

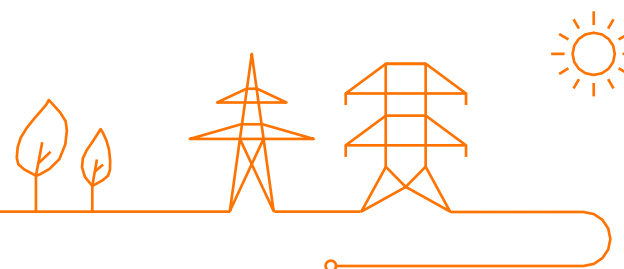
**Cost benefit analysis on Requirements for
generators applicable on existing and new
generating units between 1 and 25 MW**

Workshop with market parties

03/07/2023 | N. Bragard, O. Bronckart, C. Hoedenaeken, S. Temtem

Agenda

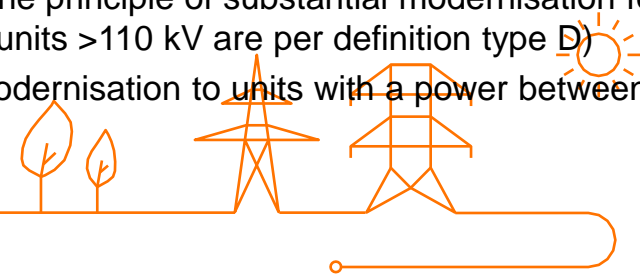
- 1. Objectives of the incentive**
2. High level methodology
3. Discussion market parties
4. Planning and milestones



Objective of the incentive

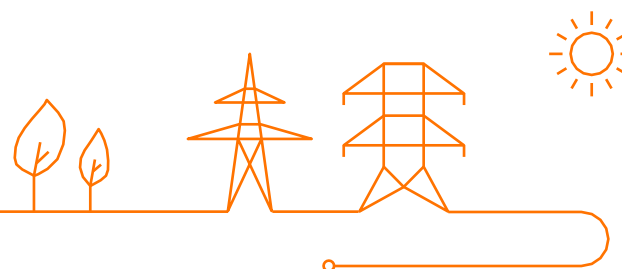
The objective of the incentive is to :

- Identify the differences between the prescriptions applicable to existing and new PGMs between 1 and 25 MW (not included) and connected to Elia grid (Belgium).
- Perform a cost-benefit analysis :
 - Focused on the PGMs with a power between 1 and 25 MW
 - on the possible application on existing PGMs of requirements applicable to new PGMs
 - by applying the methodology described in the EU code RfG (art 4, 38 & 39)
- The outcomes of the CBA will be used as an input for:
 - Application of Art 4.1b of the EU code RfG (application of some new requirements on existing units by the regulatory authority, after public consultation)
 - Possible prolongation of the derogation from the application of the principle of substantial modernisation for PGMs of type D with a maximal installed capacity lower than 25 MW and > 110 kV (all units >110 kV are per definition type D)
 - Evaluate the opportunity to extend the concept of substantial modernisation to units with a power between 1 and 25 MW (currently substantial modernisation is only applicable to type C & D units)



Agenda

1. Objective of the incentive
- 2. High level methodology**
3. Discussion market parties
4. Planning and milestones



What are the requirements applicable to new PGMs between 1 and 25 MW ?

Official requirements (also sent to clients)



Elia all levels : EU Codes (RFG&DCC)



Elia regional level: Requirements of general application
→ approved officially by the 3 regional regulators



Elia federal and regional levels : Grid codes



Elia all levels : Connection contract approved by all regulators



Elia all levels : "Technische richtlijnen voor de aansluiting van decentrale producties" & "Technische specificatie voor de aansluiting van netgebruikers"



Elia all levels : RGIE

Internal notes

Requirements	Requirements Reference Document	Compliance	Overall Status
1) Data Questionnaire			
1	data questionnaire	FGC: Art 354 and Annex 3	Compliance proof
2) PGM internal statement of compliance (RGIE, Icc max, fault clearing time, agreement on protection scheme)			
Open			
2	Equipment and protection requirements - RGIE	RFG : Article 32	Compliance proof
2	Equipment and protection requirements - Annexe 1B - Icc max	Grid codes annexes applicable to new installations (FTR : art. 43)	Compliance proof
2	Equipment and protection requirements - Annexe 2B - Protections	Grid codes annexes applicable to new installations (FTR : art. 44)	Compliance proof
2	Specific protections scheme agreement	GR RFG: 4.2.1	Compliance proof
3) Statement of Compliance via simulations or by proof/documentation			
Open			
1	Simulation models	Simulation Document	Model
1	Model documentation/Userguide	Simulation Document	Model
3	Frequency withstand capability	GR RFG: 3.1.1	Compliance proof
3	Rate of Change of Frequency (ROCOF)	GR RFG: 3.1.2	Compliance proof
3	Maximum allowable Power Reduction	GR RFG: 3.1.5	Compliance proof
3	Voltage withstand capability	GR RFG: 2.1.1	Compliance proof
3	LFSM-O	GR RFG: 3.1.4	Simulation Needed
3	Reactive Power Capability	GR RFG: 4.4.2	Simulation Needed
3	Fault Ride Through	GR RFG: 4.4.1	Simulation Needed
3	Fault current & dynamic voltage support	GR RFG: 4.4.3	Simulation Needed
3	Post-fault power active recovery	GR RFG: 4.4.4	Simulation Needed
4	Information exchanges (communication channels)	GR RFG: 4.2.2	Open
4	Information exchanges (content)	GR RFG: 4.2.2	Open
5	Remote Control Reductions	GR RFG: 4.1.1	Compliance proof
6	Power quality requirements (if required)	Connection contract	Compliance proof
7	Automatic Connection	GR RFG: 3.1.7	Compliance proof
7	Automatic Reconnections	GR RFG: 4.1.2	Compliance proof
8	Loss of Main Protection by ROCOF	GR RFG: 3.1.3	Compliance proof
4) Presence of a decoupling protection			
8	Verification of presence of decoupling protection (Elia standards)		Compliance proof
5) Compliance statement of the connection (VISA for MSI) and requested additional equipment by Elia			
Open			
0	Compliance of the connection	FGC: 159	Visa for MSI and/or compliance proof
6) Planned tests			
Open			
0	List and agreement of planned tests	FGC: Art. 177	List of tests
ION			
NOK			
7) Statement of Compliance by field tests			
Open			
3	Active Power Control	GR RFG: 4.1.1	Test needed
3	LFSM-O	GR RFG: 3.1.4	Test needed
3	Voltage Control	GR RFG: 4.4.2	Test needed
3	Reactive Power Capability	GR RFG: 4.4.2	Report
4	Telecom tests (communication channels)	GR RFG: 4.2.2	Test needed
4	Telecom tests (content)	GR RFG: 4.2.2	Open
6	Power quality tests (if required)	Connection contract	Test needed
7	Automatic Reconnection	GR RFG: 4.1.2	Test needed
0	Test Report		Report
0	Wire Break Test		Test needed
8) Committed Data submission (updated data questionnaire, model tuning and validation)			
Open			
1	Availability of updated data questionnaire		Compliance proof
FON			
NOK			

Example of a check-list for compliance of a type B PPM

Types of requirements for new PGMs type B:

- 1) Data questionnaire & models
- 2) Internal compliance proof (RGIE) & protection scheme
- 3) Voltage & frequency requirements
- 4) Real-time information / Telecom requirements
- 5) Balancing/Congestion management requirements
- 6) Power quality requirements (as from 10 MW)
- 7) Emergency & restoration requirements
- 8) Protections requirements



Comparison with requirements applicable to existing PGMs between 1 and 25 MW?

Requirements applicable to existing units

Comparison table

Official requirements



Elia federal and regional levels: Grid codes (section existing units)



Elia all levels: Connection contract approved by all regulators

Internal notes



Elia all levels: "Technische richtlijnen voor de aansluiting van decentrale producties" &

"Technische specificatie voor de aansluiting van netgebruikers"

Official requirements



Elia all levels: RGIE

Requirements	Applicable to Existing unit ?
1) Data Questionnaire	
1 data questionnaire	Y
2) PGM internal statement of compliance (RGIE, lcc max, fault clearing time, agreement on protection scheme)	
2 Equipment and protection requirements - RGIE	Y
2 Equipment and protection requirements - Annexe 1B - lcc max	Y
2 Equipment and protection requirements - Annexe 2B - Protections	Y
2 Specific protections scheme agreement	Y
3) Statement of Compliance via simulations or by proof/documentation	
1 Simulation models	Y
1 Model documentation/Userguide	Y
3 Frequency withstand capability	Y
3 Rate of Change of Frequency (ROCOF)	N
3 Maximum allowable Power Reduction	Y
3 Voltage withstand capability	Y
3 DelTU/F range	Y
3 LFSM-O	N
3 no equipment that will act against the primary control of the system	Y
3 Reactive Power Capability	Y
3 Fault Ride Through	Y
3 Fault current & dynamic voltage support	Y
3 Post-fault power active recovery	Y
3 Voltage Control	N
4 Information exchanges (communication channels)	N
4 Information exchanges (content)	N
5 Remote Control Reductions	N
6 Power quality requirements (if required)	Y
7 Automatic Connection	N
7 Automatic Reconnections	N
8 Loss of Main Protection by ROCOF	Y
4) Presence of a decoupling protection	
8 Verification of presence of decoupling protection (Elia standards)	Y
5) Compliance statement of the connection (VISA for MSI) and requested additional equipment by Elia	
O Compliance of the connection	Y
6) Planned tests	
O List and agreement of planned tests	N
ION	
7) Statement of Compliance by field tests	
3 Active Power Control	N
3 LFSM-O	N
3 Voltage Control	N
3 Reactive Power Capability	N
4 Telecom tests (communication channels)	N
4 Telecom tests (content)	N
6 Power quality tests (if required)	N
7 Automatic Reconnection	N
O Test Report	N
O Wire Break Test	N
8) Committed Data submission (updated data questionnaire, model tuning and validation)	
1 Availability of updated data questionnaire	N
FON	

For example only... work in progress...

