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Leonardo da Vinci

UNDERSTAND
sEcUring electricity

Pre-Reading

A Part of the UNDERSTAND Training Program

Pilot version

UNDERSTAND
sEcUring electricity

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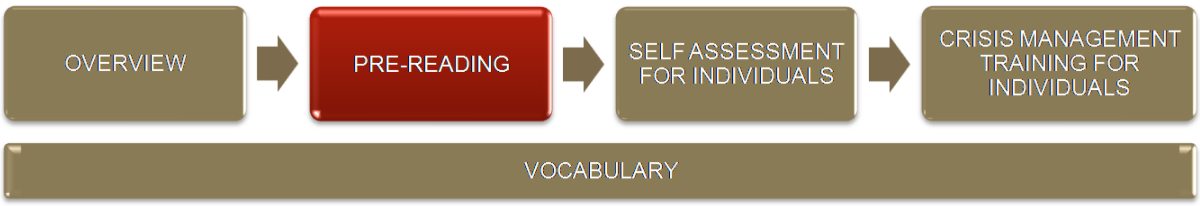
Pre-reading

This Pre-Reading is part of the UNDERSTAND Training Program. The program consists of four stand-alone but interconnected modules seen in the model below. The purpose of the Pre-Reading is to strengthen the individual's understanding of the contents of the other modules. It can also be used as an inspiration as well as a way to prepare for the Crisis Management Training and the Self Assessment for Individuals. The Pre-Reading includes the UNDERSTAND White Paper, a number of Good Practice Examples in the energy sector and a Self Assessment for Organisations. The Pre-Reading is entirely based on self-study. It is an optional activity that should be seen as separate from the Crisis Management Training, it serves to enhance the understanding of the training.



Contents of the Pre-Reading

The White Paper is a review of all current national and transnational policies on energy supply management, with a view to distil essential drivers, future trends and current best practice. The good practice examples illustrate 9 different cases taken from all over the world. The Self Assessment for Organisations demonstrates a valuable method for raising awareness, from top management down, about risks and the organisation's competence to cope with them. A short description of the three documents can be found below.

White Paper

The White Paper on European system for the energy supply security management sector reviews current national and transnational policies on energy supply management with a view to distilling essential drivers, future trends and current best practice.

"Today's changed conditions place unusual demands on personnel that demand qualities which go beyond a technical body of knowledge. Development of these qualities 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."

The paper describes the electric power system in the EU, with a specific focus on contemporary issues and problems. The authors discuss security of electricity supply in more detail. The aim is to identify the different components of security of supply in order to understand how blackouts fit in to a larger context. Three case studies of European blackouts that cascaded from one country to another are described. The authors conclude their paper by reviewing the measures to prevent and mitigate blackouts.

Good Practice Examples

The good practice examples illustrate 9 different case studies of how organisations successfully have worked with incident management and preparedness from a number of perspectives. The examples cover areas such as preparatory measures, immediate actions, managing the incident, lessons learned, cross-border dependency and more.

Self Assessment for Organisations

A Self Assessment is a valuable method for raising awareness, from top management down, about risks and the organisation's competence to cope with them. The Self Assessment for Organisations is based on the Capability Maturity Model Integrated (CMMI) developed at Carnegie Mellon University. There are 13 areas for assessment. This Self Assessment is voluntary but it will enhance your understanding of the Self Assessment for Induviduals included in the UNDERSTAND Training Program.

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UNDERSTAND

White Paper on Security of European Electricity Distribution

Antti Silvast
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1.8.2007

Foreword

The White Paper on Security of European Electricity Distribution is part of the project UNDERSTAND, which is establishing a training and education programme for the emergency planners and emergency operators of the European energy supply security management. The goal of this paper 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 the white paper places 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. This should inform all the forthcoming activities of the UNDERSTAND project.

The review for this paper has been collected and written by Antti Silvast and Joe Kaplinsky. The partners of UNDERSTAND have contributed to the paper by discussing the results in seminar workshops. These partners are Swedish Energy Agency (Sweden), SecLink AB (Sweden), Technical University of Ostrava (Czech Republic), ABC DIALOG (Denmark), The National Emergency Supply Agency (Finland), Lithuanian Energy Institute (Lithuania), KCEM AB (Sweden), University of Zilina (Slovakia), University of Cransfield (United Kingdom) and Link Consulting sas (Italy). The authors would like to thank the partners and also all the other energy professionals who have discussed the paper with them. We would also like to thank Petri Lievonen for assisting with the graphs of this paper.

Helsinki and London 1.8.2007,

Antti Silvast & Joe Kaplinsky

Executive summary

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.

The goal of this paper 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 the white paper places 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. We aim to distil essential drivers, future trends and current best practice.

As data, the white paper uses the internal energy market country reviews by the European Commission. We have also utilized the unedited annual reports that EU member states prepare for ERGEC (European Regulators' Group for Electricity and Gas). In addition to this, we have taken into account surveys, literature and research articles about electricity interruptions. Three serious interruptions have been studied more specifically. Discussions with energy experts have also contributed to the white paper.

Based on our review, there is a clear difference between the post-war natural monopolistic model of infrastructure provision and contemporary energy policy in Europe. The former aimed for social and economic improvement through universal electricity supply, often utilizing state investments and monopoly structures. The latter's basic aims are competitiveness, environment and security.

These shifts in underlying attitudes have impacted the ways in which electricity is provided. Aspirations for EU's truly integrated competitive markets have led to increased electricity flows over longer distances. International linkages, both within and external to the EU have become more important. But simultaneous to this, the market reforms have created a more fragmented structure for the electricity industry as a whole. In place of the old natural monopolies, there are now several generating and grid companies, market-regulating authorities, customers who manage their demand and outsourced maintenance companies. As we shall discuss in the end of this summary, this simultaneous integration and fragmentation creates a need for greater co-ordination and communication amongst electricity professionals. The situation also places unusual demands on personnel that demand qualities which go beyond a technical body of knowledge.

Supply management policies are, however, not only a matter of integrated competitive markets and institutions. The ageing of electrical distribution networks is becoming an increasingly significant factor in network adequacy. Nearly all policies we review also echo broader fears about climate change, critical infrastructure malfunctions, import dependency and in some cases, power lines and cancer. It is becoming quite evident that the new generation of engineers shall be brought up in a social atmosphere that often disapproves large energy systems for being too insecure, inefficient and harmful to the environment. In this atmosphere it is all the more important to build a shared professional culture that maintains the common goal of security of supply.

To move from policy level to closer to practice, we have studied electricity blackouts on several levels. By definition, we divide security of electricity supply to long-term adequacy of primary fuels, electricity generation, electricity networks and electricity markets, and short-term operational security. This points out that electrical supply is a series of tightly interlocking technical and social network, and all of these components need to work together in order to secure supply. Short-term operational security is simply not adequate without the long-term availability of fuels, electricity generation, networks and markets. Also central to security of supply, at least presently on the policy level, is managing the end-use of electricity in companies, public sector and homes.

The kinds of blackouts can be, broadly, divided to routine malfunctions and unforeseen incidents. Statistics point out that the number and duration of routine blackouts in EU has reached a low level. At least in the Nordic countries these routine malfunctions are usually caused by natural causes and technical faults, not by more imaginative catastrophic scenarios like natural catastrophes, terrorism or pandemics. By their nature, the routine malfunctions shall also continue to be quite inevitable.

Three case studies of serious disturbances, however, show that large-scale blackouts cease to be issues with mere technology and nature. Inquiries of the incidents point to the potentially damaging role of insufficient information exchange, lack of common understanding and misplaced communication between the key players. Operation near capacity limits and unanticipated interrelated faults are also often behind large disturbances. This suggests that the present high cross-border and long distance energy exchanges have impacted upon the operational security of electricity transmission. The blackout of Europe in 2006 also hints that the low predictability of renewable generation (in this case, wind farms) can have unfavourable effects on the security of large grids as a whole. Thus, measures designed to ensure long term security of production, such as EU's integrated markets and the move to wind, can in some case increase stresses on the grid. In this context it is all the more necessary to ensure that the security of the grid is not neglected.

The final level of blackouts we study is the attitudes of electricity end-users. Studies of blackout assessments point out that these attitudes are somewhat ambiguous. For many social groups and situations, blackouts are more unacceptable than ever before: they just want the systems to work. This is consistent result as most companies and people have more appliances than ten years ago. The critical customers can demand very reliable supply. Regulatory reforms, in which the governments see themselves as protectors of consumer rights, further stress the importance of serving all the customers. This importance of electricity also places great demands on communication towards the media and customers during emergencies.

On the other hand, some part of the public is at times fatalistic and even relaxed about blackouts, seeing them as sort-of enforced break from work. Such fatalism probably links to the inescapability of blackouts, but it can also reflect the way in which today's culture places great emphasis on saving energy and minimizing its use. This has gone so far that a “voluntary blackout” phenomenon has arisen, in which people are asked to extinguish all lights in order to highlight the dangers of climate change. The only unambiguous result seems to be that most people and organisations, whether they are disturbed by blackouts or not, are not willing to pay higher prices for more reliable electricity supply.

We conclude our paper by reviewing the measures to prevent and mitigate blackouts. These measures with their shortcomings emphasise that responsibility is central to maintaining electricity supply. There are several contemporary discussions that obscure this matter. Firstly, global markets can be seen as liable actor in their own, motivating the companies to provide secure supply only when it makes economic sense. Even regulation somewhat reproduces this aim by taking a very economic view on electricity supply. On the other hand, the official strategies of managing electricity demand tend to shift the responsibility from public sector and private companies to the individual consumers of electricity. Discussions of distributed generation would also pass on liability to the local areas that generate near point of use and utilize responsive demand.

In contrast to leaving the liability to markets, localities and consumers, we want to stress on the importance of team working, common purpose and quick establishment of a “chain of command” in the companies during emergencies. This should also be the starting point for UNDERSTAND project. Both schools and universities have shifted 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. These activities should primarily be supported in the concrete context of a real job, as many of the professional networks are relatively informal, and can cut across different organisations. One-to-one mentoring, structured group discussions and simulation training play an important role in providing the focus necessary for effective team work training.

Building upon and maintaining a shared culture can play a decisive role in ensuring continuity, especially in emergency situations. The question of continuity is not simply about demographic ageing of personnel, as it is often framed, but about where the next generation of engineers will come from.

Electricity supply relies on individuals who are willing and able to enter into a career in the electrical supply industry and are committed to *keep the lights always on*. This rests on an understanding of the common goal of security of supply, even among organisations in commercial competition.

Shared culture also has a subjective side which 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 like heavier regulation and state interventions. 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.

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 after the terrorist strikes towards commuter trains in Madrid and London, infrastructure has acquired a less positive political meaning: that of a security threat. In its “Green paper On a European Programme for Critical Infrastructure Protection”, European Commission (2005) 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 critical infrastructure 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. At the end of year 2006, the European Commission also proposed a directive on critical infrastructure protection.

