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TITLE: **Europe's Electrical Vulnerability Geography: Historical Interpretations of the 2006 'European Blackout'**

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Abstract: The so-called "European Blackout" of 4 November 2006 counts as a key example of present day transnational infrastructure vulnerability and an important reference in current debates on transnational electricity infrastructure governance. This is best examplified by the debate itself, where proponents of more European Union (EU) influence spoke of a "blackout", and most transmission network operators interpreted the same event as a "disturbance".

Several commentators from both sides argued that to understand what happened, one must look at history. Yet almost none of the official policy responses goes more than a decade deep. As an answer and supplement to that, this paper uses novel historical research to make visible how historical choices, path dependencies, and ways of dealing with these later, shaped Europe's electric vulnerability geography.

We show that the decentralized organization of transnational electricity infrastructure, often associated with power grid fragility today, was a deliberate historical choice for economic as well as reliability reasons. We also address the (meso)regional logic of the failure, foregrounding how stakeholders from different parts of Europe historically chose to collaborate in different ways with due consequences for their involvement in, or exclusion from, the 2006 disturbance. Finally the paper concludes that today's notion of electricity infrastructure “vulnerability” is contested as many stakeholders still find the system extremely reliable, and that this contestation is tied into ongoing struggles over transnational electricity infrastructure governance.

Europe's Electrical Vulnerability Geography:

Historical Interpretations of the 2006 'European Blackout'

Erik van der Vleuten & Vincent Lagendijk[*]

Prologue: Contours of a critical event

On the evening of Saturday 4 November 2006, the German electric power Transmission System Operator (TSO) E.ON Netz disconnected an extra-high voltage line over the Ems River on request of a Northern German shipyard. This was in order for the large cruise ship Norwegian Pearl to safely make the passage from the yard to the North Sea. Other power lines were supposed to take over the duties of the disconnected line. In theory, this was a routine operation, which had been carried out some fourteen times since 1995 to facilitate similar passages. Yet due to a curious combination of events, this time would be different. At 21:38 and 21:39 the 380 kV double circuit line was switched off. This increased the load on other lines in the network, several of which came to operate near their maximum capacity. Following further fluctuations of electric currents, one of them overloaded – a connection (tie-line) between the E.ON Netz system and the neighbouring RWE system. This triggered the line's automatic protection, shutting it down at 22:10:13. The sequence of events that followed is astounding. Within 14 seconds, a cascade of overloads tripping power lines spread through Germany; every line that tripped increased the burden on the rest of the system. In the next 5 seconds the failure cascaded as far as Romania to the East, Croatia to the Southeast, and Spain to the Southwest. Synchronization of the continental network was lost; overloads and underloads proliferated throughout the subcontinent causing more lines and generating units to fail. The incident now affected electricity supply in about 20 European countries. Supply was cut selectively to some 15 million households. Via the Spain-Morocco cable the disturbance even reached Morocco, Algeria and Tunisia, where lines tripped and consumers were left in the dark (UCTE 2006b, 2007). If an incident in Northern Germany can make the lights go out in Tunisia within a matter of seconds, we may speak of a noteworthy transnational critical event.

Subsequent discussions about this disturbance are as intriguing to the student of transnational infrastructure vulnerabilities and European Integration as the event itself. Newspapers spoke of a "mega-blackout" and spotlighted the alleged fragility of Europe's electric power grid. Pro-European union (EU) politicians like Romano Prodi and Andris Piebalgs, the current energy commissioner at

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the European Commission, blamed the blackout on the decentralized governance structure of transnational electricity transmission, located in the hands of transmission companies and their international associations. For Piebalgs, “the blackouts [...] are unacceptable” and “confirm the need for a common European approach” (Commission of the European Communities, 2006b). Interestingly, power sector spokespersons arrived at opposite conclusions: existing security measures and the sector’s decentralized governance structure had worked extremely well to contain and repair the disturbance: Indeed, a long lasting, all-European blackout had been “adequately prevented” and “the decentralized responsibilities of TSOs have demonstrated their efficiency.” (UCTE 2007: 6, 8). In the end, the fragility discourse proved most potent and the EU became increasingly influential in transnational electricity infrastructure governance.

Introduction

For decades most literature about energy-related vulnerability and risk has been concerned with import disruptions (Plummer 1981; Andrews 2005; Reymond 2007; Weisser 2007; Gnansounou 2008; Gupta 2008; World Energy Council 2008), pollution (Lave & Silverman 1976; Proops et al. 1996; Syri et al. 2001; Haas et al. 2008), or accidents (Perrow 1984; Hirschberg et al. 2004, 2008; Sovacool 2008) involving primary energy sources – mostly oil, gas, coal, hydro, and nuclear. A recent body of scholarship adds energy vulnerabilities associated with energy supply as *critical infrastructure*. This concept spotlights the infrastructural dimensions of energy - electric power grids, gas supply networks – and the associated vulnerabilities that follow from massive societal and economic dependency on uninterrupted energy infrastructure services. In this emerging literature blackouts, next to terrorist attacks, are routinely cited as key examples demonstrating the criticality of modern infrastructure. Moreover, electric power networks are counted among the most “critical” of all critical infrastructure (Lukasik 2003, p.208; Perrow 2007, p.11; Kröger 2008). They merit specific study (e.g. Amin 2002, 2005; Watts 2003; De Bruijne 2006; Gheorghe et al. 2006, 2007) and are prioritized in Critical Infrastructure Protection programs (PCCIP 1997; Commission of the European Communities 2005, 2006a; Fritzon et. al. 2007).

The so-called “European Blackout” of Saturday 4 November 2006 stands out as a particular vivid illustration of transnational infrastructure vulnerability with allegedly Europe-wide implications. In this paper, we use a historical perspective to bring into view several long-term developments that help interpret this event and subsequent political debates.

To start with, a number of official investigation reports and other analyses of the blackout of 4 November 2006 invoke “history” as a key cause. Yet they discuss it only in very general terms. We therefore provide a more detailed historical account of European electricity grid development and how this development helped shape Europe’s electrical vulnerability geography as displayed at 4/11 (using this for shorthand, we acknowledge that the events of the 11th of September 2001, 9/11 in U.S. spelling, were much graver). We focus on two aspects of this vulnerability geography. First, we address the decentralized (from a European perspective) organization of today’s transnational power collaboration that stirs so much discussion today. In our interpretation we shall emphasize that it is the outcome of a long struggle, in which centralization and top-down construction of a European power grid always was an option, but quite deliberately became a road not taken. Second, we address the (meso)regional dynamics of European grid building that shaped the spatial logic of 4/11.

Next we address subsequent debates on European electric power infrastructure governance that the event seemingly triggered. We argue that current perceptions of a “highly vulnerable” electric power system and associated calls for increased EU interference in transnational electricity infrastructure governance should not be taken at face value. Instead these should be examined in two relevant and interrelated historical contexts: (1) the history of transnational infrastructure governance, in which for a long time many agencies – including the EU and its predecessor organizations – have competed for influence on transnational electric power infrastructure governance; and (2) the historical development of electricity infrastructure reliability and vulnerability perceptions, which posits EU spokespersons and electricity transmission sector representatives in opposite camps. We will frame these diverging political and sector perceptions of vulnerability against the history of risk perceptions, management and measures in Europe's electric power sector.

4/11 and the historiography of Europe's electric power infrastructure

Before proceeding, however, we will briefly address the relevance and current state of European power grid historiography. We already noted above that the relevance of history for understanding 4/11 has been acknowledged repeatedly. Asking how the 2006 blackout could happen again after the wake-up calls of the large 2003 blackouts in the US/Canada and in Italy (affecting Austrian, French, Slovenian and Swiss systems as well), Bialek (2007: 54) notes that "to answer why the blackouts have happened we have to look at the developments of the last 50-60 years". The authoritative Union for the Coordination of Transmission of Electricity (UCTE) final investigation report likewise place the event prominently in a historical context. Both Bialek and the UCTE report argue that the European interconnected transmission system was originally designed for the past situation of self-contained utilities with weak tie-lines to neighbouring networks, primarily serving mutual emergency assistance in a bilateral governance model. The era of liberalization, however, caused commercial long distance electricity trade between national subsystems causing a bulk use of power lines for which they were not designed. This "fundamental change of paradigm" (UCTE 2007: 5 and 13) made the system vulnerable to disturbances. The same observation was made after the Italian blackout of 2003 (UCTE 2004b: 3).

This general observation is as deep as the historical analysis goes. Having noted how historical processes shape today's infrastructure vulnerability, investigation reports and other analyses focus on short-term "root causes" and short-term solutions, as they should. These immediate roots of 4/11 were many. Indeed, the UCTE final investigation report reads like a case of Charles Perrow's (1984) *Normal Accident Theory*, where unanticipated combinations of multiple events in complex systems ultimately produce failure. Here we will do no more than briefly mention this cavalcade of interacting events that in the above-mentioned historical context produced 4/11: Environmental, licensing, and construction time barriers to strengthening the grid; strained operation of the grid near its maximum capacity as emerging "common practice" among operators; a number of extra-high voltage transmission system elements being down for scheduled maintenance immediately prior to the disturbance; temporarily adjusted settings of several E.ON. Netz substations (normal procedure yet crucial in retrospect); German weather conditions producing high wind power output, causing particular high flows from Germany to the Netherlands and Poland; an overall continental grid condition of long-distance flows from North-Eastern to South-Western Europe; late changes in the scheduled power line shutdown to facilitate the cruise ship passing; failure of E.ON. Netz to perform repeated numerical analysis of the N-1 secure state of its network (meaning that one failing element will not produce a cascade); operation of other lines near their maximum after the shutdown; fluctuations in the grid (which are common) increasing the strain even more; discovery that a crucial tie-line (the one that would trip first) between the E.ON. Netz and RWE transmission zones had lower protection settings on the RWE side than on the E.ON. Netz side; response to this situation; and a dispatcher change of specific substation settings that slightly increased, instead of decreased, the load on the critical tie-line, which under the accumulated circumstances was sufficient to cross the lower protection threshold on the RWE side and automatically trip the line.

Then a cascade followed, each tripped line increasing the burden on others leading to new failures as cascades do (Nedic et. al. 2006). Acknowledging this combination of events, the UCTE report is careful not to point at the final dispatcher mistake as the "cause" of the blackout. Quite understandable from an organizational point of view, it points instead at breaks with UCTE procedure and aims: (1) the non-fulfilment and non-checking of the N-1 criterion by E.ON. Netz and (2) poor communication between the TSO's involved, in particular E.ON. Netz and RWE. This latter conclusion, as we shall see below, was gratefully picked up by actors pursuing a EU-agenda.

