European Network of
Transmission System Operators
for Electricity

Rate of Change of Frequency (ROCOF) withstand capability

ENTSO-E guidance document for national implementation for network codes on grid connection

16 November 2016

DESCRIPTION

Code(s) & Article(s)	NC RfG: Articles 13 (1) (b) and 15 (5) (b) (iii) NC DCC: Articles 28 (2) (k) and 29 (2) (g) NC HVDC: Articles 12 and 39 (3)
Introduction	The requirement aims at ensuring that power generating modules (NC RfG), demand units offering Demand Response (DR) services (DCC), HVDC systems and DC-connected power park modules shall not disconnect from the network up to a maximum rate of change of frequency (df/dt). A large rate of change of frequency (RoCoF) may occur after a severe system incident (e.g. system split or loss of large generator in a smaller system). The facilities shall remain connected to contribute to stabilize and restore the network to normal operating states.
NC frame	NC RfG and DCC require that the Relevant TSO shall define/require the df/dt (RoCoF), which a power generating module (RfG) or a Demand Unit (DCC) shall at least be capable of withstanding. NC HVDC specifies explicitly, that • HVDC systems shall not disconnect from the network up to a rate of change of frequency (df/dt) of ± 2.5 Hz/s measured at any point in time as an average of the RoCoF for the previous 1 second, and • DC-connected power park modules shall not disconnect from the network up to a RoCoF (df/dt) of ± 2.0 Hz/s
Further info	Further implementation guidance on NC RfG, NC DCC and NC HVDC: Supporting documentation of HVDC network code: • Network Code for HVDC Connections and DC-connected Power Park Modules - Requirement Outlines (30. April 2014) External supporting documents: • All Island TSO Facilitation of Renewables Studies(see attachment) • Summary of Studies on Rate of Change of Frequency events on the All-Island System (Aug 2012) (see attachment) • Chapter 4 of GB ETYS 2012 diagram on severe reduction in total system inertia 2012 to 2030 (see attachment) • Loss of Mains Protection (see attachment) • RoCoF Alternative Solutions Technology Assessment (see attachment) • Increased Wind Generation in Ireland and Northern Ireland and the Impact on Rate of Change of Frequency[1]

[1] http://www.eirgridprojects.com/site-files/library/EirGrid/Increased Wind Generation in Ireland and Northern Ireland and the Impact on Rate of Change of Frequency.pdf

ENTSO-E AISBL • Avenue de Cortenbergh 100 • 1000 Brussels • Belgium • Tel + 32 2 741 09 50 • Fax + 32 2 741 09 51 • info@entsoe.eu • www. entsoe.eu

	• Frequency Stability Evaluation Criteria for the Synchronous Zone of Continental Europe[2]

INTERDEPENDENCIES

Between CNCs	The selection of the maximum (df/dt) values to be withstood needs to be chosen by collaboration between the connection codes in order to ensure equitable behaviour of the relevant system users in case of rapid frequency changes bearing in mind the different scope of application of the CNCs. NC HVDC introduces an explicit limit for HVDC systems (2.5 Hz/s), which is above the limit for DC-connected power park modules (2.0 Hz/s). The rationale behind these choices is to have a margin between the capability of HVDC systems and power generating modules to ensure that HVDC systems will disconnect last in order to enable power generating modules and demand units to contribute to stabilize and restore the network to normal operating states as long as possible.
With other NCs	COMMISSION REGULATION (EU) …/… of XXX establishing a Guideline on Electricity Transmission System Operation, adopted by the EC on 04.05.2016, Article 39 ("Dynamic stability management ")
System characteristics	To define the RoCoF withstand capability correctly, the characteristics of an entire synchronous area must be considered. The capability shall be determined based on analysis of a normative incident for the network concerned. Such a normative incident could be a defined system split of a large synchronous area with a significant change of inertia and power imbalance in the resulting subsystems (e.g. historic events like the Italy blackout in 2003 and the Continental Europe 3-way split in November 2006). With regard to smaller synchronous areas with low inertia the loss of the largest power generating module or HVDC link may define the normative incident instead (e.g. increase of loss of a single unit up to 1800 MW in GB which would commonly exceed the until recent existing GB threshold level of RoCoF-based Loss of Mains (LOM) protection [0.125 Hz/s][3]). Since one main concern is the decrease of system inertia, chosen scenarios should reflect situations with low inertia, e.g. high share of non-synchronous renewable generation or high import/export scenarios in case of system splits. For example, on 23rd of August 2015, renewable energy generation in Germany covered 84% of domestic demand[4]. The RoCoF withstand capability should be assessed on not only the present network but also account for the expected capability that will be required over the asset life of concerned installations accounting for future changes in the network and its demand and generation portfolio. Also the capability of existing connected generators will be taken into account.

