Project UNDERSTAND
White Paper on Security of European Electricity Distribution

Antti Silvast
Joe Kaplinsky

Draft 17.4.2007

Table of contents

Introduction: why electricity distribution is critical infrastructure

It is a common assertion that infrastructure systems only gain wide public attention of when they fail. But if infrastructure only enters the public eye in exceptional circumstances this is not because it plays a marginal role in everyday life. On the contrary, the reliability of modern infrastructure is precisely what has allowed it to play a taken for granted, invisible, role underpinning society.

Services such as electricity, water, transportation and communication have assumed a central place in modern society for over a century. During the last 50 years, infrastructure has been a positive instrument for economic transformation, a mechanism for the provision of welfare and a vital system that has to be managed (Collier & Lakoff 2006).

But more recently, and especially with heightened awareness of terrorism, infrastructure has acquired a less positive meaning: that of a security threat. In its "Green paper On a European Programme for Critical Infrastructure Protection, European Commission (2004) writes:

> Critical infrastructure include those physical resources, services, and information technology facilities, networks and infrastructure assets which, if disrupted or destroyed, would have a serious impact on the health, safety, security or economic well-being of Citizens or the effective functioning of governments. (…) To save the lives and property of people at risk in the EU from terrorism, natural disasters and accidents, any disruptions or manipulations of CI should, to the extent possible, be brief, infrequent, manageable, geographically isolated and minimally detrimental to the welfare of the Member States, their citizens and the European Union.

In the same paper, there is another more specific definition: "European critical infrastructure" is those infrastructure assets, which, if disrupted or destroyed, would have a serious impact on the health, safety, security, economic or social well-being of two or more member states.

By these criteria the electricity supply system surely constitutes "critical infrastructure", and has been subject to renewed attention in this light.

Electrical supply can be understood as a series of tightly interlocking technical and social networks. At the technical level electricity supply begins with access to primary fuels, such as gas, coal or uranium for generation of electricity at power stations. Power reaches customers through the transmission and distribution grid, and is then consumed in an astonishing variety of uses both domestically and in industry. These chains continue in both directions - on the one hand back into mining and so forth, and on the other forward into the whole spectrum of social and economic activities.

At the social level these activities are held together by commercial, legal and regulatory networks. In addition, the operation of the energy system requires personnel to move through a system that begins with training, continues with the development of interactions with peers and colleagues, and concludes with need to communicate lessons learned to a new generation. Many of these professional networks are relatively informal, and can cut across different organisations. Even if hard to pin down, this shared "culture" can nevertheless play a decisive role in ensuring continuity, especially in emergency situations.

A break at any point in the chain will result in disruption. Even short electricity interruptions cause major problems with transport, communication, waste disposal, drinking water, sewage management and mobile phone systems. Electricity interruptions can have serious consequences for people’s welfare and health and surveys estimate the costs of electricity outages to be 1-3 decades higher than electricity price (Silvast et al 2006). Furthermore, electricity interruptions have not been brief or infrequent. There’s more than one interruption per customer per year in almost all EU member states (CEER 2005) and some interruptions have lasted up to several weeks.

Nor have the disturbances been geographically isolated. In 2006, a substation fault in Germany led to disturbances in the whole interconnected grid of continental Europe. In 2003, a fault led to loss of all transmission lines between Sweden and Denmark. Also in 2003, overloaded transmission lines between Switzerland and Italy resulted in the collapse of the entire Italian electricity system.

In all these cases the weak point in the chain has proven to be the transmission grid. Much public attention has been focused on problems associated with energy generation, such as greenhouse emissions, fossil fuel depletion and nuclear safety. This has overshadowed the need to ensure the security of the grid. Indeed, in some cases measures designed to ensure long term security of production, such as the move to wind, have increased stresses on the grid. In this context it is all the more necessary to ensure that the security of the grid is not neglected.

As will be illustrated further in subsequent case studies, blackouts are complex events. While they are usually triggered by simple failures of individual components, most components in a blackout remain unharmed. Indeed, blackouts occur over regions far larger than could be served by single power stations of transmission lines. Blackouts are caused by loss of co-ordination across the grid without which the system can no longer operate. It is the maintenance of this stability over wide areas that requires careful management and intervention by transmission system operators.

The goal of this document is to provide a basis for understanding how the threat to security of electricity supply from blackouts may be mitigated through improved training at the level of transmission system operators. To this end we place the question of blackouts in context through analysis of the European power system and review of current national and EU-wide policies on energy supply management with a view to distilling essential drivers, future trends and current best practice.

We have taken into account firstly surveys, literature and research articles about electricity interruptions. We have also utilized all the internal energy market country reviews by the European Commission (2006b). To get a better grip on member states’ own perspective, we have utilized the unedited annual reports that EU member states prepare for ERGEC (European Regulators’ Group for Electricity and Gas) (2006a). The authors have also had useful discussions with electricity experts both in meetings and by email. Furthermore, one of the authors is gathering documents, seminar notes and interviews for a PhD concerning electricity blackouts and their prevention. This ongoing process has influenced and provided data for this document.

While focusing on the question of blackouts, this work and its conclusions is informed by the following main themes:

1. Resilient systems.

Resilience, a term borrowed from ecology, means the capacity of a system to respond to emergencies. Resiliency can involve redundancy, substitutability, diversity and possibility of decoupling and dispersion. The capacity of a system to respond to emergencies depends on deeper factors than emergency planning. A resilient system emphasises long-term planning and capacity building which enables both emergency responses and servicing robust economic growth.

2. Globalisation

International linkages, both within and external to the EU have become more important. Energy professionals with specific expertise often need to understand wider local, national and international contexts of their decisions.

3. Sustainability

The demand for sustainability is increasingly shaping the energy industry. This challenge needs to be understood in developing a resilient system capable of ensuring energy security. The elements of diversification of energy sources and implementation of renewable energy as a part of sustainability will be involved.

4. Public acceptability

Public acceptability has become a key question both for long-term investment decisions (for example, in relation to nuclear power). Winning public acceptance is critical to successful innovation for all energy professionals. Well-prepared communication between operators and public is essential here. It should be emphasised that this is not simply a matter of presentation of the sort that could usefully be outsourced to public relations specialists. A precondition for such communication is that the operators themselves have a clear common understanding of their role. An incoherent message cannot be communicated and cannot win support.

5. Emergency responses

Resilient systems make best use of existing resources in emergency planning and response. This emphasises the importance of adequate infrastructural investment and the important resource that exists amongst industry workers and the public, who will often be first responders.

The document has five subsequent sections. First, we review the contemporary issues and problems within the electric power system in the EU. Second we define the different elements of security of electricity supply. Third, we describe blackouts in more detail, including their number, duration, major blackouts and case studies of three large failures. Here we also survey normal people's valuations about blackouts. In the fourth part, we will see existing countermeasures to blackouts both at national and EU-wide level. In the fifth and final part, we conclude the output of the document, linking it to our main themes of resiliency, globalisation, sustainability, public acceptability and emergency responses.

1. The electric power system in the EU

This section describes the electric power system in the EU, with a specific focus on contemporary issues and problems. From a purely technical point of view, electrical transmission technology has changed relatively little during its development since the late 19th century. While the transformative impact of digital technology is much anticipated, the main long term innovation has been in the larger scale of networks.

However, the social context in which electricity is provided has seen drastic, sometimes even dramatic changes. In the present social settings, energy politics in Europe aims for three goals: competitiveness, using renewable energy sources and security of supply (Commission of the European Communities 2006a).

We will start by contrasting the post-war monopolistic model with the liberalised market model of providing electricity. This shall include market-based methods for network planning and managing cross-border interconnections. Due to competitive principles, the maintenance of electricity networks has also been outsourced from the utility companies. Other prominent contemporary issue is the ageing personnel of utility companies. Also linking with liberalisation is securing the investments into the ageing electricity networks. However, it should be stressed that liberalisation does not imply full-blown “deregulated” competitive markets. This will be pointed out in the review of how the electricity markets are heavily regulated.

We conclude this section by examining how policy choices, public support and different mechanisms are aiding the rise of renewable energy.

From national monopolies to EU-wide liberalised markets

Electricity differs from many other necessities like water and gas in that it is not possible to store in significant amounts. This means that electricity demand and supply must be balanced on a continuous basis, second by second. Although this has always been technically true, it is important to notice the shifting social context of providing electricity.

In the 19th and early 20th century electricity utilities had been private companies, who supplied electricity locally. The situation shifted during the World Wars and especially after the Second World War, when state intervention and state-investments into electricity distribution became normal. Infrastructure investment were considered the principal tool for economic development of states. Even if all utility companies were not state-owned, the utilities shared the idea that electricity should be provided for the sake of public interest. It was central to policy thinking that electricity was a broadly similar service available to all at similar cost. This provision was almost always handled by national or local infrastructure monopolies (Graham & Marvin 2002).

The 1990s saw the new emerging trend of liberalising electricity provision. The electricity markets were first opened for competition in the UK and Norway in the early 1990s. Sweden and Finland followed shortly after. Today, the EU internal energy market directive enforces liberalisation to all EU member states, with a fixed deadline of July 2007.

Liberalisation in the context of electricity provision means that electricity generation, transmission and distribution are separated into a number of different segments open to competitive entry.

Electricity generation becomes open to independent power producers, who enter the market with range of technologies (e.g. small renewable, conventional generation) and compete with incumbent generators. Electricity transmission and distribution retain their natural monopoly status for economic reasons - it is not feasible to have more than one electricity grid. However, a variety of economic mechanisms create competition, for example by allowing customers switch the utility with whom they contract for consumed energy.

EU has repeatedly stated that the aspiration for the internal energy market is the creation of one truly integrated competitive market which would provide the EU with secure energy supply. Basic to this is the development of cross-border trading within the internal market. Though it is improbable that mandatory targets for cross-border trading are set, the European Council has asked that the member states with interconnections at least 10% of electricity and gas interconnection capacity by 2010 (Commission of the European Communities 2007a).

From purely technical point of view, synchronous electricity regions over several countries are not new. Developments such as the harmonisation of single phase voltage and frequency under the standard EN 50160 are minor adjustments when set against the ongoing intensification of cross-border links.

The Union for the Co-ordination of Transmission of Electricity (UCTE) had already connected several European countries, including Austria, Belgium, France, Netherlands and Italy by 1951. However, due to market principles, the European electricity networks now have to accommodate increased electricity flows over longer distances. For instance, figure 1 shows the flows of energy in the UCTE system in December 2006.

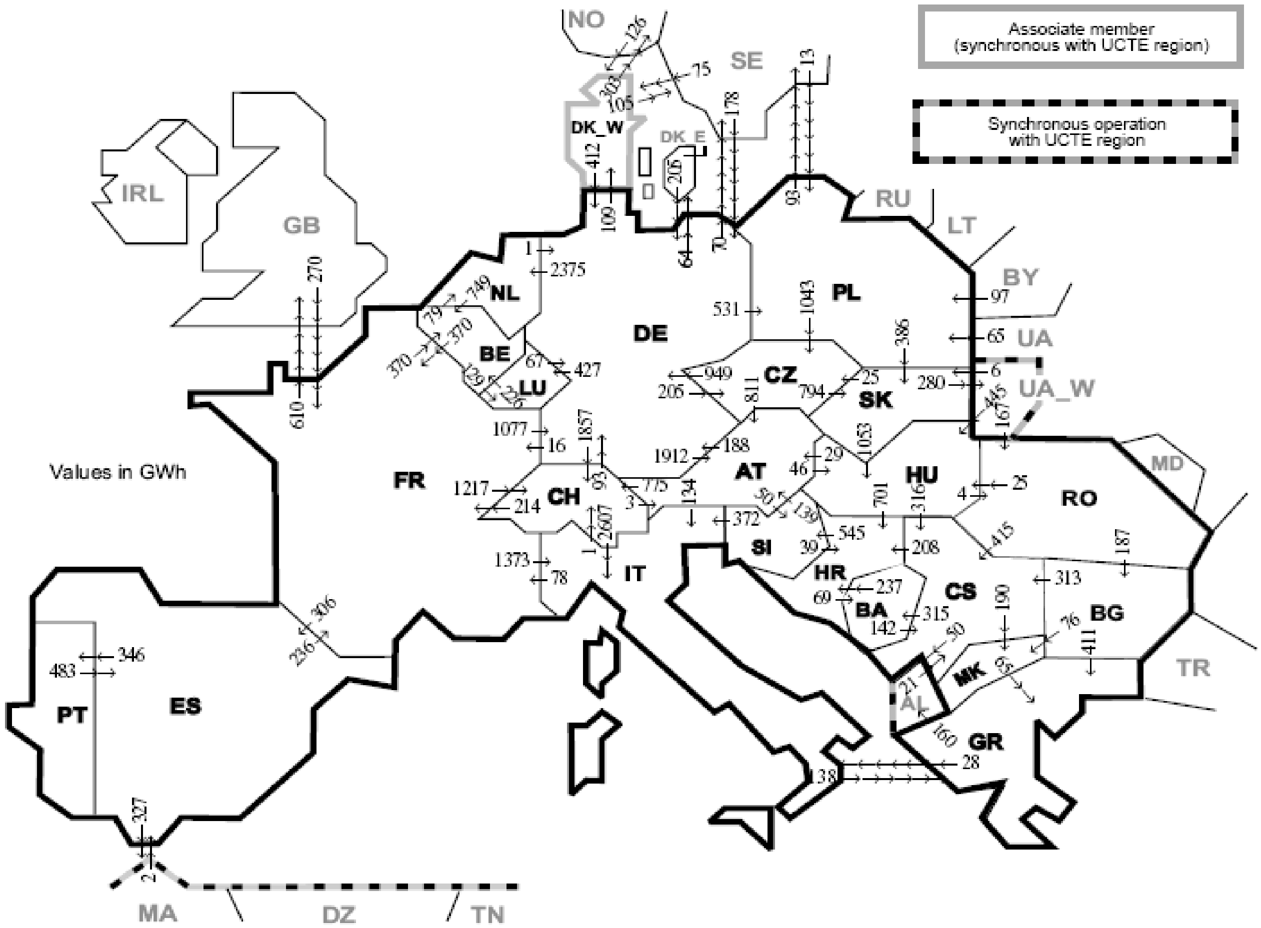

Figure 1. Physical flows of energy in the UCTE system in December 2006 (provisional values). Reproduced from UCTE Monthly Statistics.

