



# Stakeholder document for the principles of IGCC

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IGCC Expert Group

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## Objective of this document and target audience

The present document aims to share the principles of the IGCC project as derived by the IGCC MLA and the different common documents produced by IGCC. The target audience is initially non-IGCC TSOs and NRAs but also other stakeholders as a step towards the implementation of the European target for the Imbalance Netting process according to the stipulations of the GL EB. The GL requires that several proposals on the principles of the European target for Imbalance netting process have to be developed by the TSOs, discussed with stakeholders and approved by the NRAs, therefore motivation of this document is to share the current status of IGCC as a step in that direction.

This document is a public document available in the dedicated website for IGCC at ENTSO-E.

## Definitions

Name	Description
<b>Affected TSO</b>	Means a TSO affected by IGCC power exchanges acknowledged as affected by a dedicated ENTSO-E group. An IGCC Member can also be an Affected TSO.
<b>aFRR</b>	Means the Frequency Restoration Reserves that will be activated by an automatic control device.
<b>aFRR Coordinated balancing area, aFRR CoBA</b>	Means a region in which TSOs are exchanging aFRR balancing energy.
<b>aFRR-Optimization System</b>	Means a central, modularly designed, jointly utilized IT tool (hardware and software) for optimization of aFRR activation operated by the Host TSO.
<b>aFRR-Demand, <math>P_{demand}</math></b>	Means a certain amount of aFRR that is required by the IGCC Member in order to control the ACE to zero in MW. The aFRR-Demand is the sum of the already activated aFRR and the ACE without the influence of the Correction. Negative value - the LFC Area is in power surplus and indicates that negative aFRR needs to be activated. Positive value - vice versa.
<b>Area Control Error or ACE <math>P_{ACE}</math></b>	Means Area Control Error of the LFC Area including Correction in MW. Negative value: the LFC Area is in power deficit and positive aFRR needs to be activated in order to control the ACE to zero. Positive value: vice versa.
<b>ATC-Limit</b>	Means a Limit for the IGCC power exchange on one Border between two IGCC Members.
<b>Border</b>	Means a set of physical transmission lines linking adjacent LFC Areas.

<b>Concerned Border</b>	Means a border between two IGCC Members, used for IGCC power exchange.
<b>Critical branch</b>	Means a network element monitored for congestion management purpose for which a Flow-Based Limit can be applied. The critical branch is defined by at least one IGCC Member.
<b>Imbalance Netting Coordinated Area</b>	Means a region in which TSOs are operating the imbalance netting process.
<b>ENTSO-E</b>	Means the European Network of Transmission System Operators for Electricity as established in the Regulation (EC) 714/2009 of the European Parliament and of the Council of 13 July 2009 on conditions for access to the network for cross-border exchanges in electricity and repealing Regulation (EC) 1228/2003.
<b>Facilitating Party</b>	Means an IGCC Member that takes over the tasks related to organising meetings, preparing work as well as reporting for the IGCC Expert Group and IGCC Steering Committee meetings.
<b>Flow-Based Limit</b>	Means a limit of IGCC induced power flow on a critical branch or a transmission corridor (a set of critical branches).  In the context of IGCC, Flow-Based refers to real time monitoring of flows induced by IGCC on critical branches. It differs from flow-based approach defined in CACM GL.
<b>FRR</b>	Means frequency restoration reserves delivering active power reserves, activated for a Synchronous Area consisting of one LFC Block to restore system frequency to the nominal frequency and for a Synchronous Area consisting of more than one LFC Area to restore the power balance to the scheduled value of each LFC Area.
<b>Host TSO</b>	The IGCC Member hosting, operating and maintaining the aFRR-Optimization System.
<b>IGCC</b>	Means International Grid Control Cooperation.
<b>IGCC EG</b>	Means the IGCC Expert Group.
<b>IGCC Member</b>	Means any party (TSO) who has signed the MLA.
<b>IGCC Operation Status</b>	Means a signal sent by the aFRR-Optimization System to the IGCC Member to indicate the actual status (on/off) of the operation of IGCC.
<b>IGCC Opportunity Price</b>	Means the price reflecting the value of the avoided activation of positive or negative aFRR energy due to the Imbalance Netting.

<b>IGCC SC</b>	Means the IGCC Steering Committee.
<b>Imbalance Netting</b>	Means a process agreed between TSOs of two or more LFC Areas within one or more than one Synchronous Areas, that allows for the avoidance of simultaneous aFRR activation in opposite directions by taking into account the respective area control errors as well as the activated aFRR and correcting the input of the involved frequency restoration processes accordingly.
<b>Invoicing TSO</b>	Means an IGCC Member that issues invoices and sends them to other IGCC Member(s). It is the IGCC Member with whom the invoiced IGCC Member performs billing.
<b>Limits</b>	Means a constraint sent by an IGCC Member to the aFRR-Optimization System and taken into account by the aFRR-Optimization System for the calculation of the Correction.
<b>LFC Area</b>	Means a part of a Synchronous Area or an entire Synchronous Area, physically demarcated by points of measurement of interconnectors to other LFC Areas, operated by one or more TSOs fulfilling the obligations of an LFC Area.
<b>LFC Block</b>	Means a part of a Synchronous Area or an entire Synchronous Area, physically demarcated by points of measurement of interconnectors to other LFC Blocks, consisting of one or more LFC Areas, operated by one or more TSOs fulfilling the obligations of an LFC Block.
<b>Multilateral Agreement MLA or</b>	Means the multilateral agreement of IGCC.
<b>National Regulatory Authority</b>	Means a national regulatory authority referred to in chapter IX of the Directive 2009/72/EC concerning common rules for the internal market in electricity and repealing Directive 2003/54/EC.
<b>Optimization Region</b>	Two or more neighbouring LFC Blocks of which at least one is operated by an IGCC Member performing Imbalance Netting between each other before performing Imbalance Netting with the other IGCC Members.
<b>Participation Status</b>	Means a signal sent by the aFRR-Optimization System to the IGCC Member to indicate the actual participation status (on/off) of the IGCC Member.
<b>Participation Status Request</b>	Means a signal sent by the IGCC Member to the aFRR-Optimization System to allow manual connection or disconnection (suspension) to or from IGCC (on/off).
<b>Profile-Limit</b>	Means a Limit for the total IGCC power exchange of one LFC Area.
<b>Synchronous Area</b>	Means an area covered by interconnected TSOs with a common system frequency in a steady-state such as the Synchronous Areas

	Continental Europe (CE), Great Britain (GB), Ireland (IRE) and Northern Europe (NE).
<b>TSO or TSOs</b>	Means transmission system operator(s).
<b>Virtual Tie-Line</b>	Means an additional input of the controllers of the involved areas that has the same effect as a measuring value of a physical tie-line and allows exchange of electric energy between the respective areas.

## 1. Introduction

The International Grid Control Cooperation (IGCC) is a project operating the Imbalance Netting process which currently involves 11 TSOs from 8 countries. These are the TSOs from AT (APG), BE (Elia), CH (Swissgrid), CZ (CEPS), DE (50Hz, Amprion, TenneT DE, TransnetBW), DK (Energinet.dk), FR (RTE), NL (TenneT NL).



Figure 1-1: TSOs that are currently IGCC Members

To support the implementation of the “Electricity Balancing” Guideline (GL EB), several pilot projects have been set up. IGCC has been validated by ENTSO-E as a pilot project for the Imbalance Netting process and it has been also endorsed as a starting point for the European target for the Imbalance Netting process, to be further developed in line with the provisions of GL EB.