While these immediate factors have been scrutinized and are leading to new security measures, the long term developments that produced the setting for today's transnational vulnerabilities as exposed on 4 November 2006 have not been addressed in any detail. This paper will therefore delve deeper into European power grid history. Devising a history of the European power grid, however, is not a straight forward exercise. A first problem is that academic historic scholarship on electricity networks – as well as other infrastructure – has overwhelmingly addressed national or subnational developments (for reviews see Van der Vleuten and Kaijser 2005; Lagendijk 2008: 20-30). Studies looking beyond the single country usually took a national comparison format (Hughes 1983; Kaijser and Hedkin 1995; Varaschin 1997; Van der Vleuten 1999; Millward 2005), implicitly maintaining the (sub)national as their unquestioned unit of analysis. With very few exceptions, histories of electrification looking at networks *across* borders were lacking or constituted merely add-ons to national electrification histories.

A second difficulty involves the very concept of a "European" power grid. Notions of "Europe" vary with time and political paradigm. Surely a serious historical inquiry cannot take for granted the dominant Cold War meaning of "Europe reserving the term for Western countries, which was the original context for the development of the UCTE (as an organization set up by the OEEC). By the same token it cannot uncritically equate "Europe" to the EU, a meaning that rapidly gained currency in the last two decades in popular understanding and as the scholarly category to which all analysis must converge, much like previous scholarship tended to make the nation-state its natural research container. A European power grid history needs to acknowledge that Interwar plans for such a grid routinely stretched from Portugal to Russia, and that indeed by the late 1960s power lines electrically linked Northern Scandinavia to Southern Italy and Lisbon to Moscow. Such a broad scope is needed also to understand why 4/11 affected Lisbon and Tunis, but not Stockholm and St. Petersburg.

Only recently a transnational perspective in scholarly technological history (Misa and Schot 2005; Van der Vleuten 2008) and a sustained research effort into European infrastructure history produced work on European electricity infrastructure history (notably Lagendijk 2008) that takes account of these problems, and on which we shall build further here.

Historicizing the Blackout: Centralized vs. decentralized electric power system building

We start by developing two storylines on transnational power grid history that shaped Europe's electrical vulnerability geography as displayed at 4/11. First, we provide historical background and periodization for the decentralized (from a European perspective) organization of today's transnational power collaboration that stirs so much discussion. In the next section we will focus on the meso-regional logic of power collaboration and present-day electricity infratsructure vulnerability.

We start the first theme with the observation that the problem of national compartmentalization in electricity supply was absent in the earliest period of cross-border collaboration, roughly before the First World War. High voltage transmission developed rapidly since the 1890s, but was not yet interpreted in national, let alone continental, contexts. Early cross-border power lines served local or (micro)regional purposes. Since national borders were not yet key obstacles, such local or micro-regional systems were established within as well as across political borders. Neither were state governments important players yet. Some important cross-border systems were set up by (now obsolete) financial holding companies established by banks and equipment producers like AEG, Brown Boveri & Cie (merged into ABB and Alstom), and Siemens. From 1906 a 40 kV line supplied Rhine waterpower generated at the Swiss-German town of Rheinfelden to Guebwiller in Alsace, France. In the same year an export-oriented plant at Bruscio, Switzerland, started to feed Alpine waterpower into Northern Italy by 23 and 55 kV lines. In other cases, existing utilities connected across borders. For instance, from 1915 surplus hydropower from *Sydkraft* (currently E.ON. Sverige) in Southern Sweden was exported to the thermal power-based system of NESA (currently DONG Energy) in North-eastern Denmark using a 6 MW, 25 kV AC submarine cable under the Sound, paid for by the receiving power company (Kaijser 1997: 6).

In the Interwar years the historic context alluded to in current discussions started to emerge. While several existing electric utility owners – large and small commercial companies, municipalities and other lower governments, rural cooperatives - competed for a position in the booming electricity sector (Van der Vleuten 1999), two important new players joined the game. First, the war witnessed not only state governments introducing obligatory border passport requirements that stayed in place after the war, but also a steep rise of economic nationalism. State governments increased their grip on the electric power sector through legislation on prices, hydropower resource development, electricity export restrictions, developing electricity as national service, and national power grid planning. Legislation organizing such power grids was for instance introduced in France (1928), the UK (1926), Portugal (1926) and Germany (1919) (Lagendijk 2008: 56-57). Even in countries where such acts were not accepted, they were often still drafted, hotly debated, and influenced power grid developments (e.g. Van der Vleuten 1999). The nation-state, in short, became a lead category for electrification.

Second, this development was contested not only by existing players like private, municipal, or cooperative utilities, resisting state interference with varying degrees of success (often national grids only emerged after the renewed crisis of World War II, if at all). Electric nationalism was also countered by an electric internationalism (compare Schot & Lagendijk 2008). In the first half of the 1920s new international organizations like the International Council on Large Electric Systems (CIGRE, 1921), the Union of producers and Distributors of Electricity (UNIPEDE , 1925, currently EURELECTRIC), the World Power Conference (1924, currently World Energy Council), and also the League of Nations discussed the proliferation of economic nationalism and worked to enable international power exchanges. In these settings, around 1930 ideas emerged for a European electricity grid, which we would today call a “supergrid” (e.g. Higgins 2008). These included plans like Georg Viel’s 1929 scheme of 3,000 kilometres of 400 kV grids stretching from Trondhjem, Norway in the Northwest to Lisbon, Portugal in the Southwest and via Lviv (now Ukraine, then Poland), Vilnius and Riga into Russia in the East. Also Oskar Oliven’s 1930 scheme of 9,750 kms of 200/400 kV lines stretched from Lisbon and Trondhjem to Rostow, Russia. Moreover, such plans from the engineering world connected with a Europeanist political agenda. Doubtful about the political road to a United States of Europe, Europeanists politicians captured infrastructure as a low-key means to integrate Europe economically and culturally. For them, a European high voltage grid would make Europe’s scattered energy sources available to all, modernize the economy, create mutual interdependence preventing war more effectively than paper treaties, and even create a spiritual bond among Europe’s peoples.

However, the politically preferred model of top-down construction of a European power grid, backed by political will and international financing, became a road not taken. Representatives from the electricity sector preferred a gradual approach of building national networks that could later be interconnected, while in the context of economic depression and increasing national strategic interests international financing plans were torpedoed. The Europeanist politicians became isolated, and the push for international electricity system building transformed into an international regulatory and gradual approach by the above-mentioned international organizations.

Importantly, while national developments became the focal point of electrification, cross-border interconnection and electricity exchange initiated by electric utilities (and following utility interests) grew steadily in its shadow. Already by the mid-1920s the first electric power import/export statistics showed exchanges between German and Austrian, Czechoslovakian, Danish, Dutch, French, Lithuanian, Luxembourg, Polish, Sarre, and Swiss utilities; between Swiss and French, German, Italian utilities; and between Swedish, Norwegian, and Finnish utilities (Lagendijk 2008: 45).

In a third period, roughly covering the Second World War and Cold War, the confrontation between a top-down and gradual road to a European grid was repeated. The renewed push for a European supergrid came first from Nazi Germany, depicting infrastructure as a form of *Grossraumtechnik* serving to integrate their *Neuropa*. Work on an underground high voltage direct current (HVDC) grid interconnecting the envisioned *Reich* from London and Oslo to Barcelona and Stalino (currently Donetsk, Ukraine) was frustrated by the course of the war. New high voltage alternating current (HVAC) connections to e.g. the Netherlands and Austria were built, but served the more mundane motive of feeding foreign energy sources into the war economy (Maier 2006). After the war, in the context of rebuilding a war-torn Europe, US Marshall Planners pushed the idea of a top-down, supranational, jointly owned and financed European power grid. They saw transnational infrastructure as a means to rapidly rebuild an integrated Western Europe and at the same time construct an economic and military barrier to the spread of communism.

Yet again, national and sector interest (now often represented by ministers responsible for nationalized utilities) preferred to invest in national infrastructure and subsequently develop international cooperation. The model developed in the UC(P)TE zone, the part of Europe where 4/11 happened, was prepared by engineers in the Organization for European Economic Cooperation (OEEC 1948) -- the organization where European governments negotiated with the US on Marshall Plan funds -- and UNIPEDE. In the OEEC European governments managed to direct these funds towards national power system development, while the Marshall Plan's envisioned International Power Program failed to take off. As for cooperation between national systems, the OEEC committee saw no need for a European dispatch centre or European/ international ownership of plants and grids. Instead "discussion of possible interchanges .. [was to be] left to the free negotiations of the utilities concerned" (OEEC 1950: 24). The idea of "integrating Europe" was downplayed, while sector economic and efficiency gains were foregrounded as lead motive for collaboration: interconnecting an economic mix of power sources (thermal and hydro power plants) and sharing emergency power generating capacity, so that investment costs for individual utilities could be reduced (Lagendijk 2008: 134ff). Such advantages were first and foremost to be found within national borders, but also applied to cross-border collaboration (Van der Vleuten et. al. 2007: 335).

This preference materialized in the OEEC-initiated West European power pool organized by the *Union for the Production and Transport of Electricity* (UCPTE 1951, currently UCTE), aimed at the 'most effective use of the means of production and transport of electric energy in the countries of the member" as article 2 of the 1954 statutes read (UCPTE 1971, annex). This demanded a decentralized approach: "Decentralization is indispensible for economy, security, and continuity of supply on the regional level" (UCTE 1976: 153). The organization was hence set up as a non-governmental coordinating body of utility representatives (and delegates of public administrations) who participated on a voluntary basis. Participating utilities remained fully in charge not only of network building and supply in their own supply areas, but also of financing, building, and operating cross-border connections, of which they maintained full ownership. In this scheme, utilities built cross-border power lines and negotiate exchange contracts when it made sense economically. The UCPTE provided the necessary coordination and facilitation and obtained a mandate to organize emergency assistance across borders (Lagendijk 2008: 146ff).

