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Abstract

The EU does not have a truly seamless electricity transmission system in place yet. Borders still matter when system planning, expansion and operation are at stake. This fact has a negative consequence on the achievement of the European goals in the field of electricity. Three core pillars, currently missing, must be addressed by national and European policy-makers to move forward: coordination of actions and decisions, sharing of benefits and costs, and solidarity beyond costs and benefits. The importance of this pillars is apparent when considering two issues that have become particularly critical in the last few years: redispatching actions and electricity crisis management. If the three missing pillars are not taken seriously, issues like those of redispatching and crisis management can transform in insurmountable roadblocks on the path towards the establishment of a single market for electricity with high levels of security of supply and a low carbon generation mix.

Keywords

European electricity grid regulation, European electricity market integration, transmission system operation, redispatching, electricity crisis management.

1. Introduction[*]

Power plants and electricity grids in the European Union (EU) still do not operate as a single seamless system. Borders between the Member States matter despite more than two decades have passed since the issue of the first Directive concerning common rules for the internal market in electricity (Buchan and Keay, 2015; Gianfreda, Parasio and Pelagatti, 2016; Glachant, 2016; Neuhoff, Wolter and Schwenen, 2016). This is mainly due to the absence of adequate and timely answers by EU policy-makers, addressing several, often basic, questions related to: i) the coordination of actions and decisions; ii) the sharing of costs and benefits; and iii) solidarity beyond costs and benefits (Glachant, Rossetto and Vasconcelos, 2017). These are the three core but missing pillars necessary for building an integrated electricity system and allowing, in turn, the emergence of a single market. Their absence explains, to a significant extent, why the European electricity industry is currently affected by several critical issues and why the 2014 deadline for the completion of the internal energy market (IEM) was not met.

Today, coordination across borders is still limited and the framework for the allocation of costs and benefits underdeveloped. As a consequence of that, cross-border capacity is usually allocated only partially for trade and congestions frequently lead to a divergence of electricity prices, despite the coupling of most of the day-ahead national markets and the growing number of interconnectors (ACER/CEER, 2016). Furthermore, a real spirit of solidarity expanding beyond day-to-day cost and benefit responsibility is not established and formalised. Thus, cooperation during a crisis is not guaranteed, with customers of some countries possibly left in the darkness (ENTSO-E, 2015; ENTSO-E, 2017). The massive deployment of renewable energy sources (RES) for the generation of electricity and the profound wave of innovation in the field of information and communication technologies (ICT) have introduced in recent years new challenges, but also new opportunities, compounding the necessity for a prompt policy response to the issues of coordination, sharing and solidarity (Glachant and Ruester, 2014; Glachant, Rious and Vasconcelos, 2015).

In the face of the difficulties to complete the single market for electricity and the debate on the legislative proposals presented by the European Commission (EC) at the end of 2016 (EC, 2016a), this paper considers what is hindering the creation of a seamless electricity system, spanning the whole EU. The main contribution is to show that the original approach to market liberalisation and integration followed by the EU in the 1990s and early 2000s is not sufficient. Removing legal monopolies in generation and unbundling vertically integrated companies were important policy decisions but the belief that the market, building on such a new level playing field, would have done the rest was mistaken (Jamasb and Pollitt, 2005). Clear and adequate choices on how to coordinate the decisions and actions of the transmission system operators (TSOs) managing the interconnected systems are fundamental. Similarly, principles for sharing efficiently and fairly costs and benefits during the daily functioning of the system are needed. Finally, arrangements for the provision of solidarity under abnormal system conditions must be adopted and implemented by the interconnected, and interdependent, parties.

Two case studies analysed in this contribution highlight the importance of the three pillars just mentioned for the establishment of a seamless transmission system. The first is redispatching actions, while the second is crisis management. They constitute two critical issues, where progress has been difficult so far and where the problems have been compounded by the decarbonisation of the energy sector. In order to successfully remove these 'roadblocks' on the path towards an integrated European

[*] The author would like to thank Jean-Michel Glachant, Vincent Rious, Jorge Vasconcelos and Miguel Vazquez for the discussions and extensive exchange of views that led to the writing of this paper. He would also like to thank Tim Schittekatte for his comments on an earlier draft. Finally, he acknowledges the support provided by three European TSOs (Austrian Power Grid, TenneT, and Swissgrid) to the research upon which this paper is built. The usual disclaimer applies.

electricity system, EU policy-makers are required to address properly and timely the questions raised by the three missing pillars in the legislative and regulatory process.

The remainder of the paper is structured as follows. Section 2 introduces the analytical framework and describe the core pillars necessary for the establishment of a seamless electricity system. The central part of the paper then applies the framework to the two case studies. After a brief introduction in Section 3, redispatching costs are considered in Section 4, while crisis management is treated in Section 5. In each of these two sections, an introduction to the issue is followed by an analysis of the reasons why such issue is blocking the integration process and by a presentation of the possible roles and tasks that must be developed to solve it. Finally, Section 6 concludes the paper by providing a summary of the key findings and policy messages.

2. Analytical framework: the core pillars of a seamless electricity transmission system

The EU is pursuing the establishment of a single market for energy since the middle of the 1990s, but it has not yet fully succeeded in this ambitious endeavour.[1] One of the reasons for that is the presence of several seams between the electricity transmission systems that span the EU Member States. Overall, these systems are not planned, expanded and operated as if they were only one. Not entirely, at least.

The absence of a truly seamless electricity transmission system at the supranational level is relevant because a single market, in its essence, is a physical or virtual place where a given good (service) is exchanged by a set of market actors, with none of them being discriminated and prevented from trading for reasons unrelated to the quantity or the price of the good (service) traded.[2] In a single market, for instance, no actor is discriminated on the grounds of nationality or prevented from selling or buying the good (service) due to its geographical localisation. If it happens and a market actor is unable to deliver or receive the good (service) traded, then the single market breaks into smaller markets, where competition is limited to a restricted number of local producers and buyers. Resource utilisation is then likely to be less efficient.

The specific physical characteristics of electricity and the technologies currently available imply the need for a grid connecting all the producers and consumers and the need for an entity in charge of the efficient and secure operation of the whole system. They are both necessary for the establishment and proper functioning of a single market. Firstly, because no power could be transmitted from the generation units to the load units without a grid in between; and secondly because the externalities produced by the exchange of electricity by a plurality of actors could not be adequately dealt with, without an entity managing the congestions and constantly balancing the injections and withdrawals of power from the grid. Indeed, this is what a TSO is usually supposed to do, i.e. i) planning and building a transmission grid over a given area to connect the generators and the loads located within that area, and ii) operating the system under normal and abnormal conditions to ensure that the flow of electricity occurs at the minimum cost and with the lowest number and duration of interruptions.

Therefore, when neighbouring local or national electricity markets are integrated at a higher level, be it regional or continent-scale, it is essential to proceed with the integration of the respective transmission systems as well. Those systems must become seamless, that is any generator, trader or consumer of electricity linked to the interconnected transmission grid must be treated in the same way,

[1] The establishment of the IEM looks like a never ending story: any time the target seems at hand, new difficulties emerge. In 2011 the EU confidently set its goal of completing the IEM by 2014, deadline which has been later missed. Anyway, it must be acknowledged that other federal countries like the US have not been more successful in the establishment of a single ‘standard market design’ and a fully integrated electricity system (see, e.g., Bay, 2017).