As the first step taken towards a common EU market, figure 2 and table 1 show seven electricity regional market projects that were proposed in 2004. At the moment, electricity regional markets exist in the Northern and Central West regions. Furthermore, nine electricity priority projects have been suggested, including the Mediterranean electricity ring which is set to connect Europe with Arabic countries and North Africa. These latter proposals indicate that grids are set to grow in scale for the foreseeable future, even beyond the integration of grids in new member states.

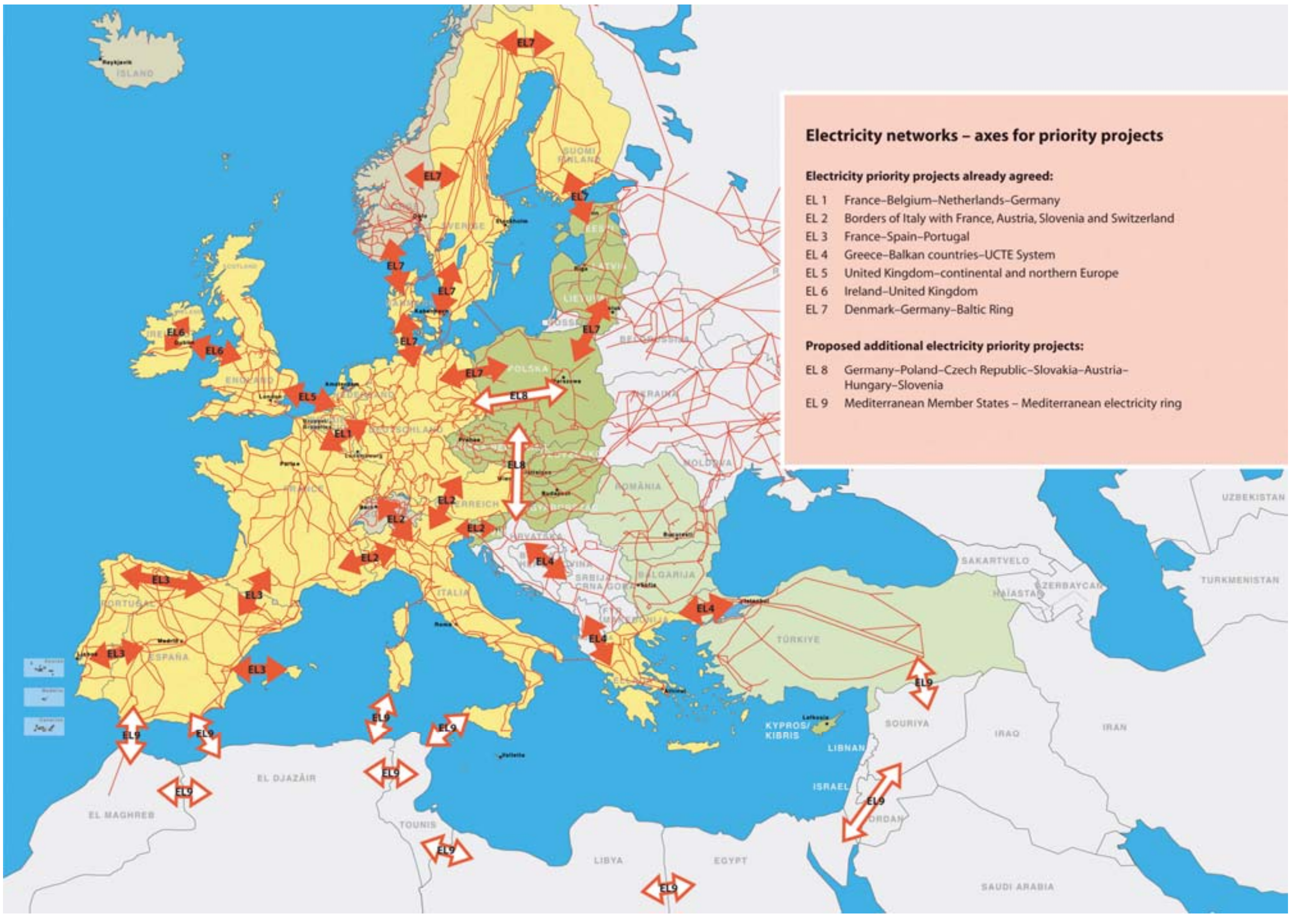

Figure 2. Electricity regional market in the EU, including priority projects. Reproduced from the Trans-European Energy Networks web site

Region	Countries	Lead regulator
Central-West	Belgium, France, Germany, Luxembourg, Netherlands	Belgium
Northern	Denmark, Finland, Germany, Norway, Poland, Sweden	Denmark
UK and Ireland	France, Republic of Ireland, UK	Great Britain
Central-South	Austria, France, Germany, Greece, Italy, Slovenia	Italy
South-West	France, Portugal, Spain	Spain
Central-East	Austria, Czech Republic, Germany, Hungary, Poland, Slovakia, Slovenia	Austria
Baltic	Estonia, Latvia, Lithuania	Latvia

Table 1. Seven electricity Regional Energy Market projects. Source: ERGEC 2005.

Cross-border exchanges

In the monopolistic model, planning of electricity generation, transmission and distribution was done centrally and on a national basis. Producers and consumers signed long-term contracts that guaranteed electricity provision. Even today in Germany most municipal distribution companies are supplied under long-term supply contracts with a duration of 20 and more years. Building new generation capacity generally required major administrative processes and in many cases was not possible for private companies. A tendency to over-investment in generation capacity was characteristic of a centralised planned electricity industry. However, in the conditions of post-war economic growth when capacity was in any case expanding this was experienced as less problematic.

The market framework replaces the monopolistic model with a new set of commercial and regulatory relationships. In the liberalized framework, the market should define the necessary level of generation and also provide adequate incentives for investors to ensure this level. Ideally, economic rationality should motivate the producers provide electricity when it makes economic sense.

The pursuit of this model has led to dismantling of the system of long term contracts between producers and consumers. A decision of the European Court of Justice has found that priority treatment of old long term contracts is in conflict with the Internal Energy Market Directive (ERGEC 2006a, 10). Placing obligations on producers to keep certain technical reserves would likewise conflict with the principles of a competitive market.

As cross-border exchanges have become a matter of market co-ordination, regulation (EC) No 1228/2003 of the European Parliament lays rules on the conditions for access to the network for cross-border exchanges in electricity. The directive promises to introduce fair, cost-reflective, transparent and directly applicable rules for these exchanges.

As for *transparency*, transmission system operators must publish estimates of available transfer capacity for each day, indicating any available transfer capacity already reserved. For example, the multinational exchange organisation Nord Pool (The Nordic Power Exchange), which is owned by the transmission system operators of Sweden and Norway, publishes on their web site daily estimates as seen in figure 3. The capacities of different interconnections are predicated for one week ahead. The safety, operational and planning standards used by transmission system operators shall also be made public according to the directive.

2007 week 12

Last updated: 2007-03-15 10:01:09

Capacities (prognosis) in MW

	Transmission connections	Time	Mon	Tue	Wed	Thu	Fri	Sat	Sun
1	North Norway (NO3) - Sweden	00-09	500	500	500	500	500	800	800
		09-17	500	500	500	500	500	800	800
		17-24	500	500	500	500	500	800	800
1	Sweden - North Norway(NO3)	00-09	450	450	450	450	450	800	800
		09-17	450	450	450	450	450	800	800
		17-24	450	450	450	450	800	800	800
2	Middle Norway (NO2) - Sweden	00-24	500	500	500	500	500	500	500
2	Sweden - Middle Norway (NO2)	00-09	350	350	350	350	350	450	450
		09-17	350	350	350	350	350	450	450
		17-24	350	350	350	350	450	450	450
3	South Norway (NO1) - Sweden	00-24	1950	1950	1950	1950	1950	1950	1950
3	Sweden - South	00-24	2000	2000	2000	2000	2000	2000	2000

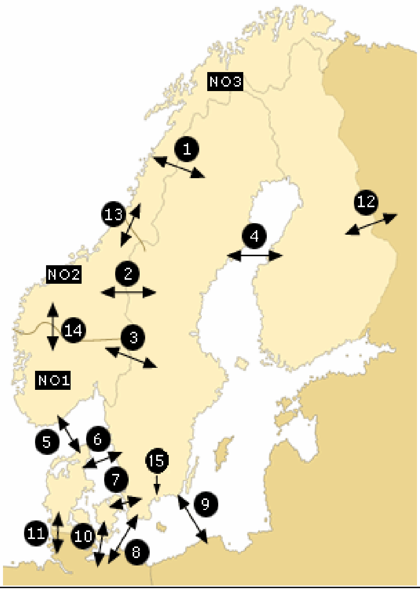

Figure 3. The prognoses of capacities in the Nordic system. Reproduced from http://www.nordpool.com

As for *cost-reflectivity and fairness*, the maximum capacity of the interconnections and the transmission networks affecting cross-border flows must be made available according to market principles (but still "complying with safety standards of secure network operation"). Also, network congestion problems shall be addressed with non-discriminatory market based solutions which give efficient economic signals to the market participants and transmission system operators involved. The market participants should inform the transmission system operators a reasonable time ahead whether they intend to use allocated capacity, and any allocated capacity that will not be used will be reattributed to the market.

In practise, these rules are applied in almost all member states through auctions. With this system, the total interconnection capacity is offered in a series of auctions, which might be held on a yearly, monthly, weekly, daily or intra-daily basis. Capacities can be auctioned for differing durations and with different characteristics (e.g. with respect to the expected reliability of the available capacity in question). Most member states organise explicit auctions. This is, for instance, the case with Czech Republic's interconnections to Poland, Slovakia and Germany. Implicit auctions (also called market splitting) are applied for wholly integrated wholesale markets like the Nordic market. In this model, electricity price of an area will vary depending on the available capacity and the amount of congestions. As seen in figure 3, the Nordic market is split into seven price areas: Finland, Sweden, West Denmark, East Denmark, South Norway, Central Norway and North Norway.

It is likely that these regimes of co-operation are only followed partly. According to Commission of the European Communities (2007a, 4), the necessary degree of co-ordination between national energy networks in terms of technical standards, balancing rules, gas quality, contact regimes, and congestion management mechanisms, which are necessary to permit cross-border trade to work effectively, is at present largely absent.

The auction system places one very identifiable risk. During periods with very high auction prices, it is more attractive for producers to sell power to the auctions than for domestic use (Doorman et al 2004). This might result in scarcity of capacity, and different member states cope with this problem differently.

Network planning and the role of Transmission System Operators

The rise of liberalisation has by no means abolished the need for central control. As a pragmatic matter transmission networks still need to be balanced and congestion still needs to be managed. There are two key means through which this happens. First, the Transmission System Operators (TSO), who are responsible for both dispatching orders to generators and managing the grid in real time. Second, there is an extensive system of regulation which does not work in real time but oversees many aspects of investment in the grid to ensure some degree of co-ordination.

As the practical role of the TSO will be seen in more detail later, we concentrate here on the role of regulation.

Regulation (EC) No 1228/2003 of the European Parliament states that transmission system operators must publish estimates of available transfer capacity of cross-border exchanges for each day. As in market-based environment this information is not readily available, it has to be predicted. One way to do this is to calculate the transmission capacity to and from member state by using simulation models. These models are based on typical seasonal base load flow cases, which have been built by using actual measurements of energy production and consumption. The calculations are made taking using the *N-1 criterion*: the transmission system should remain operational after any single fault. After the calculations, those responsible for the transmission systems determine the maximum available capacity for auctioning (see *cross-border exhchanges)*. Using similar load flow scenarios, the operational situation in neighboring countries can be included in the assessments. Transmission system operators also predict electricity consumption and capacity needs further ahead, from two years ahead (e.g. France) to even six years ahead (e.g. Portugal). The plans generally include interconnections.

An interesting example of co-ordinated planning is the case of Nordic countries, where simulations and plans are not only made inside the member states, but also exchanged between them within Nordel, a body for co-operation between the transmission system operators in the Nordic countries. The system operating agreement between the transmission system operators in Sweden, Norway, Denmark and Finland prescribes that plans and forecasts for capacity are to be continually exchanged. The transmission system operators must specify their plans for transmission and trading capacity on an hourly basis. Also to be shared are possible constraints within the sharing system and a forecast of dimensioned faults. Where applicable, plans for generator shutdowns are exchanged and co-ordinated for up to a year ahead. Also investments in interconnections between the Nordic countries and internal links having impact on the cross border trade are planned in a Pan-Nordic process.

Outsourcing maintenance

Outsourcing has been a major trend since the 1990s in both the public and private sector. Outsourcing means certain activities, like maintenance or customer service, are delegated to private companies. Demands for competition and cost-effectiveness have entered public and private sector alike. It is usually believed that a private company will produce certain activities more efficiently, at smaller cost and also at better quality. This is especially the case if the outsourced service can carry on with less workforce, machines and facilities.

In relation to security of electricity supply, the following activities can be outsourced from electricity companies (Partanen et al 2005, 58):

- **Network planning**: allocating resources like grid, workforce and information systems, and planning maintenance outages

- **Network monitoring**: balancing supply and demand. There already are common monitoring centres for several network companies. Also, some companies monitor their own network during business hours, but outsource the monitoring during nights and weekends.