Selection of requirements to be analysed via the CBA:

- Requirements already applicable to existing PGMs : **out of scope**
- Requirements applicable only for new PGMs : **in the scope**
- Requirements already applicable to existing PGMs but in a different way: **in the scope**



Number of existing and new PGMs between 1 and 25 MW

Amount of existing vs new PGMs (#)

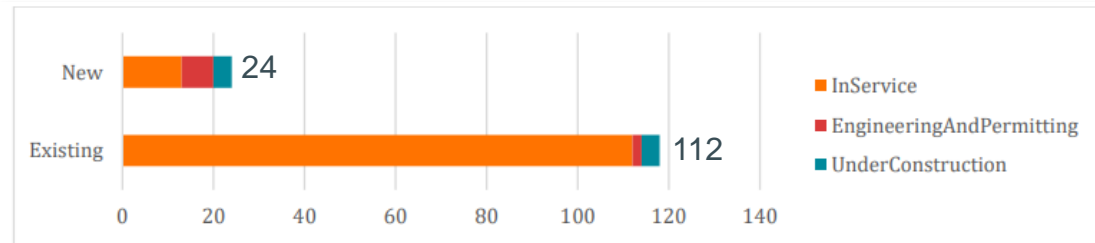


Figure 1 Amount of new and existing PGMs connected to the Elia network

Amount of existing vs new PGMs (MW)

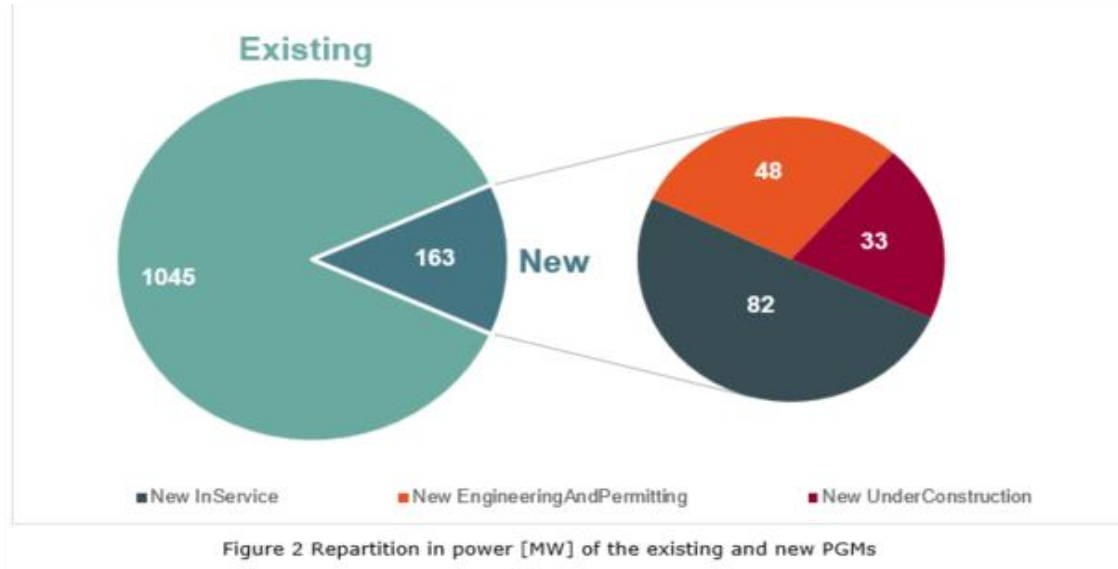


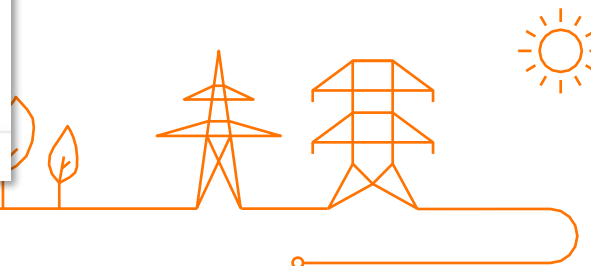
Figure 2 Repartition in power [MW] of the existing and new PGMs

From a pragmatic point of view:

- Elia communicated requirements for new PGMs as from 27/04/2019 (date of publication of federal grid code) at federal and regional level

Conclusion:

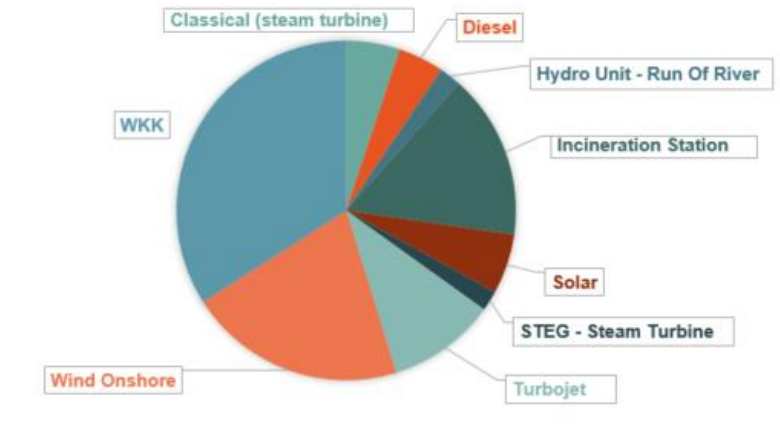
- All PGMs whose detailed study was still open after 27/04/2019 are considered as new



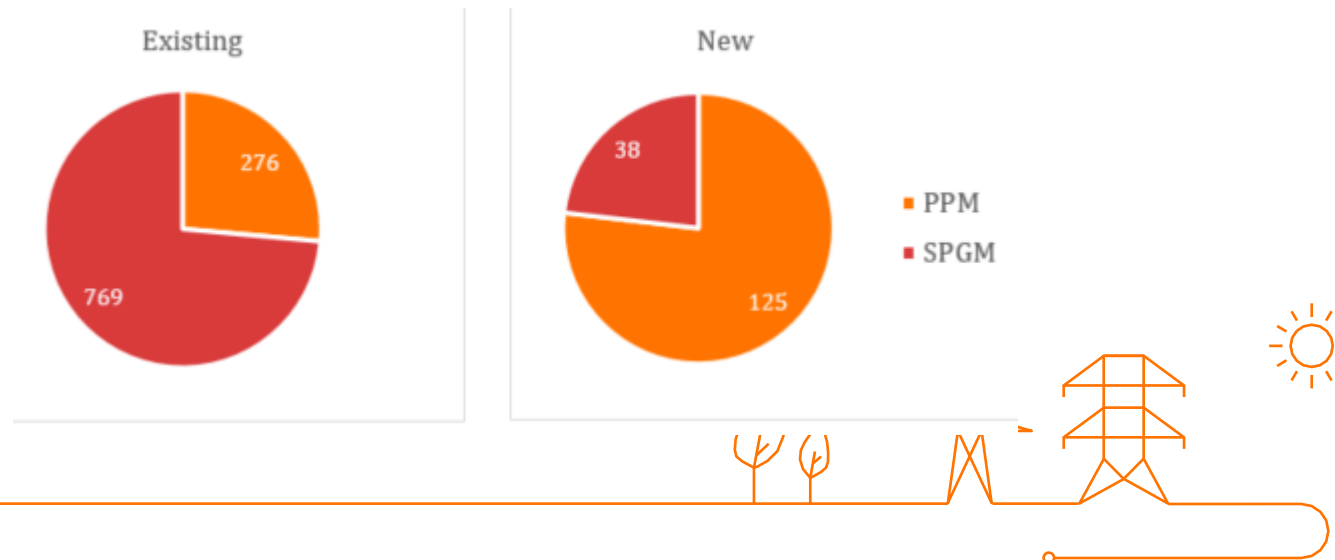
Focus on the existing PGMs between 1 and 25 MW

Repartition per type of existing PGMs

PRODUCTION TYPE	INSTALLED POWER (MW)
Classical (Steam Turbine)	53,4
Diesel	45,6
Hydro Unit - Run Of River	21,8
Incineration Station	164,318
Solar	59,63
STEG - Steam Turbine	20
Turbojet	108
Wind Onshore	216,6
WKK	355,783
TOTAL	1045,131



Repartition SPGM vs PPM for existing and new PGMs



Comparison of requirements type B PGM

Categories of requirements for PGMs:

- 1) Data questionnaire & models
- 2) Internal compliance proof (RGIE) & protection scheme
- 3) Voltage & frequency requirements
- 4) Information exchange / Telecom requirements
- 5) Balancing/congestion man. requirements
- 6) Power quality requirements
- 7) Emergency & restoration requirements
- 8) Protections requirements

More stringent or new	
Less stringent	
Small changes/identical	

Summary of the gap analysis of the requirements

Category of requirements	Sub category	GAP analysis	Remark	Eligible for incentive
Category 1	Data questionnaire & Models	Data questionnaire	Small changes	
		Models	More stringent	X
Category 2	Internal compliance proof (RGIE) & protection scheme	RGIE	Identical	
		Annex 1 : Icc max	More stringent	Not in the scope : DCC
		Annex 2 : Protections	Small changes	
		Protection schemes	Identical	
Category 3	Voltage & frequency requirements	Frequency withstand capability	Small changes	
		Rate of change of frequency (ROCOF)	More stringent	X
		Maximal allowable power reduction	Less stringent	
		LFSM-O	More stringent	X
		Voltage withstand capability	More stringent	X
		Voltage control (SPGM)	More stringent	X
		Reactive power capability	More stringent	X
		Fault Ride Trough	Less stringent	
		Fault current & dyn. Voltage support (PPM)	More stringent	X
		Oscillation and damping control	Small changes	
Post-fault power recovery (PPM)	More stringent	X		
Category 4	Information exchange / Telecom requirements	Information exchange	More stringent	X
Category 5	Balancing/congestion man. requirements	Remote control reductions	More stringent	X
Category 6	Power quality requirements		Identical	
Category 7	Emergency & restoration requirements	Automatic connection	More stringent	X
		Automatic reconnection	More stringent	X
Category 8	Protections requirements	Loss of main protection by RoCoF	Identical	
		Decoupling protection	Small changes	

CBA: Qualitative assessment

Benefits evaluation (Expert view)

3 ways to sort the requirements :

I) 4 technical families of requirements :

- Voltage
- Frequency
- Current
- Other

II) 2 operational system states :

- Normal state
- Emergency / restoration state

III) 2 ways of evaluating the robustness:

- Be robust (stay connected following an event)
- Give robustness (limit variations following an event)



Expert view
classification as
MUST /
NICE to HAVE



Benefit classification
**2 MUST = High
benefit**

Costs evaluation (Expert view)

For requirement, a cost category (LOW, MEDIUM, HIGH) has been assigned based on expert knowledge.