Although it is often represented as a novel security practice, critical infrastructure protection has clear continuities to the strategic bombing theories of WWI and WWII, the dawn of air-nuclear age and the need to protect “critical targets”, and the discussion around oil crises and electricity blackouts in the 1970s and the 1980s. However, protecting the systems vital to society has become a mainstream security and defence policy issue only after the 1990s (Collier & Lakoff 2006), in the US as well as in EU and EU member states. It is clear that energy and electricity supply have also received renewed attention in this light. This was pointed out when Russia interrupted their gas supplies to Ukraine in 2005, unleashing a debate about the future of supply of energy to the whole Europe.

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 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 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.

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. Although cross-border electricity systems are technically speaking not new, the strivings for common European electricity market have led the grids to accommodate increased electricity flows over longer distances.

3. Sustainability

The demand for sustainability is increasingly shaping the energy industry, with several EU-level steering mechanisms for sustainable energy production in-place or under-way. 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. Indeed, with the attention that sustainability is receiving in energy politics at the moment, the security of electricity grids may be at risk from this alone.

4. Public acceptability

Public acceptability has become a key question both for long-term investment decisions (for example, in relation to nuclear power and use of land for power lines). Winning public acceptance is critical to successful innovation for all energy professionals. Increasingly this means confronting public anxieties, like the fear of power lines causing cancer. 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. As blackouts are complex situations, automatic computerised maintenance management systems are entering the electricity grids and control rooms, influencing the emergency responses. Here, outsourcing maintenance from electricity companies may provide for the optimal mix of prevention and reaction, but also pose risks towards adequate reserves during emergencies.

The document has four 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 review normal people's attitudes about blackouts. In the fourth part, we will see existing countermeasures to blackouts both at national and EU-wide level.

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. Contemporary energy policy in Europe aims for three goals: competitiveness, using renewable energy sources and security of supply (Commission of the European Communities 2006a).

We start by contrasting the post-war monopolistic model with the liberalised market model of providing electricity. This includes market-based methods for network planning and managing cross-border interconnections. The introduction of competition has led to outsourcing of the maintenance of electricity networks from utility companies. Also linked with liberalisation is the securing of investment in ageing 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.

The possibility that ageing personnel will pose of major challenge to utilities has also been raised. We examine this question and suggest that the “quality” of new recruits will be more important that their “quantity”.

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

In the 19th and early 20th century electricity utilities were organised as private companies, supplying electricity locally. The situation shifted during the World Wars and especially after the Second World War, as networks grew and as state intervention and state-investments into electricity distribution became normal. Infrastructure investment was 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 centralised model was reinforced by the technical requirement to balance supply and demand continuously on a second-by-second basis.

The 1990s saw the new emerging trend of liberalising electricity provision in Europe. 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 or 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.

The 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 will be set, the European Council has asked that the member states with interconnections achieve 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.

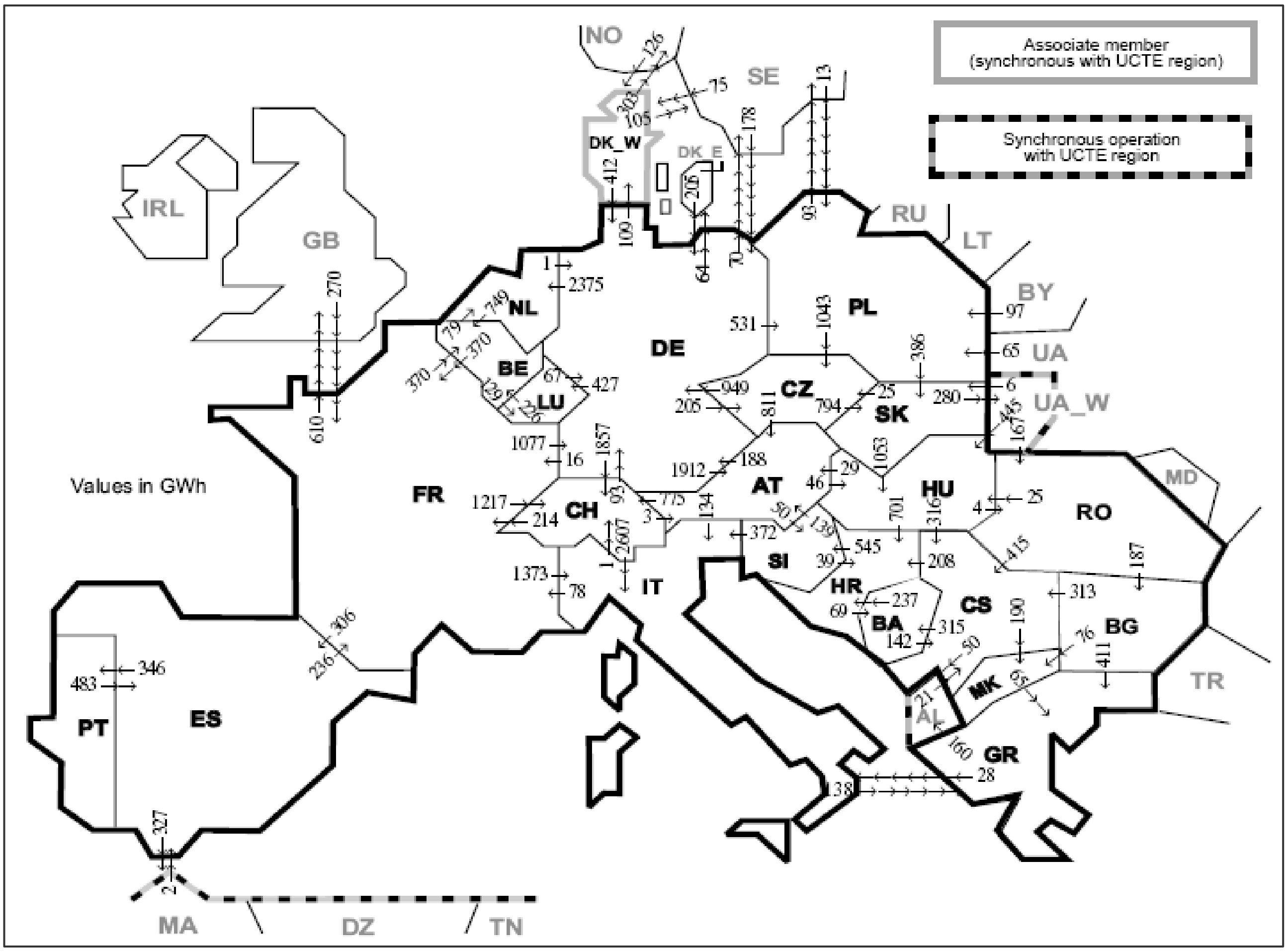

Figure 1. Physical flows of energy in the UCTE system in December 2006 (provisional values). Reproduced from UCTE Monthly Statistics.

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.

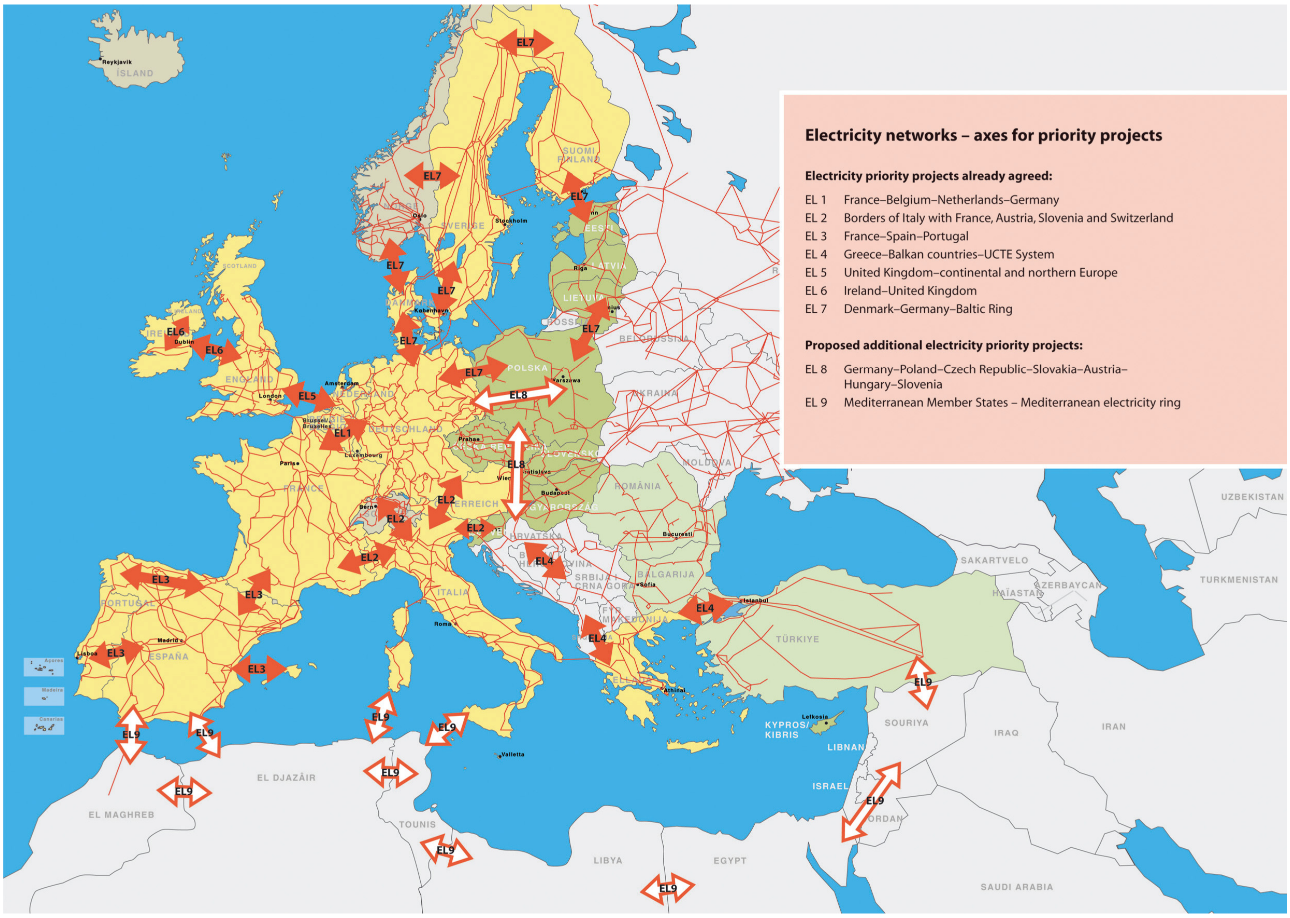

Figure 2. Electricity regional market in the EU, including priority projects. Reproduced from the Trans-European Energy Networks web site

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 contracts with a duration of 20 or 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-second world war economic growth when demand 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 the 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 out rules on the conditions for access to the network for cross-border exchanges in electricity. The regulation 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.

