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A VCG Auction for Electricity Storage

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Abstract

Energy storage seems set to play a key role in managing and balancing the future electricity system. Storage can act as a generator and as a load, providing both energy and ancillary services such as fast frequency response and operating reserve. Therefore, it can provide the desired flexibility for the network. Current mechanism designs do not take advantage of the full potential of a given storage facility and the auctions used to buy and sell potential storage products have design flaws. This paper gives an overview of how storage products are bought and sold today and the problems of the current designs. It then presents a new mechanism design to integrate storage in the most efficient way, based on social welfare.

Keywords Electricity storage, interconnectors, auctions

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A VCG auction for Electricity Storage

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Energy storage seems set to play a key role in managing and balancing the future electricity system. Storage can act as a generator and as a load, providing both energy and ancillary services such as fast frequency response and operating reserve. Therefore, it can provide the desired flexibility for the network. Current mechanism designs do not take advantage of the full potential of a given storage facility and the auctions used to buy and sell potential storage products have design flaws. This paper gives an overview of how storage products are bought and sold today and the problems of the current designs. It then presents a new mechanism design to integrate storage in the most efficient way, based on social welfare.

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I. INTRODUCTION

Energy storage is potentially of great importance to the future of the electricity system. This is because an electricity system characterised by a greater share of low carbon intermittent renewable generation technology and/or base-load nuclear and carbon capture and storage plants will be much less able to follow demand. The absence of flexible fossil fuel plants on the electricity system will mean that flexibility will need to be supplied by storage technologies. A recent study for the National Infrastructure Commission in the UK suggested that a flexible electricity system could be of the order of £8bn p.a. cheaper than a business as usual system by 2030 (Strbac et al., 2016). Storage units can be sources of load at times of excess supply and sources of supply at times of excess demand. They can also provide other non-energy electricity products (such as fast voltage support or reactive power). The key market design question around storage is how to appropriately involve storage units

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within energy and other electricity service auctions. Current market designs tend to run separate auctions for different energy products (where they run auctions at all). Future market designs could and should use auctions which simultaneously clear multi-product markets on the basis of bids from units capable of producing and demanding a range of electricity products. This paper explores one such auction/mechanism design, a double-sided Vickrey-Clarke-Groves mechanism (VCG mechanism), that would allow the participation of storage units capable of both buying and selling energy and providing reserve capacity. The VCG is built up around an allocation rule (of the objects for sale between buyers and sellers) and a payment rule where payments are determined. Payments are set independently of each bidder's own submitted bids to ensure truth-telling (Krishna, 2009). We illustrate clearly how this mechanism works in our examples below.

II. STORAGE OF TODAY

A. Storage products and the mechanism used to buy and sell them

Storage has the advantage of providing the flexibility to balance the electricity system. This is because storage offers fast response to the system, as opposed to just energy price arbitrage. However, is the mechanism design used for selling reserve products the right design to achieve an efficient allocation and/or one which optimises production costs and consumption decisions? This depends on the products for sale and the mechanism design used to sell them.

Potential storage products (hereafter just 'products') are offered together with other energy products. These products are designed for different purposes to help the System Operator (SO) optimising the system. The following tables show the products currently offered[2], the auction used to procure them and how often they are conducted[3]. We are only interested in products that are tendered[4]. Table 1 concerns GB and Table 2 ISO New England (ISO-NE).

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[2] National Grid will be contracting a new service in April 2016 - Enhanced Frequency Response (EFR) – a product to provide frequency response within 1 second.

[3] The tables are based on our interpretation of the different publicly available documents.

[4] National Grid offers non-tendered products such as "Mandatory Frequency Response" and "Fast Start", among others (NG, 2014/2015).

Table 1

Products in GB

Product[1]	**Feature**	**Mechanism**	**Conducted**
Firm Fast Reserve	Response within 2min, duration at least 15min[3]	Pay-as-bid[2]	Monthly[2]
Short-term Operating Reserve (STOR)	Response within 240min, duration at least 2h[5]	Pay-as-bid[4]	3 tenders per year[5]
Firm Frequency Response	(LF1): Response within 10s, duration at least 20s (LF2): Response within 30s, duration at least 30s (HF): Response within 10s, duration is indefinitely[8]	Pay-as-bid[7]	Monthly[6]
Reactive Power	Voltage control	Scoring, Pay-as-bid[9,10]	Every 6 months[1]

