EUI Working Papers

RSCAS 2010/45
ROBERT SCHUMAN CENTRE FOR ADVANCED STUDIES
Florence School of Regulation

“SMART REGULATION FOR SMART GRIDS”

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EUI Working Paper **RSCAS** 2010/45

ISSN 1028-3625

Printed in Italy, May 2010
European University Institute
Badia Fiesolana
I – 50014 San Domenico di Fiesole (FI)
Italy
www.eui.eu/RSCAS/Publications/
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Abstract

Climate change and security of supply policies are driving us towards a decarbonization of the electricity system. It is in this context that smart grids are being discussed. Electricity grids, and hence their regulatory frameworks, have a key role to play in facilitating this transformation of the electricity system. In this paper, we analyze what is expected from grids and what are the regulatory tools that could be used to align the incentives of grid companies and grid users with what is expected from them. We look at three empirical cases to see which regulatory tools have already been applied and find that smart grids need a coherent regulatory framework addressing grid services, grid technology innovation and grid user participation to the ongoing grid innovation. The paper concludes with what appears to be a smart regulation for smart grids

Keywords

Regulation, innovation, electricity, grids, transmission, distribution

1. Introduction[*]

Climate change and security of supply policies are driving us towards a decarbonization of the electricity system. The main challenges for grids in this context are the system integration of Distributed Generation (DG), integration of demand and storage, and integration of large scale Renewable Energy Sources (RES) (e.g. Perez-Arriaga, 2010). It is in this context that smart grids are being discussed at the national, at the European (e.g. Strategic Energy Technology – SET- Plan), and at the international level.

The motivation for this paper is the growing awareness that making grids smarter is about more than grid technology innovation; it also requires revisiting the regulation of grid services, and the regulations that affect the participation of grid users to the ongoing grid innovation. The contribution of this paper is then to investigate what is a smart regulation for grids by looking at their three complementary dimensions, i.e. grid technology innovation, new grid services, and grid user participation.

The paper starts by discussing what is expected from grids when dealing with the main challenges in a smart grids context. The paper consequently discusses the regulatory tools that could be used to align the incentives of grid companies and users with the new expectations.
The paper then analyzes three empirical cases to see which tools have already been applied and where there is room for improvement. They are: a case on the integration of DG (Orkney Isles), a case on the integration of demand and storage (Italy), and a case on the integration of large scale RES (Kriegers Flak). The paper concludes with what appears to be a smart regulation for smart grids.

2. What is expected from grids?

The liberalization of the electricity industry has had a profound impact on what is expected from grids and the regulatory frameworks have been implemented accordingly (Glachant, 2002). The main objective was to get value for money in the delivery of grid services[1], i.e. improving cost efficiency and quality of service (Joskow, 2006a), and important improvements have resulted.[2] While grids are still in the process of being adapted to this new situation, they are already facing new challenges coming from the decarbonization of the electricity system (Pollit, 2008 and Glachant, 2009).

The decarbonization of the electricity system is a high priority in the European context. Electricity grids, and hence the regulatory framework, have a key role to play in facilitating this transformation of the energy supply, the energy consumption and the electricity system. Key objectives of the European Union (EU) for the year 2020 are to increase RES to 20% of total energy consumption, reduce energy consumption by 20% with respect to 2020 forecast and reduce greenhouse gas emissions by 20% with respect to 1990 levels. More ambitious objectives are currently being developed for 2050 to go towards a complete decarbonization of the electricity system.

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[*] This work has been supported by the Italian energy company Enel. The analysis and conclusions are of course the sole responsibility of the authors.

[1] Non-discriminatory access was the third main expectation for grids after liberalization. Ensuring non discriminatory access is a key factor for the development of competition in generation, wholesale and retail markets. Different forms of unbundling and regulatory rules have been implemented to remedy incentives that grid companies that are part of vertically integrated utility with generation or retail activities may have to refuse or discourage access of competing generators or retailers to the grid. For the sake of simplicity we do not consider unbundling problems in this paper.

[2] Network regulation has played a signification role in reducing the cost of electricity supply and improving the quality of services. Jamasb and Politt (2007) for instance refer to the UK experience where the efficiency gains from incentive regulation of the distribution grids have been comparable to those gained from competition in the wholesale markets.

Decarbonization implies three main challenges for grids (Perez-Arriaga, 2010): 1) deployment and integration of DG; 2) development and integration of demand (demand response and energy efficiency) and storage and 3) enhancement of transmission grids, to allow reliable and efficient integration of significant levels 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. In this paper we will however consider the expectations separately.

The idea of smart grids and the corresponding regulatory framework appear in this new context. The process of making grids smarter should focus on the new challenges for grids: integration of DG, of responsive demand and storage and large scale RES. The regulatory framework designed to meet these challenges should not neglect the challenge coming from the liberalization process, which is to achieve value for money in the delivery of grid services.

In this section we analyze what the challenges imply in terms of expectations for grid services, grid technology innovation, and grid user participation. Such a categorization is useful to understand the different dimensions of the problem and will allow determining the appropriate regulatory tools in the next section (section 3). Table 1 lists the sample of European funded research projects that has been used to derive the main expectations discussed in this section.

Table 1: Sample of European funded research projects

Project acronyms	Integration of DG	Integration of demand and storage	Integration of large scale RES
DISPOWER, DG Grid, ELEP, Sustelnet, SA-WSN, OPENNODE, INTEGRIS, IRED, CRISTAL HIPERDNO	√		
Fenix, EU DEEP, ADDRESS, G4V	√	√	
SMARTHOUSE/SMARTGRID, SMARTCODE, ALISTORE, ESMA, SMART-A, OPEN METER		√	
TradeWind, EWIS, RELIANCE, DOWNWIND, Greennet, IRENE-40			√

2.1. Integration of Distributed Generation

Generation connected to the distribution grid can be distinguished between large and medium/small-scale and between RES and Combined Heat and Power (CHP) technologies. Only the medium and small scale-units of both RES and CHP are considered as distributed generation. To integrate more DG and to be able to do it timely, efficiently and without damaging quality of service, the main challenges, as expressed in European funded research studies on Distributed Generation, can be summarized as follow.

Grid services

Integrating DG massively implies planning and developing the grid proactively to be able to offer distribution grid services according to the need of newly connected DG. More flexibility should be introduced in the connection and access services, e.g. non-firm offers, in order to accommodate different characteristics of DG technologies (e.g. intermittency). Distribution grid operation should also facilitate the participation of DG in ancillary service and wholesale markets.

Grid technology innovation

Integrating DG massively implies also the incorporation of new technologies in the distribution grid. Indeed distribution grids should be managed actively, i.e. distribution companies will need to become system operators as much as grid owners. Active grid management implies new technologies and methods to ensure monitoring, communication and control capabilities of the distribution grid. Some technology components of active grid management still need to complete the innovation process towards standardization and competition.

User participation

To be integrated efficiently, distributed generators should be associated to the pro-active grid planning and development process that will be needed, and also in the active grid management schemes that will be implemented. Artificial barriers that reduce the grid user incentives to participate, such as grid tariffs that are not cost reflective, excessively complex connections rules, restrictions to participate in markets (like intra-day or balancing), inappropriate support schemes, etc, should be removed or corrected. New business models will need to include the delegation of control of DG from the individual units to third parties, i.e. Aggregators.

2.2. Integration of demand and storage

Integration of demand and storage is another key issue in the context of decarbonizing the electricity system. The expected benefits are energy savings and also peak savings to reduce the system capacity that is needed to deliver the required energy and to avoid the use of expensive peak power units. The latter can be achieved with flexible demand and storage facilities on the demand side. The main expectations to meet these challenges, as expressed in European funded research studies on demand and storage, can be summarized as follow.