The workings of the organization changed repeatedly, particularly in the era of Europeanization and reregulation, but the decentralized structure stayed in place so far. This led to the development of the UCTE grid we have today, and patterns of exchange on it. In some areas, utilities were extremely international-minded and developed grids and exchanges accordingly, as in the case of Austrian and Swiss power imports and exports. In other parts of Europe, cross-border grids and exchanges remained minor, as the European Commission repeatedly complained.Around the turn of the Millennium, countries such as Italy, Greece, Spain, Portugal, the U.K. and Ireland had an “interconnection capacity”- the import capacity relative to domestic generating capacity - below 5 %. For other countries (e.g. France, Germany) it was about 10%, while front runners reached over 20% (Verbong 2006). As for usage of existing networks, for Europe as a whole (in this calculation including European countries save former Soviet Union countries) the ratio of cross-border vs. domestically circulating electricity increased from 5% in 1980 to 7% in 1992 to 9% in 2004 (Energy Information Administration, 2009).

At 4/11, the prominence of national (and company) borders was visible particularly in (1) the geographical logic of the disturbance (which we will address in the next section) and (2) the response to the system disturbance by Transmission System Operators. In line with the decentralized mode of constructing and managing Europe’s power grids, each TSO in the affected zone was responsible for taking security measures to counter power imbalances in its specific supply area (UCTE 1971: 1976). At 4/11, such TSO-specific defence and restoration plans were executed, including for instance automatic and pre-programmed cutting of selected power users (load shedding) within a matter of seconds, and subsequent automatic or manual starting or shutting down of back-up emergency generation capacity within minutes. Each TSO acted according to its own preset rules and plans; little additional coordination between TSOs was needed (UCTE 2007, chapter 3). According to TSO representatives, this decentralized response worked extremely well in the case of 4/11, since most of the system was fully operational again within half an hour and the complete system up and running within two hours.

This brief historical overview explained the decentralized nature of the European power grid and its institutional setup historically. Though much critized today, this decentralized structure was by all means a deliberate choice of the past for both economic and security reasons. Decentralized and informal collaboration was repeatedly preferred to the centralized alternative, and sector economics (not least an economic mix of power sources) in specific cooperations to broader European integration politics as lead motives for cross-border electrical cooperation. This observation suggests that researchers need to carefully distinguish and evaluate these motives in present-day discussions, for in the current era of EU-led Europeanization they are often conflated. Moreover, it suggest that breakdown response measures were included in this decentralized system building approach, and – quite contrary to the perception in many policy and scholarly papers today – worked fairly well. We will return to this issue of emergency response and associated interpretations of system vulnerability or reliability in more detail below.

Europe’s electric vulnerability geography

Before doing so, however, we wish to spotlight a second aspect of 20th century European power grid development that greatly affected 4/11. In the Cold War period described above, Europe was electrically connected from Lisbon to Moscow and Trondheim to Naples. Yet this cross-border collaboration was concentrated in several transnational (meso)regions. Connections *between* these regions existed but were relatively weak. In this section we inquire how this legacy from this 1950s and 1960s, and the ways it has been dealt with in later decades, provides a historical explanation for Europe’s electric vulnerability geography as revealed in 4/11.

The UCPTE cooperation, it should be remembered, originally included only Austrian, Belgian, Dutch, French, Italian, Luxembourg, Swiss, and West-German utility representatives. Geographically it embraced the integration zone of the six founders of the European Coal and Steel Union (1951) and later the European Economic Community (1957), two direct forerunners to the European Union, plus Austria and Switzerland. Utilities outside this zone established a number of other collaborations and associated interconnections, often taking the UCPTE as example, but still – initially - choosing independence from this Western European collaboration. The resulting fragmentations in Europe's electric power grid of the 1950s and 1960s are nicely captured in the representation of power exchanges in 1975 (figure 1).

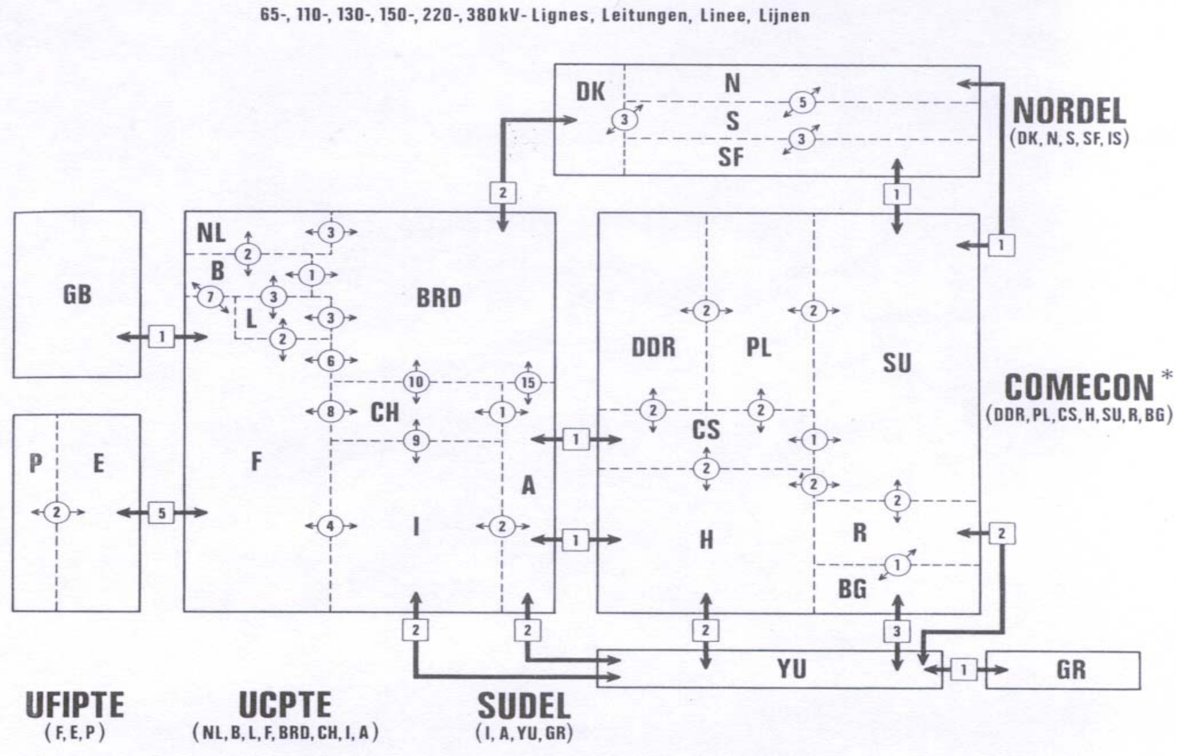

Figure 1: Europe's electrical integration and fragmentation in 1975. Source: UCPTE 1976, p 199. Reprinted with kind permission of the UCTE.

In post-war Northern Europe, for instance, a Nordic political and economic integration process initially counted as a valid alternative to Western European integration. This translated in not only the establishment of the Nordic Council (1952) and the Nordic Passport Union (1954), but also – at the suggestion of the Nordic Council - the Nordic power collaboration *Nordel* (1963) to coordinate a Nordic power grid. The organization was set up in the decentralized and voluntary image of the UCPTE. Note that *Nordel* was not a technical necessity induced by the presence of sea straits. As noted above, East-Danish and South-Swedish utilities had co-operated by HVAC submarine cables since 1915, a technology which had been greatly improved since, not least by the Swedish manufacturer Asea. The same goes for submarine HVDC cables, where Asea became a key player (Kaijser 1997; Fridlund and Maier 1996; Fridlund 1999). Besides, even utilities in continental Western Denmark, sharing a land border with West-Germany, participated in *Nordel*. Rather than technical necessity, the establishment of *Nordel* followed organizational considerations in a political context that did not – yet – accept the idea of European integration as we know it today. A similar logic informed the separate development of electric utility collaboration on the British Isles.

In Southern Europe, similar collaborations emerged. Collaboration between French, Spanish and Portuguese utilities in the *Franco-Iberian Union for Coordination and transport of Electricity* UFIPTE (1963) was again set up in the image of the UCPTE. In the South-East, the Cold War made cooperation through Yugoslavia tricky. Still several stakeholders saw advantages in making Yugoslavian hydropower resources available to countries west of the Iron Curtain. NATO, while blocking a number of other East-West links, supported the scheme that might draw Yugoslavia, after its break with the Soviet Union, closer into the Western orbit (Lagendijk & Schipper, fortcoming). A study project called *Yougelexport* evolved into cooperation via three interconnections to UCPTE partners by 1955 and eventually into SUDEL (1964), an organization associating Austrian, Italian, Yugoslavian (and since 1972 also Greek) utilities. Its formal aim was to exploit complementary hydropower resources in member countries and improve mutual security of supply. Since the Yugoslavian power authority also collaborated with its neighbours in Hungary, Romania and Bulgaria, it became a prominent connector between East and West in Cold War Europe (SUDEL 1984).

This leads us to the most significant fragmentation in Cold War electrical Europe, the so-called Iron Curtain, or, in this case, the Electric Curtain (Persoz and Remondeulaz 1992). Central and Eastern Europe were drawn into the Soviet orbit via the Council for Mutual Economic Assistance (CMEA or COMECON, 1949). Much like the OEEC establishing the UCPTE in the West, the CMEA established the *Central Dispatch Organization* to coordinate the *Interconnected Power Systems* (CDO/IPS, 1962) to foster electric integration. Power plants in Czechoslovakia, the German Democratic Republic, Hungary, Poland, Western Ukraine, and soon Romania and Bulgaria were put in synchronous operation (Persoz and Remondeulaz 1992). Finally, this collaboration was connected to a 6th electric collaboration region. The Soviet Union's Unified Power System became a huge interconnection including the Latvian, Estonian, Lithuanian, Belorussian, and Ukrainian Soviet republics.

As we know, these groupings changed form in later decades. Moreover, they developed several kinds of collaboration between them, as figure 1 also shows. We argue that the way in which this happened shaped the geographical logic of 4/11. This geography is roughly portrayed in figure 2.

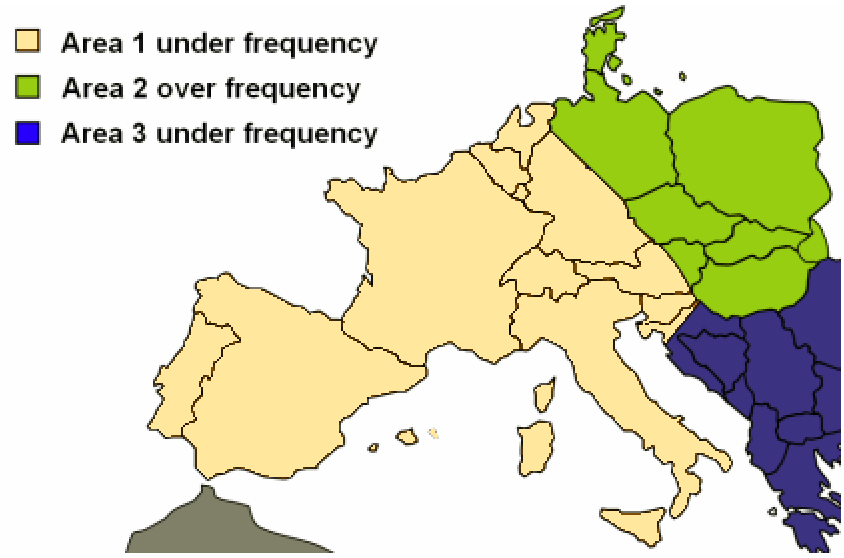

Figure 2: The regional logic of 4/11. Source: UCTE 2006a. Reprinted with kind permission of the UCTE.

