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Innovating grid regulation to regulate grid innovation: From the Orkney Isles to Kriegers Flak via Italy

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ABSTRACT

In the current context of a decarbonizing electricity system, grid innovation is needed to deal with the main challenges of integrating distributed generation, demand and storage, and large-scale renewable energy sources. Grid companies however have disincentives to innovate under the conventional regulatory framework, and if they do innovate, they are confronted with grid users that have disincentives to participate in the innovation. This paper analyzes three empirical cases where state of the art regulatory frameworks have been successful at stimulating grid innovation. The main lesson learned from the cases is that there is experience with addressing the disincentive of grid companies to innovate, but the participation of grid users in the innovation is much more an open issue.

1. Introduction

The key objectives of the European Union (EU) for the year 2020 are to reduce energy consumption by 20% with respect to 2020 forecast, to reduce greenhouse gas emissions by 20% with respect to 1990 levels, and to have 20% of total energy consumption in 2020 produced with renewable energy sources (RES). Meanwhile, even more ambitious objectives are being developed to go towards a complete decarbonization of the electricity system by 2050. Transforming the electricity system so that it can accommodate a massive amount of low carbon technologies cost efficiently asks for innovation.

Even though the need for innovation is increasing, there are indications that the R&D spending by electricity companies and to a lesser extent the R&D spending by major supplier of electrical equipment has been declining [1–6]. Jamasb and Pollitt [7] argue based on a literature review that this can be explained by the liberalization process to the extent that this process has resulted in smaller firms that are less vertically integrated and increasingly privatized, while they are now operating in a competitive and uncertain context.

The liberalization indeed introduced competition in the generation and supply of electricity, but electricity grids (transmission and distribution grids) remained a monopolistic activity[1]. Still, the sector reforms have also profoundly impacted grids and their regulatory frameworks. The resulting conventional regulatory framework for grids is mainly about improving the cost efficiency of grid companies and improving the quality of the grid services they provide (Glachant [8,9]; Joskow [10]; Agrell [11]). Important improvements in value for money grid services have resulted (Jamasb and Pollitt [12]), but grid innovation has been limited. Connor and Mitchell [13] and Bauknecht [14] argue that grid companies under the conventional regulatory framework basically keep on doing the same thing, only with reduced costs.

The contribution of this paper is to discuss the shortcomings of the conventional regulatory framework with regards to grid innovation, and the experiences with state of the art regulatory frameworks that already address these shortcomings. The paper starts by introducing the role of grids in a decarbonizing electricity system. The paper then continues with an assessment of the shortcomings of the conventional regulatory frameworks with regards to grid innovation, first from the perspective of grid companies and then

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[1] Note that in this paper, we do not enter into the debate of where in the electricity system is the optimal balance between regulated versus competitive activities. We take this balance as it is in European practice, even though this is still debated, especially for metering, and more recently also for electric vehicle charging stations.

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from the perspective of grid users. In both assessments, we discuss three empirical case studies (Orkney Isles, Italy, and Kriegers Flak) where state of the art regulatory frameworks have been successful at stimulating innovation in grids.

2. Role of grids in a decarbonizing electricity system

The three main challenges for grids in the current context of a decarbonizing electricity system are (Perez-Arriaga [15]): 1) integration of Distributed Generation (DG)[2]; 2) integration of demand (demand response and energy efficiency) and storage and 3) integration of large-scale (RES).

In practice, these challenges often appear mixed. For instance, the massive integration of plug-in electrical vehicles would include elements of DG plus demand and storage. We have however selected cases to allow for a separate discussion of the three main challenges with a case on the integration of DG (Orkney Isles), a case on the integration of demand (Italy), and a case on the integration of large-scale RES (Kriegers Flak). These cases have also been selected to include the European diversity of regulatory frameworks encompassing Denmark, Germany, Italy, Sweden, and the United Kingdom. The three cases are briefly introduced here with a special focus on the potential innovative solutions enabling a decarbonized electricity system.