CBA : Qualitative assessment

Benefits evaluation (Expert view)

4 technical families of requirements :

- **Frequency** : lack of performance or robustness in terms of frequency requirements might endanger the security of the whole synchronous area and can expose the system to black-out → **MUST for the system**
- **Voltage** : local characteristic of the system with limited perimeter → **nice to have for the system**
- **Current** : local characteristic of the system with limited perimeter → **nice to have for the system**
- **Other** : case by case analysis

2 operational system states:

- **Normal state** : system is operated within its normal operational limits → **nice to have for the system**
- **Emergency** : system is operated out of its normal operational limits → **MUST for the system**

2 ways of evaluating the robustness:

- **Be robust** (stay connected following an event) → **MUST for the system**
- **Give robustness** (limit variations following an event) → **nice to have for the system**

CBA : Qualitative assessment

Benefits evaluation (Expert view)

Criteria : at least 2 MUST = High benefit

Sub category	GAP analysis	Eligible for incentive	Frequency vs voltage vs current		Normal state vs Emergency		Be robust vs give robustness		Impact/benefit
			Classification	Benefit	Classification	Benefit	Classification	Benefit	
Models	More stringent	X	Other	Nice to have	Normal	Nice to have	Give robustness	Nice to have	MEDIUM
Rate of change of frequency (ROCOF)	More stringent	X	Frequency	MUST	Emergency	MUST	Be robust	MUST	HIGH
LFSM-O	More stringent	X	Frequency	MUST	Emergency	MUST	Give robustness	Nice to have	HIGH
Voltage withstand capability	More stringent	X	Voltage	Nice to have	Normal	Nice to have	Be robust	MUST	MEDIUM
Voltage control (SPGM)	More stringent	X	Voltage	Nice to have	Normal	Nice to have	Give robustness	Nice to have	MEDIUM
Reactive power capability	More stringent	X	Voltage	Nice to have	Normal	Nice to have	Give robustness	Nice to have	MEDIUM
Fault current & dyn. Voltage support (PPM)	More stringent	X	Voltage	Nice to have	Normal	Nice to have	Give robustness	Nice to have	MEDIUM
Post-fault power recovery (PPM)	More stringent	X	Frequency	MUST	Normal	Nice to have	Give robustness	Nice to have	MEDIUM
Information exchange	More stringent	X	Other	Nice to have	Normal	Nice to have	Give robustness	Nice to have	MEDIUM
Remote control reductions	More stringent	X	current	Nice to have	Emergency	MUST	Give robustness	Nice to have	MEDIUM
Automatic connection	More stringent	X	Frequency	MUST	Emergency	MUST	Be robust	MUST	HIGH
Automatic reconnection	More stringent	X	Frequency	MUST	Emergency	MUST	Be robust	MUST	HIGH

CBA : Qualitative assessment

Cost evaluation (Expert view)

Criteria :

- low = minor adjustments (settings)
- medium = replacement of some elements of the PGM or addition of elements
- high = replacement of major elements of the PGM

Categories of costs to be evaluated (RfG Art. 39):

- direct costs
- costs associated to loss of opportunity
- costs associated to change in maintenance and operation

Sub category	GAP analysis	Eligible for incentive	Costs
Models	More stringent	X	LOW
Rate of change of frequency (ROCOF)	More stringent	X	LOW
LFSM-O	More stringent	X	LOW
Voltage withstand capability	More stringent	X	HIGH/LOW
Voltage control (SPGM)	More stringent	X	LOW
Reactive power capability	More stringent	X	HIGH/MEDIUM
Fault current & dyn. Voltage support (PPM)	More stringent	X	HIGH/LOW
Post-fault power recovery (PPM)	More stringent	X	HIGH/LOW
Information exchange	More stringent	X	MEDIUM
Remote control reductions	More stringent	X	MEDIUM
Automatic connection	More stringent	X	LOW
Automatic reconnection	More stringent	X	MEDIUM

CBA : Qualitative results

Sub category	GAP analysis	Eligible for incentive	Frequency vs voltage vs current		Normal state vs Emergency		Be robust vs give robustness		Impact/benefit	Costs	Results of the CBA
			Classification	Benefit	Classification	Benefit	Classification	Benefit			
Models	More stringent	X	Other	Nice to have	Normal	Nice to have	Give robustness	Nice to have	MEDIUM	LOW	positive CBA
Rate of change of frequency (ROCOF)	More stringent	X	Frequency	MUST	Emergency	MUST	Be robust	MUST	HIGH	LOW	positive CBA
LFSM-O	More stringent	X	Frequency	MUST	Emergency	MUST	Give robustness	Nice to have	HIGH	LOW	positive CBA
Voltage withstand capability	More stringent	X	Voltage	Nice to have	Normal	Nice to have	Be robust	MUST	MEDIUM	HIGH/LOW	CBA to be performed
Voltage control (SPGM)	More stringent	X	Voltage	Nice to have	Normal	Nice to have	Give robustness	Nice to have	MEDIUM	LOW	positive CBA
Reactive power capability	More stringent	X	Voltage	Nice to have	Normal	Nice to have	Give robustness	Nice to have	MEDIUM	HIGH/MEDIUM	CBA to be performed
Fault current & dyn. Voltage support (PPM)	More stringent	X	Voltage	Nice to have	Normal	Nice to have	Give robustness	Nice to have	MEDIUM	HIGH/LOW	CBA to be performed
Post-fault power recovery (PPM)	More stringent	X	Frequency	MUST	Normal	Nice to have	Give robustness	Nice to have	MEDIUM	HIGH/LOW	CBA to be performed
Information exchange	More stringent	X	Other	Nice to have	Normal	Nice to have	Give robustness	Nice to have	MEDIUM	MEDIUM	CBA to be performed
Remote control reductions	More stringent	X	current	Nice to have	Emergency	MUST	Give robustness	Nice to have	MEDIUM	MEDIUM	CBA to be performed
Automatic connection	More stringent	X	Frequency	MUST	Emergency	MUST	Be robust	MUST	HIGH	LOW	positive CBA
Automatic reconnection	More stringent	X	Frequency	MUST	Emergency	MUST	Be robust	MUST	HIGH	MEDIUM	positive CBA

Key findings :

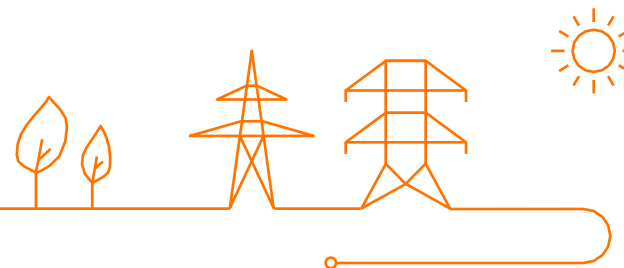
- Requirements with a **HIGH impact/benefit** and a **NON-HIGH Costs** have a positive CBA
- Requirements with a **MEDIUM impact/benefit** and **LOW costs** have a positive CBA
- **Other requirements should be further investigated through a quantitative CBA**

Call for inputs from market parties :

- confirm the categories of costs (low/medium/high)
- give detailed costs estimations for the quantitative CBA to be performed

Agenda

1. Objectives
2. High level methodology
- 3. Discussion market parties**
4. Planning and milestones



Category 1 : Data Questionnaire & models

Simulation models and model documentation / User guide

Existing generating unit

NOT DEFINED

Simple model with blocks diagrams

New generating unit

Simulation Model Requirement – Toward Grid Users

	Facility types	Synchronous generation facilities	Power Park Modules facilities
Generation facility	Type A ⁴	Static simulation model	Static simulation model
	Type B ⁵	Static simulation model RMS simulation model EMT simulation model	Static simulation model RMS simulation model EMT simulation model
	Type C	Static simulation model RMS simulation model EMT simulation model	Static simulation model RMS simulation model EMT simulation model ⁶
	Type D	Static simulation model RMS simulation model EMT simulation model	Static simulation model RMS simulation model EMT simulation model
Demand Facility		Static simulation model RMS simulation model EMT simulation model	

Table 1. Simulation model requirements for specific facility types

Applies to all PGMs

Impact/benefit	Costs	Results of the CBA
MEDIUM	LOW	positive CBA

More stringent or new

Categorie 3 : Voltage and Frequency

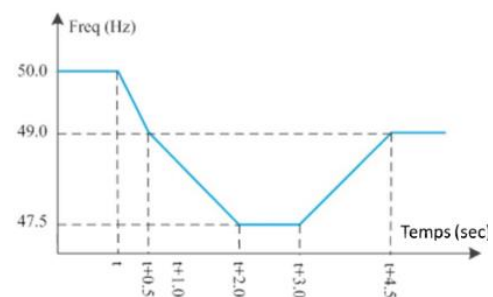
Rate of change of frequency (ROCOF)

Existing generating unit

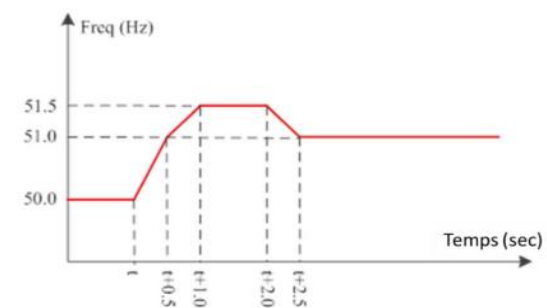
NOT DEFINED

New generating unit Art. 83 §2

Profil de sous-fréquence



Profil de sur-fréquence



Frequency Range

Duration

Up to 2Hz/sec

500 ms

Applies to all PGMs

Impact/benefit	Costs	Results of the CBA
HIGH	LOW	positive CBA

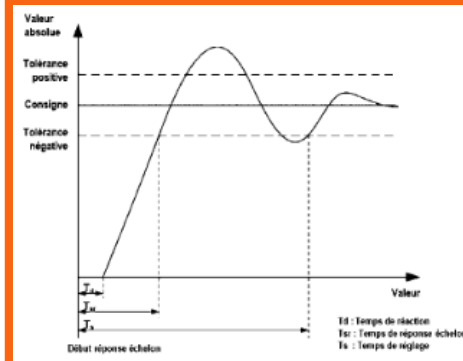
Categorie 3 : Voltage and Frequency LFSM-O

Existing generating unit

NOT DEFINED

New generating unit Art.88 §1 (SPGM)
Art. 92 §2 (PPM)

Limited Frequency Sensitivity Mode –Over-frequency (LFSMO)