### 1.1. Basic principle of Imbalance Netting

As part of their responsibility for the transmission system, the IGCC Members as Transmission System Operators (TSOs) are obliged to maintain the balance between electricity generation and consumption at all times in their respective LFC Areas. The IGCC is based on an automatic Frequency Restoration Reserves (aFRR)-Optimization System for the avoidance of counter activation of aFRR.

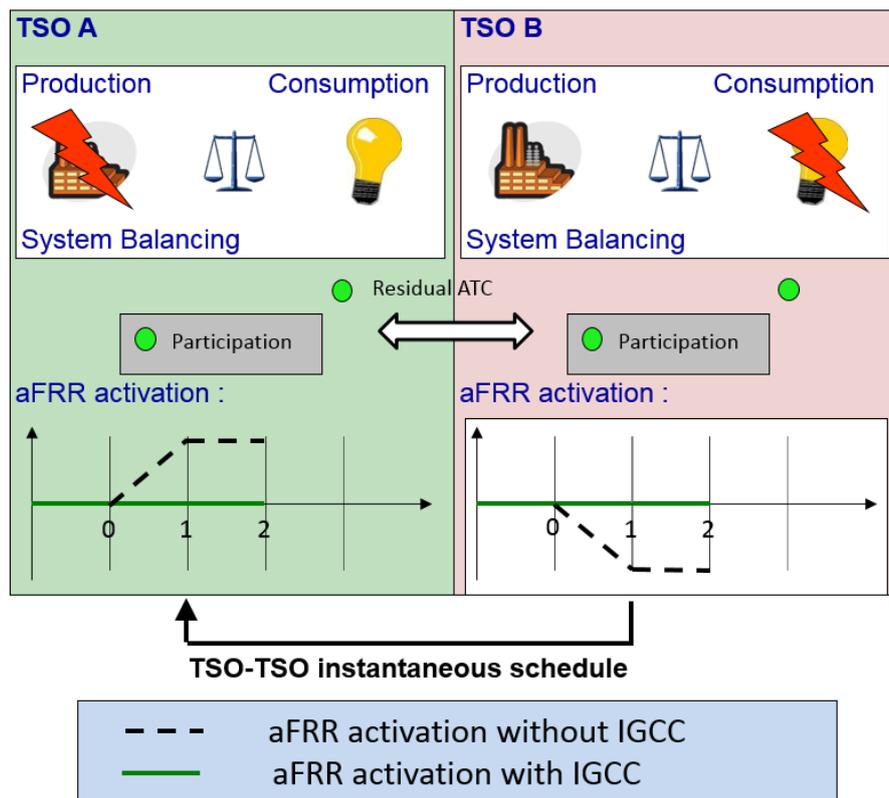


Figure 1-2: Operating principle of imbalance netting

Imbalance Netting in the context of IGCC is the process agreed between TSOs of two or more LFC Areas within one or more than one Synchronous Areas, that allows for the avoidance of simultaneous aFRR activation in opposite directions by taking into account the availability of cross-border transmission capacity (cf. 3.1.1), the respective area control errors as well as the activated aFRR and correcting the input of the involved frequency restoration processes accordingly.

The implementation of the process is based on the communication of the power-frequency control of a single TSO which enables online balancing of the different power imbalances. The aFRR-Demand of participating LFC Areas is reported to the aFRR-Optimization System, which returns a Correction to the secondary controllers or aFRR-Optimization System of each IGCC Member after each optimization step. In this sense, the counter activation of the aFRR is avoided and therefore the use of aFRR is optimized.

## 1.2. Historical evolution

The implementation of the first development phase of the Grid Control Cooperation between German TSOs made it possible to implement the Imbalance Netting process which aimed to avoid the counter activation of aFRR within the German Control Block, consisting of four Control Areas, in 2010.

With the Grid Control Cooperation developed within the German LFC Block, the international Optimization potential could be exploited by extension to other LFC Areas. This created an opportunity for further prevention of counter-activation of aFRR leading to an increase of

operational security and economic benefit while not affecting the (possible) alteration of national framework conditions.

Imbalance Netting across LFC Areas enables all participating TSOs to decrease the use of balancing energy, increase system security and increase frequency quality. The experience with the initial German Grid Control Cooperation has been transferred to the IGCC, which has been established by entering into bilateral accession agreements of the four German TSOs and Energinet, TenneT NL, Swissgrid, ČEPS, Elia and APG until April 2014. RTE joined the project with the role of Observer in May 2014.

The objective of the IGCC Members is that the cooperation will be taken as a reference by other European TSOs in order to implement the GL EB once it enters into force. Therefore, the IGCC Members started working in September 2013 on the development of a Multilateral Agreement (MLA), acknowledging that this MLA should be in line with the GL EB. The MLA was completed and entered into force in January 2016 replacing the previous bilateral agreements. RTE became the first member of IGCC which became a full member of the cooperation by signing the newly developed IGCC MLA.



Figure 1-3: Historical evolution of IGCC

### 1.3. Scope and objectives of IGCC based on the IGCC MLA

The aim of IGCC as stipulated in the IGCC MLA is:

- a. to foster the cooperation between IGCC Members,
- b. to lower the amount of activated aFRR,
- c. to strengthen the security of supply and
- d. to generate social welfare for each IGCC Member

by operating the IGCC among the IGCC Members in a transparent and reliable way.

In order to achieve this successful operation of IGCC, the cooperation of all IGCC Members is required, therefore it is envisaged that all IGCC Members should do that in a fair and cooperative manner in order to achieve the abovementioned objectives.

The IGCC Members would like to use the experiences gained from IGCC to discuss and study further evolution of the cooperation in order to gain operational experience for the cross-border exchange of balancing services, in particular regarding the operation of the Imbalance Netting process and to gain market design experience regarding the exchange of aFRR, e.g. for providing inputs to the proposals for the European target for the aFRR process.

In the context of being a reference project for implementation of the Imbalance Netting process across Europe, the gained experience and knowledge will then contribute to the implementation of the target model for Imbalance Netting at European level as identified in the GL EB.

Notwithstanding the above objectives and visions, it is clearly stipulated in the MLA that each IGCC Member remains solely responsible for the operational security of its transmission network, including the operation of its load-frequency-control.

#### **1.4. Joining IGCC**

As a starting point for the implementation of the European target for the Imbalance Netting process, IGCC is subject to be extended to other TSOs in the near future. For the TSOs interested in joining the cooperation, IGCC developed an implementation guide „*Guide on how to become an IGCC Member*” which describes all the necessary steps to fulfil and an indicative timeline before being able to participate in IGCC. With this Guide, a step towards the implementation of the GL EB is made, since TSOs that will implement the Imbalance Netting process and will join IGCC do have a roadmap with the necessary steps for planning of their participation in IGCC.

The implementation guide is available on ENTSO-E website for IGCC.

## 2. Governance structure and decision making

The IGCC is characterised by a clearly defined working structure and decision process.

### 2.1. Working structure

The working structure of the IGCC is divided into two levels, a decision making level and an expert level. The IGCC Steering Committee (IGCC SC) is the decision making body of the IGCC and has the power to take binding decisions. Decisions are made within the rights and obligations of the MLA framework, upon topics related to the design, operation and implementation of IGCC. The IGCC SC meets at least twice per year. The expert level is formed by the IGCC Expert Group (IGCC EG) and prepares background materials (e.g. new concepts, analyses and impact assessments) for the IGCC SC. The IGCC EG meets regularly either physically or by conference call.