[2] https://www.entsoe.eu/Documents/SOC%20documents/RGCE_SPD_frequency_stability_criteria_v10.pdf
[3] Frequency Changes during Large Disturbances WG ppt (see attachments)
[4] https://energy-charts.de/power_de.htm

ENTSO-E AISBL • Avenue de Cortenbergh 100 • 1000 Brussels • Belgium • Tel + 32 2 741 09 50 • Fax + 32 2 741 09 51 • info@entsoe.eu • www. entsoe.eu

	The RoCoF withstand capability should ideally be provided as a change in frequency over a defined time period which negates short term transients and therefore reflects the actual change in synchronous network frequency). However, in practice this may interfere with protective controls of generators or LOM protections schemes. Hence, changes relevant to protections, e.g. Loss of Mains protection, using RoCoF but driven by other needs can be considered. Other LOM protection systems (e.g. inter-tripping, satellite protection and load shedding[5]) might also be considered as alternative measures. Finally, All-Island studies show large df/dt deviation between different bus-bars for the first few cycles, eventually converging to one value, pointing to the importance of the length of the measurement time window for calculation of df/dt[6].
Technology characteristics	Given the uncertainty on system characteristics and their future evolution, power generating modules need to be robust against changes to the system and shall provide RoCoF withstand capability which accounts for these varying system conditions (e.g. in Ireland, analysis has shown that there will be on average a 25% reduction in on-line synchronous inertia by 2020 which has significant implications for the RoCoF) The scenarios which define the minimum RoCoF withstand capability requirements have to reflect technological changes (e.g. share of generation in operation contributing to system inertia) on the network. Hence, it is important that the RoCoF withstand capability requirement accounts for reduced network strength due to higher penetration of converter-connected components like PPMs, HVDC systems, and demand, when defining these scenarios. The identified minimum RoCoF withstand capability shall apply to all installations regardless of technology. Although the inherent capability may vary for different generation technologies, a single minimum RoCoF withstand capability needs to be required to ensure stability of the network. A common value of RoCoF withstand capability of a synchronous area shall not inhibit a TSO requiring further inherent withstand capabilities not to be unreasonably withheld e.g. to manage system operation of parts of its network which may be exposed to a higher risk of islanding. DNV KEMA studies for Irish TSOs[7] also show the dependency of individual unit stability on time window size, which higher df/dt values are bearable by generators if the time window is small enough and vice versa. This again indicates the importance of time window size. In addition, leading power factor of generators will increase their vulnerability to high RoCoF values.

[5] see attachment on Loss of Mains Protection
[6] see attachment (Summary of studies on Rate of Change of Frequency events on the All-Island System)
[7] https://thales.entsoe.eu/sites/al/ImplementationGuidances/XIGD09_8.pdf?Web=1

ENTSO-E AISBL • Avenue de Cortenbergh 100 • 1000 Brussels • Belgium • Tel + 32 2 741 09 50 • Fax + 32 2 741 09 51 • info@entsoe.eu • www. entsoe.eu

According to CENELEC TS50549-1/-2 generating units connected to LV networks above 16A and MV networks shall be able to operate with rates of change of frequency up to 2, 5 Hz/s[8] [9].

Loss of Mains RoCoF type protection & settings, although not explicitly part of Article 13 (1) (b) of NC RfG, are covered in Article 14 (5) (b) on Protection Coordination. These requirements should be carefully set by collaboration.

COLLABORATION

TSO – TSO	Although not explicitly requested in the connection network codes, it would be reasonable to consider collaboration for the RoCoF withstand capability criteria (including) within each synchronous area. This includes the maximum RoCoF value to be withstood, the size of measurement rolling window but also frequency and RoCoF measurement technique. Therefore, TSO – TSO collaboration within a synchronous control area would ensure that a minimum RoCoF withstand requirement is applied to all relevant system users.
TSO – DSO	Based on article 13 (b), a power-generating module shall be capable of staying connected to the network and operate at rates of change of frequency up to a value specified by the relevant TSO, unless disconnection was triggered by rate-of-change-of-frequency-type loss of mains protection. The relevant system operator, in coordination with the relevant TSO, shall specify this rate-of-change-of-frequency-type loss of mains protection.
RSO – Grid User	The relevant system operator needs to take care, that the parameters of RoCoF withstand capability defined by the relevant TSO are applied to system users.

8 https://www.cenelec.eu/dyn/www/f?p=104:110:1376998791841501::::FSP_ORG_ID,FSP_PROJECT,FSP_LANG_ID:1258595,53799,25

9 https://www.cenelec.eu/dyn/www/f?p=104:110:1376998791841501::::FSP_ORG_ID,FSP_PROJECT,FSP_LANG_ID:1258595,45870,25

ENTSO-E AISBL • Avenue de Cortenbergh 100 • 1000 Brussels • Belgium • Tel + 32 2 741 09 50 • Fax + 32 2 741 09 51 • info@entsoe.eu • www. entsoe.eu