Grid services

Integrating demand and storage implies increasing the flexibility of grid services for instance by introducing bi-directional information services. Grid companies have a key role to play in using and also producing valuable information for users of grid services. Note that in this paper we assume that metering is an activity that is part of distribution system, which is the case in most European countries, except for the UK and Germany. There may also be a role for grid companies in assisting energy consumers in interpreting and reacting to this information or facilitating the access to third party services companies (e.g. Aggregators, etc). Grid companies should also use the information themselves to coordinate and optimize the operation of the grid, for instance by applying active grid management.

Grid technology innovation

Integrating demand and storage also implies the incorporation of new technologies in the distribution grid, such as smart (bi-directional) meters and the corresponding information and communication infrastructure that is needed to enhance the monitoring and controlling capabilities of distribution grids. Some components necessary for active grid management also need to complete the innovation process towards standardization and competition (e.g. smart meters, etc).

User participation

To be integrated efficiently, consumers will need to receive more information, but they should also be incentivized to use this information. Artificial barriers that reduce the consumer incentives to participate, such as artificially low regulated end consumer prices, flat grid tariffs, restrictions to participate in markets, inappropriate energy efficiency schemes, etc, should be removed or corrected. New business models will need to include the delegation of control of demand from consumers to third parties, i.e. Aggregators, Energy Service Company, etc. Some components necessary for active participation of demand and storage also need to complete the innovation process towards standardization and competition (e.g. smart appliances, storage facilities, electrical vehicles, etc) or will need to be rolled-out by grid companies (e.g. recharging installations for electric vehicles)[3].

2.3. Integration of large scale RES

Large scale RES connected to the transmission network will play a key role in the context of a decarbonizing electricity system. Off-shore wind power and concentrated solar power are two of the most promising technologies. To be able to integrate more large-scale RES and to be able to do it timelier and efficiently, the main expectations, as expressed in European funded research studies on large scale RES, can be summarized as follows.

Grid services

Integrating large scale RES massively implies that grid reinforcements will be needed. Moreover, large amounts of intermittent offshore wind energy may considerably increase the costs of balancing the system and the capacity needed to achieve system adequacy. Connection and access services should also become more flexible (e.g. non-firm offers). The large-scale development of offshore wind energy also calls for a change in the grid planning and development philosophy (see e.g. Rious et al, 2009). A more proactive approach is needed (both for on-shore and off-shore) in close coordination with other transmission companies.

Grid technology innovation

Integrating large scale RES massively also implies the incorporation of new technologies in the transmission grid, such as HVDC for off-shore grids. Some components necessary for these kinds of grids still need to complete the innovation process towards standardization and competition.[4] This process will need to be coordinated with the electricity component manufacturers, at least for the definition of standards.

User participation

To be integrated efficiently, large scale RES should participate in the pro-active grid planning and development. Artificial barriers that reduce the grid user incentives to participate, such as grid tariffs that are not cost reflective, excessively complex connections rules, restrictions to participate in markets, inappropriate support schemes, etc, should be removed or corrected. New business models should be tested and implemented to increase the incentives of large-scale RES units, for instance to participate by providing ancillary services.

3. What are the regulatory tools to align incentives with what is expected?

The previous section highlighted the main expectations for grids in a context of decarbonizing the electricity system. This section presents a high level description of the regulatory tools that could align the incentives of grid companies and users with what is expected from them.

3.1. Regulation of grid companies

Grid companies like any other company use inputs to produce outputs. The inputs they use are their resources, including the technologies they use, and the outputs are the quantities and qualities of the

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[3] Just like with smart meters, an important decision will need to be made on what are regulated activities or infrastructures we want to be rolled-out by grid companies, and what can be left to competition.

[4] These technologies and their role in the context of a decarbonizing electricity system in Europe will be further discussed in the case study on Kriegers Flak (section 4.3.).

services they provide. Outputs by grid companies therefore also include innovations to provide new services or new service qualities.

When using inputs to produce outputs, grid companies make costs. Assuming that the outputs are well defined, two main types of regulation can be applied to remunerate the costs. Remuneration can be agreed before costs are made (then: ex-ante) or they can simply be reimbursed after they have been made (then: ex-post). Naturally, in terms of incentives for efficiency by cutting grid costs, the today’s preferred approach for regulation is to agree the allowed revenues ex-ante to limit the risk that grid users need to pay too much for the services they require from grids.[5] In practice it can however be difficult to regulate ex ante the costs of the new grid services for two main reasons. First, costs of these new services can be uncertain. Second, there is a renewed information asymmetry between the regulator and the grid company regarding these new services.

Because of similar difficulties, existing regulatory frameworks are already in between ex-ante and ex-post[6]. Typical price cap or revenue cap frameworks, often presented as ex-ante approaches, include price or allowed revenue revisions at the end of the regulatory period, which is fixed normally between 3 and 5 years. This way, at regular intervals, agreed remuneration can be adjusted using the information on actual costs in the previous period. Under such a scheme, the grid company still has an incentive to cut costs under its allowed revenue to increase its profit. The strength of the incentive depends on the length of the regulatory period and also on how the regulator uses the actual costs from one period to adjust the remuneration for the next period. Naturally, the incentive to cut costs will be stronger for longer regulatory periods. Moreover, price or revenue cap frameworks in practice do not include all types of costs. Certain costs can be ‘pass through’[7], implying that they are excluded from the ex-ante scheme, and are simply reimbursed ex-post.

Incentive schemes for grid companies to reduce costs need to be accompanied by a regulation of the services to provide, either by regulating the services (outputs) or by regulating the resources the grid companies use to provide the services (inputs). Theoretically, output regulation is superior to input regulation because the company normally has more capabilities and information (than the regulator) to choose the best combination of inputs to produce a given output.[8] Output regulation has been applied to grid companies since liberalization. The most typical example is quality of service incentives schemes.[9] Output regulation has also been applied to system operation costs in distribution (e.g. losses) and in transmission (e.g. losses, congestion and balancing).[10]

In practice, it can however be difficult to regulate outputs for four main reasons. First, it can be difficult to define and measure the output. Second, how inputs lead to outputs can be uncertain.

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[5] Ex-post schemes reduce the incentives to minimize costs. Ex-post schemes are also said to be prone to overinvestment because grid companies under such a scheme have a preference for capital inputs. This input distortion is known as the Averch-Johnson effect (see Averch and Johnson, 1962).

[6] There is an extensive literature on how these difficulties, which are in fact moral hazard and adverse selection problems, can be addressed with mixed approaches, such as profit sharing contracts and menu of contracts. See for instance Laffont-Tirole (1993), Joskow (2006a, 2006b, 2007, 2008a) and the Ofgem debate on RPI-X@20.

[7] Cost pass through is typically applied to costs that cannot be controlled by the grid companies, such as new taxation, pensions or transmission or distribution licensees.

[8] See for instance Maskin-Riley (1985), the Ofgem debate on RPI-X@20, and the ERGEG position paper on smart grids (E09-EQS-30-04).

[9] For a detailed discussion on the theory and practice of quality of service regulation, see for instance Sappington (2005), Joskow (2006a) and Fumagalli et. al. (2007). Dimensions of quality that have already been targeted by incentive regulation include: voltage dips, harmonics, flicker, unsupplied energy, number of outages, number of minutes per outage, company response times to outages caused by severe weather events, quality of telephone responses, customer satisfaction, etc.

[10] For a detailed discussion on incentive schemes for these kinds of system operation costs, see for instance Léautier (2000), Joskow and Tirole (2002), Vogelsang (2006), Stoft (2006) and Joskow (2006a).

Because of these difficulties, regulatory frameworks in practice tend to be in between input and output. Intermediate outputs or proxies[11] are often used when the actual outputs are difficult to measure or uncertain.[12] Third, regulatory periods are relatively short. Because of this time length difficulty, investment is difficult to regulate through output regulation because the resulting output is typically not realized in the same regulatory period as the costs are made while the outputs also typically span several regulatory periods.[13] This implies that incentivizing grid companies to cut costs is more difficult for capital expenditures (CAPEX) than for operating expenditures (OPEX). So in practice OPEX is often subject to stronger efficiency incentives than CAPEX. Fourth, in a context of regional grids with national regulations, there can be a need to coordinate output regulation to avoid opportunistic behavior. This is for instance the case for output regulation of congestion.[14]

To sum up: what is commonly referred to as incentive or performance based regulation is more ex-ante and more output based than what is commonly referred to cost-of-service regulation. Each regulatory framework for grids tries to balance incentives to efficiently produce valuable services against informational rents and uncertainties. Recognizing this, in what follows we discuss the regulatory tools that can be used to align the incentives of grid companies with the expectations in terms of new grid services, and grid technology innovation.