Each IGCC Member has one representative in the IGCC SC and one in the IGCC EG. The working structure of IGCC is supported by an assigned Facilitating Party and a convener of IGCC EG.

The role of Facilitating Party (FP) is fulfilled by one of the IGCC Members and supports both the IGCC EG and the IGCC SC by tasks related to organising meetings, preparing work as well as reporting. The FP is always present at the meetings of the IGCC SC and IGCC EG. The IGCC Member who fulfils the FP role may delegate an additional representative for this supporting role.

The role of the convener of the IGCC EG is also fulfilled by one of the IGCC Members and supports the IGCC EG by organizing the work and besides acts as a single point of contact between IGCC EG and IGCC SC.



Figure 2-1: IGCC working structure

### 2.2. Principles for decision making

The aim of the decision making process of the IGCC is to reach unanimous decisions. For this purpose, each IGCC Member is obliged to take part in the decision process. However, each IGCC Member has the right to abstain from voting and then its vote is not taken into account for reaching unanimity.

Voting by the IGCC SC can take place during a physical meeting or by email. However, to initiate a decision process at least 2/3 of all IGCC Members need to be present in person.

If no unanimous decision can be reached, a second voting round is organised within 50 calendar days, during which the IGCC Members cooperate to find a suitable solution for all IGCC Members.

The second voting round is based on two criteria 'A' and 'B' representing different voting powers. A decision is adopted in the second voting round if both 75% of voting criterion A and 65% of voting criterion B is in favour of the decision.

### 2.2.1. Second round of voting

For voting criterion A each country is provided with one vote. This vote is equally divided over the number of IGCC Members operating in a specific country.

For voting criterion B the voting power of each IGCC Member is represented by the number of inhabitants living in the geographical area of the IGCC Member.

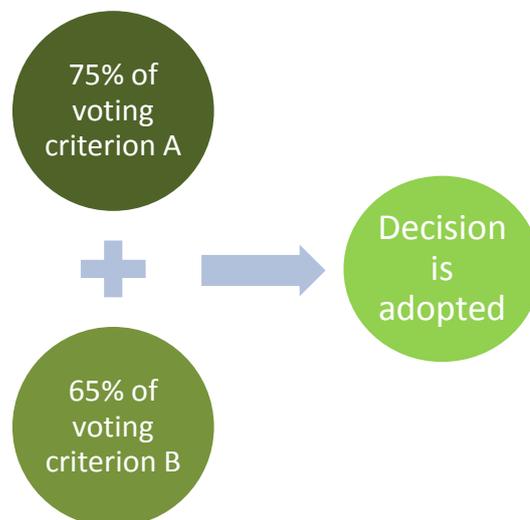


Figure 2-2: IGCC voting criteria

### 2.3. Cost sharing principle

Costs related to the IGCC are within the cooperation divided into 'individual costs', which are borne by each IGCC Member individually, and 'one-time shared costs'.

Individual costs are solely the responsibility of each IGCC Member and include:

- Costs for development, implementation, operation and maintenance of the technical infrastructure and procedures according to the requirements set in the MLA and any additional individual requirements.
- Any IGCC related costs for employees and travelling.
- The operational costs of the Host TSO are individual costs for the Host TSO.

One-time shared costs are shared according to the voting power shares of voting criterion B or according to any other cost sharing key if explicitly agreed within the decision process. These costs result from IGCC SC decisions on proposals related to:

- New functionalities in the aFRR-Optimization System that impact the IGCC exchange

- Assignment for joint studies

#### **2.4. Adaptation of the MLA**

The cooperation has recognised, in the light of future expansion of the cooperation and the current dynamics in the field of balancing regulations, that the MLA should allow for gradual development. The MLA therefore consists of one main agreement and five Annexes in which topics are described which are more prone to change and which do not include the basic principles of the MLA. These Annexes of the MLA can be amended by an IGCC SC decision and become effective after the last signature of the IGCC Members.

Notwithstanding the above, it is noted that the IGCC MLA main agreement can also be amended if this is considered necessary by the IGCC Members.

### 3. IGCC Algorithm – Description of the optimization

The IGCC deals exclusively with Imbalance Netting. The assignment of Imbalance Netting potential among IGCC Members in each real-time optimization cycle is based upon the principles of proportional distribution and non-discrimination.

The Correction of the IGCC Members as calculated by the aFRR-Optimization System is integrated into the aFRR control loops of the LFC Areas to which the IGCC Member belongs. The basic principles of the aFRR-Optimization System are the following:

- each IGCC Member calculates the aFRR-Demand of the LFC Area to which the IGCC Member belongs;
- the aFRR-Demands and Limits are sent to the aFRR-Optimization System;
- the aFRR-Optimization System calculates the Corrections whilst respecting the Limits; and
- the Corrections are sent to the IGCC Members and are used as input for the aFRR control loops of the LFC Areas;

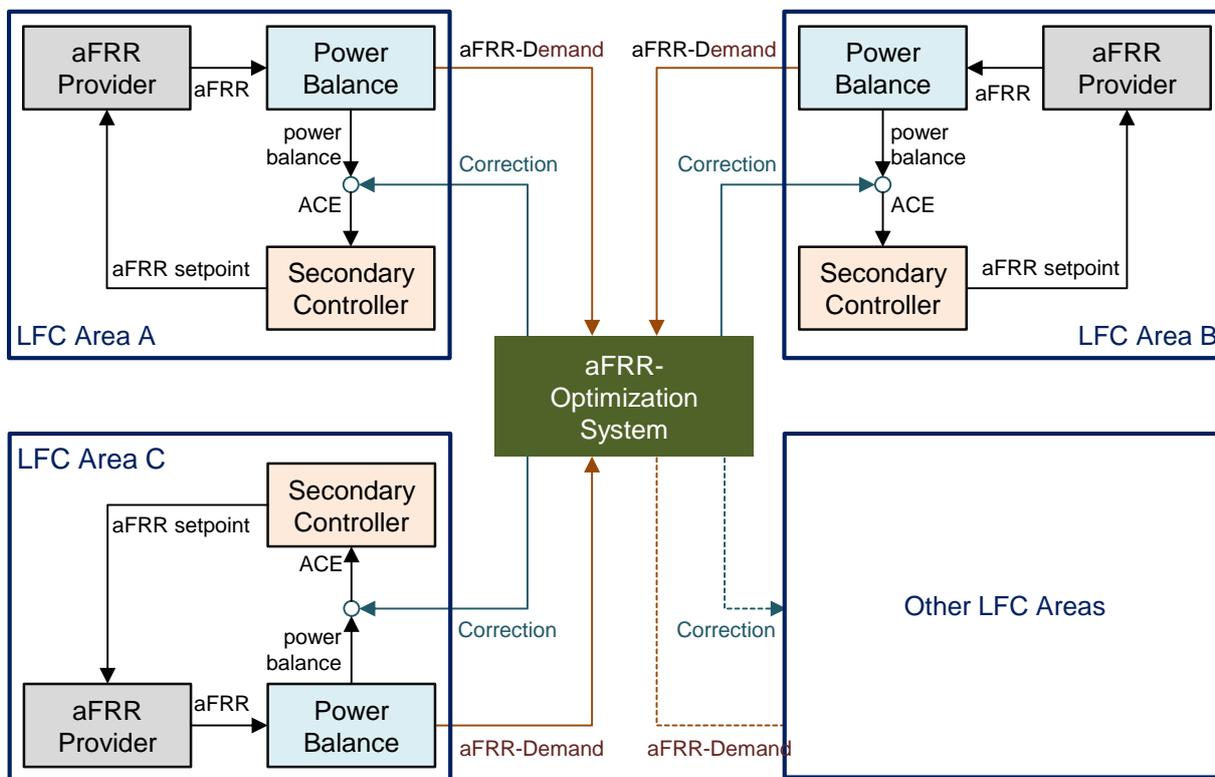


Figure 3-1: Basic principle of aFRR-Optimization System

Figure 3-2 shows the integration of the aFRR-Optimization System into the secondary control loop of a IGCC Member based on definitions and sign conventions of Table 1. The exact implementation in the SCADA system of an individual IGCC Member may vary as long as the control structure according to Figure 3-2 is respected. In particular, the following equations that show the ACE of one TSO reduced by its correction value from the imbalance netting and the aFRR-Demand which is the overall imbalance that have to be covered by aFRR shall be fulfilled:

$$P_{ACE} = P_{meas} - P_{prog} + K\Delta f - P_{corr}$$

$$P_{Demand} = P_{aFRR} - P_{ACE} - P_{corr}$$

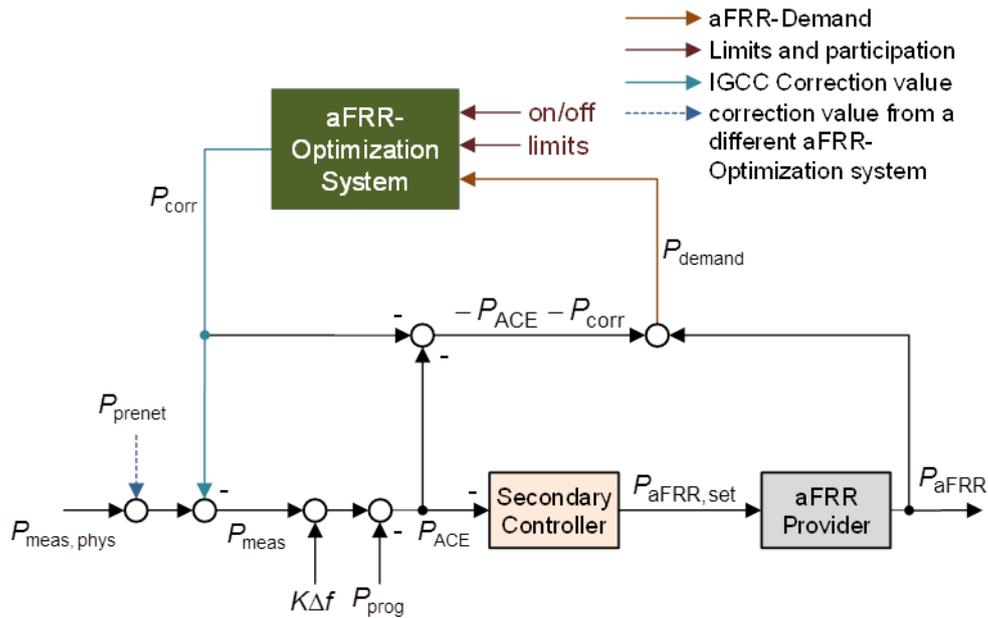


Figure 3-2: Integration into the Secondary Control Loop

Table 1: Integration into the Secondary Control Loop – Sign Conventions

Name	Symbol	Description
<b>Prenetted aFRR-Demand</b>	$P_{prenet}$	Means the amount of aFRR-Demand netted in an Optimization Region not optimized by the aFRR-Optimization System of the IGCC.
<b>Measured power exchange</b>	$P_{meas}$	Means the measured power exchange of the LFC Area in MW. Positive value: the LFC Area exports. Negative value; vice versa.
<b>Frequency component of Area Control Error</b>	$K\Delta f$	Frequency deviation is positive in case of actual frequency above scheduled frequency. Frequency deviation is negative in case of actual frequency below scheduled frequency.
<b>Scheduled power exchange</b>	$P_{prog}$	Means a scheduled power exchange of the LFC Area in MW. Positive value: the LFC Area exports. Negative value: vice versa.
<b>Required aFRR activation</b>	$P_{aFRR,set}$	Means a required activation of aFRR to control ACE of the IGCC Member to zero in MW. Negative value: the LFC Area is long and negative aFRR needs to be activated in order to control the ACE to zero. Positive value: vice versa.

<b>Activated aFRR</b>	$P_{aFRR}$	<p>Means the activated aFRR, measured or estimated, as determined by each LFC Area that controls the ACE of the LFC Area to zero in MW.</p> <p>Negative value: the LFC Area is long and negative aFRR is activated in order to control the ACE to zero. Positive value: vice versa.</p>
<b>Correction</b>	$P_{corr}$	<p>Means the amount of power exchange of the IGCC Member with other IGCC Members in MW. The Correction is calculated by the aFRR-Optimization System and has the opposite sign of the corresponding aFRR-Demand. The Correction value is treated as an agreed upon active power flow over a Virtual Tie-Line between two IGCC Members.</p> <p>Negative value: leads to power import of the IGCC Member from IGCC (supply of positive aFRR to LFC Area). Positive value: vice versa.</p>

Figure 3-3 illustrates the calculation of the Correction values without Limits. LFC Areas A and B are short (1000 MW in total) while LFC Areas C and D are long (-500 MW in total).

Therefore, the optimization target is to fully net the aFRR-Demands of C and D and to distribute the netting for A and B according to the respective shares of the overall positive aFRR-Demand. Since there are no Limits, the optimization target can be reached (the deviation from the optimization target is zero).

LFC Block	A	B	C	D
aFRR-Demand [MW]	200	800	-50	-450
Share of Total Positive Demand [pu]	$200/(200+800) = 0.2$	$800/(200+800) = 0.8$	n/a	n/a
Share of Total Negative Demand [pu]	n/a	n/a	$-50/(-50+(-450)) = 0.1$	$-450/(-50+(-450)) = 0.9$
Correction - Optimisation Target [MW]	$-0.2 \cdot 500 = -100$	$-0.8 \cdot 500 = -400$	$0.1 \cdot 500 = 50$	$0.9 \cdot 500 = 450$
Correction Value (Optimisation Result) [MW]	-100	-400	50	450
Remaining aFRR-Demand [MW]	$200+(-100) = 100$	$800+(-400) = 400$	$-50+50 = 0$	$-450+450 = 0$
Deviation from Target [MW]	$-100-(-100) = 0$	$-400-(-400) = 0$	$50-50 = 0$	$450-450 = 0$
Deviation/aFRR-Demand (Absolute Value) [pu]	$ 0/200  = 0$	$ 0/800  = 0$	$ 0/50  = 0$	$ 0/450  = 0$