[2] We do not consider here issues of quality or product differentiation. However, this does not limit the scope of our analysis, since electricity is usually considered a homogenous good, i.e. a commodity.

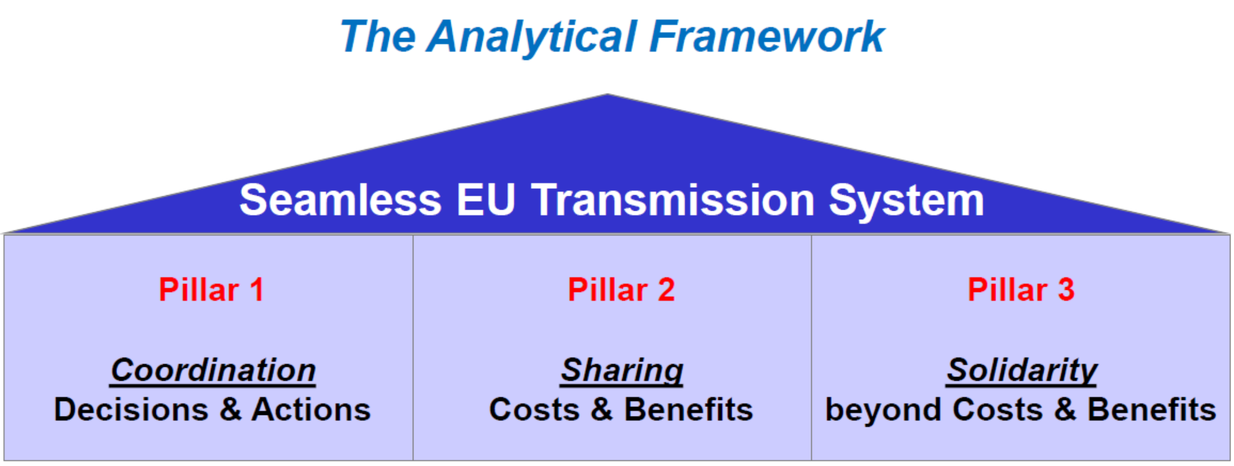
irrespective of the specific local or national system to which it belongs. In this way, its participation in the single market will be ensured. To be clear, the existence of a seamless transmission system and the integrity of the single market do not mean, for instance, that congestions should never occur and that prices should always be the same everywhere. On the contrary, to have occasionally a congestion on some grid elements implies that the transmission system is not oversized. Nevertheless, network users should not be systematically and persistently constrained in their possibility to deliver or receive electricity due to a lack of physical transmission capacity or the way such capacity is managed. If it happens, then it is difficult for those users to be really part of the single market.

The integration of electricity markets and systems at the supranational level is not the result of a spontaneous process, but it requires a strong commitment by policy-makers of different countries and the implementation of adequate policies to remove the physical and institutional barriers to efficient trade and smooth system planning and operation (Olmos and Pérez-Arriaga, 2013; Baritaud and Volk, 2014). Altough several studies have been devoted to consider the economic effects – both benefits and costs – of the integration of electricity markets and systems (see, among others, Finon and Romano, 2009; Böckers, Haucap and Heimeshoff, 2013; Boffa and Sapio, 2015; Gugler, Jaxhimusa and Leibensteiner, 2016; Newberry, Strbac and Viehoff 2016), there is, until recently, less research available that identifies more precisely what are the preconditions and the adequate policies to implement for establishing a successful and lasting single market for electricity and a truly seamless transmission system (Amundsen and Bergman, 2006; Tangerås, 2012; Gerbaulet et al., 2014; ECORYS, DNV-GL and ECN, 2015; Makkonen, Nilsson and Viljainen, 2015; Oseni and Pollitt, 2016; Roques and Verghaege, 2016).

However, based on the literature, the discussion with industry representatives and sound reasoning, it is possible to argue that three key features enable the establishment of a seamless transmission system for electricity (Glachant, Rossetto and Vasconcelos, 2017). They are (Figure 1):

1. Coordination of actions and decisions;
2. Costs and benefits sharing;
3. Solidarity beyond costs and benefits.

Figure 1: The three core pillars of a seamless transmission system



These three features represent fundamental pillars for the building of a genuinely European transmission system, which in turn can properly support the single market edifice. Firstly, a comprehensive set of tools is necessary for coordinating the actions and decisions undertaken at the national and supranational level by network users (generators and load units), network operators and regulatory bodies. In addition to it, we need clear principles on how to share, among the various stakeholders, the costs and the benefits of the integrated system and its transition to a decarbonised future. Finally, it is essential that the members of an integrated electricity system show solidarity beyond narrow cost and benefit responsibility to cope effectively and fairly with emergencies and abnormal conditions that threaten the continuous and secure supply of electricity.

Unfortunately, the EU is currently missing, at least to a certain extent, these three pillars. This contributes to explain why a truly European and seamless transmission system is absent and the completion of the single market project has been taking so long. It also tells why the move to a low-carbon energy sector is so complicated and expensive. Indeed, the objective of decarbonisation through the integration of RES increases further the pressure to address these missing pillars and justifies the fourth 'Energy Package' presented by the EC in late 2016 (EC, 2016a; Buchan and Keay, 2015; de Menezes and Houllier, 2016; Newbery et al., 2017; Turmes, 2017).

2.1 Coordination of actions and decisions

In the electricity industry, coordination is required for achieving consistent infrastructure development, reliable system operation and efficient commercial transactions.[3] Due to the particular characteristics of electricity, the achievement of those three major objectives is interdependent, requiring a holistic analysis of the specific coordination mechanisms to adopt among the different available possibilities. Before the liberalisation era, coordination in the electricity sector was ensured by the vertically integrated firms that usually enjoyed a legal or de facto monopoly position at the national or local level.[4] The expansion of the grid was planned together with the growth of the generation fleet, and unit dispatch was performed internally to the firm in order to ensure at the same time efficient electricity generation and system reliability. Vertically integrated monopolists were also responsible for the coordination at the international level, through the development of voluntary cooperation, mainly to enhance security of supply at a lower cost.[5]

The restructuring of the industry in Europe during the 1990s and the unbundling of the incumbents called for the revision of the existing coordination solutions and their adjustment or outright substitution with new mechanisms coherent with decentralised choices in generation, consumption and investment (see, among others, Brunekreeft, 2015). In order to coordinate commercial transactions, markets had to be developed at the wholesale level and, eventually, at the retail level as well. New ways to manage system operation and coordinate it with the outcomes of a competitive market setting were adopted, having in mind the double goal of ensuring a level playing field to all market actors and the secure and safe use of the available infrastructure and other resources. Entirely new mechanisms for managing system planning and expansion were implemented too, since the development of transmission and generation assets was no more under the control of the same firm (Rious, Perez and Glachant, 2011).

The establishment of a supranational electricity market covering several interconnected systems all over Europe understandably adds a further dimension to the coordination challenge. Coordination,

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3 The high level of coordination required is due to the main physical and economic characteristics of electricity: a wire must connect generators and consumers; demand for electricity is highly variable over time; electricity cannot be easily stored and its flows do not follow, in a meshed grid, commercial transactions but the path of least resistance; production or consumption choices by an individual actor have direct impact on what other actors can do; reliability is, at least for the moment, a public good and not a private one; etc. (see, among several possibilities, Laloux and Rivier, 2013).