We shall first discuss the historical logic of which regions were affected by 4/11 and which were not. As figure 2 shows, 4/11 *did* affect the Iberian Peninsula, the Balkans, much of Central Eastern Europe and, in a different colour yet still included in figure 2, parts of North Africa. This geography obviously corresponds to the UCTE zone plus areas that operate synchronously, such as Western Ukraine, Albania, and Morocco, Algeria and Tunisia, jointly known as the *Trans European*

Synchronously Interconnected System (TESIS). Cascading failure, after all, is a property of synchronically connected networks. The areas outside the reach of 4/11 were connected to the TESIS zone, but in an asynchronic fashion, for instance by direct current connection (HVDC) or pocket operation, both of which stopped the 4/11 cascading failure. What needs historical explanation, then, is why collaborating actors chose for either synchronized or asynchronic connection to the original UCTE grid where, much later, the system failure of 4/11 emerged. We argue that such choices were historically contingent, and that historic processes such as complicated actor negotiations and choices as well as path dependencies and ways of dealing with these explain the current status of these connections, with due consequences for Europe's electrical vulnerability geography as exposed at 4/11.

Within the UCPTE, parallel operation of power stations in one transnational synchronized system was the preferred mode of operation from the beginning and remains so today as further expansion of the synchronized area is contemplated. From the 1950s UCTE spokespersons foregrounded both economic and reliability advantages of synchronous cooperation. As for economics, besides traditional arguments exploiting an economic mix of power sources was the most important argument for trans-border collaboration: an original aim of the UCPTE (explicitly stated in its 1954 statutes) was to eliminate losses of excess hydropower in post-war Europe. In a synchronously operated power pool, hydropower plants would no longer have excess hydropower to go to waste; instead all available water could be led through the turbines and feed into the power pool, enabling a decrease of fuel costs in thermal power stations elsewhere in the system. Hydropower wastes had largely been eliminated in the UCTE zone by 1970 (UCPTE 1976). As for reliability, synchronous collaboration implied that any failure of a power station in the grid would be contained and counteracted in a matter of seconds by other generators in the pool. Such failure would cause a decrease of the system frequency, which by virtue of its linear correlation with the rotation speed of electromagnetic machines would instantaneous decrease of the number of revolutions of all turbines in the pool. Conversely, by virtue of the same relationship the still operational generators jointly counteract a further frequency drop; the larger the pool, the more generators to stabilize the frequency, the less impact of failure. Furthermore, plant managers could then locally speed up their turbines up and bring the frequency back to the standard 50 Hz. In this way, the "all production units in the synchronous system jointly counterbalance the disturbance of one power station, regardless if this power stations would be located in Lisbon, Palermo or Hamburg, le Havre or Vienna" (UCPTE 1976: 167), an arrangement known as "primary control". On the other hand, it was recognized that synchronous collaboration did entail a risk for a new type of disturbance in the form of cascading failure. Hence the UCPTE strategy of enlarging the synchronous cooperation zone while at the same time taking measures to prevent or contain cascading failure (see below).

Of the groupings established in the 1950s and 60s, similar arguments led the South-Western UFIPTE and South-Eastern SUDEL rapidly into synchronized interconnection to UCPTE partners. UFIPTE members did so in 1964; the SUDEL group eventually chose the same path. Inspired by the twin aims of exploiting the complementarities of hydro and thermal power stations and increasing reliability of supply, the partners initially constructed a separate ring SUDEL ring in Southern Austria, North-eastern Italy, and Western Yugoslavia, operational in 1970 (SUDEL 1984: 16-17). The ring could be connected to the UCPTE or the CDO-IPS system at will. By 1970 the Yugoslavian partner operated 10 interconnections with CDO-IPS partners and 10 with UCPTE partners (Lagendijk 2008: 188, table 5.2). From 1975 SUDEL chose synchronous collaboration with the grids of both its UCPTE partners, which in 1977 was extended to Greece. This move was credited with great stability and quality improvements for particularly the Yugoslavian and Greek systems (SUDEL 1984: 20). Yugoslavian collaboration with its COMECON neighbours now happened via HVDC links or other asynchronous couplings. Both UFIPTE and SUDEL members became full UCPTE members in 1987.

The same happened later with Central Eastern European countries in the 1990s (Persoz and Remondeulaz 1992; Hammons et. al. 1998). During the Cold War, the power systems of four Central Eastern European countries were synchronically connected to the Soviet United Power

System in 1962 and later other systems were added. Breaches in the Electric Curtain were rare and used HVDC or pocket mode. The end of the Cold War, however, produced a political, economic and also electrical reorientation in Central Eastern and Eastern European countries. Polish, Czech, Slovak, and Hungarian power companies now contemplated synchronous connection to the UCPTE zone, seeking reliable and economic collaboration in anticipation of an economic boom and trade flows with Western Europe – an in the meantime exploit export possibilities to the Western economies. To facilitate this process they set up the new association CENTREL (1992-2006), and by 1995 synchronic cooperation with the Eastern UPS system was replaced by synchronic cooperation with the UCPTE zone. Cooperation to the east now happened by asynchronic links. CENTREL members gained full UCPTE membership in 1999 and CENTREL was terminated in 2006 (Lagendijk 2008: 201-204). The Western-Ukraine power system continued to collaborate with the CENTREL system and synchronized in 2002. Romanian and Bulgarian power systems took a similar trajectory and, after the turmoil of the Yugoslavian wars, became full UCTE members in 2003 and were included in the UCTE synchronous operation in 2004 (Hammons et. al. 2000; UCTE 2004c; Feist 2004). Europe's Electric Curtain, and in its footprints the barrier to the 4/11 failure, had moved eastward to the UPS border.

Finally, it is noteworthy that the Trans-European Synchronously Interconnected System TESIS and, accordingly, the geography of 4/11, includes Morocco, Algeria and Tunisia. The relevant historical choice here was for synchronous operation through a HVAC Spain-Morocco submarine interconnection in 1997, despite the fact that HVDC had been considered. Indeed, the original HVAC cable had been designed for an anticipated change to HVDC operation, but this change was not implemented because HVAC connection was found to improve the stability of the Moroccan system (Granadino & Amerdoul 1999; Zobaa 2004). Thus it was possible, at 4/11, that a frequency drop on the Spanish side triggered the underfrequency protection on the Moroccan side and tripped the submarine cable, interrupting Moroccan imports, and causing a deficit in the Moroccan system. Since the Moroccan system was already interconnected synchronously to the Algerian and Tunisian systems, these were also drawn into the vulnerability space of 4/11 (De Montravel et. al. 2006; UCTE 2007: 39).

Other electric power collaborations and individual power companies, by contrast, chose not to develop synchronous cooperation with UCPTE partners and as a result fell outside the 4/11 sphere of influence. Given the advantages of synchronous operation, why did they choose differently?

To the North, *Nordel* partners did develop intense collaboration with UCPTE partners. However, here is a historic legacy of choosing for asynchronous couplings in the form of High Voltage Direct Current (HVDC) cables such as the Konti-Scan (Sweden - Denmark, 1961), Skagerrak (Norway – Denmark, 1977), Baltic (Sweden – Germany, 1994), Kontek (Denmark-Germany, 1995), SwePol (Sweden-Poland, 2000) and latest the NorNed (Norway – Netherlands, 2008) cables (figure 3). These links do not transmit frequency disturbances. At 4/11, traffic on most of these cables was not affected at all. The Skagerak and Konti-skan cables possessing emergency frequently regulation even countered the disturbance, without any impact on the *Nordel* systems north of the HVDC links (UCTE 2007: 38-39). Thus 4/11 stopped at the Nordic HVDC barrier.

The historical choices and path dependencies behind this situation is best illustrated for the case of Denmark. Until their merger in 2005 Denmark had two *Nordel* partners, *Eltrans* for mainland Western Denmark and *Elkraft* for the densely populated islands of Eastern Denmark, where the capital Copenhagen is situated. Eastern *Elkraft* or its constituent organizations historically collaborated in *Nordel* by HVAC submarine cables since 1915, as mentioned repeatedly above. Plans for synchronous collaboration between Norwegian, Swedish, east-Danish and German partners – implying synchronization between Scandinavia and Continental European systems – were rejected as expensive and risky, since it demanded a number of modifications of the existing system (Wistoft et. al. 1992: 87). Direct collaboration with UCTE partners was started only in 1995 with the Kontek cable to Germany using HVDC transmission. East Denmark thus followed the *Nordel* pattern described above, and was not affected by 4/11.

Figure 3 - Connections between NORDEL and the continent (2008)

The West-Danish situation, however, developed the opposite way (Van der Vleuten 1998, 1999). *Eltrans* and in particular its most Southern member had historically developed collaboration with Northern German power companies since the 1920s. As a result, the West-Danish *Eltrans* grid of the 1950s was synchronized with the continental UCTE system to which it was physically connected. Rather than changing this historic collaboration, *Eltrans* chose to maintain and expand it as the cheapest way to achieve the benefits of interconnection. In the early 1960s, with its German partners at the negotiating table, *Eltrans* developed cooperation with its more northern *Nordel* partners through the Konti-Skan (and later Skagerrak) HVDC cable, which was found cheaper than AC connection and the associated synchronization of Nordel and UCPTE systems (Wistoft et. al. 1992: 88). From a vulnerability perspective, then, these historical choices left Western Denmark outside the protective HVDC barrier that shielded other *Nordel* areas from impacts of 4/11 as figure 2 indicates.

The boundaries of 4/11 to the West and East followed a similar historical logic. The UK has been connected to France by HVDC since 1961. Again this was a contingent historical choice: A study committee had earlier recommended a HVAC connection, while noting HVDC advantages such as higher capacity, reliability of operation, independent control of the British and French networks, and providing a barrier to cascading failure. Yet intensive Swedish lobbying on behalf of HVDC supplier Asea won the French and British parties for a direct current connection (Fridlund 1999: 185-190). Almost half a century later, the present *Interconnexion France England* carrying some 2000 MW from France remained unaffected by the 4/11 events (UCTE 2007: 39).