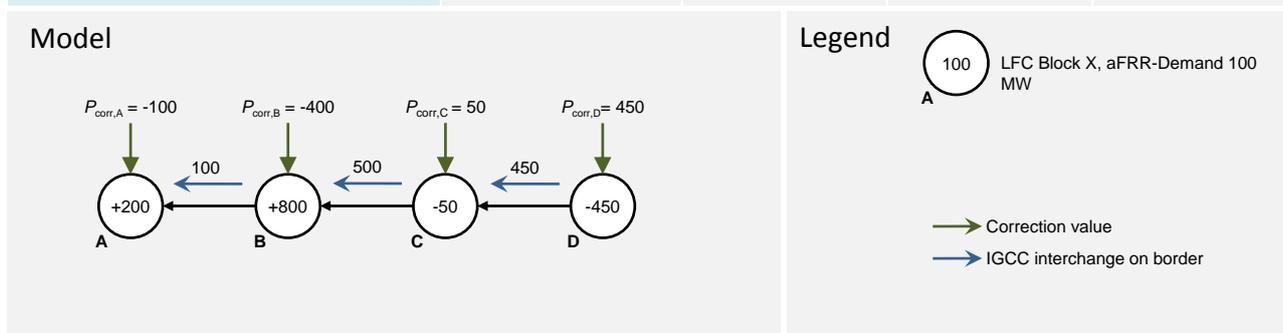


Figure 3-3: Example without consideration of restrictions

The power exchange between LFC Blocks is implemented according to the ENTSO-E definitions of Virtual Tie-Lines (as defined in the ENTSO-E RGCE Operation Handbook, Policy 1, B-D6.2 and in the SO GL, Article 3). The LFC Area may be part of different cooperations related to aFRR. In particular, the LFC Area may be part of an Optimization Region and perform

a pre-netting of imbalances with LFC Areas which are not part of IGCC (cf. Pre-netting and Optimization Regions section). In this case, the respective correction value ( $P_{\text{prenet}}$ ) shall be treated in the same way as other tie-lines which are part of the ACE calculation.

The determination of the IGCC energy quantities is performed for each settlement period (15 minutes). The IGCC energy quantities for each IGCC Member and each settlement period consist of two values, the IGCC import and the IGCC export of the IGCC Member.

All Borders between IGCC Members shall be part of IGCC. The exclusion of the Border is possible in these cases:

- a. The exclusion of a Border might be necessary due to ENTSO-E rules or regulatory decision (can be unilateral, bilateral or regional depending on the concerned border).
- b. A Border between IGCC Members can be excluded upon unilateral decision from the side of one of the involved IGCC Members in case either operational or technical problems or strong detrimental effects in terms of costs and benefits are expected and made transparent to other IGCC Members.
- c. A Border between IGCC Members can be excluded or included upon their bilateral agreement and the reasons for it shall be made transparent to other IGCC Members.

### 3.1. Principles of limitations

All IGCC Members cooperate to implement the Limits to ensure operational security and transparency of information related to the respective operational procedures and methodologies. The Host TSO implements the Limits into the aFRR-Optimization System.

Three types of Limits are combined and used by IGCC algorithm in real time:

- ATC-Limits (Default limits)
- Profile-Limits
- Flow-Based Limits

Those Limits are taken into account in real time as boundary conditions by the IGCC algorithm to ensure that the resulting Corrections of each IGCC Member respect and guarantee simultaneously all those Limits.

The IGCC Members of a Concerned Border must agree on the provision of the ATC-Limits to the aFRR-Optimization System and appoint at least one of the two IGCC Members as responsible for implementing the necessary data exchange in cooperation with the Host TSO.

In case both IGCC Members provide values for the ATC-Limits of the same Concerned Border or Flow-Based Limits for the same flow, the minimum of both values will be used by the aFRR-Optimization System as input for the calculation (cf. example provided in **Fehler! Verweisquelle konnte nicht gefunden werden.**).

Table 2: Example for the determination of Limits

Limit	Direction	Value
<b>Defined by A</b>	from A to B	50 MW
	from B to A	110 MW
<b>Defined by B</b>	from A to B	40 MW
	from B to A	200 MW
<b>Used by aFRR-Optimization</b>	from A to B	min (50 MW, 40 MW) = 40 MW

<b>System</b>	from B to A	min (110 MW, 200 MW) = 110 MW
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### 3.1.1. ATC-Limits

The **default Limits** for Imbalance Netting interchange on a Concerned Border between two IGCC Members represent the remaining cross-border transmission capacity determined after Intraday cross zonal gate closure time and take into account the exchange of balancing energy, e.g. aFRR, mFRR, RR, or other reserves at the common border or profile (e.g. Germany - Netherlands or Netherlands - Belgium). This represents the residual available transfer capacity (ATC) for IGCC in real time which can be used to maintain the resulting IGCC interchange and Corrections within an operational safety domain.

In order to ensure operational security the IGCC exchange between the LFC Areas of the IGCC Members shall be limited according to agreed rules which may be defined additionally to the default Limits.

### 3.1.2. Profile-Limit:

The Profile-Limit means a limit for the total IGCC interchange of one LFC Area (total import or export).

Each IGCC Member has the right to limit its participation to the available aFRR capacity. Such additional limit can be defined and used by the IGCC Member.

The IGCC Members have the possibility to manually reduce such a limit in a certain situation (e.g. emergency situation) in order to be able to reduce its own participation in IGCC (cf. Operational Guideline section).

### 3.1.3. Flow-Based Limit:

The Flow-Based Limit means a limit of IGCC induced power flow on a critical branch or a transmission corridor (a set of critical branches) within an LFC area or between LFC areas.

Where the transmission capacity for IGCC exchange is not limited by an explicit or implicit allocation procedure on a Concerned Border, the IGCC Members shall agree on default values of the Flow-Based Limits which reflect a reasonable range for the exchange on one corridor or for the power flow on a critical branch (e.g. 2000 MW between German LFC Areas).

The Flow-Based Limits are used by the German IGCC Members in order to maintain operational security through reduction of physical flows resulting from IGCC exchange on transmission corridors in Germany. Flow-Based Limits may impact the IGCC exchange according to the principles described in the present section. Flow-Based Limits are currently not applied for transmission corridors of any other IGCC Member but there are some discussions within the cooperation about a possibility to extend the usage of such Limits to all IGCC Members.

A matrix  $M_{PTDF}$  is used to represent the impact of IGCC exchange on load-flows over the identified critical branches or transmission corridors.

A Power Transfer Distribution Factor (PTDF) quantifies the influence of an IGCC exchange between LFC Areas on a given grid element "C" (Critical branch or Transmission corridor). In this framework, a PTDF of 10% means that an increase of 100 MW from A to B induces an increase of  $100 \text{ MW} * 10\% = 10 \text{ MW}$  on the grid element C. For Germany, the PTDF factors

composing the matrix  $M_{PTDF}$  represent the variation of the physical flow on critical branches induced by the variation of the Correction of each IGCC Member.

As an illustration, the matrix  $M_{PTDF}$  representing the impact of IGCC exchange on load-flows over the critical branches C1 and C2 is defined in table 2.

**Table 2: Fictional PTDF Matrix**

Critical Branch	Sensitivity to IGCC export (IGCC Correction)		
	A	B	C
C1	-0.2	0.6	0.2
C2	0	-0.4	0.4

The PTDFs used by German IGCC Members in real time are currently deduced from the day ahead forecast of a common grid model.

#### 4. Pre-netting and Optimization Regions

Basically each IGCC Member has the right to pre-net its imbalance within an Optimization Region consisting of LFC Blocks which are part of the IGCC as well as in other co-operations consisting of non-IGCC LFC Blocks.

Figure 4-1 illustrates the calculation of the Correction values without Limits in case two Optimization Regions A and B are identified, as an example.

The imbalances are first pre-netted between IGCC Members within each Optimization Region in a first netting layer. The remaining imbalances of each IGCC Member of Optimization Regions A and B are then netted all together in a second netting layer.