Paramètre	Réglage SPGM
Seuil de fréquence	50.2 Hz
Statisme	5 % (réglable entre 2 % et 12 %)
Puissance de référence Pref	Puissance maximale
Temps de réaction	Par défaut aussi rapidement que techniquement possible (sans délai intentionnel), des dispositions spécifiques pourraient être applicables en accord avec le gestionnaire de réseau de transport.
Temps de réponse échelon	≤ 5 minutes pour une augmentation de puissance active de 20 % de Pmax. Une réaction lente n'est pas d'application pour le cas d'une augmentation qui suit rapidement (en quelques secondes) une phase de diminution) ≤ 8 secondes pour une diminution de puissance active de 45 % de Pmax
Temps de réglage	≤ 6 minutes pour une augmentation de puissance active (Une réaction lente n'est pas d'application pour le cas d'une augmentation qui suit rapidement une phase de diminution) ≤ 30s pour une diminution de puissance active

Paramètre	Réglage PPM
Seuil de fréquence	50.2 Hz
Statisme	5 % (réglable entre 2 % et 12 %)
Puissance de référence Pref	Par défaut, il s'agit de la production effective de puissance active au moment où est atteint le seuil LFSM-O; une référence égale à la puissance maximale peut être prescrite au cas par cas.
Temps de réaction	Par défaut aussi rapidement que techniquement possible (sans délai intentionnel), des dispositions spécifiques pourraient être applicables en accord avec le gestionnaire de réseau de transport.
Temps de réponse échelon	Pour la production d'électricité éolienne : ≤ 5 secondes pour une augmentation de puissance active de 20 % de Pmax. Une réaction plus lente pour un point opérationnel ≤ 50 % Pmax est acceptable tant que qu'elle est au-dessous de 5 secondes ≤ 2 secondes pour une diminution de puissance active de 50 % de Pmax Pour le reste : ≤10 secondes pour une augmentation de puissance active de 50 % de Pmax ≤ 2 secondes pour une diminution de puissance active de 50 % de Pmax
Temps de réglage	≤ 30 secondes pour une augmentation de puissance active ≤ 20 secondes pour une diminution de puissance active

Applies to SPGMs and PPMs

Impact/benefit	Costs	Results of the CBA
HIGH	LOW	positive CBA

More stringent or new

Categorie 3 : Voltage and Frequency

Voltage withstand capability

Existing generating unit Art.65 §2

Voltage Range	Duration
0.9-1.05	Unlimited

Upper and downer limit not speicfied

for any connection point voltage between 0.9 and 1.05 of the normal operating voltage, the generating unit considered as existing must ensure an unlimited time period for operation, except in the case of a limitation due to restrictions on the generator voltage generator voltage or the generator stator current. A limitation on the stator current may not intervene in the fast voltage setting

New generating unit Art. 85 §2

Voltage Range <300kV	Duration
0.85 pu – 0.9 pu	60 minutes
0.9 pu – 1.118 pu	Unlimited
1.118 pu – 1.15 pu	TBA for Type A,B,C 20 min for Type D
Voltage Range >300kV	Duration
0.85 pu – 0.9 pu	60 minutes
0.9 pu – 1.05 pu	Unlimited
1.05 pu – 1.10 pu	TBA for Type A,B,C 20 min for Type D

Applies to SPGMs and PPMs

More stringent or new	
-----------------------	--

Impact/benefit	Costs	Results of the CBA
MEDIUM	HIGH/LOW	CBA to be performed

Categorie 3 : Voltage and Frequency

Voltage control (SPGM)

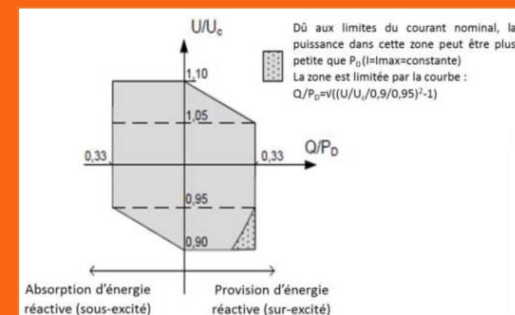
Existing generating unit Art. 69 Titre 3

$P_{max} < 25\text{MW}$ without MVAR contract
 $Q=0$ MVAR -> Voltage setpoint defined by Q

New generating unit Art.89§2 SPGM

SPGM:

- **Qfix:** maintain a constant reactive power within the P/Q capabilities.
- **Q(U):** maintain a constant alternator voltage within the P/Q capabilities.
- For all those control modes the setpoint should be remotely selectable.



Optional for PPM (for info see simulation document)

Impact/benefit	Costs	Results of the CBA
MEDIUM	LOW	positive CBA

Categorie 3 : Voltage and Frequency

Reactive power capability (PPM)

Existing generating unit Art. 58 §2

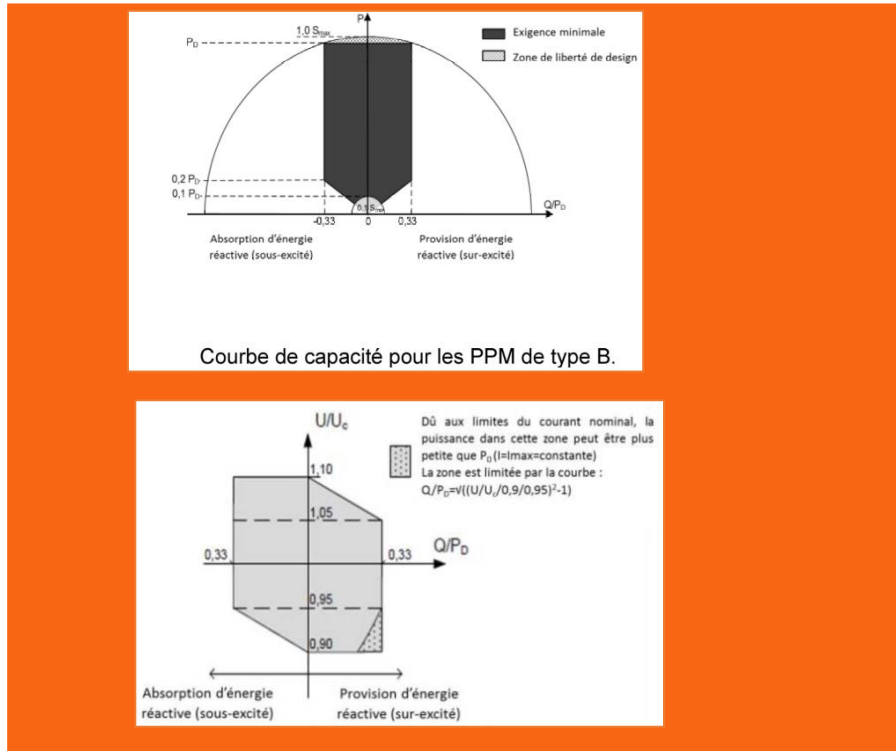
FGC Art. 58 §2 refers to Elia (prescriptions spécifiques): Any value of the active power between Min and Maximum at **nominal Voltage** must be able to respectively absorb or supply at the point connection, reactive power includes at least, **-0.2 Pmax and 0.35 Pmax**.

-20% < Q < +35% on-shore WF

-25% < Q < +25% offshore WF

Mandatory

New generating unit Art. 93 §2



Applies to SPGMs and PPMs

Impact/benefit	Costs	Results of the CBA
MEDIUM	MEDIUM (SPGM) HIGH/MEDIUM (PPM)	CBA to be performed

More stringent or new

Categorie 3 : Voltage and Frequency

Reactive power capability (SPGM)

Existing generating unit Art.65 §1

Any value of the active power between Min and Maximum at **nominal** operating Voltage must be able to respectively absorb or supply at the point connection, reactive power includes at least, -0.1 Pmax and 0.45 Pmax.
-10% < Q < +45% for Synchronous Generation

Mandatory

New generating unit Art.89 §1

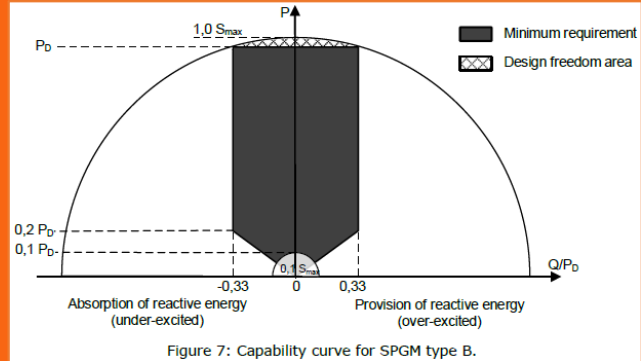
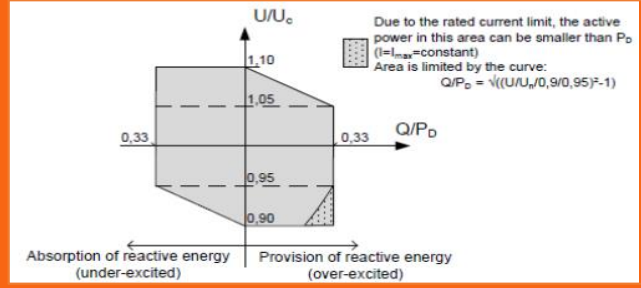


Figure 7: Capability curve for SPGM type B.



Applies to SPGMs and PPMs

Impact/benefit	Costs	Results of the CBA
MEDIUM	MEDIUM (SPGM) HIGH/MEDIUM (PPM)	CBA to be performed

More stringent or new	
-----------------------	--

Categorie 3 : Voltage and Frequency

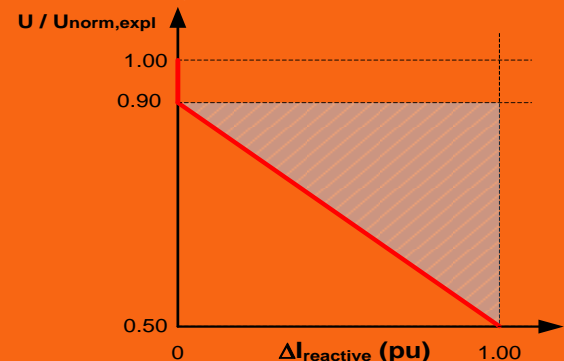
Fault current & dynamic voltage support

Existing generating unit FGC Art. 58 §2

New generating unit Art.93 §3 PPM

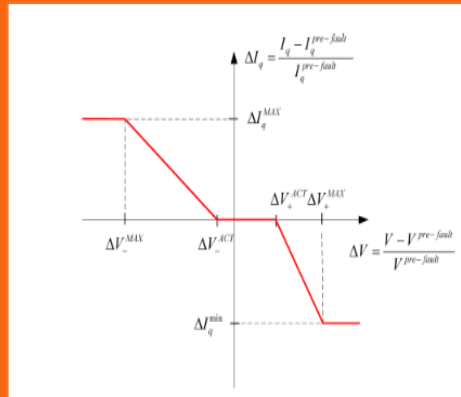
FGC Art. 58 §2 refers to Elia (prescriptions spécifiques):

- Injection of additional reactive current determined by the figure below, where for voltages between 1 and 0.9 in pu of $U_{nom,expl}$, the wind park should follow the normal voltage droop control modeOptional



Mandatory

- Parameter Site Specific defined in the connection offer
- Active current is decreased to give priority to reactive current
- K factor define by Grid Study
- Capable to block this function in weak grid (Activation).