- **Preventive maintenance**: routine inspections of components

- **Reactive maintenance**: fixing and reporting faults

- **Customer service**: communicating to customers via "contact centres", also during disturbances

All of these outsourcings pose challenges. First one is related to communication. A "contact centre" needs to known which customers it is operating with. The outsourced maintenance team that is closest to a fault needs to be mobilised. Information and communication technologies help here, but this requires building new systems and regimes of co-operation. Security of supply also requires that the outsourced service knows the local area where it is fixing a fault.

A more general concern can be posed towards reserves and whether optimising resources is lowering preparedness for large disturbances. Also, the workforce can oppose outsourcing, leading to difficulties in the outsourcing process and uncertainty in the work environment. Indeed, recommendations for outsourcing note that some activities are so close to the companies' core function that they should not be outsourced at all. A research report on electricity companies' outsourcing (Partanen et al 2005, 58) mentions network planning as this kind of activity. On the other hand, the report supports the outsourcing of maintenance, customer service and network monitoring.

Finally and significantly, it is quite hard to measure the savings achieved with outsourcing. The electricity companies have traditionally not been very aware of the exact costs of maintenance, customer service, network monitoring and network planning. If implemented in ill manner, the outsourcing can bring hidden costs to running the electricity company (Partanen et al 2005).

Ageing personnel

While we have not found any EU-wide data on ageing personnel, the statistic of Finland show a trend that could be common to the whole EU. From 1990 to 2003, the amount of personnel has dropped significantly. Also, growing number of workers are approaching their pension age, when compared between 1996 and 2004.

Year	persons
1990	20703
1991	20784
1992	20216
1993	18123
1994	16848
1995	16462
1996	16399
1997	15949
1998	15599
1999	14996
2000	14900
2001	13692
2002	12923
2003	12323

Table. The number of personnel in electricity and district heating in Finland. Reproduced from Finnish Energy Industries 2006.

	Year	Year
	2004	**1996**
less than 30 years	5	8
30-34 years	17	11
35-39 years	18	15
40-44 years	17	18
45-49 years	15	21
50-54 years	12	15
55-59 years	6	9
more than 59 years	10	3

Table. The average age of personnel in electricity and district heating industry in Finland, %. Reproduced from Finnish Energy Industries 2006.

Investment and ageing networks

The ageing of electrical distribution networks is becoming an increasingly significant factor in network adequacy. While any capital equipment will begin to age as soon as the investment takes place, the concept of an ageing infrastructure is more subtle. It refers to the average age of equipment, which depends in turn on the rate at which equipment is replaced.

The lifetimes of the components that make up the distribution grid vary. If they are only replaced on failure then components may have very long lives. Components such as wooden poles may exceptionally last over 100 years. Some circuit breakers are still in service that were manufactured after the First World War, and transformers may exceptionally last longer than 75 years.

However, as they age all components become more susceptible to failure. Typically as components age beyond a design life of 40 to 50 years, the failure rates rapidly rise. The past pattern of investment explains why an ageing infrastructure is becoming an acute problem.

Much of the present infrastructure was put in place during the post-second world war economic expansion of the 1950s to 1960s. It is many of these components that are reaching the end of their design lifetimes. Although a lesser effect, this pattern is exacerbated by investments that followed in the recessionary period of the 1970s. In order to cut costs in the more austere economic conditions, design specifications were lowered so that equipment commissioned in the 1970s often had somewhat lower lifetimes.

As a result of this past pattern of investment many components are simultaneously reaching stages of their lives at which the failure rate is heightened, and this phenomenon is often at its most intense where demand is rapidly rising around the periphery of metropolitan areas.

The need to manage the pattern of ageing infrastructure implies the need for a more sophisticated maintenance strategy which does not simply rely on replacement on failure. This was discussed briefly above in the section on maintenance. It will also require corresponding changes in the EU approach to infrastructure investment.

This is seen most sharply in the difficulty obtaining new rights of way for transmission infrastructure. This difficulty has resulted in strategies such as using new technologies to run existing lines closer to their limits and the bundling of more transmission paths into a single right of way. Both of which strategies can contribute to heightened vulnerability.

The European Commission (2003) has stated its concern for investments in the Proposal for a Directive concerning measures to safeguard security of electricity supply and infrastructure investment. According to the proposal, a truly functioning, integrated electricity market requires significant investment in transmission networks. The directive proposes that member States must have a regulatory framework in place which supports investments. Transmission system operators must submit multiannual investment strategies to their national regulatory authorities. The regulators may also intervene to speed up the completion of projects, for example by offering financial incentives. The Commission also proposes that work on certain projects be allocated by tender if the transmission system operator is unable or unwilling to implement the projects in question.

However, the need to renew ageing networks has not been prioritised in EU energy policy goals, which have focused on the single energy market and the environment. Even the proposed directive supports interconnections primarily as means for the internal market to function properly. In its Priority Interconnection Plan, the European Commission (2007a, 5) observes that the amounts invested in cross-border infrastructure in Europe appear dramatically low. Only €200 million yearly is invested in electricity grids with the purpose of increasing cross-border transmission capacity. This represents only 5% of total annual investment for electricity grids in the EU, Norway, Switzerland and Turkey.

Inside EU, investment have too often been reduced to a matter of renewables and energy saving. The first priority of the proposed investment directive is the need for the “unacceptable trends” in energy consumption to be constrained. Furthermore, where new generation investment is necessary, the directive requires this should, to a large extent, come from renewables and co-generation facilities.

Regulation of electricity transmission and distribution

With all the discourse of liberalisation, it should be stressed that electricity markets are not full-blown "deregulated" competitive markets. On the contrary, to avoid situations where the market mechanisms fail to deliver competitive and secure electricity, almost all EU member states regulate the electricity companies' operation.

The primary cause for regulation is to avoid the distribution and transmission companies misusing their monopoly positions for large revenues. Indeed, while state intervention into the economy is widely assumed to be in retreat, few question the legitimacy of the expansion of its role as a protector of consumer rights.

The regulator is an authority that monitors the operation of transmission and distribution companies and gives incentives for the companies to compete with each other. All regulators in the EU are separate from the electricity industry and the relevant ministries. However, in Austria, France, Germany, Greece, Italy, Malta, Norway, Slovenia and Spain the relevant ministries retain some powers to approve, reject or amend regulatory decisions (ERGEC 2006a, 7).

Up until about 2000, regulation usually took the form of price-caps for electricity distribution and transmission prices. However, if the quality of distribution and transmission is not monitored, these financial pressure on companies can lead to a decline in quality, through e.g. companies not investing in the network, cutting back maintenance costs or reducing workforce. A new form of regulation, which has received increasing attention and has been already adopted by growing number of European regulators, is to regulate the quality of electricity. This comprises of three aspects:

- **measuring actual and perceived levels of quality –** gathering data on the service actually provided and on customers' perception.
- **promoting continuity improvement**, which means giving utilities incentives to evaluate their investment and management decisions not only in light of their costs but also taking into account the effects on actual quality levels.
- **ensuring good continuity levels to consumers**, especially worst-served ones.

We will concentrate here on the regulation of failures to distribute electricity. We will not handle the regulation of electricity voltage quality, because it is not closely related to the subject of our report. We will also not write about commercial quality standards (e.g. resolving billing issues); but for customer perspective, see section *The social impacts of blackouts*.

Measuring actual and perceived levels of quality

All countries of a CEER (2005) survey, with the exception of Poland, have protocols that require companies to monitor their supply interruptions and publish the data for benchmarking. The regulators of Great Britain, Portugal, Hungary and Italy also conduct customer surveys on the subject of customer satisfaction. Some countries have surveyed other issues like customer willingness-to-pay for improvement of electricity supply and customer expectations for service levels. This customer information has been used by regulators while deciding on the choice of quality factors and services to be monitored.

Promoting continuity improvement

The regulators can promote continuity improvement by introducing incentive/penalty regimes. These kind of schemes were in place in eight countries out of 19 surveyed in 2005: Italy (from 2000), Norway and Ireland (from 2001), Great Britain (from 2002), Hungary and Portugal (from 2003), Sweden (from 2004), and Estonia (from 2005). Finland will introduce its incentive/penalty regime in 2008. In 2005 other countries that expressed interest in introducing an incentive/penalty regime were France, Lithuania (from 2008), Poland, Spain, and Slovenia.

The incentive/penalty schemes are all based on the same principle: the allowed revenues of the company are modified upward or downward depending on its performance in terms of continuity of supply. This continuity is measured as the distance between actual performance and a predefined target. The schemes can include one (typically duration of interruption per customer or energy not supplied), two (typically duration and number of interruptions per customer) or more indicators. The targets are determined by doing a comparison of distributors of similar territories and network layouts. The targets are normally given for a set number of years in advance, usually for the duration of the regulatory period.

The regulators also periodically review the scheme, allowing them to introduce modifications, enlarge the scope of the regulation and remove incentives or targets.

Ensuring good continuity levels to consumers

A significant number of countries have introduced standards for the maximum duration of interruptions per consumer. This is a form of customer protection, especially when there are automatic compensation payments when companies fail to meet standards. There is a large difference between this maximum duration, from the 4 hours in Belgium and 6 hours in France to Great Britain, where the duration is 18 hours for normal weather conditions. Also the compensation varies: in France, it is 2 % of the power-dependent part of the tariff - a few euros for a domestic customer - , but around 36 euros in Great Britain for the same type of customer. Some countries' regulators also place quality standards for the maximum yearly number of unplanned interruptions per single customer. Again, the variation of these numbers is very large.

These customer compensations come with restrictions. The CEER (2005, 63) strongly recommend that regulators establish a precise definition of “force majeure” situations, where compensations are not paid. In most of the surveyed countries, these kind of restrictions are already in place. "Force majeure" situations include for instance energy shortages, natural disasters, heavy winds and glazed frost, and also order by public authority, strikes, war and terrorism. As a notable exception, in Finland storms and snow do not qualify as being “out of control” of the distribution companies. Great Britain, on the other hand, has resolved the issue by differentiating the maximum duration standards according to the severity of weather conditions.

Public acceptability of generation and fuels

An important longer-term aspect for electricity generation is the public acceptance of various generation technologies and fuels. The rise of climate change policies in all political parties has impact on power generation choices, often restricting the selection. The European Commission (2007b, 14) has proposed a binding target of increasing the level of renewable energy in the EU's overall mix to 20% by 2020. Even at the moment, all EU member states stimulate investments in production capacity that uses renewable and low carbon emission fuels. For an example from EU wind market development, see figure 4.

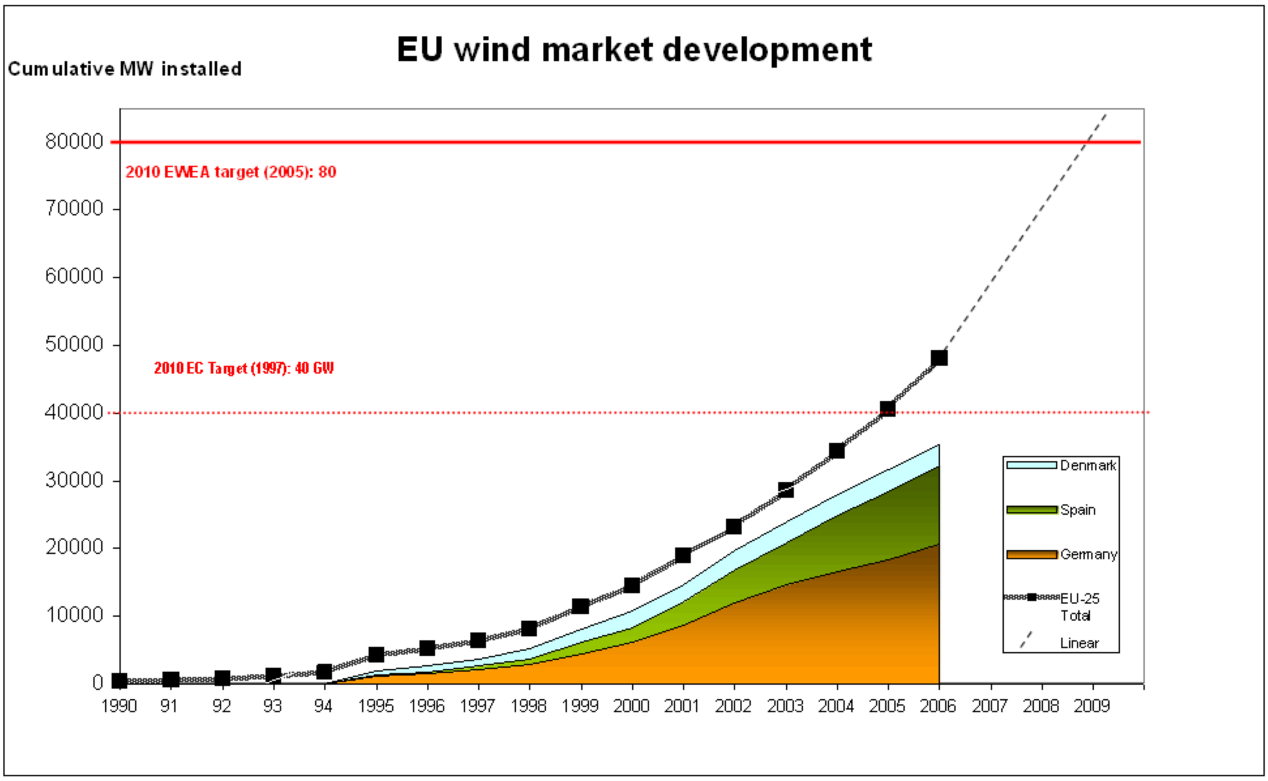

Figure 4. EU wind market development. Based on a figure from the European Wind Energy Association (EWEA)

Two market-based schemes are already in operation. *The EU emissions trading scheme*, concerning all EU member states since 2005, is an international trading system for CO^2 emissions, which enables the participating companies to buy or sell emission allowances. This is done in order for the member states to reach the greenhouse gas caps set by the Kyoto Protocol. As a result, generation that contains more carbon will be relatively more expensive than generation that contains less carbon. Secondly, *the green certificate scheme*, operational in UK, Italy, Belgium, Sweden, Poland, Romania and Bulgaria, is a trading scheme of certificates for generating or purchasing renewable energy. Similarly to the emissions trading scheme, the green certificate scheme lowers the relative production costs of renewable energy.