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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

So far as *cost-reflectivity and fairness* go, 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 partly followed. 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 creates 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.

The practical role of the TSO will be seen in more detail later. Here we concentrate 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 environments 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. Using these calculations the requirements of the *N-1 criterion* are derived: 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 exchanges)*. Using similar load flow scenarios, the operational situation in neighbouring 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. Investments in interconnections between the Nordic countries and internal links having impact on the cross border trade are also 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 now generally 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 operate with fewer machines and facilities, and a smaller workforce.

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", both in routine operation and also during disturbances

All of these outsourcings pose challenges, most obviously related to communication. A "contact centre" needs to know 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 over reserves and whether optimisation of resources by individual outsourced units lowers overall preparedness for large disturbances. Here, too, communication and co-ordination are important albeit not necessarily in real time.

Another difficulty that has emerged with outsourcing is opposition from the workforce, leading to difficulties in the outsourcing process, uncertainty in the work environment and morale problems. 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.

The more cultural meaning of outsourcing can be observed from a recent PhD dissertation (Syrjälä 2006). The researcher interviewed 35 contractors, who were outsourced from a Finnish distribution company in 2001. According to the interviews, the welfare of workers decreased after the reform. Though the change in ownership and new ownership policy carried some hope for the future, uncertainty was created by the new approach of “management of change”. The contractors felt powerless in the face of economic forces. Eventually, the workers concluded that the organisational culture came down to making money to the new owners. This raises the important point that outsourcing is not only a question of economics, but also of work culture and workforce motivation.

Ageing personnel

The population in EU is aging, as the generation of post-war baby-boomers, now aged 55 to 65, reaches retirement age in the following five years. A recent projection claims that the size of the working-age population (15-64 years) in EU will decrease by 48 million between now and 2050 (Commission of the European Communities 2006c, 4). Figure 4 shows population projections for males in the EU in 2004 and 2015. This clearly shows that the peak age group will move from 35-39 years to 45-49 years. Also, the amount of males over 65 years will grow significantly.

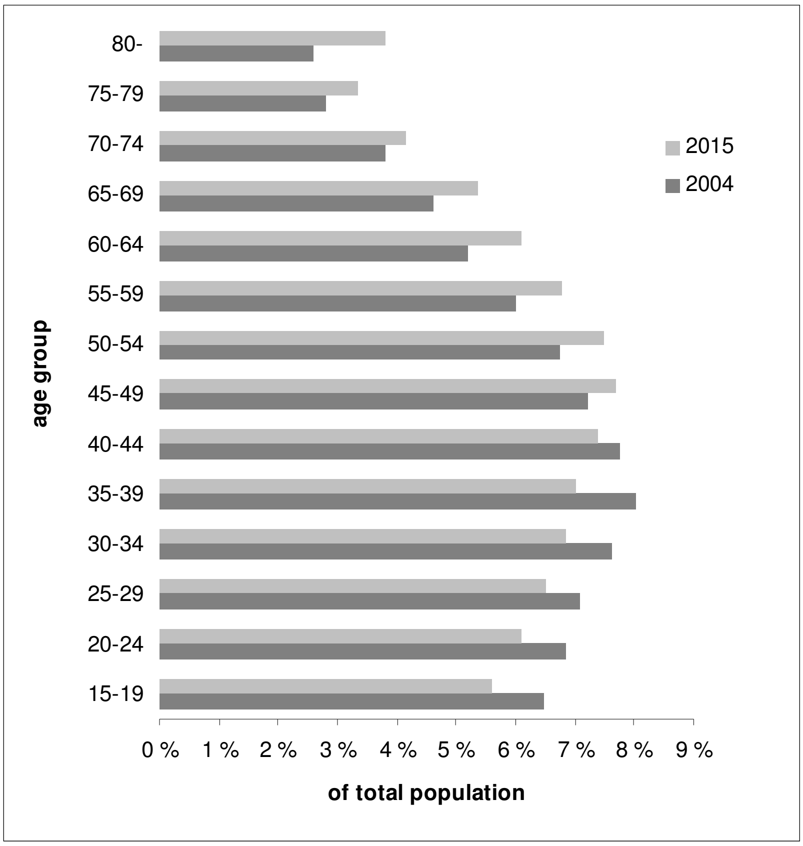

Figure 4. Population projections for males by age group in EU-25 countries. Source: EuroStat

In principal, all industries will face this issue of demographic ageing. However, statistics from utility personnel suggest that this problem should be quite manageable. Below are figures from two EU member states' personnel in utility companies. The UK's age distribution is practically evenly distributed, with the majority of workforce being from 35 to 44 years old. Over one third of the personnel are under 35 years old, potentially replacing the generation of baby-boomers once they retire. The Finnish statistics, from 1996 and 2004, show admittedly different trend, but not dramatically. In eight year's time, the age distribution's peak has moved from 35-39 years to 45-49 years. Never the less, over one fifth of personnel still remain under 35 years of age.

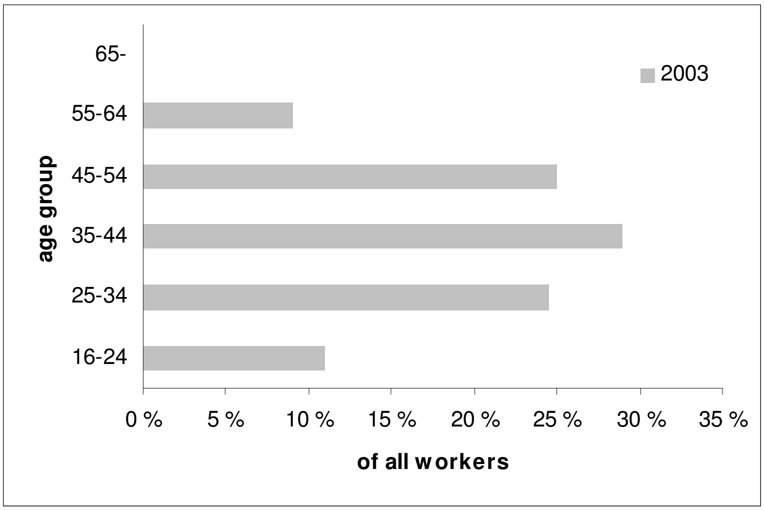

Figure 5. Age distribution of the personnel in the electricity, gas and water supply sector in UK, 2003/2004. (SSDA 2004.)

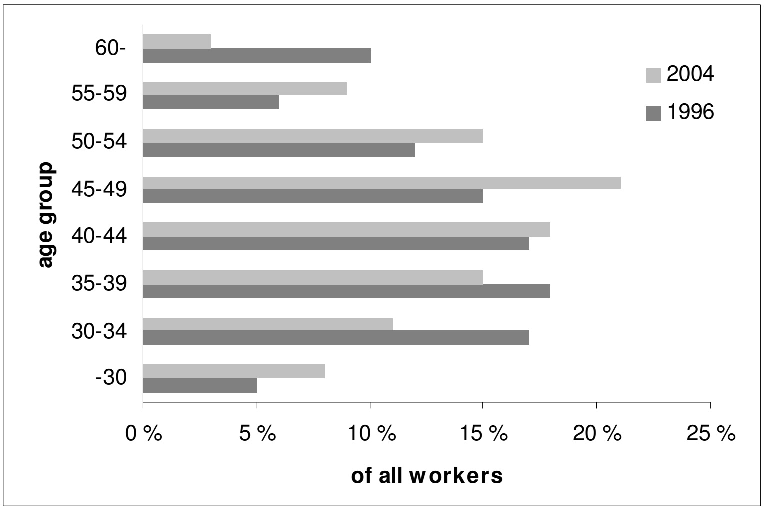

Figure 6. Age distribution of the personnel in the electricity and district heating supply sector in Finland, 1996 and 2004. (Reproduced from Finnish Energy Industries.)

A related issue the reduction in the size of the workforce. Below are two figures on the development of workforce in utilities of Europe. For most countries observed, the number of persons employed enters a steady downward trend after the mid-1990s. Even if there is slight upturn with Sweden and Spain since the early 2000s, this does not alter the overall pattern in which the total number of persons employed in utilities in the EU-25 dropped by over 200 000 persons between 1999 and 2003. It should however be noted that in 2004, the number of persons in the whole EU-25 had again increased by 50 000.

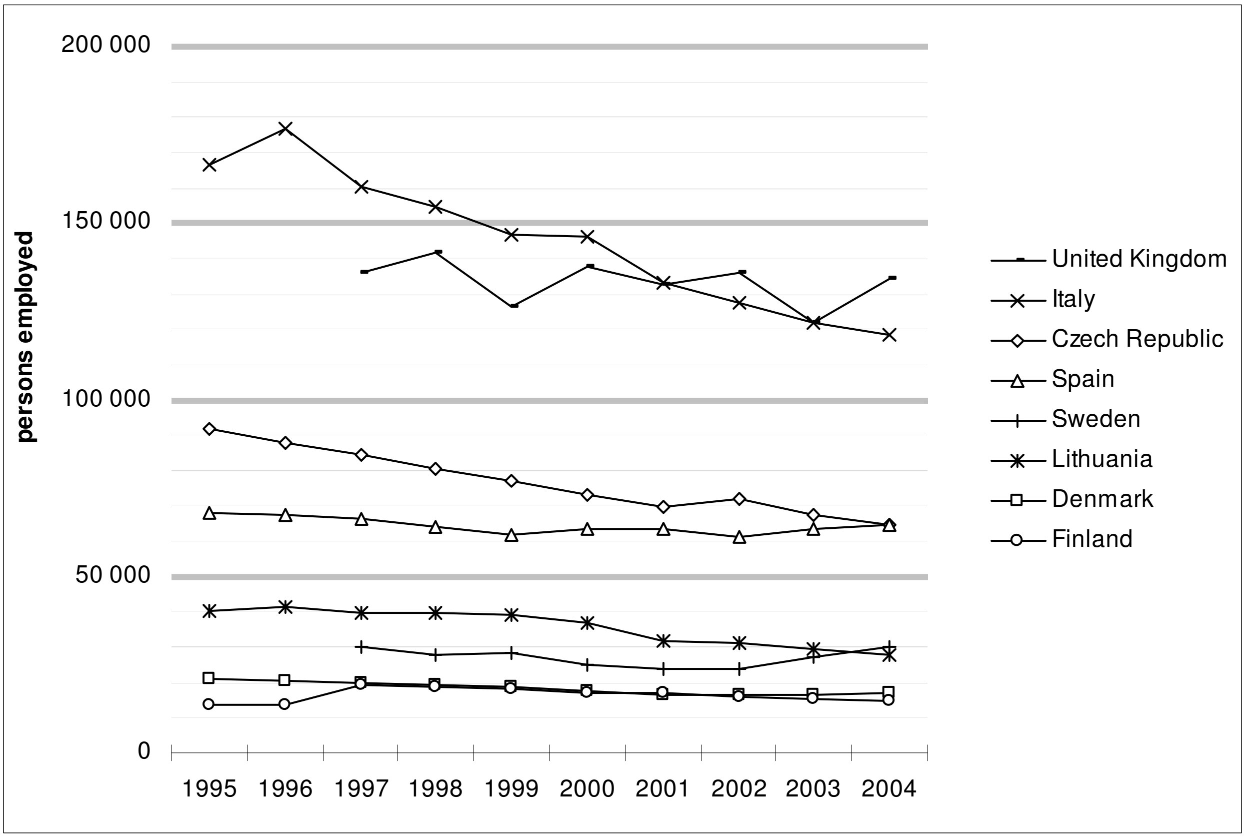

Figure 7. Number of persons employed in the electricity, gas and water sectors. Source: EuroStat