Note 1: NG (2014/2015), Note 2: NG (2013), Note 3: NG (2016a), Note 4: NG (2015a), Note 5: NG (2015b), Note 6: NG (2015c), Note 7: NG (2014a), Note 8: NG (2014b), LF1: low frequency, primary response, LF2: low frequency, secondary response, HF: high frequency, Note 9: NG (2016b), Note 10: 2014c

Table 2

Products in ISO-NE

Product[1]	**Feature**	**Mechanism**	**Conducted**
Regulation Market	Increase or decrease every 4s[1]	Uniform-price, highest offer sets the price[2]	Daily[2]
Forward Reserve Market	TMNSR: Response within 10min TMOR: Response with 30min[3,4]	Uniform-price[3]	Every 6 months[3]
Real-Time Reserve Pricing	First contingency loss: 100% delivery within 10min[6] Second contingency loss: 50% delivery with 30min[6]	Uniform-price[6,5]	Daily[6]
Voltage Support	Voltage Control	Generator's claimed capacity[5]	Annually[5]

Note 1: ISO-NE (2014), Note 2: ISO-NE (2013a), Note 3: ISO-NE (2013b), Note 4: ISO-NE (2016), Note 5: ISO (2015a), Note 6: ISO-NE (2015b)

This paper is interested in the number of products offered to illustrate the need for simultaneous market clearing in multi-product markets. GB and ISO-NE offer four products. However, future market will consider more products. To support this, Ireland is in a process of designing a new electricity market, including a range of new electricity products. Currently (see Appendix), they have seven products, but are discussing the need for more (SEM, 2013)[6].

Overall, system operators seem interested in defining many products in the sense that the individual products are designed for different purposes and procured over different time intervals. They depend on what the SO may need to ensure delivery and reliability of the

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[5] According to ISO-NE (2015b, p.11), prices (and quantities) are based on the real-time energy offers of resources and not separate real-time reserve offers. In other words, a price (and consequent quantity) is set at the intersection between supply and demand.

[6] As part of the design process, a suggestion for a new package auction design has been proposed by a consulting firm (DotEcon, 2015). The set up is different from ours and its properties are not formally laid out, so we would expect it to deliver different outcomes from ours.

network. For example, one product can work well for batteries and another one for pump-storage.

B. Problems of current mechanism designs

One of the main lessons from existing systems is that they tend to run separate auctions for distinct energy products. There is no coordination between the different sales of electricity products or between auctions in the sense that there is no simultaneous clearing process across auctions/product markets. Failure to simultaneously clear interrelated markets is a source of inefficiency. Inefficiency arises when, for example, a bidder can learn from already conducted auctions to place a higher untruthful price on a product where there is expected to be less competition. The bidder can therefore gain from knowing what markets may be less competitive.

At least one way forward is to ensure a simultaneous clearing process across auctions/products and to give units the opportunity to submit package bids (submit bids on a group of products). This feature is important in the area of electricity where gains are to be earned from cost synergies.

Furthermore, products are designed for different purposes and conducted for different time intervals. They are designed for what the market and the SO may need in order to ensure delivery and reliability of the network. Given these features, the markets are still not fully designed to reflect the full capabilities of new electrical energy storage (such as grid-scale batteries) and its features. Storage has the special feature of being able to be a supplier (generator) and demander (load) of electricity. The feature makes storage useful from the perspective of a SO to balance the system. Current systems do not allow a given unit to simultaneously act as a supplier, demander and/or as reserve capacity.

A SO is interested in balancing the system. The existing systems do not allow the SO to express consistent preferences on the products for sale. The supply and prices are determined via bids submitted by suppliers and demanders. If a SO is to be allowed to balance a system in an efficient way, it needs to express complex preferences (a utility function) for different types of products.

The current auction designs used today have problems. Importantly, they are not based on economic welfare (Krishna, 2009). The focus seems only to be lowest possible price. Often, price minimisation and economic welfare cannot be achieved simultaneously (Zhan, 2008). Indeed attempts to minimise price in the short run, may cause bidders to strategically alter their bids upwards (i.e. bid untruthfully), thus raising prices in the longer run. The literature discusses how to characterise electricity service. Is electricity, with all its energy and power quality, characteristics as a private good or as a public good? The conclusion seems to be that the delivery and reliability characteristics should be identified as being public goods, whereas real power and reactive power are technically private goods (Kiesling, L. and Giberson, M., 1997; Joskow, P. and Tirole, J., 2007; Schulze W. et al., 2008).