4 This situation is still valid in some areas of the US, in Japan and in many developing countries, where the electricity industry was not restructured in the past decades and some variants of the traditional model still apply.

5 In Europe a good example of voluntary cooperation is represented by the Union for the Coordination of Production and Transmission of Electricity (UCPTE) established in 1951 (Baritaud and Volk, 2014, p. 15).

both at the planning and operational stage, must be ensured not only among the market actors, the market operator, the TSO and the regulator of a single national system, but among the corresponding entities of all the interconnected systems. Even putting aside the thousands of generators and consumers acting in the liberalised market, this means, in the EU, the necessity to coordinate 34 TSOs,[6] 17 nominated electricity market operators (NEMOs)[7] and 28 national regulatory authorities (NRAs), not to mention the national governments and all the corresponding entities of neighbouring and interconnected countries like Norway and Switzerland.

Regrettably, in the 1990s and the early 2000s EU legislation provided little or no concrete guidance for the definition of the new coordination mechanisms required by the twin transition to a liberalised and supranational market.[8] Underestimation of the relevance of coordination issues and misapplication of the subsidiarity principle are apparent in the drafting of the first EU directives and regulations. Reacting to this vague framework, Member States adopted different market models, while TSOs and market operators carried on, where possible, with cross-border legacy contracts or initiated new ad hoc bilateral transactions. Old rules were adapted in a piecemeal and pragmatic way, mainly on a voluntary basis. 'Bottom-up' initiatives, like that of day-ahead market coupling or regional security coordination, tackled only partially and slowly the fragmented landscape which had emerged (Crampes, von der Fehr and Steele, 2017).

It is only with the implementation of the Third Energy Package of 2009 that some important and formal steps have been taken to increase the coordination needed for the creation of an integrated electricity transmission system in Europe and the completion of the internal market. Concerning system planning and investment coordination, the Package foresaw the establishment of the European Network of Transmission System Operators for Electricity (ENTSO-E) and the obligation for it to prepare every two years a comprehensive Ten-Year Network Development Plan (TYNDP), covering the whole Europe. The construction of interconnections is still a lengthy process, facing several delays, but this is currently mainly due to permitting procedures and public opposition at the local level (IEA, 2014b, p. 142-143). Besides, the Third Package fostered the coordination of the regulatory function by the creation of the Agency for the Cooperation of Energy Regulators (ACER). As the name evidently indicates, this entity is not a proper European energy regulator, but rather a body for enhancing the coordination of NRAs when dealing with cross-border regulatory issues as, for instance, cost allocation of new interconnection. Finally, specific provisions in the Third Package called for the adoption of network codes and guidelines, defining the technical details of system and market coordination. Those binding acts, although weaker from a political point of view and lower in terms of the legal hierarchy, eventually address in a coordinated and harmonised way vital issues like cross-border capacity calculation and congestion management or grid connection requirements (Meeus and Schittekatte, 2017).

Hence, progress in coordinating the actions and decision of the European electricity transmission system is ongoing, but it is for the moment not enough, as the lengthy and not yet completed procedure for the adoption of the network codes and their implementation makes apparent. The two roadblocks analysed later will confirm that as well.

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6 ENTSO-E has currently 43 members. However, only 34 of them belong to EU Member States. The remaining nine belong to EU neighbouring countries. See ENTSO-E website https://www.entsoe.eu/about-entso-e/inside-entso-e/member-companies/Pages/default.aspx.

7 According to the Article 2 (23) of the Commission Regulation (EU) 2015/1222, a NEMO is "*an entity designated by the competent authority to perform tasks related to single day-ahead or single intraday coupling*". ACER publishes the list of NEMOs on its website.

8 Legislation adopted by the EU in 1996 and 2003 focused mainly on the unbundling of national incumbents, the establishment of independent NRAs and the opening of the retail market to competition (see, e.g., Jamasb and Pollitt, 2005; Buchan, 2009). The liberalisation model followed was similar to that adopted during the restructuring of the British electricity industry, which in fact concerned only one country, i.e. Britain.

2.2 Costs and benefits sharing

The design of coordination schemes for the daily functioning of any electricity system involves, implicitly or explicitly, choices about how to share the costs and the benefits among the various stakeholders on a permanent basis. Distinct decisions affect particular groups (generators, consumers, network operators, etc.) in different ways. Moving from a given coordination scheme to another arrangement has inevitably distributive implications, i.e. someone will gain and someone else will lose, at least in the short term.[9]

The identification and the implementation of appropriate principles for sharing the costs and the benefits of an electricity system are essential to promote an efficient use of scarce resources like the capacity of a congested transmission line, to ensure the provision of public goods like frequency or voltage regulation, and the broad acceptance of costly public policies like the massive deployment of renewables. Actors playing a role in the system must receive effective and efficient economic signals able to induce proper behaviours. TSOs, for instance, must be incentivised to expand the grid up to the optimal size, to efficiently spend on investments and maintenance, and to maximise the amount of capacity made available to market operators, without endangering the secure and continuous operation of the system. At the same time, network users must feel that they are treated fairly and that the costs allocated to them are proportionate or justified by an evident public interest. Industrial consumers, for instance, must contribute to the uptake of renewable energy sources but in a way that does not undermine significantly their capacity to compete on international markets for energy-intensive goods. However, providing fair and efficient economic incentives and penalties in the real world is not an easy task because of the imperfect information available and the widespread uncertainty concerning the present and future state of the electricity system (Glachant and Pignon, 2005).

The decision to integrate formerly separated electricity systems and to design new coordination mechanisms that cross several political borders undoubtedly complicate further the issue of costs and benefits sharing while, at the same time, making the identification of a solution more urgent (Finon and Romano, 2009). On the one hand, it complicates the issue because the number of decision-makers tends to increase and the characteristics of the various constituencies and stakeholder groups tend to differ more widely for economic, geographical and historical reasons. On the other hand, it also makes the identification of a solution more urgent for two reasons. Firstly, because the application of different principles and rules on how to allocate the costs and benefits generates seams in the interconnected transmission system, undermining the level playing field for market actors located in different countries.[10] Harmonisation of the regulation in place is usually necessary in these cases to prevent net welfare losses derived from the misallocation of resources in the single market. Secondly, because the different 'shareholders' and the not necessarily overlapping 'missions' of national TSOs and NRAs require that fairness and efficiency are followed as guiding principles for the sharing of costs and benefits. If fairness and efficiency are followed, then continued cooperation and coordination between the various actors of the interconnected systems are fostered and the establishment of a seamless transmission system across political borders becomes smoother.[11]

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9 A good example of the distributional consequences of a change in coordination schemes is represented by the reconfiguration of bidding zones in an electricity market based on zonal prices. See, for instance, Egerer, Weibezahn and Hermann (2016) on the German case.

10 A clear example of this are transmission network tariffs, whose not harmonised structure and level may penalise the generators of a country and favour those located in another one (Reuster et al., 2012; CEPA, 2015).

11 Consider the case of a national energy regulator tasked with the duty to minimize the cost for the network service borne by the network users located in its own country. If a decision proposed at the supranational level leads to an unfair or not very efficient allocation of costs and benefits, which eventually penalizes the network users or the TSO of that country, it is then likely that the energy regulator of that country will oppose such decision, possibly leading to a stalemate in negotiations.