More stringent or new	
-----------------------	--

Impact/benefit	Costs	Results of the CBA
MEDIUM	HIGH/LOW	CBA to be performed

Categorie 3 : Voltage and Frequency

Post-fault power active recovery

Existing generating unit FGC Art. 58 §2

FGC Art. 58 §2 refers to Elia (prescriptions spécifiques):

- Following the fault clearance the active power recovery shall be provided with a gradient of at least 0.2 p.u/s.

Mandatory

New generating unit Art.95 PPM

- Parameter Site Specific define in the connection offer
- Minimum:
- P>90% within 5 sec of resuming normal voltage range (>0,9 p.u)

More stringent or new

Impact/benefit	Costs	Results of the CBA
MEDIUM	HIGH/LOW	CBA to be performed

Categorie 4 : Information exchange / telecom requirements

Information exchange

Existing generating unit

NOT DEFINED

New generating unit. GR RfG 4.2.2

4.2.2 Information exchanges [Art 14-5(d)]

Real time measurement requirements:

PGM Type B connected to Elia:

- position of the circuit breakers at the connection point (or another point of interaction agreed with the Elia);
- active and reactive power at the connection point (or another point of interaction agreed with the Elia); and
- net active and reactive power of power generating facility in the case of power generating facility with consumption other than auxiliary consumption.

In case of technical infeasibility to communicate this information, gross active and reactive power of power generating facility could be accepted but it has to be agreed during the connection process with Elia on a case by case level and fixed in the individual connection contract.

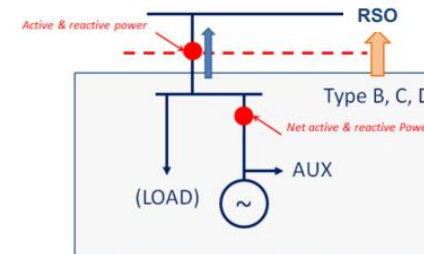


Figure 6: Clarification of the concept of net and gross measurement.

Real-time measurement is defined as a measurement (representation of the current state of a facility) that is refreshed at a rate higher (faster frequency of refreshing) than one minute.

For data related to automatic load-frequency control processes & flexible generation, it shall not be longer than 10 s.

For other purposes, it shall be as fast as possible and, in any case, not longer than one minute.

Note that other real-time measurements could be required by the relevant system operator depending on the location of the PGM, type of prime mover and the availability of measurements.

During the connection procedure of the unit, the exact list of signals to exchange, the communication protocols and infrastructure requirements are communicated by the relevant system operator⁴.

Impact/benefit	Costs	Results of the CBA
MEDIUM	MEDIUM	CBA to be performed

More stringent or new

Categorie 5 : Balancing/congestion management

Remote control reduction

Existing generating unit

NOT DEFINED

New generating unit. GR RfG 4.2.1

4.1.1 Remote control reduction of active power [Art 14 -2]

Respecting the applicable regional regulatory provisions, the right to request additional equipment to allow active power to be remotely operated will be asserted by Elia as relevant system operator in due time.

Impact/benefit	Costs	Results of the CBA
MEDIUM	MEDIUM (SPGM) HIGH/MEDIUM (PPM)	CBA to be performed

More stringent or new

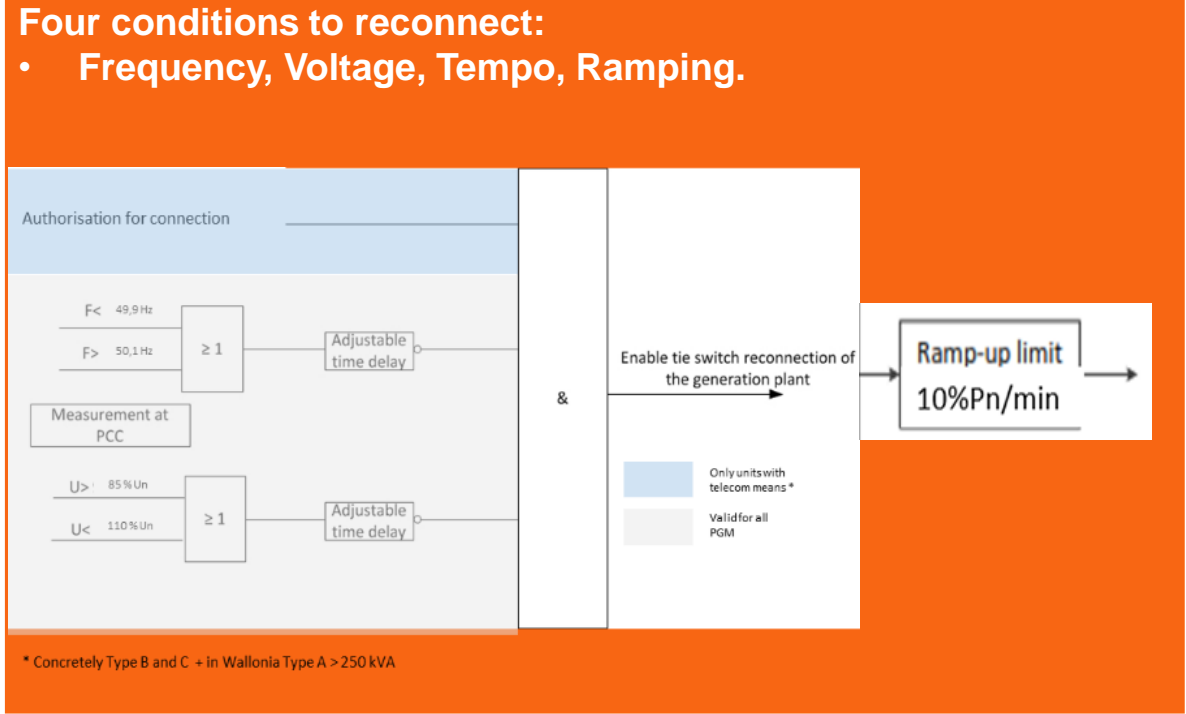
Category 7 : Emergency & restoration requirements

Automatic connection and automatic reconnection

Existing generating unit

NOT DEFINED

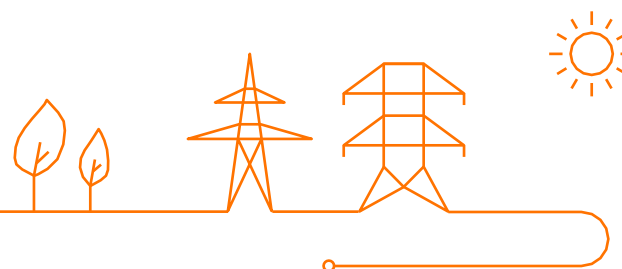
New generating unit. Art. 83 §6



	Impact/benefit	Costs	Results of the CBA
Automatic connection	HIGH	LOW	positive CBA
Automatic reconnection	HIGH	MEDIUM	positive CBA

Agenda

- Objectives
- High level methodology
- Discussion market parties
- **Planning and milestones**



Planning and milestones

- **Phase 1 : Preparation of work – Elia**

- Inventory of existing and new PGMs between 1 & 25 MW
- Comparison of the requirements applicable to existing and new PGMs
- First evaluation of the requirements in terms of benefits for the grid and selection of candidate requirements for the CBA
- First proposal for the different categories of costs to take into account

- **Phase 2: Evaluation with market parties – Elia & Market parties**

- Of the candidate requirements for the CBA
- Of the CBA methodology
- Of the categories of costs

- **Phase 3: Data collection and CBA – Elia & Market parties**

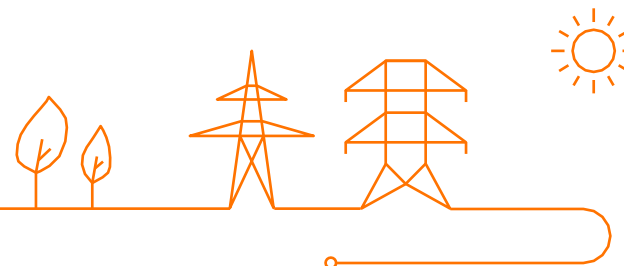
- Data collection with market parties for the costs part for the selected requirements for the CBA
- CBA performed by Elia