3.1.1. Smart regulation for the expected grid services

The incentives of grid companies to provide the services that are expected from them in a smart grids context will need to be corrected. At least to respond to the following regulatory challenges: 1) cost increase; 2) revenue decrease 3) lack of incentives.

First issue, the cost increase. The integration of DG, demand and storage, and large scale RES increases the grid costs[15]. Naturally, the grid company will not make significant new costs (e.g. grid reinforcement, voltage control, specific maintenance, smart meters, etc.), without a guaranteed adjusted remuneration. Several of the previously mentioned European funded research studies (Table 1) are indicating that the integration of DG, demand and storage, and large scale RES will increase the system operation costs (e.g. the cost of having losses or congestions) and also the costs of maintaining the quality of service (e.g. voltage quality and supply continuity), while many grid companies are strongly incentivized by the existing regulatory frame to reduce system operation costs and improve that quality of supply.

Second issue, the revenue decrease. The integration of DG, demand and storage reduces the grid revenues. Less energy delivered implies fewer services are needed, so to the extent that integrating more DG and more demand and storage reduces the energy that needs to be distributed or transmitted, the integration will reduce the grid company revenues (Perez-Arriaga, 2010).

Third issue, the lack of incentives. Grid companies do not have any particular incentive to integrate DG, demand and storage, and large scale RES. Even if integration costs and/or reduction in revenue would be taken into account in the grid company’s remuneration, this does not necessarily mean that the company has an incentive to do the best or to do better than the minimum required.

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[11] See for instance the ERGEG position paper on smart grids (E09-EQS-30-04) for a list of possible indicators that can be used for output regulation in the context of smart grids.

[12] The targeted dimensions of quality mentioned in footnote 9 are in fact proxies for quality of service.

[13] See for instance Stern (2006), Crouch (2006), Alexander (2006) or Guthrie (2006) for a detailed discussion on the regulation of investments.

[14] If a national grid company is strongly incentivized to reduce congestion costs nationally, it can ‘export’ them to the borders by limiting interconnection capacity. See for instance Glachant-Pignon (2005) or Lévêque et al (2009).

[15] See for instance Cossent et. al. (2009).

A smart regulation for grid services addresses these three issues. The first two issues can be dealt with by correcting the distortion of incentives in the existing regulatory frameworks, while the third issue is about introducing additional incentives. For this third issue there is a potential for output regulation. There are output proxies to measure how grid companies perform when integrating DG, demand and storage, and large scale RES, for instance the capacity of DG they connect (as in the Orkney Isles case in section 4.1.), the facilitated energy and peak savings on the demand side (as in the case of Italy in section 4.2.) and the large scale RES units they connect.

However, how inputs lead to these outputs is somewhat uncertain because the potential for DG, the potential energy and peak savings on the demand side, and the potential for large scale RES in the area where the grid company is active would need to be accounted for. National regulators will also need to coordinate their output regulations, at least for what concerns the integration of large-scale RES (as in the Kriegers Flak case in section 4.3.).

3.1.2. Smart regulation for the expected grid technology innovation

The incentives of grid companies to implement the grid technology innovation that is expected from them in a smart grids context will need to be corrected. At least to respond to the following regulatory challenges: 1) short term costs for long term benefits 2) distributed benefits and 3) missing standards. Of course they are general issues in technology innovation, but the electricity system is particularly affected, and the liberalization process did have a strong impact to reduce the R&D expenditures of electric utilities.[16]

First issue, the long term benefits with shorter term costs. Innovation in general (not only electricity grids, and not only the electricity sector) can suffer from market failures and regulation could be needed to correct them.[17] Failures include the limited appropriation of results (spill-over, etc), the outcome uncertainty and certain indivisibilities. Specifically when grid companies are strongly incentivized to cut costs, they treat innovation as a cost that can easily be cut. This behavior is inevitably reinforced when the potential benefits, if any, will only materialize in following regulatory periods[18]. For the expected integration of DG with active grid management and the integration of demand with smart metering, grid companies should substantially substitute CAPEX for OPEX, while they are incentivized to do the opposite (see section 3.1.: cutting OPEX is often stronger incentivized than cutting CAPEX) [19].

Second issue, the distributed benefits. The existence of network externalities implies that system-wide costs and benefits do not always coincide. Specifically for grid companies the benefits from grid technology innovation are often distributed among several grid users. For instance, active grid management allows DG developers to connect more timely and efficiently, and the same applies to off-shore grids for large scale RES developers. Another example is smart meters which can bring benefits to grid users (e.g., consumers, generators, etc) as well as to grid companies.

Third issue, the standards. In an innovation process, standards can be justified for several reasons notably: reducing variety of technology (to allow competition to reduce costs) and ensuring

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[16] Even though it is still debated, see for instance Markard and Truffer (2006), there are indications that the R&D expenditures of electric utilities declined as a result of the liberalization process. See for instance the empirical evidence presented in Mayo and Flynn (1988), Dooley (1998), Margolis and Kammen (1999), Bell and Schneider (1999) and Sterlacchini (2006). Based on a literature review, Jamasb and Pollit (2008) conclude that this is not surprising because the main aspects of the liberalization process are known to have a negative effect on R&D spending and technology adoption, i.e. the size reduction of companies, unbundling, and competition and uncertainty.

[17] See for instance Ferguson and Ferguson (1994) or Martin and Scott (1999).

[18] See for instance Bailey (1987), Dobbs (2004).

[19] Cohen and Sanyal (2004) show that incentive regulation (in the form of price cap) has significantly negative effects on utilities' internal and external R&D expenditures.

interoperability (to avoid lock-in technologies and stimulate the delivery of complementary goods or services).[20] We for instance expect grid companies to innovate with off-shore grids, but the involved technology (multi-terminal HVDC VSC) is not mature, i.e. standards are missing. Still, standards for off-shore grids are crucial to allow future interconnection of the national off-shore grids. We also expect grid companies and grid users to take advantage of smart meters, but again standards will be crucial.

A smart regulation for grid technology innovation should address these three issues. The first two can be dealt with by introducing specific regulatory measures for grid technology innovation, while the third is about anticipating and remedying potential problems with innovation.

There is a potential for output regulation to deal with these issues. Output regulation for grid services (see section 3.1.1.), can help to bring nearly mature technologies to commercialization (see the Orkney Isles case in section 4.1. and the case on Italy in section 4.2.). The output can also be incentivized over more than one regulatory period, even though reservations still apply (informational rent and uncertainty, see section 3.1.).

However, output regulation for grid technology innovation certainly has its limitations for infant technologies at the R&D stage or still in transition between R&D and commercialization (i.e. tests or pilot projects). Outputs at this stage are difficult to measure and R&D spending does not necessarily produce significant amount of outputs. This is why several regulators in Europe have started to design specific grid innovation funding mechanisms (e.g. see the UK in section 4.1., Italy in section 4.2. and European Commission in section 4.3.), which is then more an input type of regulation. A good mechanism will include competitive processes, extending the funding beyond grid companies, and it should also be possible for grid companies to do the necessary demonstration projects. The latter can require a specific regulatory frame where grid companies are allowed to test innovations that are not yet compatible with the existing general regulations. This could seem obvious as a “rule of reason for innovation”, but is often not authorized in practice by regulatory ruling conceived for a low grid technology innovation era. Note finally that R&D, just like capital costs for investments, produce outputs over several regulatory periods so that just like with investments, a specific regulated planning process could be required.