A step forward in ensuring a welfare optimum is to illicit truth-telling from bidding storage units. In other words, if all units state true willingness to pay (WTP) and cost, the mechanism can place the electricity products for sale in the hands of those who value them the most. This is an issue in current systems, where none of the currently used mechanism designs fully incentivise bidders to reveal true WTP and cost and allocate the electricity products efficiently. Therefore, the welfare optimum may not be achieved.

The auction designs used today have elements of cost inefficiency. Take for example the uniform-price double auction for wholesale electricity energy and consider an environment of many small and cheaper units and one bigger more expensive unit. It can be shown that a uniform-price across an area (maybe a constrained area) means an unnecessarily high cost/price for all final consumers since the more expensive unit by itself will increase the price for the whole market.

III. A FRAMEWORK ON HOW TO IMPLEMENT A VCG MECHANISM FOR STORAGE

We suggest the use of multiple markets, including a range of reserve markets along with the day-ahead energy market. The reserve markets (hereafter reserve market) will contain products designed only for reserve capacity. Reserve market products will be sold via a new design – a double-sided VCG mechanism, which is a combination of an allocation rule to find the winners of the assignment process and a payment rule to determine the payments. We simultaneously determine allocation and pricing across products, and package bidding is allowed. Thus, each storage facility simultaneously bids into multiple markets. The mechanism is based on social welfare and achieves by itself truth-telling, individual rationality and efficiency. There will be a price per provider, not a uniform-price. Contracts (to sell products) will be to deliver to the reserve market, and/or to deliver to the day-ahead/energy market to increase competition. A storage unit can be supplier as well as demander of electricity in the assignment procedure. The SO submits offers and therefore, it is given the opportunity to express preferences on offered contracts.

A. Examples[7]

Consider the environment of one SO and four bidders – Storage 1 to 4 (hereafter S1-S4). Let S1 and S2 be demanders of electricity and S3 and S4 be suppliers of electricity. Suppose two contracts are for sale, namely a contract to provide electricity to the energy market (EM), totalling 2 MWh, and a contract to provide reserve capacity (FFR), totalling 2 MWh. Assume also that each demander wants 2 MWh and each supplier has 2 MWh they want to sell. These products give the SO the opportunity to ensure reserve capacity and to increase competition in the EM. The following shows two examples. The first example ends up having two winners, whereas the second example has one winner.

Example 1

Table 3 shows the submitted offers and bids. The SO, S1 and S2 submit preferences/WTP, marked with a plus. S3 and S4 submit costs to be paid by the final consumers, market with a minus.

Table 3

Submitted offers and bids

Agents\Contracts	EM/2 MWh (£/MWh)	FFR/2 MWh (£/MWh)	EM/2 MWh + FFR/2 MWh (£/MWh)
SO	110	150	-
S1	120	-	250
S2	-	120	240
S3	-90	-110	-200
S4	-100	-100	-190

Table 3 shows, for example, that the SO has submitted preferences on both contracts. It shows that it prefers reserve capacity with the higher bid of £150 compared to the bid of £110. In other words, it expects a competitive EM. Interestingly, S1-S4 have submitted package bids combined of EM and FFR.

Using the VCG mechanism, the allocation rule suggests that S1 and S3 are the winners of contract EM (S1 buys from S3) and SO and S4 are the winners of contract FFR (SO buys from S4). This is the allocation that maximises the difference between submitted offers and bids: (£120+£150)-(£90+£100)=£80. This is because the VCG mechanism allocates the object for

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[7] Throughout this paper, we assume (1) no learning between assignment procedures, (2) units cannot bid as being supplier and demander on the same time, (3) there are no budget constraints and (4) products are pre-defined. These assumptions can be relaxed or justified in subsequent work.

sale to highest value bidders and procures it from the cheapest sellers. The VCG payment rule suggests that S1 and S0 pay £110 and £120 and S3 and S4 are paid £100 and £110. Hence, the network cost by itself is £210 (£100+£110). The simplified example shows that buyers pay the second highest price and sellers receive the next lowest bidder's bid. This ensures that both buyers and sellers bid truthfully.

Example 2

Compared to Table 3, S1 has changed its package bid from £250 to £290.

