Study on the future design of the ancillary service of voltage and reactive power control

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Executive Summary

From the beginning of the unbundled energy market functioning, Elia has been procuring the service of voltage & reactive power control from third parties through tendering procedures.

Large generators have been until now almost exclusively providing the service to Elia through their Access Responsible Parties under the form of automatic and manual reactive power (provided at the demand of Elia).

There are however different drivers to change the current design of the service of of voltage & reactive power control (“MVAR service”).

A benchmark study has demonstrated that Elia is not aligned with other EU TSO’s in terms of contracting procedure for this service. In almost every country currently the MVAR service is a mandatory service arranged via bilateral contracts and settled at regulated prices.

This study reveals the absence of many basic conditions which are required for having an efficient market functioning for the MVAR service. This is confirmed by the practical experience that in the last couple of years most of the prices offered via the existing tendering procedure were considered as unreasonable by the regulator and therefore ex post reasonable prices needed to be determined via a royal decree.

Recently introduced Network Codes and consequent changes in the Federal Grid Code will have a considerable impact in the service rules & procedures.

Moreover, the shift in the energy landscape in Belgium from large centralized to small decentralized generation requires Elia to develop a new framework with which to valorize new potential for the service.

Besides, Elia has set as objective to develop ancillary services which are technology neutral and which can be delivered by other parties then the Access Responsible Party. Whereas for other services this objective has yet been achieved (eg. FCR) or a road map is in development (iCAROS, aFRR, mFRR), no design changes occurred or were yet planned for the MVAR service regarding this objective.

Considering this, Elia has assessed the different possible design configurations for the MVAR service. As result Elia proposes to:

1) move towards a mandatory provision with regulated prices;
2) Develop a new role being the Voltage Service Provider designated by the grid user or where applicable the DSO/CDSO;
3) create a coherent framework by combining the incentives to limit the need for regulation given by the tariff with incentives to actively regulate voltage & reactive power given by the MVAR ancillary service;
4) create a framework for the participation of new technologies.

Finally, Elia presents an implementation plan for the proposed solution including an overview of changes to be made in the legal & contractual framework and implementations on the market and Elia’s side. Based on the assessment the entry into force of the proposed design could be possible by 2020. However it is also underlined that an implementation on time of the required changes in the legal framework is an absolute precondition.

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1 Introduction to the study

1.1 In a nutshell

Voltage stability is essential to ensure efficient operation of the high-voltage grid, as well as any other medium or low voltage electrical grid. Users of the Elia grid have an obligation to be able to maintain the injection and absorption of reactive energy to and from the Elia grid within certain levels and are incentivized to do so by the grid tariff[1].

On top of auto-regulation by grid users, Elia actively manages to maintain grid voltages at a suitable, stable level by activating manually or automatically reactive power on assets that are connected to its grid. By generating or absorbing reactive energy, they contribute to controlling and stabilizing the grid voltage. This service of voltage & reactive power control is organised via the "MVAR service".

Today, producers with units providing these services supply Elia with a reactive power band that is dedicated to voltage control. A distinction is made between units providing "automatic" and "manual" control. Automatic control is provided automatically around the clock by units that are in operation in response to voltage variations measured at their interface with the grid, whereas manual control is provided on an occasional basis at Elia's request. Elia pays the producers for these services in proportion to measured reactive power.

The evolving landscape of the energy transition, as well Elia's continuous efforts to ensure longer term cost expenditure efficiency for society and to facilitate the integration of new market parties, requires an evolution of the MVAR service design so that it can adapt to future needs.

The MVAR service underwent a major redesign already in 2015, touching several of its core aspects such as, among others, operational exchanges, activation rules, remuneration or delivery control rules.

Today, the introduction of the EU Network Codes (NC's) together with the subsequent amendment of the Federal Grid Code (FGC) requires an adaptation of the MVAR service to the new legal framework, but also provides an opportunity to develop some other features such as the opening up to new market parties.

In the present study Elia:

1) Analyzes the impact of the new legal framework (EU Network Codes and Elia's proposal for amendment of the FGC), in particular in terms of regulation capabilities of different market parties (chapter 5);
2) Analyzes the new subsequent requirements for Significant Grid Users (SGU's) (as these are mentioned in the Network Codes), organically integrated throughout the study (chapters 5 and 6);
3) Evaluates different configurations for participation of new market parties, such as (transmission-connected) demand, Distribution System Operators (DSO's) and/or Distribution System (DS)-connected assets, Closed Distribution System Operators (CDSO's) or Closed Distribution System (CDS)-connected assets (chapters 5 and 9);
4) Evaluates different configurations for the contracting procedure, notably in aspects such as obligation to provide, remuneration, tendering (or not), contract duration, price structure etc (chapters 6 and 7).

Furthermore, in relation to above-mentioned aspects, Elia studies and evaluates options concerning relation of the MVAR service with the related tariffs and the incentive they give, as well as some high-level principles concerning delivery control and settlement as linked to evolutions on above aspects. The link to tariffs has been included in this report to give stakeholders a view on the overall impact of the proposed design. Based on

[1] As foreseen in the Federal Grid Code

the feedback from stakeholders during the present consultation period, Elia will evaluate the proposals and perform an in depth assessment of their feasibility. A definitive choice will be made in the context of the proposal of tariffs for the tariff period 2020-2023.

The study evaluates different configurations possible taking into account their technical and legal feasibility and economic opportunity (wherever this is possible), always in the perspective to ensure longer term cost expenditure efficiency for society, while resulting in some recommendations for entry into force for the 1st of January 2020 (pending validation of the relevant legal framework).

Regarding remuneration of the service provision, the advantages and disadvantages of different price configurations are listed. It should be noted that in parts of the study economic opportunity was only evaluated in a qualitative way due to uncertainty on the decided service price levels, as for configurations with regulated price structures and levels, it falls within the competency of the regulator. Hence, the determination of price structure and level shall be organised in a later stage after this study. Nevertheless it is yet useful to gather relevant input from stakeholders regarding these topics via the current study.

In the present study we refer to assets providing the MVAR service as "units". This terminology includes generation units as well as demand facilities as well as any other asset providing the MVAR ancillary service to Elia.

1.2 Voltage control

The transmission of electrical power is subject to one particular principle of good practice: to limit losses, the voltage level must be as high as possible[2] while the current must be as low as possible, within the limits imposed by the grid and by voltage limitations of each node[3]. These conditions enable maximum power to be transmitted while safeguarding the production units from ageing prematurely. However, the limited insulation capacity of the relevant lines and cables means that it is essential that the voltage in the grid does not exceed a certain level locally. Elia is responsible for controlling voltage and relies on the assistance of the producers connected to its grid in order to do so.

Injection or absorption of MVAR's at each node induces voltage differences between nodes; Elia must regulate reactive energy injection and absorption to:

1) Maintain voltage within operational limits at each node;
2) Maintain the reactive balance at 0 within limited zones;
3) Maintain the reactive balance for the Belgian system at 0;

In any situation, Elia must dispose of sufficient regulation capacity to be able to stabilize voltage as mentioned above in case of a dimensioning incident[4] and, once stabilized, maintain it within its safe ranges.

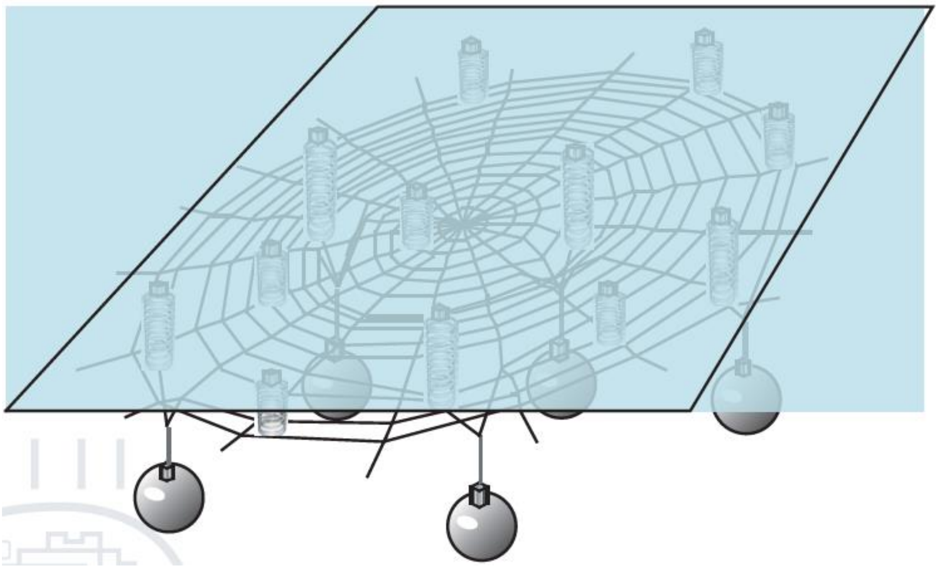
Voltage fluctuations are inevitable due to the influence of:

- the fluctuations in power that are caused by the offtakes and injections that industrial activity and intermittent generation in Belgium entails;
- flows from the transmission-connected distribution grids, to which (very volatile) residential and other demand grid users are connected;
- electrical flows and topological changes in the grid.

[2] Albeit contained within specific operational limits, depending on the momentary charging of the local grid.
[3] Also depending on the grid users connected to it.
[4] I.e. the loss of a nuclear reactor that would define the grid's capability to react

The grid's reaction to such fluctuations is similar to a web, which must be supported by a flexible force (illustrated by the springs in the drawing below) so that it can withstand the tugging to which it is subjected. In Elia's meshed grid the springs represent reactive energy. As for the "nodes" attached to the web, these symbolise various operations affecting the grid, such as injections, offtakes and foreign electrical flows.

Whereas the frequency in the grid is influenced by the behaviour of active energy, the voltage is affected by reactive energy. As active energy is very easy to transport, frequency can be managed at national and European levels. However, due to transmission losses, influence on voltage and network loading, the lower the considered voltage level, the more the voltage has to be managed locally. This means that the production units that take part in controlling voltage have to be strategically located.



This energy is currently partially supplied by producers: in line with the voltage level measured in the grid, production units stabilize the voltage by absorbing or generating reactive energy. This service, supplying reactive energy to Elia, is governed by a MVAR service contract between Elia and the producer concerned.

In addition to managing the reactive energy supplied by the producers, Elia makes use of a number of means of its own to stabilize grid voltage, such as manual or automatic control of transformers or management of the park of reactor and capacitor banks in the Elia grid.

There are several factors causing reactive power offtakes or injections which need to be covered with regulation means that are at Elia's disposal as explained in Table 1.

Such may be injection or offtakes of reactive power from distribution grids or neighboring transmission grids, reactive loads connected to the Elia grid or even volatile injections from intermittent renewable energy sources (RES). On the other hand, Elia may regulate reactive power using its own reactive controlling elements, contracted elements belonging to third parties connected to the Elia grid or contracted production units.

Factors causing needs	Regulation means
Reactive load	TSO owned reactive controlling elements
Inherent behaviour transmission grid	Production units with a contract for MVAR ancillary services (if P≠0)
Intermittent generation (RES)	
Coupled distribution grids	
Neighboring transmission grids	

Table 1: Factors causing needs VS means for regulation of reactive power within the Elia grid

Elia uses a series of technical regulation means and/or techniques to cover its needs in voltage control:

Increasing voltage	*Decreasing voltage*
Capacitor	Reactor (self)
Generation MVAR production	Generation MVAR absorption
Limit active flows, to keep lines in capacitive range	Increase active flows, to push lines further into inductive range
Outage planning (cancel planned outage of cables)	Taking cables and long lines out of service
MVAR import from neighbouring grids	MVAR export to neighbouring grids

Table 2: Technical means & methods for voltage regulation at the Elia grid

Capacities of production or absorption of reactive power by generation units are some of key contributors to reactive power management to this day. Similarly, reactors and capacitor banks installed at substations of transmission-connected distribution grids or demand facilities may also help in managing reactive power in the transmission grid in the future.

TSO's prioritize reactive energy that comes :

1) as a by-product of generation of active energy, or:

2) from Reactive Power Management (RPM) assets installed by grid users for their own voltage regulation and that have an additional unused capacity to put at Elia's disposal.

Elia prioritizes above resources because they do not require specific investments.

Elia regularly performs power planning studies to verify whether existing capacities from third parties suffice to satisfy the grid's regulation needs, and if not it identifies certain nodes in the grid which require reinforcements in years to come by installing its own reactors and/or capacitor banks.

It should be noted that the current framework of the MVAR ancillary service is aimed at generation units and does not foresee to use any capabilities that grid users might have within their own capacitors and reactors.

2 Today's picture

2.1 Preface

In this chapter today's overall reactive power mechanism is described. Technical & operational features of the MVAR ancillary service, its legal & contractual framework, overall design (including incentives for auto-regulation given by the tariff), together with a picture of activated volumes & costs over recent years.

It should be underlined that the MVAR ancillary service underwent a major redesign in 2015 This change had as an objective to improve the data exchange between service providers and Elia and to establish a better control of delivery of the MVAR service.

Some core elements of this design are presented in this chapter, but do not constitute the main focus of the studied changes as explained in section 1.

It should be noted that in this chapter Elia refers to production units because such units have been traditionally providing the service to this day. The following chapters of this study discuss the participation of other types of units to the MVAR ancillary service.

2.2 Technical & Operational features

2.2.1 Automatic and manual control

There are two types of MVAR service: automatic control and manual control.

In the present study units that are capable of providing automatic control are mentioned as "controlling units", whereas units that are only capable of providing manual control are called "non-controlling units".

2.2.1.1 Automatic control

Automatic voltage control takes place around the clock at production units that are in operation. If these units (via their terminals) detect a voltage fluctuation, they immediately and automatically make the appropriate adjustments to their reactive energy production. The units use, for example, voltage regulators that can perform a correction within a matter of just a few seconds. This kind of regulation is performed to regulate voltage also at local grids (using the right voltage measurements).

In general, automatic control must be activated at all times to immediately counter any voltage deviations and keep the voltage within limits in the concerned area.

2.2.1.2 Manual control

Manual voltage control is activated following communication between Elia's control center and the operators of the production unit via which the voltage control service is to be provided to Elia.

This service can today be provided by controlling and non-controlling production units.

Unlike automatic control, manual control is provided by the producer at Elia's request. For each asset participating in the manual voltage control a specific capability band is contractually agreed.

2.2.2 Controlling production units and non-controlling production units

Elia ensures that the providers taking part in the MVAR service are able to supply or absorb enough reactive power to meet the requirements stipulated in the contract between Elia and the provider. To meet these requirements, the production units must have certain technical features that vary depending on whether the unit is a controlling production unit or a non-controlling production unit.

The current FGC defines these units as follows:

Art. 68: *"All units of which active nominal power P_{nom} is superior or equal to 25MW is a controlling production unit independently from the voltage level of its connection point"*.

Art. 69: *"Any controlling production unit must be able, on first request by the system operator, to adapt – automatically and without delay – its supply of reactive power in the event of slow voltage fluctuations (over a period of minutes) and quick voltage fluctuations (over a period of a fraction of a second)."*

Art. 70: *"Any non-controlling production unit must be able to adapt its supply of reactive power to the requirements of the grid (at the very least via commutation of its reactive power production between two levels agreed between the system operator and the grid user concerned)."*

This means that according to provisions of the current FGC units above 25MW must be able to deliver the automatic and manual services, whereas units below 25MW must be able to deliver only manual control.

2.2.1 Compensation mode

Certain units (non-synchronous power modules) may regulate voltage by compensating with reactive energy using the circuits of their power electronics.

Compensation is done without producing any active power; instead, when compensating units offtake active power from the grid that they use for their power electronics systems.

2.2.2 Band reserved for voltage control

The controlling and non-controlling production units that take part in voltage control supply Elia with a regulation band [MVAR-band] that can be used for generating or absorbing reactive power. Reactive power is used to restore the voltage to an acceptable level if there is any voltage fluctuation. The regulation operation is carried out by adjusting the instructions given to the production units.

In the case of automatic control, reactive energy is activated automatically, within the bounds of the band that is provided by the producer.

In the case of manual control, Elia asks the producer to activate reactive energy upwards or downwards, depending on the band specified in the contract.

For controlling units, Elia may request to modify the set points of injection of reactive energy within any point of the unit's operating range, including 0MVAR.

For non-controlling units, Elia may only request production of reactive energy equal to the upper level of the band (Qband+) and absorption of reactive energy equal to the lower level of the band (Qband-).