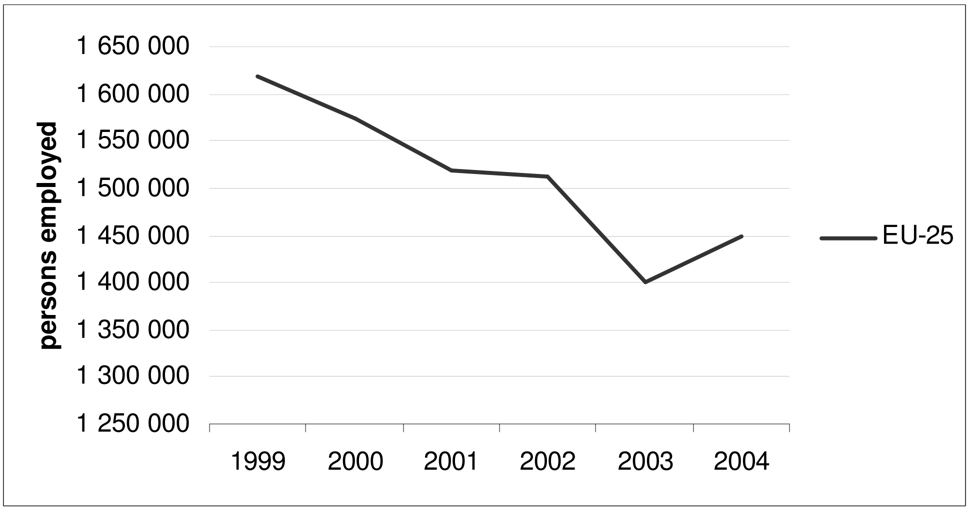

Figure 8. Number of persons employed in the electricity, gas and water sector, EU-25. Source: EuroStat

But even if demographic ageing and reducing workforce do pose new problems, there are several policy methods to deal with them. Firstly, the value of education should be emphasized. The electricity industry is already involved in many projects that aim to make the industry more attractive to younger generations. These projects primarily aim for high-quality versatile training, as energy systems are becoming increasingly interwoven with other technologies, markets and also different social expectations. Secondly, increasing the rate of participation of men and women aged over 55 is very important in an ageing population. The personnel in electricity companies can be encouraged to continue in working life even after the age of 60. Thirdly, it must be acknowledged that over the next 15 to 20 years significant net immigration into Europe will continue. In 2004 alone, the EU registered 1.8 million immigrants. Eurostat's conservative projection is that around 40 million people will emigrate to the European Union between now and 2050 (Commission of the European Communities 2006c, 4). As many of them are working-age, the immigrants' employment into electricity companies can be supported.

Quality of personnel

As seen above, the anxiety over an ageing workforce is not substantiated by demographic statistics. It would be premature, however, to dismiss such anxiety out of hand. The concern is not simply about ageing *per se*. Rather, the broader question is where the next generation of engineers will come from. There is a requirement not simply for individuals of the right age, but individuals who are willing and able to enter into a career in the electrical supply industry. This aspect of the question has not just a quantitative but also a qualitative dimension.

Here education is most obviously relevant, and there has been ongoing concern over both the content of science curricula and the uptake of available courses (Commission of the European Communities 2007c).

Harder to assess, but of potentially even greater relevance is impact of changing social norms and attitudes on a new generation of engineers. Training consists not only of assimilating a body of technical information but also of socialisation into a certain set of moral and social responsibilities. It is in this area where the process of education has become profoundly ambiguous about the value and importance of infrastructure engineering.

The value of infrastructure is often acknowledged in a perfunctory way. But today's culture places great emphasis on the harmful aspect of electricity generation. This has gone so far that a "voluntary blackout" phenomenon has arisen, in which people are asked to extinguish all lights in order to highlight the dangers of climate change. The UK has seen public protests attracting young people demanding the shut down of Drax B, the largest power station in the country. Elsewhere in Europe, such as in Germany, protests against nuclear power, and especially the transport of nuclear waste have been longstanding.

It is inevitable that such a cultural atmosphere will be reflected in the new generation of engineers which has grown up surrounded by it. This development emphasises the need to create a coherent sense of purpose amongst electricity workers which will enable them to fully value their contribution to society. Without such coherence any organisation will be less effective both in its day to day operations and, especially, under emergency conditions.

This requirement will not be met by superficial mission statements. The limitations of such statements is that they tend to take a narrower view from within a particular organisation. There is little capacity at present for individual organisations to take stock of larger social changes and to find productive responses to them.

This is a key opportunity for the training to be undertaken by the UNDERSTAND project. There is a need to provide a framework to foster a common sense of purpose that is shared across the industry and goes beyond the more narrow or immediate responsibilities of a particular organisation.

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 example of power lines illustrates once again the significance of public acceptability for the electrical industry. Much of the hostility to power lines has been driven by the fear that they may cause cancer. This claim has not been substantiated in the scientific literature (Preece et al. 2000). But the scientific facts have had only a marginal impact on public perception which, in turn, creates a real effect on, for example, house prices that cannot be ignored even by those who see no risk.

The European Commission (2003) has stated its concern over investment 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 that supports investments. Transmission system operators must submit multi-annual 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 the EU, investment has 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 regulatory reforms question the claim that electricity provision is a natural monopoly, which was essential to the justification for state intervention in the modern grid development. Questions have been raised, for example, about the increasing returns to scale that could be enjoyed by monopolistic electricity providers. The solution to this is to promote new forms of partial and regulated competition between grid companies. The regulation techniques are driven, in many cases, by a “public” goal of increasing consumer welfare (Collier 2006). 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 pressures 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 such as customer willingness-to-pay for improvement of electricity supply and customer expectations for service levels. This customer information has been used by regulators in 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.

There are two main types of continuity indicators, first for the number and second for the duration of outages. The number of outages per customer in a year is termed Customer Interruption (CI) or System Average Interruption Frequency Index (SAIFI). It indicates *how many times* energy is not supplied in a year. The cumulative yearly duration of interruptions per customer is generally referred as Customer Minutes Lost (CML) or System Average Interruption Duration Index (SAIDI). It indicates *how long*, in a given year, energy is not supplied

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 variation in 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 the 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.

Placing regulation in context

At EU-level, the striving for regulated competition of electricity provision is fairly new. However, in the US very same form of debates date back to the 1970s. The late 1970s had seen a series of infrastructure failures, most notably the New York City blackout of 1977. These gave rise to a broadening perception that US infrastructure was falling apart. Specific breakdowns in infrastructure were tracked back to the declining rates of public sector investment. This led to similar reforms that are now happening in the EU: the natural monopolies of electricity provision were opened for competition, but only partially and in a regulated manner. But eventually the debate in the US proved inconclusive. It did not become clear how infrastructure policies should be changed, or even whether there had been an infrastructure shortage (Gramlich 1994). (Collier 2006.)

Unfortunately little research has gone into an important subject for our report: how engineers themselves experience regulation. However, a parallel can be drawn from the public sector in Finland. As of late some public organisations, notably the university system (Patomäki 2005), have been reformed by the public authorities to introduce targets and quotas for efficiency and competitiveness. This has created extensive new assessments and managerial chores. More and more time must spent on keeping these regulative assessment going. In the longer term, this can lead organisations to focus on those details that are measured by the regulators. In the shorter term, regulatory burden can lead to lack motivation and inspiration from the part of the workers. At the moment, no conclusion exists of whether this has meant or means better efficiency.

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 as a universal concern has impacted 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 9.

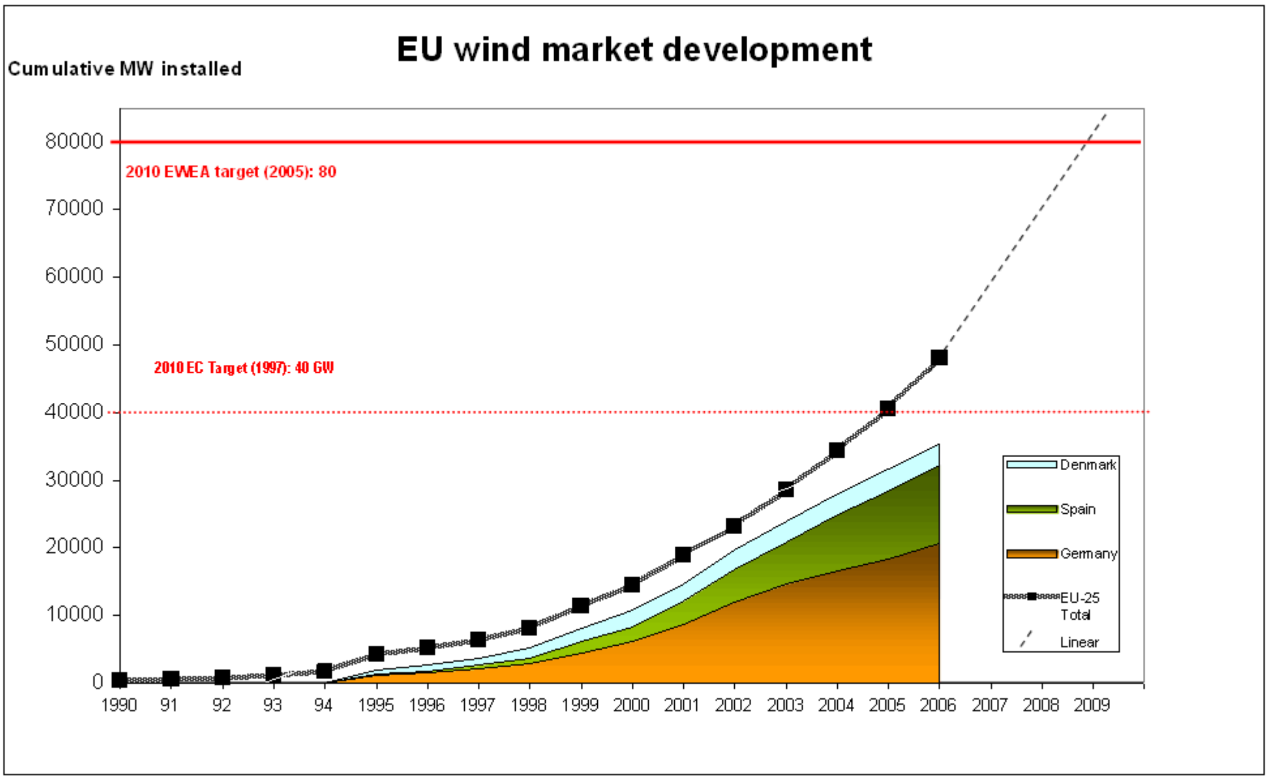

Figure 9. EU wind market development. Based on a figure from the European Wind Energy Association (EWEA)

Two market-based schemes are already in operation. *The EU emissions trading scheme*, operating in all EU member states since 2005, is an international trading system for CO_2 emissions, enabling the participating companies to buy or sell emission allowances. This is done to ensure member states reach the greenhouse gas caps set by the Kyoto Protocol. As a result, generation that produces more carbon will be relatively more expensive than generation that produces 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 the 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.