Setting clear principles on costs and benefits sharing can be politically sensitive, because it requires an agreement defining short term ‘winners and losers’ among different categories of market actors, network users and Member States. This explains the reluctance, both at the European and at the national level, to openly discuss those principles and to address explicitly the allocative question. As a result, redistribution has been done implicitly or avoided altogether, maintaining the suboptimal status quo. In fact, such inertia has been the cause of conflicts, inefficiencies and unfair situations, delaying the necessary adoption of new agreements crucial for the establishment of a genuinely integrated electricity system.

In the first two Energy Packages, there was little reference to any sharing principle and most of the initiatives were taken at the beginning on a voluntary basis by TSOs and national governments, often at the regional level. Eight European TSOs, for instance, signed in 2002 an agreement to abolish cross-border network tariffs and establish an inter-TSO compensation mechanism (ITC), whose scope was later expanded (Reuster et al., 2012, p. 25). It is only with the Third Package (2009), the Energy Infrastructure Package (2013) and their implementation that some clearer decisions have been finally taken or are under more explicit discussion at the EU level. Progress is visible in all relevant areas: system planning and expansion, system operation and market operation. The process for the identification of the Projects of Common Interest, for example, provides a procedure for evaluating cross-border infrastructure projects and allocating European funding to them. Methodologies for cost-benefit analysis (CBA) are being improved (Meeus and Keyaerts, 2015; Keyaerts, Schittekatte and Meeus, 2016). On the other hand, network codes and guidelines like Commission Regulation 2015/1222 identify principles or ask for the definition of methodologies detailing the way to share congestion income and redispatching costs between TSOs (Meeus and Schitteckatte, 2017). Finally, interconnection capacity made available by the TSOs is now allocated mainly through implicit auctions to those actors that value it the most, thereby optimising the transactions on the day-ahead market (ACER/CEER, 2016).

Nevertheless, in several cases the debate on how to share the costs and benefits of the integrated electricity system is still not settled, as in the case of the review of the bidding zone configuration or the allocation of the costs for the support of RES. Indeed, on some issues, the Third Package simply kicked the can down the road and postponed the final decisions on how to share the benefits and costs, putting the TSOs and the NRAs in charge of defining the implementing methodologies through a lengthy decision-making process. As a result, sharing represents an essential but still missing pillar in the building of a seamless transmission system spanning the whole Europe.

2.3 Solidarity

Tools for the coordination of actions and decisions and principles for sharing costs and benefits under normal conditions are not enough for building and preserving a seamless electricity transmission system. In any electricity system, special coordination mechanisms are needed for coping with abnormal situations like extreme weather conditions or the sudden disruption of a major supply route of primary energy. In these circumstances, continuity of supply, especially for the most vulnerable customers, is usually the primary concern and derogation to the standard cost and benefit sharing procedures is generally allowed. This application of solidarity among the various ‘parts’ of the electricity system should not be surprising, given the fact that the operation of the electric grid is rife with externalities, imbalances propagate at the speed of light and the economic damages can be substantial even for a blackout lasting only few minutes. In a context of imperfect coordination and sharing mechanisms, and expensive system failures, markets may be unable to deliver efficient results quickly. Therefore, solidarity means that markets are partially or totally suspended and the TSO tries first to fix the emergency by going beyond a narrow view on cost and benefit responsibility. Then, when the situation in the system is again under control, markets functioning is restored and the TSO looks back on what happened, identifies the responsibilities and possibly implements, up to a certain extent, compensatory solutions.

Solidarity is a crucial pillar for a system, like the European one, that aims to integrate several national systems in a seamless way. There are at least two reasons for that. First, it makes sense to show solidarity among systems that are more and more interdependent due to the increasing level of interconnection capacity, cross-border trade and generation mix complementarities. By sharing the limited available resources and by supporting each other, national electricity systems may react faster and more economically to contingencies and supply shortages. The second justification for solidarity is more political: by showing solidarity to their integrated neighbours in times of need, national systems strengthen their mutual bonds and might ease the institutional and political barriers that hinder the move towards a deeper cooperation and integration. However, despite the importance of the political motive, it is useful to remember that solidarity across borders is not a *fait accompli* forever. Rather the opposite. To 'feel' the sense of sympathy and reciprocity that justifies solidarity among countries, "*it is important that there is sufficient symmetry of, first, the levels of market and grid adequacy and, second, the efforts to maximise the economic value of sustained [...] consumption*" (Keyaerts, 2016, p. 3).[12] Besides that, to be sustainable over time, solidarity must be called into action only during genuinely abnormal conditions and not for the everyday functioning of the integrated system. Finally, clear roles and operational rules must be defined ex-ante for effectively managing emergencies as soon as they materialise.

A spirit of solidarity between the members of what should be an "*ever closer Union*" is a fundamental principle enshrined in the EU Treaties.[13] The importance of solidarity, together with trust, was recognised for the delivery of secure energy to the citizens of the EU also in the 2015 communication on the Energy Union (EC, 2015). Disappointingly, despite such high-level declarations, solidarity is not yet a concept well developed in European legislation, at least as far as the electricity sector is concerned. After the conflicts between Russia and Ukraine of 2006, 2009 and 2014, the importance of solidarity has been acknowledged in relation to natural gas.[14] The same did not happen to electricity, where at the moment there is only a vague reference to solidarity, lacking any operational substance.[15] In the electricity Regulation and the electricity Directive adopted in 2009, there is practically no mention of solidarity, while there are several references to it in the corresponding Directive for gas.[16] This absence is even more striking after the wave of blackouts that struck some European countries in the first decade of this century and that were partly due to problems

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[12] Keyaerts develops his analysis with reference to the case of gas supply disruptions. However, *mutatis mutandis*, the reasoning could be equally applied to the case of electricity. In particular, he argues that the first requisite is necessary to avoid the perception, especially if disruptions repeat, that one of the countries does not invest adequately on a resilient infrastructure and market, but simply free-rides on the efforts and the solidarity of its neighbours. The second requisite is necessary to ensure that coordinated reactions and solidarity at the regional level make economic sense and are more efficient than nationally oriented reactions. To satisfy this second requisite, Keyaerts suggests to follow two principles: first, use economic incentives as long as possible to allocate scarce supplies; second, minimise the losses of rationing consumption after economic incentives have played their part (i.e., curtailing low value consumption before high value consumption).

[13] Article 194.1, Title XXI, Part Three of the Treaty on the Functioning of the European Union (TFEU) states explicitly that: "Union policy on energy shall aim, in a spirit of solidarity between member States, to: a) ensure the functioning of the energy market; b) ensure security of energy supply in the Union; c) promote energy efficiency and energy saving and the development of new and renewable forms of energy; and d) promote the interconnection of energy networks". The term 'solidarity' appears several other times throughout the text of the TFEU and the Treaty on the European Union.

[14] The fact that many of the EU Member States relies on one external source for the supply of gas can contribute to explain why solidarity is 'felt' more strongly in this field rather than in electricity, where countries usually rely or could eventually rely mainly on domestic production.

[15] The situation could change in the future with the adoption of the current proposal by the EC for a Regulation on risk-preparedness in the electricity sector and repealing Directive 2005/89/EC (EC, 2016b).