2.3 Existing legal framework

Today the legal framework for Reactive Power Management (RPM) is organized as follows:

Law of 29 April 1999 ("Loi relative à l'organisation du marché de l'électricité" or « E-Law »):

(a) **Art.12:** Connection and use of grid infrastructure of the electric system are subject to a tariff, according to principles described in this article;

(b) **Art. 12 quinquies:** Principles of procurement of MVAR ancillary services, including MVAR, competences of the regulator and the king in assessment and determination of final volumes & prices to be procured in case they are considered as non-reasonable or in case of insufficient volumes;

Federal Grid Code of 19 December 2002:

(c) **Art. 60:** Competence of the TSO to take necessary actions to compensate reactive energy whenever the load of a certain grid user causes an additional offtake of reactive energy or disrupts security, safety and/or efficiency of the grid;

(d) Art. 68-74:

- All generation units with a P_{nom} equal or superior to 25MW are considered as controlling units;
- Controlling units must be capable of adapting automatically their provision of reactive power to the grid in function of voltage;
- All non-controlling units must be capable of shifting their provision of reactive energy at minimum between two set points agreed with the concerned grid operator;
- Controlling units should be capable of injecting/absorbing at the connection point reactive power equal at least between -0,1*P_{nom} and 0,45*P_{nom};
- Controlling units should be capable of regulating between 0,9 and 1,05 times the nominal grid voltage;
- By derogation to the general rule, these requirements for local production Units[5] must be respected at the output of the power unit (and not at the connection point);
- Controlling units need to have a relative sensibility coefficient (relation between voltage and injection/absorption of reactive power, otherwise designated under the term *droop*) within a certain value range;

(e) Art. 75: The TSO and the Grid User must agree upon the active/reactive service area of the generator in function of voltage;

(f) Art. 78: To offer the MVAR ancillary service a unit needs to be controlling or non-controlling;

(g) **Art. 257-260:**

- Competences of the TSO to determine specifications concerning availability and supply of the voltage & reactive control service;
- Supply of the voltage & reactive control service through a competitive procedure and/or a tender;
- Definition of a transparent and non-discriminatory procedure;
- Competence of the regulator to impose a price for the service;
- The TSO is competent to determine the quantity of control volume to be offered and delivered by controlling units;
- Non-controlling generators must adapt their injection/absorption of reactive power from the grid immediately whenever asked to by the TSO;
- Above regulation should be performed within limits agreed between the TSO and the Grid User;

[5] Meaning generation units that are behind the same connection point as a load facility, connected to the same voltage level, to the same Elia post and that are located at the same site as the load facility.

(h) **Art. 207-209:** For a certain timeframe (15 minutes), the TSO bestows Access Contract Holders with a quantity of reactive power for their access point for capacitive and inductive use (without any compensation between the two); this quantity is equal to 32,9% of the active power consumed at the same timeframe. Any excess of this quantity at the given timeframe will be sanctioned by a tariff.

(i) Art. 310-311: In the framework of the MVAR ancillary service, the TSO communicates to generators the set points necessary for voltage regulation for both regulating and non-regulating units using technical means to be specified in the ancillary service contract. The generator may not modify these set points without prior approval by the TSO.

(j) Art. 323: The TSO must determine in the connection contract necessary localisation of measurements to be used for reactive power.

Legal provisions for RPM are described in the law of 29 April 1999, but mostly in the Federal Grid Code, who describes obligations of grid users in terms of auto-regulation, capability of active regulation and sets the framework for the incentive mechanism laid down by a tariff. In this sense, the Federal Grid Code is the backbone of Elia's "MVAR toolkit" and any change in the latter's components should be compliant with it.

2.4 Connection requirements

Connection requirements for generators and demand units are formulated in the FGC and require:

1) Demand units to regulate their injection and/or absorption of reactive energy to not inject or absorb more than 32,9% of their active power offtake (Art. 207-209); any excesses of this value should be sanctioned by a tariff set by Elia;

2) Generators to be **capable of regulating** their injection and/or absorption of reactive energy in function of grid voltage (which translates to the "Automatic" service) or in function of a request by Elia (which translates to the "Automatic" service);

These capability obligations can be resumed as follows:

	Q Capability		Q Control/ Auto voltage control	
	Absorption	Injection	Manual	Automatic
TS-Connected generators P<25MW	no requirement	no requirement	Minimum 2 set points	no requirement
TS-Connected generators P>=25MW	-10%	45%	all set points	all set points
TS connected demand facilities	no requirement	no requirement	no requirement	no requirement
TS connected distribution systems	no requirement	no requirement	no requirement	no requirement

Table 3: Requirements for reactive regulation capability from current FGC

2.5 Current product design

2.5.1 Procurement of the MVAR ancillary service

Currently, Art. 12 quinquies of the E-Law and Art. 257.§2 of the FGC foresee that Elia organizes a tender for the procurement of the MVAR ancillary service.

Each year, Elia organizes a tender (following rules of public tendering as stipulated in the public procurement law of 15 June 2006) in which market parties participate voluntarily.

It should be noted that according to Articles 69 and 70 of the current FGC controlling and non-controlling units have the obligation to be capable of offering the automatic and manual voltage control services, however there is no obligation to offer it to Elia.

The tendering period is one calendar year (from 1st of January to 31st of December). The criteria for a unit to be contracted are:

1) Minimal volume to be produced or absorbed: 5 MVAR in injection and/or absorption;
2) Fulfilment of the technical requirements specified in the Federal Grid Code;
3) Fulfilment of the technical requirements specified in the contract template.

Candidates undergo a qualification procedure, in which they are screened against some criteria such as financial robustness and legal compliance.

Once accepted, candidates submit offers in which they specify the technical specifications of the power units (identification, technical bands for injection and absorption and if applicable in compensation mode, etc.).

Further details on current pricing structure of the service can be found in the MVAR bidding instructions document that is publicly available[6].

According to Art. 12 quinquies of Law of 29 April 1999, Elia communicates a report containing all received offers to the regulator and the minister. Based on this report, the CREG communicates another report to the minister indicating in an explicit and motivated way whether received offers are "manifestly unreasonable" or not.

When the CREG's report concludes that prices are "manifestly unreasonable" or at Elia's request, the King may, following a proposal by the Minister, for the sake of security of supply impose a public service obligation covering the volumes and prices of the MVAR ancillary service.

As can be observed in Table 4, in all recent years a public service obligation by Royal Decrees has been imposed on the vast majority of units participating to the service:

	Offered		Royal Decree		
	Providers	**Units**	**Providers**	**Units**	**Units (%)**
2016	6	56	3	48	86%
2017	4	37	3	36	97%
2018	4	41	3	40	98%

Table 4: Occurrence of imposition of public service obligations through RD's for MVAR in recent years

2.5.2 MVAR ancillary service design summary

Current design principles for the MVAR service are provided in the MVAR contract, subject to Articles 68 to 74, 76 to 78, 119 to 121, 257 to 260 and 310 to 311 of the FGC.

For coherence reasons, the terms starting with a capital letter in the present section correspond to their definition in the MVAR contract.

The contract designates as "Supplier" *"the Access Responsible Party of the Production Unit(s) considered"* who "*has the right to transfer the rights and obligations...to a Third Party*" in case of a transfer of Production Unit(s) subject of the contract. The Supplier provides the service under authorization of the Grid User concerned and commits to provide proof of the agreement *"at Elia's first request"*.

Duration of the contract is set to 1 year.

[6] Link: http://www.elia.be/~/media/files/Elia/Products-and-services/ancillary%20services/purchase%20of%20ancillary%20services/Bidding%20Instructions%20MVAR%202018.pdf

Power units are distinguished according to their ability to provide Reactive Power in compensatory mode. Also, the contract makes a distinction between Controlling and Non-Controlling Power units according to their ability ("Controlling") or not ("Non-Controlling") to provide the Local Voltage Control Service (cited as "automatic service" in the rest of the present study). Non-Controlling Units only provide the Centralized Service (cited as "manual service" in the rest of the present study).

Requirements	Local Voltage Control Service	Centralized Voltage Control Service
Delivery of the service	Injection Point (high-voltage side of step-up transformer of the Production Unit)	Injection Point (high-voltage side of step-up transformer of the Production Unit)
Controlling Production Units	Yes	Yes
Non-Controlling Production Units	No	Yes

Table 5: Service delivery by controlling & non-controlling power units foreseen by the MVAR contract

2.5.2.1 Activation

The Local Voltage Control Service consists of an automatic regulation of injected or absorbed Reactive Power in relation to a voltage set point as measured at the Injection Point (high-voltage side of step-up transformer of the Production Unit), whereas the Centralized Voltage Control Service consists of a punctual regulation of injected or absorbed Reactive Power based on a specific Set Value communicated (also at Injection Point level) by Elia.

Supplier is expected to activate the contracted services only whenever production units are running and are injecting more than a minimum of active power (P_{min}).

For the Local Voltage Control Service, regulation of Reactive Power injection or absorption happens between the unit's declared technical active power limits ($Q_{tech\ max}$ and $Q_{tech\ min}$), according to a certain sensitivity coefficient (α_{eq}) that is declared by the Supplier and calculated according to a formula indicated by Elia; the said formula takes into account the unit's relative reactive power injection/absorption sensitivity to voltage variations.

$$\alpha\_eq = -\frac{\left(\dfrac{\Delta Qnet}{0{,}45 \times Pnom}\right)}{\left(\dfrac{\Delta Unet}{Unorm, \exp}\right)}$$

Where:

(k) Qnet is the Reactive Power measured on the HV side of the step-up transformer;

(l) Unet is the voltage measured on the HV side of the step-up transformer;

(m) Qnet is the difference between the Reactive Power before and after the network voltage variation;

(n) Unet is the difference between the network voltage before and after the network voltage variation;

(o) Unorm,exp is the normal operating voltage (average voltage at which the Transmission Grid is operated).

Activation of Centralized Voltage Control is made according to following criteria:

(p) Geographical location of the Production Unit

(q) Activation prices

(r) Current Set Value of the unit, or

(s) Other technical requirements identified by Elia's dispatching.

Activation of the Centralized Voltage Control service is communicated by Elia by exchanging messages through Elia's dedicated platform (ReVolt). Elia communicates in its message the unit concerned and the quantity of Reactive Power requested. The Supplier is expected to react within 5 minutes after reception by Elia of the confirmation message.

Once the requested Set Value is attained, the Supplier is expected to maintain it unchanged until further notice by Elia. Once a unit is restarted, it may operate at its standard Reactive Power Set Value (fixed in the contract).

2.5.2.2 Delivery Control & penalties

Elia controls delivery of both services by using samples in which the measured reactive power injected or absorbed by the supplier corresponds to the reaction that was requested.

Requested reactive power is calculated by considering activation orders or voltage measurements and comparing them to delivered reactive power at the specific connection point (15' metering for automatic service and 30"measurements for manual service). Control of samples for each service is done separately.

If the delivered volume does not correspond to what was requested by Elia the Supplier is inflicted with a remuneration reduction.

2.5.2.3 Remuneration

Received remuneration is for all measured MVARh at the specific connection point as per price communicated by the Supplier or imposed by the King as mentioned in 2.5.1.

2.5.2.4 Data exchange

To perform the MVAR ancillary service, following data must be exchanged between Elia and the supplier:

Data	Channel	Direction
Reactive power measurement for Local Voltage Control Service (15')	Elia's SCADA connection	Supplier to Elia
Reactive power measurement for Centralized Voltage Control Service (30")	Elia's SCADA connection	Supplier to Elia
Voltage	Elia's SCADA connection	Supplier to Elia
Set Value	B2B XML message (ReVolt IT application)	Elia to supplier
Acknowledgement of reception of Set Value	B2B XML message (ReVolt IT application)	Supplier to Elia

Table 6: Data exchanges between service provider and Elia for provision of the MVAR ancillary service

2.6 Tarification of reactive energy

2.6.1 Preface

Elia uses the tariff to incentivize grid users to maintain their injection/absorption of reactive energy to its grid within certain limits.

As foreseen by Art.12 of the law of 29 April 1999, Elia applies the tariff to Access Contract Holders, according to a proposal made by Elia and validated by the regulator for a certain duration. Current tariff methodology is subject to Elia's approved methodology for the period 2016-192019; the next tariff period is to be 2020-2023.

In the current tariff methodology there are 2 components directly related to MVAR:

1) The "additional MVAR" tariff;
2) The tariff for the management of the electric system, who in part also concerns reactive power management of the Elia grid;

According to the access contract, consumption of both reactive and active power that are used for invoicing are measured at the high-voltage side of the step-up transformer at the level of Elia's specific access point.

MVAR service provision as well as the tariff are considered at access point level. However, in some cases (such as for the railway traction grid) connection points that are dispersed geographically are regrouped within a single access point. In such cases provision of the service should be possible at connection point level. Such cases will need to be evaluated one by one between Elia and the Voltage Service Provider (VSP, as defined in chapter 6). In principle the MVAR service is expected to be provided at the interface between the SGU's grid and the transmission grid. In the specific case of DSO's this point is the "interconnection point" according to FGC terminology.

2.6.2 Tariffs for the offtake of additional reactive energy

According to Art. 207 to 209 of the FGC, ACH's may withdraw or inject a quantity of reactive power from the Elia grid via their access point for their own capacitive and inductive use (without any compensation between the two); this quantity is equal to 32,9% of the active power consumed at the same timeframe. Any excess of this quantity at the given timeframe must be sanctioned by a tariff.

In respect of the above requirement, Elia has fixed in its tariff proposal for 2016-2019, a "tariff for additional reactive energy", of which an example is described in the figure hereunder:

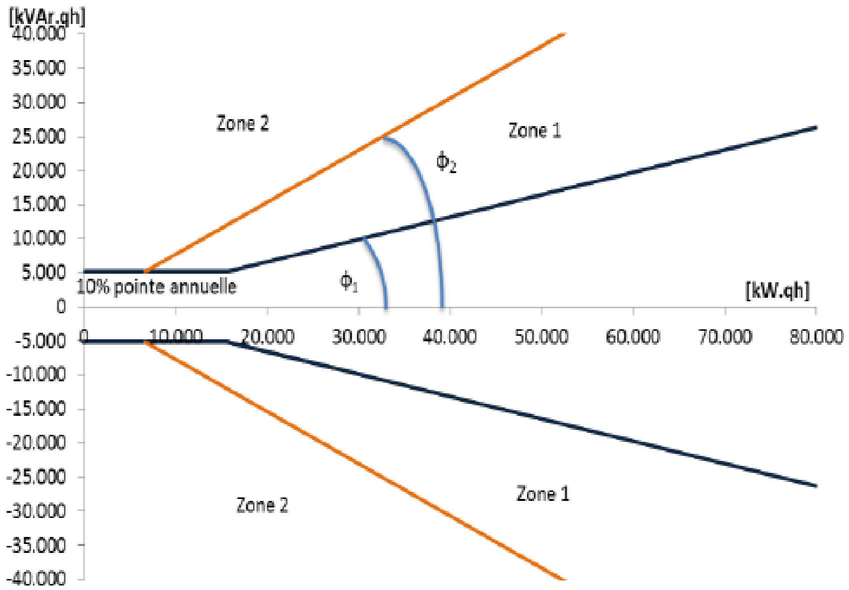


Figure 1: Tolerance area for tarification of additional MVAR for transmission-connected distribution systems (example)

To give a better incentive for regulating reactive power, Elia has split the tariff to be paid in 2 zones:

(t) **Zone 1 :** 0,8≤cos φ(t)≤0,95 (equal to 0,767>tg φ(t)>0,329)

(u) **Zone 2 :** (0,8>cos φ(t)) (equal to 0,767<tg φ(t))

In the above figure, the 32,9% limitation for a certain quarter hour means that:

(v) **tg φ(t)** should be inferior to 0,329, or that

(w) **cos φ(t)** (which is equivalent to the facility's power factor) be superior to 0,95.

Also, in case the offtaken active energy does not exceed, on a quarterly basis, 10% of the yearly peak in a given offtake point, the offtake of additional reactive energy is defined in respect of 32,9% of the 10% of the yearly peak in this offtake point.

The yearly peak is monthly ex-post determined as the maximum peak over the 12 last months, i.e. the current month of invoicing and the 11 preceding months, without taking into consideration the tariff period for yearly peak.

When active power flow from the grid is negative (=access point is injecting active power to the grid), the access point is not subject to a tariff.

This means that considering all the above, the tolerance area for which no tariff for the offtake of additional reactive energy is applied for an access point over a certain quarter-hourly injection or offtake of reactive power could be schematized as can be seen in Figure 22.