2.1. Integration of distributed generation in the Orkney Isles

The Orkney Isles in the north of Scotland are well-known for their attractive wind energy potential. The Orkney Isles grid is however a typical rural distribution grid where demand is low and the connection with the mainland transmission grid is weak because it was designed to feed this low demand. The Orkney Isles grid, like most distribution grids, is passive in the sense that it does not have the necessary infrastructure to control the output of the generators it connects, i.e. it has not been designed to host generation.

For this reason, the Orkney Isles distribution company could not connect more DG by 2005, while there was still a lot of generation potential. To remedy this situation, the Orkney Isles distribution company, supported by the energy regulator in the UK, became one of the first to implement an active grid management system for distribution grids. This can avoid expensive upgrades to the distribution grid that would only be used in some hours of the year where demand is low and the wind is blowing at full capacity. In the case of the Orkney Isles, almost 50% of additional distributed generation can be connected to the Orkney Isles distribution grid with this innovative solution without having to expand the distribution grid or the connection to the mainland, instead the generation output is curtailed in the few hours of the year where demand is low and the wind is blowing at full capacity (Currie et al. [16]).

2.2. Integration of demand in Italy

The Italian situation with an untapped potential at the demand side to reduce consumption or shift consumption from peak hours to off-peak hours so that investment in more expensive peak generation units can be avoided is a very typical situation in Europe and elsewhere. If consumers, like household, could increasingly manage their consumption, or contract with third parties to manage their consumption, or buy electric appliances that self-manage their consumption, this potential would increasingly materialize. This however requires real time consumption metering, consumer feedback, automation, increased billing frequency, etc, while the conventional metering and communication infrastructures in distribution grids are not designed to facilitate these kinds of services.

The distribution companies in Italy, supported by the Italian energy regulator, became one of the first to implement a large-scale deployment of so-called smart meters with 90% of low voltage customers having such a meter in 2010. Distribution companies have achieved significant operational cost savings by using these meters for automatic meter readings, improved billing, etc (Gallo [17]).

2.3. Integration of large-scale RES in Kriegers Flak

The Kriegers Flak area between Denmark, Germany and Sweden is well-known for its off-shore wind energy potential. The area is however deep into the Baltic Sea where there is no transmission grid to connect to. Traditionally, the involved transmission companies would each develop a separate solution for the wind farms that fall under their responsibility (Swider et al. [18]). However, there is often an opportunity to develop a joint solution that would interconnect the wind farms, i.e. an off-shore transmission grid. In moments of low wind, this off-shore grid could then be used to exchange energy between the countries. This is especially interesting in the case of Kriegers Flak where there are substantial trade opportunities between the involved countries. This off-shore grid solution would also be more reliable because the wind energy generated by one country's off-shore wind farm can escape to the mainland via the connection of another country's off-shore wind farm in case one of the connections would fail.

The joint feasibility study by the transmission companies[3] in 2010 concluded that the higher costs of an innovative off-shore grid solution are more than justified by the significantly higher benefits. The technology that the transmission companies intend to use for the off-shore grid solution, i.e. a multi-terminal HVDC-VSC system (Cole and Belmans [19]), would be the first large-scale implementation of its kind. This technology is considered to be exactly what Europe needs to realize its vision of a super trans-national grid to unlock the large-scale RES potentials. However, contrary to the case of Orkney Isles or Italy, in the case of Kriegers Flak it is uncertain whether the innovation will be implemented because it requires a cooperative and proactive approach from the transmission companies to avoid coordination problems, and cooperation from wind developers, which as we will discuss in what follows is far from trivial under the conventional regulatory framework.

From these three cases it can be seen that innovation process (innovative solution) requires the participation of regulated grid companies (distribution and transmission) as well as the grid users (DG, electricity consumers, and off-shore wind producers). In the following two sections we look at the regulatory frameworks from these two perspectives.

3. Perspective of grid companies

Today's preferred approach for regulators is to agree ex-ante on the allowed revenue of grid companies so that these companies can make a profit by cutting costs.[4] The longer the period over which

[2] Distributed generation corresponds to all medium/small-scale power plants connected to the distribution system. DG includes Renewable Energy Sources (RES) and Combined Heat and Power (CHP) supply technologies.