Table 4

Submitted offers and bids

Agents\Contracts	**EM/2 MWh (£/MWh)**	**FFR/2 MWh (£/MWh)**	**EM/2 MWh + FFR/2 MWh (£/MWh)**
SO	110	150	-
S1	120	-	290
S2	-	120	240
S3	-90	-110	-200
S4	-100	-100	-190

The allocation rule now suggests that S1 and S4 are the winners of both contracts since £290-£190=£100 is greater than the £270-£190=£80 from Table 4. The payment rule suggests that S1 pays £240 and S4 is paid £200. The package bids are of interest because the network cost is now £200 instead of the £210 from having two different winners/suppliers.

Notice that both examples have a VCG surplus - Example 1 with a total surplus of (110+120)-(100+110)=20 and Example 2 with a surplus of (£240-£200)=£40.

IV. INTERCONNECTORS BETWEEN DIFFERENT COUNTRIES

Until now, the focus of the paper has been on the allocation of electricity storage products within a system controlled by a single SO. However, the VCG mechanism can be extended to contain several SOs. This makes our mechanism useful in other areas such as the allocation of electricity interconnector use. For example, take Great Britain (GB) that currently has interconnectors to France, the Netherlands, Northern Ireland and the Republic of Ireland (Ofgem, 2014) and will have them to Belgium, Norway and Denmark by 2022 (Ofgem, 2016).

Our presented mechanism should in this context be seen as one clearing process across product markets and across counties, that is, coupling different markets into one market. Different national SOs are given the opportunity to express preferences towards the products needed to manage their own networks and suppliers are assumed to be able to deliver across countries without diverse administrative procedures.

Based on Table 4, suppose now that we have two SOs (for example, the SO in GB, marked as SO(GB), and the SO in France, marked as SO(France)) and five bidders – Storage 1 to 5, where four of the five are in GB (as in Table 4) and one is from France (hereafter S1(GB)-S4(GB) and S(France)). Let S1(GB) and S2(GB) be demanders of electricity and S3(GB), S4(GB) and S(France) be suppliers of electricity. Table 5 shows the submitted offers and bids.

Table 5

Submitted offers and bids across an interconnector

Agents\Contracts	**EM/2 MWh (£/MWh)**	**FFR/2 MWh (£/MWh)**	**EM/2 MWh + FFR/2 MWh (£/MWh)**
SO(GB)	110	150	-
SO(France)	140	-	-
S1(GB)	120	-	290
S2(GB)	-	120	240
S3(GB)	-90	-110	-200
S4(GB)	-100	-100	-190
S(France)	-110	-90	-195

The allocation rule suggests that SO(France) and S3(GB) are the winners of contract EM, S0(France) buys from S3(GB), and SO(GB) and S(France) are the winners of contract FFR, SO(GB) buys from S(France). Note that (£140+£150)-(£90+£90)=£110 is greater than (£290-£190)=£100. The payment rule suggests that SO(France) pays £120 and S3(GB) is paid £100 and S0(GB) pays £120 and S(France) is paid £100.

In theory, the presented design will ensure the efficiency of trading day-ahead, intra-day and sharing balancing services (Newbery et al, 2015).

V. CONCLUSION

This paper presents a new mechanism design to sell storage products. It is built on multiple markets and package bidding. The mechanism presented is the VCG mechanism that is based on social welfare which has the expected features – truth-telling, individual rationality and efficiency – and results in simultaneous pricing of the different products. With our design, storage can now be part of the energy market and/or be a reserve supplier or demander. The SO is part of the design and therefore, it is given the opportunity to express preferences on offered contracts, based on its desire to balance the system in a context where flexibility needs to be properly priced. We show how the design can be extended to include coupled electricity markets.

One drawback of our design is the complexity of package bidding, which is a general problem for all package auctions. Package bidding may cause less sophisticated bidders to make mistakes or deter them from participating in the first place. This may reduce social welfare. To meet the challenge, one could consider the use of proxy agents (well-known in eBay auctions, see e.g. Ockenfels and Roth, 2002) in order to minimise the potential loss in welfare. The mechanism could offer the bidders to submit bids to a neutral-programmed proxy agent. This will ensure some kind of bid-guidance or limited bidding combinations to simplify decisions and potential errors from bidders. Proxy bidders can also be subject to regulation which reduces the potential for gaming. This will secure a professional bidding market. We will explore this in future work.