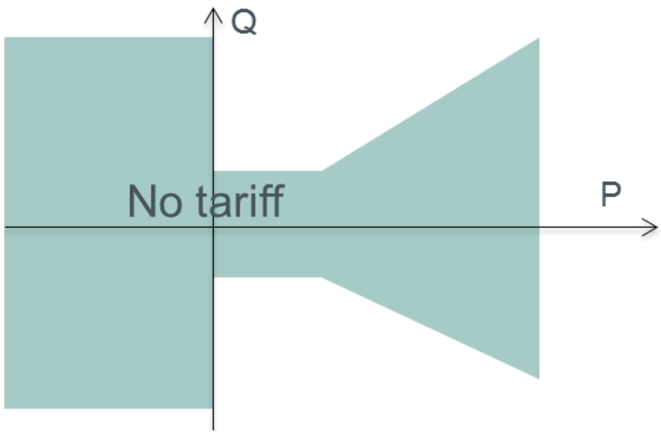


Figure 2: Tariff exemption areas

If a power unit is delivering the MVAR service behind a certain access point, the entire access point is exempted from the tariff. This design decision was made to avoid penalizing Access Contract Holders because they deliver MVAR services to support the grid, although this means also that any load units connected to the same access point are exempted from paying the additional MVAR tariff.

The detailed "Additional MVAR" tariff calculation method can be consulted in Elia's tariff methodology[7].

2.6.3 Tariffs for the management of the electric system

The "tariff for additional reactive energy", invoiced for injection/absorption of reactive energy, concerns the part of reactive energy that is outside limits fixed by the FGC (Art. 209 §4 and §5); however, given the tolerance, Elia still needs to cover for a part of the injected reactive power that is within bounds. This cost, considered as normal exploitation cost, is covered by the "tariff for management of the electric system", invoiced for consumption of active energy.

The detailed "management of the electric system" tariff calculation method can be consulted in Elia's tariff methodology[2].

2.7 Activated volumes

In 2016 and 2017, Elia made use of reactive power volumes as can be seen in Figure 3, Table 7 and Figure 5, for both the automatic and manual services:

	Reactive production (Mvarh)		Reactive absorption (Mvarh)	
	2017	2016	2017	2016
Total	**814.549**	**991.367**	**4.599.270**	**4.615.860**
Nuclear	442.676	451.791	2.774.075	2.725.595
Thermal	398.864	533.151	1.236.851	1.245.251
Hydro	776	224	511.759	608.228
Wind	7.146	6.202	76.584	36.787

Table 7: Reactive power production and absorption used by Elia in 2016 and 2017

[7] Available here: http://www.elia.be/~/media/files/Elia/Products-and-services/Toegang/Tariffs/2016/Publication-tarifs-2016-2019_FR2.pdf

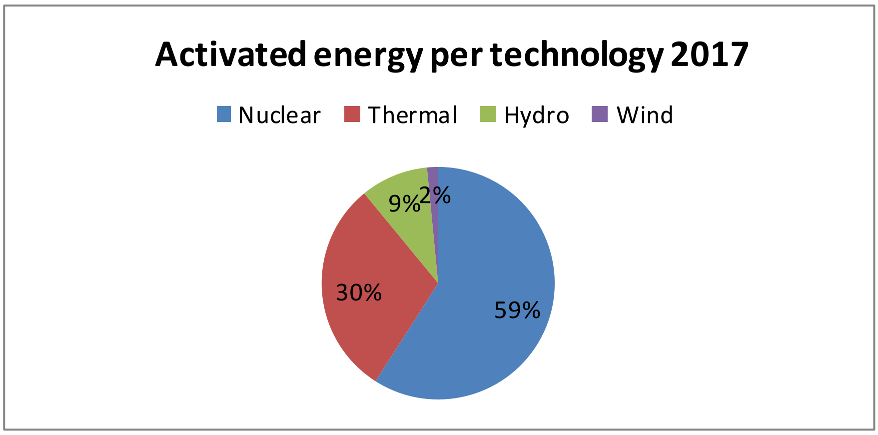


Figure 3: Repartition of reactive resources used in 2017 (in number of activated MVARh per energy source).

As can be seen in Figure 3 and Table 7 Elia depends to a large extent on large generation units (nuclear and gas-fired power plants, representing up to 89% of the total used energy) and less on hydro and wind (11%). Given the progressive switch of the generation mix towards smaller decentralized generation, the above figures underline the need to adapt the MVAR service to the future mix.

Moreover, as can be seen in Figure 4, Elia activated much more often controlling than non-controlling units; this can mainly be explained by the small number of non-controlling units participating in the service and their smaller capacities. This graph confirms the practical experience that currently the voltage regulation is mainly done via the automatic services.

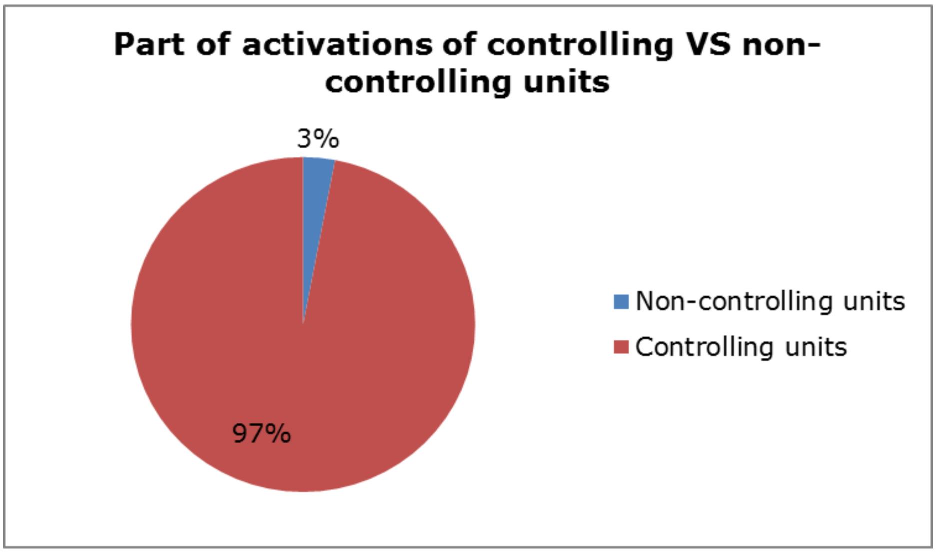


Figure 4: Part of activations of controlling VS non-controlling units in 2017

Furthermore, Figure 5 clearly indicates that Elia requests steadily more MVARh in absorption than in generation; this is due to the fact that Elia needs more often reactive power to regulate voltage in low load situations.

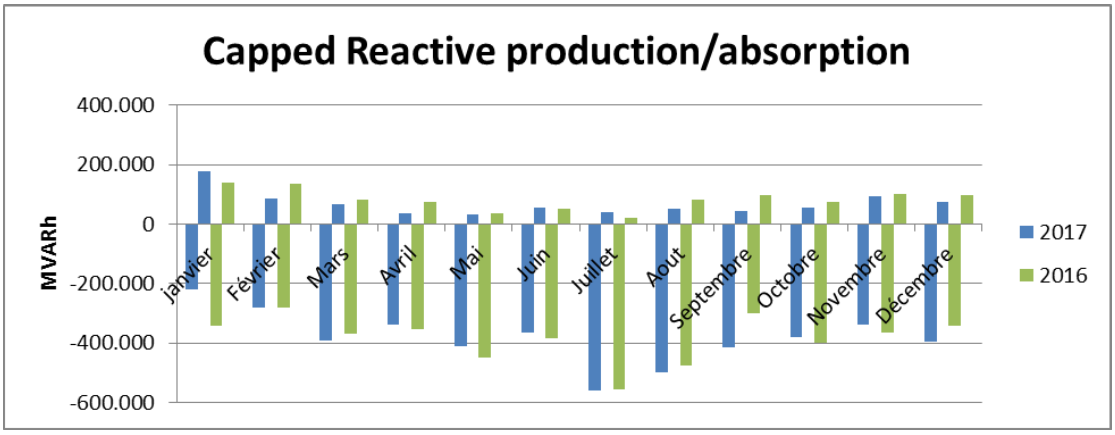


Figure 5: Capped[8] MVARh production VS absorption per month in 2016 and 2017 (in numbers of activated MVARh).

Elia uses considerably more volumes in absorption than in production, which reflects the fact that capacities in Belgium are mostly required for moments of low charging of the grid, when peak units (often controllable) are not running.

Elia used its bulk of reactive energy from large regulating centralized units, especially for nuclear (59%), due to its large capacities and almost permanent running. This element is interesting for the service's evolution, since these units are expected to largely reduce their total installed capacity in years to come, to be replaced by decentralized generation units, located in lower voltage levels and with an intermittent generation.

[8] As referring to quarter-hours of active delivery of the service by production units

3 EU benchmark

3.1 Preface

In 2017 Consentec, in an assignment ordered by Elia, performed a study at 11 other European TSO's[9] on the organization of the MVAR ancillary service for reactive power and voltage regulation (see Annex 1 for details).

The benchmark concerned contracting procedures for the MVAR service, answering questions related to whether the service is mandatory or not, whether contracts are bilateral or not and how prices are set and by whom.

The study shows that Belgium is the sole country in Europe where the MVAR service is procured entirely via a market based tendering procedure.

3.2 Bilateral contracting instead of tender participation

The first highlight concerns the absence of tendering to contract the service at most TSO's (see annex 1). Only in Belgium and in the Netherlands (only partially) generators are not obliged to offer the service to the TSO and consequently Elia and Tennet NL organize yearly tenders. In other countries, the generators (when in running mode) are obliged to provide voltage regulation services to the TSO. Concrete modalities are formalized in bilateral contracts (often included in the connection contract) for the lifetime duration of the unit.

Two TSO's (National Grid and Energinet.dk) organize occasional tenders for non-mandatory services (e.g., to contract enhanced capacity (UK) or in periods that the generator is not scheduled for commercial dispatch (DK). Tennet NL has contracts of different duration: default "flat-rate contracts" to cover the entire contract period of 1 year and other "time-based contracts" to overcome specific moments during the year with additional needs for voltage regulation. Tenders for additional, voluntary services are for contract periods ranging from 1 hour to multiple months.

Conclusion of the EU Benchmark regarding contracting:

Trend towards:

- Mandatory provision of MVAR AS for generators
- No tender unless for voluntary provision to cover specific, additional needs
- Default bilateral contracts
- Default lifetime contract duration

3.3 Remuneration at regulated prices representing active power losses

A second highlight relates to the remuneration of the voltage regulation service: despite the mainly mandatory character most TSO's remunerate the service.

Only in Denmark and Sweden the mandatory service is free of charge, although also in those countries questions are raised to remunerate the service.

Only in Belgium and the Netherlands the provider offers free prices (TSO with tender procedure). In all other countries where the service is remunerated, the prices are regulated based on a proposal made by the TSO or the regulator. In several cases (all German TSO, RTE, Statnett, Swissgrid) the prices were once determined based on scientific analyses and expert opinions and can be indexed yearly.

[9] TSOs in the benchmark study: Elia, 50Hertz, Amprion, Energinet.dk, National Grid, RTE, Statnett, Svenska Kraftnät, Swissgrid, Tennet DE, Tennet NL, TransnetBW

The prices value mostly represent a compensation of losses and maintenance related to wear & tear caused by delivering reactive power regulation. As only reactive power production (and not reactive power absorption) increases active power losses, some TSO's only remunerate the service when the generator is producing reactive power (Amprion, Tennet DE, TransnetBW).

Conclusion of the EU Benchmark regarding remuneration:

Trend towards:

- Remuneration also for mandatory MVAR AS service
- Prices set by competent authorities
- Regulated prices (mostly €/MVARh)
- Remuneration of losses and maintenance due to MVAR AS

4 Drivers for change

4.1 Preface

In the present chapter are analysed the main reasons for which Elia proposes evolutions that feature in this study.

The reasons stated below set the short-term (improve contracting procedure) and long-term (meet operational needs in the evolving energy landscape) objectives for the proposed redesign.

4.2 Frequent prices imposition

As can be seen in Table 4, imposition of prices for the services is very common; with 86% to 98% of providing units having had a public service obligation imposed by Royal Decree in recent years.

This is an indication that an efficient market cannot be organised for the procurement of the MVAR service. The frequent public service obligation imposition by Royal Decree at imposed prices lead de facto to a situation very close to the regulated markets currently being practiced in most of the other EU countries.

The imposition of public service obligation via a Royal Decree, to be organised at the end of the year in a very short time frame, is basically re-starting the negotiation procedure handled via the tendering, but then in a different format. It is therefore questionable whether it is efficient to maintain the contracting procedure as organised today.

It is important to align the MVAR product contract with market reality to ensure a cost efficient market outcome. Different configurations need to be studied also under the light of the framework set by the new Network Codes, as is done in section 6.

4.3 EU benchmark

The EU benchmark presented in section that Elia is almost a unique case in Europe in terms of MVAR contracting. Almost all TSO's apply an obligation to provide the service at regulated prices; in the same sense, Network Codes (Art. 29 SOGL) logic confirms such spirit for reactive power regulation by giving the right to TSO's to solicit all MVAR regulation capabilities present in their grids.

Provisions of EU Network Codes (and particularly System Operator Guidelines Art. 29) constitute an opportunity for Elia to align with the spirit of the EU Network Codes and find a solution that is cost-efficient in the long term.

4.4 Evolution of MVAR service offer

The transition from centralized to decentralized generation holds some important challenges for RPM in general:

1) Less running centralized production units (today providing the bulk of reactive power);
2) New production situated at lower voltage levels, often at distribution grid level.

   The MVAR service may also be offered by technologies other than the ones that provide the service today. RPM assets such as condensator batteries or reactors that exist within the perimeters of grid users' installations may very well offer the service. Such assets are dispersed within local grids and are installed to regulate the local grid's voltage; however it should be possible that grid users be capable to use these assets to provide the service if they have any remaining regulation capacities on top of what they use for their own regulation. With the new design for the MVAR service Elia wishes to provide a framework for these assets.

Elia needs to capture this potential by setting a level-playing field for new & existing market parties within a technology-neutral framework.

4.5 Operational needs

This new energy landscape also holds some new needs for regulation:

1) Inherent grid behaviour as decentralized generation leads to more frequent situations of very high/very low load;
2) More cross-border flows due to new interconnections and market integration.

Increased operational needs create all the more a necessity to find a way to involve market parties in lower voltage levels in auto-regulating their reactive power injection/offtake; it is thus all the more important to develop a design that will allow the integration of new market parties in the service, in respect of constraints of their relevant system operators, while continuing to incentivize them to auto-regulate.

4.6 EU Network Codes

The new Network Codes (Requirements for Generators (RfG), Demand Connection Code (DCC), System Operation Guidelines (SOGL), High Voltage Direct Current Code (HVDC Code)) from the European Union have a considerable impact on Reactive Power Management that needs to be taken into account in current practice.

Most features concerning the service were included in Elia's proposal for amendment of the FGC, submitted to the Minister at 17/05/2018 and with an expected entry into force at Q2 of 2019.

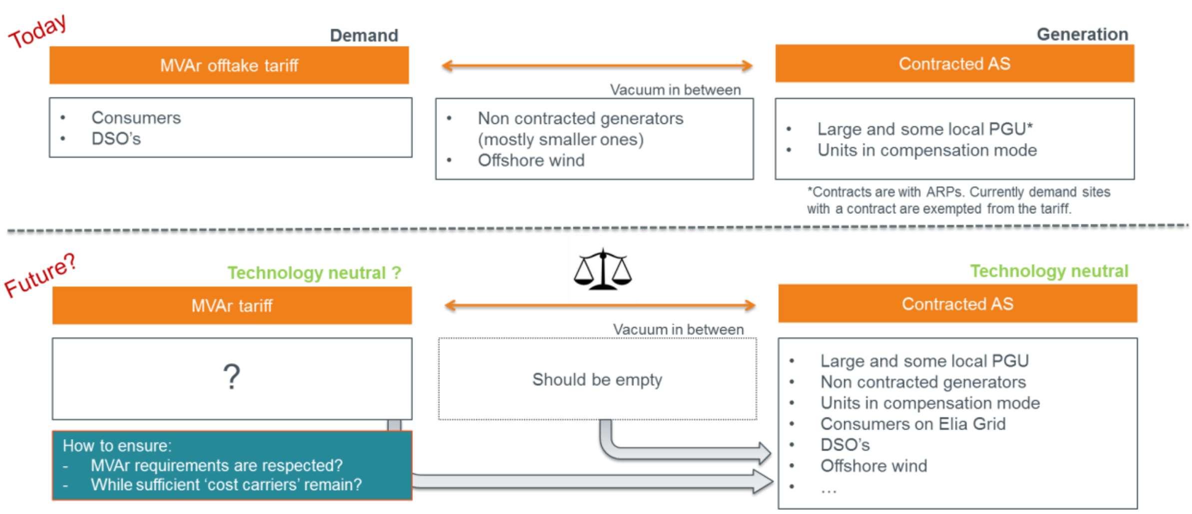
In the same way, the General Requirements that were also required by the Network Codes imposed a number of changes in requirements for Significant Grid Users that need to be taken into consideration.