As for less market-based instruments, for instance Austria, Denmark, Germany, Greece, Czech Republic and Finland have introduced or are possibly introducing minimum purchase prices ("feed-in-tariffs") for which the distribution or transmission system operator must buy renewable electricity. In Latvia, this framework is one step stricter: a public supplier of electricity has *an* *obligation* to purchase electricity that is produced within the country by cogeneration of electricity and heat or from renewable resources. Also, for example in Norway and Finland the State can grant investment subsidy for power plant construction project if the new production is based on renewables.

Due to policies of climate change, the role of nuclear power has seen a remarkable shift in the last years. With its low carbon emissions, stable costs and economic efficiency, nuclear power has become a politically sound option in many member states. Though EU leaves it to each member state to decide whether or not to rely on nuclear electricity, many states have changed their agenda. Less than one year ago, UK was planning the retirement of its nuclear power plants, now it is opting for more nuclear generation. The EU emissions trading scheme has also benefited the production costs of nuclear power.

2. Security of supply

This section discusses security of electricity supply in more detail. The aim identify the different components of security of supply in order to understand how blackouts fit in to a larger context.

Security of supply definition

Security of electricity supply (SOS) can be defined as following:

> "The ability of the electrical power system to provide electricity to end-users with a specified level of continuity and quality in a sustainable manner." (EurElectric 2004.)

Security is thus defined in relation to the electrical power system's provision to the end-users. This point has important implications: First, that the basic purpose and social responsibility of all actors in the electricity industry is to provide electricity to the-end user, not only to handle the actor's own responsibility. Second, SOS is only fulfilled once all elements of the electricity supply chain (primary materials, generation, transmission, markets, end-use) function properly (see figure 5).

As we have noted, electricity supply and demand must be balanced second by second. But there are many longer-scale issues, such as ensuring the investments into electricity generation and networks for years ahead. Especially political and public acceptance of electricity technology raises new forms of questions. No-one would oppose that the physical supply of electricity is balanced with demand second by second. However, with the decisions on primary fuels, generation technologies, building of new grids including interconnections and market mechanisms, public and political issues become much more important. Thus, in the following, we will handle each aspect of SOS in their own chapter.

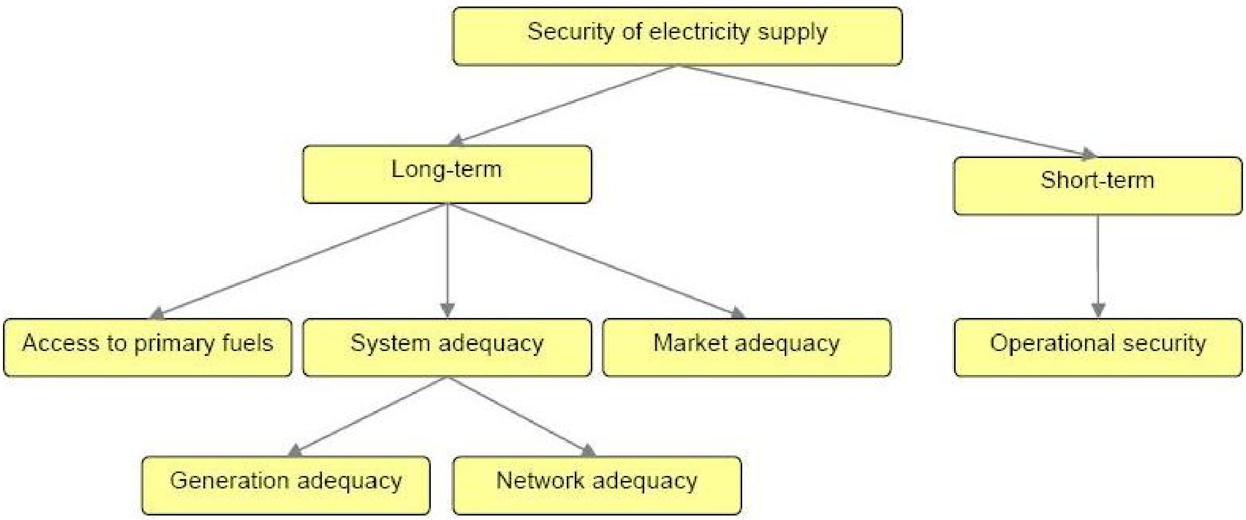

Figure 5. The different aspects of security of electricity supply. (EurElectric 2004.)

Access to primary fuels

As the first step of electricity supply, the electricity needs to be generated. Electricity can be generated from variety of materials: e.g. uranium, coal, oil, gas, forest converted chips, turf, water, wind, the sun or the tides. These materials have different issues regarding SOS. Oil and gas will continue to meet over half the EU's energy needs, with import dependence high in both sectors (over 90 % for oil and some 80% for gas in 2030). Electricity generation will also continue to be heavily dependent on gas. EU sees it important to promote diversity with regard to source, supplier, transport route and transport method of fuels and increase the proportion of energy from “politically stable areas” (The Commission of European Communities 2007b, 12-14).

As the EU note, nuclear power is less vulnerable to fuel price changes than coal or gas-fired generation (ibid, 17). Uranium is based on sources which are sufficient for many decades and widely distributed around the globe. Renewable energy can also counter import dependency because it is often produced domestically.

Generation adequacy

Adequacy of electricity generation means there is sufficient electricity generating capacity to meet demand. This covers routine base load and peak load situations. SOS issues include scarcity of raw materials and long-term outages of major electricity plants. In areas with high electricity import-dependency, the generation from other regions must also be adequate.

As we observed in the background chapter, the public acceptability of various fuels and technologies is an important aspect of SOS of electricity generation. The rise of climate change policies in all political parties has impact on power generation choices, often restricting the selection.

Network adequacy

Adequacy of electricity transmission is the availability of electricity network infrastructure to meet demand. This covers cross-border interconnections. SOS issues have already been largely covered in the background chapter: they mainly have to do with securing investments into the infrastructure and ensuring there is enough workforce to handle the routine and emergency maintenance of the grid. Especially important in an interconnected system is to ensure that there is enough cross-border network capacity. As with generation adequacy, public acceptability of electricity transmission is an important aspect of SOS. EurElectric (2004, 13) notes that opposition from environmental or local groups has been a hindrance in carrying out new transmission line projects, especially cross-border lines.

Market adequacy

The liberalised market model has already been covered in the previous background chapter and in-depth review will not be in place here. However, we notice one further issue with electricity end-pricing. As EurElectric (2004) point out, SOS is not fulfilled - even if technically or from a pure market organization point of view the system functions - if electricity prices rise enduringly to levels which are not affordable for a substantial portion of the population. The EU energy market directive actually mentions “protection of the rights of the most vulnerable customers” as part of the internal markets. Electricity pre-payment systems in UK and Belgium may constitute a new form of electricity poverty: people who cannot afford to pay their bill switch off “voluntarily”. Even if the effects are usually not this drastic, increase in electricity prices has led to a growing public critique that the majority of benefits of competitive markets are not passed on to customers but remain with the electricity companies.

Short-term operational security

Short-term operational security means the operational security of the system as a whole and its assets. It requires adequate technical reserves together with other system services. An important criterion used to describe the operational security is the *N-1 security principle*. This principle states that the electric power system has to withstand any single fault. Some recommendations also include the amount of time that the system can remain in this N-1 state: in the case of Nordic system, the single fault has to be corrected within 15 minutes.

As we shall observe in the case studies of several blackouts, most accident reports largely focus on these short-term operational issues, even at the expense of longer-term background factors.

Electricity end-use

Finally, also electricity end-use efficiency and energy saving can be seen as a way to improve SOS. The EU directive on energy end-use efficiency (The European Parliament and the Council of the European Union 2003), which sets a national indicative energy savings target of 9 % for nine years, claims that improved energy end-use efficiency and managed demand for energy will contribute to improved security of supply and also help the Community reduce its dependence on energy imports. In the directive’s articles, there are demands for improved energy metering, more informative billing, energy-efficient tariffs and energy-efficient services for end-users.

3. Blackouts

Blackout has become the common definition for the moment when electricity supply and demand are not balanced and SOS fails. These failures of course have many other impacts besides the lights going out, but we will use this term for its commonality. This part describes blackouts in detail: how common they are, the already-occurred major blackouts and three case studies of European blackouts that cascaded from one country to the others. In the final section, we will also stress that operational engineers have social responsibility, as blackouts have drastic impacts for the society on whole and its citizens.

Number of blackouts in EU

CEER (2005) have collected benchmarking for duration and amount of blackouts in different EU states from 1999 to 2004. The number of unplanned interruptions seems quite small for many countries, Great Britain and Netherlands having less than one interruption per customer per year for the whole period. On the contrast, some countries' numbers are larger, especially Portugal, Spain, Italy, Hungary and Finland. But on the whole, both the number and duration of interruptions show a significant downward trend. One can however clearly observe the exceptional events, like the storm in Finland in 2001 and Italy's large cascading blackout from 2003.

Country	Year					
	1999	2000	2001	2002	2003	2004
Finland	198,0	129,6	468,0	284,4	212,4	103,0
France	459,0	176,0	59,0	52,0	69,3	57,1
Great Britain			75,8	101,3	72,7	87,3
Hungary	411,0	241,2	250,2	196,8	155,4	137,4
Italy	191,8	187,4	149,1	114,7	546,1	90,5
Ireland	273,6	257,9	199,3	230,2	171,9	162,8
Latvia					14,0	8,5
Lithuania						190,0
Netherlands	26,0	27,0	34,0	28,0	30,0	24,0
Portugal			530,7	468,0	406,2	217,8
Spain	156,4	145,4	179,7	142,6	141,9	123,6
Sweden	165,8	89,2	162,9	101,8	148,1	59,7

Table 2.1. Minutes lost per customer per year. (CEER 2005, 116.)

Country	Year					
	1999	2000	2001	2002	2003	2004
Finland	3,32	2,89	6,61	3,34	3,97	4,00
France	1,22	1,20	1,20	1,20	1,43	1,30
Great Britain			0,84	0,82	0,79	0,75
Hungary	3,09	2,29	2,13	2,03	2,05	1,90
Italy	3,81	3,59	3,29	2,76	3,96	2,48
Ireland	1,15	1,49	1,31	1,37	1,50	1,70
Latvia						0,04
Lithuania					0,04	1,58
Netherlands	0,40	0,40	0,40	0,30	0,40	0,30
Portugal			7,51	7,35	5,96	3,66
Spain			3,30	2,65	2,60	2,06
Sweden	1,38	1,23	1,34	1,32	1,64	1,05

Table 2.2. Interruptions per customer per year. (CEER 2005, 117.)

Summary of major blackouts in Europe

The recent large-scale blackouts in Europe are summarised in table 3. Even if these events can be defined ”exceptional”, the interruptions actually seem quite frequent. In about seven year's time, there has been more than one exceptional blackout every two years. There were even two very large blackouts in Europe in 2003, coinciding with the large blackout in northern America the same year.

There is a clear a distinction between those blackouts caused by nature and those that were caused by other faults. In the table, the nature-caused disturbances (Sweden 2005 and France 1999) stay inside one country. However, their duration can extend to several weeks, and thus the costs of the interruptions are extensive. This long duration is most likely caused by the large damage of strong storms, and also by the dangerous repairing conditions during the events. Blackouts not caused by nature, on the other hand, are much shorter, but concern more end-users, occasionally cascading from one country to another. In the following chapters, we will study in detail three such failures: Europe 2006, Italy/Switzerland 2003 and Sweden/Denmark 2003.

Country, year	Type of incident	Consequences in the power system	Social consequences		
			No of end-users interrupted	Stip. Duration, energy not supplied	Estimated costs to whole society
Sweden/Denmark, 2003	Disconnector short circuit followed by double busbar short circuit	Loss of all lines and generation separation of Southern Sweden/Denmark, voltage collapse	0.86 million in Sweden and 2.4 million in Denmark	2.1 hours, 18 GWh	145 - 180 million €
France, 1999	Two consecutive storms, extreme wind	Extensive outages, 0.4 % of the total network length damaged	1.4-3.5 million, 193 million m^3 wood damaged	2 days - 2 weeks, 400 GWh	11,5 billion €
Italy/Switzerland 2003	Overloading lines between Switzerland and Italy	Collapse of the entire Italian electric power system	55 million	18 hours, ?	?
Sweden, 2005	Storm Gudrun, extreme wind	Extensive damage of overhead lines in Southern Sweden	0.7 million, 70 million m^3 wood damaged	1 day - 5 weeks, 111 GWh	400 million €
Central Europe 2006	Busbar fault at a substation in Germany	Disturbances in the whole interconnected grid in Europe	15 million households	Less than 2 hours, ?	?

Table 3. Examples of blackouts. (Kjølle et al 2006.)

Case study 1: Europe 2006

On November 4th 2006, an incident in the North German electricity transmission area caused supply disruptions to more than 15 million households on the European continent. Electricity transmission was back to normal in less than 2 hours. The most affected area was France where 5 million customers were cut-off. In Germany millions of customers were affected. In Belgium, the Netherlands, Italy and Spain some hundreds of thousands of customers were without electricity. In the terms of involved countries, the incident is the most significant disturbance on the synchronously interconnected grid in continental Europe. In terms of affected customers, it comes just after the disturbances in Italy in 2003 (see case study 2).