Conclusions for chapter

Today, the liberalisation of electricity markets and climate change policies have changed the basic assumptions of electricity provision. Contemporary energy policies focus increasingly on environmentally responsible generation and customer welfare. Regulatory reforms question the claim that electricity provision is a natural monopoly, on the basis that monopolistic providers could enjoy returns to scale at the expense of quality. In a similar manner, the reductions of personnel and outsourcings from electricity companies are backed by arguments for the need to adapt to the demands of global networked economy.

Technical competence remains a key demand on today's electrical transmission operators. The more fragmented structure of the industry creates a need for greater co-ordination and communication. But the demands on co-ordination and communication now go substantially beyond this.

The question of ensuring that a new generation of engineers is imbued with a common sense of purpose both within the industry as a whole and in their ability to justify their actions to the public is an essential motivation for the UNDERSTAND project as a whole. However, we are critical of the manner in which the governments and EU frame quality, purely as a question of integrated competitive markets for one and reducing energy use for the other.

We claim that these contemporary goals have not found a shared basis for maintaining a reliable electricity supply. A clear indicator of this is the co-operation between national electricity networks in EU, necessary for the integrated competitive markets to work, but currently largely absent. The experience from outsourcings also supports that once electricity supply is subjected to economic forces, the workers can lose their motivation. Environmental concerns, on the other hand, tend to prioritise greenhouse emissions, fossil fuel depletion and nuclear safety over the continuity of the electricity grid.

As starting point for UNDERSTAND project, we stress that today's changed conditions place unusual demands on personnel that demand qualities which go beyond a technical body of knowledge.

Security of supply

This section discusses security of electricity supply in more detail. The aim is to 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 (security of supply) 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, security of supply is only fulfilled once all elements of the electricity supply chain (primary materials, generation, transmission, markets, end-use) function properly (see figure 10).

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. Political and public acceptance of electricity technology, especially, raise new forms of question. 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 security of supply in their own section.

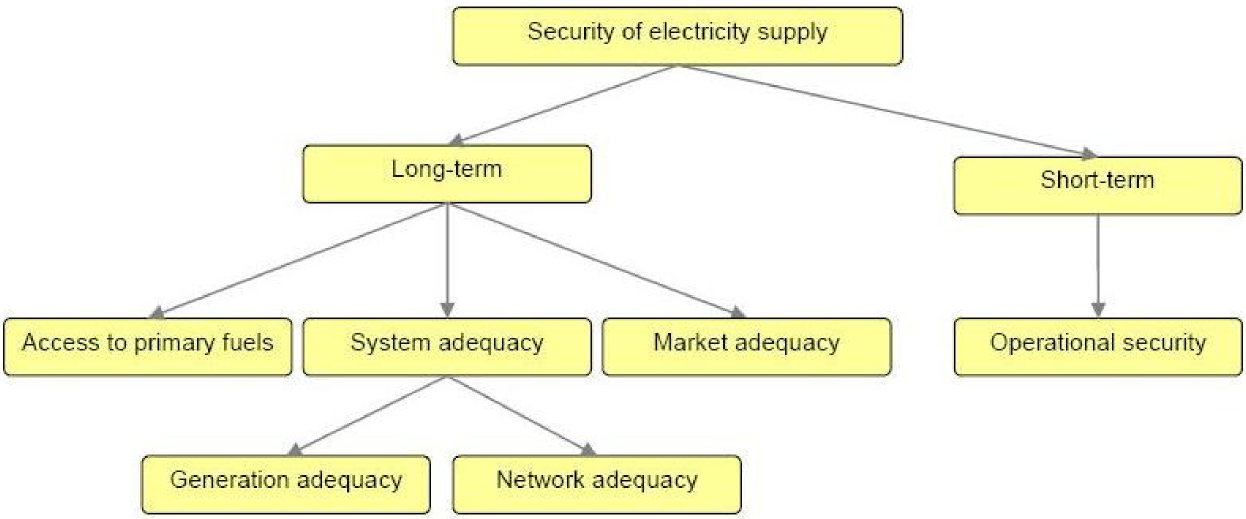

Figure 10. The different aspects of security of electricity supply. (EurElectric 2004.)

Access to primary fuels

As a first step, electricity needs to be generated. Electricity can be generated from variety of materials: e.g. uranium, coal, oil, gas, forestry chips, turf, water, wind, the sun or the tides. These materials have different issues regarding security of supply. 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. The EU sees it as 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. Security of supply 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.

Network adequacy

Adequacy of electricity transmission is the availability of electricity network infrastructure to meet demand. This covers cross-border interconnections. Security of supply issues mainly have to do with securing investments into the infrastructure and ensuring there are sufficient personnel 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 security of supply. 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, security of supply is not fulfilled - even if technically or from a pure market organization point of view the system functions - if electricity prices rise persistently 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 market. 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 of 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 operators have 15 minutes to return the system to an N-1 secure state, either by correcting the fault or changing in the system.

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, electricity end-use efficiency and energy saving can be seen as a way to improve security of supply. 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% over 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.

Conclusions for chapter

We have divided security of electricity supply in to long-term adequacy of primary fuels, electricity generation, electricity networks and electricity markets, and short-term operational security. This shows electrical supply as a series of tightly interlocking technical and social networks, all the components of which need to work together in order to secure supply. Short-term operational security is simply not adequate without the long-term availability of fuels, electricity generation, networks and markets. At present, managing electricity demand is also seen as a central part of security of supply both in companies and at policy level.

We place stress on the social levels of these activities, often neglected by pure engineering studies. The boundaries set by commercial, legal and regulatory networks play an important part in supplying electricity. Many issues also link with public acceptability, especially of land use in relation to power lines and of generation choices in relation to environmental concerns. With managing demand, electricity companies become entangled with complicated sociological questions on the role of electricity and responsibilities of the end-user.

Blackouts

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

Number and causes of blackouts in EU

CEER (2005) have collected benchmarking for the duration and number of blackouts in different EU states from 1999 to 2004 (tables 2 and 3). 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. By contrast, some countries' numbers are larger, especially Portugal, Spain, Italy, Ireland, Hungary and Finland. But on the whole, both the number and duration of interruptions show a significant downward trend. One can also clearly observe the exceptional events, such as 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. 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 3. Interruptions per customer per year. (CEER 2005, 117.)

The Nordic countries have gathered extensive statistics on the causes of interruptions. Though these are specific to Nordic conditions and no such numbers seem to exist for other interconnected regions like UCTE, it is useful to observe the distribution. According to these statistics, blackouts are extensively caused by natural causes, especially lightning. Technical faults are also common, but so are blackouts whose background reason remains unknown. The quantity of external causes is notably small: from none in Iceland and one percent in Sweden and Norway to four percent in Finland and eleven percent in Denmark. Notably, this class of external causes is where one would place catastrophic interruptions like those caused by disease pandemics, environmental crises and terrorism. As serious as these dangers would be if realized, they are also not at all common. Judging by this distribution, mitigation for normal disturbances like lightning should receive much more attention than imaginative catastrophe scenarios.

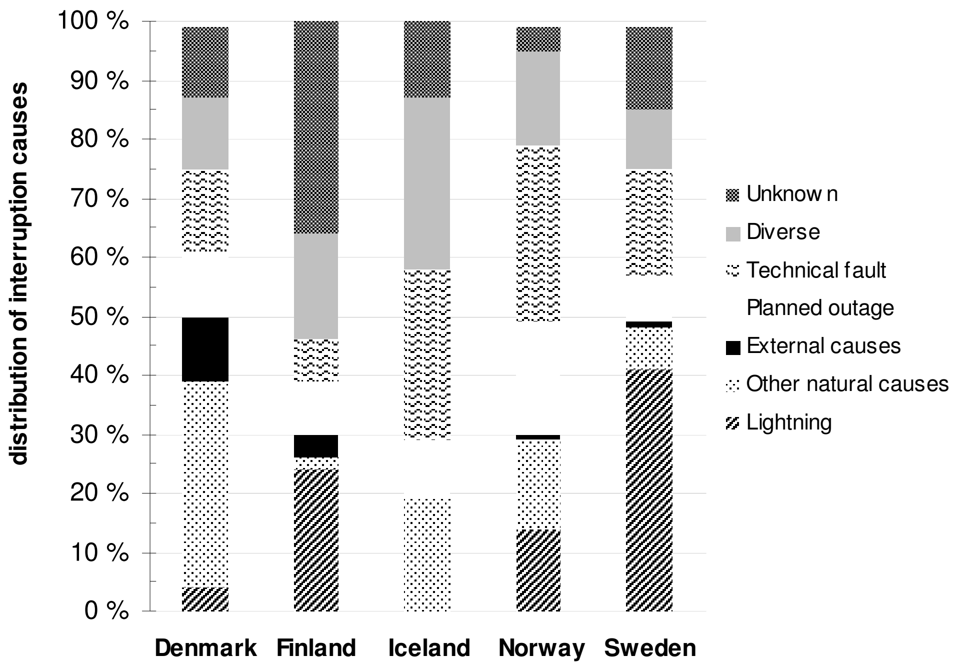

Figure 11. Interruption causes inside the Nordel area. (Nordel 2005.)

Summary of major blackouts in Europe

The recent large-scale blackouts in Europe are summarised in table 5. Even if these events can be defined as “exceptional”, the interruptions actually seem quite frequent. Over about seven years, 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 high. This long duration is most likely caused by the large damage of strong storms, and also by the dangerous repair 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		
			Number 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 5. 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 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 regarded as insecure at 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 of 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.