Connection requirements as set by the DCC, RfG and HVDC Code expand the range of units that are capable to deliver the service, while SOGL lays down the general philosophy of their participation to the service.

Obligations from Network Codes (as explained in section 5) provide a robust framework for Elia to build on for a future-proof service.

4.7 In consequence: overview of what needs to be changed

For the aforementioned reasons Elia needs to make a shift in its MVAR incentive mechanisms to close a gap between the incentive given to market parties to control their reactive power behaviour and the provision of an active MVAR service to Elia:



Today, demand parties (consumers directly connected to the Elia grid, transmission-connected CDSO's and DSO's) who are introducing the need for reactive energy regulation, are asked to pay tariffs. The aim of these tariffs is to finance provision of the service and to incentivize grid users to respect operational limits. On the opposite, generators with controllable units are mobilized to help Elia counteract the effect of reactive energy in the system and are paid for it.

In today's picture a framework is still missing for transmission-connected generators that are not contracted (since the service is to this day voluntary) and off-shore wind generation, who is expected to play a big role for the Belgian system in years to come.

Elia also needs to integrate in the service transmission-connected grid users such as DSO's, CDS's or demand facilities, who might have assets capable of providing MVAR service within their local grids, while maintaining the incentive to control their reactive power injection/absorption towards the grid.

Concretely, to reach this desired situation Elia should:

1. Create a global scheme to extend the delivery of the service to all (new & existing) market parties who can deliver it (based on the requirements of NC but also current and reviewed FGC);
2. Create a mechanism so that parties who are not obliged by law to deliver the service can participate;
3. create a solution for the participation of units connected to CDS's or to public distribution systems, or even transmission-connected DSO's and CDSO's themselves;
4. Create a solution for the interaction between the incentive for auto-regulation given by the tariff and provision of the ancillary service to avoid double remunerations or double penalizations.

5 Impact of Network Codes and proposal for amendment of the Federal Grid Code

5.1 Preface

The introduction of the Network Codes (NC) constitutes an important driver for change as stated in section 4. Their transposition to Belgian law was made in Elia's proposal for amendment of the FGC, that is currently in the process for approval by the Minister and awaiting an expected entry into force in Q2 of 2019.

The Network Codes set a robust framework covering many aspects:

1) Framework for use of regulation capabilities within the transmission system by the TSO and distribution system operators (System Operation Guidelines ("SOGL") Art. 29);
2) Provision of the reactive power regulation service coming by transmission-connected distribution systems (SOGL Art. 29);
3) Connection requirements for Significant Grid Users (different articles in RfG, DCC and HVDC).

The term Significant Grid Users (or SGU's) defines grid users that have a considerable impact on the grid and that need to be taken into account for the grid's operational security.

SO GL designates the following parties as SGU's for the transmission grid:

1) New & existing power transmission-connected generating modules (or PGM's) of type B, C or D according to NC classification;
2) New & existing transmission-connected demand facilities;
3) New & existing transmission-connected distribution systems;
4) New & existing transmission-connected High Voltage Direct Current (HVDC) systems.

In the present chapter, we analyse the impact of the above mentioned framework and its impact on the MVAR ancillary service, together with related requirements for SGU's.

In the present section, for the sake of coherence, the terminology of the concerned legal texts is used.

Disclaimer: The notion of RSO (Relevant System Operator) is key to understand the context and guidelines of the Network Codes. On many occasions, Network Codes assign rights and responsibilities to RSO's, who are expected to define connection requirements of grid users connected to their grids and use their reactive capacities to provide a service to the TSO if they want to (in roles that are also further explained in chapter 9). Elia is the RSO for all transmission-connected GU's in Belgium; in the case of CDS's, the CDSO is the RSO, whereas in the case of public distribution systems the DSO is the RSO. To avoid any misinterpretation, in the present study Elia refers only to transmission-connected distribution systems.

5.2 Scope of EU Network Codes

From the package of Network Codes introduced by the European Commission, the following texts have an impact on the MVAR ancillary service:

1) **Requirements for Generators** (Commission Regulation (EU) 2016/631 of 14 April 2016 establishing a network code on requirements for grid connection of generators);
2) **Demand Connection Code** (Commission Regulation (EU) 2016/1388 of 17 August 2016 establishing a Network Code on Demand Connection);

3) **High Voltage Direct Current Network Code** (Commission Regulation (EU) 2016/1447 of 26 August 2016 establishing a network code on requirements for grid connection of high voltage direct current systems and direct current-connected power park modules), and

4) **System Operator Guidelines** (Commission Regulation (EU) 2017/1485 of 2 August 2017 establishing a guideline on electricity transmission system operation).

RfG, DCC and HVDC Code only concern assets connected to the grid after entry into force of relevant regulations.

It is noted once more that connection requirements defined by Elia only concern SGU's connected to the Elia grid.

5.3 Requirements for Generators

The articles of RfG described hereinafter have an impact on the MVAR service.

5.3.1 Connection requirements

The RfG stipulates in Art. 17-22 and 25 that new type B, C and D Synchronous Generation Power Modules (SPGM's)[11], Power Park Modules (PPM's)[12] and offshore PPM's are required to be capable of regulating reactive power automatically within certain limits.

In particular for new type B SPGM's:

i. **Art. 17§2** stipulates : *with regard to reactive power capability, the relevant system operator shall have the right to specify the capability of a synchronous power-generating module to provide reactive power;*

> This means that if for example a certain new type B SPGM is connected to a CDS grid, the CDS should specify connection requirements in regards of reactive power capabilities.

The same aforementioned requirement is repeated for new type B PPM's in Art.20§2 (a).

For new type C SPGM's:

i. **Art 18§2 (a)**: *with regard to reactive power capability, the relevant system operator may specify supplementary reactive power to be provided if the connection point of a synchronous power-generating module is neither located at the high-voltage terminals of the step-up transformer to the voltage level of the connection point nor at the alternator terminals, if no step-up transformer exists. This supplementary reactive power shall compensate the reactive power demand of the high-voltage line or cable between the high-voltage terminals of the step-up transformer of the synchronous power-generating module or its alternator terminals, if no step-up transformer exists, and the connection point and shall be provided by the responsible owner of that line or cable;*

> This means that the RSO may request from new type C&D SPGM's that they have an additional reactive power capability to compensate for any demand coming from any elements connecting the SPGM to its RSO connection point.

ii. **Art. 18§2 (b)**: *the relevant system operator in coordination with the relevant TSO shall specify the reactive power provision capability requirements in the context of varying voltage.*

> This means for example, that if a certain new type C SPGM is connected to a CDS grid, it is the CDS's responsibility to specify

[11] According to RfG classification
[12] According to RfG classification

connection requirements in regards of reactive power capabilities in coordination with the relevant TSO.

The same aforementioned requirements of Art. 18 are repeated for new type D SPGM's in Art.19§1.

For new type C&D PPM's (including off-shore wind) the general requirements formulated for new type C&D SPGM's in Art. 18 and Art. 19 in regards to reactive power capability are repeated in Articles 21, 22 and 25.

Articles 18§2(b), 18§2(c), 19§1, 21§3(b), 21§3(c), 22 and 25§5 specify some minimum requirements of reactive power capability for new type C&D SPGM's and PPM's (including off-shore wind units) in terms of reactive power capabilities to be respected at the connection point with the RSO. These values concerning new transmission-connected units were transcribed by Elia in its proposal for amendment of the FGC; an overview of these can be found in Table 9.

In particular for new type C PPM's, according to Art. 21§3 (d), the RfG requires that they be capable of regulating in voltage control mode, reactive control mode or power factor control mode.

According also to Art. 21§3 (d): *the relevant system operator, in coordination with the relevant TSO and with the power park module owner, shall specify which of the above three reactive power control mode options and associated setpoints is to apply, and what further equipment is needed to make the adjustment of the relevant setpoint operable remotely;*

The same aforementioned requirements are repeated for new type D PPM's and new off-shore wind in Art. 22 and Art. 25§4 respectively.

Impact: the Network Code specifies that new type B, C & D SPGM's, PPM's and off-shore PPM's need to be controlling. Minimum technical limits for new type C & D units, that need to be controlling, are clearly defined (as is currently the case in Belgium), whereas for new type B units the RfG gives the RSO the right to set requirements concerning the technical limits himself. Similar connection requirements already apply in Belgium, except for type B units that are only obliged to be able to regulate their reactive power injection/absorption between 2 operating points.

5.3.2 Installation notification and compliance simulations & testing

Operational notifications (Art. 29)

The power-generating facility owner needs to demonstrate to the RSO that it has complied with formulated connection requirements by completing successfully the operational notification procedure for connection of each power-generating module described in Articles 30 to 37 (Art. 29).

In particular for new type C & D PGM's, owners should submit a Power Generating Module Document ("PGMD"), containing (among others) technical data relevant to the PGM's grid connection, equipment certificates issued by an authorised certifier and compliancy test reports.

Compliance tests (Art. 42, 44-46)

Owners of PGM's are also expected to perform specific tests described by the RfG, with which to prove their compliance with connection requirements.

Instead of performing these tests, owners of PGM's also have the right of providing equipment certificates issued by an authorized certifier.

Compliance simulations (Art. 43, 52, 53, 55, 56)

The RSO may require from the power-generating facility owners to provide simulations demonstrating the unit's compliance with connection requirements (Art. 43).

The RSO may perform his own simulation to challenge the ones made by the unit owner, for which the unit owner must provide all relevant technical data.

Instead of all or part of those simulations, the power-generating facility owner may use equipment certificates issued by an authorised certifier, which must be provided to the RSO.

Impact: the Network Code gives a more detailed procedure and guidelines to demonstrate reactive power capabilities for all kinds of new units who are required to do so. These procedures are useful to determine the volume to be made available to the TSO for the MVAR ancillary service (in cases where Elia is the RSO).

5.4 Demand Connection Code

5.4.1 Connection requirements and provision of MVAR ancillary service by, transmission-connected, demand facilities, distribution systems and CDS's (Articles 15, 28, 35, 36, 41, 42, 43, 44, 46 &47)

Art. 15§1 stipulates: "*Transmission-connected demand facilities and transmission-connected distribution systems shall be capable of maintaining their steady-state operation at their connection point within a reactive power range specified by the relevant TSO, according to the following conditions:*

a) for transmission-connected demand facilities, the actual reactive power range specified by the relevant TSO for importing and exporting reactive power shall not be wider than 48 percent of the larger of the maximum import capacity or maximum export capacity (0,9 power factor import or export of active power), except in situations where either technical or financial system benefits are demonstrated, for transmission-connected demand facilities, by the transmission-connected demand facility owner and accepted by the relevant TSO;

b) for transmission-connected distribution systems, the actual reactive power range specified by the relevant TSO for importing and exporting reactive power shall not be wider than:

i. 48 percent (i.e. 0,9 power factor) of the larger of the maximum import capability or maximum export capability during reactive power import (consumption); and

ii. 48 percent (i.e. 0,9 power factor) of the larger of the maximum import capability or maximum export capability during reactive power export (production); except in situations where either technical or financial system benefits are proved by the relevant TSO and the transmission-connected distribution system operator through joint analysis;"

Whereas concerning where these requirements are set, Art. 15 (f) states :

Requirement values are to be met at the connection point unless for cases in which a connection point is shared between a power generating module and a demand facility; in these cases equivalent requirements are to be met at the point defined in relevant agreements or national law.

Relevant requirements as set by Elia for transmission-connected SGU's in its proposal for amendment of the FGC can be found in Table 9.

Impact: In Art.15 the DCC stipulates a requirement for new transmission-connected distribution grids and new transmission-connected demand facilities to maintain reactive power injection and absorption within certain limits.

Connection requirements stipulate a capability to remain connected to the connecting grid when injecting or absorbing a certain quantity of reactive power to and from it. These capabilities do not in themselves imply also a capability to actively regulate injection and absorption of reactive power. In the same way, they are neither a tolerance for normal operation similar to the one applied for the "additional MVAR tariff". For example, if a new demand facility is required to be capable of remaining connected to the grid within a band of -15%/+33% of its active power, this does not necessarily mean that the facility needs to be able to control its reactive power injection or absorption within this band. In particular for transmission-connected demand facilities and transmission-connected distribution systems (including CDS's), provision of the service is strictly voluntary (according to Art. 250 of Elia's proposal for amendment of the FGC).

According to Art. 15§3 : "*Without prejudice to point (b) of paragraph 1, the relevant TSO may require the transmission-connected distribution system to actively control the exchange of reactive power at the connection point for the benefit of the entire system. The relevant TSO and the transmission-connected distribution system operator shall agree on a method to carry out this control, to ensure the justified level of security of supply for both parties. The justification shall include a roadmap in which the steps and the timeline for fulfilling the requirement are specified.*"

And according to Art. 15§4: "*In accordance with paragraph 3, the transmission-connected distribution system operator may require the relevant TSO to consider its transmission-connected distribution system for reactive power management.*"

According to Art. 28, demand facilities and closed distribution systems may offer demand response reactive power management to their RSO's and relevant TSO's, under specific conditions (either individually or, where it is not part of a transmission-connected demand facility, collectively as part of demand aggregation through a third party). These conditions include among others being able to operate in specific voltage ranges, be equipped to receive (directly or via a third party) instructions from the RSO or the TSO to perform the service, or be capable of regulating their consumption within a certain required timeframe.

The compliance of a demand unit used by a demand facility or a closed distribution system to provide demand response services to relevant TSOs, shall be jointly assessed by the TSO and the RSO, and if applicable in coordination with the third party involved in demand aggregation. The TSO and relevant system operator have the right to reevaluate this compliancy by requesting simulation and/or compliance testing after a modification or replacement of any equipment that may have an impact on compliance.

Impact: Demand facilities and CDS's may propose voluntarily the MVAR ancillary service through demand response, under the condition of respecting service requirements.

5.5 HVDC Code

The HVDC code states that the reactive power exchanged between new HVDC systems and the network at the connection point need to be agreed with the RSO in coordination with the relevant TSO (Art. 21), whereas HVDC systems need to be capable of regulating reactive energy (automatically and upon TSO request) within certain specified boundaries. These boundaries are to be agreed with the RSO and in coordination with the relevant TSO, within the minimum bounds specified by the HVDC code. For transmission-connected HVDC systems the values specified by Elia are included in Table 9, as foreseen by Elia's amendment proposal of the FGC) (Art.20).

Furthermore, the HVDC code specifies that new HVDC systems must be capable of regulating in reactive control mode, voltage control mode or power factor control mode (only reactive control mode is used in Belgium) (Art. 22). The control mode is to be agreed with the RSO in coordination with the relevant TSO.

Impact: The Network Codes fix a clear obligation for new HVDC systems to put at the RSO's disposal a certain regulating capacity.

5.6 System Operation Guidelines

The European Guideline on System Operation prescribes requirements for operational information exchange, TSO obligations, and remedial actions related to reactive power management.

5.6.1 Operational Information Exchange

SOGL foresee an exchange of information between certain SGU's, TSO's and distribution system operators (when applicable) to ensure system safe operation. This information includes some structural information, such as reactive power capabilities, some scheduled information, such as forecasted restrictions in capability for PGM's or even a forecast of reactive power consumption by demand facilities, together with real-time information on reactive power injection/absorption at the connection point.

The exchange of information happens between SGU's (as mentioned in Art. 2 of SOGL), relevant TSO's and DSO's to which the SGU has a connection point.

Impact: On top of large power plants, also other SGUs will be required to exchange information with Elia in regards to reactive power. The scope of the required information exchange becomes larger.

In general the SOGL refers to Closed Distribution Systems both under their capacity of SGU (only for transmission-connected CDS's) and distribution system. In several occasions, CDS's are referred to as a subset of "distribution systems", under which capacity certain requirements apply to them. Hence, when referring to "distribution systems" or "distribution system operators" in this section (section 5.6, and this section only), the mentions also concern respectively closed distribution systems or closed distribution system operators, following SOGL classification. This classification is also confirmed in ENTSO-E document "*All TSOs' proposal for the Key Organisational Requirements, Roles and Responsibilities (KORRR) relating to Data Exchange in accordance with Article 40(6) of Commission Regulation (EU) 2017/1485 of 2 August 2017 establishing a Guideline on Electricity Transmission System Operation*"[14].