[3] Kriegers Flak Combined Grid Solution, Feasibility Study, available at:http://www.50hertz-transmission.net/cps/rde/xbcr/trm_de/2010-02-24_Final_Feasibility_Study_Public.pdf

[4] This typical regulatory scheme is often called *price cap* or *revenue cap* indicating that the revenue of the company is agreed ex-ante and it is independent from the realized cost of the company. The regulatory framework of grid companies has changed the last two decades going from *cost of service* schemes to more price cap or revenue cap schemes.

the revenues are fixed, the stronger the incentive to cut costs during this period, but the more difficult it is to agree ex-ante on the allowed revenue. In practice, regulatory periods are limited to 3–5 years so that at regular intervals the remuneration can be adjusted based on the information of actual costs in the previous period. Limiting the regulatory period is necessary due to cost uncertainties and information asymmetries between the regulatory authority and the grid company.

As it is more difficult to incentivize grid companies to reduce capital expenditures (CAPEX) than operating expenditures (OPEX)[5], in practice, OPEX is often subject to stronger efficiency incentives than CAPEX.

Besides the inputs (resources), also the outputs (grid services) of grid companies have been increasingly regulated since the liberalization process has been introduced. A typical example of output regulation is quality of service regulation[6], but output regulation has also been applied to system operation costs in distribution (e.g. losses) and in transmission (e.g. losses, congestion and balancing)[7]. The use of output regulation in practice is however limited because it can be difficult to define and measure outputs and how inputs lead to outputs can also be uncertain.

In what follows, we first discuss the shortcomings of the conventional regulatory framework with regards to innovation from the perspective of the grid company, and then discuss the state of the art regulatory frameworks that have been applied to address these shortcomings in the cases that we introduced in Section 2.

3.1. Shortcomings of the conventional regulatory framework

Under the conventional regulatory framework, innovation often becomes a cost (OPEX) that can be cut so that grid companies from one regulatory period to the next keep on doing the same thing, only with reduced costs. In what follows, we illustrate for the three cases introduced in Section 2 that grid companies can even have incentives to work against the integration of DG, the integration of demand, or the integration of large-scale RES.

Massive DG, as in the Orkney Isles case, for instance increases losses in the distribution grid, while grid companies are often incentivized to decrease losses. Furthermore, the main innovation we expect from distribution companies to deal with massive DG (i.e. active grid management) implies an increase in OPEX (i.e. managing DG) to avoid an increase in CAPEX (i.e. an upgrade of the distribution grid), while the distribution company is incentivized to do the opposite.

Integrating demand, as in the case of Italy, can achieve energy savings and peak energy savings, while the distributed volumes are typically revenue drivers of distribution companies. By facilitating a consumption reduction or a shift in consumption from peak to off-peak hours, the needed electricity system capacity also reduces, including the needed distribution capacity, so that also here we are expecting grid companies to increase OPEX (i.e. facilitation of information services to grid users) to avoid an increase in CAPEX (i.e. an upgrade of the distribution grid), while they are incentivized to do the opposite.

Massive RES, as in the Kriegers Flak case, requires proactive transmission grid planning and development, while grid companies are typically not allowed to anticipate costs, i.e. they are only supposed to react when the RES developer applies to be connected. The innovative off-shore grid solution that the transmission grid companies are pursuing also implies a higher cost for them than the conventional separate solution, while the potentially higher benefits are not for them.

3.2. State of the art regulatory frameworks

In what follows, we look for the state of the art regulatory frameworks that have been stimulating the grid innovations in the three case studies introduced in Section 2.

3.2.1. Integration of distributed generation in the Orkney Isles

Distribution companies in the UK have a target for how much DG capacity they are supposed to connect and their allowed revenue for connecting this DG is agreed ex-ante. Moreover allowed revenue is automatically adjusted with ex-ante fixed amount when the DG connection is higher than the target. Thus, distribution companies in the UK have an incentive to effectively and efficiently connect DG.