3.2. Regulation of grid users

When consuming or producing electricity, grid users automatically consume a bundle of grid services for which they are charged a regulated price. These charges are giving incentives to grid users, but grid users also have incentives from their own activities for which they consume and produce electricity. Recognizing this double issue, in what follows we discuss the regulatory tools that can be used to align the incentives of grid users with their expected participation to the ongoing innovation of grids.

3.2.1. Smart ‘grid’ regulation for expected grid user participation

The incentives for grid users to participate to the ongoing innovation in a smart grids context will need to be corrected. At least to respond to the following regulatory challenges: 1) definition of grid services; 2) charging for these grid services.

First issue, the definition of grid services. DG, demand and storage, and large-scale RES when they produce or consume electricity, also consume a bundle of grid services. The flexibility of these grid services, the rules and procedures associated with them, are not always in line with the expected smart

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[20] These two reasons have given origin to two types of standards: variety reduction standards and compatibility or interface standards (Swann, 2000).

grids optimum. For instance connection policies are not designed to deal with massive connection from DG, demand and storage, and large-scale RES, in combination with scarce grid capacity. The current policy is often simply “first come first serve”, which in general leads to distortions, especially in a context of massive connections.[21]

Second issue, the charging for grid services. To integrate DG, demand and storage, and large-scale RES cost efficiently, right price signals have to be given to the developers and consumers, while existing grid tariffs are frequently not cost reflective. Moreover, the grid users’ rewards to participate in the provision of ancillary services are often distorted that prevents their participation (see e.g. Vandezande et. al 2010). Worse, there can be rules that are simply barring them from participating.

A smart ‘grid’ regulation for the expected grid user participation should address these two issues. Grid company license conditions already oblige operators to charge cost reflectively, to facilitate competition and act non-discriminatory. However the operators have more capabilities and information than the regulator to optimize the grid charging structures. Output regulation for grid services (see section 3.1.1.), can incentivize grid companies to design more dynamic charging structures encouraging grid users to actively manage their demand for grid services in more expensive locations and at more expensive (peak) times.

3.2.2. Smart ‘user’ regulation for the expected grid user participation

The incentives for grid users to participate to the ongoing innovation in the way that is expected from them in a smart grids context will need to be corrected. At least to respond to the following regulatory challenges: 1) regulated end-consumer prices and other barriers; 2) support schemes.

First issue, the regulated end-consumer prices and other barriers. Integration of demand with smart meters implies receiving improved market signal information, but demand in many parts of Europe is still subject to regulated end consumer tariffs that block market signals.[22] Moreover, the participation of users may be limited by other barriers like high risk or economy of scale for offering new services (e.g. aggregation or energy saving services).

Second issue, the support schemes. Integration of DG with active grid management can imply reducing the production of DG, while the DG incentive under volume based support schemes is to produce as much as possible, and this incentive is typically stronger than the compensation from participating in active grid management. Integration of RES and DG with pro-active grid planning and development requires these grid users to participate to reduce the information asymmetry between them and the grid company, but they often have connection and access priorities.

A smart “user” regulation for the expected grid user participation addresses these two issues by revisiting the regulations that affect the grid user participation but which are external to grid regulation.

4. Case studies

This section analyzes three case studies to illustrate which tools have already been applied and where there is room for improvement. The three cases have been selected to focus on the main challenges, i.e. a case on integration of DG (Orkney Isles), a case on integration of demand and storage (Italy), and a case on integration of large scale RES (Kriegers flak). The cases also include the European

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[21] See for instance Tennet’s connection policy review by Brattle Group in 2007, which identifies possible distortions such as generators creating congestion to prevent rivals from connecting, or generators hoarding sites by submitting an excessive number of applications for new connections.

[22] See for instance the ERGEG Position Paper on user energy price regulation.

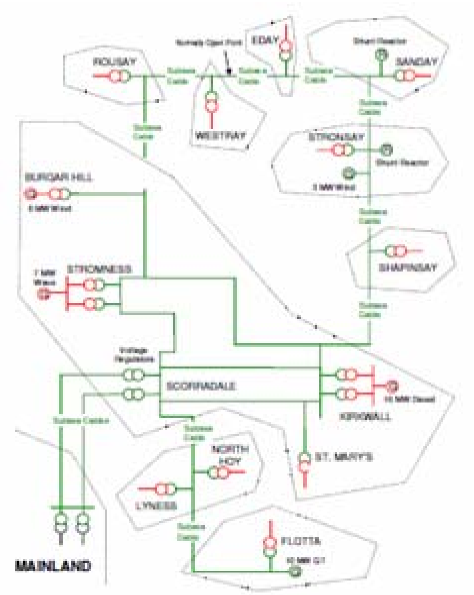
diversity of regulatory frameworks by including Denmark, Germany, Italy, Sweden, and the United Kingdom.

4.1. Orkney Isles: integrating distributed generation with active network management

4.1.1. What is the case about

The Orkney Isles in the north of Scotland are well-known for their attractive RES potential (e.g. wind, wave, tidal, etc).[23] Figure 1 illustrates the distribution grid (33 kV) of the Orkney Isles with the existing RES capacity connected to it. The Orkney distribution grid is connected to the Scottish mainland network via two 33kV submarine cables with respective capacities of 20 MVA and 30 MVA. Applying N-1 reliability rules strictly would imply that the weakest circuit with a capacity of 20 MVA would be the cap for the DG capacity that can be connected. The distribution company did however connect 47 MW by 2005. This could be achieved because a minimum demand is guaranteed on the Isles and part of the DG capacity can be interrupted when one of the circuits to the mainland trips[24]. More than this could not be accommodated under the conventional grid management.

Figure 1: Orkney Isles distribution grid (Source: University of Stratchclyde, 2007)



The distribution company[25] is implementing an innovative solution, the so-called Active Network Management (ANM), to connect more DG to the distribution grid. It will allow controlling electricity output of new generators to match the available capacity of the network in real time. This innovation is particularly helpful to wind (and wave) generators and will allow more of them to be connected to the grid. Using this alternative solution, 21 MW of additional DG can be connected (this represent almost 50 % more than current connection capacity). This solution has two main comparative advantages.

- *Cost effective and timely connection of new DG.* The alternative would have been to upgrade the Orkney's electricity grid and its connection with the mainland. This can however be costly, and

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[23] E.g. the capacity factor of existing wind generation on Orkney Isles is approximately 40% whereas in Germany average capacity factor from 2003 to 2007 has been 18.3 % (Boccard, 2009).

[24] 21 MW is interruptible, which in itself is already a flexible solution to increase the DG connection capacity. For more detailed information see for instance study by University of Strathclyde.

[25] Scottish Hydro Electric Power Distribution (SHEPD).

even if it would be worth the cost, it would take time to complete (time of construction, permits, environmental constraints, oppositions, etc) so that in the mean time active grid management can already be used to connect additional DG.

- *Make better use of the existing infrastructure.* Most DG capacity on the Orkney Isles is intermittent. Flexible and innovative network management allows maximizing the use of infrastructure with intermittent generation.

By 2009, the installation works of the core ANM system and the first two monitoring points on the Orkney distribution grid had been completed and commercial arrangements had been developed to support the ongoing operation and optimization of the ANM system. However, only two new generators connected at that time.

4.1.2. Why did we select it as on important innovative case

This case is interesting for three aspects. First, the Orkney Isles case is representative for distribution grids faced with the challenge of integrating DG. Connection is needed in a typical rural distribution network where demand is low, the distribution grid is relatively weak and there is limited connection capacity with the transmission system.
Second, the proposed innovative solution (active grid management) is one of the first implementations in its kind. Note that in this implementation a centralized dispatch approach has been chosen, which is grid oriented.

Third, several new regulatory tools oriented at promoting innovations and at integrating DG have been implemented in the UK, which will be discussed in what follows.