To the East, the Unified Power System in 2006 embraced the Commonwealth of Independent States (CIS, 1991) and the Baltic states. Though synchronization with the UCTE zone has been under investigation since the 1970s (Persoz and Remondeulaz 1992; Bondarenko et. al. 2002), it preferred asynchronous cooperation by direct current connection (either HVDC lines or back-to-back conversion stations) or operation of HVAC tie-lines in island mode (De Montravel et. al. 2007: 18-24). The UCTE also preferred this mode as synchronous collaboration of the two blocks would decrease transmission capacity available for the EU Internal Electricity Market, which was already congested. This stopped the cascading failure of 4/11. The importance of historic choice and path dependency is nicely illustrated in the strong preference in several Baltic States from the mid 1980s to disconnect from the UPS system and connect synchronously to the UCTE zone, originally a politically motivated strategy for achieving independence from Russia (Högselius 2006). Yet the economically motivated choice to continue UPS cooperation, mainly to reap the economic benefits of power export, kept the Baltic republics out of reach of 4/11. Likewise, connection of Turkey to the UCTE zone has been studied since the 1970s is still under negotiation today. 4/11 stopped because Turkish system interconnections to UCTE partners were operated in islanding mode, a form of cooperation that was already used in the cooperation with Bulgarian partners from 1975.

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Historical choices and path dependencies not only shaped who was included and excluded in the 4/11 failure, but also how the event influenced consumers in the affected area. As illustrated in figure 2, at 4/11 the TESIS grid split into four parts. Within 4 seconds from 22:10:28 to 22:10:32 the system split following tie-line trippings between E.ON. Netz and RWE, internal E.ON. Netz lines, internal APG lines in Austria, Hungarian-Croatian tie-lines, internal Croatian lines, and the Spain-Morocco cable (UCTE 2006b, 2007). The consequences for consumers depended on their location relative to these fractures.

The infrastructure history aspect we want to foreground here is that the grid fractures occurred where the historically shaped interconnections were rather weak. For instance, the split between the Western and the North-Eastern zone roughly followed the legacy of the Cold War Electrical Curtain. East-west connections across the former curtain were relative recent and weakly developed. This legacy has been dealt with differently along the former Curtain, which means that the breakline deviated from the former Electric Curtain on details.

Northern Germany, where the incident originated, is an exception: Here the breakline followed the disconnected line facilitating the cruise ship passage close to the Dutch border and then several RWE-E.ON. Netz tie-line trippings, which drew the most Northeast part of Germany and continental Denmark into the North-Eastern 4/11 zone.

Further South-East, the Cold War legacy, and ways it has been dealt with in the last 2 decades, became an important determining factor. First, the breakline followed internal E.ON. Netz trippings close to the former East German and Czech borders, served only by four cross-border tie-lines. Further south the fault line crossed Austria, another deviation to the Electric Curtain logic, which is nevertheless explained by historical path dependency and choice. While after 1989 the connections of Austria’s centres of consumption in the East (such as Vienna and Graz) to its Czech and Hungarian neighbours were strengthened, the development of internal Austrian east-west linkages remained ambiguous. Already in the late 1940s and early 1950s Marshall planners observed this problem and tried to strengthen the connection between Austria’s Western sites of Alpine hydropower production to its Eastern centres of consumption (Lagendijk 2008**:** 171), but the links remained a bottleneck. For the last three decades an Austrian ring has been under construction, but completion in the southern part of Burgenland and east of Styria is delayed due to successful local and regional protest groups opposing the impact of transmission towers on the landscape and requesting underground cabling (ICF Consulting 2002, 41; CEC 2007, 9). Without this line, which is included in the EU Trans European electricity Networks plan, only one 380 kV line is in place, which tripped on 4/11 (UCTE 2006c: 72).

The breakline then followed the Slovenia-Hungarian border, not the Austrian/Italian-Slovenian border. The northern part of former Yugoslavia has been involved in Austro-Italian cooperation since the late 1950s in SUDEL. The Yugoslavian wars fragmented the previous Yugoslavian system and directed efforts to building national systems in the new republics. In the case of independent Slovenia (1991), active economic and technological cooperation was reinforced with Austria. After the wars damages were repaired and eventually, in 2004, synchronous connection with the UCTE zone was restored (Feist 2004), but these repairs of tie-lines between former Yugoslav states restored the old links and did not facilitate much needed upgrading (which was planned and anticipated in the EU's TEN programme as EL-4). At 4/11, therefore, the Slovenian-Hungarian/Croatian border was the weak spot. Further south, the lines of frequency deviation ran across Croatia as the weaker East-West linkages tripped. Similar types of historically shaped logics applied to the breaklines between the north-Eastern and South-Eastern zones.

The consequences of this pattern for consumers differed per zone. The (again historically shaped, but we will not dwell on this here) overall system condition prior to the event was one of structural electricity export from the North-Eastern zone, notably Northern Germany (not least wind power) to the Western and South-Eastern zones. The consequences were most severe for the Western zone lost some 9 GW previously imported from the North-Eastern zone and could no longer match consumption. The resulting frequency drop caused the tripping of some 11 GW of generation units, increasing the imbalance between production and consumption to nearly 20 GW. This situation was countered by load shedding, that is, selectively cutting of consumers (and pump storage plants) in an automatic and pre-defined fashion to restore the balance between production and consumption. As a result over 15 million households were left temporarily in the dark. The North-Eastern zone, by contrast, was left with a production surplus of over 10 GW causing a frequency rise. The resulting tripping of generators (particularly wind power) lowered the surplus, which was further countered manually by decreasing generation output. In the South-Eastern zone, the split caused a modest deficit of 770 MW. The frequency stayed above the threshold and no consumers were put into the dark. The North-African zone, as we saw, had power shortages leading to load shedding and blackout (UCTE 2007).

The vulnerability geography of 4/11 can be analyzed in further detail, as historically shaped grid topologies, and (im)balances between domestic production, imports, and consumption in individual supply areas resulted in different vulnerabilities. While only 3% of Dutch and 0.1% of Swiss consumers were shed, this was the case for ca. 20% of Portuguese consumers. We will not go into further detail here, but merely note this aspect of the 4/11 vulnerability geography as pictured in figure 4.

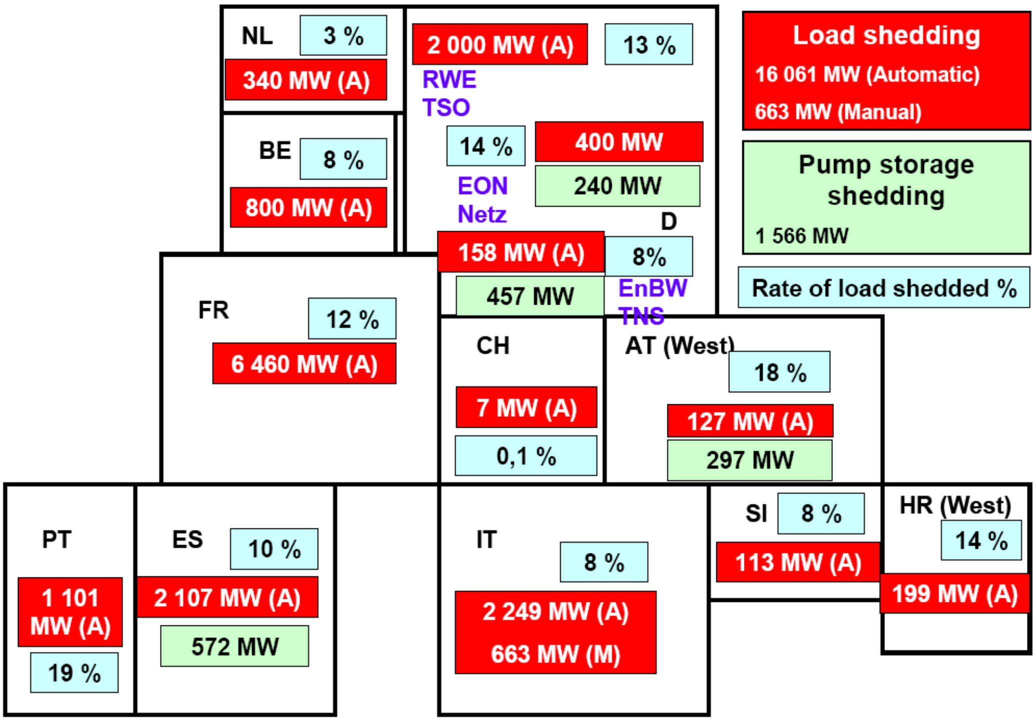

Figure 4: The vulnerability geography of the Western UCTE zone at 4/11, indicating how many consumers (and pump storage plants) were shed per country. Source: UCTE 2007, 26. Reprinted with kind permission of the UCTE.

Interpreting and governing vulnerability

Having discussed how historical path dependencies and ways to deal with these shaped the logic of 4/11, we will now turn to subsequent discussions that the event seemingly triggered. After 4/11 newspaper reports were quick to foreground the alleged fragility of the European power grid, which they blamed in particular on its insufficient governance structure, decentralized in the hands of transmission companies and their international associations. For instance, the Associated Press article "German-triggered blackout exposes fragile European power network" (*International Herald Tribune* and *USA Today*, 5 November 2006) cited EU politicians arguing for an increased role of the European Union in electricity matters. Italian Prime Minister and former European Commission President Romano Prodi argued that there is a "contradiction between having European [power] links and not having one European [power] authority...We depend on each other but without being able to help each other, without a central authority" (Ibid[1]). Allegedly the existing decentralized and voluntary organizational framework "was no longer *Zeitgemäss*" (*Frankfurter Allgemeine, 6 November* 2006). EU Energy Commissioner Andris Piebalgs agreed and stated that "these blackouts ... are unacceptable" and "confirm the need for a proper European energy policy. Energy security is better delivered through a common European approach rather than 27 different approaches" (Commission of the European Communities 2006b). When the UCTE interim investigation report became available, Piebalgs continued in a press release that "it is now clear that the EU internal market needs stronger cooperation … Soon I will propose concrete measures to address this problem", including as an EU-level regulator and formally binding legislation and perhaps even a European priority interconnection plan (Commission of the European Communities 2006c). An investigation report by the ERGEG (European Regulators Group for Electricity and Gas), established a few years earlier on EC initiative to support the introduction of EC legislation in Member States, further confirmed that "the events of November 4 uncover a legal and regulatory gap in Europe's electricity market" and that EU action and legislation was needed (ERGEG 2007: 4). These observations are important because they helped legitimize new EU legislation and a new EU-level regulator that have since been established or are well under way (Piebalgs 2009; Commission of the European Communities 2009).