[16] In the Directive 2009/73/EC concerning common rules for the internal market in natural gas and repealing Directive 2003/EC/EC, references to solidarity occur in the preamble and in Article 6. However, solidarity was already mentioned in the Council Directive 2004/67/EC on the security of natural gas supply. The relevance of the concept grew in Regulation 994 that repealed and replaced it in 2010.

of coordination and cooperation among the interconnected TSOs (Baritaud and Volk, 2014, pp. 14-15).[17] The Directive on electricity security of supply (2005/89/EC), drafted right after the 2003 Italian blackout, is somewhat generic and of little practical impact. Member States have to define transparent, stable and non-discriminatory policies on security of supply that are compatible with the internal market. Among those policies, they are obliged to ensure that system operators merely exchange information relating to the operation of the networks. Even the current draft of a Network Code on emergency and restoration provides no substantial definition of solidarity.

Since electricity security of supply is considered to lie in the national remit, its regulation at the European level is less developed and this may explain why solidarity is not developed too. The management of the critical situation in the European grid of January 2017 or the solar eclipse of March 2015 confirmed the impression that in the EU solidarity is often implemented on a voluntary basis by TSOs (ENTSO-E/SolarPower Europe, 2015; ENTSO-E, 2017). Ad hoc solutions are sometimes provided in a somewhat obscure way, while uncoordinated decisions, sometimes induced by national governments, may lead to the closure of borders and system collapse.[18] Solidarity, therefore, can still be considered a missing pillar of the European electricity system.

3. Application of the analytical framework: two roadblocks

The analytical framework proposed in the previous section may look quite abstract or general in terms of content. Saying that we need coordination tools, clear sharing principles and solidarity beyond costs and benefits to achieve a seamless electricity transmission system in Europe may sound trivial. Nevertheless, the framework defined by the three pillars unveils its utility and powerfulness when concretely applied to the problems that are currently affecting the integration and decarbonisation process of the European electricity industry.

To illustrate that, we consider two issues where progress has been difficult so far and new developments are compounding the challenges that the electricity system has to cope with. These two ‘roadblocks’ on the path to an integrated and decarbonised electricity system are respectively redispatching actions and crisis management. Analysing them through the framework discussed above allows us to grasp the nature of the problems better and to identify some possible solutions to move forward.

In the next two sections, we provide a description for each of the two issues, an explanation of why they are hindering the integration process and some logical steps, coherent with the analytical framework developed in Section 2, that should be implemented to address them.

4. Roadblock one: Redispatching actions

TSOs are legally responsible for the management of electricity flows on their network and for the secure operation of the whole electricity system. As a consequence, if they notice that the outcome of the market transactions and the production/consumption decisions of network users lead or may lead to the creation of congestions, then they intervene by deploying a wide range of remedial measures that restore the compatibility between the actual or planned energy flows and the flows that the system can accommodate with a reasonable security margin. The same measures are applied to cope with

[17] The most relevant blackouts happened in England in August 2003, Denmark, Sweden and Italy in September 2003, and in the whole UCTE area in November 2006 (IEA, 2005; Veloza and Santamaria, 2016).

[18] While Western Europe was able to sustain the cold spell and the corresponding capacity shortage in January 2017, parts of South East Europe had a different fate. Bulgaria, after having unsuccessfully asked for support to its neighbours, had to temporarily curtail export (ENTSO-E, 2017).

contingencies like the unplanned outage of a power plant or with forecast errors in the demand patterns and generation by intermittent RES.

Among the various remedial measures, one of the most implemented is 'redispatching'.[19] Following market gate closure, the TSO asks certain power plants to reduce or to increase the generation of power, thereby altering the energy flows and relieving the actual or potential congestion in the network. The practice of redispatching is not new at all, but in recent years European TSOs have increased its use significantly to cope with the growing frequency of congestions on their networks. Corresponding costs have gone up as well.[20]

The rapid deployment of RES, often characterised by variable production – wind and solar photovoltaic in particular – and the increase of cross-border electricity trade are among the main reasons behind this enhanced need for redispatching. Besides, the slow development of the transmission infrastructure, both at the national level and among the national grids (interconnections), is often constraining the energy flows, especially in areas where the addition of new RES power plants or the retirement of traditional large dependable units like the nuclear ones have been particularly fast (e.g. Germany). In this context, some features of the market design applied in several European countries have further complicated the situation and increase the need for TSOs to implement remedial measures and redispatching actions in particular.[21]

4.1 Why it is a roadblock

Redispatching actions currently constitute a roadblock to the establishment of a seamless transmission system for at least four reasons. First, they represent a significant source of costs for the system – more than 2.1 billion euro in 2015 alone – that are socialised through network tariffs, affecting directly or indirectly the incontestable part of the end-consumers' electricity bill. In turn, this limit the scope for competition in the wholesale and retail markets (ACER/CEER, 2016, p. 26).

Second, the growth of redispatching costs may induce TSOs to resort to other remedial measures like reducing the amount of cross-border capacity offered for market transactions (Glachant and Pignon, 2005). In turn, this leads to the underutilisation of interconnections and more frequent congestions between national systems. Price divergence or the lack of further price convergence, actually observed in many areas of the EU in the past few years, can be at least partially explained in this way (ACER/CEER, 2016).

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19 According to the terminology applied by ACER and CEER there are different types of remedial actions. Changing grid topology is a preventive remedial measure that does not result in significant costs for the TSO. Offering less cross-border capacity is a preventive measures that comes with a cost for the whole electricity system. On the contrary, redispatching, counter-trading and the curtailment of capacity already allocated are curative remedial measures, particularly costly for the TSO (ACER/CEER, 2015, p. 170).

20 The cost of redispatching, both internal and cross-border, has increased from around 1.3 billion euro in 2014 to more than 2.1 in 2015. Germany, Spain, the United Kingdom and Poland are among the countries that spent more on it (ACER/CEER, 2015, p. 171; ACER/CEER, 2016, pp. 27).

21 Among the features of the traditional market design that may increase the need for redispatching, there are portfolio bidding and not properly configured bidding zones. The first allows a generator to choose how to respect its power injection obligations by selecting which power plant to dispatch out of his portfolio. As a result, the precise distribution of power injections is not known by the system operator ahead of real-time. In a grid that is not particularly meshed or where there are significant bottlenecks, this implies that congestions may not be easily detected by the system operator before they occur. The second feature allows the formation of a single price for a wide geographical area. By hiding bottlenecks in the grid, not properly configured bidding zones may not provide network users adequate signals about the value of the energy they inject or withdraw from a particular point of the system. As a result, they tend to inject or withdraw an amount of energy that is not efficient from a system point of view, i.e. that may not go in the direction of relieving the congestions in the grid.

Third, the massive implementation of redispatching actions to solve network congestions poses a risk for the secure operation of the system. By asking flexible power plants to change their production schedule, the system may well exhaust the available resources for coping with a sudden outage in the generation fleet or the trip of a grid element. In turn, this may imply a violation of the N-1 security rule and lead to severe consequences, if an outage actually takes place.[22]

Fourth and final, the use of redispatching actions may discourage the cooperation among the different TSOs. Indeed, the lack of a precise definition and measurement of the costs induced by redispatching, together with the absence of generally accepted principles for sharing those costs, create uncertainty on the distributive impact of cooperation.[23] Given the national liability of each TSO, improvements in the necessary coordination across borders are consequently difficult and slow. In some cases, the extreme solution adopted is to physically 'split' the interconnected synchronised system by installing phase shifters at the border.[24]

4.2 How to address the roadblock

Looking at redispatching actions through the lens of the three pillars presented in Section 2 highlights what is needed to remove such roadblock and contribute to the establishment of a seamless transmission system in Europe. It is apparent that more and stronger coordination tools are required. The same is true for clear and workable cost and benefit sharing principles. On the contrary, solidarity is not directly at stake, since redispatching costs pertain to the everyday functioning of the electricity system.