[14] *"All TSOs' proposal for the Key Organisational Requirements, Roles and Responsibilities (KORRR) relating to Data Exchange in accordance with Article 40(6) of Commission Regulation (EU) 2017/1485 of 2 August 2017 establishing a Guideline on Electricity Transmission System Operation",* ENTSO-E, 27/02/2018, available here: https://docstore.entsoe.eu/Documents/Network%20codes%20documents/Implementation/sys/1.a.180227_KORRR_final.pdf

TS-connected PGM B/C/D (art. 45-47)	DS-connected PGM B/C/D (art. 48-50)	TS-connected demand facility (art. 52)	TS-connected DSO (@TSO-DSO connection point) (art. 43)
Structural information			
Voltage and reactive power control capability (should be delivered 3 months after the entry into force of the SOGL (see article 28))	Reactive power control capability	Reactive power control characteristics (to be delivered 3 months after the entry into force of the SOGL (see article 28))	
	Voltage level and location		
			Reactors and capacitors in the substations (to be updated at least every 6 months)
Scheduled information			
Forecasted restriction in reactive power control capability	Forecasted restriction in reactive power control capability: not needed for Elia	Forecasted restriction in reactive power control capability: not needed for Elia	
		Forecasted reactive power consumption in day-ahead	
		Forecasted reactive power consumption in intraday: not needed for Elia	
Real-time information			
Reactive power at the connection point or other agreed point of interaction	Reactive power flows and voltage at the connection point (could be aggregated)	Reactive power at the connection point	Reactive power in line bay, in transformer bay, in power generating facility bay, in reactor and capacitor bay
			Busbar voltages
Legend: (grey text = not needed for Elia) (Orange shading = mandatory by SOGL ; no shading = proposed by SOGL and confirmed by Elia)			

Table 8: Operational information to be exchanged between Elia and SGU's concerning MVAR according to SOGL

5.6.2 TSO obligations

The SOGL (art. 27) prescribes the determination of a normal-state voltage range on each TSO connection point. In case the voltage at the connection point is outside this range, the SOGL (art. 22) lists the following remedial actions to control voltage and reactive power:

Article 27 Obligations of all TSOs regarding voltage limits

1) **Internal actions by the TSO:**
   i. *tap changes of the power transformers;*
   ii. *switching of the capacitors and reactors;*
   iii. *switching of the power-electronics-based voltage and reactive power management devices;*
2) **Actions by the TSO on TS-connected assets:**
   - *instructing transmission-connected significant grid users to block automatic voltage and reactive power control of transformers*[15]*;*
   - *instructing transmission-connected significant grid users to activate on their facilities the remedial actions set out in points (i) to (iii) if voltage deterioration jeopardizes operational security or threatens to lead to a voltage collapse in a transmission system;*
   - *requesting the change of reactive power output or voltage set point of the transmission-connected synchronous power generating modules;*
   - *requesting the change of reactive power output of the converters of transmission-connected non-synchronous power generating modules;*
3) **Actions by the TSO on TS-connected DSO:**
   - *instructing transmission-connected DSOs to block automatic voltage and reactive power control of transformers;*
   - *instructing transmission-connected DSOs to activate on their facilities the remedial actions set out in points (i) to (iii) if voltage deterioration jeopardises operational security or threatens to lead to a voltage collapse in a transmission system.*

In addition article 29 lists the following obligations and rights of a TSO for voltage and reactive power management:

Article 29 Obligations of all TSOs concerning voltage and reactive power management in system operation

3. Each TSO shall ensure reactive power reserve, with adequate volume and time response, in order to keep the voltages within its control area and on interconnectors within the ranges set out in Annex II.

6. Each TSO shall be entitled to use all available transmission-connected reactive power capabilities within its control area for effective reactive power management and maintaining the voltage ranges set out in Tables 1 and 2 of Annex II of this Regulation.

9. When relevant for the voltage and reactive power management of the transmission system, a TSO may require, in coordination with a DSO, a distribution-connected significant grid users to follow voltage control instructions.

[15] Requests to block automatic voltage control could be useful in case the TSO observes that the machine does not properly perform the automatic voltage control, but such requests should be rare.

The TSO has the responsibility to ensure sufficient reserves for daily operations.

The TSO is aware of the power capabilities of all TSO-connected PGM B/C/D, and if requested, also of DS-connected PGM B/C/D and TSO-connected demand facilities (see Sections 5.3 and 5.4).

The TSO has the right to use all available reactive power capabilities on the TSO grid, and if agreed with the DSO, also the capabilities of DS-connected SGUs. In this sense it is important to note that Article 29 §6 is not compatible with current voluntary tendering procedure. Indeed today all SGUs can decide whether they want to participate in the tendering procedure or not. To ensure compliancy with SOGL, in the future all transmission-connected assets capable of regulating reactive power at the connection point level need to be included in a contract of the MVAR service. Hence the current existing voluntary tendering procedure needs to be adjusted.

Impact: the prescriptions of Art 27 and 29 imply the largest impact on the design of the current MVAR ancillary service as it provides for a right to Elia to solicit all (and not only the "tendered") available transmission-connected capabilities as well as, in coordination with the DSO, distribution-connected assets for its regulation needs.

5.6.3 DSO obligations

Following article 29 it is the responsibility of the DSO to ensure that agreements on TSO-DSO interconnection points are respected and to take actions accordingly (e.g., use the available reactive power capabilities of PGMs connected to the concerned substation).

Article 29 Obligations of all TSOs concerning voltage and reactive power management in system operation

5. Each TSO shall agree with the transmission-connected DSO on the reactive power set points, power factor ranges and voltage set points for voltage control at the connection point between the TSO and the DSO in accordance with Article 15 of Commission Regulation No [000/2015 DCC]. To ensure that those parameters are maintained, each DSO shall use its reactive power sources and have the right to give voltage control instructions to distribution-connected significant grid users.

Impact: on top of the articles listed in section 5.6.2, SOGL indicates that a DSO may solicit any reactive regulation capacities connected at its grid level to respond to a regulation request submitted by the TSO.

5.7 Elia's proposal for amendment of the FGC

Elia recently submitted to the Belgian Federal Public Service Energy (FPS Energy), after consultation of the market, a proposal to revise the FGC ('Federaal Technisch Reglement'/'Règlement Technique Fédéral') to align it with changes introduced by the Network Codes.

In addition, as required by the connection network codes and as relevant system operator, Elia drafted proposals for requirements of general application ('general requirements').

Elia's proposals for the above texts can be found here: http://www.elia.be/en/users-group/Working-Group-Belgian-Grid/Proposal-Federal-Grid-Code-and-General-Requirements.

It should be noted that the procedure for the amendment of the FGC is still ongoing, meaning that it is possible that some of these be proposals might still change in the text's last version.

Most importantly the following changes were made in regard to the MVAR service:

1) New connection requirements concerning reactive power capability for all new, transmission-connected, power units, demand facilities and distribution systems (including CDS's) as foreseen in NC's;
2) Amendment of Art.250 (Art. 257 in current applicable FGC), describing modalities of provision of the MVAR service to the TSO by transmission-connected SGU's.

It should be noted that article numbers in this study refer to the numbering of Elia's amendment proposal unless stated explicitly.

Besides the above mentioned evolution of the FGC, the regional grid codes (local transport and distribution) are to be amended, among others especially regarding the mandatory participation of assets connected to voltage levels below 150 kV.

5.7.1 Provisions concerning storage

RfG does not provide clear guidelines in regard to storage facilities. Some installations (notably pump-storage) are mentioned explicitly, however there is no other clear reference to technologies such as batteries.

To close this gap, Elia made a proposal in its proposal for amendment of the FGC, where it specifies connection requirements and MVAR provision modalities for transmission-connected storage (Art. 102).

Furthermore, in its proposal for amendment of Art. 250, Elia includes transmission-connected storage units in the SGU's that should provide the MVAR service mandatorily.

This of course applies to transmission-connected storage facilities for which Elia is a RSO; these requirements do not apply for storage facilities that are within a CDS or public distribution system. Transmission-connected CDSO's and DSO's having within their grids such installations may propose them to Elia voluntarily in the framework of their participation to the service as presented in sections 9.2 and 9.3.

5.7.2 Connection requirements for transmission-connected SGU's (articles 39, 65 to 71, 79 and 92, 96, 102, 107, 109, 110, 114, 127)

It should be pointed out that in matter of connection requirements, there is a difference between RfG and DCC: RfG sets reactive capability requirements for units to be proven at connection point level for all PGM's except new type B PGM's, whereas DCC sets requirements for connection points. Art. 15 (f) of DCC (as quoted in section 5.4.1) mentions that in case of co-existence of a demand facility and a generation unit behind a connection point "*equivalent requirements are to be met at the point defined in relevant agreements or national law*". This issue has been raised in the past by stakeholders, and Elia's reply was that:

- New PGM's concerned by RfG requirements need to prove their capabilities at the connection point regardless of other facilities connected to the same point.
- New demand facilities concerned by DCC requirements also need to prove their capabilities at the connection point regardless of other facilities connected to the same point.

In Elia's proposal for amendment of the FGC there is a distinction between:

- existing transmission-connected units, covered in articles 65 to 71, for which connection requirements that were already foreseen in the current Federal Grid Code apply;
- new transmission-connected units, covered in Articles 92, 96, 102, 107, 109, 110, 114 and 127 for which the requirements foreseen in the Network Codes are transcribed.

Elia's proposal for amendment of the FGC stipulates that capability requirements are to be respected for new and existing units at the unit's connection point to the transmission grid, with the exception of:

1) new type B generators, for which requirements are to be respected at the output of the generator's step-up transformer should it exist, or at the unit's inverter output;
2) existing units that are connected at the same connection point as a load facility (Local Production units according to FGC terminology, as also explained in section 2.3), for which requirements are to be respected at the unit's inverter output.

For new type B units, it is stipulated in Elia's proposal for General Requirements that the concerned unit's owner should in any case demonstrate the unit's resulting capabilities at the connection point with the transmission grid.

It is important to note that, as also mentioned in section 5.4, connection requirements refer to capabilities at the connection point (except for new type B units and existing Local Production units as defined in the FGC and explained in section 2.3), without considering the effect of other assets connected in the local user grid. This means that for example, a type C unit that is connected in the same connection point as a demand facility, should prove its reactive power capabilities without considering the effect of the demand facility. In such a context this might mean that the aforementioned unit is capable of regulating in itself, and thus fulfils its connection requirements, but its real capabilities might be influenced by the (uncontrolled) reactive behaviour of the demand facility.

In overview, connection requirements for all transmission-connected units are described in Table 9 hereunder:

		U_{nom}[16]	Absorption[17][18]	Injection[19][20]	Voltage range	Cable compensation	manual ΔQ	remote ΔQ	V droop
Existing TS-connected generators	P<25MW		no requirement	no requirement	no requirement	no requirement	2 set points	no	no
	P>=25MW		-10%	45%	[0.9-1.05] of $U_{expl,norm}$	?	all set points	all set points	automatic on droop characteristic all droop characteristics
New TS-connected generators	SPGM B		-33%	33%	[0.9-1.10] of $U_{expl,norm}$	no requirement	all set points	all set points	cst V @ alternator side
	PPM B		-33%	33%	[0.9-1.10] of $U_{expl,norm}$	no requirement	all set points	all set points	no
	SPGM C&D	<=300kV	-25%	45%	[0.9-1.10] of $U_{expl,norm}$	yes	all set points	all set points	automatic on droop characteristic
		>300kV			[0.9-1.05] of $U_{expl,norm}$				all droop characteristics
	PPM C&D	<=300kV	-30% (*)	-30% (*)	[0.9-1.10] of $U_{expl,norm}$	yes	all set points	all set points	automatic on droop characteristic
		>300kV			[0.9-1.05] of $U_{expl,norm}$				all droop characteristics
Existing TS-connected demand facilities			no requirement	no requirement					
New TS-connected demand facilities			-15%	33%					
Existing TS-connected distribution systems and CDS			no requirement	no requirement					
New TS-connected distribution systems and CDS		>=30kV	-15%	33%					
		<30kV	-15%	21%					

Table 9: Connection requirements for existing & new, transmission-connected, generation units, demand facilities & distribution systems foreseen in Elia's amendment proposal of the FGC

16 Level of connection to the Elia grid
17 Reactive power capabilities expressed as percentage of the facility's installed active power
18 Capabilities are no complete rectangular in U-Q plane
19 Reactive power capabilities expressed as percentage of the facility's installed active power
20 Capabilities are no complete rectangular in U-Q plane

Impact: in line with Network Codes requirements, Elia's proposal of amendment of the FGC sets new requirements for reactive power capabilities for new (transmission-connected) generators, and sets requirements for new demand units and distribution systems for which no requirements existed before. Requirements for existing installations remain unchanged.

5.7.3 Article 250 in Elia's proposal for amendment of the FGC (Article 257 in current Federal Grid Code)

Article 250 in Elia's proposal for amendment of the FGC fixes the framework for the participation of different grid users in the MVAR ancillary service.

In particular:

1) **Art. 250 §1:** The TSO defines the technical specifications, participation conditions and eventually financial conditions for participation to the service in the Terms and Conditions, in a transparent and non-discriminatory way. These Terms and Conditions are to be approved by the federal regulator and are based on financial guidelines set beforehand by the latter;

Impact: The MVAR service, currently subject of a non-regulated 1-year contract will be subject to regulated Terms & Conditions to be approved by the CREG.

2) **Art. 250 §2:** Transmission grid users whose facilities are required to be capable of reactive control under articles 65 to 71 and 92, 96, 102, 107, 109, 110, 114, 127 are obliged to provide the service upon the TSO's demand and at measure of their technical capabilities.

Impact: Transmission-connected units concerned by the mentioned articles (Existing type B,C,D PGM's, new type B,C,D SPGM's, PPM's and SPM's and new HVDC interconnections as listed in Art. 250 §2) shall be obliged to provide the MVAR service to Elia, instead of what was before a voluntary participation.

3) **Art. 250 §3:** All transmission grid users not obliged to provide the service by Art. 250§1 may provide the service to the TSO voluntarily.

Impact: Transmission-connected units not referred to in §2 (demand, distribution systems) may offer the MVAR service to Elia on a voluntary basis on top of obliged parties.

4) **Art. 250 §4:** Provision of the service to the TSO by assets within a transmission-connected DSO and CDSO grid are described in the service's Terms & Conditions and must be subject to the DSO's or CDSO's approval, and in respect of the DSO's and CDSO's operational limits and constraints;

Impact: Units connected in a transmission-connected distribution system or CDS shall only provide the service under the authorization of DSO's or CDSO's respectively.

5) **Art. 250 §5:** The transmission-connected grid user can provide the service himself or through a third party;

Impact: Responsibility for providing the service shall lie with transmission-connected grid users, who may however mandate another party (a Voltage Service Provider) to offer it in their behalf. Currently ARP's are the offering parties, but may also transfer the contract to a third party.

6) **Art. 250 §6:** Participation is also subject to a contract to be signed between the TSO and the service provider. This contract is also to be approved by the federal regulator.

Impact: Service provision shall be subject also to a contract (in the same way as will be the case for active power ancillary services), regulated by the Terms & Conditions and approved by the CREG.

The impact of these proposed adaptations can be resumed in the following table:

Subject	AS IS	TO BE
Contracting	Tender	Not specified
Service provision	Voluntary	Mandatory for transmission-connected: - New PGM, SPGM, PPM, SPM type C, D - Existing units type C, D and some type B - HVDC interconnections
Volume to be provided	No obliged volume	"Technical capacity"
Voluntary participants	All participants voluntary	Transmission-connected DSO, CDS, demand facilities on top of obliged parties

Table 10: Changes from proposed amendment of Art. 257 of the FGC

In consequence, transmission-connected grid users are concerned as follows by an obligatory and voluntary participation:

Transmission-connected Grid User	"Manual" service	"Automatic" service	Reactive power regulation capabilities	FGC article containing connection requirements on reactive power regulation capabilities
New Type B,C,D SPGM	Obliged	Obliged	Specified by FGC	Art. 92
New Type C,D PPM, SPM	Obliged	Obliged	Specified by FGC	Art. 96, 102
New Type B PPM, SPM	Obliged	Obliged	Specified by FGC	Art. 96, 102
Existing generators type C,D	Obliged	Obliged	Specified by FGC	Art. 68
Existing generators type B connected	Obliged	Voluntary	To be agreed with system operator	Art. 67
New HVDC interconnections	Obliged	Obliged	Specified by FGC	Art. 107
New generators connected on a HVDC link	Obliged	Obliged	Specified by FGC	Art.109
New HVDC conversion stations at isolated extremity	Obliged	Obliged	Specified by FGC	Art. 110
New off-shore generators with on-shore connection points	Obliged	Obliged	Specified by FGC	Art. 114 & Art. 121
New off-shore generators with off-shore connection points	Obliged	Obliged	Specified by FGC	Art. 127 & Art.134
Direct clients with demand facilities	Voluntary	Voluntary	No obligation	N/A
DSO's	Voluntary	Voluntary	No obligation	N/A
CDSO's	Voluntary	Voluntary	No obligation	N/A

Table 11: Participation of different types of grid users to the MVAR service according to proposal of amendment of FGC

6 Contracting

6.1 Preface

In Elia's proposal for amendment of Article 250 of the Federal Grid Code (Art. 257 in the current FGC) contracting mode for the service is to be proposed by the TSO and approved by the regulator.