Several scholars support this position that the current vulnerability relates to outdated governance systems, necessitating "a higher level of coordination" or new regulatory bodies regulation (e.g. Gheorghe et. al. 2006, 2007). From a historic perspective, however, we would not take for granted these two claims of power grid fragility and the necessity of EU-level intervention to repair it. As noted in the introduction, both claims were contested by sector representatives arguing that disturbances like 4/11 are extremely rare, and that existing safety measures and governance structures worked well to contain and repair the 4/11 system failure. Most of the network was back on track within 30 minutes, and all of it in less than two hours. On behalf of Transmission System Operator RWE, Theo Horstmann therefore stated that "the networks safety measures worked perfectly"; French power distributor RTE president André Merlin agreed that "Europe's power network had worked smoothly" (both cited in the *International Herald Tribune* of November 5). The UCTE 4/11 final investigation report later also argued that "the decentralized responsibilities of TSOs have demonstrated their efficiency" (UCTE 2006:6).

We must therefore observe that interpretations of the vulnerability and optimal governance mode of Europe's power systems were not unambiguous but contested. It is tempting to refer to a similar debate on interpretations of large technical system reliability in organizational sociology. On

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[1] Due to a spelling mistake in *Herald Tribune*/ *USA Today* articles, we here site the version in *BBC News*, 6 november 2006.

one hand, Normal Accident Theory (Perrow 1984; 2007) foregrounded that modern technological systems, prominently including electricity supply, have become so complex, with many feedbacks, causal loops, and possibilities for cascading failure, that they become susceptible to breakdown that cannot be predicted or anticipated. Breakdown and vulnerability became an inherent, 'normal condition' of such systems and are the subject of inquiry. On the other hand, High Reliability Theory was developed to study why many such complex technological systems, again prominently including electric power systems, in fact operate at exceptionally high reliability levels and rarely break down. Apparently, build-in redundancies, continuous organizational adaptation, and other security measures go a long way in preventing disruptive failure (Roberts 1990; La Porte 1996; Rochlin 1996). Taking this observation of conflicting interpretations a step further, Summerton and Berner (2003) found that risk perceptions and associated governance responses are subject to negotiation between stakeholders and thus have a logic and history of their own that merits separate inquiry.

A historical perspective brings into view how both the competition for dominance in transnational infrastructure governance and the interpretation of infrastructure as vulnerable or reliable have a historical dynamic of their own. In this following sections we therefore address the historical dynamics of (1) power sector work to eliminate vulnerabilities, which resulted in perceptions of high system reliability at the time of 4/11 and of decentralized, sector transnational infrastructure governance as adequate; and (2) EU efforts to absorb the energy and electricity domains in its sphere of influence, which involved an emerging perception of electricity infrastructure as inherently vulnerable in dire need of EU governance.

The making of a High Reliability Organization

As noted above, the UCPTE from its beginning in the early 1950s interpreted transnational collaboration in a synchronously operated electric power pool as advantageous for both economic and reliability reasons – in case of failure back-up capacity could be drawn from the power pool, and the larger the synchronously operating power pool, the lower the impact of failure of a single unit. At the same time, transnational synchronous operation introduced the possibility of a different type of failure in the form of cross-border cascading failure, where overloads and underloads could transplant throughout the network. Sector organizations such as UNIPEDE and the UCPTE therefore amply studied measures of anticipating this new form of failure from the 1950s. Indeed, the UCPTE made system reliability it a cornerstone of its activity (De Heem 1952; UCPTE 1959; Cahen and Faves 1964).

By the mid 1960s, when the 1965 rolling blackout in the United States provided a renewed sense of urgency, the UCPTE distinguished a number of potential system disturbances and associated counter measures that their members should implement (UCPTE 1965, 1966). The overall strategy was that the Western European system should consist of interconnected yet separately managed networks, and that decentralized network managers were responsible for the reliability of supply in their own areas. Another crucial principle was that a short-time disruption was "more acceptable than the effects of a comprehensive network disturbance with an unavoidable interruption of supply for a long time" (UCPTE 1966: 6-7).

These principles inspired a set of precautionary measures, many of which and helped to contain 4/11 almost half a century later. A number of design principles should reduce the chance of disturbance in all member areas. If disturbances should nevertheless happen, it was important to prevent long-lasting damage. Therefore all system elements should possess protection equipment automatically disconnecting the element if system parameters fell beneath predefined thresholds, shutting it down before it burnt down. Once the system parameters came above their thresholds again, the element should be automatically re-connected. At 4/11, it was such automatic protection gear that caused the line and generator trippings, and soon after brought them on-line again.

To absorb and counter such failures, UCPTE members should provide for sufficient back-up capacity throughout the interconnected system. This included generation capacity - members should at all times run back-up capacity (in the 1960s corresponding to some 3-5% of the expected load or the largest power station in the pool), and construct emergency generating units that could be started relatively fast, such as gas turbines. It also included other equipment: Cross-border interconnections, in particular, should have ample spare capacity to be used in case of incidents. Later the general rule became that entire system must always be operated with at least so-called single back-up capacity (N-1 backup), denoting that if one system element fails, the other elements are able to absorb the additional load (UCPTE 1990: 22). This rule was violated at 4/11.

Should cascading failure happen despite these measures, cascading overloads should be countered by automatically tripping generators, while cascading frequency drops should be contained by selectively disconnecting consumers. For this purpose members should develop predetermined load shedding programs, disconnecting consumers in a controlled fashion if the frequency dropped under a certain threshold. These should preferably be executed automatically by means of frequency relays. At 4/11, indeed the blackouts for some 15 million households were due not to malfunctioning equipment but to such controlled load shedding, which secured uninterrupted supply of the large majority of households in the infected zone.

Next, UCPTE members were responsible for improving the system parameters in their own supply areas. To facilitate coordination of such decentralized response, further counter measures by control centres, telephone and telex connections between the control centres of neighbouring members should facilitate the coordination of decentralized responses, but at 4/11 little additional coordination proved necessary. A final measure proposed in the mid 1960s was the introduction of measurement equipment was needed to detect irregularities in the operation of power station, load centres, or international TIE lines. These later grew into data processing programs such as SCADA (Supervisory Control and Data Acquisition) and EMS (Energy Management System).

These procedures required considerable investments in the 1950s and 1960s, and they seemed to work: In the 1970s and 1980s the UCPTE system counted as highly reliable. Simulations suggested that local failures did not lead to cascading failure and did not compromise overall system security (e.g. UCPTE 1986). At the eve of neoliberalization, the UCPTE concluded that although it could not provide absolute guarantees, coordinated purposeful action produces “a very high degree of reliability of power supplies, without incurring costs which are out of all proportion” (UCPTE 1990, 20). The organization emphasised that such reliability was best achieved in the informal and decentralized governance model of the UCPTE: “A European centralized control centre … does not exist and could not function properly, because it would not be able to see the needs of the separate regional networks. Instead, the UCPTE encourages specialists to reach mutual agreement … Then the UCPTE proposed measures will be translated into practice thanks to the influence of these specialists in their respective countries” (UCPTE 1976, 188).

Yet it is this precisely this model that has been accused for inadequacy in recent years. One hypothesis is that neoliberalization changed this secure state of affairs. The restructuring policies of the 1990s (privatization, liberalization, deregulation) led to institutional fragmentation, which might have affected the reliability of the Europe’s electricity infrastructure negatively: in the new unbundled institutional framework, UCPTE infrastructure vulnerability governance might no longer work. Current research on critical infrastructure in an institutionally fragmented environment, however, does not univocally support this hypothesis (Roe et. al. 2005; De Bruijne 2006; De Bruijne and Van Eeten 2007). While on one hand critical infrastructure indeed became more complicated to manage, on the other hand infrastructure organizations worked hard to cope with the new challenges and found ways to secure systems even in these difficult conditions, for instance by improving resilience-based strategies rather than risk anticipation strategies and investing in real-time monitoring and control options. Although they may operate closer to their limits, in general critical infrastructure still provides extremely reliable services. Even during events carved into public memory as exceptionally severe illustrations of neoliberal vulnerability, such as the rolling blackouts in California of 2000/2001, the lights largely stayed on.

The UCPTE, accordingly, continued its work for a reliable electric power system during the years of institutional restructuring. As the European Union pushed the Internal Electricity Market and the associated unbundling of electricity production and transport, governing cross-border flows became a responsibility of what were now called Transmission System Operators. To anticipate these changes the UCPTE first changed from personal to company membership in 1996, then changed its name to UCTE in 1999 (dropping the P for production to signal that it was now an TSO organization), and then in 2001 re-established itself as an international association under Belgian law; it had developed from a gentlemen's "club" to a system security rule setter and system adequacy "watchdog" association (UCTE 2000: 27).

In this new situation, too, the UCTE perception of Europe's electric power system remained one of high reliability. Initially the UCTE was alarmed by the new developments: competitive pressures might jeopardise system security and increase the possibilities of black-outs (UCPTE 1998: 15), and the common carrier principle might complicate international coordination. The UCTE then entered in a debate with the European Commission to accommodate its concerns in EU policy, and was quickly reassured: a few years later the UCTE disagreed with critics who held that institutional unbundling, competition, and short term profit would necessarily compromise system security. UCTE spokespersons argued that such fear was based on the "wrong assumption" that power supply had not been cost-driven and solely security focused in the pre-competition era, while in reality there had always been trade-offs. Furthermore, deregulation of production and supply certainly implied mutations in vulnerability governance but did not render it obsolete: "the UCTE believes that the new deregulated market environment is compatible with an adequate level of system reliability" (UCTE 2000: 25). To take one example, the costs for primary control providing immediate reserve and frequency stabilization was previously integrated in the overall prices of generation and transmission. After deregulation and unbundling, power generators offered generation reserve to TSO's, implying more complex contractual arrangements but also more transparency since the price of primary control was explicit. The UCTE itself distributed primary control responsibilities between TSO's and specified technical parameters; TSOs had decentralized autonomy in how to achieve these norms.