The Union for the Coordination of Transmission of Electricity (UCTE) have released a final report on the incident (UCTE 2007), from which the following account is drawn. The events started when the German transmission system operator E.ON Netz were asked to disconnect a high voltage line for the transfer of a ship on November 5th at 01:00. This type of operation had been carried out successfully several times in the past. The transmission system operator informed the neighbouring operators, so that they could carry out N-1 security analysis with load flow calculations on their network. This analysis confirmed a high loading of the grid, which, however, was not seen insecure this time of night.

On November 3rd, the shipyard requested an earlier disconnection, this time on November 4th at 22:00. At that time, the electricity exchange programs and physical electricity flows between countries were not unusual. The only point to be emphasized is that international electricity trade and the obligatory exchange of wind feed-in inside Germany had resulted in significant electricity flows from Germany to the Netherlands and to Poland. E.ON gave the ship permission for the earlier schedule. However, the neighbouring system operators were informed only at 19:00 on November 4th and no special security analyses were carried by them prior to the disconnection. Ten minutes before the opening the high voltage line, a neighbouring German transmission system operator made load flow calculations and concluded that the grid would be highly loaded, but still secure.

The opening of the high voltage line took place at 21:39. Then, between 22:05 and 22:07, the increase of load between two German areas triggered an alarm with an immediate reaction by the neighbouring German operators. These operators requested a restoration of secure conditions. An empirical assessment of corrective switching measures was carried out, but without load flow calculations. The dispatchers expected that a coupling of busbars in the substation at the end of the line would reduce current on it. This was applied at 22:10 without any further co-ordination between system operators due to the rush.

The coupling led to the opposite to what was expected: the current on the line increased and the line was automatically tripped as a result of the overload. This led to immediate cascade trippings all over the UCTE system, which split into three islands (West, North-East and South-East) with significant power imbalances in each area. The power imbalance in the Western area induced a frequency drop that caused the large-scale interruption of electricity supply.

UCTE identify two main causes for the incident.

- **The non fulfilment of the N-1 criterion.** After the manual disconnection the high voltage line, the N-1 criterion was not fulfilled in E.ON Netz grid and some its neighbouring system operators. Also, physical flows between operators were very close to protection settings at the substation at the end of the line. As a result, even a relatively small power flow deviation could trigger the cascade of line tripping.

- **Insufficient inter-TSO co-ordination.** The initial planning of the switch-off was duly prepared by the directly involved transmission system operators. However, the rescheduling of this event was only communicated by E.ON Netz very late. Also, E.ON Netz gave no specific attention to that protection devices have different settings on different grids.

The UCTE also points out some other critical factors behind the incident: no access to real-time data from the power units connected to the distribution grids, lack of coordination between the transmission system operators during the event, lack of joint simulation training with neighbouring transmission system operators and also, lack of coordination between operators' internal procedures (grid-related vs. market-related vs. other adjustments).

The report concludes that the disturbance on November 4th 2006 and the splitting of the interconnected system were not caused by extraordinary climatic conditions or technical failures, but by factors in the E.ON Netz control area. Due to the good performance of countermeasures activated at the UCTE level in the individual control areas, a Europe-wide black-out was avoided. The UCTE gives five recommendations:

- The application of N-1 criteria through better definition and mandatory simulations of contingencies in own and neighbouring systems.
- The reconsidering of transmission system operator's defence plans and clarifying the duties of involved parties within a national framework.
- Developing standard criteria for regional and inter-regional transmission system operator co-ordination.
- Setting up an information platform allowing operators to observe in real time the actual state of the whole UCTE system.
- Adapting the regulatory and legal framework of electricity transmission, in terms of the transmission system operators receiving more information about and more control over electricity generation.

These main conclusions take a technical and also fairly short-term perspective on SOS, focusing on operation and communication. However, the UCTE report also mentions more long-term factors. Firstly, the UCTE note that market developments have resulted in higher cross-border and long-distance energy exchanges, and that this can introduce "short term commercial objectives" into generating, transmitting and distributing electricity. The markets aim at optimizing the produced power depending on short term price differences. As a result, the UCTE interconnected system is operated nearer and nearer to its limits. The "hourly changing trade volume of thousands of megawatts" was not taken into account when the electricity grids were designed some 50 years ago. In contrast to previous times, when mutual assistance between national subsystems was assured, day-to-day grid operation has become much more challenging. (UCTE 2007, 12-13.)

As we have pointed out, and all commentators on the November blackout seem to agree, frameworks of regulation have been established precisely to prevent and mitigate market failures of this sort. The UCTE (2007, 13) call for clear and consistent harmonized regulatory framework across member states. EU Energy Commissioner Piebalgs says these events have again confirmed the need for a proper European energy policy, as energy security is "better delivered through a common European approach rather than 27 different approaches" (EU 2007). Similarly, Council of European Energy Regulators sees the need for an integrated European electricity grid subject to proper regulatory oversight (CEER 2007).

However, the UCTE report shows that they are not necessarily in agreement with the CEER and the EU on how the transmission should be regulated. The UCTE (2007, 13) claim that regulatory regimes actually often make operation more difficult for transmission system operators. The situation today is that transmission system operators face strict constraints through regulation, while flexibility is admitted to the “market players” (UCTE 2007, 61). The CEER (2007), however, sees the need for new legislation which would *impose* European obligations on network companies to co-operate and in turn that there be effective independent regulators to oversee the fulfilment of those obligations. As another difference, the UCTE recommends that system operators should have more intervention rights and generation data especially during emergency situations. This is in contrast to CEER’s and EU’s recommendations of more transmission and distribution unbundling. Also, according to the UCTE (2007, 59), the harmonized regulatory framework should define the role of each partner during emergencies more precisely: transmission system operators as well as distribution system operators, industrial customers and public authorities. Whether regulation at EU level could be this precise, with significant differences between member states, remains to be seen.

As a second wider issue, UCTE (2007, 53) claim that the role of wind generation during the events was “evidently negative”. As wind generation is connected to the distribution grid, not the transmission grid, the transmission system operators has no way to start or stop wind farms. With its high share in generation, the wind generation significantly influences the operation of the power system in some areas such as Germany. Thus the whole transmission system of an area can become dependent on weather conditions. Also, when there is frequency deviation in the grid as in the case of November 4th, wind generation disconnects more easily from the grid than generation connected to the transmission system (UCTE 2007, 13). This further added to the power imbalance.

The predictability of decentralised generation (e.g. wind farms, small-scale solar panels installed on private homes) can be low, but its share of generating capacity is growing due to climate policy and public pressures. In the longer run, decentralised generation needs to be considered while building and investing into electricity networks. For emergencies, new platforms of co-operation should be developed. Clear regulation and energy politics that enables this is one of the key issues. As the President of the European Transmission System Operator (ETSO) underlines: network operators need to know about future decisions concerning the energy mix so that they can operate and design the network accordingly.(EurActiv 2007).

Case Study 2: Italy and Switzerland 2003

On Sunday, 28th September 2003 the Italian power system faced its worst disruption in 50 years, which also affected parts of Switzerland. A total of 56 million people were influenced by the blackouts. In Switzerland, electricity was restored in 1.5 hours and in Italy services were completely restored to all customers in 18 hours. In the terms of affected customers, this is the most significant disturbance on the synchronously interconnected grid on continental Europe.

Several investigations have been conducted of the event. The UCTE summarise the incidents in their report (UCTE 2004). The event started at 3 am with the failure of the Swiss Mettlen-Lavorgo 380 kV line. The load on the line was relatively high prior to the failure, with loading levels at around 86 % of maximum capacity. The high loading resulted in overheating of conductors, which increased the potential for a short circuit cased between a line and an object on the ground, such as a tree. The Mettlen-Lavorgo line failed as a result of a flashover with a tree.

ETRANS (the Swiss high voltage transmission system co-ordinator) tried several times to reclose the line, both automatically and manually. Reclosing is a routine procedure where those lines that remain physically intact after the line tripping are reconnected. However, this failed because of the high power flows into Italy at the time. At 3.11 am, ETRANS phoned the Italian transmission system operator GRTN. ETRANS asked GRTN to reduce Italian imports by 300 MW, because Italy was importing around that amount more than the scheduled power transfers. Italy reduced its import 10 minutes after the phone call. However, this was insufficient to relieve the overload in Switzerland.

After the Mettlen-Lavorgo line had failed, the loads on other neighbouring lines increased. In particular, the Swiss 380 kV Sils-Soazza line was operating at 110 % of its normal maximum rate. UCTE operating standards state that an overload of this magnitude can be maintained in emergency situations, but not for long periods. Under operating standards, the Swiss operator had less than 15 minutes to reduce the overload. But at 03:24am the Sils-Soazza line tripped, the reason being, again, overheating of conductors and a flashover with a tree. Subsequently, other lines became overloaded and lines inside Switzerland, between Switzerland and Italy and between Switzerland and France tripped. At this point the Italian system lost synchronisation with the UCTE network and all remaining interconnectors from Italy were disconnected by automatic protection devices.

Next, instability phenomena started in Italy's system. Very low voltage levels in northern Italy tripped several generators, and separation from the UCTE network caused a large generation shortage, resulting into fast frequency drop throughout the Italian power system. GRTN had an automatic under-frequency plan, which failed because it was "hard-wired" for a different situation and because there was relatively little load to shed on a Sunday morning. Primary frequency control, automatic shedding of pumped storage power plants and some industrial demand helped to slow the rate of decline, but could not prevent the collapse of the entire Italian power system.

The loss of demand in Italy also resulted in a significant fall in load on the whole UCTE system, leading to a sharp increase in frequency across the UCTE system. There was a potential danger for cascading failure across Europe, but system operators in France, Germany and Belgium prevented it with successful emergency responses.

The UCTE Report notes that the integrated system was operating in accordance with N-1 security standard prior to the failure of the Mettlen-Lavorgo line. UCTE identifies two main causes for the event:

- **The inability of the Swiss system operator to reclose the Mettlen-Lavorgo line after its initial failure.** The 10 minutes lost were critical and without the delay, the tripping of Sils-Soazze line could have been avoided.
- **The subsequent responses by the Swiss and Italian system operators**. The operators were significantly slow in their responses, especially since the N-1 criteria had been lost after the tripping of the Mettlen-Lavorgo line. The accounts of the conversation between the operators were later discovered different, and this ineffective communication and information exchange may have contributed to an ineffective response.

The UCTE also note two additional causes which, while not decisive, were still significant for the whole event. First, the angle and voltage instability in Italy just prior to its collapse and second, possibly, insufficient tree cutting under the power lines.

The UCTE report gives the following recommendations for the whole UCTE area:

1. For interconnections between UCTE control blocks mandatory emergency procedures should be put in place, jointly trained for and evaluated at regular intervals.
2. Determine and harmonise criteria for the N-1 security, including in the contingency analysis of voltage and frequency instabilities.
3. Improve the day ahead congestion forecasts (DACF).
4. Extend the real-time data exchange between neighbouring transmission system operators.
5. Determine minimum requirements for generation equipment, defence plans and restoration plans.
6. Implement load-frequency control strategies for splits of the synchronous area.
7. Improve the wide area measurement system (WAMS) for analysing and monitoring the entire UCTE system.

The national transmission system operators receive following additional recommendations:

- National regulation should enforce minimum requirements for generation units with respect to frequency and voltage disturbances.
- National regulations should enforce defence and restoration plans for operators, and these should be jointly simulated, trained and evaluated by all involved parties.
- Tree trimming practices should be evaluated and audited.
- In case of severe voltage drop, the blocking of on load tap changers of transformers should be accepted.

In its arguments, this UCTE report is very close to that of on the European blackout in 2006 (see case study 1). The main conclusions and recommendations are quite technical and have mostly to do with short-term operation and communication. Also a longer-term argument continued into the 2006 report: the opposition towards some principles of the competitive markets. For instance, the UCTE states that this event shows that due to the high power flows resulting from the opening of the electricity market, a system-wide disruption may transpire (UCTE 2004, 94). Also, the UCTE sees that market parties continuously use all available sourcing outside Italy as far as is allowed by the transmission grid, irrespective of the consumption level (UCTE 2004, 57) – a dubious remark, as the event happened at the time of the week when the electricity load draws close to its minimum.

However, in contrast to the 2006 report, this UCTE report takes a distinctively positive stance on regulation. The arguments of the Italian and French regulators (CRE and AEG 2004), who also investigated the Italian blackout, concur: like the UCTE, the regulators insist on enforced legal and regulatory frameworks for secure planning and operation. One reason for this shift in the attitude of UCTE may be the hardening regulation of both EU and national level during the last three years. The transmission system operators see this trend and may wish to retain some of their liberties. In the political and regulatory environment of 2007, the operators may wish to act in emergencies on voluntary rather than on enforced basis.

Case Study 3: Sweden and Denmark 2003

The Nordic transmission system faced its worst disruption in 20 years on Tuesday 23th September 2003. Between around 12:30pm and 12:35 pm, a combination of mechanical faults in southern Sweden created conditions that were beyond the capacity of normal reserves. As a consequence, supplies to southern Sweden and eastern Denmark, including Copenhagen, were disrupted. In Sweden, services were cut from 1.6 million people and in Denmark from 2.4 million people. The affected areas included provincial centres, airports and rail services. Powers was restored to all users in about 2 hours.

The transmission system operators of Denmark and Sweden have prepared final reports on the incident (Elkraft System 2003; Svenska Kraftnät 2003; 2004; see also IEA 2005, 90-99). The reports state that prior to the disturbance operating conditions were stable and within tolerances set in operational planning and grid security assessments. Several components were out for maintenance at the time, including nuclear generating units in Sweden and the transmission lines connecting central and southern Sweden, Sweden and continental Europe and Zealand and Germany. However, contingency planning had taken this work into account.

At 12:30pm, a Swedish nuclear plant shut down due to mechanical problems. The Nordic system frequency began to fall, but this was a standard N-1 contingency event. It was managed through spinning generating reserves from Norway, northern Sweden and Finland, and the system returned to a stable state in less than a minute.