4.1.3. Which regulatory tools (could) have been applied in this case

4.1.3.1. Grid Services

Distribution companies in the UK are regulated with a DG oriented output regulation from 2000. The regulation increases the grid companies' revenue proportionally to the connected DG capacity, in comparison with a capacity baseline.[26] This mechanism ensures that the extra cost generated by new DG capacity can be covered. Moreover, this gives incentives to the distribution company to connect more DG capacity than the baseline and to do that efficiently: if they spend less than the (ex ante) allowed revenue for new DG capacity, they can keep part of the savings. This mechanism also gives incentives to the distribution companies to propose new and flexible services (non-firm connections) in order to attract DG developers.

4.1.3.2. Innovation

The Orkney distribution company has benefitted from two innovation funding mechanisms implemented in UK: IFI (Innovation Funding Incentive) and RPZ (Registered Power Zone).[27] These mechanisms have been designed for different types of innovation spending. IFI cover R&D and RPZ

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[26] The capacity related element allows a distribution company to recover £1.5/kW/annum for new generation connections for a 15 year period (see www.ofgem.gov.uk).

[27] Under IFI mechanism a distribution company is allowed to spend up to 0.5% of its Combined Distribution Network Revenue for innovation projects (not only DG). RPZ incentive mechanism aims to encourage the distribution companies to apply technical innovation in the way they connect new DG to their grids. The RPZ incentive mechanism combines pass-through and capacity-related elements. An incentive package of up to £500,000 per year is allowed to each distribution company for RPZ projects. The capacity related element allows a distribution company to recover £1.5/kW/annum for new generation connections for a 15 year period. This element is increased to £4.5/kW/year in an RPZ for the first 5 years. Note that RPZ in 2010 has been replaced by Low Carbon Network Fund.

is focused on demonstration and deployment. Using these instruments, the Orkney distribution company has been able to finance several parts of its innovation initiative.

4.1.3.3. Grid user participation

Difficulties with renewable DG projects in the UK have been well documented.[28] The support scheme applied in the UK, i.e. the green certificates' ROC scheme, implies more risk for DG developers relative to other countries (e.g. feed in tariff).[29] Intermittent generators are very sensitive to the quantity (total and hourly) they produce because of the high impact for the viability of the project. Offering flexible distribution services to DG improves the access condition of DG and increases their incentives for participation. However, the (centralized) ANM solution applied in Orkney Isles implies several new risks for DG developers. ANM supposes that new DG can be curtailed following the real time available capacity of the network. The curtailment is organized in a hierarchical way (last connected DG is curtailed first). There are two main risks for the wind developers with this system. First, the distribution companies do not make a contractual engagement on the maximal hours of curtailment and there is no compensation for curtailment. Second the curtailment is decided hierarchically. When deciding the DG project, the developer can have an idea about total hours of curtailment, but the hours of curtailment for a specific DG unit depends on the hierarchical position of this unit, which is not known upfront.

To sum up: the Orkney Isles case illustrates that output regulation and specific mechanisms for innovation can incentivize grid companies to undertake the expected grid technology innovation, i.e. active grid management in this case. The case also illustrates that these regulatory tools are necessary but not sufficient for achieving a smart grid, as there is room for improvement of the user participation.

4.2. Italy: completing the low-voltage demand integration by giving access to the smart meter

4.2.1. What is the case about

Italy is well-known for being a frontrunner in smart metering with 90% of low voltage customers having such a meter. The strategic choices of Enel[30,31] at the beginning of the decade, and the subsequent deliberations of the Italian Authority (AEEG)[32], stimulated the acceleration in their deployment in domestic environment (Benzi, 2009).

As a result, distribution companies have already activated the functionalities of the meters that have permitted them to rapidly capture operational cost savings. With an investment of about € 2 billion (R&D, production and installation of meters, production and installation of concentrators, IT system development), savings have been estimated at € 500 million per year for Enel Distribuzione (Gallo,

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[28] See for instance Hiroux-Saguan (2010) or Klessmann et al (2008).

[29] Under current support scheme renewable resources sell electricity and ROC certificates to the respective markets. Moreover renewable resources have to pay charges for balancing power and the balancing mechanism in UK is known to over-penalize imbalances.

[30] Enel Distribuzione voluntarily started installing smart meters at low-voltage level in 2001, motivated by the expected operational savings as well as to become a world leader in smart grid operation and technology, i.e. the 'Telegestore project', see for instance Cannatelli (2004) and Gallo (2010).

[31] Even though there are around 150 distribution companies in Italy (including distribution companies operating in small islands and remote mountain valleys), Enel Distribuzione is the largest with a customer base of more than 30 million low-voltage customers, accounting for 85% of the total.

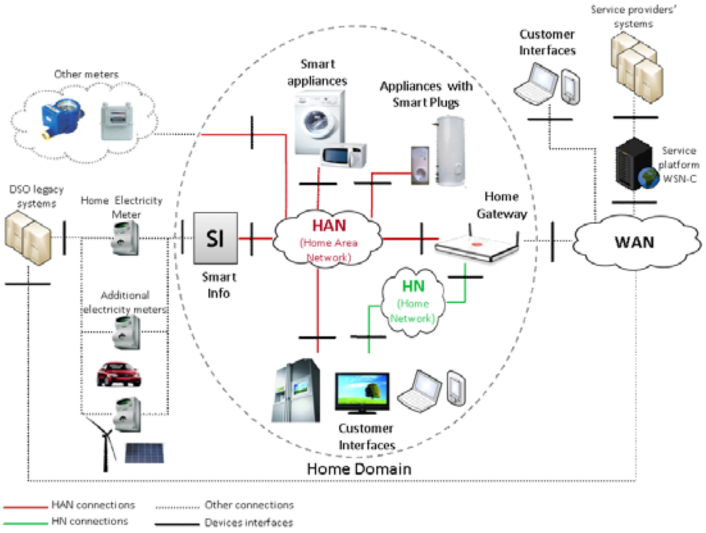
[32] AEEG defined the minimum functional requirements for smart meters and smart metering systems and imposed in 2006 to all the distribution companies to install smart metering.

2010). Access[33,34] to the meter will now be needed to give feedback to consumers and to enable third parties (suppliers, aggregators, energy service companies, etc) to develop new services based on the functionalities of the meter, i.e. demand management, integration of smart appliances, improve feedback to consumers, etc.

For what concerns feedback to consumers, a recent Government decree[35] foresees that distribution companies should install a visual display for electricity and energy customers. The so-called "Smart Info" device (Figure 2) is an innovative solution considered by Enel Distribuzione to comply with this new legislation. The device has a USB connection and can make the meter accessible from every plug in the house, as it communicates via Power Line Communication.[36] This solution has two main advantages:

- First, it would allow distribution companies to comply with new legislation concerning the required visual display.
- Second, besides enabling visual display, the device could also contribute to improving third party access to the smart meters in Italy by enabling third parties to develop new services via the USB connection that is provided with this device.

Figure 2: Giving access to the meter with SI interface (Smart Info) (Source: Enel Distribuzione, 2010)



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[33] The meters in Italy have been deployed when common standards were absent (i.e. proprietary technology) so that currently the interoperability of the meters is limited (Vasconcelos 2008, Haney et. al 2009). As discussed in Benzi (2009), future communication protocols will be a non-proprietary and standards are being developed at the European level.

[34] How to give access is currently debated and is being standardized at the European level. The debate is about how to make the data from the meters available through a gateway, and what should be the minimum specifications of this gateway to balance data accessibility with a sufficient protection of the data, see for instance the ADDRESS project.

[35] Legislative decree 30 may 2008, n. 115/08.

[36] The proposed solution is integrated in the Telegestore architecture, which has a proprietary communication protocol.

4.2.2. Why did we select it as on important innovative case

The case is interesting for two aspects. First, Italy has the largest smart meter base in the world. Most European countries are preparing a roll-out of smart meters and the Italian experience is an important experience for these ongoing initiatives.
Second, several new regulatory tools oriented at promoting innovations and at completing the integration of demand have been implemented in Italy, which will be discussed in what follows.