Meanwhile, security rules were tightened, particular with a security package in 2002. Existing rules were sharpened and systematized in the eight policies of the Operational Handbook, seven of which were in force at 4/11 (on load frequency control and performance; scheduling and accounting; operational security; coordinated operational planning; emergency operations; communication infrastructures; and data exchange policies). The remaining policy on operational training was released after the blackout. In order to enforce these standards, a multilateral agreement should make the operation handbook specifications legally binding for participating TSO's in the UCTE area, which entered into force in 2005. Finally, the so-called *Compliance Monitoring and Enforcement Process* was developed to verify TSO implementation of the agreed standards and measures in case of non-compliance. A pilot was running in 2006 and published in 2007; this system was not yet fully operational during 4/11 (UCTE 2007: 12).

As the result of this sustained effort to secure European electricity infrastructure in years of radical restructuring, many stakeholders and analysts still considered Western Europe's electric power system extremely secure. The UCTE system adequacy forecast for 2003-2005 and other documents noted that although cross-border power flows were increasing and in some locations the system was increasingly operated near its limits, "the security of the UCTE system as a whole seems to be not at risk" (UCTE 2002b: 5).The Italian Blackout of 2003 did not fundamentally change this view: to the UCTE it confirmed that there was little slack in the system at some points, not least concerning Italian reserve generation capacity and load shedding programs. Yet the disturbance (which originated in Switzerland) was contained everywhere except in Italy. Besides, in Italy itself supply was restored within 5 hours in Northern Italy and 10 hours in the entire mainland. The UCTE found “no fundamental deficiencies in the existing rule setting of the UCTE system” (UCTE 2003, 11; 2004b). Also the existing decentralized governance mode remained unquestioned: “The blackout and subsequent investigation has cast no doubt on this [decentralized] model in principle. On the contrary, the lack of a grid operator’s empowerment and independence could be identified as a potential security risk” (UCTE 2004b: 10). What was needed, however, was implementation of compliance with UCTE standards the organisation was already working for. In 2004, UCTE members again succeeded to run their systems in “a highly secure and reliable manner” (UCTE 2004c: 5). A year later the adequacy forecast for 2005-2015 again did not anticipate major risk and expected a “reasonable security margin” by 2010 (UCTE 2005: 5).

Some economists have taken this argument of infrastructure reliability a step further: for instance, just prior to 4/11 a group of Dutch economists issuing a number of reliability studies emphasised that what is needed is not a zero failure perception of reliability, but rather a so-called social optimum: additional security is possible only at disproportionately high cost. Yet “the power grid of most Western European countries is highly reliable. Most utilities provide power more than 99% of the time” (Baarsma et. al. 2005: 1). Moreover, the current high reliability levels result from the past ‘engineering practices’ might have lead to ‘over-investment’ in power grids (ibid); indeed, from an economic perspective, consumers might prefer a reliability decrease if they come with lower electricity costs (Baarsma 2004, 9; compare Kling 2007).

It is in the historical lineage sketched in this section that the UCTE interpreted 4/11 as a demonstration of the well-functioning of UCTE reliability measures and its associated decentralized governance mode. Although improvements in UCTE rules and practices were possible and recommended, reconstructions of 4/11 showed that he disturbance had never been beyond control. After all, it was not equipment malfunctioning but pre-installed equipment protection gear that caused the trippings as it was supposed to, securing the equipment from harm, an enabling quick recovery when system parameters improved. Controlled load shedding and other pre-defined measures mostly kept the lights on. The areas sacrificed to achieve this overall system performance were back on-line mostly within 30 minutes and everywhere within 2 hours thanks to effective decentralized management response. In the final analysis the impact of 4/11 on consumers was limited, especially when compared to disturbances in low and medium voltage distribution networks (where by far most faults happen). In the Netherlands, for instance, for consumers and small businesses 4/11 made up less than 2% of the annual average power outage per consumer per year (Ministry of Economic Affairs 2007: 11).

This sector perception of high reliability, however, was very different from the message conveyed in most newspaper reports after 4/11 and subsequent EU policy making. We shall now turn to this perception of extreme system vulnerability, which informed European Union policymakers and connected to EU proposals and implementation of new transnational electricity infrastructure governance modes.

Governing power: The EU and transnational infrastructure governance

To make sense of the EU perception of, and response to, 4/11, we have to consider the historical process of EU involvement in transnational energy infrastructure governance. the phenomenon of transnational infrastructure governance of course precedes EU involvement by decades (Djelic and Sahlin-Andersson 2008; Schipper and Van der Vleuten 2008), despite the problematic habit of EU spokespersons to equate cross-border European cooperation and integration with EU institutional history, that is, the development of the EU and its direct forerunners: the *European Coal and Steel Community* (ECSC, 1951), the *European Economic Community EEC* and *Euratom* (1957), and the *European Communities* combining these organizations (1967). Thus EU Commissioner Piebalg's call for a "European energy policy" as opposed to "27 different approaches" (Commission of the European Communities 2006b) neglects how for over a century a number of international organizations have worked together with representatives of states and utilities for transnational infrastructure development and governance, for the domain of electricity resulting in today's power grid and exchanges as described in previous sections. Such international organizations as the International Electrotechnical Commission (established 1906), UNIPEDE, the UCPTE and similar organizations, the International Energy Agency (1974), and also electricity commissions of the League of Nations (1919), the UN Economic Commission for Europe (UNECE,1947), or the Organisation for European Economic Cooperation (OEEC, 1948) all predominantly used "soft power" of facilitation and negotiation, research and best practice development, standards, recommendations and voluntary agreement.

We therefore interpret the history of Brussels-involvement in transnational energy and electricity infrastructure governance as a long and strained negotiation process, in particular between EU-forerunner organizations, sector collaborations and organizations, and state governments. When the EU predecessors were born in the 1950s as collaborations between six member states (Belgium, France, Italy, Luxembourg, the Netherlands and West-Germany), there were several attempts to gain foothold in existing transnational infrastructure governance. For instance, the Spaak Report (Spaak et. al. 1956: 40, 126, 134) preparing the Rome treaties (the EEC and EURATOM treaties, 1957) discussed common policies for telecommunications, transports, and energy. Yet the balance of power between stakeholders in the 1950s, 60s and 70s resulted in placing transnational infrastructure governance in the hands the respective sectors and their own international organizations, largely bypassing the Brussels organisations.

This logic has already been described for telecom and transport infrastructure. A common telecommunications policy, though suggested in the Spaak report, was not included in the EEC treaty due to lack of consensus. Some EEC member governments continued to push for a common telecommunications policy (including improvement and operation of a transnational telecommunications network), but failed as other members preferred less restrictive organizational settings with much broader membership such as the International Telecommunications Union and the Conference of European Post and Telecom administrations, which was set up in 1959 as a sector, non-governmental alternative to EEC governance (Laborie 2006).

Contrary to telecommunications, the transport domain did make it into the 1957 EEC treaty, announcing a Common Transport Policy as a logical next step in the integration process. Yet again it failed to come off the ground until as the European Court's *inactivity verdict* of the EU's transport efforts market a new beginning in 1985 (Schipper 2008). Again, this does not mean that transnational transport collaboration and governance did not exist, but that European governments and other stakeholders preferred collaboration outside the EEC framework in institutions such as the UNECE and the Conference of European Ministers of Transport established in 1953 (Van der Vleuten et. al. 2007; Henrich-Franke 2008; Schipper 2008), jointly developing and implementing for instance the European E-road network. In this period EEC initiatives in European patent and research cooperation, too, poorly developed as member governments preferred to cooperate outside the EEC framework (Kranakis 2004: 2008).

An explicit common energy policy, like telecommunications policy, lacked in the 1957 EEC treaty. However, failure of a common response to the reopening of the Suez Canal in 1957 – which threatened domestic coal production in several member states – had placed a common energy policy firmly on the agenda by the early 1960s, aiming for a common energy marked and security of supply (Daintith and Hancher 1986). Just like in the case of transport, however, a common policy failed to materialize in the 1950s, 60s and 70s, and observers have commented that "[t]here is general agreement that energy policy must be ranked as one of the Community's major failures" (Padgett 1992: 56; compare Kohl 1978). Again state government representatives making EEC decisions did not agree on a common community energy policy, leaving transnational energy governance implicitly or explicitly in the hands of stakeholders and international organizations outside the Brussels framework.

Moreover, if energy policy was addressed, electricity infrastructure was still seen as well-placed in the hands of sector organizations, and largely excluded from debates. Already the 1956 Spaak report found that electricity and gas infrastructure was dealt with satisfactorily by sector organizations, which were well prepared to address their technical and economic specificities; these domains therefore were less urgent candidates for a common policy (Spaak et. al. 1956: 126). Work on a common energy policy in the early 1960s, located at an Interexecutive Working Group on Energy (set up jointly by the EEC, ECSC and EURATOM in 1961), also foregrounded energy source problematiques rather than infrastructure issues. A common policy on fuels, however, was repeatedly frustrated by Member State concerns of domestic coal market protection (Lucas 1977: 35). By 1964 a Protocol of Agreement on Energy Policy introduced a fairer competition between energy sources, a wider diversification of oil supplies, and prices as low and stable as possible. Another major point would be the provision of Community procedures to harmonize national measures in the energy sector (Hassan & Duncan 1994: 164). With the 1967 merger treaty, merging the three Communities ECSC, EEC and EURATOM into a single European Community, the Working Group on Energy was replaced by the Directorate-General for Energy (DG XVII), but much of the momentum created by the 1964 Protocol and the subsequent Suez crisis vanished and no concrete measures were taken. Only in 1968 the Council accepted Guidelines for a Common Energy Policy to change the situation of severely hindered trade and transit of energy within the Community (Commission of the European Communities 1968), seeking secure supply and low and stable prices. This time, network-dependent energy forms like electricity were mentioned as needing common regulations for open access and tariffs. But again results were disappointing. Even the 1973 Arab oil embargo did not lead to an extension of Community energy policy; rather it proved once more that energy “is an extremely sensitive area of national sovereignty” in which member states were reluctant to tie their hands in the Brussels cooperation (Kohl 1978: 111).

The Brussels organizations only started to interfere seriously with electricity infrastructure governance in the 1980s, in parallel with new initiatives in the domains of telecommunications and transport. The first breakthrough was the Single European Act (1986), which set a target date (1992, later postponed) for realizing a common energy market, including an internal market for electricity (CEC 1987; Schmidt 1998). The Treaty on European Union (1992) added EU involvement with Trans European Network planning and financing as a complimentary measure, and by 1994 the first priority interconnection lists were decided (European Council 1994).