Grid innovations, such as the active grid management system in the Orkney Isles, are stimulated by two schemes in the UK. For the development of this system, the distribution company could rely on the Innovation Funding Incentive (IFI) scheme that is a form of innovation input regulation, providing R&D funding for grid innovation by grid companies. Besides funding, the distribution company in Orkney Isles is also rewarded for using this active grid management system to connect additional DG through the Registered Power Zone (RPZ) scheme. This scheme is therefore a form of innovation output regulation.

To sum up, the state of the art regulatory framework in the UK addresses innovation separately and also recognizes that there are different innovation stages that can require a different regulation. Output regulation can indeed help to bring nearly mature technologies to commercialization, but it certainly has its limitations for infant technologies for which innovation input regulation can be more appropriate.

3.2.2. Integration of demand in Italy

Distribution companies in Italy are obliged to deploy smart meters with certain minimum requirements, but the obligation has been supported by a dedicated metering tariff that incentivizes a cost efficient deployment. Metering assets are rewarded with higher capital remuneration (investment in innovation is riskier), but they also have stronger incentives to cut costs (new assets have not yet been subject to cost cutting incentives so that there is still a higher potential to cut costs).

Grid innovations, such as smart metering, are stimulated by two schemes in Italy. For R&D, there is a dedicated component in the grid tariff, and innovation projects can receive higher capital remuneration. To make sure that this public money is also used for the public benefit, grid companies that want to receive funding from these schemes are required to make the research results publicly available, and the technologies that are developed under these schemes need to be non-proprietary. Both schemes are a form of innovation input regulation.

To sum up, the state of the art regulatory framework in Italy therefore addresses innovation separately and also recognizes that there are different innovation stages that can require a different regulation. The Italian practice is mainly input regulation, but funding is not unconditional so that indirectly also the output is regulated.

3.2.3. Integration of large-scale RES in Kriegers Flak

Transmission companies in the Kriegers Flak area are expected to cooperate. The ministers of Sweden, Germany and Denmark

[5] One of the reasons is that CAPEX is used for investments whose benefits are typically not realized in the same regulatory period as the costs have to be made.

[6] For a detailed discussion on the theory and practice of quality of service regulation, see for instance Joskow [10], Sappington [20], and Fumagalli et al. [21].

[7] For a detailed discussion on incentive schemes for these kinds of system operation costs, see for instance Joskow [10], Léautier [22], Vogelsang [23] and Stoft [24].

signed an agreement on off-shore wind power cooperation and the European Economic Recovery Program has committed 150 million Euros for the Kriegers Flak off-shore grid solution.

Grid innovations, such as the off-shore grid solution for Kriegers Flak, are however subject to the national regulatory frameworks, which are not aligned. For instance, in Sweden it is the wind developer instead of the transmission company that is responsible to connect its off-shore wind farm to the mainland transmission grid. Not surprisingly, the Swedish transmission company decided for the moment not to develop its part of the joint venture, while the Danish and the German counterparts are still pursuing this innovation.

To sum up, the state of the art regulatory framework in Europe recognizes that certain grid innovations can be of a common European interest which can then also justify European funding.

4. Perspective of grid users

Today's preferred approach for regulators is to set cost reflective charges for grid services with the idea that then grid users would consume these services cost efficiently. Cost reflective charges for grid services (and the definition of grid services) are however difficult to implement because of their complexity, and because of the information asymmetry between the regulator and the grid company.

Furthermore, grid users are not only driven by grid charges, they are driven rather by the activities for which they produce or consume a certain amount of electricity, and for which they then automatically also consume a bundle of grid services. This is especially the case in a decarbonizing electricity system with support schemes for low carbon technologies, such as RES or DG support schemes that strongly incentivize these generators to produce to maximize their subsidies.

In what follows, we first discuss the shortcomings of the conventional regulatory framework with regards to innovation from the perspective of the grid user, and then discuss the state of the art regulatory frameworks that have been applied to address these shortcomings in the cases that we introduced in Section 2.