Under the Nordic system security standards, operators have 15 minutes to return the system to an N-1 secure state. But at 12:35pm, a double busbar failure occurred at a 400 kV substation on the west coast of Sweden, caused by a flashover between two busbars. This represented a serious system failure, corresponding a N-2 event. Four 400 kV transmission lines were disconnected, two of which had provided a key link between central and southern Sweden, while the other two had connected a nuclear unit to the transmission network. As a result, the path along the west coast of Sweden and the production of the nuclear generators was lost.

The sudden loss of generation and transmission capacity triggered large power oscillations, low voltages and drop in system frequency, leading to automatic under-frequency load shedding. Power flows increased on the remaining lines between central and southern Sweden, and this flow was amplified by responses from generators in northern Sweden, Norway and Finland to the loss of the nuclear units. After 90 seconds, the power oscillations began to fade and the load levels began to recover, leading to even further stress on the 400 kV transmission links between central and southern Sweden.

As a result, the voltage levels on the 400 kV transmission lines dropped to critical levels, and this led to voltage collapse in the transmission network of the southwest of Stockholm. Distance relays in central and southern Sweden registered this event as a distant short circuit, severing all remaining lines between northern and southern Sweden. An electrical island formed, consisting of southern Sweden and eastern Denmark. The large generation deficit led to collapse of frequency and voltage, triggering generator and network protection devices. The islanded system collapsed at 12:37pm and Eastern Denmark was automatically disconnected from southern Sweden by protection devices on the link between the countries.

The reports note that the system was operating at an N-1 secure condition prior to the first fault. Operational reserves were also deployed appropriately to return the system to stable condition. The key reason for the outage was that a second major fault occurred within the 15 minute period allowed under Nordel operating practises to return the system to an N-1 secure state. Neither increased production in eastern Denmark nor imports from the European continent would have been capable of preventing the incident. The reports conclude that large disturbances can stem from a sequence of interrelated faults that would be manageable if they appeared alone.

The reports give following key recommendations:

- Assess the planning and operational standards of the Nordic system, checking whether current technical standards and operational practices are consistent with the efficient operation of electricity markets and community expectations.
- When there is a shortage of generation capacity, automatic load shedding should be considered.
- Ensure that appropriate balance is maintained between protecting the infrastructure and maintaining services during emergencies.
- Ensure that consumer disconnection and restoration during load shedding are appropriately prioritised.
- Strengthen restoration processes, dedicating specific plants and generators to restoration after blackouts.
- Enforce technical requirements for external disturbances on generators.
- Develop tools and protection devices in which information for the whole Nordic system can be integrated.
- Review and adjust communication strategies, to strengthen timely flow of information to distributors, consumers, authorities and the media.
- Eliminate the risks of flashovers between two busbars.
- Enforce inspections and scheduled replacements of critical parts of the power system.
- Review the methodology and resources applied to outsourced maintenance.
- Consider investing into transmission lines to improve system reliability, especially upgrading the transmission lines to southern Sweden and constructing new generation in southern Sweden.

These reports remain for most part technical and the non-technical recommendations for communication and regulation are very general. Clearly differing from the two UCTE reports (see case studies 1 and 2), the liberalization of markets has no significant role in these reports. In its only mention of the markets, the Elkraft System (2003, 7) states that the failure gives grounds for considering whether the development of the electricity market has changed the conditions for system operation; but Elkraft System does not assess what these changed conditions may be. Also, regulation of electricity transmission is not mentioned. Perhaps this is because the incident was so clearly caused by two technical faults, and there was no need to address the market and regulation structures behind the failures. Outside the technical recommendations, the very general demands of e.g. “timely flow of information” to different stakeholders or “appropriate prioritization” of consumer disconnection leave much room for interpretation.

The social impacts of blackouts

During interruptions, all electrical technology such as computers, appliances, lights and electric heating are of course unavailable. But as seen in table 4, there are also potential losses through knock on effects on other forms of infrastructures. Even short interruptions cause major problems with transport, communication, waste disposal, drinking water, sewage management and mobile phone systems. Whereas in the 1970s it was common practice to perform maintenance "cold" in the early morning hours, today any such attempt would see widespread disruption as alarm clocks were reset and much of the population overslept!

Interruptions of over a day lead to an effective end to traffic and flooding of sewage: though water, gas and conventional telephone systems seem to stay available even then.

Additionally, one should note that electricity interruptions affect directly the electricity infrastructure itself. There is an especially vicious circle between electricity and communications: no electricity means difficulties for communication, and no communications means, in the contemporary context, difficulties for electricity.

Infrastructure	0-2 hours	2-8 hours	8-24 hours	24 hours >>
Transport	Depends on characteristics of area and nature of train-system. Electricity dependent: no traffic, non-dependent on electricity: traffic with delays. Urban systems stop, road traffic in chaos	Delays increase and ripple through to un-affected parts of the system. No traffic at all on affected parts	No traffic at all, fuel supply problems	No public transport
Communication	Difficult to supply information, outages of transmission poles	Information back set, more personnel needed		Availability of personnel decreases
Waste disposal	Difficult due to traffic congestions, delay in disposal of waste		Collection is difficult, possible un-hygienic circumstances	
Electricity			Difficult to keep communication up	Possible problems with fuel supply for generators
Drink water	Production: control of remote stations Distribution: local pressure drops on stations without generators, in case of loss of pressure devices: nor water on higher floors			Water is guaranteed
Sewage management	Low lying areas, with rainfall: flooding of sewer water after 2 hours	Flooding in higher areas as well	Also flooding in case of no rain	flooding
Gas	Generally no problems, receivers will endure problems in energy dependent systems; climate control, watersupply.			In case of pressure loss: temperature drops
Telecommunication	Telephone is assured, possible problems with GSM systems, internal operators outage. No fax, congestion in telephone network			Telephone system assured. Possible problems with generators due to fuel supply problems

Table 4. Overview of the loss of functionalities in infrastructures over time due to loss of electrical power. (Logtmeijer, Di Mauro & Nordvik 2005, 12.)

The first way to valuate these impacts is to calculate their costs. A rough general level for blackout costs can be obtained by dividing the gross national product of a country by the total electricity used. In Finland in 2005, for instance, this would be 1.72 euros for each kWh missed. But this estimate misses any personal and social risk perceptions of different electricity end-users. Some academic research has gone into surveying the costs of electricity outages of different customer groups. This research has relied on questionnaires that ask end-users directly how much economic harm they experience from electricity outages.

Figure 6 summarizes results from the UK, Norway, Sweden, Denmark, Finland and the US. We can draw some conclusions from these large studies. First, when compared to electricity price, outage costs are very high. In the case of households in Finland, the difference is 1-2 orders of magnitude, while for commercial and industrial customers, it can be 2-3 orders of magnitude. The UK costs of 0.6 eur/kW for residential and 12.9 eur/kW for commercial are admittedly lower, but still compared to current electricity prices, they are very high. This importance seems to be on the rise: a comparison of a similar sample from Nordic studies from 1994 and 2005 suggests that outage costs have grown about two-fold over a decade (Silvast et al 2005, 94).

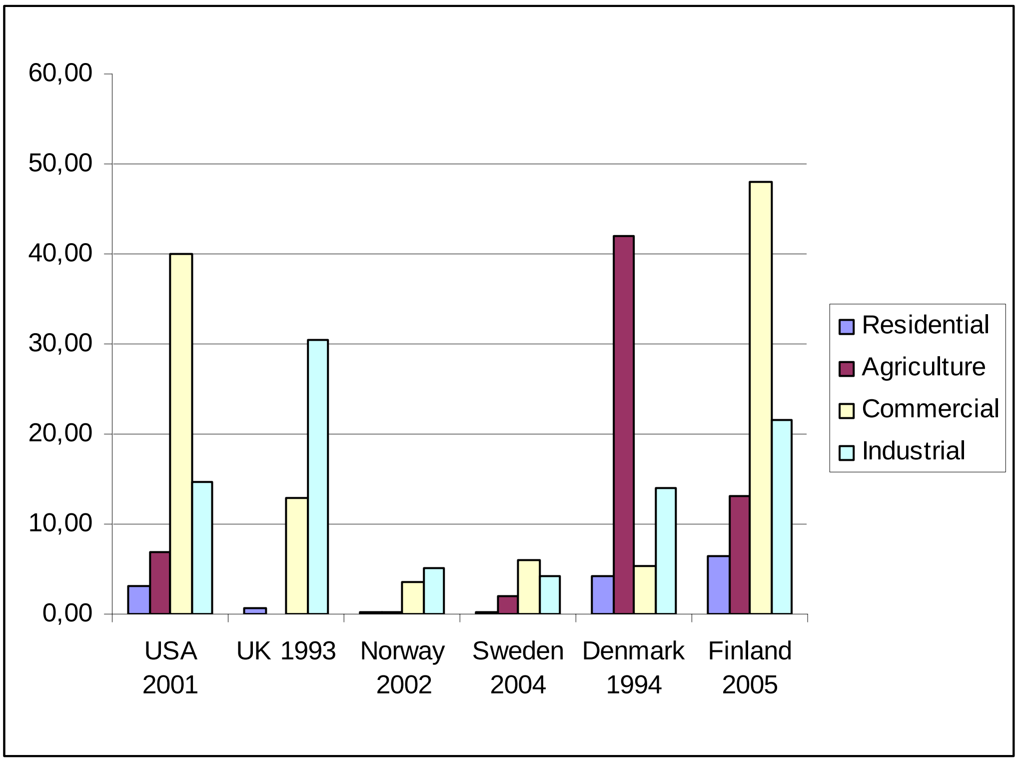

Figure 6. Costs of 1 hour outage (eur/kW). (Silvast et al 2005, 24; 100.)

As a second conclusion, the dispersion of the cost estimates of different customers is very large. Figure 6 points to notably high costs for commercial sector in the US and Finland and agriculture in Denmark. Only the UK has highest costs for industrial activities. More extensive results (Silvast et al 2006) suggest that interruption costs have a large variation depending on time of occurrence, interruption duration and type of activity (high for e.g. banks, insurance companies and electric heaters). In addition, the geographical location seems to have a big influence. This dispersion is pointed by the statistical distribution in figure 7, taken from a Finnish study. There is a well-centred mass in the beginning of the distribution. At higher values, however, there is a relatively equally spread area, which reaches very high cost values. This shows that some individual customers have higher than usual outage cost values.

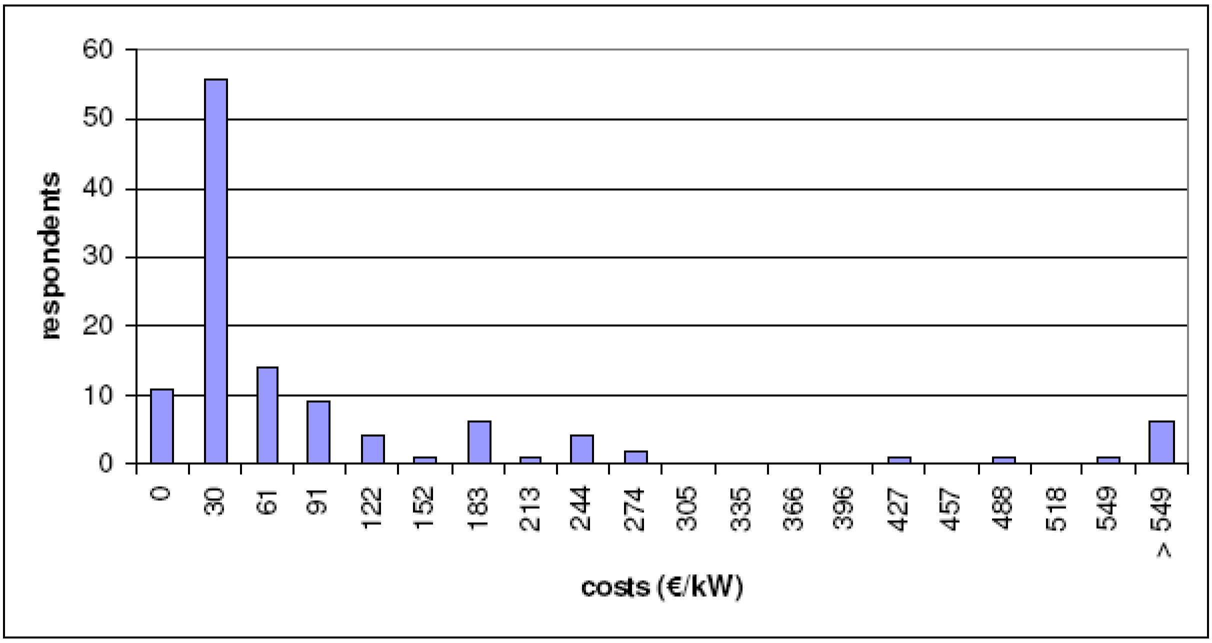

Figure 7. Costs of 1 hour outages among the commercial customers studied. (Silvast et al 2006, 7.)

In addition to these cost-benefit-surveys, there exists more qualitative studies on blackout perceptions (Silvast 2006, Yuill 2004). Interviews about blackouts suggest that people are sometimes quite fatalistic and even relaxed about blackouts, seeing them as sort-of enforced break from work. Most people also accept that natural phenomena like lightning and wind can cause electricity outages. On the other hand, if blackouts start to cause direct economic harm or create unusual difficulties, lay people can be very critical of the electric utilities. Whence, criticism is targeted towards the "profit-seeking" and low investments of utility companies, a theme which is probably familiar because of its political and media coverage.

While utilities tend to point to technical problems, people then find these kinds of explanations unacceptable. Paradoxically, the technical network behind electricity provision does not get less "black-boxed" in the public mind when the distribution is interrupted. On the contrary, long blackouts prove to people how important it is to have electricity that is "black-boxed" and invisible in its structure. They just want the system to work.