Redispatching actions call for cross-border coordination in system and market operation to minimise overall costs, take into account spill-over effects and ensure security (Kunz and Zerrahn, 2015; Kunz and Zerrahn, 2016). Cross-border coordination in system operation is important because it is possible that the cheapest or the most effective and secure way to handle a congestion, both internal to a specific control area or cross-border, is to coordinate the actions of more than one TSO at a time, eventually redispatching one or more power plants in the areas neighbouring the one suffering congestion (multilateral redispatching). It is equally possible that the choice to re-dispatch a power plant inside a given control area has negative a spill-over in the neighbouring systems. To avoid this outcome, TSOs have to look beyond the borders of their control areas and adopt a regional approach, sharing the information on the state of the system and coordinating the various remedial measures, redispatching included. Regional Security Coordinators like Coreso and TSCnet try to do exactly this, that is they provide services to the member TSOs in order to improve the coordination and the secure operation of the interconnected systems (IEA, 2014b, pp. 136-138; ENTSO-E, 2016a; Roques and Verhaeghe, 2016; Crampes, von der Fehr and Steele, 2017).

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[22] An example of this occurred at the end of summer 2015 when the Polish electricity system endured a difficult situation for several days due to an exceptional heat wave and a protracted drought. The necessity to implement redispatching actions to manage unscheduled flows at the German border exhausted or nearly exhausted the flexible resources and limited the possibility to import energy for supporting the domestic supply and demand balance. The N-1 security rule was violated for quite a few hours and at some point demand by large energy consumers had to be curtailed (PSE, 2015).

[23] ACER and CEER lament that available data on the volumes and costs of congestion related remedial measures in Europe are not complete nor easily comparable. Some NRAs do not provide such data to ACER or do not have it at all, while others make available information that is only partial or does not correspond to the same definition (ACER/CEER, 2016, pp. 26-28). To be clear, redispatching costs are measured at national level in order to allow cost recovery for the TSOs. However, the way they are classified, aggregated and reported is not the same in every Member State of the EU, so that it is at the moment impossible to know with precision their amount on a fully comparable basis.

[24] This is what the German TSO 50Hertz and the Polish TSO PSE Operator decided to do in order to better manage and eventually limit electricity overflows from Germany to Poland (PSE, 2016). Those flows are mainly due to the massive deployment of wind capacity in the North of Germany, the retirement of nuclear capacity in the South and the delay in the strengthening of the grid assets connecting the North and the South of the country. The single bidding zone grouping together Germany and Austria is also considered to be part of the problem (ACER, 2015).

However, better coordination in system operation is not enough. Improvements in the way market actors are coordinated in the integrated European electricity system are equally essential. As mentioned above, one of the deep-rooted reasons for the increased use of redispatching actions in Europe is the inadequate configuration of bidding zones for day-ahead and intraday electricity markets. The assumption that national grids are like a copper plate, where market players can sell and buy electricity almost without any restraint, is an essential element of the European Power Target Model.[25] However, for a zonal market to work efficiently, bidding zones should not be structurally affected by internal congestions. Today, most of the European bidding zones follow national borders, often hiding relevant bottlenecks to the flow of electricity foreseen by the commercial transactions executed in wholesale markets.[26] Therefore, redispatching is indispensable not only to adjust the system to unexpected outages or errors in the forecast of load and generation by intermittent RES but also to reconcile market outcomes with the flows that the grid can accommodate. With more adequately defined bidding zones the result of market transactions would naturally be less alien to the physical reality of the grid and require less adjustment after gate closure.[27] The current review of the bidding zone configuration undertaken by ENTSO-E in accordance to the Commission Regulation

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[25] The European Power Target Model emerged informally in the past few years during the drafting of the framework Guidelines and the Network Codes by ENTSO-E, ACER, the EC and Member States. It currently constitutes the common foundation to the single market for electricity and is characterized by three key elements:

1) The definition of a Europe-wide merit order and an energy price equilibrium in the day-ahead market from bids made in organised power exchanges;

2) A simplification of the underlying physical infrastructure through the assumption that national grids can work as a copper plate or a small set of copper plates (bidding zones), where transmission capacity is efficiently allocated together with energy (implicit auctioning);

3) Reconciliation of the market outcomes and the physical needs at the balancing stage through redispatching and other remedial actions performed by the TSOs.

The combined effect of these key elements is market coupling, i.e. the emergence of a single price for all the European interconnected power systems, as long as no congestion occurs over interconnections or, in the case of flow-based coupled markets, over any defined critical network element of the interconnected systems. Such a single price is computed on the basis of the efficient use of both transmission and generation capacity and is theoretically able to adequately remunerate generation costs (Glachant, 2016).

Another element of the EU Power Target Model, as initially articulated by the EC, is the reliance on energy-only markets (EOM). However, there are reasons for doubting that EOMs are enough to remunerate investment in generation capacity, especially after the massive penetration of renewables in the electricity mix. Therefore, despite the rather negative view of the EC, capacity remuneration mechanisms have been implemented or are under discussion in several European countries (Keay, 2013; IEA, 2014b).

[26] Exceptions are represented by Norway, Sweden, Denmark and Italy, which all have more than one zone. On the contrary, Austria, Germany and Luxemburg are currently part of a single bidding zone.

[27] The current physical reality of the electricity grid in Europe is to a large extent a legacy of the pre-liberalisation and pre-integration era. Besides, it is often not in line with the recent developments in generation capacity and is hardly adequate to the achievement of the EU decarbonisation goals in a cost effective way. Therefore, an optimal management of the current infrastructure is a first fundamental step to take, but it is not enough. In the long run, it is as much as important to provide the right framework for the optimal expansion of the network. However, since the adaptation of the grid requires a long time frame (from five to ten years) and since some improvements on this issue have already been achieved, network planning and expansion are not addressed in this contribution.

2015/1222 is a significant step forward in this direction.[28] If confirmed by the analysis, ill-designed bidding zones should be split or redrawn consequently.[29]

Both the implementation of cross-border coordinated redispatching actions and the revision of bidding zone configuration have relevant implications in terms of costs and benefits. Some stakeholders may have to bear significant costs, while others may gain most of the benefits. For instance, a TSO, following a multilateral redispatching programme, may have to re-dispatch – at a cost – power plants within its control area, while another TSO could, as a result, see the congestions within its network disappear without doing anything. Therefore, solving the issue represented by redispatching actions calls, first, for the identification of costs and benefits and, second, for their sharing among interconnected systems.

Identification of costs in a transparent and harmonised way is necessary because, without it, it would be impossible to discuss concretely and agree on any sharing rule. Without having a precise idea of the economic value at stake and the possible impact on the TSOs' balances, both TSOs and their respective NRAs would be very cautious on any procedure for allocating costs and benefits. Necessary agreements to improve coordination between the TSOs would be probably delayed.