4.1. Shortcomings of the conventional regulatory framework

Under the conventional regulatory framework, the participation of grid users to the ongoing innovation is often problematic. In what follows we illustrate for the three cases introduced in Section 2 that grid users often have incentives to work against innovations by grid companies.

Active (distribution) grid management implies that generators can be curtailed, i.e. they can be denied access to the grid in moments of peak generation when the distribution grid gets congested. Even if such curtailment can be limited to the few hours where demand is low and the wind blows at full capacity, generators have a disincentive to participate in such an innovation. Support schemes that reward DG based on their output without considering the system operation constraints (e.g. congestion, security, etc), further aggravate this disincentive.

Smart metering implies that consumers can receive market signals in their homes, but this requires access to the meter which requires more than just installing the meter for the use of the distribution companies (Benzi [25]). And even if consumers have full access to the meter, regulated end-consumer prices as in the case of Italy can (partly) block these market signals so that grid users have a disincentive to participate in such an innovation.

Off-shore grids jointly developed across borders, as in the Kriegers Flak case, require cooperation from wind developers, but wind developers have a disincentive to participate in such an innovation because they often have priority grid connection and access rights.

4.2. State of the art regulatory frameworks

In what follows, we look for the state of the art regulatory frameworks that have been stimulating the participation by grid users to the ongoing grid innovation in the three case studies introduced in Section 2.

In the Orkney Isles case, participation to the active grid management system is mandatory for generators that want to newly connect to the distribution grid. By 2009, the active grid management system had been completed, commercial arrangements had been developed, and two new generators had been connected. DGs that were already connected before this system has been deployed do not have to participate, and they are also not incentivized to participate so that they do not.

In the case of Italy, access to the meter has initially been limited, but is improving more recently. Distribution companies have for instance been obliged to install a visual display that provides customer feedback enabling their participation to this innovation.

In the case of Kriegers Flak, the Swedish wind park has been postponed and the Danish wind park has been reduced from 400 MW to 300 MW, all elements that of course complicate the development of the off-shore grid.

To sum up, the state of the art regulatory framework is not yet adequately addressing the participation of grid users to the ongoing grid innovations.

5. Conclusions

The conventional regulatory framework that has been successful at incentivizing grid companies to provide value for money grid services, has its shortcomings in the current context where grid innovation is needed to allow Europe to achieve its ambitious energy policy targets. The main shortcomings of the conventional regulatory framework are that grid companies have disincentives to innovate, and if they do innovate, they are confronted with grid users that have disincentives to participate in the ongoing innovation.

For this paper, we selected three empirical cases where grid companies have deployed (or intend to deploy) innovative grid technologies to integrate DG (Orkney Isles), to integrate demand (Italy), and to integrate large-scale RES (Kriegers Flak). The three cases have in common that the disincentives for grid companies to innovate have been addressed by state of the art regulatory frameworks that include dedicated schemes that support this innovation. This suggests that innovation by grid companies needs to be regulated separately from the conventional regulatory framework.

In the case of Orkney Isles, the distribution company benefited from innovation funding support as well innovation outcome rewards for the active grid management scheme it developed and then also deployed. In the case of Italy, the distribution companies have been obliged to deploy smart meters, but the obligation has been supported by a dedicated metering tariff that incentivizes a cost efficient deployment. In the case of Kriegers Flak, the transmission companies have received political backing for the off-shore transmission grid they intend to develop jointly, and they have also been awarded with European funding support.

Even though from the perspective of grid companies, these state of the art regulatory frameworks started to address the shortcomings of the conventional framework with regards to grid innovation, the participation of grid users to the ongoing innovations is still largely an open issue. In the case of Orkney Isles, new

DGs are obliged to participate to the active grid management system, while already connected DGs do not participate. In the case of Italy, access to the smart meters is being improved to enable consumer participation. In the case of Kriegers Flak, the wind developers for whom the off-shore transmission grid is being developed do not have any incentive to participate in this innovation. In other words, the ongoing grid innovation will require additional innovation in grid regulation (hence the paper title).