VI. REFERENCES

CER (2015). *Regulator's 2014 National Report to the European Commission: Commission for Energy Regulation (CER) - Ireland*. Ireland. Available at: http://www.ceer.eu/portal/page/portal/EER_HOME/EER_PUBLICATIONS/NATIONAL_REPORTS/National_Reporting_2015/NR_En/C15_NR_Ireland-EN.pdf.

DotEcon (2015), *DS3 System Services auction design report*. London: DotEcon, Available at: http://www.dotecon.com/assets/images/SEM-15-105a-DotEcon-DS3-System-Services-Auction-Design-Report-December-2015.pdf.

IEA-RETD (2015). *Integration of Variable Renewable Energy: Volume II: Case studies.* Mott MaxDonald. Available at: http://iea-retd.org/wp-content/uploads/2015/01/Report-Volume-II-Case-studies.pdf.

ISO-NE (2013a). *ISO New England Manual for Market Operations Manual M-11*. Holyoke: ISO-New England. Available at: http://www.iso-ne.com/participate/rules-procedures/manuals.

ISO-NE (2013b). *ISO New England Manual for Forward Reserve Manual M-36*. Holyoke: ISO-New England. Available at: http://www.iso-ne.com/participate/rules-procedures/manuals.

ISO-NE (2014). *Introduction to New England's Energy & Ancillary Markets*. Holyoke: ISO-New England. Available at: http://isonewengland.net/static-assets/documents/2014/08/iso101-t3-mktcore.pdf.

ISO-NE (2015a). *Section II ISO New England Open access transmission tariff*. Holyoke: ISO-New England. Available at: http://www.iso-ne.com/static-assets/documents/regulatory/tariff/sect_2/oatt/sect_ii.pdf.

ISO-NE (2015b). *ISO New England Operating Procedure No. 8 Operating Reserve and Regulation*. Holyoke: ISO-New England. Available at: http://www.iso-ne.com/rules_proceds/operating/isone/op8/op8_rto_final.pdf.

ISO-NE (2016). *Forward Reserve Market and Real-Time Reserve Pricing*. Holyoke: ISO-New England. Available at: Available at: http://www.iso-ne.com/markets-operations/markets/reserves.

Kiesling, L. and Giberson, M. (1997). 'Electric network reliability as a public good', *Perspectives*, Vol 11, pp. 1-7.

Krishna, V. (2009). Auction Theory, 2nd edn, Academic Press.

Joskow, P. and Tirole, J. (2007). 'Reliability and competitive electricity markets', *RAND Journal of Economics*, Vol. 38(1), pp. 60-84.

Newbery, D., Strbac, G. and Viehoff, I. (2015). 'The benefits of integrating European electricity markets', EPRG Working Paper 1504, University of Cambridge.

National Grid (2013). *Firm Fast Reserve Explanation and Tender Guidance Document*. London: National Grid. Available at: http://www.nationalgrid.com/uk/electricity/balancing/services/reserveservices/fastreserve/

National Grid (2014a). *Firm Frequency Response Pro-Forma Sheets*. London: National Grid. Available at: http://www2.nationalgrid.com/uk/services/balancing-services/frequency-response/firm-frequency-response/.

National Grid (2014b). *Firm Frequency Response Review Detailed Change Proposals (DCP - 13)*. London: National Grid. Available at: http://www2.nationalgrid.com/UK/Services/Balancing-services/Frequency-response/Firm-

Frequency-Response/Firm-Frequency-Response-Information/.

National Grid (2014c). *Reactive Power Market Reactive Market Report Thirty Fourth Tender Round for Obligatory and Enhanced Reactive Power Service*. London: National Grid. Available at: http://www2.nationalgrid.com/UK/Services/Balancing-services/Reactive-power-services/Enhanced-Reactive-Power-Services/ERPS-Information/.

National Grid (2014/2015). *Procurement Guidelines Report*. London: National Grid. Available at: http://www2.nationalgrid.com/UK/Industry-information/Business-compliance/Procurement-and-System-Management-Documents/. .

National Grid (2015a). *Short Term Operating Reserve E-Tender Guidance Document*. London: National Grid. Available at: http://www2.nationalgrid.com/uk/services/balancing-services/reserve-services/short-term-operating-reserve/.

National Grid (2015b). *Short Term Operating Reserve General Description of the Service*. London: National Grid. Available at: http://www2.nationalgrid.com/uk/services/balancing-services/reserve-services/short-term-operating-reserve/.