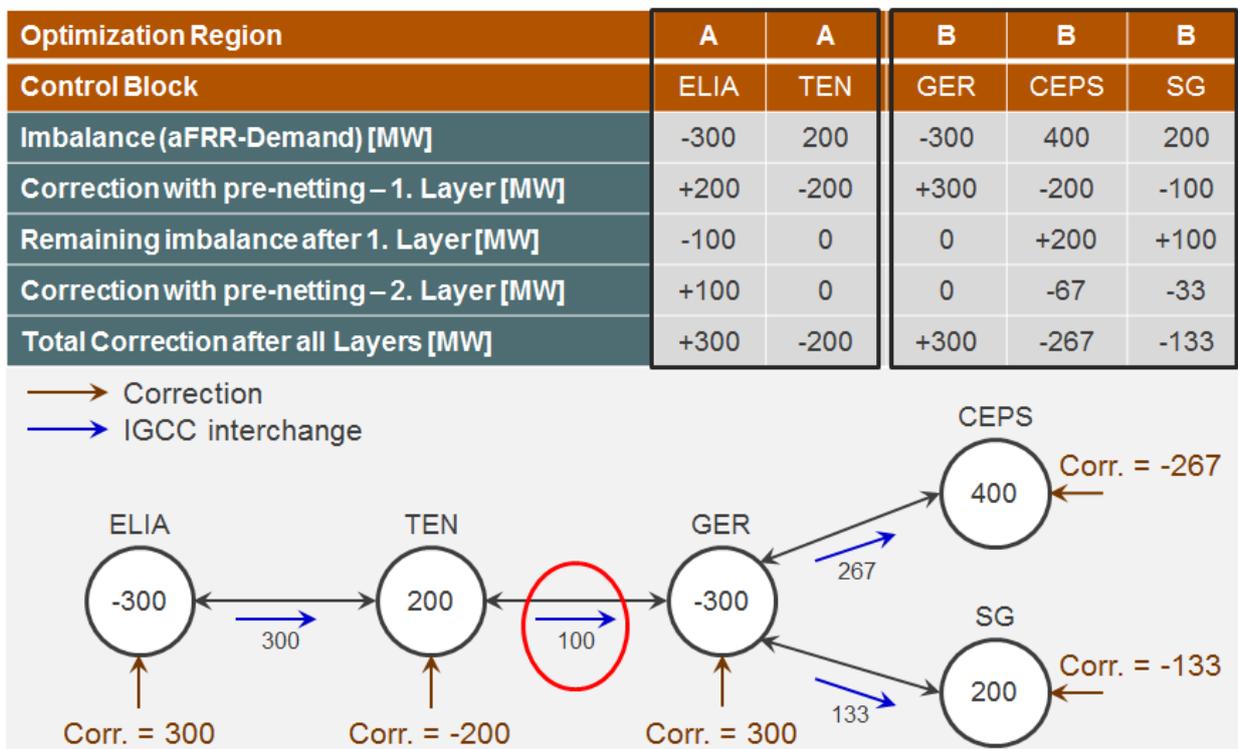


Figure 4-1: Illustration of a pre-netting situation

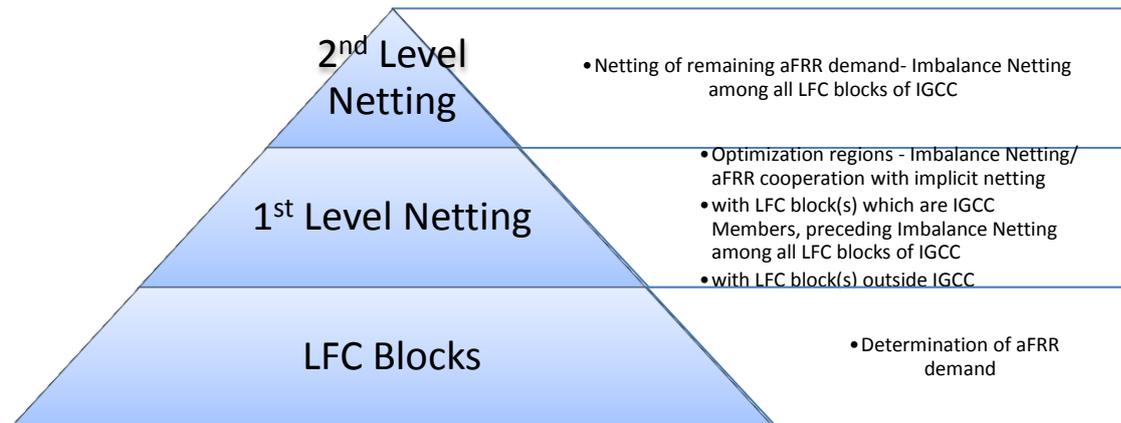
To participate in the IGCC Optimization Region each IGCC Member has to fulfil the following rules:

- Implicit Imbalance Netting (e.g. a common merit order list for aFRR) between two or more LFC Blocks participating in IGCC, is considered as Imbalance Netting.
- Each LFC Block participating in IGCC can have only one Imbalance Netting with other LFC Block(s) which are IGCC Members, preceding Imbalance Netting among all LFC Blocks of IGCC.
- Each LFC Block participating in IGCC can participate in one other Imbalance Netting cooperation outside IGCC.

Each IGCC Member has the right to change its participation in an Optimization Region. The participation of an IGCC Member in the Optimization Region is voluntary.

The aFRR-Optimization System has to be then adapted in accordance with the defined Optimization Regions.

According to the stipulations above, in Figure 4- the netting layers in operation for IGCC used by the aFRR-Optimization System are described:



**Figure 4-2: Netting layers currently used by aFRR-Optimization System for IGCC**

Following technical analysis performed by the IGCC TSOs, and given the above stipulations which form the current basis for the possible evolution of pre-netting within the European target for the Imbalance Netting process, the IGCC TSOs concluded on the following understanding from technical/operational and social welfare perspective:

#### **4.1. Technical and economical remarks on pre-netting within the European Imbalance Netting process**

The following section provides some remarks and conclusions on pre-netting based on already gained experiences within IGCC. Statements in the following sections are based on either operational security or benefit distributional issues. This chapter should give to reader a better understanding of the evolution of pre-netting, as well as benefits and drawbacks from pre-netting within the European Imbalance netting process.

Historically, the Optimization Regions were introduced mainly to accommodate participation to different initiatives.

Introducing the Optimization Regions within the Imbalance Netting process can lead to un-proportional distribution of netting potential, however the total amount of netted imbalances is equal with or without pre-netting.

In relation to operational security pre-netting might, but not always does, lead to an average reduction of physical flows. Pre-netting might therefore not always be the most effective measure to reduce the physical flows in Optimization Regions. In case TSOs perform a common dimensioning (LFC Block), pre-netting is necessary to favor the access to the transmission capacities for aFRR activation. Without pre-netting within LFC Block the transmission capacity might be already used for imbalance netting between non-LFC Block members. Therefore, the pre-netting is considered mandatory in an LFC Block.

In case TSOs perform cross border common aFRR activation (aFRR CoBA), pre-netting could be performed to achieve a priority access to transfer capacities. If this is the case, the aFRR cooperation would form an Optimization Region.

From a benefit perspective, the principle of pro-rata netting energy allocation does not consider balancing energy costs (physical cooperation) - therefore, the pro-rata allocation does not necessarily lead to a social welfare optimum for the overall Imbalance Netting process. In result, pre-netting within the Imbalance Netting process leads to a deviation from the pro-rata allocation in the Imbalance Netting process, which affects the distribution of benefits to individual LFC Blocks. Moreover, an implicit pre-netting of an aFRR CoBA might lead to an un-proportional distribution of the netting potential in favor of the aFRR CoBA.