4.2.3. Which regulatory tools (could) have been applied in this case

4.2.3.1. Grid Services

The economic regulation for distribution companies in Italy is a (ex-ante) price cap regulation with a regulatory period of 4 years. Grid companies under this scheme are incentivized to reduce operational costs, for instance by using smart meters to reduce cost in purchasing and logistics, field operations (e.g. reading), customer services and revenue protection (fraud or non-technical losses). Distribution companies in Italy are also subject to quality of service regulation incentivizing them to improve quality levels but also, *inter alia*, to use smart meters to record quality of supply (number and duration of interruptions at individual level).

From 2004, there is also special tariff for metering in Italy that has been separated from the distribution tariff to give fine-tuned incentives to metering services[37]. In the regulatory period 2008-2011, metering and distribution have a different remuneration with metering having stronger incentives to cut costs than distribution assets.[38]

Additional output regulation could be considered to incentivize the distribution companies to improve the availability of the metering data to customers and third parties. Defining the right output will need more extensive study, but this could for instance be the capacity of demand response added to the system, the number of customers participating in energy saving services, etc.

4.2.3.2. Innovation

Italy has a general interest R&D component in the grid tariff,[39] which is to fund all research and development activities that have an impact on the electricity system. The knowledge results of R&D projects funded with such a levy are made public on the web.

In order to incentivize demonstration projects, the regulatory authority recently issued a competitive procedure[40] to incentivize active grid projects that can be supplemented with experimental demand response schemes. An extra remuneration of WACC (2% for 12 years) will be given to best demonstration projects that will be selected; a mandatory requirement is that non-proprietary communication protocols are used to allow demonstration project for participating in the competitive procedure. A key issue for regulation will also be to ensure minimum requirements, such as interoperability and openness of new innovative solutions.

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[37] See for instance the presentation by Ferruccio Villa at the 2009 ERGEG workshop on smart metering.

[38] AEEG 348/07 (Italian regulator): metering has X factor of 5% with a WACC of 7.2%, while distribution has a X factor 1.9% with a WACC of 7%.

[39] Public Interest Energy Research Project “Ricerca di Sistema” from the Italian Ministry for Productive Activities Decree n. 79 of 16 March 1999. Consumers pay for a levy on the final tariff which is yearly updated by the regulatory commission. In 2006, this levy amounted to 0.03 c€/kWh.

[40] AEEG ARG/elt 39/10.

"Smart Info" has not been developed under these schemes, but it is an enabler towards active participation of demand. The concepts of demand activation are being developed in the European funded research project ADDRESS, which is coordinated by Enel Distribuzione.[41]

4.2.3.3. Grid user participation

The white certificate scheme in Italy incentivizes energy savings in a market-compatible manner, implying that grid users (consumers, suppliers, aggregators, energy service companies, etc) are incentivized to develop the new services that would be enabled by an improved access to the meters in Italy. This system is already in place since 2004 and includes targets, sanctions and cost recovery. It is a market based instrument with also a certificates trading scheme[42]. The definition of the technical rules, implementation measures, monitoring and enforcement of the mechanism are a responsibility of the Italian regulator.

Second, AEEG launched a transition towards mandatory Time-of-Use (ToU) prices[43]. The same two-band system will be applied to customers that are still part of the universal supply regime and customers that already switched to the free market to eliminate distortive barriers between the two. The price differential between peak and off-peak hours can also have a positive effect on the participation of grid users on the demand side.

To sum up: the Italian case illustrates that several regulatory tools have been implemented to promote user participation on the demand side (new legislation on visual display, white certificates, ToU prices). The expected outcomes from this incentivized side user participation will be fully achieved by improving the access to the smart meters, which is ongoing.

4.3. Kriegers Flak: connecting off-shore wind with a multi-terminal HVDC VSC system

4.3.1. What is the case about

The Kriegers Flak area in the Baltic Sea is well-suited for offshore wind power plants. The potential has been estimated for a total capacity of 1600 MW spread out over the Danish, German and Swedish parts of Kriegers Flak.

The Transmission System Operators (TSOs)[44] are considering an innovative solution to connect the wind farms that are being developed in this area to their transmission grids. The innovation is to connect the wind farms with a combined solution instead of separate solutions (Figure 3). The combined solution has two main comparative advantages:

- *Connection capacity can be pooled*: by allowing the energy produced by one wind farm to escape via the connection of another wind farm in case there are problems with its connection. This would imply a more efficient use of the connections and a more reliable connection for wind farms.

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[41] ADDRESS is a large-scale Integrated Project co-funded by the European Commission under the 7th Framework Programme in the Energy area for the "Development of Interactive Distribution Energy Networks". It is carried out by a Consortium of 25 partners from 11 European countries. The total budget is 16 M€ with 9M€ financing by the European Commission.

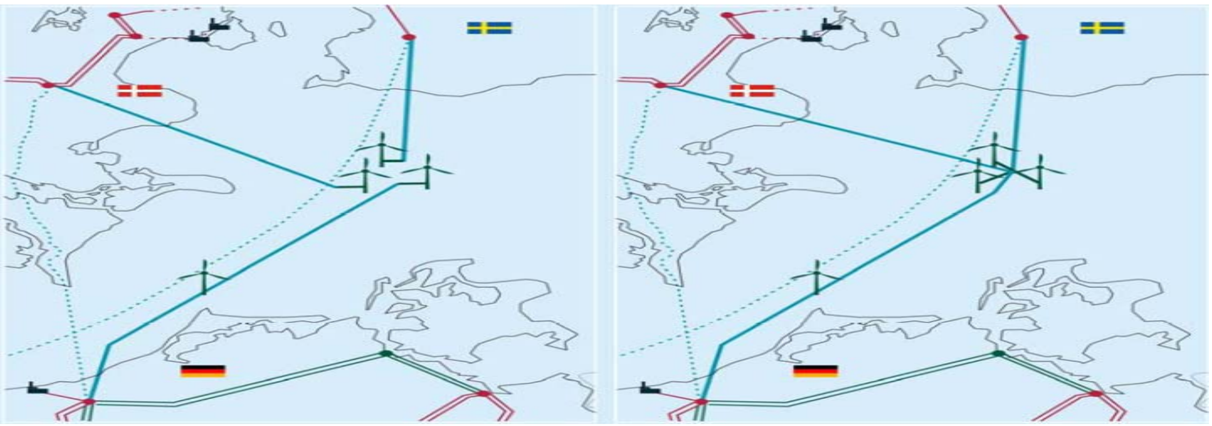
[42] Annual Report AEEG 2009: the average price of a certificate in 2008 was 69.11 euro, in comparison with 48.25 euro in 2007.

[43] Annual Report AEEG 2009: from July 1st 2010 to December 2011 all household customers will be progressively put under this regime.

[44] 50Hertz Transmission for Germany, Energinet.dk for Denmark and Svenska Kraftnät for Sweden.

- *Interconnection capacity can be provided*: by allowing the capacity that is not used by the wind farms to be used to transfer energy from a low price zone to a high price zone. This would imply a more efficient use of the connections and an improved integration of markets.

Figure 3: separate and combined solution for Kriegers Flak
(Source: pre-feasibility study by the TSOs, 2009)



4.3.2. Why did we select it as on important innovative case

This case is interesting for three aspects. First, the Kriegers Flak case is representative for transmission grids faced with the challenge of integrating large-scale RES. Connection is needed off-shore and there is an opportunity for transmission companies to coordinate.

Second, the proposed innovative solution (multi-terminal High Voltage Direct Current Voltage Source Converter system, HVDC VSC)[45] is the first implementation in its kind, while it is generally considered to be the technology Europe needs to realize its vision of a super grid to unlock the large scale RES potentials. The multi-terminal version would be the first large scale implementation of this new technology, and several authors are indicating areas for research that still need to be tackled. The main issue is that the circuit breakers or switchgear that is needed to make this innovative solution work are not yet commercially available[46].