In this period, the EU managed to assert itself firmly as an important player in transnational electricity infrastructure governance, despite protest of the electric power sector. UCPTE spokespersons complained that apart from the hassle and problems de members would encounter while restructuring, the proposed internal market would lead to increased competition across borders between utilities that traditionally coordinated and collaborated international exchanges closely and successfully. Still, unlike in previous decades member state governments now often backed the European Commission instead of electric power interests. This change in the balance of power made opposition by sector representatives less effective. As an alternative strategy, sector organizations now started to lobby the EU and their national governments for modifications in policy packages with varying degrees of success; the negotiated character of this process shows for instance in the different ways of “downloading” EU policy to the national level, where different member states arrived at different solutions (Padgett 2003). At the international level, the UCPTE and UNIPEDE reoriented their efforts towards Brussels. The UCPTE settled permanently in Brussels in 2001. In opposing increased EU influence, then, the sector’s organization was clearly drawn into the EU orbit. The transnational infrastructure governance landscape further changed as the UCTE, Nordel, and the TSOs of Ireland and Great Britain then jointly established the European Transmission System Operators (ETSO 1999) to harmonize network access and conditions for usage, in particular for international electricity trade (UCTE 2002a: 27). The European Commission also set up the European Regulators Group for Electricity and Gas (ERGEG 2003) as an association of national regulators to assist the implementation of EC directives (De Palacio 2003: 34).

Importantly, while successfully entering the domain of transnational electricity infrastructure governance, EU spokespersons and documents rarely questioned electricity infrastructure reliability and the sector's decentralized governance mode, as it would two decades later. The vulnerability-perception of Europe's electric power infrastructure had not yet taken root. In its policy document *The Internal Market* the European Commission (1988: 68-69) praised the highly interconnected electric power system in the Community and recognized that international exchanges were managed well by sector organizations such as UCPTE and *Nordel* without government interference. The EU therefore focused on different governance issues such as monopoly control and ownership of exchanges, power plants and transmission networks, paving the way for a common carrier system with 3rd party access and competition between power producers. This would increase energy trade between member states, further rationalize the sector, increase security of supply, and reduce energy costs (Padgett 1992: 57). Also in the next step, the formulation of the Trans-European Network program for electricity infrastructure, reliability and its governance were not problematized. Focus remained on economic advantages and much attention went to electric power grids in Central and Eastern European countries through the PHARE and TACIS programs.

The EU perception of electricity infrastructure as vulnerable only entered centre stage with the Italian Blackout of 2003 and smaller blackouts in Denmark, Sweden and the UK in the same year. As UCTE President Martin Fuchs observed, the issue of "security of supply issue has come to largely dominate the discussion in terms of energy policy. Transmission system operators' functions and activities have never before been a matter of such considerable interest to politics and public" (UCTE 2003: 4). Indeed, the energy security debate launched by the European Commission in 2001 still had been about fossil fuel import dependencies and the necessity of e.g. keeping oil stocks in EU member countries and diversifying supply; electricity did not figure at all, as it would in later EU energy security documents. Yet a week after the Italian blackout, the Italian Minister of Productive Activities Antonio Marzano, chairing the EU Energy Ministers Energy Council, together with European Energy Commissioner Loyola de Palacio placed the "security of energy systems, in particular electrical power" at the top of the agenda for the next meeting of EU energy ministers (Commission of the European Communities 2003). Two months after the Italian Blackout the European Commission had proposed a directive for the security of electricity supply and infrastructure. Proposing rules for member state governments and TSO's on electricity infrastructure security, it was formally adopted after several amendments in 2005 (EurActiv 2007).

From 2003, then, electricity infrastructure vulnerability became a key concern of EU policymakers and entwined with other policy initiatives; it became an integral part of the movement of extending EU influence into the domain of transnational electricity infrastructure governance which we summarized above. Why was this so? We propose – pending further research – that the foregrounding of infrastructure vulnerability, so different from the sector's own perspective, resonated well with the rapid emergence of security thinking in EU contexts. EU analysts have observed a rapidly emerging policy concern with security and safety of "European" citizens in the last decade or so: They speak of a new EU "security identity" associated with an emerging "protection policy space", which addresses transboundary threats from disaster response and counter-terrorism to food safety and avian influenza (Boin, Ekengren & Rhinard 2006). This development produced an acceleration in the formal European integration process as EU interference in these fields seems hard to resist. The EU program for Critical Infrastructure Protection negotiated in the wake of the Madrid (2004) and London (2005) terrorist attacks fits this pattern; the renewed focus on energy security in the early 2000s following the 1999 oil price was situated near its beginning. More recently, the framing of the recent Third Energy Package illustrates this development. It is presented as a response to the threats of global warming and energy vulnerability. Even the familiar European Commission concern for an internal energy market, previously framed positively as building an inner market, boosting economic growth, and employment, is recast in defensive terms as a counter move to the threat of vulnerability (for "investments will not be made in an uncertain regulatory environment") next to threats to Europe's competitive position (Piebalgs 2009: 5).

We propose that it is this context of ongoing EU attempts to add energy to its sphere of influence since the mid 1980s, and the growing EU security identity since the late 1990s, which caused EU politicians to react very differently to the shock of the Italian Blackout of 2003 as compared to power sector representatives. This pattern was repeated at 4/11. EU Commissioner Piebalgs found in the blackout a confirmation of the security threat stemming from transnational electricity grids, and captured the opportunity to strengthen his argument for EU policy measures he was in the process of designing. Incidentally, more recently Piebalgs also used the recent financial crisis as a supportive argument for the Commission's energy measures (EurActiv 2008). Given the current balance of power between stakeholders, EU advance in the domain of transnational energy electricity infrastructure governance seems rather successful so far and resulted in a number of unprecedented policy measures, not least the EU's Third Legislative Package (then still in draft) including plans for an EU-wide electricity infrastructure regulatory agency.

Unable to resist such EU pressure, the UCTE did not manage to push its position of the safety and adequacy of transnational electricity infrastructure and its preferred sector and decentralized governance model as it had done successfully in earlier decades. Instead it tries to anticipate increasing EU influence, for instance by organizing security conferences and latest by establishing a collaboration other regional TSO associations in the European Network of Transmission System Operators for Electricity (ENTSO-E, established 2008), a stronger international TSO organisation of (ETSO 2008). This sector strategy of a "proactive step ahead", anticipating the establishment of an EU-level regulator, once more seems to draw the sector further into the EU orbit.

Conclusions

This article has framed the blackout, or disturbance, of November 11 2006 in historical context. Following Bialek (2007) we argue that to understand 4/11 and European electric infrastructure vulnerability, one must look at history. We have provided historical data to fill in the black box of history that figures in existing analysis of 4/11 and electricity infrastructure vulnerability. While doing so, we have used our historical perspective to develop four interpretations of 4/11 and its subsequent debates that we found underrepresented in existing political and scholarly discussions.

Two of these interpretations address how historic choices, path dependencies and the ways that these have been dealt with shaped the geographical logic of 4/11. The historic record of transnational electric infrastructure building shows that the decentralized (from a European perspective) organization of today's power collaboration that is often blamed for today's crises was the outcome of a long struggle. We emphasize, however, that this decentralized structure was a deliberate choice of the past serving sector goals of economy and reliability: Centralization and top-down construction of a European power grid was repeatedly pushed as an option, but at crucial moments in the 1930s and 1950s stakeholders favoured decentralized and informal collaboration to the centralized alternative, and sector economics (not least an economic mix of power sources) in specific cooperations to broader EU politics as lead motives for cross-border electrical cooperation.

This observation suggests that researchers need to carefully distinguish and evaluate these motives in present-day discussions, for in the current era of Europeanization they are often conflated.

Then we addressed the meso-regional logic of 4/11. During the 1950s and 1960s Europe was electrically connected, but this process was contained in several transnational meso-regions. The UCPTE collaboration in continental Western Europe (where 4/11 originated) was followed by similar initiatives elsewhere. Connections between these regions existed but were relatively weak. This legacy from this 1950s and 1960s, and the ways it has been dealt with in later decades, shaped the geography of 4/11. Thus, the UCPTE system expanded as existing collaborations and individual partners chose to join in terms of synchronous operation and often UCPTE membership. This process drew South-Western and South-Eastern Europe as well as several North African countries into the vulnerability geography of 4/11. Others, like electric power associations in most of the Nordic countries, the British Isles, and the Commonwealth of Independent States plus the Baltic countries, chose to maintain a higher degree of independence while collaborating with UCPTE partners. They cooperated through asynchronous couplings such as HVDC connections, which halted the cascading failure of 4/11. As a result of these choices and historical processes, 4/11 could affect Paris, Lisbon and Tunis but not Copenhagen and St. Petersburg. Within the expanded UCPTE-centred collaboration, too, historical choices and path dependencies affected how 4/11 influenced consumers in the affected area. This vulnerability geography of a European blackout is interesting because it does not correspond to the EU version of Europe and because synchronous operation between blocks, including the UPS of CIS/Baltics, and Turkey, is still on the table. Synchronization may have many advantages but also comes with vulnerability to cascading failure.

Two other interpretations concern the reception of 4/11. The recent perception of Europe’s power grids as ‘fragile’ and associated calls for EU interference in transnational electricity infrastructure governance should not be taken for granted. Instead they should be interpreted in the context of two historic processes: the development of reliability and vulnerability perceptions of transnational electricity infrastructure since the 1950s, and the struggle for influence of the European Union and its forerunners organizations since the same decade.

We showed how these processes became interrelated: the power sector instituted a governance structure to turn a potentially hazardous transnational system into a high reliability operation, producing a widely shared perception of reliable power grids. Some economists even speak of overinvestment in reliability at the expense of low electricity prices for consumers. Indeed, before transnational electricity infrastructure counted as ‘reliable’ for EU politicians and sector representatives alike. Before 2003 no major transnational incidents occurred in Western Europe’s power grids, and disturbances were contained to the local and subregional levels. The attempts of the EU and its forerunner organizations to draw the energy domain in its sphere of influence focused on other issues, such as import security and the construction of an internal market. The Italian Blackout of 2003 first demonstrated the emerging gap between EU policymakers and sector representatives on reliability issues. While the sector interpreted and dealt with these issues in its historic tradition of building a High Reliability Organization, for EU spokespersons the blackout resonated with the combined concerns of expanding EU influence into the energy domain and the recent security turn in EU thinking and action. This pattern was repeated at 4/11; despite the fact that the lights stayed on for the overwhelming majority of European households and businesses and that selective blackouts were repaired mostly within half an hour, for EU spokespersons it highlighted once more a new form of transnational vulnerability that they increasingly considered a duty for EU regulation.

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