The 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 security of supply, 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, the 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. 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 affected 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 caused 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 in 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:

- For interconnections between UCTE control blocks mandatory emergency procedures should be put in place, jointly trained for and evaluated at regular intervals.
- Determine and harmonise criteria for the N-1 security, including in the contingency analysis of voltage and frequency instabilities.
- Improve the day ahead congestion forecasts (DACF).
- Extend the real-time data exchange between neighbouring transmission system operators.
- Determine minimum requirements for generation equipment, defence plans and restoration plans.
- Implement load-frequency control strategies for splits of the synchronous area.
- 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 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 at 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 23rd 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 to an 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 investment in 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 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 6, there are also potential losses through knock on effects on other forms of infrastructure. 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 directly affect 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.

<table>
<tr><th>Infrastructure</th><th>0-2 hours</th><th>2-8 hours</th><th>8-24 hours</th><th>24 hours >></th></tr>
<tr><td>Transport</td><td>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</td><td>Delays increase and ripple through to un-affected parts of the system. No traffic at all on affected parts</td><td>No traffic at all, fuel supply problems</td><td>No public transport</td></tr>
<tr><td>Communication</td><td>Difficult to supply information, outages of transmission poles</td><td colspan="2">Information back set, more personnel needed</td><td>Availability of personnel decreases</td></tr>
<tr><td>Waste disposal</td><td colspan="2">Difficult due to traffic congestions, delay in disposal of waste</td><td colspan="2">Collection is difficult, possible un-hygienic circumstances</td></tr>
<tr><td>Electricity</td><td></td><td></td><td>Difficult to keep communication up</td><td>Possible problems with fuel supply for generators</td></tr>
<tr><td>Drink water</td><td colspan="3">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</td><td>Water is guaranteed</td></tr>
<tr><td>Sewage management</td><td>Low lying areas, with rainfall: flooding of sewer water after 2 hours</td><td>Flooding in higher areas as well</td><td>Also flooding in case of no rain</td><td>flooding</td></tr>
<tr><td>Gas</td><td colspan="3">Generally no problems, receivers will endure problems in energy dependent systems; climate control, watersupply.</td><td>In case of pressure loss: temperature drops</td></tr>
<tr><td>Telecommunication</td><td colspan="3">Telephone is assured, possible problems with GSM systems, internal operators outage. No fax, congestion in telephone network</td><td>Telephone system assured. Possible problems with generators due to fuel supply problems</td></tr>
</table>

Table 6. 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 evaluate 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). This should not necessarily be interpreted cynically as an “addiction”, i.e. people “being hostages to electricity” (Leslie 1999, 175) or “so dependent on machines that turning them off would amount to suicide" (Joy 2000, 239) to pick a few examples from the media. Rather, people generally tend to value their free time more than before, and thus want to have electricity when they need it.

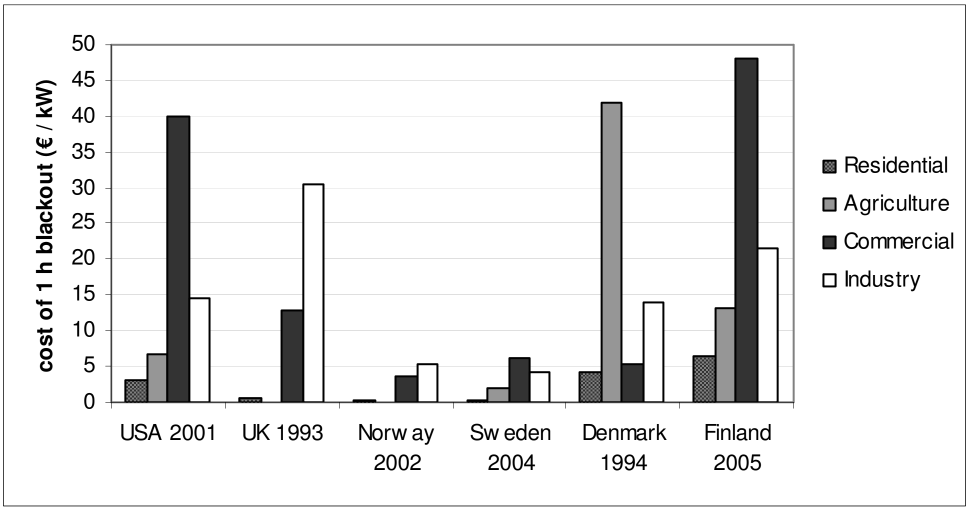

Figure 12. Costs of 1 hour blackout (€/kW). (Silvast et al 2005, 24; 100.)

As a second conclusion, the dispersion of the cost estimates of different customers is very large. Figure 12 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 indicated by the statistical distribution in figure 13, taken from a Finnish study. There is a well-centred mass near the beginning of the distribution. At higher values, however, there is a relatively equally spread area, which reaches very high costs. This shows that some individual customers have higher than usual outage cost values.

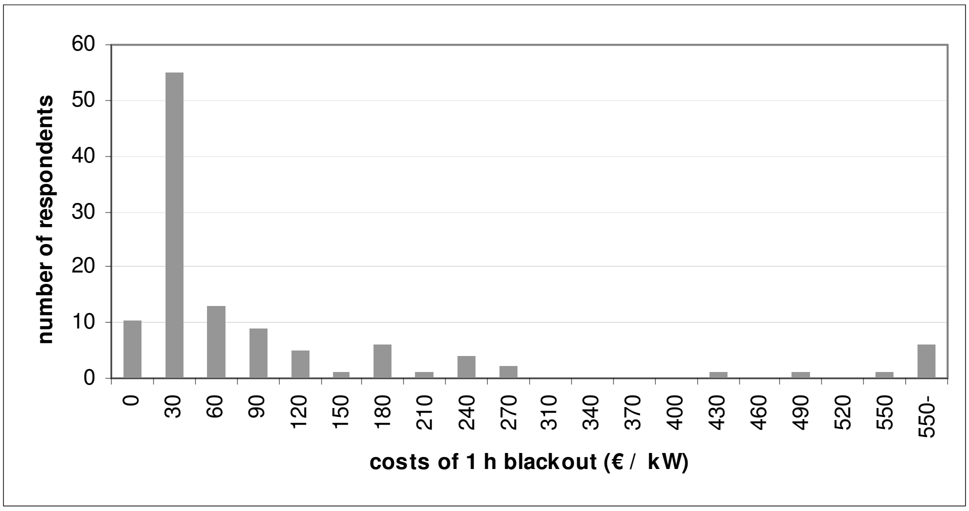

Figure 13. Costs of 1 hour blackout (€/kW) among commercial customers in Finland. (Silvast et al 2006, 7.)

In addition to these cost-benefit-surveys, there exist more qualitative studies on blackout perceptions (Silvast 2006, Yuill 2004). Interviews 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 such as 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.

Conclusions for chapter

This chapter has detailed electricity blackouts on several levels. Statistics point out that the number and duration of blackouts in EU is reaching a low routine level, serious disturbances notwithstanding. At least in the Nordic countries routine blackouts are caused by natural causes and technical faults, not by more imaginative catastrophic scenarios like natural catastrophes, terrorism or pandemics.

Three case studies of serious disturbances, however, show that large-scale blackouts cease to be issues with mere technology and nature. Inquiries of these accidents point to the potentially damaging role of insufficient information exchange, lack of common understanding and misplaced communication between the key players. Operation near capacity limits and unanticipated interrelated faults are also often behind large disturbances. The latter suggests that the present high cross-border and long distance energy exchanges have impacted upon the operational security of electricity transmission. The blackout of Europe in 2006 also hints that the low predictability of renewable generation (in this case, wind farms) can have unfavourable effects on the security of the grid as a whole.

While technical systems are essential for electricity supply, the true impacts of blackouts are always faced by the electricity end-users. Studies of these impacts can only conclude that the attitudes of end-users are somewhat ambiguous. For many social groups and situations, blackouts are more unacceptable than ever before: they just want the systems to work. On the other hand, some part of the public is at times fatalistic and even relaxed about blackouts, seeing them as sort-of enforced break from work. The only unambiguous result seems to be that people and organisations are not willing to pay higher prices for more reliable electricity supply.

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 means to reduce the risk of cascading electric power failures, and standardisation as another solution.

Reserve generation capacity

In addition to planning and co-ordination, the transmission system operators maintain their capacity with reserve power. This consists of active and reactive power reserves that can be activated manually within a 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 are sufficient 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 in 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 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 on 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, security of supply is seen not only as matter of functioning systems, but also respectful end-use of electricity. Alongside the 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, the public sector and the commercial sector. But while potential for household responses exists, measuring their impact would require such exact metering that is not widely used at present (see Koponen et al 2006). Thus at the moment, aiming for demand management of households remains mostly about promoting the value and morality of rational electricity use.

Related to the demand-side discussion are aspirations for decentralised electricity networks. Critics of centralised energy systems have often argued that the centralised systems are too large and structurally coupled, thus prone to failure (see Farrell, Zerriffi & Dowlatabi 2004, 436-438). Decentralised generation sets the alternative of electricity generation near point of use, also utilizing responsive demand from the users and generators that require no imported fuel supply. Though these arguments are usually connected with environmentalist thinking (Rifkin 2003), also the EU (2007, 15) has stated that it aims to use fuel cell and hydrogen technologies to exploit their benefits in decentralised generation and transport.

It should be noted that much discussion of the need for demand management, with its emphasis on billing, metering and local generation 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 and cooperation.

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 security of supply 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 security of supply has made electricity generation and supply a concern for politicians and regulators, in both old and new member states. Hungary illustrates this, stating that one of the essential requirements of 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, the 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) have protested that regulatory demands incur substantial financial burdens. EurElectric (2006) also consider 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.

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 benchmark 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 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.

Conclusions for chapter

The measures we have reviewed in this chapter emphasise the importance of responsibility for security of supply. There are several contemporary discussions that obscure this question. On the one hand, global markets can be seen as a liable actor in their own, motivating the companies to provide secure supply only when it makes economic sense. On the other hand, the official strategies of managing electricity demand tend to shift the responsibility from public sector and private companies to individual users of electricity. This takes place in a social atmosphere that deprecates energy consumption, and can effect the way in which personnel understand the importance of security of supply. Discussions of distributed generation would also pass on liability to the local areas that generate near point of use and utilize responsive demand.

In contrast to leaving the liability to markets, localities and consumers, we want to stress on the importance of team working, common purpose and quick establishment of a “chain of command” during emergencies. Both schools and universities have shifted 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. These activities should primarily be supported in the concrete context of a real job. One-to-one mentoring, structured group discussions and simulation training play an important role in providing the focus necessary for effective team work training.

The rise of regulatory and protectionist tendencies clearly points to the limits of pure market processes. However, the development of common cross-industry benchmark knowledge standards is a method that lends itself to developing links that can supplement direct market contracts without a direct role for the state. It offers the creation of a forum through which, with industry participation, a common set of understandings can be created.