However, once costs and benefits are identified and calculated using an agreed methodology, they must be allocated as well, eventually according to a set of principles that provide fairness and efficiency. Fairness is needed because the TSOs and their respective NRAs should feel they are treated properly and cooperation is grounded on reciprocity, hence it is politically acceptable. Efficiency is necessary because every TSOs should be induced to operate its system in a way that minimises the costs and the risks for grid users, both those located in its control area and those located within the interconnected systems.

European TSOs have discussed and sometimes agreed on how to share the costs related to remedial actions at the bilateral or multilateral level. Different methods are implemented (ACER and ENTSO-E, 2012; ENTSO-E, 2014b). The principle that inspires many of them is the 'requester pays' principle, according to which the costs of any remedial measure are paid by the TSO(s) that has (have) asked for assistance, regardless of where the cause of the congestion to solve lies. This principle hardly satisfies the criteria of fairness and efficiency (Vukasovic and Vujasinovic, 2014).[30]

Given the political sensitivity of any redistributive choice and the national liability of TSOs and NRAs, it is crucial that the Member States and the EU institutions reach a clear agreement on the regulatory framework for sharing the costs and benefits of congestion management. Such arrangement should not be restricted to the allocation of redispatching costs but should also cover the allocation of the costs and benefits derived from the adoption, if necessary, of a new bidding zone configuration. If this high-level political agreement on regulatory principles is not achieved because of diverging national interests and vetoes by the Member States, then national and European bodies endowed with technical and regulatory expertise like ENTSO-E and ACER will probably remain stuck to piecemeal,

[28] In August 2012, ACER invited ENTSO-E to initiate a pilot project on the assessment and review of the bidding zone configuration. A Technical Report was published by ENTSO-E in January 2014, followed by a Market Report by ACER in March 2014. Based on those early results, ENTSO-E began in Spring 2015 an investigation on the technical and economic efficiency of the current European bidding zones, together with the possibility of splitting the German-Austrian single zone. The results of this study, initially expected by the end of 2016, are now due in 2018. For more details, see ENTSO-E, 2014a; ACER, 2014; and ENTSO-E, 2015.

[29] A zone configuration subject to continuous changes has negative consequences for market operators, because it increases the uncertainty generators and buyers of electricity have to cope with. Therefore, the assessment and review of bidding zone configuration shall not be too frequent or triggered by modest and possibly temporary congestions.

[30] In late 2016 ACER recommended the use of the 'polluter pays' principle for the definition of the common methodologies on the sharing of redispatching and counter-trading costs (ACER, 2016).

suboptimal and temporary solutions. Indeed, political agreement is a prerequisite for technical and regulatory entities to act.[31]

5. Roadblock two: Crisis management

Electricity systems are intrinsically unstable, because small differences between the amount of energy injected and the amount withdrawn can lead, in a very short time frame, to an increase or a decrease in frequency which, if security limits are exceeded, can activate a domino effect and bring to the collapse of the whole system. Extreme conditions, like a strong cold snap in winter or a prolonged heat wave in summer, can severely stress electricity systems. Under these circumstances, market forces may not work efficiently and timely. Emergency actions to guarantee the continuous and reliable supply of electricity may be required.

National governments are usually very sensitive to this issue, because the damages caused by a blackout, even a short one, are very relevant in economic terms and visible for the general public. Therefore, security of supply normally falls in the national remit and during the development of national electricity systems TSOs have generally received from their governments the explicit responsibility to ensure the secure and continuous functioning of the system, and to manage the scarce resources available within their control areas during times of crisis (Baritaud and Volk, 2014; Mastropietro, Rodilla and Batlle, 2015). In order to fulfil their obligations, TSOs have developed and occasionally implement crisis management schemes, whose goal is the minimisation of disruptions and the protection of the most vulnerable network customers. Different choices have been taken regarding the level of reliability pursued, which (class of) network users should be protected and which should be curtailed in case of need, or how to acquire the resources for coping with an emergency. The result is heterogeneity in the schemes adopted at the international level and within the EU as well.

Despite the improvements in the ICT and power electronics, ensuring security of electricity supply has become more challenging in the last decade. The increased volatility in demand, the growing cross-border trade of electricity within large interconnected systems and the rapid deployment of intermittent RES have posed new threats and complicated further the work of TSOs (Baritaud, 2012; IEA, 2014a; IEA, 2016). Non-dispatchable RES with low variable costs like wind and solar photovoltaic are particularly problematic, since their integration calls for more flexibility by other generators and eventually by demand as well. However, non-dispatchable RES tend simultaneously to depress wholesale energy prices and reduce the load factor of conventional power plants. As a result, they undermine the economic viability of dependable units like gas-fired power plants, which are still needed as a back-up for moments of low solar radiation or lack of wind.

A reduction of investments in new conventional generation capacity, coupled with the retirement or the mothballing of several old or uncompetitive plants, mostly running on fossil fuels and nuclear energy, is clearly visible in Europe (IEA, 2014b; Buchan and Keay, 2015).[32] Therefore, despite apparently wide reserve margins in overall capacity, quite a few European electricity systems do not

[31] The protracted debate on the review of the bidding zone configuration in Europe is a good example of the deadlock that the lack of political agreement on key sharing principles can generate.

[32] The amount of dependable capacity available in Europe is lower than few years ago. According to Eurostat (http://ec.europa.eu/eurostat/statistics-explained/index.php/Electricity_and_heat_statistics), between 2010 and 2015 total installed capacity in the EU has increased from 883.9 GW to 981.9 GW (+11,1%). However, in the same time interval the amount of nuclear and fossil fuel fired generation capacity has decreased by 9.8 GW (-7,4%) and 32.2 GW (-7%) respectively. Data from ENTSO-E , the association of European TSOs, partly confirm the trend for 2016, with an expansion of capacity fuelled by new renewables (solar and wind) and a stable amount of conventional capacity (decommissioning of oil, coal and nuclear almost balanced by new installations of hydro and gas). See ENTSO-E (2016b), pp. 11-12.

appear to be entirely adequate today. Critical situations, especially when adverse weather conditions materialise, have become more frequent.[33] The integration at the European level further highlights the challenges for efficient and effective crisis management schemes, because a growing number of interconnections and a rising cross-border trade increase the interdependence of the various national systems. As a result, an emergency taking place in one country can more easily have an impact on its neighbours. Hence, the achievement of a secure system management becomes more difficult for TSOs acting individually.

5.1 Why it is a roadblock

Crisis management currently represents a roadblock on the path towards the establishment of a seamless electricity transmission system in Europe for at least three reasons. First, the management of disruptions in the EU remains uneven, despite some attempt to harmonise it, for instance through the drafting of a common network code on emergency and restoration.[34] Thus, for a specific category of network users the probability of load shedding is not the same everywhere in the Union and there is still uncertainty regarding the management of cross-border contracts by countries experiencing a shortage. Indeed, a national government may well prefer to put first the interest of domestic electricity consumers and impose or 'strongly' support the decision by the national TSO to curtail export capacity. In turn, this deters cross-border trade because of the difficulty to hedge such a risk. A distortion of the single market and inefficiencies in the investment process are likely to follow (Mastropietro, Rodilla and Batlle, 2015).

Second, in a context of interdependence the propensity to adopt a national approach to security of supply and crisis management can lead to expensive and risky solutions. If the electricity system in one country is under stress, while a neighbouring and interconnected one has some idle power plants, then it is highly probable that cooperation between the two countries provides a more cost-efficient and effective way of dealing with such a critical situation. By sharing resources, shocks can be better managed and the need for specific, and potentially distorting, national policies targeting capacity adequacy may be scaled down.