However, within an aFRR-CoBA the netting energy is allocated based on balancing energy costs (social welfare optimum of the aFRR-CoBA, given that all corresponding settlements within the aFRR CoBA lead to this) thus a pro-rata allocation would lead to a decrease of social welfare for the aFRR-CoBA.

## 5. Operational processes

Each IGCC Member has the right to temporarily suspend or restrict its participation in the IGCC, to restrict the IGCC power exchange with one or more neighbouring IGCC Members as well as to restrict the transit through its grid under one of the following conditions:

- a. suspension or restriction is necessary to ensure the operational security;
- b. a technical reason has occurred such as:
  - i. major troubles within the LFC Area of the IGCC Member (e.g. local blackouts or network splitting);
  - ii. maintenance or malfunctioning of the IGCC Member's local IT system(s) related to IGCC;
  - iii. problems with the determination of the operational values (e.g. aFRR-Demand, Limits etc.);
  - iv. problems with operational security (e.g. high physical flows within the LFC Area or at any Border);
- c. suspension or restriction is necessary to fulfil a requirement of a TSO whose operational security could be negatively affected due to IGCC Member's exchange in IGCC; or
- d. suspension or restriction is necessary to comply with the requirements from a relevant national authority or agreements derived from these requirements which may bind the requesting IGCC Member.

An economic optimization is not a valid reason for the IGCC Member to suspend or restrict its participation.

Each IGCC Member that exercises its right of suspension or restriction is obliged to explain the reasons for this within 14 calendar days after request of IGCC Members. If these suspensions or restrictions appear systematically, each IGCC Member has the right to propose adaptation.

All IGCC Members cooperate to achieve a stable, robust and reliable IGCC operation. This chapter defines guidelines for IGCC operation while each IGCC Member remains solely responsible for the security of supply of its LFC Area.

### 5.1. Responsibility for operation

Each IGCC Member remains solely responsible for:

- the operation and the security of supply of its LFC Area; and
- the correctness and quality of data provided as input for the aFRR-Optimization System.

The IGCC exchange between LFC Areas is not to be considered as guaranteed balancing energy delivery. Each IGCC Member takes into account:

- the volatility of IGCC exchange;
- the possibility of a sudden suspension of participation (e.g. due to connection failures);  
or
- the impact of incorrect aFRR-Demand or Limits.

The abovementioned reflections have to be especially taken into consideration for activation of mFRR.

It is not possible to overwrite the Correction manually. This is to ensure that the sum of all Corrections (exchanged power) between IGCC Members is zero at any time.

## 5.2.Reduction or suspension of participation by the aFRR-Optimization System

Each IGCC Member can be automatically disconnected from IGCC after a time out if the aFRR-Demand signal is not delivered or is marked as valid but unchanged for an agreed time period or marked as invalid according to IEC 60870-5-101 protocol and its standards. As soon as the signal is delivered or changed, while being valid, or marked as valid, according to the IEC protocol, the IGCC Member is automatically reconnected by the aFRR-Optimization System. Time out intervals are the same for each IGCC Member.

Other signal modalities shall be agreed between the Host TSO and an IGCC Member.

If ATC-Limits are not delivered or marked as incorrect, the following procedure is applied depending on the respective scenarios:

- Scenario 1: Two IGCC Members (A and B) define redundant values for ATC-Limits
  - If the Limit defined by IGCC Member A is delivered and is marked as correct and the Limit defined by IGCC Member B is not delivered or marked as incorrect, then the last delivered and correct Limit provided by IGCC Member B is taken into account.
  - The Limit defined by IGCC Member A is not delivered or is marked as incorrect and the Limit defined by IGCC Member B is not delivered or is marked as incorrect then the Limit is set to zero.
- Scenario 2: Only one IGCC Member defines values for ATC-Limits - if the Limit defined by the IGCC Member is not delivered or is marked as incorrect the Limit is set to zero.

For Profile-Limits and Flow-Based Limits, if the Limits are not delivered or marked as incorrect, the last delivered and correct value is considered.

Additionally and only for safety reasons, the Host TSO can manually disconnect the IGCC Member from the IGCC on request of this IGCC Member. In this case, the requesting IGCC Member will inform the disconnected IGCC Member via phone call.

## 5.3.Temporary reduction or suspension of participation by IGCC Members

Each IGCC Member may change its Limits or suspend its participation by setting its Participation Status Request to “off”. Main reasons are:

- major troubles within the LFC Area of the IGCC Member (e.g. local blackouts or network splitting);
- maintenance or malfunctioning of the IGCC Member’s local IT system(s) related to IGCC;
- problems with the determination of the operational values (e.g. aFRR-Demand, Limits etc.);
- problems with operational security (e.g. high physical flows within the LFC Area or at any Border);

In case of problems with operational security, IGCC Members may support each other by reducing their participation upon request. Each IGCC Member notifies other IGCC Members about planned or unplanned temporary reductions or suspensions of its participation in IGCC.

#### **5.4. Temporary reduction or suspension of participation by Affected TSO**

In general, an Affected TSO can request a temporary reduction or suspension of participation of any IGCC Member. Each Affected TSO uses the IGCC standardized procedure in order to request for a reduction or suspension: this is usually set as well in the system operation agreements between concerned IGCC Member(s) and the Affected TSO. Therefore, at least the following information shall be required by the IGCC Member from the Affected TSO to keep consistency and simplicity in case of finding the information:

- brief description of reason(s) for the reduction or suspension;
- starting time and duration of the reduction or suspension; and
- defined Limits.

The IGCC standardized procedure is available on ENTSO-E website.

The IGCC Member receiving a request for reduction or suspension shall immediately inform the Host TSO and, if applicable, the IGCC Member(s) which import and/or export Limits are to be changed.

## 6. Settlement principles

The basic idea behind the settlement within IGCC Optimization Region is to share gained benefits in a fair manner between IGCC Members. For each settlement period, which is 15 minutes, the IGCC energy quantities are determined, which consist of 2 values, the IGCC imports and IGCC exports for each IGCC Member.

The IGCC settlement prices are determined by the Host TSO based upon the IGCC Opportunity prices for IGCC imports and IGCC exports of each IGCC Member. The methodology for the calculation of Opportunity Prices lies within the responsibility of each IGCC Member and differs from party to party, but the principle of the methodologies is to reflect the opportunity value of the avoided aFRR and is to that extend harmonized.

As the term “Opportunity” indicates these prices are usually defined based on costs or prices of an alternative provision of the respective netted energy (i.e. aFRR energy). Diverging definitions might be necessary e.g. due to legal or regulatory stipulations.

The potential benefits gained from IGCC arise from the price difference between the Opportunity Price (reflecting the local aFRR energy price) and the IGCC price. The following example shows the potential benefits resulting from Imbalance Netting from the perspective of one IGCC Member. The example assumes the following scenario:

- Without participating in IGCC the IGCC Member needs to activate 100 MWh of aFRR for 50 €/MWh in order to control the ACE to zero.
- With participating in IGCC the amount of aFRR activation is reduced by 40 MWh which means that the IGCC Member only activates 60 MWh of aFRR, and due to the reduced activation at a lower price of 45 €/MWh. (This benefit can be called merit order effect and applies to TSOs with merit order activation. )

The total benefit for each individual IGCC Member before IGCC settlement can be calculated by subtracting the costs with IGCC (2700 €) from the costs without IGCC (5000 €) and amounts to 2300 €.

