European Network of
Transmission System Operators
for Electricity

Overview: Operational Limits and Conditions for Frequency Coupling

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1. Introduction

This paper mainly outlines which frequency coupling services could be envisaged between synchronous areas and describes each of the possible services. It also explains the interactions with existing frequency services within a synchronous area. Thirdly, it relates the frequency coupling services to the requirements of the Guideline on electricity transmission system operation (GL SO). Frequency coupling is defined as "frequency coupling process meaning a process agreed between all TSOs of two synchronous areas that allows linking the activation of frequency containment reserves by an adaptation of HVDC flows between the synchronous areas".

2. Why frequency coupling?

First of all Frequency coupling between synchronous areas is a powerful way to enhance system security. The notion that any synchronous area could receive assistance via a HVDC-interconnector whenever it needs from another synchronous area ensures an increased reliability and robustness of the synchronous area. A second reason that accompanies the first reason is that it might be financial less expensive for a TSO or a synchronous area to do so. And with the restriction that any frequency coupling service is only possible when there is capacity available after the last intraday auction, it is very rational indeed to perform a frequency coupling service. Frequency coupling services are so helpful for TSOs that they have been implemented on several HVDC interconnectors already for years[1].

The GL SO acknowledged these considerations and states in articles 173 and 174 that all TSOs of a synchronous area shall have the right to implement a frequency coupling process. Please, note that the technical design of the frequency coupling shall be specified in the synchronous area operational agreements. This is being done because of the importance that any of these services comply with existing system security standards and are at the same time compatible with the existing frequency processes within each synchronous area.

[1] For instance a service between the synchronous areas of Continental Europe and Great Britain, between Great Britain and Ireland, between Mallorca and Continental Europe and between Nordic area and Baltic States.

3. Description of frequency coupling services

When describing frequency coupling services, an important notion that overlay all possibilities, is the distinction between static services and dynamic services.

A *static* service is one where a response signal is *stepwise* activated on the HVDC Interconnector when a predefined frequency deviation is reached[2].

A *dynamic* service is one where a response signal is *continuously* activated on the HVDC Interconnector based on the actual frequency deviation of one or more synchronous areas.

The following classes of frequency coupling are all dynamic services:

- **FCR exchange** (FE) is a process agreed between two synchronous areas where one synchronous area delivers FCR to the other. The service would only heed the frequency deviation of one synchronous area and "ignores" the other.

- **Frequency netting** (FN) is a process agreed between two or more synchronous areas that reduces counter activations of FCR only when the synchronous areas have frequency deviations, which have an opposite sign. Frequency netting hence always improves the instantaneous frequency quality of all participating synchronous areas in case there are frequency deviations with opposite signs.

- **Frequency optimisation** (FO) is a process agreed between two or more synchronous areas that improves overall frequency quality by mutual FCR support between synchronous areas. This is arranged such that the frequency in all synchronous areas are used and optimised to ensure that the sum of the absolute frequency deviations is minimised. Frequency optimisation hence improves the average frequency quality of those SAs involved.

These classes are illustrated in the figure below, where f1 and f2 represent the frequency of synchronous area 1 and 2 respectively.

[2] The static services are currently being developed and will be added in a later stage.

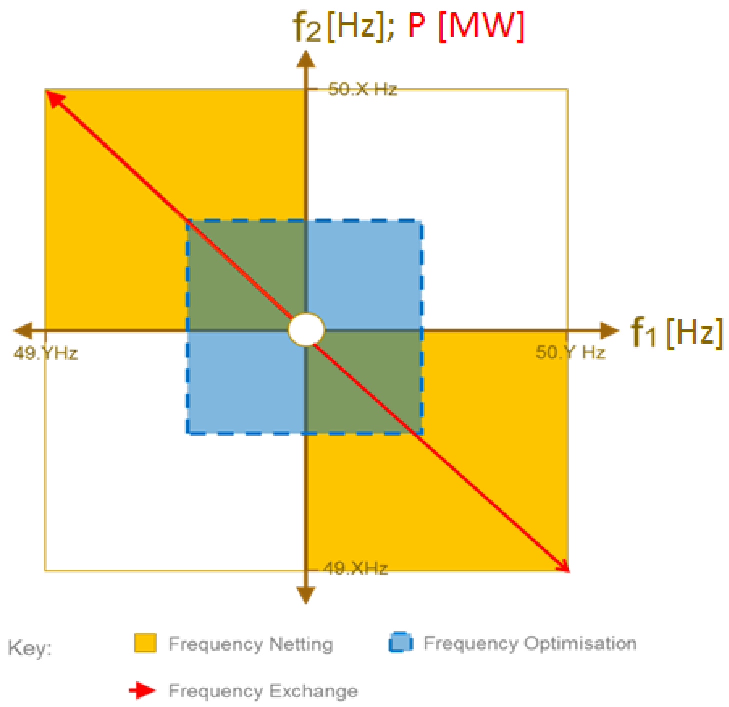

Figure 1: Illustration of the different frequency coupling classes and how they relate to the frequencies of the synchronous areas (showing two synchronous areas only). For frequency exchange, the x-axis (f1 [Hz]) relates to the frequency of the receiving SA, whereas the y-axis (P[MW]) relates to the power shifted from providing to receiving SA.