4. Dealing with blackouts

In this section we will review the measures the member states take to deal with blackouts. These include technical, educational and political means. The most technical and practical means are maintaining reserve generation capacity and maintenance of the network. We then move to more educational projects, reviewing how operators train for and simulate emergencies. We will discuss the rise of market protectionism as political mean to reduce the risk of cascading electric power failures, and standardisation as another solution. Also, we will start to review the current debate on decentralised generation.

Reserve generation capacity

In addition to planning and co-ordination, the transmission system operators maintain their capacity with reserve power. "The fast disturbance reserve", as it is called, consists of active and reactive power reserves that can be activated manually within certain time scope. After activating this reserve, the electric power system should be restored to such a state that it can withstand another potential disturbance. Compensation is paid to power producers who reserve reactive power in their generators. Hungary, for instance, has stockpiled energy sources that is enough for 8 days of operation. In the Nordic grid each country must have a volume of fast disturbance reserve that equals a fault that covers the whole country.

Maintenance engineering

A shift toward resilience implies a greater emphasis on maintenance as a means to pre-empt emergencies. This shift is already taking place, driven by the need to cope with an ageing infrastructure. Any maintenance regime is in practice a mixture of preventive and reactive maintenance, where preventive maintenance replaces components before failure and reactive maintenance after failure. Today's strategies of reliability centred maintenance seek to use a predictive maintenance strategy to find the optimal mix.

The capacity to predict failure is potentially significant making decisions about re-routing of power through a grid, as it is secondary failures that can often trigger a larger scale blackout. This implies that dispatchers should be familiar with the more sophisticated computerised maintenance management systems now in place.

In the event that a blackout cannot be avoided, closer co-ordination with now outsourced maintenance organisations should facilitate prioritisation of reconnections and more rapid restoration of the grid to its normal operating state.

Education and training for emergency response

At present a wide variety of training is in place (Knight, 2001).

The starting point for training is recruitment of either school or university graduates. Both schools and universities are shifting toward an ever greater emphasis on communication, team working and transferable skills on the grounds that this is necessary to meet the needs of industry (Little 1999). However, there is as yet little evidence to suggest that such courses at school, undergraduate or postgraduate level are a substitute for more focused learning opportunities available in the concrete context of a real job. Indeed it has even been questioned whether the concept of "transferable skills" is a useful one (Holmes, 2000, 2001). The lack of focus in such generalist courses is not a problem that can easily be overcome.

Training within industry takes several forms.

One-to-one mentoring plays a key role in passing on knowledge between generations and inducting workers into new roles. It is not necessary for junior operators to be assigned a single mentor as shift rotations will usually mean that people work together in different combinations.

Structured group discussions and training courses both play an important role. It is already known to organise discussions around emergency situations and disturbances in other utilities (Knight 2001), and this should be encouraged. Such training can play an important role in ensuring coherence across an entire group, but can be costly in terms of time.

Other training opportunities include the commissioning of new facilities and self tuition, since many operator jobs involve periods of high activity interleaved with longer periods of inactivity.

In addition simulation training discussed in the next section discussed in the next section plays an important role.

Industry will continue to rely on universities, management and business schools to supplement in house training. This is especially true at higher levels and at smaller utilities. However, while such development may take place in collaboration with academic institutions, the development of industry specific training represents a useful opportunity to provide the focus necessary for effective team work training. In addition, such training could provide an opportunity to forge common links that go beyond a single organisation to build tacit knowledge across the whole of European infrastructure.

Simulation Training

Existing training programmes make extensive use of simulators. A first objective is to ensure that operators are entirely familiar with facilities, procedures and interfaces during an emergency situation. This should allow concentration to be directed into decision making rather than what should be the routine aspects of control room operation. This objective is met by use of simulators that replicate, to a greater or lesser extent, the appearance and layout of real control systems.

Such systems ideally use mimic boards including the use of displays, audible and visual alarms found in real systems. Alternatively, stand-by control rooms or spare equipment in an operational control room can be used. (Here, of course, care should be taken to minimize the risk of confusion between training and real-time data.)

Stand alone, PC-type systems, are also used. In this case, however, other objectives of simulation training may be more significant.

A second objective of simulations is to develop knowledge of the way in which the system responds under the unusual dynamic or degraded conditions encountered during an emergency. This aspect of simulation requires that the simulation response approximates the real world. This is achieved through use of a mathematical model and play back of data for demand profiles or external faults.

Overall control of the simulation is run by a trainer who is able to initiate events and to communicate with the trainee by sending and receiving messages as a representative of the ‘outside world’.

A third objective of simulations is to improve team working and communication. At present this function extends only to a single control room. Communications with other centres, such as generating stations or other control rooms, are ‘simulated’ through communication with the trainer. For reasons detailed earlier, such communications are becoming more significant in ensuring system security. The need for communications training could be addressed either through extension of simulations to co-ordinated exercises or through the development of alternative mechanisms.

Overall, simulations are designed to cover a wide range of contingencies including multiple faults and responses ranging all the way to system splitting and behaviour under black start conditions.

Existing simulation training

In the UK The National Grid Company has installed a dispatch training simulator in stand-by control rooms which covers both the technical and commercial aspects of fault control. It covered the entire transmission network including some 250 generators, 170 substations, 970 supply point loads, 188 voltage control mechanisms, 10,000 circuit breakers, and interconnections to Scotland and France.

Training is provided at basic, operational and advanced levels. Teams of between four and ten operators are accommodated, with experienced shift teams training two or three times per year. Advanced courses consist of four or five scenarios, with participants rotated through a number of roles and each scenario lasting up to several hours. Courses have also been developed for managers and oriented toward external communications.

Demand-side management

Increasingly, SOS is seen not only as matter of functioning systems, but also respectful end-use of electricity. Alonside EU, the electricity industry has been very active in promoting the demand-side management of electricity end-use. The industry union EurElectric (2004) names several ways through which the customers can “play a role” in decreasing demand for peaking electricity capacity: interruptible contracts, managing consumption through metering and using “market instruments fairly”. In strong contrast with the earlier public interest viewpoint of electrification, EurElectric (2006, 3) even comments that it is not clear whether customers are actually demanding higher quality of electricity supply, “and, importantly, whether they are prepared to pay for it”.

During peak-load situations, experience has shown that industrial demand-side response can play a part in balancing supply and demand. The same is true for large-scale consumers in agriculture, public sector and commercial sector. But while potential for household responses exists, measuring their impact would require such exact metering that is not widely spread at the moment (see

Koponen et al 2006). Thus at the moment, aiming for demand management of households remains mostly about promoting the value and moral of rational electricity use.

It should be noted that much discussion of the need for demand management, with its emphasis on billing and metering to ensure that customers are constantly "aware" of the "true cost" of their consumption, takes place in a social atmosphere that deprecates energy consumption. It should not be assumed that energy companies themselves are immune to such a widespread way of thinking. It is not hard to see how such ways of thinking could have knock on effects for the way in which personnel understand the importance of security of supply.

Decentralised electricity systems

The most radical response to SOS is to have done with the traditional electric power system. The debate on centralised vs. decentralised electricity networks carries this element. Decentralised networks means electricity generation near point of use, often utilizing responsive demand from the users and renewables that require no fuel supply. Critics of centralised energy systems have argued that the centralised systems are too large and structurally coupled, thus prone to failure, whereas decentralised systems are supposedly *resilient* (see Farrell, Zerriffi & Dowlatabi 2004, 436-438). Resilience, a term borrowed from ecology, implies modular structures, redundancy, substitutability, diversity, possibility of decoupling and dispersion.

In its new energy policy program, EU (2007, 15) has stated that it aims to use fuel cell and hydrogen technologies to exploit their benefits in decentralised generation and transport. Lately, the environmental commentator Jeremy Rifkin (2003) has also advocated for a hydrogen-powered distributed electricity network, which utilizes Internet technology. The key arguments is that this kind of network should be less vulnerable to blackouts.

The discussion of distributed generation is not new. Similar themes about the vulnerabilities of centralised electricity grids emerged in the US military discourse already in the early 1980s (see Farell, Zerriffi & Fowlatabi 2004, 427). This discourse has highlighted the strengths, but also the weak points of distributed generation.

The general technological picture of distributed generation may be compelling. With minimal need for centralised control, the whole network becomes less vulnerable for failures in single points. However, any discussion of electric power systems is also about ideas. As such, the arguments for distributed generation offer fairly idealised vision of decentralised systems and renewable energy sources. Efficiency, renewability, decentralisation and security get automatically linked together, with relatively little question as to whether renewable energy is always efficient and secure. This also excludes the possibility of large-scale renewable generation (like large wind farms) or small-scale non-renewable generation (like small nuclear reactors).

The reliability of large-scale electricity grids has traditionally been good and has improved over the years. A sufficiently large grid will be able to capture the time-diversity of electricity demand, leading to higher load factor and lower costs. Also, as we have shown, there are already quite good practises for network coordination, backup power and line-worker safety in large electricity grids. Universal solutions for these issues with distributed generation do not exist at the moment.

The arguments for decentralised generation also tend to ignore the details of markets and regulation (Farell, Zerriffi & Dowlatabi 2004, 427). Even if decentralised systems do provide for more resilient systems, one should recall that all systems have to be implemented in certain market and social conditions. Indeed, the current European electricity system with its liberalised markets, networks, generation and fuel supply is already in many ways less centralised than the previous monopolistic systems.

On the other hand, there may be potential antagonisms between the interest of large energy firms operating a centralised infrastructure and those who deploy decentralised technologies. This problem alone may significantly limit the potential of decentralised technologies (ibid, 438). Consequently, distributed generation should not be dismissed simply on the grounds that the traditional electricity system has already acquired momentum. In time, possibly through government intervention, markets, regulation and operating practises will most likely form around distributed generation.

An interesting development in this field is the SmartGrids, a project for European technology platform that was started in 2004. It aims to make the best possible use of both large centralised networks and smaller distributed power sources. The projects resulting from SmartGrids aim to stimulate investments in new network and associated information technologies. Integrated research and demonstration projects are envisaged, striving for successful adaptation strategy to the context of the present electricity industry. SmartGrids importantly underlines that "smarter" solutions are not only needed for small distributed power sources. Information technologies can also be utilized in the centralised plants and networks in form of automation, computation, sensors and communications.

With all the attention it is receiving, it should be mentioned that decentralised systems hardly feature in our data. In the ERGEC reports, only two member states (Germany, France) mention decentralised generation in short passages. However, this does not mean that it could feature as a more prominent political question in the future. For instance Netherlands has already successfully deployed decentralised generation, though interestingly through incumbent utility companies.

Standards as an alternative to the rise of protectionism and regulation?

The issues covered in previous sections indicate that the benefits of liberalized and open markets are not as wholeheartedly agreed on as the EU internal energy market directive would make it seem. ERGEC (2006a) note this trend, pointing out that political support for liberalization seems to be counterbalanced by companies' perceived risks of being held responsible for potential underinvestment, weakened SOS and high prices. The rise of climate change policies often adds up to the same trend: the market is perceived not to deliver sufficiently secure and sustainable electricity at low prices.

In an ideal market situation, electricity supply and demand should be balanced by the price of electricity (Doorman et al 2004). However, the politicizing of SOS has made electricity generation and supply also a concern for politicians and regulators, in both old and new member states. Hungary illustrates this, stating that one of the essential requirements of the market opening is that "the security of electricity supply shall not be jeopardized neither in the short, nor in the long run." The Czech transmission system operator is not planning to build any new cross-border lines in the next few years, because of the neighbouring transmission system operators' "insufficient domestic transmission capacities”. Spain, and the Iberian Peninsula generally, mostly lacks cross-border interconnections, and the Iberian market is practically isolated from the rest of Europe. In Hungary, UK and Finland, the plans to build new nuclear capacity are constantly being backed with arguments of lowering energy import dependency, even from other EU countries.

The question of how electricity systems should be managed remains problematic. The tendency for national regulators has been to demand higher continuity and more secure transmission and distribution systems, on the assumption that higher standards justify the costs involved. The EU has proposed same sort of objective. But the tightening regulation has not been accepted easily by the industry. The industry union EurElectric (2006) has protested that regulatory demands incur substantial financial burdens. EurElectric (2006) also considers it is not clear whether customers are prepared to pay for higher quality of supply. As another identifiable problem, the regulation practices of different member states are far from harmonized. The contemporary tendency to put regulators under national political control further contributes to this fragmentation of regulation.

National measures that involve state intervention can distort competition and will easily be put under the scrutiny of European competition authorities. Yet, considering the social importance of electricity and the monopolistic history of electricity companies, the viewpoints against liberalized markets are understandable. Experience from electric power exchanges over recent years also shows positive aspects of market principles. These aspects don’t have to necessarily follow the deterministic discourse of “market forces” and “the abilities of free market”; instead, they can be pragmatic. For example, when the level of technical reserve is defined by system operators in the markets, new efficient regimes of co-operation can emerge between states. Physical and purely financial traders can play an important role in the integration of electricity systems of different member states. An example is the co-ordinated planning between the transmission system operators of the Nordic market. With effective crisis response mechanisms in place, receiving energy from another state can actually improve SOS by reducing the need for generation capacity inside the member state. Also, comparison shows that prices on the continental Europe are more in line with each other than they were a few years ago (ERGEC 2006a).

The rise of regulatory and protectionist tendencies clearly points to the limits of pure market processes. However, there are alternatives to direct market interventions. The development of common cross-industry bench-mark knowledge standards is a method that lends itself to developing links that can supplement direct market contracts without a direct role for the state.

But while the objective accountability offered by standards has a role to play, the subjective side of developing meeting standards should not be underestimated. In blackout or near blackout situations critical decisions need to be made rapidly under conditions of limited knowledge. This puts a premium on communication which rests not simply on book-knowledge or vocabulary but also on more shared tacit assumptions about common goals.

By their nature the necessary links cannot be imposed through bureaucratic requirements. What the development of standards offers is the creation of a forum through which, with industry participation, a common set of understandings can be created.

5. Outputs for UNDERSTAND project

As a result of the current draft of our document, we present the following core benchmarks.