In this study Elia has evaluated several different configurations in order to determine the optimal procedure:

1.	Remuneration	Should the service be remunerated? Should there be a market based or a regulated procedure to fix the prices of the service?
2.	Obligation	Should the service be mandatory for certain units or should it be provided voluntarily?
3.	Contract duration	Should there be lifelong or shorter-term contracts?

In the present chapter, the different configurations stated above are evaluated for their technical and legal feasibility and their economic opportunity.

According to the pertinence of the different configurations Elia also makes a suggestion on the optimal procedure for contracting and evaluates additional elements to develop its suggestion for the contracting procedure.

6.2 Fundamentals of reactive power

To better evaluate different contracting alternatives, it is important to remind certain technical & operational aspects of the MVAR ancillary service and of reactive power in general.

Due to its influence on voltage, transmission losses and network loading, reactive power can neither be transported over long (electric) distances nor across (many) voltage levels. Therefore, reactive power must be provided by local assets on an appropriate voltage level.

The lower the voltage level of the connection point a unit, the less effective it is in influencing the voltage in the high-voltage transmission system. On the other hand, the reactive power needs of the lower voltage levels can better be covered by units connected to these voltage levels than by units connected to the higher-voltage grid.

To illustrate the meaning of "electric distances", in the following example the "electrical distance" between a unit situated at the 10kV grid and a 380kV station, has been transformed into an equivalent length of 380 kV overhead line according to its impedance ratios (Table 12).

Example: A unit providing the MVAR service is connected to a 110/10 kV substation via a cable of 1,5 km length. The substation itself is connected to a 380/110 kV station with a 110-kV overhead line of 50 km. The line equivalent of this distance between the unit and 380/110kV station is then approximately 4.300 km of 380-kV overhead line. **This means that the effect of the unit on the voltage of the 380kV grid at this station is similar to the one of a unit connected directly to the 380 kV grid more than 4.000 km away.**

Equipment	*Equivalent length of 380 kV overhead line, approx. [km]*
1 km overhead line 220 kV	3
1 km overhead line 110 kV	15
1 km cable 10 kV	700
1 km cable 0.4 kV	300.000
Transformer 380/110 kV	200
Transformer 110/10 kV	2.300
Transformer 10/0,4 kV	70.000
Machine transformer large generation unit 380/27 kV	150

Table 12: Comparison of impedance ratios of typical network equipment with a 380 kV overhead line

Therefore, the service must be provided locally and between not many voltage levels.

Automatic regulation is provided in permanence whenever a power generator is running and without prior activation by Elia in function of the local grid voltage.

The manual service however is activated by Elia's operators based on system needs considering the characteristics per unit (electrical distance between the unit and the node to be regulated or unit's droop characteristics among others).

The selection of the providing assets is complex as specific technical constraints and the cost of the individual contributions need to be considered. For example, an operator will decide to use a unit to regulate depending on its electrical proximity to the node that he wishes to regulate, its voltage level of connection, the unit's margins for voltage regulation, its droop characteristics etc.

Currently this optimization is not automated and activations are activated based on estimates and experiences. Currently there is seldom the possibility to make a choice between several units which can be used to resolve the MVAR need for a specific network node. Therefore no automatic optimization method, which would be a complex and expensive tool, has been implemented.

Each unit is activated by Elia for a desired effect on specific nodes and according to the unit's specific characteristics and grid location. One unit cannot substitute the other for the same effect in a certain node.

6.3 Should there be a market-based or regulated contracting procedure?

In the current unbundled context, the provision of ancillary services for the grid operations is organised via market mechanisms operated by Elia. In an efficient and liquid market, providers are expected to deliver the required volumes at the lowest possible cost for society. Therefore, if the right conditions for perfect competition are present, Elia prefers a market based approach for contracting of an ancillary service.

In economic theory, to have a perfect competition (or in other words an efficient market), the following conditions (among others) are assumed to prevail:

Assumptions behind a Perfectly Competitive Market

1. Many suppliers each with an insignificant share of the market – this means that each firm is too small relative to the overall market to affect price via a change in its own supply – each individual firm is assumed to be a price taker;

2. An identical output produced by each firm – in other words, the market supplies homogeneous or standardised products that are perfect substitutes for each other. Consumers perceive the products to be identical;

3. Consumers have perfect information about the prices charged by sellers in the market– so if some firms decide to charge a price higher than the ruling market price, there will be a large substitution effect away from this firm.

Source; http://www.tutor2u.net/economics/content/topics/competition/competition.htm

By its nature, the MVAR ancillary service does not respect the above conditions.

First of all, given that reactive power cannot be transported over long distances, the organization of any large-scale market is unfeasible. In practice this means that for each network node competition would need to be organised.

In particular for the automatic service, which is also the most important for the grid, Elia does not select any volumes; regulation capacities need to be mobilized at all times at their full capability depending on local voltage. In other words units offering the automatic service will be activated anyhow irrespective the cost for activation. Hence, the only (theoretical) available room for competition would have been between non-controlling units providing the manual service only, and at certain nodes where these are numerous and only competing between them, since controlling units provide a different service.

Even in this case though, above conditions are not respected:

1) **There are not many suppliers with insignificant market shares:** Given the local provision of the service in several nodes of the grid, there are not many different sellers (for automatic or manual services): i.e. all units capable of regulating on the 380kV grid belong to the same service provider whereas in other voltage levels number of sellers is also very limited:

    a. 380kV: 1 provider

    b. 150kV: 4 providers

    c. 70kV: 3 providers

    d. 36kV: 2 providers

    In 2017, there were only 2 non-controlling units providing the service, all of these units belonging to the same market party. It is thus evident that competition would not have been possible.

2) **Output produced by each firm is not identical:** Given that each activated asset has a different effect on the grid according to its location and characteristics, it cannot be considered that products are homogeneous. Hence the MVAR delivery by one assets is almost never a perfect substitute for the delivery by another asset.

3) **It is not reasonably possible to provide market parties with perfect information on prices:** Activations of the manual service depend not only on grid topology but also on unit characteristics and

unit availability. In order to create a transparent market for the manual service Elia would have to invest on a power flow model and implement a publication platform that would provide per node the relevant service providers an economic signal of the offered prices & volumes.

Given the characteristics of the MVAR ancillary service, market mechanisms may not ensure the liquidity required for regulation at reasonable costs for society. This is acknowledged by the results of the benchmark which shows that in most of the EU countries the provision of the MVAR product is ensured by a regulated market.

6.4 Should the service be voluntary or obligatory?

Due to the fact that MVAR provision is requested locally and (for its greatest part) automatically, most EU TSO's require that all available units regulate reactive power when running.

Availability of dispersed regulation capacities is essential to the grid, as the more numerous and dispersed regulation means are within the grid, the more the total volume of activated MVAR will decrease (and thus improving of cost efficiency for society). This increase in efficiency can be explained by the fact that the more MVAR regulation would happen close to the right node the less losses would be entailed. Hence, it is highly preferable that all available capacity is activated when needed.

Moreover, and in line with current practices by European TSO's[21], Network Codes (SOGL Art. 29 §6) state that the TSO may solicit all reactive power regulation capacities within its grid.

Elia's proposal for amendment of the FGC applies this provision in Art. 250 §2, by referring explicitly to the mandatory connection requirements of certain transmission-connected units.

The need for dispersed local regulation capacities requires a mandatory service provision from concerned parties (as mentioned in Art. 250§2 of Elia's proposal for amendment of the FGC) as is also the case in other EU countries. Moreover, such mandatory provision is aligned with Art 29 §6 of SOGL.

6.5 Should there be lifelong or shorter-term contracts?

Currently contract duration of the MVAR service matches tendering cycles (1 year). The logic of short-term contracts is appropriate in case of contracting through tender to ensure that prices are updated regularly in response to competition, hence ensuring efficient costs expenditure for society.

However, as explained in previous sections, in Belgium competition in the MVAR provision market is scarce - as can also derived from the fact that in recent years, in a majority of cases prices were deemed unreasonable by the regulator (cf. Table 4).

Moreover, considering Elia's recommendation to have regulated prices and a mandatory participation in the service it is more logic to implement regulated contracts where the settlement prices may be renegotiated or indexed annually without having to undergo a contract signature process.

Furthermore, voluntary parties who wish to participate to the service should also be given the possibility to modify their offered volume in frequent intervals (i.e. one month) without having to resign a contract.

In a configuration as proposed in previous sections (mandatory default contracts) short-term contracts would have no sense. Hence, Elia

[21] As also explained in section 3

proposes to adopt lifelong contracts (as is the case in most EU countries).

6.6 Service provision by a Voltage Service Provider

Currently, the MVAR contract is signed between Elia and the ARP that is appointed for the concerned asset providing the service. The ARP may transfer this contract to a third party who fully assumes his responsibilities.

Elia proposes the introduction of a new Voltage Service Provider (VSP) role. The VSP should be the de facto provider of the MVAR service towards Elia, and may be any party appointed by a grid user.

Grid users could appoint a VSP to undertake their obligations deriving from a MVAR contract (also in line with Art. 250§6 of the FGC). Otherwise, grid users are by default their own VSP.

The VSP as an appointed party should be contractually, technically and operationally responsible for delivery of the service to Elia. Once mandated by the grid user, he should be the signatory of the MVAR contract (as referred to Art. 250 §1 and §4 and as proposed in previous sections). The VSP has to provide Elia with a mandate from the grid user (similar to the grid user declaration for active power ancillary services).

In case of a shared connection to the transmission grid between different grid users, Elia suggests that it may be possible that grid users may appoint different VSP's only if it is proven in the prequalification study (see chapter 8) that:

1) There is no interference between the different grid user's capability of regulating reactive power;
2) There is a distinct metering & measuring perimeter allowing to isolate the delivery of the MVAR service by the different grid user's facilities and to calculate in a correct way the "additional MVAR" tariffs;

It should be made clear that in its current role, the VSP may not act as an aggregator. The local nature of the service requires that for any aggregation whatsoever clear topology relations need to be defined by Elia beforehand which is not currently foreseen.

With this suggestion, Elia aims at opening up the MVAR service provision to all types of market players who might act as intermediaries between grid users and Elia as foreseen also by the Network Codes.

6.7 Reactive power band evaluation

In a context of lifelong bilateral mandatory contracts (for grid users who will have to provide a mandatory service), and in line with SOGL Art. 29 provisions, it is essential to determine the capacities that grid users concerned by the obligation will put at Elia's disposal.

As required by Article 250 of Elia's proposal for amendment of the Federal Grid Code, certain parties (referred to by mention of their connection requirements[22] foreseen by Elia's proposal for amendment of the FGC) that are capable of regulating reactive power according to their mandatory connection requirements, should provide the service within **technical limits** of their installations.

It is important to note that by the above formulation, it is implied that these grid users should put at Elia's disposal all available capacities (and

[22] To be respected at connection point level except for local production units (who according to definition given in the Federal Grid Code are units connected behind a same Access Point as a demand facility) and new type B units.

not only what is foreseen in their connection requirements), that they are capable of coordinating at their connection point with Elia[23].

This would imply for providers concerned by the obligation:

1) For **new transmission-connected units[24],** all reactive power capabilities resulting from simulations and tests described in the RfG and relevant articles of Elia's proposal for amendment of the FGC, taking into account controllability at the connection point level. As foreseen by Elia's proposal for amendment of the FGC, the demonstration of reactive power capabilities is to be made as part of the connection procedure and is to be formalised in the connection contract; results of the simulations are to be annexed to the facility's connection contract and should be reviewed in case of a major overhaul or repowering. These could also be reviewed at the grid user's request.
2) For **existing transmission-connected units[25],** all reactive power capabilities that are controllable at the connection point, and resulting from a common evaluation of capabilities with Elia.

Evaluation of the reactive power band for existing units will be done in an ad-hoc procedure between Elia and the grid user.

1) **For existing transmission-connected units that have already delivered the service** in the last year of application of the tendering procedure, the considered reactive power capability is considered to be equal to the one offered in the last tender;
2) **For existing transmission-connected units that haven't been contracted so far:**
    a. **For type C, D units that were connected to the grid after 2002[26]**, the connection requirements of the current FGC will apply. The grid user may indicate a deviation from these requirements for reasons of controllability (i.e. because of the unit being a local production). Any such request should be motivated by providing sufficient explanations on grid topology, description of any local grid assets that may affect reactive power capabilities at the connection point and/or Energy Management System (EMS) constraints. The grid user's request needs to be evaluated by Elia and the competent regulator who will decide whether an exemption is justified.
    b. **For all other units (type B units & type C,D units connected before 2002),** the grid user will need to provide Elia with technical data relative to his capabilities at the connection point according to a questionnaire established by Elia (i.e. similar to current practice for the Black Start ancillary service). Elia will then jointly evaluate with the grid user his capability to be put at Elia's disposal.

The outcome of the above simulations should be the grid user's reactive power capabilities at the connection point (considering also effect of other grid assets).

Units for which the above procedure confirms a capability of more than 5 MVAR in injection and/or absorption should then be obliged to provide the service to Elia.

The performance of above simulations and tests is the obligation of the grid user concerned by the provision obligation and should be performed before the signature of a MVAR ancillary service contract.

[23] Refer also to disclaimer in section 5.7.2.
[24] Refer to Table 9
[25] Refer to Table 9
[26] Year of entry into force of current FGC containing connection requirements relative to MVAR

Voluntary parties are not concerned by this evaluation and may put at Elia's disposal any reactive power capabilities without prior simulation through their VSP.

Any market party that wishes to do so, may also propose to Elia a volume starting from 0,1 MVAR.

All participants will need to undergo a prequalification procedure prior to delivering the service as explained in section 8.

7 Remuneration & Price Structure

7.1 Preface

In Elia's proposal for amendment of Article 250 of the FGC (Art. 257 in the current FGC) the TSO should develop the Terms and Conditions for the MVAR service that will be subject to regulatory approval. The Terms and Conditions should include financial modalities in respect of the regulator's decisions.

Related to choices made for contracting as presented in previous sections, there are different options for service remuneration and pricing:

1. Remuneration	Should the service be remunerated or not? What should providers be remunerated for? Should there be a remuneration for capacity or delivered energy?
2. Pricing	Should there be regulated prices or should there be free pricing? How should regulated prices be fixed?
3. Price structure	What is the best price structure to better reflect costs? Should there be technology-based prices or a universal price?

In the present chapter, above options are evaluated according to their feasibility and economic opportunity.

Disclaimer : When addressing the pro's and con's of a regulated price structure the present study does not give any elements for determining price levels, but only remuneration and price structure features. Any price determination, if necessary, will be the responsibility of the regulator and not Elia.

7.2 Should the service be remunerated or not?

In Elia's benchmark of EU TSO's practices[27] it can be seen that in almost all studied countries, with the exception of Sweden and Denmark, the MVAR service is remunerated.

This choice can be justified from the fact that producing MVAR's as a service towards the TSO's entails additional costs for the grid user. They MVAR's produced for both automatic and manual services cost the same to VSPs and are measured in the same way by Elia.

Moreover, without any remuneration it will be very difficult to encourage non-obliged parties to offer their capabilities to Elia. Hence, for the above reasons it could be logic that both automatic and manual services would be remunerated.

Alternatively some TSO's only compensate delivered MVAR's in case of a manual activation. One could argue that automatic voltage regulation – for technical reasons – need to be delivered anyhow by big power plants.

2 different alternatives are identified:

➔ Remunerate MVAR only on moments when the manual service is activated

➔ Remunerate all activated MVAR (automatic & manual).

[27] Please refer to section 3

7.3 What should VSPs be remunerated for?

The generation or consumption of reactive power in units providing the MVAR service leads to active power losses at the generator (in case of generation units), the machine transformer and the connection line.

Reactive energy supplied is metered at the grid connection point of the respective power unit (interface between TSO and grid user) and reactive power requirements refer to this point (except for cases mentioned section 5.3). Thus, losses occurring on equipment located "before" the grid connection point (from the perspective of the grid user) are always implicitly borne by the unit operator and are consequently included in the overall efficiency of the unit.

The coverage of the losses will result in an increased primary energy use, reduced active energy infeed into the system or an active power consumption from the grid (in compensatory mode). Therefore, when the any remuneration for reactive power provision **should consider these incremental losses**.

The cost of active power losses may depend on:

1) Revenue scheme (wholesale market or subsidies) ➔ for assets that only sell active power to the wholesale market active losses are less costly than for assets which obtain besides the whole sale price also subsidies (eg. Green certificates)
2) Injection or absorption of reactive power ➔ absorption of reactive power causes much less losses;
3) Voltage level ➔ losses are more important on lower voltage levels;

Further to these electrical losses, **additional wear** due to higher stress for the unit constitutes another type of cost due to reactive power provision. However, the determination of wear caused by reactive power provision is complex, and in most EU countries is not considered for remuneration.