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Good Practice Examples

Good Practice Examples

The Good Practice Examples use case studies of how an organisation has worked successfully with crisis management from the following perspectives:

- Preparatory Measures, Immediate Actions and Assessment
- Managing the Crisis, Crisis Communication and Staff Policy
- Recovery and Lessons Learned
- Cross-border Activity and Dependency

One or more examples per category are used to demonstrate how a country or an organisation has successfully acted with relevance to the different perspectives. The good practice examples used in this paper are:

- New Zealand 1998: The large power failure in Auckland, New Zealand
- US and Canada 2003: The largest supply disruption in North American history
- Italy 2003: Italy's greatest supply distortion ever.
- Sweden and Denmark 2003: The worst power failure in the history of the Nordic Transmission System
- Australia 2004: A major power disturbance
- Sweden 2005: A quarter of a million people were left without power following a storm that swept forests down in Southern Sweden
- Europe 2006: The European grid's largest disruption ever
- Sweden 2008: OSART investigations
- BALTSO and BRELL: preparatory measures in order to cushion the effects when the unforeseen happens

Preparatory Measures, Immediate Actions and Assessment

US and Canada 2003
The largest supply disruption in North American history struck at 4.13 pm, 14 August 2003. At 4.20 pm, the Independent Electricity Market Operator of Ontario (IMO) suspended the wholesale electricity market, declared a provincial state of emergency, issued manual dispatch instructions for coordination of the restoration of the system and later urged users to reduce consumption by 50%. IMO's Crisis Management Support Team (CMST) was communicating with key stakeholders within minutes of the disruption. Transmission of energy from adjacent systems significantly assisted the restoration. Most services were restored after 48h and all services were functional after four days.

Italy 2003
At 3.25 am on 28 September 2003, the Italian grid was separated from the Union for the Co-ordination of Transmission of Electricity (UCTE) system leading to Italy's greatest supply distortion ever. This affected also small parts of Switzerland and France. As Italian demand on the UCTE system dropped, the frequency increased sharply. Pressure on lines across continental Europe increased substantially and the system instability threatened to interrupt transmission systems reaching far beyond the Italian borders. However, successfully implemented emergency responses in France, Germany and Belgium were able to isolate the effects and prevent a cascading outage across the UCTE network. These measures included automatic and manual disconnection from the lines connected with Italy, based on incident information that reached these countries within the established emergency procedures and via improvised communication.

The Baltic Countries, Russia and Belarus

The Eastern European countries and Russia countries have taken several preparatory measures in order to cushion the effects when the unforeseen happens. This system for managing disruption risk comprises several components. BALTSO is the cooperation organisation of Estonian, Latvian and Lithuanian Transmission System operators. All members of BALTSO operate within the BRELL (Belarus, Russia, Estonia, Latvia and Lithuania) agreement, which works to ensure compatibility between the power systems in the region as well as with coordinating regional decisions with requirements from the EU. BRELL, in its turn, is part of the IPS/UPS power system covering 14 countries. All BRELL members also have access to the SCADA-system which is a visual tool for sharing data from the whole BRELL grid.

Conclusions

- Reduction of escalation can be met by measures to decrease demand and reduce consumption
- Manual dispatch mitigates the risk for system failure and a subsequent escalation of the crisis
- A pre-organised central point for information dissemination protects relations with key stakeholders and takes pressure off government's emergency communications
- Technical and organisational compatibility with neighbouring systems facilitates cross-border cooperation
- Prepared emergency responses isolates the effects of the crisis and can prevent a cascading outage across connected regions
- Thoughtful organisational design improves country compatibility and transparency of information in a crisis

Managing the Crisis, Crisis Communication and Staff Policy

Sweden and Denmark 2003

Southern Sweden and Eastern Denmark saw the worst power failure in the history of the Nordic Transmission System on 23 September 2003, starting at 12.37pm. The area is closely integrated and when a disturbance happens in one of the Nordic countries, it is likely to spread but the other countries will help with their reserves in order to cope with the disturbance. In this case Norway and Finland managed to deliver about 50% of the loss. Communication between transmission system parties was initiated swiftly and was maintained throughout the restoration. Media was directed to non-operative staff and press meetings and releases conveyed a message that focused on how to restore the problem rather than its cause. Fast media, such as the radio, was prioritised and additional information was also given directly to key stakeholders. The main network was restored within an hour of the first collapse.

Europe 2006

On 4 November 2006, a ship was about to pass one of the high voltage lines in Northern Germany. The scheduling of a temporary disconnection of the lines was not communicated sufficiently, so the Transmission System Operators (TSOs) could not coordinate enough for the resulting shift in power balance. Thus the UCTE system split into three islands with significant power imbalances in each area, causing the European grid's largest disruption ever, affecting more than 15 million households on the European continent. It took less than two hours for transmission to be back to normal. Good performance of countermeasures activated at the UCTE level in the individual control areas prevented a Europe-wide black-out and – in spite of their initial lack of co-ordination – the subsequent performance of TSO's allowed for successful restoration within a short period of time.

Conclusions

- Rapid and continuous communication between well-integrated transmission system parties facilitates identification of the crisis and spreads information of developments
- Swift handling of the media with constructive messages, clear priorities and direct information to key stakeholders decreases public pressure
- Activation of pre-determined countermeasures prevents escalation of the crisis
- Initial lack of coordination was solved alongside the crisis and quickly adapted the organisation to the new, unforeseen situation

Recovery and Lessons Learned

UCTE Policies After 2006
The new policy suggestions from the Union for the Co-ordination of Transmission of Electricity (UCTE) are the results of previous crises. Following the grid disturbances that affected 15 million European households on 4 November 2006, the UTCE conducted an investigation leading to a number of recommendations. It was concluded that the disturbance was triggered by causes within the normal control area while compliant security standards were in force. The grid has been designed to be an “essential backbone” of European power supply, but adjustments to the large energy demand brought the system physics close to its limits. The UCTE investigation suggests new policies on load-frequency control and performance, scheduling and accounting, operational security, coordinated operational planning, and a revision of emergency procedures, communication infrastructures and data exchanges.

Sweden 2008
On 11 February 2008, inspectors from the International Atomic Energy Agency (IAEA) arrived at Sweden’s Forsmark nuclear power plant. Already in 2004, reports from the World Association of Nuclear Operators (WANO) pointed to insufficiencies and near-misses. Public debate on nuclear security had been vivid in Sweden. IAEA’s inspectors would make a so-called OSART investigation (Operational Safety Review Team) during three weeks to examine security and reliability with a special focus on the organisation’s culture of security. The following areas were to be studied: management and control, education, maintenance, technical support, experience feedback, radiation protection, chemistry, accident preparedness and operations. Following this, all Swedish nuclear power plants would be examined the same way as Forsmark was. IAEA then recommends changes and controls the implementation of these after one and a half year.

Conclusions

- Analysis ranging from micro to macro level discovered that change of paradigms may cause hands-on crises
- Based on incidents, adequate measures not to change the conditions but to deal with more and less possible situations was suggested
- Thorough and consistent security inspection based on near misses rather than on incidents may prevent full-blown crises
- External, independent experts perform assessments of what lessons that need to be learned and they control that these lessons have been implemented

Cross-border Activity and Dependency

Sweden 2005

A quarter of a million people were left without power following a storm that swept forests down in Southern Sweden on 8-9 January 2005. Within 48 hours of the winds that measured up to 50 m/s, the responsible company had custom-made a new, military-like crisis organisation. Large numbers of extra staff and vast amounts of materiel was assembled from national and international supplies within a short period of time, requiring substantial cooperation and coordination with other countries. Shortly, the new organisation was staffed by workers from seven countries and Sweden received materiel from all over the world. Companies acted across boundaries and staff took on new roles; local factories rearranged production in order to help and local communities provided much needed area expertise and ground support. 200 000 people had electricity back within one week. After 36 days, the last house had power.

Australia 2004

During a major power disturbance on 13 August 2004, a system operator with the right jurisdiction was able to mobilise resources from interconnected regions, preventing escalation of the black-out. The back-up system – the Frequency Control Ancillary Services (FCAS) – that could have been in place for this particular kind of multiple contingency event was in fact not, as the probability for a disturbance of this kind was very low indeed. But with sufficient authority and scope, the system operator was able to solve this ad hoc by asking adjacent service providers to provide as much FCAS as they could spare at the time. Due to this, a complete disruption could be avoided. Although the power transfers temporarily exceeded security limits by up to one fourth, they were reduced to normal within half of the allowed period of time. Eventually all but one of the affected generating units was in service within 24 hours.

New Zealand 1998

Flexibility and coordination of national and international resources proved essential during the large power failure in Auckland, New Zealand in 1998. The impact of the crisis that lasted from February and in some areas all the way until May was largest in Auckland's Central Business District (CBD). During the first day of the emergency, systems with pre-installed reserve power sources worked while everything else went down. However, a sufficient amount of back-up power could be drawn together shortly from within the country and internationally. Coordination was further facilitated as telecommunications in the CBD stayed operational throughout the crisis, helping to use the possibilities and resources for relocating business from CBD to other parts of Auckland and New Zealand. The financial sector demonstrated particular flexibility and companies responsible for critical modern infrastructure vigilantly expanded their roles by engaging actively in their costumers' crisis management.

Conclusions

- Organisations can adapt to new situations and thereby measure up to unforeseen scales of crisis
- Urgent need for mobilisation of materiel motivates stakeholders and dependants to perform out of their roles in order to fulfil the demands put by the crisis
- Organisations' foresightedness attribute key personnel with the right scope of authority and action for dealing with a crisis
- Although the needed redundancy might not be pre-installed, correct organisational priorities can allow for flexible solutions during emergency
- Emergency power supplies allows for support of coordination hubs, which can enable systems to use built-in flexibility and change locations while losing a minimum of business value
- Companies that own privatised, critical infrastructure can take on responsibility for supporting needs of their clients' even is these needs are outside the business range

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Self Assessment for Organisations

A Self Assessment is a valuable method for raising awareness, from top management down, about risks and the organisation's competence to cope with them. The Self Assessment for Organisations is based on the Capability Maturity Model Integrated (CMMI) developed at Carnegie Mellon University. There are 13 areas for assessment. This Self Assessment is voluntary but it will enhance your understanding of the Self Assessment for Individuals included in the UNDERSTAND Training Program.

Cooperation

On which maturity level is your organisation in cooperation across the border(s)? What is your target and how do you plan to achieve it?

Initial level 1: Contacts across the border are taken only when there is a problem or when we have a concrete proposal for common development. It is unclear whom to contact in each situation.

Repeatable level 2: We have established contact person and responsibility lists on each side. We have defined situations when to contact and what information to exchange. These contacts are taken regularly. The cooperation is considered an operational matter and is in the interest of operational management.

Defined level 3: We have planned and agreed in writing with our counterpart about the work processes and technical processes that need cooperation. The goals and methods to achieve them are specified in cooperation.

Managed level 4: The defined processes (level 3) are monitored and controlled in cross-border cooperation. The cooperation is considered a strategic matter and is in the interest of top management and downwards.