- **Phase 4 : Public consultation - Elia & Market parties**

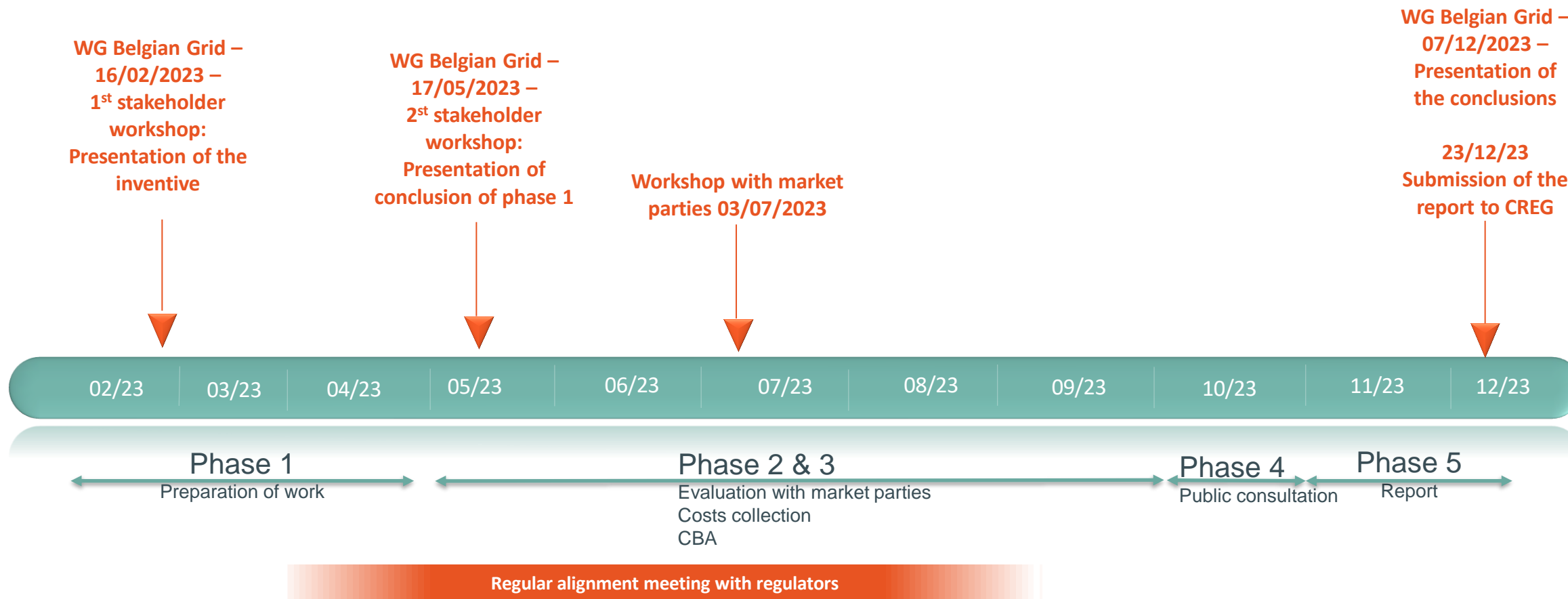
- **Phase 5 : Report and conclusions – Elia**



Workshops & discussions
with market parties
Call for inputs from market
parties !



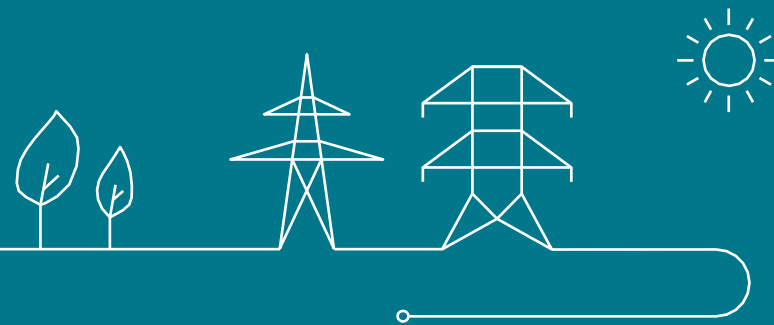
Planning and milestones



Thank you.



Back-up slides



Context : EU code (RfG) and requirements on new installations

RfG

EU CODE (2016/631)



Directly applicable

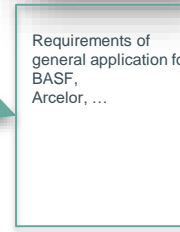
Elia federal level Elia regional level CDS DSOs



Elia federal level (2019):
Requirements of general application directly translated into articles of the Federal Technical Regulation approved by CREG



Elia regional level (2019):
Requirements of general application (2019)
→ approved officially by the 3 regional regulators



CDS level:
Requirements of general application to be defined by each CDSO and approved by relevant regulator

Elia gives statement of compliance for the new PGMs (FON)

CDSO gives statement of compliance

The new requirements are applicable to :

- Power generating modules considered as “new”
- Power generating modules considered as “existing” in several cases (see next slide)



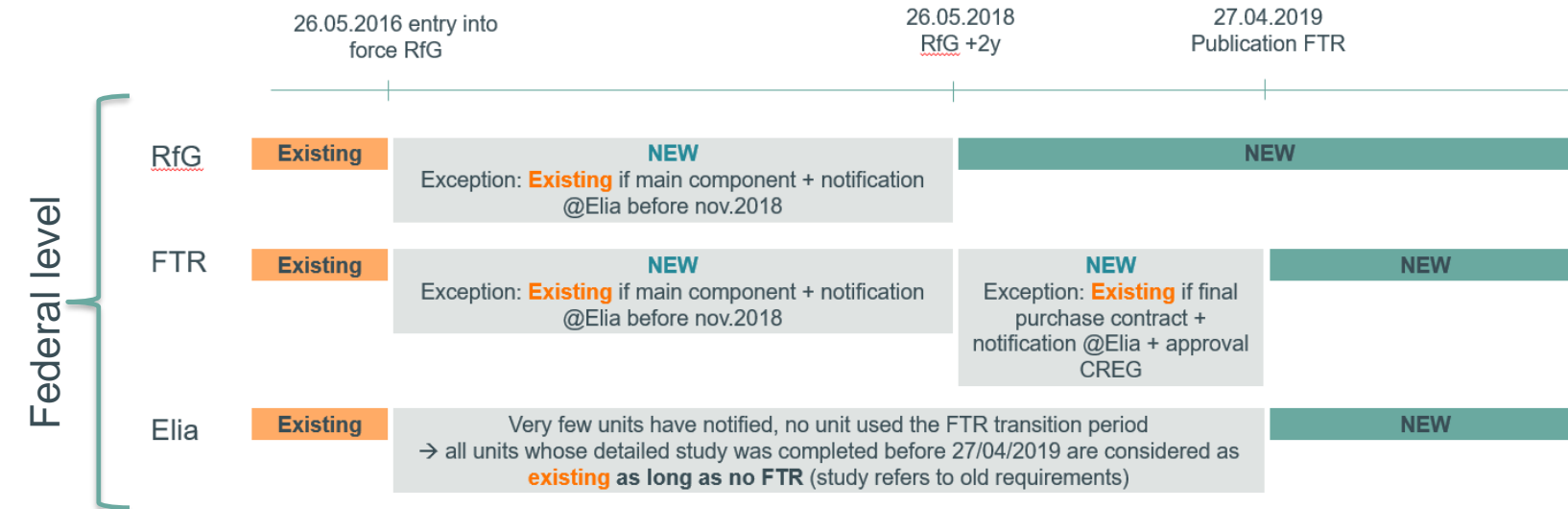
Context : EU code (RfG) and article 4 (application to existing installations)

The new requirements are applicable to “existing” PGMs in the following cases:

- Substantial modernisation of PGMs type C & D units (according to the criteria published by Elia) – *RfG Art. 4.1a*
- A regulatory authority decides to apply to existing PGMs some or all criteria applicable to new PGMs – *RfG Art 4.1b*
 - based on evolution of the system requirements such as RES penetration, smart grids, distributed or demand response
 - based on the proposal of the TSO
 - after a transparent cost-benefit analysis
 - after taking into account the legitimate expectations of the PGMs owners
 - after a public consultation
- The cost-benefit analysis should take into account – *RfG Art 3:*
 - The costs of requiring compliance to RfG and new requirements
 - The socioeconomic benefits resulting from applying the RfG and new requirements
 - The potential of alternative measures to achieve the required performances
- Before carrying out the cost-benefit analysis, the relevant TSO should : – *RfG Art 4*
 - Carry out a preliminary qualitative comparison of costs and benefit
 - Obtain approval from regulator



Definition of existing PGMs versus new PGMs

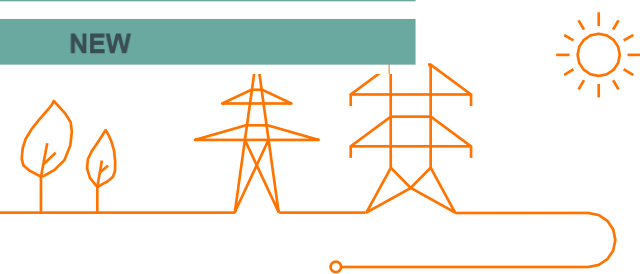
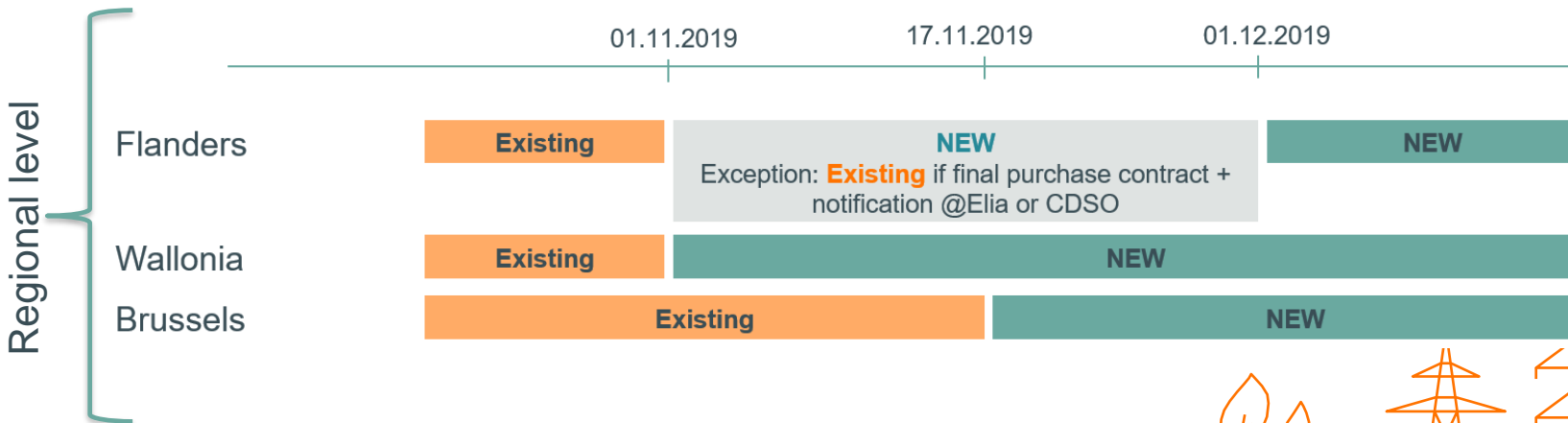


From a pragmatic point of view:

- Elia communicated requirements for new PGMs as from 27/04/2019

Conclusion:

- All PGMs whose detailed study was still open after 27/04/2019 are considered as new