Finally, units may also price **market risks** in case of forced outages. For example, when a generation unit is operated for a long period close to its technical extreme the unit may suffer an outage during which it will not be able to provide active power or ancillary services. When the market risk is considered as relevant, this risk might be also mitigated by an adequate determination of the reactive power range (see section 7.6.2).

When a remuneration is considered as required for a MVAR service, the corresponding prices should at least reflect the incremental active energy losses for provision of the MVAR service. A pricing proposal (to be made by the regulator) should evaluate the pertinence of other cost components to be remunerated or not for the service.

7.3.1 One-off cost components

One-off cost components can occur as a result of the need to equip units with communication devices to receive activation requests from the TSO or the need to install necessary metering/measuring equipment.

For grid users that are obliged to deliver the service, above actions and investments are part of the grid user’s capability to deliver the service; hence for these parties these should not be remunerated.

Similarly Elia by default shall not compensate one-off components to parties who would like to offer on a voluntary basis the MVAR service. Any cost related to metering (when applicable) and tools and processes to exchange signals need to be considered by the party in their decision to start offering the MVAR service to Elia.

One-off cost components such as communication & metering costs constitute part of the provider's capability to provide the service and should hence not be remunerated.

7.4 Should there be a remuneration for capacity or a remuneration for provided energy?

An important question will be if prices are dependent on the capacity to provide MVAR AS (irrespective of its actual activation) or the amount of reactive energy delivered (i.e. dependent of the activation).

From a perspective of cost-reflectiveness of prices, both of these approaches can be considered justified, so that even a combination of capacity-based and energy-based price components is conceivable, in principle. It appears questionable, however, if this degree of complexity is appropriate for this service, in general. EU benchmarking has shown that the pricing regimes applied in other countries typically comprise only one price component.

Table 13 gives an overview of relevant pros and cons of capacity-based vs. energy-based pricing approaches.

Capacity remuneration		Energy remuneration	
Pros	**Cons**	**Pros**	**Cons**
Can incentivize investments	Volume needs must be limited by Elia	Only remuneration of real needs	Short-term signal provides little certainty to new VSPs
	Does not reflect service availability	Better reflection of costs	

Table 13: Pros and Cons of a capacity VS energy remuneration

A capacity remuneration could incentivize investments from voluntary participants, however it wouldn't take into account availability of units (since units only provide the service when running). Furthermore, as explained in section 6.4, the more units providing the service the less volume should be activated. Remunerating capacity would not allow to take this effect into account and Elia would have to limit remunerated capacities per area, which is also not coherent with the need to have always more units providing the service.

On the other hand, a remuneration of provided energy (as is done in most other EU countries) allows to only remunerate what has been activated by Elia instead of a potential, leading to increased cost-efficiency for society. Moreover, since costs for service provision are variable (per MVARh), remuneration of provided energy allows to remunerate VSPs for their real costs.

Besides, contrary to a capacity remuneration, energy remuneration does not allow for a long-term visibility for the market to make large investments. Nevertheless, given that provision of the MVAR service should come from assets that are in priority meant to produce active power or to regulate voltage in local grids, one-off cost components only concern metering & communication (as mentioned in section 7.3.1) which are relatively low.

Based on above arguments Elia concluded already in 2015 that an energy remuneration would be much more meaningful.

Elia proposes to continue with the design change which has been implemented since 2015: remunerating energy (based on measured or calculated MVARh) instead of capacity (installed MVAR's put at disposal).

7.5 Should there be regulated prices or a free pricing?

As stated in section 6.3, a sufficiently liquid market cannot be ensured due to the characteristics of the MVAR ancillary service. Regulation is needed.

In Elia's benchmark of EU TSO's practices[28] it can be seen that in the majority of studied countries regulated prices are used. In some cases the price level is decided by the TSO and in some cases the regulator.

This means that an actor other than the providers of the MVAR service – e.g. the regulator or the TSO – defines the price level at which the VSPs have to offer this service. Often, this pricing model is combined with an obligation for the VSPs to take part in MVAR AS within defined technical ranges (as also suggested for Belgium). The levels of the regulated prices are usually intended to reflect the additional costs that a VSP incurs by delivering MVAR AS[29].

This pricing regime has the advantage that even in the very likely situation that there is no or only little competition of VSPs at relevant locations in the grid, VSPs are not able to exercise market power by offering bids at excessive prices or by withholding their resources.

In a context of mandatory service provision via a regulated contracting procedure (as suggested in section 6), free prices make no sense. Indeed, in Belgium competition in the MVAR provision market is scarce - as can also derived from the fact that in recent years, in a majority of cases prices were deemed unreasonable by the regulator.

Based on this conclusion, default regulated contracts at regulated prices based on the contractual framework described in Elia's proposal for amendment of the FGC (Terms & Conditions approved by the federal regulator) appear to be the most suitable way of contracting MVAR.

7.6 How should regulated prices be fixed?

In all countries where the prices for remuneration of reactive power are regulated, this is done based on a scientific analysis of cost of delivery.

In these countries prices are fixed by the TSO or the regulator. Considering the Belgian context, the Belgian regulator has the competence to evaluate whether the offered prices are reasonable. Following this, it would be logic then that the regulator will determine the regulated prices.

The exact way of determining price levels should be determined by the regulator.

7.6.1 Technology-based pricing VS universal pricing

In a regulated prices context, it is important to determine whether price levels should vary (and if so based on which criteria) or whether they should be universal. As explained in section 7.3, cost components can vary mostly depending on revenue schemes (wholesale market or subsidies), voltage levels and active power losses generated in local grids. This means that the costs depend mostly indirectly from the energy transformation technology.

Table 14 gives an overview of relevant pros and cons of technology-based vs. universal pricing approaches.

[28] Please refer to section 3
[29] It should be noted that in bilateral contracts a price lower than the default regulated price should also be possible in case of a mutual agreement.

Technology-based pricing		Universal pricing	
Pros	**Cons**	**Pros**	**Cons**
More relevant remuneration for different assets	Requires perfect knowledge of assets delivering	Reflects situation of multi-technology service provision	May entail higher costs for certain units, or windfall profits for others
	Difficulty in assessing all parameters to reveal real cost		

Table 14: Pros and cons of technology-based pricing VS universal pricing

The main argument for technology pricing is that it would avoid to over or under-remunerate certain assets depending on the chosen price levels.

Technology-specific pricing would require perfect knowledge of repartition of MVARh provided between all assets behind each connection point. However, given that provision of the MVAR service is required at the interface with the Elia grid, it is possible that different units with different technologies and different costs provide requested MVARh. This is especially the case for grid assets situated in lower voltages, and even more for assets connected to public distribution systems or CDS's. Assets such as capacitor banks or smaller storage units could for example provide the MVAR service with possibly lower costs that should be evaluated in case of a technology-oriented remuneration.

Universal or technology-based pricing depends mainly on what is exactly remunerated for the service (see also section 7.3).

7.6.2 Fixed prices VS prices depending on reactive power range

In 2015, Elia implemented a remuneration for reactive energy instead of reservation of a capacity, with service providers proposing different prices depending on reactive power ranges.

In particular for the range pricing, operating generation units closer to their operating limits entails additional tear & wear costs; unique pricing would mean that service providers would probably need to consider the highest potential operational cost when fixing their prices.

For example, in its projections for 2018, Elia foresaw an activation of approximatively 5.443.313 MVARh, with each unit operating at different ranges (based on 2017 history), differentiated for injection and absorption.

In the hypothesis of a price unique for injection/absorption and the entire reactive power range, where service providers would have proposed their maximal prices, costs for the same volume would have increased by **+22%.**

Similarly, if we considered that providers proposed their average prices instead of their highest prices, total costs for the same volume would have increased by **+4%.**

Currently pricing is done within the bands of 0-50% and 50-100% of the unit's reactive power range (in generation and absorption); however it is considered that a band closer to technical extremes (i.e. 80 or 90% of the unit's technical capability) would be more pertinent.

Different prices according to reactive power bands and differentiation between injection & absorption are more efficient in reflecting costs by different market parties. These can be used – when needed – to reflect additional tear & wear and market risks when operating close to the unit’s technical limits in a cost-efficient way.

7.7 Conclusions

In the context of a service provision through default regulated contracts, remuneration and price structure are key to ensure that:

1) Obligated parties cover their relevant costs;
2) Voluntary parties are attracted to put additional volumes at Elia’s disposal.

Remuneration of provided energy instead of capacity allows to remunerate VSP’s real costs and is more cost-efficient for society.

Given the lack of competition and non-fulfilment of market criteria for the service, a free pricing may not result in long term efficient cost expenditure for this service; to be sure to maintain prices within a reasonable level, a regulated prices approach is proposed instead whereby the regulator should fix prices considering costs & cost structure.

Regarding price structure, the advantages and disadvantages of those different configurations are listed. No recommendation is made regarding the service price level because currently the assessment of the reasonableness of the offered prices falls within the perimeter of competence of the regulator and not of Elia. Logically, if the proposed design option of regulated price levels is pursued, the determination of the regulated service price(s) remuneration and price structure shall become the responsibility of the regulator.

8 Relation of the future MVAR service with incentive by "Additional MVAR" Tariff" and remuneration

8.1 Preface

As mentioned in section 2.6, Elia uses an "additional MVAR" tariff to provide grid users with an incentive to regulate their injection or offtake of reactive energy within specified limits. When the active power flow from the grid is negative (=access point is injecting active power to the grid), the access point is not subject to a tariff.

If currently a power unit is delivering the MVAR service behind a certain access point, the entire access point is exempted from the tariff. This design decision was made to avoid penalizing Access Contract Holders because they deliver MVAR services to support the grid, although this means also that any load units connected to the same access point are exempted from paying the additional MVAR tariff.

In chapter 4 we explained that more decentralised production units will be capable of delivering MVAR services to the grid and that for operational needs it is important to capture these new capabilities regarding the delivery of MVAR services. In the current design principles, this would however imply that the number of grid users exempted from the tariff would increase.

In this section Elia first describes how the volume of delivered MVAR services will be calculated in the future. We also make a suggestion on how access points delivering the MVAR service could be still exposed to an additional MVAR tariff incentivising them to still control their reactive power injection/absorption towards the grid.

This assessment is included in order to give stakeholders the opportunity to get an idea about the global impact of the proposed design. Based on the feedback from stakeholders Elia will evaluate the proposals and perform an in-depth assessment of their feasibility. Another question would be then whether the new mechanism of grid users with offtake could be extended to all grid users. A definitive choice will be made in the context of the proposal of tariffs for the next tariff period.

8.2 Remuneration for delivering the MVAR service

Elia suggest to evolve to a design where – dependent on the conditions – 2 different solutions can be applied to remunerate the service:

1) Use the reactive power volume <u>requested</u> by Elia to remunerate at the access point level;
2) Use the reactive power volume <u>delivered</u> to Elia to remunerate at the access point level;

<u>Solution n°1:</u> Use the reactive power volume <u>requested</u> by Elia to remunerate at the access point level.

In this solution, Elia would only remunerate volumes requested by Elia for each quarter-hour (Q_{req}). Delivery control for the MVAR service would be applied in the same logic as today[30], where Elia checks a number samples per month. For each sample, Elia verifies whether the VSP changed his injection or absorption of reactive as was requested within the requested timeframe.

[30] Also consult section 2.5.2.2.

The check may be performed at the access point or power unit level when necessary.

If the VSP fails to meet the requirement for a certain activation, his remuneration would be reduced accordingly (under same rules as today).

Delivery control would be performed in samples for whenever an activation is requested: if Elia chose to control for these intervals, it would compare Q_{req} to the delta between 2 concerned Q_{meas} values as is the case currently.

Of course, the main condition to be verified ex ante is always that reactive power regulation should be visible at the access point level (as is the case for all access points).

Solution 2: Use the reactive power volume delivered by assets providing the service (Q_{del_PU}) to remunerate at the access point level.

Elia would only remunerate volumes delivered for each quarter-hour at the access point level, based on Q_{del_PU}. Delivery control would be performed in the same way as for solution n°1 (which is the same as today) at the access point or power unit level when necessary.

A basic requirement for this solution would be to have adapted[31] metering equipment close to the asset providing the service[32]. This would of course mean that a unit directly connected to the Elia grid could use its access points metering installations.

Solution n°1 is only feasible for any access point if the following 3 conditions are respected:

1. The assets behind the access point **only provide the manual service**.

   Calculating a requested volume for the manual service is easy, while calculating a requested volume for each quarter-hour for the automatic service requires a complex calculation, for which Elia would require high precision voltage measurements, and precise technical data on the units which might not be easy to obtain for a constellation of small units such as the ones that might be used at a MV or LV grid;

2. The **access holder agrees that a VSP is active** on its access point and agrees to apply solution 1.

   If Elia deduces the requested volume (Q_{req}) from total metered volume (Q_{tot_AP}) to calculate the volume to be used for calculation of the tariff (Q_{load}), the party paying the tariff might be impacted if the party delivering the ancillary service did not react accordingly; In practice this would mean that the same party is fulfilling both roles or alternatively that the VSP and access holder have a mutual agreement (opt-out);

3. Only **one VSP is appointed for the entire access point**. In the opposite case, it would not be possible to determine for delivery control which part of reactive energy corresponds to each VSP.

Solution n°1 is also adapted for assets providing a stepwise reaction, such as for example capacitor banks; in theory it could also be adapted for assets providing an automatic stepwise reaction, although modalities should further be studied in the event that market parties wish to

[31] According to Elia submetering requirements that can be found on Elia's website: http://www.elia.be/~/media/files/Elia/Grid-data/Extranet/General-Technical-Requirements-Submetering-SDR-and-R3_EN.pdf

[32] Allowing to isolate the effect of any other local grid assets

provide such a service and be included in the service's Terms & Conditions.

Solution n°2 would apply to all cases that don't fill the criteria for solution n°1.

Dependent on the conditions as described section 6.6 it still might be not possible to accept different BSPs behind the same access point.

In any case, and after determination of reactive capabilities to be put at Elia's disposal for mandatory providers, prior to delivery by the concerned assets, all VSP's (mandatory or voluntary) should undergo a **prequalification** phase in which they should:

1) Agree with Elia on the solution (n°1 or n°2) that should be used for remuneration according to aforementioned criteria;
2) Agree with Elia on the metering & measurement perimeter to be applied (for remuneration, or operational exchanges);
3) In case solution 2 needs to be applied, the relation between reactive power provided at the level of the asset providing the service and the access point.
4) Confirm their capability to deliver the service by performing a simulation test;

8.3 Potential Impact on tariff for additional MVAR

As mentioned, in the current rules the entire access point is exempted from the tariff in case one single asset behind this access point is delivering MVAR services. In order to keep the right incentives for grid users Elia therefore suggest to abandon the current exemption mechanism. More specific a tariff for additional MVAR will be applied irrespective of whether behind an access point assets are delivering MVAR services or not.

In practical Elia proposes to correct the reactive power measures at the access point as follows before it used to calculate the costs associated to additional MVAR tariff:

- In case the reactive power volume requested by Elia is used to remunerate the MVAR service (solution 1 in section 8.2), the requested volume would be also used for the correction;
- In case the delivered reactive power volume is used to settle the MVAR service (solution 2 in section 8.2), the delivered volume would be also used for the correction.

In any case, during the analysis for the tariff proposal, Elia will carefully study the relation between active and reactive power injected or offtaken at the access point, destined for the service or for own use, to avoid unjust penalizing of grid users (in particular for access points that have both an injection and offtake, including DSO's and CDS's).

Elia is going to assess the feasibility of this concept further the upcoming months. In case of positive evaluation, such a mechanism offers the possibility to also apply an additional MVAR tariff to access points injecting active power. This extension would allow to incentivize grid users and distribution systems behind access points with a net injection to use their reactive regulating capabilities to control their injection or absorption of reactive energy to the grid.

As earlier explained, the suggestions in the section are included in this study in order to gather relevant feedback from stakeholders as a first input to the tariff proposal for 2020-2023 by Elia which shall be developed in the course of 2019.

9 Integration of new participants in the MVAR service

9.1 Preface

In the evolving energy landscape, decentralized generation will play an increasingly important role in regulation of voltage of the Elia grid. The role of large centralized generation that was traditionally used to regulate reactive power is expected to become less important (especially after the phasing out of Belgium's nuclear power plants in 2025).

Furthermore, factors that were considered having a non-controllable effect to the grid until now (see Table 1), such as distribution grids and reactive load consumers, start seeking a more active role in regulating voltage as they become more and more capable of controlling their asset's reactive behaviour.