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References

[1] Bell RA, Schneide TR. Balkanization and the future of electricity R&D. The Electricity Journal 1999;12(6):87–98.
[2] Dooley JJ. Unintended consequences: energy R&D in a deregulated energy market. Energy Pol 1998;26(7):547–55.
[3] Mayo JW, Flynn JE. The effects of regulation on research and development: theory and evidence. J Bus Univ Chicago 1988;61(3):321–6.
[4] Margolis M, Kammen DM. Underinvestment: the energy technology and R&D policy challenge. Science 1999;285:690–2.
[5] Ragwitz M, Miola A. Evidence from RD&D spending for renewable energy sources in the EU. Renewable Energy 2005;30:1635–47.
[6] Sterlacchini A. The R&D drop in European utilities: should we care about it? DRUID Working Paper 06–19. Danish Research Unit for Industrial Dynamics; 2006.
[7] Jamasb T, Pollitt M. Liberalisation and R&D in network industries: the case of the electricity industry. Res Pol 2008;37(6–7):995–1008.
[8] Glachant JM. Why regulate deregulated network industries? J Netw Indust 2002;3:297–311.
[9] Glachant JM. Regulating networks in the new economy. EUI RSCAS 2009/05, Loyola de Palacio Programme on Energy Policy.
[10] Joskow PL. Incentive Regulation in Theory and Practice: Electricity Distribution and Transmission Networks. AEI-Brookings Joint Center Working Paper 2005 No. 05–18.
[11] Agrell PJ, Bogetoft P. Network regulation under climate policy review. Regulatory Round Table 2010. Loyola de Palacio Programme on Energy Policy.
[12] Jamasb T, Pollitt M. Incentive regulation of electricity distribution networks: lessons of experience from Britain. Energy Pol 2007;35(12):6163–87.
[13] Connor P, Mitchell C. A review of four European regulatory systems and their impact on the deployment of distributed generation. 2002 Sustelnet Project Report.
[14] Bauknecht D, Leprich U, Späth P, Skytte K, Esnault B. Regulating innovation and innovating regulation. 2007 DG Grid Project Report.
[15] Pérez-Arriaga I. Regulatory Instruments for Deployment of Clean Energy Technologies. EUI RSCAS 2010/25, Loyola de Palacio Programme on Energy Policy.
[16] Currie RAF, Ault GW, Macleman DF, Fordyce RW, Smith, MA, Mcdonald JR. Design and trial of an active power flow management scheme on the North-Scotland network. Proceedings 19th International Conference on Electricity Distribution (CIRED) 2007, Vienna.
[17] Gallo L. Già pronti per la rivoluzione delle smart grid. Nuova Energia. n°2/2010.
[18] Swider DJ, Beurskens L, Davidson S, Twidell J, Pyrko J, Prüggler W, et al. Conditions and costs for renewables electricity grid connection: examples in Europe. Renewable Energy 2008;33:1832–42.
[19] Cole S, Belmans R. Transmission of bulk power, the history and applications of voltage-source converter high-voltage direct current systems. IEEE Ind Electron Mag; 2009, September.
[20] Sappington D. Regulating service quality: a survey. J Regul Econ 2005;27(2):123–54.
[21] Fumagalli E, Lo Schiavo L, Delestre F. Service quality regulation in electricity distribution and retail. Berlin Heidelberg: Springer-Verlag; 2007.
[22] Léautier TO. Regulation of an electric power transmission company. Energy J 2000;21:61–92.
[23] Vogelsang I. Electricity transmission pricing and performance based regulation. Energy J 2006;27(4):97–127.
[24] Stoft S. Problems of transmission investment in a deregulated power market. In: Lévêque, editor. Competitive electricity markets and sustainability. Edward Elgar; 2006.
[25] Benzi F. Smart Meters Interfacing the Households. Proceedings AEIT Annual Conference 2009, Catania.