Category 1 : Data Questionnaire & models

Data questionnaire

Existing generating unit FGC: Art 354 & Annex 3

3 Generator information

Manufacturer: *Siemens AG*
 Type: *S6200-100A-4P*
 Year manufactured: *2002*

Snom	Rated apparent power (+ related ambient temperature) MVA	<i>50,00</i>
Pnom	Rated active power (+ related ambient temperature) MW	<i>42,5</i>
Unom	Rated terminal voltage kV	<i>10,50</i>
U ₁	Tolerance on the terminal voltage above the rated voltage %	<i>10%</i>
U ₂	Tolerance on the terminal voltage under the rated voltage %	<i>10%</i>
Inom	Rated stator current at standard cooling condition kA	<i>2,749</i>
Cos	Rated power factor	<i>0,85</i>
nom	Rated speed	<i>1500 rpm</i>
PD ² alt x m ²	Moment of inertia (generator + excitor) <i>rotor compl. 172,395</i>	<i>ton m²</i>

Bijlage 11 - 2/14

New generating unit: FGC: Art 354 & Annex 3

8.1 Transformer (generating unit and generating system)

Symbol	Data Description	Units	Value
	Transformer identification number	Text	
	If this is a <i>generating unit</i> transformer, the list of <i>generating units</i> to which this information applies.	Text	
	Manufacturer and manufacturer's type designation or product name.	Text	
	Possible ground connection impedance (at primary and/or secondary winding)?	Text	
	Connection of an auxiliary tertiary winding in delta?	Text	
	Shell or Core type transformer?	Text	
	Free or forced fluxes magnetic path?	Text	

8.1.1 Design Data Sheet

Symbol	Data Description	Units	Value
Snom	Apparent nominal power	MVA	
Unom1	Machine-side nominal voltage	kV	
Unom2	Network-side nominal voltage	kV	
Xcc	Short circuit reactance	Ucc%	
Pcu	Copper losses	kW	
Pfe	Iron losses	kW	
Im	Magnetising current	A	
GTW	Number of windings		

Applies to all PGMs

Category 2 : Internal compliance proof and equipments capabilities

Internal compliance proof (RGIE) & Protection scheme

- RGIE:

→ not in the scope

- Annexe 1 – Icc max

1B. Caractéristiques techniques d'une installation considérée comme nouvelle conformément à l'article 35, §§ 7, alinéa 1^{er}, 8 et 9

Niveau de tension (kV)	Um Equipement (kV)	LIWV Uw (kV)	I dynamique (kA)	Disjoncteurs Isc (kA)	Autres équipements travées haute tension		Liaison en câble souterrain / ligne aérienne	
					I thermique		I thermique (3φ et 1φ)	
					Durée	(kA)	Durée	(kA)
380	420	1425	160 ou 125 (*)	63 ou 50 (*)	≥ 1 s	63 ou 50 (*)	0,6 s	50
220	245	1050	125 ou 100(*)	50 ou 40 (*)	≥ 1 s	50 ou 40 (*)	0,6 s	40
150	170	750	125 ou 100 (*)	50 ou 40 (*)	≥ 1 s	50 ou 40 (*)	0,6 s	40
110	123	550	100	40	≥ 1 s	40	0,6 s	Cable: 40 Ligne: 40 ou 31,5 (*)
70	82.5	380	100 ou 80 ou 50 (*)	40 ou 31,5 ou 20 (*)	≥ 1 s	40 ou 31,5 ou 20 (*)	0,6 s	Cable: 25 Ligne: 25 ou 20(*)
36	40.5 (42)	200 ou ≥ 170 (*)	100 ou 80(*)	40 ou 31,5 (*)	≥ 1,2 s	40 ou 31,5 (*)	3φ: 1,2 s 1φ: 1,2 s	3φ: 31,5 1φ: 4
30	36	170	100 ou 80 (*)	40 ou 31,5 (*)	≥ 1,2 s	40 ou 31,5 (*)	1,2 s	1φ: 4
26	30	145	80 ou 63 (*)	31,5 ou 25 (*)	≥ 2 s (1)	31,5 ou 25 (*)	1,2 s	
15	17,5	95	63	25	≥ 2 s (1)	25		
11-12	17,5	95	63	25	≥ 2 s (1)	25	3φ: 2 s 1φ: 3,3 s	3φ: 25 1φ: 4
10	12	75	63	25	≥ 2 s (1)	25		
6	7,2	60	63	25	≥ 2 s (1)	25		

(*): suivant la décision du gestionnaire du réseau

(1): correspondant au temps de déclenchement de la protection en réserve

Vu pour être annexé à Notre arrêté du 22 avril 2019 établissant un règlement technique pour la gestion du réseau de transport et l'accès à celui-ci.

1A. Caractéristiques techniques d'une installation considérée comme existante existante conformément à l'article 35, §§ 7, alinéa 1^{er}, 8 et 9

Niveau de tension (kV)	Um Equipement (kV)	LIWV Uw (kV)	Disjoncteurs Isc (kA)	Autres équipements		
				I thermique		I dynamique (kA)
				Durée	(kA)	
380	420	1550 ou 1425 (*)	50 ou 63 (*)	≥ 1 s	50	125
220	245	1050	40	≥ 1 s	40	100
150	170	750	40 ou 50 (*)	≥ 1 s	40	100
70	82.5	Hors Zone Liège	380	≥ 1 s	20	50
		Zone Liège	380	≥ 1 s	31,5	80
36	40,5	200 ou ≥ 170 (*)	31,5	≥ 1,2 s	31,5	80
30	36	170	31,5	≥ 1,2 s	31,5	80
26	30	145	25	≥ 2 s (1)	25	63
15	17,5	95	20	≥ 2 s (1)	20	50
11-12	17,5	95	25	≥ 2 s (1)	25	63
10	12	75	25	≥ 2 s (1)	25	63
6	7,2	60	25	≥ 2 s (1)	25	63
				Duur	(kA)	

(*): suivant décision gestionnaire du réseau.

(1): correspondant au temps de déclenchement de la protection en réserve

Out of scope : DCC

More stringent or new

Internal compliance proof (RGIE) & Protection scheme

- Annexe 2 – Temps d'élimination maximal d'un défaut

Annexe 2. Temps maximal d'élimination d'un défaut par protections

Un utilisateur du réseau de transport peut dévier des données mentionnées ci-dessous uniquement pour des raisons motivées et sous condition de l'approbation notifiée du gestionnaire de réseau de transport. Chaque déviation devra être signalée dans le contrat de raccordement applicable.

2A. Temps maximal d'élimination d'un défaut par protections pour une installation considérée comme existante existante conformément à l'article 35, §§ 7, alinéa 1^{er}, 8 et 9.

Niveau de tension (kV)	LIGNES, CABLES, TRANSFO *									Défaut JEUX DE BARRES		
	Base (ms)	Refus Protect (ms)	Refus Disj. (ms)	Refus Disj. (ms)	Réserve ligne/câble suivant (ms)	Réserve jeux de barres suivants (ms) ****		Réenclenchement ligne (ms)		Base (ms)	Réserve du couplage (ms)	
						Déf. mono	déf. poly	mono.	Poly_phasé		déf. mono.	déf. poly
380	100	100	300	170	1000	500	250	1	10	100	250	170
220	120	120	-	-	1000	600	600	1	***	100	300	300
150	120	120	-	-	1000	600	600	1	***	100	300	300
70	120**	2250	-	-	1000	600	600	-	***	600	-	-
36	120	2250	-	-	1200	1200	1200	-	***	600	-	-
30	120	2250	-	-	1200	1200	1200	-	***	600	-	-
15	1100	3100	-	-	-	1800	1800	-	***	1800	-	-
12	1100	3100	-	-	-	1800	1800	-	***	1800	-	-
10	1100	3100	-	-	-	1800	1800	-	***	1800	-	-

* Transformateur: niveau de tension = tension nominale max. du transformateur

** Pour les lignes, cette valeur est d'application pour l'extrémité située le plus proche du défaut; pour l'autre extrémité, un temps d'élimination de 500 ms est autorisé.

*** A déterminer par le gestionnaire du réseau en fonction des paramètres de réglage des protections des installations avoisinantes

**** Aussi applicable pour défaut entre transformateur de courant et disjoncteur

Remarque: Tous les temps sont les valeurs maximales permises.

2B. Temps maximal d'élimination d'un défaut par protections pour une installation nouvelle au sens de la législation applicable et de l'article 71, § 2.

Niveau de tension (kV)	LIGNES, CABLES, TRANSFO *									DEFAULT JEUX DE BARRES		
	Base (ms)	Refus Protect (ms)	Refus Disj.(ms) *****	Refus Disj.(ms) *****	Réserve ligne/câble suivant (ms)	Réserve jeux de barres suivants (ms)		Réenclenchement ligne (s)		Base (ms)	Réserve du couplage (ms)	
						Déf. mono	déf. poly	mono.	Pol ypha sé		déf. mono.	déf. poly
380	100	100	300	250	1000	500	270	1	10; 16	100	170	170
220	120	120	300	300	1000	600	600	1	***	100	330	330
150	120	120	300	300	1000	600	600	1	***	100	330	330
110	120**	2250	300	300	1000	600	600	-	***	100	330	330
70	120**	2250	-	-	1000	600	600	-	***	600	-	-
30-36	120**	2250	-	-	1200	1200	1200	-	***	600	-	-
10-29,9kV	1100	3100	-	-	-	1800	1800	-	***	1800	-	-

* Transformateur: niveau de tension = tension nominale max. du transformateur

** Pour les lignes, cette valeur est d'application pour l'extrémité située le plus proche du défaut; pour l'autre extrémité, un temps d'élimination de 500 ms est autorisé.