Third, several new regulatory tools oriented at promoting innovations and at integrating large scale RES (off-shore wind) have been implemented in Denmark, Germany and Sweden, which will be discussed in what follows

4.3.3. Which regulatory tools (could) have been applied in this case

4.3.3.1. Grid Services

Grid services needed for integrating efficiently large off-shore wind resources at Kriegers Flak call for a close coordination between the transmission companies in the area. Indeed, the main finding of the

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[45] HVDC systems consist of a cable designed to host a direct current (DC), and a station at both sides of the cable that converts this direct current into an alternating current to allow the system to be connected to the transmission grids it is interconnecting, which are alternating current (AC). HVDC systems have been mainly used to interconnect grids with different frequencies and/or a large distance submarine cable route between them. Typical examples are the interconnections between the Nordic area and the European continent. HVDC VSC is an innovation of "classical" HVDC, making the technology more suited for combined DC grid solutions. A few HVDC VSC systems have already been used in an interconnection setting, but standards have yet to be developed.

[46] See for instance Cole and Belmans (2009), and Van Hertem and Ghandhari (2010).

feasibility study, published in a joint report of the three TSOs, is that the combined (coordinated) solution generates positive net benefits relative to the separate solution. However, current regulatory tools are not incentivizing coordination between grid companies.

TSOs are subject to regulations that are mainly national in scope. Output regulations in practice are therefore targeting internal service improvements and cost savings.[47] TSOs have no specific incentive to enable the integration of large scale off-shore wind or to increase the interconnection capabilities with neighbored countries.

Beside this lack of incentives to coordinate, other regulations may also distort the incentives to cooperate. For instance, renewable (& off-shore wind) connection rules are different for the three countries.[48] In Germany there are obligations imposed on TSO’s under the 2004 Renewables Law (Erneuerbare-Energien-Gesetz EEG), which requires TSOs to connect all renewable energy projects to the grid when requested regardless of capacity and to undertake the necessary reinforcement. This, combined with the current German wind support scheme giving incentives to build before 2015 (see section 4.3.3.3), implies the German TSOs are very active in developing and planning the grid on-shore and off-shore. In the other extreme, in Sweden, it is the owner of the offshore wind power plants that is responsible for making the connection to the onshore grid so that the Swedish TSO is more passive than its German counterpart.[49] Moreover, as the project also considers interconnection capacities, the rules for the allocation of congestion rent needs to be clarified.

Not surprisingly, as a result the technical solution the grid companies are pursuing is a multi-terminal HVDC VSC system with an AC solution for the first wind farm that needs to be connected in Germany before the combined solution can be ready. Furthermore, the Swedish TSO has decided not to participate in the development for the time being because the Swedish wind farms are not expected to be built in the foreseeable future. Note however that the Swedish part of the development could anyway have been argued to go ahead already now based on the benefits from interconnection. It is not clear whether this has been considered or not in the decision.

4.3.3.2. Innovation

The innovative combined solution is more costly for the grid companies and more risky. This has been remedied with 150 million Euros financial support from the European Commission for the combined offshore grid connection as part of the European Economic Recovery Program.

Moreover, in 2007, the ministers of Sweden, Germany and Denmark have signed an agreement on offshore wind power cooperation regarding environment, grid connection and R&D. The main focus of the declaration are common research projects so that Kriegers Flak could become a common pilot project with the aim of developing and indentifying common best practices.

It would also be sensible to think ahead and set a goal for a practical and future-oriented standard for VSC (e.g. voltage). It is important for a future DC-grid that new converters, from different suppliers, could be added to existing VSC HVDC links, just as different components can be added to the AC-system.

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[47] In Germany, revenue cap incentive regulation has been effective since January 2009. In Sweden, a government bill adopted in 2008, changes have been proposed to the Electricity Act of 1997. The changes signify a transition from ex-post regulation to ex-ante regulation. By 2011, the Swedish regulator will define a regulatory method for ex ante regulation given incentive to reduce grid cost and improve service quality (the first regulatory period will be 2012-2015). In Denmark economic regulation is based on ex-post principle including book values of regulated assets.

[48] There are several other regulatory issues that make coordination difficult (different priority rules, balancing and market design, interconnection, etc).

[49] However, it is the TSO who is responsible for new interconnectors from Sweden and this creates a grey zone about the responsibility in this combined off-shore wind/interconnector project.

4.3.3.3. Grid user participation

There are indications that the coordination between wind developers and TSOs in this case could be improved. For instance, 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 a combined solution.

This could be partly explained by the very different conditions under which the wind developers in the three countries are investing, i.e. differences in support schemes, connection costs, and balancing costs. In Germany, the support is based on feed-in tariffs, in Sweden on electricity certificates, and for the Danish part of Kriegers Flak the support scheme is likely to be market price plus a premium.[50] Moreover there are specific conditions in Germany to give stronger incentive to build wind farms before 2015.[51] Sweden has a system of type ‘deep cost’ whereas Denmark and Germany use ‘shallow cost’. The rules concerning wind balancing costs are also different: wind farms have to pay balancing costs in Denmark and Sweden whereas balancing costs are not paid by wind farms.

To sum up, Kriegers flak case shows that coordination will be crucial for innovation cases with several countries involved. Regulatory tools should be designed not only to coordinate grid services, grid innovation and user participation in one country but also across borders.

5. Conclusions

Smart grids in a context of decarbonizing the electricity system is mainly about system integration. It is about integrating Distributed Generation, integrating demand and storage, and integrating large scale Renewable Energy Sources. Making grids smarter is not an objective in itself, but grid technology innovation will be needed to address these system integration challenges. Grids will however only be smart if grid companies also develop new services based on the grid technology innovations, and if grid users participate in this ongoing grid innovation by using the technologies and the new services that will be derived from the technologies.

This paper discusses what appears to be a smart regulation for smart grids in this context. First, it is important to recognize the new grid service requirements and their respective costs. A smart regulation of grid services will also aim to include these service outputs in the revenue drivers of grid companies. This implies that new services have to be defined and measured (using proxies, etc) recognizing that innovation is not the target in itself. Grid users should participate at this definition as they are not willing to pay for services they do not value or did not ask for.

Second, regulation of grid technology innovation needs to be addressed separately. Extending output regulation over several regulatory periods could help, but it is likely that grid technology innovation will need a specific regulatory mechanism with strong governance (as investment planning process) to ensure the transition from R&D to value for money grid services. When designing specific innovation mechanisms, beneficiaries of the technology innovation and the grid new services have to be identified and ranked (i.e. grid companies, energy producers or suppliers, consumers, the whole society, etc). Societal issues, as general Climate Change challenges, should be addressed by governments and public money should contribute to ensure the electric system transformation process. Third, several regulations have been indentified that distort the grid user participation to the ongoing grid innovation. Even though they are external to grid regulation, they will need to be addressed (e.g. support schemes).

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[50] May 2009, an Analysis of Offshore Grid Connection at Kriegers Flak in the Baltic Sea Joint Pre-feasibility Study By Energinet.dk Svenska Kraftnät Vattenfall Europe Transmission

[51] Feed-in-tariff of 13 ct/kWh in Germany is augmented 2ct/kWh if construction on new farms starts before end of 2015 (TradeWind, 2007).

Finally, innovating with the regulatory frame, the grid technology and services and the user participation implies to experiment and to ensure that learning loops will take place. Regulatory frame has to open "experimental areas". Test and pilots will be necessary to accumulate experience and to accommodate trial and error process. Smart grids need a coherent regulatory framework addressing grid services, grid technology innovation and grid user participation to the ongoing grid innovation.

References

Alexander, I., (2006), Capital efficiency, its measurements and its role in regulatory reviews of utility industries: Lessons from developed and developing countries, Utilities Policy, 14, 245-250.

Averch, H., and Johnson, L.L., (1962), Behavior of the Firm Under Regulatory Constraint, American Economic Review, 52, 1059-69.

Bailey, E.E., (1974), Innovation and regulation. Journal of Public Economics, 3, 285–295.