Third and final, the lack of coordination, sharing and solidarity in the field of crisis management can be not only inefficient and risky in the short term, but it may also have long term adverse effects on the cooperation among EU Member States and the further development of the single market. If countries, at times of crisis, follow an 'every man for himself' approach and do not provide support to their neighbours in difficulty, or if imperfect coordination among TSOs leads to a major blackout affecting several systems, distrust and scepticism on the neighbours will eventually grow. The temptation to develop nationally oriented crisis management policies will become stronger and possibly reverberate negatively on other policy issues as well.

5.2 How to address the roadblock

The analytical framework developed in Section 2 allows the identification of some possible steps for unlocking what is currently blocking the development of a seamless electricity system with regard to crisis management.

First, it is clear from the analysis that more coordination of actions and decisions is needed, because in an interconnected system the choice made by a TSO usually has an impact on the situation the other TSOs have to cope with. As recently illustrated by the electricity crisis of January 2017,

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[33] A recent example is represented by the cold spell of January 2017 (ENTSO-E, 2016b; ENTSO-E 2017).

[34] The network code is awaiting the final approval and is expected to enter into force by the end of 2017 or early 2018. For further information see: https://www.entsoe.eu/major-projects/network-code-development/updates-milestones/Pages/default.aspx.

coordination at the supranational level is essential to increase the probability of managing an emergency successfully. However, given the speed with which emergencies evolve in the electricity sector, coordination must be grounded on pre-established rules and procedures that define transparently the roles of the different actors involved and the actions they have to implement. The experience of previous crises should be used as a starting point to discuss and define, at least at the regional level, such rules and procedures without waiting for the next emergency to materialise.

Second, workable principles for sharing the costs and benefits of crisis management must be agreed upon by policy-makers and implemented by technical and regulatory entities. Indeed, without a clear agreement on how to allocate the costs, coordination is difficult to sustain. By applying the reasoning presented by Keyaerts (2016), it is possible to argue that market forces should be relied upon, as far as possible, for the allocation of scarce resources to those that value them most. A temporary increase in electricity prices that reflects scarcity might be politically uncomfortable, but it is the best way to align efficiently demand to the available supply. If interconnection capacity is not curtailed, price spikes in the country affected by shortage will 'attract' energy from the neighbouring systems, where producers will be induced to generate more and consumers to buy less. As a result, the available resources in the interconnected system will be allocated in a way to reduce the severity of the shortage automatically.[35]

By preserving market transactions, the costs of an emergency are shared according to market prices. This implies that end-consumers of a country that provides support to the one in difficulty will bear part of the burden, while the generators will enjoy part of the benefits. This may be politically controversial and justify the call for the third ingredient to a seamless electricity system pointed out in Section 2, that is solidarity. Showing solidarity to the neighbours and partners of an ever closer Union is essential during a crisis. The narrow national interest, i.e. ensuring electricity at low prices to domestic customers, should not lead to close 'electric borders'. Following the 'every man for himself' approach can be harmful both in the short and the long term. In the short term, because relying only on internal resources may be counterproductive and not sufficient to cope with the crisis. In the long term, because trust and cooperation at the supranational level can be damaged, eventually worsening the problem of coordination.

Solidarity is particularly needed when the crisis affects simultaneously two or more neighbouring countries. In this case, markets tend to stop working properly. Prices can jump near the estimated value of lost load (VOLL) or even try to settle above it (London Economics, 2013). Hence, they cannot be relied upon anymore. Standard rules and procedures must be suspended and demand rationed administratively.[36] In this occasion, the TSOs of the interconnected countries must cooperate in a spirit of solidarity, pooling and coordinating the scarce available resources. A narrow focus on cost and benefit responsibility of the different parties should be temporarily put aside. In fact, the actions undertaken by the TSOs must aim, under the supervision of their respective NRAs, at minimising the risk of significant service disruptions (i.e. blackouts) and the impact on the most vulnerable consumers (i.e. households and small firms that cannot easily switch to other sources of energy for satisfying their needs).

The national responsibility of TSOs and, at times, distrust of neighbours hinder the concrete implementation of solidarity. Therefore, a robust regulatory and governance framework approved by national governments is necessary to overcome such situation and give the possibility, but also the

[35] Trying to avoid price spikes not only can reduce allocative efficiency in the short term, but it may also deter, in the longer term, investments in dependable generation capacity and undermine system adequacy. This is the so-called missing money problem.

[36] To ensure that solidarity is politically sustainable over time, it is important to guarantee that low value energy consumption is administratively rationed before high value energy consumption. In other words, preserving the possibility for someone to consume energy that he values little undermines the support for solidarity, even more if this occurs across borders.

duty, to TSOs and NRAs to develop, approve and implement clear and transparent technical rules and procedures for managing crisis situations.[37]

6. Conclusions

The integration of the European electricity markets looks like a never-ending story. Anytime the endpoint seems to be on the horizon, new challenges emerge and new solutions must be implemented to overcome them. Ten to 15 years ago it seemed that unbundling national incumbents and establishing independent NRAs would have been the decisive breakthrough for establishing a level playing field at the European level. However, it was a mistake and the deadline for the completion of the single market was later indefinitely postponed.

This contribution argues that one of the main reasons behind this protracted delay is the fact that the EU still lacks a truly seamless transmission system for electricity, spanning all its Member States. In turn, this is due to the fact that it still misses a proper set of tools for coordinating actions and decisions, an agreement on clear and workable principles for sharing costs and benefits, and, finally, solidarity beyond costs and benefits under abnormal conditions. These features represent three core pillars necessary for the integration of national electricity transmission systems. They need to be addressed, if there is a will to complete the single market and manage the challenges – but also exploiting the opportunities – raised by the push for decarbonisation and the current wave of technological innovation.

Two case studies are adduced here as evidence of the utility to think in terms of coordination, sharing and solidarity, when dealing with the critical issues that characterise the current European electricity system. These two case studies are, respectively, redispatching actions and crisis management. They are nowadays the subject of intense policy debate and represent real roadblocks on the path towards a seamless electricity system in Europe.

Overall, the case studies show that although different solutions are possible, it is fundamental to address the missing pillars identified by the analytical framework proposed in this contribution. Besides, the case studies highlight the fact that a general and high-level political agreement on the regulatory and governance framework must be struck first. After that, regulatory and technical experts like NRAs and TSOs can start implementing detailed solutions to the problems that hinder the further integration of the national electricity systems and the transition to a low-carbon and digitalised energy sector. Since technical and regulatory entities cannot go much further alone – no major decision is purely technical but inevitably presents a political dimension – blocking or avoiding such political agreement prolongs the current status quo. A status quo, it is important to remember, which is a source of many inefficiencies – i.e. it is expensive – and of unfair, or even dangerous, situations.

[37] Rules and procedures must define in particular what can legitimately triggers markets suspension, load shedding implementation, and how to refund curtailed market transactions and transmission rights. Rules and procedures must also detail when it is lawful to curtail interconnection capacity for security reasons. It must be noted that transparent rules on emergency situations would benefit market players, because they would reduce uncertainty. Hence, market players would be able to optimise better the use of their economic resources.

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