Another important notion is that not all services can be used in all system states. As shown in the table 2 below, the frequency coupling services have boundary conditions linked to the defined system states, assuming the states are constant and not changing. It is also crucial to mention that, when designing the frequency coupling services, the goal should be to avoid exiting the normal state as a result of using frequency coupling services.

	Providing	Receiving
Frequency Netting	Normal: ✔ Alert: ✔ Emergency: ✔ Blackout/Restoration: ×	Normal: ✔ Alert: ✔ Emergency: ✔ Restoration: ✔ Blackout: ×
Frequency Optimisation	Normal: ✔ Alert: - only if netting Emergency: - only if netting Blackout/Restoration: ×	Normal: ✔ Alert: - only where benefitting receiver Emergency: - only where benefitting receiver Restoration: ✔ Blackout: ×
Frequency Exchange	Normal: ✔ Alert: × Emergency: × Blackout/Restoration: ×	Normal: ✔ Alert: ✔ Emergency: ✔ Restoration: ✔ Blackout: ×

Table 1: relationship between providing and receiving TSOs

4. Limits

The frequency coupling services cannot continue unconditionally. We have seen in the previous chapter that any service should not be detrimental to system security. TSOs have therefore set limits to how many support can be provided to other synchronous areas and also set limits per HVDC Interconnector.

The table 2 below lists all limits for each of the three frequency coupling services which should ensure compliance with SOGL. These limits are based on current practise and can be revised if necessary in the future.

	Frequency Exchange	Frequency Netting	Frequency Optimisation
Parties	TSO/TSO exchanges	SA-SA assistance	SA-SA assistance
Backup	Physical FCR backup required	None	None
Benefit	To capture FCR price spread between LFC-blocks from different SA's	To capture frequency quality improvement ▶instantaneously	To capture frequency quality improvement ▶ on average
HVDC IC limit	5% of importing SA's FCR – for CE/Nordics - 150MW to CE - 100MW to Nordics - variable to GB/Ireland	None	5% of importing SA's FCR - for CE/Nordics - 150MW to CE - 100MW to Nordics - variable to GB/Ireland
LFC block limit	SOGL requirements – for CE/Nordics - max import = 70%*LFC block FCR - max export = max [100MW; 30%*LFC block FCR]	None	None
Total SA limit	None	None	Limited to 270MW - If sharing applied = reducing FCR amounts No limit - If no sharing applied = keeping FCR amounts

Table 2: comparison of limits. The LFC Block limit for NO is not specified in annex 6 of SO GL, however it is considered fair, transparent and safe from a technical point of view. The 270 MW applies only for CE; NO and GB could use the same methodology (K-factor x 10mHz) approach, but are not obliged to do so.

Please note:

1. As is explained above, FCR exchange is seen as an FCR-product which is the reason why we apply the same rules as specified in the SOGL. As a result of this and because the exchanged FCR capacity is required as additional FCR capacity in the proving SA, no total limit between synchronous areas is necessary.

2. The purpose of frequency netting is to improve the frequency quality on all sides, instantaneously but only when the frequency deviations are opposed in sign. As a result of this functionality there are no additional limitations required.

3. Frequency optimisation is facilitated in each participating synchronous area by a connecting and a receiving TSO, in order to improve the frequency quality on all sides on average, where support is possible even when the frequency deviations have the same sign. As a result of this and because in certain cases this can result in FCR exchange behaviour, the same limitation for each HVDC line as for FCR exchange applies.

4. As GB and Ireland are not obliged to enforce the 5 % FCR limit (SOGL, article 156, paragraph 6), there is no value shown. Due to current system requirements this limit is assessed continuously in real time.
5. Similarly to the 5% limit, GB and Ireland do not have to enforce the LFC block limitations as written in Annex 6 of SOGL. It means that only the Total Limit SA-SA applies to GB and Ireland.
6. Even though there are no explicit limitations for GB and Ireland, enforcing the LFC block rule will implicitly limit the import and export between synchronous areas.
7. Between synchronous areas who have no limitations as listed in the table, they should jointly agree a methodology that takes into account the following: avoid internal congestions, ensure even distribution of FCR in case of network splitting and avoid stability of the FCP is affected. Currently this only applies between GB and Ireland.