1. Resilient systems

A resilient system is largely matter of co-ordination. This is true both between operators and within operators. Co-operation is not only a matter of clarity of communication, important as that is. It rests on an understanding of the common goal of SOS, even among organisations in commercial competition. This is a precondition for both effective communication and the making of prioritisation decisions under emergency conditions.

Between operators and outsourced service providers, regimes of co-operation and communication should be supported. Not only monitoring and maintenance, but also longer-scale network planning should be co-ordinated. Within operators, there should be good co-ordination between internal procedures, e.g. market-related, grid-related and other adjustments. The different electricity, regulatory and market systems within EU member states pose further challenges. The EU-wide educational system should be both understandable and acceptable in the practical contexts of transmission operation in different member states.

2. Globalisation

While we agree that energy professionals need to understand wider contexts for their decisions, the question of responsibility is important. Some international, national and even local issues fall into the domain of authorities, governments and the EU, not the transmission system operators. The examples of such threats include terrorism, pandemics and environmental catastrophes. The EU-wide educational system should distinguish between the probable dangers and theoretical risks of electricity transmission.

3. Sustainability

Many market steering mechanisms and political forces are pushing toward a sustainable energy system. The challenges of distributed energy are apparent in Europe’s blackout of 2006. The educational system should note that sustainable energy sources are often more distributed than traditional centralised systems. With less centralised control, matters of co-ordination become more important.

4. Public acceptability

Public acceptability is important not only for fuel and generation choices (e.g. nuclear or renewables), but also the electricity grid. Blackouts pose dangers to peoples’ welfare and health, not just appliances. This is especially true for the at-risk customers, if not in all cases for the general public. Also the demand-side management of users can pose dangers to welfare and health of the vulnerable groups. Communication strategies should be efficient, but also respectful of the great importance of electricity. Furthermore, the communication should be timely and simple enough, both for the customers and the media. The educational system should include courses on communication, media and customer relations. This should also have longer term benefits acceptability of power lines and rights of way.

5. Emergency responses

Co-ordination between operators and within operators form an important part of emergency response. Many of these professional networks are also relatively informal. The voluntary character of emergency preparedness should be supported in the educational system. Boundaries formed by markets and regulatory regimes should also be noticed. As with resiliency, the different electricity, regulatory and market systems within EU member states pose further challenges for the education.

References

Collier, Stephen & Lakoff, Andrew (2006). “How ‘Critical Infrastructure’ Became a Security Problem”, Critical Infrastructure Protection and Changing Logic of Risk and Security Workshop 2006, 1-40.

Commission of the European Communities (2003). “Proposal for a directive concerning measures to safeguard security of electricity supply and infrastructure investment.” COM(2003) 740

Commission of the European Communities (2005). “Green Paper on a European Programme for Critical Infrastructure Protection”. COM(2005) 576 final.

Commission of the European Communities (2006a). "Green Paper on a European Strategy for Sustainable, Competitive and Secure Energy". SEC (2006) 317.

Commission of the European Communities (2006b). "Prospects for the internal gas and electricity market: Implementation report". COM(2006) 841 final.

Commission of the European Communities (2007a). "Priority Interconnection Plan". COM(2006) 846 final, SEC(2007) 12.

Commission of the European Communities (2007b). "An Energy Policy for Europe”. SEC(2007) 12.

Council of European Energy Regulators (2005). “Third Benchmarking Report on Quality of Electricity Supply 2005”.

Council of European Energy Regulators (2006). “European Energy Regulators investigate blackout in Europe”. Press release.

CRE (Commission de Regulation de l’Energie) and AEEG (Autorita per l’Energia Elettrica e il Gas) (2004). “Report on the Events of September 28th, 2003 Culminating in the Separation of the Italian Power System from the other UCTE Networks, CRE and AEEG.” This publication can be viewed at www.autorita.energia.it/inglese/press/eng_index.htm

Doorman, Gerard; Kjølle, Gjerd; Uhlen, Kjetil; Huse, Einar & Flatabø, Nils (2004). ”Vulnerability of the Nordic Power System”. Report to the Nordic Council of Ministers.

Elkraft System (2003). “Power Failure in Eastern Denmark and Southern Sweden on 23 September 2003: Final Report on the Course of Events”. Elkraft System, Ballerup, Denmark.

ERGEC (2005). “Electricity Regional Initiative Launched to Accelerate Single European Energy Market”. Press release

ERGEC (2006a). “Assessment of the development of the European Energy Market 2006”.

ERGEC (2006b). Country Reports. Link: http://www.ergeg.org/portal/page/portal/ERGEG_HOME/ERGEG_DOCS/NATIONAL_REPORTS/2006

EurActiv (2007). “Blackout puts outdated power grid in spotlight”. Link: http://www.euractiv.com/en/energy/blackout-puts-outdated-power-grid-spotlight/article-159530

EurElectric (2004). “Security of Electricity Supply”. Discussion Paper.

EurElectric (2006). “Comments on the CEER 3rd Benchmarking Report on Quality of Electricity Supply 2005”.

European Union (2006). “Energy Commissioner Andris Piebalgs reacts to Saturday's blackouts”. Press release.

Farell, Zerriffi & Fowlatabi (2004). “Energy Infrastructure and Security”. Annu. Rev. Environ. Resour.29:421–69.

Gheorghe et al (2006) “Critical Infrastructures at Risk: Securing the European Electric Power System”. Springer

Graham, Stephen & Marvin, Simon (2001). “Splintering urbanism: Networked infrastructures, technological mobilities and the urban condition.” London: Sage.

Holmes, L (2000) What can performance tell us about learning? Explicating a troubled concept, European Journal of Work and Organizational Psychology, Volume 9, Number 2, 1 June 2000, pp. 253-266(14)

Holmes, L (2001) Reconsidering Graduate Employability: the 'graduate identity' approach, Quality in Higher Education, Volume 7, Number 2, 1 July 2001, pp. 111-119(9)

International Energy Agency (2005). “Learning from the Blackouts: Transmission System Security in Competitive Electricity Markets”.

Kjølle, Gerd; Ryen, Kjetil; Hestnes, Birger & Ween, Hans (2005). ”Vulnerability of electric power networks”. Nordic Distribution and Asset Management Conference 2006..

Koponen, Pekka; Kärkkäinen, Seppo; Farin, Juho & Pihala, Hannu (2006). ”Markkinahintasignaaleihin perustuva pienkuluttajien sähkönkäytön ohjaus.” VTT research report.

Knight, U. G. (2001) “Power Systems in Emergencies: From contingency planning to crisis management”. Wiley

Little, R (1999) Educating the Infrastructure Professional, Public Works Management & Policy, Vol. 4, No. 2, 93-99

Logtmeijer, Di Mauro & Nordvik (2005). “Regional vulnerability for energy disruptions”. Institute for the Protection and Security of the Citizen.

Partanen, Jarmo; Viljainen, Satu; Lassila, Jukka; Honkapuro, Samuli; Tahvanainen, Kaisa; Järventausta, Pertti; Mäkinen, Antti; Trygg, Petri; Kivikko, Kimmo; Antila, Sauli; Toivonen, Janne; Kulmala, Harri & Antola, Juha (2005). ”Palveluliiketoiminnan kehittymismahdollisuudet sähköverkkoliiketoiminnassa.” Tampere University of Technology and Lappeenranta University of Technology.

Philipson, Lorrin and Willis, H. Lee (2006).. “Understanding Electric Utilities and De-Regulation”. 2nd Edition, Boca Raton:Taylor and Francis

Rifkin, Jeremy (2003). ”Powering the People”. The Guardian, Tuesday August 19, 2003.

Short, T. A., (2006). “ Distribution Reliability and Power Quality”. Boca Raton:Taylor and Francis

Silvast, Antti (2006). ”Keskeytyksestä kritiikkeihin: sähkönjakelun häiriöiden kokemuksia ja kohtaamisia.” Master’s Thesis. Department of Sociology, University of Helsinki.

Silvast, Antti; Heine, Pirjo; Lehtonen, Matti; Kivikko, Kimmo; Mäkinen, Antti & Järventausta, Pertti (2005). ”Sähkönjakelun keskeytyksestä aiheutuva haitta.” Helsinki University of Technology.

Silvast, Antti; Lehtonen, Matti; Heine, Pirjo; Kivikko, Kimmo; Mäkinen, Antti & Järventausta, Pertti (2006). ”Outage costs in electrical distribution networks – a Finnish study”. Nordic Distribution and Asset Management Conference 2006.

Svenska Kraftnät (2003). “The black-out in southern Sweden and eastern Denmark, September 23, 2003 – Preliminary Report”. Svenska Kraftnät, Vällingby, Sweden.

Svenska Kraftnät (2004). “The black-out in southern Sweden and eastern Denmark, September 23, 2003, Svenska Kraftnät.” This publication can be viewed on the Svenska Kraftnät website at www.svk.se/upload/3813/ IEEE_engelskpresentation_jul2003_2230.pdf.

The European Parliament and the Council of the European Union (2003). “Regulation on conditions for access to the network for cross-border exchanges in electricity”. EC 1228/2003.

The European Parliament and the Council of the European Union (2006). “Directive on energy end-use efficiency and energy services”. 2006/32/EC.

UCTE (2004). “Final Report of the Investigation Committee on the 28 September 2003 Blackout in Italy.”

UCTE (2007). “Final Report: System Disturbance on 4 November 2006”.

Yuill, Chris (2004). Emotions After Dark - a Sociological Impression of the 2003 New York Blackout. Sociological Research Online, 9(3).

Appendix 1. The data

Member state	**ERGEC data (year)**	**CEER data (year)**
Austria	2005	2005
Belgium	2005	2005
Bulgaria	-	-
Cyprus	no interconnections	
Czech Republic	2006	2005
Denmark	2006	-
Estonia	2006	2005
Finland	2006	2005
France	2006	2005
Germany	2006	-
Greece	2006	2005
Hungary	2006	2005
Ireland	2006	2005
Italy	2006	2005
Latvia	2006	2005
Lithuania	2006	2005
Luxembourg	2006	-
Malta	no interconnections	
Norway*	2006	2005
The Netherlands	2006	-
Poland	2006	2005
Portugal	2005	2005
Romania	-	-
Slovakia	2006	-
Slovenia	2006	2005
Spain	2006	2005
Sweden	2006	2005
United Kingdom	2006	2005

Table A1. EU Member states' annual reports to European Commission in 2006. (ERGEC 2006a; CEER 2005.)

*: not in the EU, but part of the Nordic energy market

Appendix 2. Effects of faults

1. Effect of a sudden loss of generation (or import from another part of the system)

Possible result	***Containment actions (in order of preference)***	***Time available to implement action***	***Possible further effects***
Frequency fall	Increase generation Reduce demand	.1 seconds to seconds	Insufficient demand disconnected will lead to cumulative loss of generation and system collapse. Excessive disconnection of demand or poor damping of governors may lead to oscillation of frequency, cumulative loss of generation and system collapse.
Transmission overload	Increase generation Reconfigure network Reduce demand	Seconds to minutes	Sequential tripping of overload circuits, possibly leading to an uncontrolled system split. This implies (possibly large) generator-demand imbalances in each section.
Transient instability	Increase generation Reconfigure network Reduce demand	Milliseconds	System oscillations and tripping of circuits (e.g. on impedance-protection) possibly leading to an uncontrolled system split, as above.
System oscillations	Increase generation Reconfigure network Reduce demand	Seconds to minutes	Build up of oscillations and circuit trippings up to an uncontrolled system split, as above.
Voltage drop	Increase generation (real and / or reactive power) Reconfigure network Reduce demand	Milliseconds or seconds to minutes	Cumulative voltage fall as tap changers operate. Transmission voltages fall and currents increase with circuit trippings and generator excitation systems limiting leading to system voltage collapse and probable system instability.

2. Effect of a sudden loss of demand (or export to another part of the system)

Possible result	***Containment actions (in order of preference)***	***Time available to implement action***	***Possible further effects***
Frequency rise	Reduce generation	.1 seconds to seconds	Over responsive governors may lead to oscillation of frequency. Cumulative loss of generation and demand with possible total loss of system.
Voltage rise	Reduce reactive power on sources Reduce generation	.1 seconds to seconds to minutes	If not halted a severe voltage rise will lead to extensive faults and tripping of circuits possibly resulting in system collapse.
Transmission overload	Reduce generation Reconfigure network	Seconds to minutes	Sequential tripping of overloaded circuits leading to possible uncontrolled system split. This implies (possibly large) generator-demand imbalances in each section.
Transient instability	Reduce generation Reconfigure network	Milliseconds	System oscillations and tripping of circuits (e.g. on impedance-protection) possibly leading to an uncontrolled system split, as above.
System oscillations	Reduce generation	Seconds to minutes	Build up of oscillations and circuit trippings up to an uncontrolled system split, as above.

3. Effect of a sudden loss of transmission (no system split)

Possible result	***Containment actions (in order of preference)***	***Time available to implement action***	***Possible further effects***
Transmission overload	Reconfigure network Adjust generation Adjust generation and demand	Seconds to minutes	Sequential tripping of overloaded circuits leading to possible uncontrolled system split. This implies (possibly large) generator-demand imbalances in each section.
Transient instability	Reconfigure network Adjust generation Adjust generation and demand	Milliseconds	System oscillations and tripping of circuits (e.g. on impedance-protection) possibly leading to an uncontrolled system split, as above.
System oscillation	Reconfigure network Adjust generation Adjust generation and demand	Seconds to minutes	Build up of oscillations and circuit trippings up to an uncontrolled system split, as above.
Voltage fall	Reconfigure network Adjust generation (real and/or reactive power) Adjust generation and demand	Seconds to minutes	Cumulative voltage fall as tap changers operate. Transmission voltages fall and currents increase with circuit trippings and generator excitation systems limiting leading to system voltage collapse and probable system instability.