Bell, R.A., and Schneider, T.R., (1999), Balkanization and the future of electricity R&D, The Electricity Journal, 12(6), 87–98.

Benzi, F., (2009), Smart Meters Interfacing the Households, (2009), AEIT Annual Conference, Catania September 2009.

Boccard, N., (2009), Capacity factor of wind power realized values vs. estimates, Energy Policy 37 (2009) 2679–2688.

Cannatelli V. (2004), Enel Telegestore Project is on Track, Metering International, Issue 1, 2004, pp. 16–20.

Choen, W. M., and Sanyal (2004), R&D choice in restructured industries: In-house v/s collaborative research in the US electricity industry.

Cole, S., and Belmans, R., Transmission of Bulk Power (2009), The History and Applications of Voltage-Source Converter High-Voltage Direct Current Systems, IEEE Industrial Electronics Magazine, September, 6 pages.

Cossent, R., Gómez, T., Frías, P., (2009), Towards a future with large penetration of distributed generation: Is the current regulation of electricity distribution ready? Regulatory recommendations under a European perspective, Energy Policy, 37(3), 1145-1155.

Crouch, M., (2006), Investment under RPI-X: Practical experience with an incentive compatible approach in the GB electricity distribution sector, Utilities Policy, 14, 240-244.

Dobbs, I.M., (2004), Intertemporal price cap regulation under uncertainty, Economic Journal, 114, 421–440.

Dooley, J.J., (1998), Unintended Consequences: Energy R&D in a Deregulated Energy Market, Energy Policy, 26(7), 547-555.

Ferguson, P. R., and Ferguson, G. J., (1994), Industrial Economics: Issues and Perspectives (2nd ed.), Macmillan: London.

Fumagalli, E., Lo Schiavo, L., and, Delestre, F., (2007), Service quality regulation in electricity distribution and retail. Springer-Verlag, Berlin Heidelberg.

Gallo, L., (2010), Già pronti per la rivoluzione delle smart grid, Nuova Energia" n°2/2010.

Glachant, J.-M., (2002), Why Regulate Deregulated Network Industries? Journal of Network Industries, 3, 297-311.

Glachant, J.-M., (2009), Regulating networks in the new economy, EUI RSCAS; 2009/05; Loyola de Palacio Programme on Energy Policy.

Glachant, JM., Pignon, V., (2005), Nordic Congestion's Arrangement as a Model for Europe? Physical constraints and Economic Incentives", Utilities Policy, 13, 153-162;

Guthrie, G., (2006), Regulating Infrastructure: The Impact on Risk and Investment, Journal of Economic Literature, XLIV, 925-972.

Haney A. B., Jamasb T. and Pollits M., (2009), Smart Metering and Electricity Demand: Technology, Economics and International Experience, EPRG Working Paper EPRG0903, Cambridge Working Paper in Economics 0905.

Hiroux, C. and Saguan, M. (2010), Large-scale wind power in European electricity markets: time for revisiting support schemes and market designs?, Energy Policy forthcoming.

Hughes, T.P., (1987), The evolution of large technological systems. In: Bijker,W., Hughes, T.P., Pinch, T. (Eds.), The Social Construction of Technological Systems. Cambridge, MA, 51–82.

Jamasb, T., and Pollitt, M., (2007), Incentive regulation of electricity distribution networks: Lessons of experience from Britain, Energy Policy, 35(12), 6163-6187.

Jamasb, T., and Pollitt, M., (2008), Liberalisation and R&D in network industries: The case of the electricity industry, Research Policy, 37(6-7), 995-1008.

Joskow, P., and Tirole, J., (2002). Transmission investment: alternative institutional frameworks. Mimeo.

Joskow, P.L., (2006a), Incentive Regulation in Theory and Practice: Electric Distribution and Transmission, prepared for the National Bureau of Economic Research regulation project.

Joskow, P.L., (2006b), Incentive Regulation for Electricity Networks, CESifo Dice Report, 2/2006.

Joskow, P.L., (2007), Regulation of Natural Monopolies, in A.M. Polinsky and S. Shavell (ed.), Handbook of Law and Economics (Volume 2), Elsevier: Amsterdam.

Joskow, P.L., (2008a), Incentive Regulation and Its Application to Electricity Networks, Review of Network Economics, 7(4), 547-560.

Joskow, P. L. (2008b), Lessons learned from electricity market liberalization, The Energy Journal, 29(2), 9-42.

Klessmann, C., Nabe, Ch., Burges, K., 2008. Pros and cons of exposing renewable to electricity market risks –A comparison of the market integration approaches in Germany, Spain and the UK, Energy Policy, Volume 36, Issue 10.

Laffont, J-J., and Tirole, J., (1993), A Theory of Incentives in Regulation and Procurement. MIT Press: Cambridge, MA.

Léautier, T. O., (2000), Regulation of an Electric Power Transmission Company, The Energy Journal, 21, 61-92.

Lévêque, F., Glachant, JM., Saguan M., and de Muizon, G., (2009), How to rationalize the debate about EU Energy Third Package? Revisiting criteria to compare electricity transmission organization, EUI RSCAS; 2009/15; Loyola de Palacio Programme on Energy Policy.

Margolis, M., and Kammen, D.M., (1999), Underinvestment: the energy technology and R&D policy challenge. Science 285, 690–692.

Markard, J., and Truffer, B., (2006), Innovation processes in large technical systems: Market liberalization as a driver for radical change? Research Policy, 35(5), 609-625.

Martin S. and Scott J., (1999), The Nature of Innovation Market Failure and the Design of Public Support for Private Innovation, March 1999.

Maskin, E., and Riley, J., (1985), Input Versus Output Incentive Schemes, Journal of Public Economics, 28, 1-23.

Mayo, J.W., and Flynn, J.E., (1988), The effects of regulation on research and development: theory and evidence, Journal of Business, 61 (3), 321–326.

Pérez-Arriaga, I., (2010), Regulatory Instruments for Deployment of Clean Energy Technologies, EUI RSCAS; 2010/25; Loyola de Palacio Programme on Energy Policy.

Pollitt, M., (2008), The Future of Electricity (and Gas) Regulation in Low-carbon Policy World, The Energy journal, 29(2), 63-94.

Rious, V., Glachant, J.M., and Dessante, P., (2010), Transmission Network Investment as an Anticipation Problem, EUI RSCAS; 2010/04; Loyola de Palacio Programme on Energy Policy.

Sappington, D., (2005), Regulating service quality: a survey, Journal of regulatory economics, 27(2), 123-154.

Sterlacchini, A., (2006), The R&D drop in European utilities: should we care about it? DRUID Working Paper 06-19, Danish Research Unit for Industrial Dynamics.

Stern, J., (2006), Capital efficiency and infrastructure regulation: Editorial introduction, Utilities Policy, 14, 219-223.

Stoft, S., (2006), Problems of transmission investment in a deregulated power market, in Lévêque ed. Competitive Electricity Markets and Sustainability, Edward Elgar.

Swan, P., (2000), The economics of standardization, Final Report for Standards and Technical Regulations Directorate Department of Trade and Industry.

Sweeney, G., (1981), Adoption of cost-saving innovations by a regulated firm, American Economic Review, 71(3), 437–447.

Vasconcelos, J., (2009), Survey of Regulatory and Technological Developments Concerning Smart Metering in the European Union Electricity Market, RSCAS EUI, PP 2008/01, Florence School of Regulation.

Vandezande, L., Meeus, L., Belmans, R., Saguan, M., Glachant, J.-M., (2010), Well-functioning balancing markets: A prerequisite for wind power integration, Energy Policy, In Press, Corrected Proof, Available online 12 August 2009.

Van Hertem, D., and Ghandhari, M., (2010), Multi-terminal VSC HVDC for the European supergrid: obstacles, KULeuven working paper.

Vogelsang, I., (2006), Electricity Transmission Pricing and Performance Based Regulation, The Energy Journal, 27(4), 97-127.

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