Scenario with and without IGCC (40 MWh of netted imbalance)			
	Activated aFRR	Average Price of Activated aFRR	Costs
Without IGCC	100 MWh	50 €/MWh	5000 €
With IGCC	60 MWh	45 €/MWh	2700 €
Difference	40 MWh	5 €/MWh	2300 €

Benefit Components of IGCC	
Energy Component	$(100 \text{ MWh} - 60 \text{ MWh}) \cdot 50 \text{ €/MWh} = 2000 \text{ €}$
Price Component	$(100 \text{ MWh} - 40 \text{ MWh}) \cdot (50 \text{ €/MWh} - 45 \text{ €/MWh}) = 300 \text{ €}$
Total Benefit	$100 \text{ MWh} \cdot 50 \text{ €/MWh} - 60 \text{ MWh} \cdot 45 \text{ €/MWh} = 2300 \text{ €}$

As the example shows there are two general effects which lead to benefits from Imbalance Netting:

- Imbalance Netting reduces the amount of activated aFRR (energy component);
- Imbalance Netting reduces the average price of activated aFRR (merit order effect)

Since the prices for aFRR energy are different for each IGCC Member, the resulting benefits for each IGCC Member are also different. A fair distribution of the overall benefits is achieved by the settlement of the IGCC energy quantities exchanged for Imbalance Netting.

### 6.1. Calculation of IGCC Opportunity Prices

The Opportunity Prices of each IGCC Member form the basis for the subsequent settlement. The IGCC Opportunity Price of each IGCC Member:

- shall currently reflect the value of netted imbalances, i.e. avoided aFRR energy costs due to the avoidance of aFRR activation;
- is usually based on aFRR energy prices.

In case of a change that substantially affects the IGCC Opportunity Price calculation of an IGCC Member (e.g. change in national market design or the calculations of aFRR energy prices) all IGCC Members shall discuss the consequences of this change with each other and adapt any necessary documents accordingly.

### 6.2. Calculation of IGCC Settlement amount

#### 6.2.1. Initial IGCC settlement

The IGCC settlement price is determined for each IGCC settlement period based on IGCC energy quantities and IGCC Opportunity Prices. The IGCC Settlement Price is the weighted average of all Opportunity Prices.

Correspondingly, each IGCC settlement amount is calculated based upon each IGCC Member's imports and exports and the IGCC settlement price. The following formula shows the calculation of the IGCC settlement price based on the above mentioned inputs. Additionally the corresponding table explains the abbreviations used in the formula.

$$P_{IGCC}(t) = \frac{\sum_{m=1}^M E_{Imp}(t, m) * C_{Imp}(t, m) + \sum_{m=1}^M E_{Exp}(t, m) * C_{Exp}(t, m)}{\sum_{m=1}^M E_{Imp}(t, m) + \sum_{m=1}^M E_{Exp}(t, m)}$$

Variable	Description	Unit	Sign Convention
$M$	Number of IGCC Members	-	-
$m$	IGCC Member	-	-
$t$	Settlement period	-	-
$E_{Imp}(t, m)$	IGCC import of IGCC Member $m$	MWh	Always positive
$E_{Exp}(t, m)$	IGCC export of IGCC Member $m$	MWh	Always positive
$C_{Imp}(t, m)$	IGCC Opportunity Price for import of IGCC Member $m$	€/MWh	Positive, if the IGCC Member $m$ pays for activation of positive aFRR. Negative, if the IGCC Member $m$ is paid for activation of positive aFRR.
$C_{Exp}(t, m)$	IGCC Opportunity Price for export of IGCC Member $m$	€/MWh	Positive, if the IGCC Member $m$ is paid for activation of negative aFRR. Negative, if the IGCC Member $m$ pays for activation of negative aFRR.
$P_{IGCC}(t)$	IGCC settlement price	€/MWh	Positive or negative

### 6.2.2. Reasons for adaptation identified

The IGCC settlement price depends on the energy exchanged and on the Opportunity Prices of the IGCC Members.

The increasing number of participants with different market design frameworks lead to higher spreads between the Opportunity Prices that resulted initiating discussion on how to define benefit and what is considered as fair benefit distribution within IGCC (based on the stipulations of the MLA) and whether a benefit re-distribution in IGCC is necessary at all. In addition, this could result in settlement periods with negative benefits for single IGCC Members while the overall benefit of the IGCC is positive. This effect is present in the scenario when an IGCC Member has to pay an IGCC settlement price to the cooperation which exceeds its local Opportunity Price for avoided aFRR energy costs.

### 6.2.3. Current IGCC settlement

The IGCC Members agreed to modify the settlement in order to eliminate the effect of negative benefits to foster and not to hinder further expansion of the IGCC.

The individual IGCC benefit for each member is defined as the difference between a member's IGCC settlement amount compared to its opportunity costs. The overall benefit of the IGCC cooperation is the sum of all individual benefits.

In case of negative individual benefits in a settlement period for one or more IGCC Members but positive overall benefit of the IGCC, an ex-post adjustment of settlement amounts is introduced, where the settlement amount is adjusted in the following way:

- IGCC Members with negative benefits distribute their negative individual benefits to the IGCC Members with positive benefits in order to shift their negative benefits to zero.
- IGCC Members with positive benefits reduce their positive benefits by the amount of negative benefit proportionally to their share of the total sum of positive benefit.
- IGCC Members with a zero energy balance (imports = exports) are excluded from the adjustment procedure.<sup>1</sup>

The adjustment made to the settlement leads to an adjustment of settlement prices which vary from member to member depending on their benefit before the adjustment.

All IGCC imports and exports are settled with the IGCC adjusted settlement prices of each IGCC Member.

#### **6.2.4. Settlement discussions and future steps within IGCC about settlement**

Within IGCC other settlement formulas were discussed as well, in particular:

- The so called “equal benefit” settlement leads to a proportional distribution of total cost savings which are evaluated as a difference between the opportunity price and the IGCC settlement price. This leads to equal benefit in “€ per MWh per settlement period” for all IGCC Members but to diverging settlement prices per IGCC Member for energy received from or delivered to the IGCC.
- Settlement with a reference price for the exchanged energy, e.g. based on the spot market or fixed prices of the individual IGCC Members or a general fixed price. Such a methodology would indirectly guarantee a distribution of benefits for exchanged IGCC energy at least as long as aFRR markets are not harmonized. This leads to decoupling the IGCC prices from the local aFRR prices.

If an opportunity-based settlement system is applied, the settlement between the involved partners and distribution of benefits between the control areas depends on the respective input prices (e.g. opportunity prices), and as well as on the settlement methodology (mathematical formula) itself. These differences originate currently from the different designs and approaches of the respective aFRR markets and from the different regulatory provisions underlying the definition of the input prices for settlement and distribution. The complexity of the settlement arises through the diversity of the possible approaches.

The IGCC Members concluded that a further investigation requires a broader view of social welfare before concluding on a settlement formula, and therefore they aim to continue evaluating the settlement options, while the currently applicable settlement method remains applicable. Thus the IGCC TSOs continue to work on the topic, not excluding other potential solutions, with the aim to create further understanding within IGCC and to serve as inputs to the discussions in the European target for the Imbalance Netting process.

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<sup>1</sup> This is due to computational reasons. The adjusted settlement price is derived as the ratio of the adjusted settlement amount and the balance of exchanged energy (imports – exports) and would therefore result in a division by zero.