*** A déterminer par le gestionnaire du réseau en fonction des paramètres de réglage des protections des installations avoisinantes

**** Aussi applicable pour défaut entre transformateur de courant et disjoncteur; ces valeurs sont valables pour les deux extrémités des lignes connectées au jeu de barre concerné

***** Seulement pour les disjoncteurs des barres haute tension raccordées aux jeux de barre

Category 2 : Internal compliance proof and equipments capabilities



Internal compliance proof (RGIE) & Protection scheme

- Agreement on protection scheme : no changes

Categorie 3 : Voltage and Frequency

Frequency withstand capability

Existing generating unit Art.56

Frequency Range	Duration
< 47,5 Hz	Islanding
48,0 Hz – 48,5 Hz	Mutual Agreement
48,5 Hz – 51,0 Hz	Unlimited
51,0 Hz – 52,5 Hz	Mutual Agreement
> 52,5 Hz	Islanding

Mandatory

New generating unit Art. 83 §1

Frequency Range	Duration
47,5 Hz – 48,5 Hz	30 minutes
48,5 Hz – 49,0 Hz	30 minutes
49,0 Hz – 51,0 Hz	Unlimited
51,0 Hz – 51,5 Hz	30 minutes
51,5 Hz – 52,0 Hz	Mutual Agreement

Applies to all PGMs

Categorie 3 : Voltage and Frequency

Maximum allowable power reduction

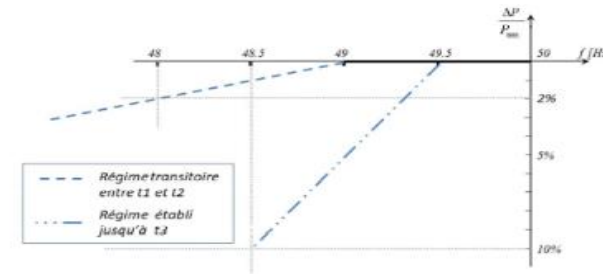
Existing generating unit FGC: Art.59

In the event of a sudden change or significant deviation in frequency, no device of a power generation unit or a non-synchronous storage or a non-synchronous storage facility considered as existing, may interfere with the primary control of the system

Mandatory

Less stringent

New generating unit Art. 83 §4



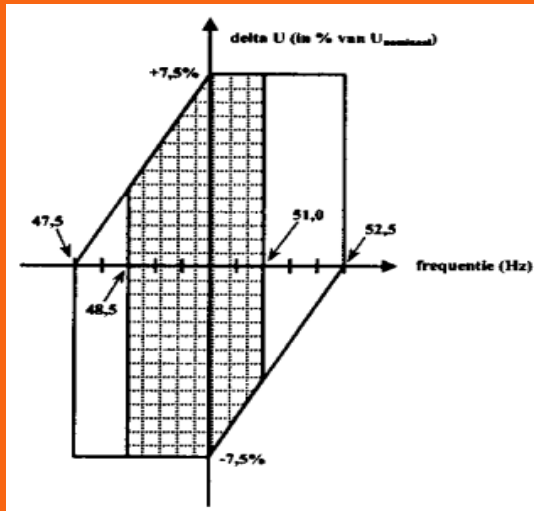
	Paramètres	Réglage
Période de régime transitoire	Seuil de fréquence	49 Hz
	Limite	2 % / Hz
	t 1 (début)	≤ 2 s
	t 2 (fin)	30 s
Période de régime établi	Seuil de fréquence	49.5 Hz
	Limite	10 % / Hz
	t 3 (fin)	30 minutes

Applies to SPGMs and PPMs

Categorie 3 : Voltage and Frequency

Delta U versus Frequency

Existing generating unit Art. 57



Mandatory

New generating unit

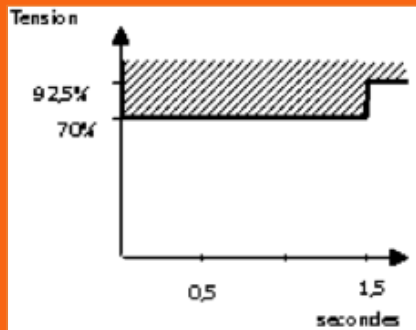
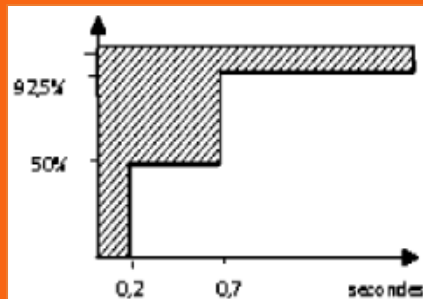
NOT DEFINED

Applies to generator terminal

Categorie 3 : Voltage and Frequency

Fault Ride Trough

Existing generating unit Art.58 §1

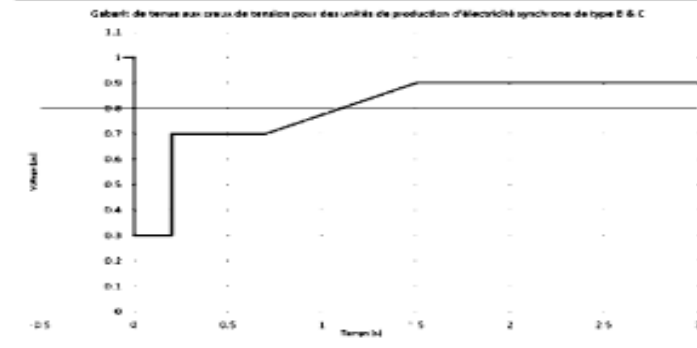


Mandatory

New generating unit Art.90 SPGM

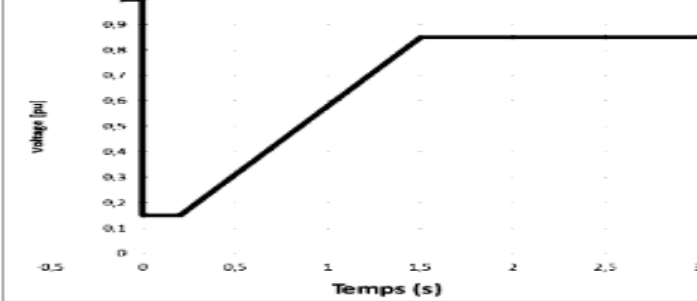
SPGM

Le profil d'exigence de tenue aux creux de tension pour SPGM de type B et C



PPM

Gabarit de tenue aux creux de tension pour parc non synchrone de générateurs de type B & C



Applies to SPGMs and PPMs

Incentive CBA type B |

Less stringent

Categorie 3 : Voltage and Frequency Oscillation and damping control

Existing generating unit Art. 69

Titre 2. Exigences applicables à toute installation et tout raccordement au réseau de transport.

CHAPITRE 1^{er}. Dispositions générales.

Art. 36. § 1^{er}. Le présent titre établit les exigences applicables à toute installation et tout raccordement au réseau de transport, que ceux-ci soient considérés comme existant ou nouveau en application des codes de réseau européens RfG, DCC et HVDC.

CHAPITRE 5. Autres dispositions.

Art. 69. § 1^{er}. L'utilisateur du réseau de transport et le gestionnaire de réseau de transport conviennent, en ce qui concerne les aspects non couverts par le présent arrêté et qui sont directement liés à la sécurité, la fiabilité et l'efficacité du réseau de transport, des exigences techniques générales minimales, des paramètres de réglage et des spécifications techniques fonctionnelles minimales à adopter en ce qui concerne les installations de l'utilisateur du réseau de transport, dont en particulier :

- 1° le domaine de fonctionnement du générateur dans le plan actif-réactif en fonction de la tension d'exploitation ;
- 2° l'adaptation du régulateur turbine à l'ilotage de l'unité de production d'électricité (capacité et moment de l'ilotage) ;
- 3° la plage de réglage du gain du régulateur de vitesse ;
- 4° le statisme réactif ;
- 5° la stabilité statique et dynamique ;
- 6° la résistance aux creux de tension du générateur et des équipements auxiliaires ;
- 7° le plafond d'excitation ;
- 8° la synchronisation au réseau de transport en exploitation normale et exceptionnelle;
- 9° la capacité de l'unité de production d'électricité de fournir des services auxiliaires ;
- 10° pour les ensembles de production d'électricité comprenant plusieurs unités de production d'électricité avec auxiliaires communs et unités de production d'électricité à cycle combiné, la possibilité de pannes de mode commun y compris le contrôle-commande ;

11° le Power System Stabiliser ;

New generating unit Art. 69

Titre 2. Exigences applicables à toute installation et tout raccordement au réseau de transport.

CHAPITRE 1^{er}. Dispositions générales.

Art. 36. § 1^{er}. Le présent titre établit les exigences applicables à toute installation et tout raccordement au réseau de transport, que ceux-ci soient considérés comme existant ou nouveau en application des codes de réseau européens RfG, DCC et HVDC.

CHAPITRE 5. Autres dispositions.

Art. 69. § 1^{er}. L'utilisateur du réseau de transport et le gestionnaire de réseau de transport conviennent, en ce qui concerne les aspects non couverts par le présent arrêté et qui sont directement liés à la sécurité, la fiabilité et l'efficacité du réseau de transport, des exigences techniques générales minimales, des paramètres de réglage et des spécifications techniques fonctionnelles minimales à adopter en ce qui concerne les installations de l'utilisateur du réseau de transport, dont en particulier :

- 1° le domaine de fonctionnement du générateur dans le plan actif-réactif en fonction de la tension d'exploitation ;
- 2° l'adaptation du régulateur turbine à l'ilotage de l'unité de production d'électricité (capacité et moment de l'ilotage) ;
- 3° la plage de réglage du gain du régulateur de vitesse ;
- 4° le statisme réactif ;
- 5° la stabilité statique et dynamique ;
- 6° la résistance aux creux de tension du générateur et des équipements auxiliaires ;
- 7° le plafond d'excitation ;
- 8° la synchronisation au réseau de transport en exploitation normale et exceptionnelle;
- 9° la capacité de l'unité de production d'électricité de fournir des services auxiliaires ;
- 10° pour les ensembles de production d'électricité comprenant plusieurs unités de production d'électricité avec auxiliaires communs et unités de production d'électricité à cycle combiné, la possibilité de pannes de mode commun y compris le contrôle-commande ;

11° le Power System Stabiliser ;


Category 6 : Power quality requirements



- The power quality requirements are currently described in the connection contract for both existing and new PGMs.

Loss of main protection by RoCoF


- the implementation of a RoCoF protection is not requested by Elia

Small change/Identical 

Decoupling protection

Existing generating unit

	Threshold	Temporization
Frequency relay		
f<	47.5 Hz	0 ms
f>	51.5 Hz	0 ms
Voltage relay		
U>	110% Un or 100% U_{max}	0-100 ms
U<t	70% Un	1.5 - 3 s
U<<t	30% Un	300 ms
U₀>³	5 - 25%	2 - 5 s

Small change/Identical 

New generating unit

	Threshold	Temporization
Frequency relay		
f<	47.5 Hz	0 ms
f>	51.5 Hz	0 ms
Voltage relay		
U>	110% Un	100 ms
U<t	70% Un	1.5 - 3 s
U<<t	15% Un	300 ms
U₀>⁴	5 - 25%	2 - 5 s