Optimised level 5: The managed processes (level 4) are constantly being improved in cross-border cooperation through the monitoring feedback and by introducing innovative processes to better serve both TSO's jointly agreed needs.

Training

On which maturity level is your organisation in training across the border(s)? What is your target and how do you plan to achieve it?

Initial level 1: We have never participated in training across borders. We only train locally.

Repeatable level 2: We have had a series of cross-border training session and continue to do so, on an operational level.

Defined level 3: We have a well defined joint training program. The goals and methods of training are defined in cooperation. All personnel who deal with cross-border transmission are trained at regular intervals.

Managed level 4: The defined training (level 3) is monitored and controlled in cross-border cooperation. Training is considered a strategic matter and is in the interest of top management and downwards.

Optimised level 5: The managed training (level 4) is constantly being improved systematic through feedback handling and using innovative ideas. Outside consultants are used.

Risk analysis

On which maturity level is your organisation in cross-border risk analysis? What is your target and how do you plan to achieve it?

Initial level 1: Risks are considered from a narrow and domestic only point of view. Examples: fires and technical failures. No systematic risk mapping or risk assessment is done in the company. Instead, the company relies on insurances.

Repeatable level 2: A risk analysis is done regularly by experts responsible of this area. Also human error risks are considered. Risks are classified according to effect and probability assessment. Risk data is exchanged across the border.

Defined level 3: Risk analysis is a well defined part of operational continuity management cycle. Risk analysis is a defined responsibility of middle management level, but involves people from across the company. Systematic methods (e.g. statistical, mathematical, data gathering, possible reasons for event -analysis; possible alternative consequences of event -analysis) are used in risk analysis. A wide spectrum of consequences is considered, including societal consequences. Risk analysis is done together with the counterpart across the border.

Managed level 4: The well defined risk analysis (level 3) is done and controlled in cross-border cooperation from top management downwards.

Optimised level 5: The risk analysis process (level 4) is constantly being improved by systematic feedback handling and using innovative ideas. Outside experts are used here.

Contingency planning

On which maturity level is your organisation in cross-border contingency planning? What is your target and how do you plan to achieve it?

Initial level 1: We have made contingency plans, but they have not been discussed across the border. They are not based on a joint risk analysis.

Repeatable level 2: We come together on an operative level at regular intervals with our counterpart across the border, exchange our contingency plans, and discuss them to make sure that both parties understand them.

Defined level 3: Our contingency planning regarding cross-border transmission is done with the counterpart across the border. It is based on a written agreement and a joint analysis of risks.

Managed level 4: The defined planning (level 3) is done and controlled in cross-border cooperation from top management downwards.

Optimised level 5: The managed planning (level 4) is constantly being improved in cross-border cooperation through feedback and by introducing innovative plans to better serve both TSO’s jointly agreed needs.

Implementation

On which maturity level is your organisation in implementation of the cross-border contingency plans? What is your target and how do you plan to achieve it?

Initial level 1: We implement our own plans. Our counterpart across the border is only occasionally informed on our measures.

Repeatable level 2: Operative exercises are carried out together. Investment to facilities, equipment, material, methods, education, and exercises are informed across the border. Error logs are in place.

Defined level 3: We implement the plans the way we have agreed in the joint contingency planning phase. Our top management is informed about the error logs, and some key findings are also communicated across borders.

Managed level 4: The defined implementation (level 3) is done and controlled in cross-border cooperation from top management downwards.

Optimised level 5: The managed implementation (level 4) is constantly being improved by level 5 (optimised) contingency planning. Ideas for better planning are systematically collected in the implementation phase.

Exercises

On which maturity level is your organisation in cross-border exercises? What is your target and how do you plan to achieve it?

Initial level 1: We have either not had a cross-border exercise, or we have but have not agreed on the next exercise.

Repeatable level 2: We have had a series of cross-border exercises and continue to do so, on an operational level. We have kept the scale of the exercises moderate, mostly tabletop type, and not involved large groups of people, or many members of the business network.

Defined level 3: We have a well defined framework of exercises, which involves all relevant business partners on both sides of the border. We have planned several steps ahead the learning areas where exercises are needed. The results of the exercises are incorporated in each company's written procedures.

Managed level 4: The defined exercise processes (level 3) are monitored and controlled in cross-border cooperation. The cooperation is considered a strategic matter and is in the interest of top management and downwards.

Optimised level 5: The managed exercising (level 4) is constantly being improved in cross-border cooperation through feedback and by introducing innovative ideas to better serve both TSOs' jointly agreed needs.

Identifying a crisis

On which maturity level is your organisation in identifying and recognising a cross-border crisis situation in your organisation? What is your target and how do you plan to achieve it?

Initial level 1: Our contingency plans are uncertain about what constitutes a crisis. Normal disturbances might be wrongly identified as a crisis, but on the other hand, more serious incidents might not receive enough attention. Much of the actual crisis management is improvised.

Repeatable level 2: Our plans define how disturbances gradually develop more serious. These definitions have been discussed across the borders. We don't waste time in deciding if the situation is a crisis.

Defined level 3: In addition to defining different kinds of crises, we are prepared for the complicated character of crisis management. Our contingency plans are based on a written agreement and a joint analysis of risks between the neighbouring TSOs.

Managed level 4: The definition of crises and crisis management (level 3) is done and controlled in cross-border cooperation from top management downwards.

Optimised level 5: The definition of crises and crisis management (level 4) is constantly being improved by level 5 (optimised) contingency planning. Ideas for better planning are systematically collected in exercises and real crises.

Leadership

On which maturity level is your organisation in leadership in a cross-border crisis situation? What is your target and how do you plan to achieve it?

Initial level 1: Cross-border contacts are taken only when there is a problem and many of the contacts are improvised. It is unclear who leads the action both across borders and between national sectors like transmission, distribution and authorities.

Repeatable level 2: Cross-border cooperation is considered an operational matter and is in the interest of operational management. Our contingency plans underline that the leading responsibility of crisis management is with the operator who has had the incident or who is most seriously affected by it, but we don't disturb the responsibility areas of each actor.

Defined level 3: We have planned and agreed in writing with our counterpart about cooperation during crises. The leadership and responsibility takes different forms during normal disturbances, risks of events, incidents, and crises.

Managed level 4: Crisis leadership and responsibility (level 3) is done and controlled in cross-border cooperation from top management downwards.

Optimised level 5: The definition of leadership and responsibility (level 4) is constantly being improved by level 5 (optimised) contingency planning. Ideas for better leadership are systematically collected in exercises and real crises.

Communication between those who can solve the crisis

What is the maturity of communication in your organisation between those parties that can solve a cross-border crisis situation? What is your target and how do you plan to achieve it?

Initial level 1: Contacts between parties are taken only when there is a problem. It has not been planned whom to contact in each situation.

Repeatable level 2: Cooperation is considered an operational matter and is in the interest of operational management. In addition to cross-border contacts, there are routine contacts towards other services such as fire departments, forest companies and teleoperators, and regular coordination with the authorities.

Defined level 3: We have planned and agreed in writing with our counterparts about cooperation during crises. Our contingency plans include guidelines for coordination with the authorities and other relevant sectors.

Managed level 4: The defined communication (level 3) is done and controlled in cross-border cooperation from top management downwards.

Optimised level 5: The managed communication (level 4) is constantly being improved by level 5 (optimised) contingency planning. Ideas for better communication are systematically collected from exercises and real crises.

Media communication

What is the maturity of media communication in your organisation in a cross-border crisis situation? What is your target and how do you plan to achieve it?

Initial level 1: Media does not receive the right kind of information, whence the crisis escalates as a media event. There is not enough openness and not enough careful thought in our media relations.
Repeatable level 2: Media is contacted regularly during the crisis through interviews, press conferences and information on the web site. We have established a contact person list for the local media and keep in touch also during routine operation.

Defined level 3: We have written a cross-border crisis communication plan with guidelines on media relations. Our own personnel is familiar with these practices.

Managed level 4: We are on a managed level. The defined communication (level 3) is done and controlled in cross-border cooperation from top management downwards.

Optimised level 5: The managed communication (level 4) is constantly being improved by level 5 (optimised) contingency planning. Ideas for better communication are systematically collected in exercises and real crises.

Communication technologies

What is the maturity of using communication technologies in your organisation in a cross-border crisis? What is your target and how do you plan to achieve it?

Initial level 1: The use of communication technologies is mostly improvised during the crisis. The grid maintenance has not been provided with sufficient communication means. There are also situations where we come to rely too much on communication technologies and not enough on situation awareness.

Repeatable level 2: We use primarily the everyday communication methods, like telephone and the computerised control system. There are secured, tested, and regularly exercised communication channels in place for all parties involved, in case the situation requires it. The movements and measures of the grid maintenance groups are optimised before the batteries of the mobile phone base stations run out.

Defined level 3: We have rules about when to use the secured crisis communication methods. We also know in practice how to use them. Communication technology is, however, not used at the expense of situation awareness.

Managed level 4: The defined communication (level 3) is done and controlled in cross-border cooperation from top management downwards.

Optimised level 5: The managed communication methods and technologies (level 4) are constantly being improved. Ideas for better communication methods and technologies are systematically collected from exercises and real crises.

Recovery

When you think about actual experiences, on which maturity level is your organisation in the cross-border recovery cooperation from crises? What is your target and how do you plan to achieve it?

Initial level 1: We make sure that our side gets up and running. We only inform our counterpart across the border when we have solved our problems.

Repeatable level 2: We exchange recovery plans and recovery situation reports on an operative level. We volunteer and welcome ideas both ways across the border for faster and better recovery.

Defined level 3: We keep constant touch during the recovery according to predefined rules. We also give and receive assistance across the border when it is useful and within the resources available.

Managed level 4: The defined recovery (level 3) is done and controlled in cross-border cooperation from top management downwards.

Optimised level 5: The managed recovery (level 4) is constantly being improved by systematically collecting ideas during the recovery phase. (The best ideas will then be innovatively used in the lessons learned phase.)

Lessons learned

When you think about actual experiences, on which maturity level is your organisation in the cross-border handling of lessons learned from crises? What is your target and how do you plan to achieve it?

Initial level 1: We keep our lessons learned sessions on our side only. We sometimes report on our ideas to the counterpart, though.

Repeatable level 2: We always have a joint session after a cross-border transmission crisis or after a near crisis situation. The way we use the results of the session vary. Error logs are in place.

Defined level 3: The sessions are documented and are always taken into account in the next joint contingency planning round. Our top management is informed about the error logs, and some key findings are also communicated across borders.

Managed level 4: The defined lessons learned sessions (level 3) are done and controlled in cross-border cooperation from top management downwards.

Optimised level 5: The methods for handling lessons learned are regularly improved by using new approaches from social sciences and pedagogy. The improvement possibility is always on the session agenda.