abs(SD_c^{aFRR}))} = 114,61\text{€/MWh}$$

Next, the weighted average value of the AGC cycle aFRR clearing prices, for period Δt_2 during which the HETS Operator remains disconnected from the European platform, is calculated in accordance with equation (7) of Section 5.2 and the results of the above table, as follows:

$$MP_{WAE,\Delta t_2}^{aFRR} = \frac{\sum_{c19,c20}(abs(SD_c^{aFRR,up}) \times MP_c^{aFRR,up})}{\sum_{c19,c20}(abs(SD_c^{aFRR,up}))} = 260 \text{ €/MWh}$$

To obtain the weighted average value of the AGC cycle aFRR clearing prices in the imbalance clearing period t , the resulting values for the two partial periods Δt_1 and Δt_2 are weighted as follows:

$$\begin{aligned} MP_{WAE,t}^{aFRR} &= MP_{WAE,\Delta t_1}^{aFRR} * \Delta t_1(\%) + MP_{WAE,\Delta t_2}^{aFRR} * \Delta t_2(\%) = 114,61 * 90\% + 260 * 10\% \\ &= 129,14\text{€/MWh} \end{aligned}$$

The imbalance price is calculated in accordance with equation (5) shown in Section 5.2 and takes into account the weighted average clearing price of the AGC cycle aFRR clearing prices calculated above, as follows:

$$\begin{aligned} IP_t &= \max (MP_{WAE,t}^{aFRR}; BEP_{mFRR,t}^{up}; VOAA_t^{up}; VOAA_t^{dn}) = \max (129,14; 40; 20; 25) \\ &= 129,14 \text{ €/MWh} \end{aligned}$$