National Grid (2015c). *Firm Frequency Response Frequently Asked Questions*. London: National Grid. Available at: http://www2.nationalgrid.com/uk/services/balancing-services/frequency-response/firm-frequency-response/.

National Grid (2016a). *Fast Reserve*. London: National Grid. Available at: http://www2.nationalgrid.com/uk/services/balancing-services/reserve-services/fast-reserve/.

National Grid (2016b). *Reactive Power Market Obligatory and Enhanced Reactive Power Services Invitation to Tender and Guidance Notes for the Completion of Tenders*. London: National Grid. Available at: http://www2.nationalgrid.com/UK/Services/Balancing-services/Reactive-power-services/Enhanced-Reactive-Power-Services/ERPS-Information/.

Ockenfels, A and Roth, AE (2002). 'The Timing of Bids in Internet Auctions: Market Design, Bidder Behavior, and Arificial Agents'. *AI Magazine*, Fall 2002, pp. 79-88.Ofgem (2014). *Electricity Interconnectors factsheet*. London: Ofgem.Available at: https://www.ofgem.gov.uk/sites/default/files/docs/2014/05/electricity_interconnectors_factsheet.pdf.

Ofgem (2016). *Electricity interconnectors*. London: Ofgem. Available at: https://www.ofgem.gov.uk/electricity/transmission-networks/electricity-interconnectors.

Schulze W., Thomas, R. J., Mount, T., Schuler, R., Zimmerman, R., Cross, G., Tylavsky, D., Shawhan, D. and Toomey, D. (2008). *Reliability, Electric Power, and Public vs. Private Goods: A New Look at the Role of Markets*. Cornell University.

SEM (2013). *Single Electricity Market: DS3 System Services*. Ireland. Available at: http://www.allislandproject.org/GetAttachment.aspx?id=7ddb3f7a-a84f-488e-91b4-87e03ac37e71.

Strbac, G., Konstantelos, I., Pollitt, M. and Green, R. (2016), *Delivering a Future Proof Energy Infrastructure*, Report for the National Infrastructure Commission, Imperial College London and University of Cambridge Energy Policy Research Group, February

Zhan, R.L. (2008). 'Optimality and efficiency in auctions design: A survey'. In: *Pareto Optimality, Game Theory and Equilibria*. Springer, New York.

VII. APPENDIX

The appendix shows the products currently defined in Ireland and potential new products which might be defined in the future, the auction mechanism used to procure them and how often they are conducted.

Table 6

Existing products in Ireland

Product[1]	**Feature**[1]	**Mechanism**[2]	**Conducted**[3]
Steady-state reactive power	Voltage control	Regulated payments	Annually
Primary Operating Reserve	Sustainable from between 5s to 15s	Regulated payments	Annually
Secondary Operating Reserve	Sustainable from between 15s to 90s	Regulated payments	Annually
Tertiary Operating Reserve 1	Sustainable from between 90s to 5min	Regulated payments	Annually
Tertiary Operating Reserve 2	Sustainable from between 5min to 20min	Regulated payments	Annually
Replacement Reserve (De-Synchronised)	Sustainable from between 20min to 1h	Regulated payments	Annually

Replacement Reserve (Synchronised)	Sustainable from between 20min to 1h	Regulated payments	Annually

Note 1: SEM (2013), Note 2: IEA-RETD (2015), Note 3: CER (2015)

Table 7

New products in Ireland

Product[1]	**Feature**[1]	**Mechanism**	**Conducted**
Synchronous Inertial Response	Immediately available	To be decided	To be decided
Fast Frequency Response	Response time is within 2s and duration is at least 8s	To be decided	To be decided
Dynamic Reactive Response	Voltage control, Rise Time no greater than 40ms, Setting Time no greater than 300ms	To be decided	To be decided
Ramping Margin 1 Hour	Ramp-up requirement is 1h and duration is 2h	To be decided	To be decided
Ramping Margin 3 Hour	Ramp-up requirement is 3h and duration is 5h	To be decided	To be decided
Ramping Margin 8 Hour	Ramp-up requirement is 8h and duration is 8h	To be decided	To be decided
Fast Post-Fault Active Power Recovery	Must remain connected to the system for at least 15min	To be decided	To be decided

Note 1: SEM (2013)