As mentioned in section 6, Elia proposes to introduce the new role of VSP in the service, to make participation possible for parties other than ARP's. In the same way, in the current chapter Elia proposes the rules for participation of other grid users, such as:

i. DS-connected assets;

ii. CDS-connected assets;

iii. Transmission-connected DSO's & CDSO's;

iv. Demand facilities.

Participation for transmission-connected DSO's, CDSO's and demand facilities according to Elia's proposal of amendment of the FGC is voluntary (Art.250§3). These assets are not obliged to participate, and can propose freely any capacities which need to be prequalified (section 8.2).

Voluntary parties will need to sign the same Terms and Conditions of the MVAr service as their obliged counterparties and will thus be remunerated for the service by receiving the same regulated price.

9.2 Participation for DS-connected assets and transmission-connected DSO's

9.2.1 Use of DS-connected decentralized generation or demand in reactive power regulation

It is interesting to note in the first place, that while potential from decentralized generation units is expected to grow in coming years, it is not expected to always replace the reactive regulation capacities of centralized generation or TSO-owned assets in the near future, for the following reasons:

1) As explained in section 6.2, MV and LV-connected units are not as efficient in regulating voltage in the HV and eHV grid;
2) New decentralized generation units (mostly type B PGM's) will be mostly connected in the DSO grid, within complex grid topologies;
3) New decentralized generation units will be mostly intermittent ones (wind & solar);
4) All above points can be also seen in Table 15 resuming Elia's projection on reactive capabilities of new generation units to come until 2030.

	Installed Power (in MW)[33] (New units 2018>2030)			Requirements (p.u.)[34]						TSO/DSO connection factor (%)[35]						DSO reduction factor[36]						New generator possibilities (New units 2018>2030)		New generator possibilities @ DSO-level (New units 2018>2030)	
				absorption			injection			TSO			DSO			absorption			injection						
	type A	type B	type C/D	type A	type B	type C/D	type A	type B	type C/D	type A	type B	type C/D	type A	type B	type C/D	type A	type B	type C/D	type A	type B	type C/D	Q absorption	Q injection	Q absorption	Q injection
CHP/CCGT	333	833	1500	0,33	0,33	0,25	0,33	0,33	0,45	0%	10%	100%	100%	90%	0%	0,2	0,3	1	0,1	0,15	0	499	751	96	48
WIND	333	833	2500	0,33	0,33	0,3	0,33	0,33	0,3	0%	10%	100%	100%	90%	0%	0,2	0,3	1	0,1	0,15	0	874	826	96	48
SOLAR	333	833	0	0,33	0,33	0,3	0,33	0,33	0,3	0%	10%	100%	100%	90%	0%	0,2	0,3	1	0,1	0,15	0	124	76	96	48
TOTAL	**1000**	**2500**	**4000**																			**1496**	**1652**	**289**	**144**

Table 15: Projections of potential for reactive regulation from new generation units 2018-2030[37]

[33] Projections for new active power capacities to be installed derive from ENTSO-E's 10 Year Network Development Plan.
[34] As formulated in RfG.
[35] Percentage of units to be connected at TSO or DSO grid.
[36] Estimation on usable capacities of units connected in the DSO grid due to grid topology.
[37] New generator capacities are calculated by applying to this capacity reactive power capability requirements from the RfG, the expected percentage of connection to TSO or DSO grid, and an expected capability reduction factor for DSO-connected units due to grid topology (commonly projected with the DSO's);

9.2.2 Structural approach in provision of the MVAR service by DS-connected grid users and by DSO's

Art. 29 of System Operator Guidelines mentions the following principles concerning participation of DS-connected assets and transmission-connected DSO's in the MVAR service:

i. *When relevant for the voltage and reactive power management of the transmission system, a TSO may require, in coordination with a DSO, a distribution-connected SGU to follow voltage control instructions.*

ii. *Each TSO shall agree with the transmission-connected DSO on the reactive power set points, power factor ranges and voltage set points for voltage control at the connection point between the TSO and the DSO in accordance with Article 15 of Commission Regulation No [000/2015 DCC]. To ensure that those parameters are maintained, each DSO shall use its reactive power sources and have the right to give voltage control instructions to distribution-connected SGUs.*

The spirit described above is directly linked to the following important aspects:

Technical aspects:

1. Assets at a lower voltage level are less efficient to regulate a much higher level (i.e. an asset in a 10kV has very little effect on 380kV voltage);
2. To automatically regulate voltage, an asset injecting or absorbing energy needs to be (electrically) close to the voltage measurement level;

Operational aspects

3. Elia requires a service at the access point hence the T-DSO interface, which is the limit of its controlling & responsibility perimeter;
4. DSO's need to regulate themselves to remain within certain reactive power limits at the T-DSO interface, for which they are subject to an "additional MVAR" tariff. Any action taken within their grid should be coordinated with their energy management system so that it doesn't impede with their own regulation;

For the above reasons, provision of the MVAR service for Elia's regulation needs by DS-connected assets should be activated by the DSO, who should act as a VSP, under his own responsibility. In any case transmission-connected DSO-connected assets to the service should only be able to participate with the explicit authorization of the relevant DSO.

Regulatory aspects:

5. Logically before signing the Terms & Conditions of the MVAR service, DSOs will need to discuss with their regional regulator[38] on whether they are allowed and if so under which conditions to participate to the MVAR service. Obviously Elia cannot make any statement regarding this point.
6. Elia will develop a design enabling each user to participate to the MVAR service. Hence from a product design point of view each transmission-connected DSO can become a VSP after having signed the Terms & Conditions of the MVAR service.

[38] An opinion given in the past by the VREG (ADV 2016 01 beleidsadvies flexibiliteit) states that DSO's may participate as a "technical aggregator" in provision of an ancillary service, but not as a "commercial aggregator".

9.3 Participation of CDS-connected assets and transmission-connected CDS's

For the same reasons as for DS-connected grid users, the MVAR service coming from transmission-connected CDS-connected assets should be activated by CDSO's in a VSP role (or a third party VSP appointed by the CDSO), who shall in their turn offer it to Elia. In any case,CDS-connected units to the service should only be able to participate with the explicit approval of the CDSO.

In the same way as for any other VSP and access point, **CDSO's as a VSP should provide a service at the T-CDSO interface, under rules formulated by the service's Terms and Conditions and at default regulated prices**.

9.4 Participation of demand facilities

TS-connected demand facilities may help Elia in regulating the grid by putting at disposal, apart from using their own local productions, their own reactive regulation means such as reactors or capacitor banks.

Reactors and capacitors banks installed within the network of grid users or distribution networks can contribute to the regulation of reactive power of the transmission grid, notably by providing a stepwise response, depending on their technical capabilities.

Since service offer from large generation units is bound to decrease in the future, Elia seeks to encourage participation of such assets; in the framework set down by the new design these should be capable of participating under the same rules as for other assets as explained in the VSP Terms & Conditions.

In theory, the MVAR service could also be provided by demand response in an indirect manner: by reducing or increasing active power offtake from the grid, a grid user could induce generation or absorption of MVAR from his local grid assets (i.e. push the local lines or cables further into capacitive range by decreasing active power offtake). Nevertheless, this method does not seem cost-efficient at present, since grid users should use significant quantities of active power to handle (much cheaper) MVAR's. In its study Elia has not identified any reasonable cases for provision of the MVAR service by demand response. However Elia remains open to an experimentation should market parties propose a reasonable business case of provision of MVAR with demand response.

In any case, it is clarified that provision of the MVAR service with the above assets should happen under the modalities described in sections 5.7, 9.3, 9.2:

- For assets within the grid of a transmission-connected demand facility, participation should be voluntary and through the VSP assigned by the grid user (the grid user can have this role himself);
- For assets within a transmission-connected DSO grid, participation should be voluntary and through the VSP assigned by the DSO (the DSO can have this role himself);
- For assets within a transmission-connected CDS grid, participation should be voluntary and through the VSP assigned by the CDSO (the CDSO can have this role himself);

10 High Level Implementation Plan

10.1 Evolution of legal framework

The most critical precondition for the implementation of the changes proposed in the current study concerns the evolution of the relevant legal framework.

In particular, timely review of Art. 12 quinquies of the law of 29 April 1999 and approval of Elia's proposal for amendment of the FGC are *sine qua non* conditions for the evolution of the contracting procedure and the definition of regulated prices for the service and the date of its implementation.

There are 2 reasons why we believe that in order to implement the proposed design for the 1st of January of a certain year, **Art. 12 quinquies needs to have been reviewed and the FGC needs to be adapted before the 1st of April of the year before**.

Current procurement procedure of the MVAR service

Under the current legal framework (Art. 12 quinquies and current version of the Federal Grid Code), Elia must launch a call for tender at latest during the month of May of year Y-1 to ensure MVAR services during the year Y. Such a launch requires at least 1 month of preparation.

Therefore, for the proposed contracting procedure to apply for the 1st of January of a certain year, Art. 12 quinquies needs to have been reviewed and the FGC needs to be adapted before the 1st of April of the year before.

The development of the MVAR service contract

As earlier mentioned in this study, Elia's proposal for amendment of the FGC requires the following:

> ***Art. 250 §1:*** *The TSO defines the technical specifications, participation conditions and eventually financial conditions for participation to the service in the Terms and Conditions, in a transparent and non-discriminatory way. These Terms and Conditions are to be approved by the federal regulator and are based on financial guidelines set beforehand by the latter*

In order to start with the new design proposal on time, Elia needs to ensure that all parties delivering the MVAR service will have signed on time the related contract.

It is estimated that the total process for having a signed and approved contract will take at least 7 months. We hereby assume at least 2 months to develop the documents, 1 month to organize a public consultation, at least 2 months for regulatory approval and 2 months to get the contracts signed by the future Voltage Service Providers. Hence and more concretely, this would mean that the drafting of the Terms and conditions will need to start the latest 7 months before entry into force of the new proposed design.

As mentioned in Elia's proposal for amendment of the FGC, the contract should respect the financial guidelines which are developed by the federal regulator. Without detailed assessment, it is clear that the development of those guidelines will also be a time consuming process (at least 2 months) which partially need to be organized once the required legal framework has been correctly implemented.

Therefore we believe that new required legal changes needs to be implemented not later than 9 months before the proposed new design shall 'go live'.

10.2 IT implementations

IT implementation work is to be executed on Elia's side:

i. Review of the tools for tariff invoicing to consider correction of invoiced reactive energy with volume requested (for DSO's and points that fulfil conditions in section 8) or delivered for the ancillary service (for all others);

ii. Incremental changes in Elia's tools to account for the new VSP role, new metering perimeters and other settlement details.

10.3 Implementations on market side

Only very minor implementations are required from **parties that are currently providing the service** (implementations in ReVolt). VSPs will be given all necessary information at least 6 months in advance, and will be expected to be ready by the date of entry into force of the service's new rules.

New connected parties for which the requirements of the reviewed Federal Grid Code apply are expected to integrate the capabilities simulations & tests in their connection procedure.

Existing parties that weren't offering the service until now but for which the service offering becomes mandatory will need to evaluate their capabilities to be put at Elia's disposal and perform simulations & tests as foreseen section 6.7 to determine the object of their obligation. Elia proposes to allow a transition period of 6 months after entry into force of the service's new design to perform these studies.

Similarly, after completing the above evaluation some of the above units will need to implement IT communication and prepare technically for providing the service. Elia proposes a lead time of 1 year to perform all above changes.

Voluntary parties may provide the service as from the moment they are ready to do so.

In this sense, Elia proposes to have a differed go-live:

All parties apart from those that weren't offering the service until now but for which the service offering becomes mandatory shall start providing under the new rules as of their entry into force.

Existing parties that weren't offering the service until now but for which the service offering becomes mandatory are obliged to start providing the service after 1,5 year from the day of entry into force of the new rules.

Based on the planning assessment, Elia believes that it should be feasible to implement the design proposal as presented in this study on 1/1/2020 on condition that the aforementioned legal preconditions are met on April 1st 2019 and that transitional measures as explained in section 10.3 are foreseen.

11 Conclusions

Until today, in line with applicable legal prescriptions, Elia has been procuring the MVAR ancillary service through a tender procedure.

The evolution of the energy landscape in the coming years will have a considerable impact on the service's provision, as needs for the service will increase while regulation means will become scarcer.

To respond to this challenge, Elia has started in 2015 an effort to modernize the service in order to open up the service to more technologies and market participants and facilitate participation of new assets, always with the aim to ensure long term efficient cost expenditure.

Experience from the past years has shown that the tender procedure has not been able to help in this direction; in Belgium competition in the MVAR provision market is scarce - as can also derived from the fact that in a majority of cases prices were deemed unreasonable by the regulator.

Moreover, benchmarking studies have shown that Belgium is to this day not aligned with EU practices in the area of MVAR contracting.

Recently introduced Network Codes and the required amendment of the Federal Grid Code provided an opportunity to propose a new framework which would optimize the contracting procedure and fully open the service to new market parties & all technologies.

In the present study Elia analyses different configurations for the contracting procedure, evaluating them on grounds of technical, operational and legal feasibility, while considering their economic opportunity.

The main challenge was to propose procedures & rules that together would bridge the gaps between:

i. parties providing the service (generators) and parties creating the need for it (demand);

ii. contracted and non-contracted assets, and

iii. assets connected to the TSO and the DSO and CDS networks.

It is estimated that the proposed changes should result on the long term in a fairer and more efficient cost expenditure for the MVAR service compared to the current design/approach as:

1) the increase of the number of units providing the service will create a more dense network of regulating units locally, thereby reducing the overall regulation need;
2) it preserves the incentive given by the tariff for all market parties thereby reducing the overall regulation needs;
3) all parties delivering MVAR services to support the Grid shall receive a remuneration.

Intrinsically, the overall cost of the MVAR service for society will also largely depend on the remuneration structure and level.

In conclusion, Elia believes that the present study achieves its goal in proposing a coherent framework that links different parties and their respective roles in the system in a way to provide a global incentive mechanism that efficiently reduces needs while ensuring sourcing of necessary volumes at a reasonable cost for society.

Annex 1: Results European Benchmark study (Consentec)

TSO	Provision of MVAR AS	Type of contract	Contract duration and updates
50Hertz (GER)	mandatory for power plants scheduled for commercial dispatch	connection contract	lifetime, yearly indexed prices
Amprion (GER)	mandatory for power plants scheduled for commercial dispatch	connection contract	lifetime, yearly indexed prices
Elia (BEL)	only for contracted units, no mandatory participation at MVAR AS	tender	1 year
Energinet.dk (DEN)	mandatory for power plants scheduled for commercial dispatch	connection contract	lifetime
National Grid (GBR)	mandatory for power plants >50MW scheduled for commercial dispatch	connection contract tender for non-mandatory service	lifetime, monthly indexed prices tender period (days. Months)
RTE (FRA)	mandatory for power plants scheduled for commercial dispatch	connection contract	lifetime, yearly indexed prices
Statnett (NOR)	mandatory for generation units ≥ 10 MVA scheduled for commercial dispatch	connection contract	Lifetime
Swissgrid (SUI)	mandatory for power plants scheduled for commercial dispatch voluntary for DSOs and demand facilities	connection contract	lifetime, yearly updated prices
Svenska Kraftnät (SWE)	mandatory for power plants scheduled for commercial dispatch	connection contract	lifetime
TenneT DE (GER)	mandatory for power plants scheduled for commercial dispatch	connection contract	lifetime, yearly indexed prices
TenneT NL (NED)	only for contracted units, no mandatory participation at MVAR AS	tender (generally) bilateral contracts (de facto)	1 year
TransnetBW (GER)	mandatory for power plants scheduled for commercial dispatch	connection contract	lifetime, no price updates for ~5 years

TSO	Prices determination	Initial price proposal	Price dependent on production/ absorption
50Hertz (GER)	compensation of losses	TSO	no
Amprion (GER)	compensation of losses compensation of network charges (phase-shifting operation mode)	TSO	yes, only remuneration of production
Elia (BEL)	no details given by the provider	provider	possible (dependent on bid)
Energinet.dk (DEN)	no compensation	none	no
National Grid (GBR)	no details available	TSO	no
RTE (FRA)	compensation of investment cost, maintenance, losses	TSO & provider	no
Statnett (NOR)	compensation of losses and additional wear	TSO	no
Swissgrid (SUI)	no details available	TSO	no
Svenska Kraftnät (SWE)	no compensation	none	no
TenneT DE (GER)	compensation of losses compensation of maintenance	TSO	yes, remuneration if MVAR production exceeds threshold
TenneT NL (NED)	no details given by the provider	provider	no
TransnetBW (GER)	compensation of losses compensation of network charges (phase-shifting operation mode)	TSO	yes, only remuneration of production