Review of Grid Codes: Ranges of Frequency Variation

Nikolay Ruban[1, a)], Aleksey Kinshin[1, b)] and Aleksandr Gusev[1, c)]

[1]*National Research Tomsk Polytechnic University, 634050 Tomsk, Russia.*

[a)] Corresponding author: rubanny@tpu.ru
[b)]aik36@tpu.ru
[c)]gusev_as@tpu.ru

Abstract. This article contains a review of grid codes throughout the world. Although grid codes addresses many issues, only four aspects related to generator-grid interaction are the most important: ranges of frequency variation, ranges of voltage variation, fault ride through capability, reactive power capability.

INTRODUCTION

This article contains a review of grid codes throughout the world. Although grid codes addresses many issues, only four aspects related to generator-grid interaction are the most important: ranges of frequency variation, ranges of voltage variation, fault ride through capability, reactive power capability. Table 1 details the reviewed European grid codes [1-5]. It must be noted the harmonizing efforts carried out in Europe by ENTSO-E (European Network of Transmission System Operators for Electricity).

TABLE 1. Reviewed European Grid Codes

Country or Region	Regulator / Grid Code Author	Language
Austria	Energie-Control Kommission	German
Belgium	Belgian Ministry of Economy	French / Flemish
Bulgaria	State Energy Regulatory Commission	Eng.
Czech Republic	Energy Regulation Office, CEPS	Czech / Eng.
Europe	ENTSO-E	Eng.
France	RTE	French
Great Britain	National Grid Electricity Transmission plc	Eng.
Germany	VDN	German / Eng.
Greece	ITSO	Greek / Eng.
Italy	TERNA S.p.A.	Italian
Lithuania	Lietuvos Energija	Eng.
Netherlands	Autoriteit, Consument & Markt	Dutch/Eng.
Poland	PSE	Polish / Eng.
Romania	ANRE	Romanian / Eng.
Scandinavia	Nordel	Eng.
Spain	Ministerio de Industria y Energia	Spanish
Switzerland	SwissGrid	French / German / Italian / Eng.

RANGES OF FREQUENCY VARIATION

Ranges of frequency variation requirement can be formulated in terms of variations in steady state (SS) and transient, interactions between frequency (F), voltage (V) and active power (P) what is shown in the table 2 as F-V, F-P

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or F-V-P. In addition to the range of frequency variation, some grid codes impose a requirement on the rate-of- change of frequency (ROCOF) withstand capability. Table 2 details the ranges of frequency variation required by European grid codes [1-5].

TABLE 2. European grid codes: frequency variation

Country or Region	Steady state Range, Hz	Transient Range, Hz	Interactions between frequency, voltage and active power
Austria	49 - 50.5	47.5 - 51.5	F-V-P
Belgium	48.5 - 51	47.5 - 52.5	F-V-P
Bulgaria	48.75 - 51.25	No	F-V-P
Czech Republic	48.5 - 50.5	47.5 - 51.5	P reductions during variations of F or V in transient
France	49.5 - 50.5	47 - 55	No
GB	49 - 51	47.5 - 51.5	Rated P for SS F ranges; P reduction with F reduction allowed
Germany	49 - 50.5	47.5 - 51	Rated P at SS V ranges
Greece	49.5 - 50.5	47 - 53	No
Italy	49 - 51	47.5 - 52	No
Lithuania	No	No	No
Netherlands	49.85 - 50.15	48 - 51	F-V-P
Poland	49 - 51	47.5 - 52.5	Rated P for SS F ranges
Romania	49.5 - 50.5	49 - 52	F-V-P
Scandinavia	49 - 50.3	47.5 - 52	F-V-P
Spain	48 - 51.5	47 - 51.5	No
Austria	49 - 50.5	47.5 - 51.5	F-V-P

Table 3 European grid codes: ROCOF details the ROCOF required by European grid codes in term of the ROCOF itself and its duration.

TABLE 3. Reviewed European Grid Codes

Country or region	ROCOF (Hz/s)	Duration (seconds)
Austria	0.2 Hz/s	10 s
Germany	0.09 Hz/s	10
Greece	0.5 Hz/s	-
Ireland	1 Hz/s	-
Switzerland	0.09 Hz/s	10
Austria	0.2 Hz/s	10 s
GB	The System Frequency could rise to 52Hz or fall to 47Hz. Electrical equipment must continue to operate within this Frequency range for at least the periods of time given in CC.6.1.3 of British grid code	

ENTSO-E has established the ranges of frequency variation requirements for 5 European regions (Baltic, Continental, Great Britain, Ireland and Nordic). Table 4 details the ranges of frequency variation required by ENTSO-E grid code in term of several features (steady-state variations, transient variation and F-V, F-P and F-V-P couplings). Figure 4 compares the ranges of frequency variation requirements of the five European frequency zones.

TABLE 4. ENTSO-E grid code: ranges of frequency variation

Country or Region	Steady state Range, Hz	Transient	Country or Region
European Union (EU)-Continental	49 - 51	47.5 - 51.5	The time limitation for the frequency decreasing applies. P reductions during operation at low frequencies broadly defined
EU-Nordic	49 - 51	47.5 - 51.5	
EU-Great Britain	49 - 51	47 - 52	
EU-Ireland	49 - 51	47.5 - 51.5	

ENTSO-E grid code states with regard to ROCOF “Generators must withstand a rate of change of frequency specified by the TSO during a certain time without disconnection”. The ENTSO-E code on requirements for grid connection of high voltage direct current systems and direct current-connected power park modules states that “An HVDC system shall be capable of staying connected to the network and operable if the network frequency changes at a rate 2-2,5 Hz/s (measured at any point in time as an average of the rate of change of frequency for the previous 1s)”.

CONCLUSION

Frequency variations occur in power systems due to active power generation and demand unbalances. The magnitude of the frequency variation depends on the magnitude of the generation-demand unbalance compared to the size of the system assuming that:

- primary frequency regulation reserves are greater than the generation-demand unbalance,
- frequency load shedding schemes are not activated, and
- primary frequency regulation system performs ideally (it is provided by all generators)

Duration of frequency excursions depend on the performance of primary, secondary and tertiary frequency regulation systems. Not only the dynamic performance of the components of the frequency regulation system is relevant but the magnitude of the reserves affects as well.

The initial rate-of-change of frequency in case of depends on the size of the generation-demand imbalance compared to the rating of the on-line synchronous generators. Frequency variation requirements imposed by grid codes are not uniform at all. Wider and longer frequency excursions are usually required in smaller systems with less performing frequency regulation systems. Rate-of-change of frequency withstand capability is also usually required in smaller (isolated) systems. It is worth to note that large rate-of-change-of-frequency occurs only in large interconnected systems in case of disturbances much more severe than the design disturbance of the system. Developments towards operation sometimes dominated by Power Electronic Power Sources (PEIPS), widely results in reducing system inertia. Analyses by ENTSO-E shows up to 10 fold reduction in p.u. for the system inertia. Therefore, codes are increasingly considering introducing requirements for PEIPS to contribute inertial systems.

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