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Perspectives on the vulnerability of the Swedish electricity distribution system

- Extreme weather conditions and climate change.

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Title
Perspectives on the Vulnerability of the Swedish Electricity Distribution System- Extreme Weather Conditions and Climate Change

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Abstract
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The result shows that the dominating cause of disturbances in the electrical network in Sweden is the weather, giving most hours of breaks. The countryside has more often disturbances than urban areas. It also emerges that it is the lines overhead that are most affected by disturbances. The system is flexible. If one line is disturbed the electricity can be distributed using another line (redundancy). It seems like there is a diversion between the respondents on how and if a future climate change really is a risk for the electricity distribution system. It is clear that the vulnerability has increased in the society during the past 10-20 years, and so has the societal costs of the disturbances because of the increasing dependence on electricity. Reducing the consequences of a weather related impact on the electrical system will make society more resilient and less vulnerable. The respondents in this study are somewhat adapting to the weather related risks that they have identified with technical solutions. It is important to learn more about how the electrical system properties influence the sensitivity in society. There is a need to investigate the dependency of electricity in society. It is also important that all the actors have the same interpretation of the difference between a recurrent event and a nature disaster. More work should be done to clarify where the responsibility for adapting the electrical sector to the possible climate change lies. This complex responsibility issue with all affected actors influences the sensitivity of society and the electrical system.

Keywords
Electricity distribution system, climate change, extreme weather conditions, Disturbance, risk, vulnerability, adaptation

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Table of contents

1. Introduction

Society is becoming more and more dependent on electricity. We need electricity for filling up our cars, elevators, our water pumps. We want lights inside and outside, we warm up a lot of houses with electricity, use computers, wireless telephones, mobiles; you name it. As a matter of fact, it is not much that would function normally if the electricity suddenly disappears in the wire. How many industries would be able to continue their production without electricity? Sometimes we get reminded about this fact. For Sweden, this year started out with big reminder on the 8th of January when a hurricane called Gudrun swept over the south of Sweden leaving 415 000 household without electricity (Alexandersson, 2005). This reminded us about the power of the weather. Some parts of our infra-structure was affected such as the roads and the electricity distribution system. Since it took a long time to repair the damage we were also reminded about the vulnerability of our society in general. About 300 000 customers lost both stationary and mobile telecommunication (Pärnerteg, 2005b). It took one week to decrease the number of households without electricity to about 50 000 but there was still a lot of hard work to do before every household got their electricity back again (Alexandersson, 2005). Sydkraft had to build 2500 km of new wires because of the total destruction of the mains and poles. Since the disturbance was severe and comprised a geographically large area as well, it took a lot of time to finish the repair work. A few people had to wait until the 29th of February for the electricity to come back again. This is a big reminder of our vulnerability to weather phenomena and it is not the only one. There have been disturbances of this size related to storms before. Both in 1999 and in 1969 there were big storms that caused a lot of disturbances. It seems like the electricity distribution system is vulnerable for storms and that the disturbance in society becomes more severe the more electricity we use. Are storms the only weather related threat?

We hear at the same time as there are disturbances due to storms, that there has been a change in the climate and there are scenarios telling us how the climate might change in the future. IPCC –The Intergovernmental Panel for Climate Change- has published scenarios giving a picture of a more mild and extreme climate (IPCC, 2001). It seems as there is a risk for an increased intensity of storms. There is some differences between the current models but still, the climate change might increase the risk for losses. An urgent question following this is if the electricity distribution system needs to be prepared for a more extreme climate? The hurricane Gudrun started a debate in the newspapers about the electrical companies and their future development and vulnerability. There were a lot of articles in the newspapers about the damages and the affected people and some criticism was raised against the electric companies. One article (Gustavsson, 2005) was complaining about the large electrical companies. Gustavsson (2005) meant that these companies are thinking in short economical terms before they invest and do maintenance work. He attacked the big profits and claimed that the electrical companies should use the billion profits to employ people for the maintenance work and hurry up with their investments plans. Another article (Hegnell, 2005) also attacked the big profits and stated that when everything is back to normal again after the storm, it is time to have a serious discussion. Hegnell (2005) referred to the fact that it was only one net distributor in the south of Sweden that had pleased customers. A handful of them had disturbances after the hurricane Gudrun, but only for a couple of hours. This was because almost the entire network was buried underground in this area a couple of years back. He meant that there is time for new strategies for the electricity companies or else the blackouts will continue (Hegnell, 2005). A couple of days after this article was published, Sydkraft, one of the largest electrical companies in Sweden answered the criticism in Smålandsposten. In the article it emerges that for Sydkraft the big storm in1969 has become the standard for storms (Haggren, 2005). The disturbances from Gudrun seemed according to the article “to

come as a total surprise". The companies did not believe that there could be so much damage. Seventy percent of the network was totally demolished. Also this article was emphatic about the need for new strategies (Haggren, 2005). This short description of a large debate makes a strong point for a need to investigate the vulnerability of the electrical system. Are the future climate change and the current climate variability and their potential consequences taken into account on the arena of the Swedish electrical system today?

2. Aim

The aim of this master-thesis is to analyse perspectives on the vulnerability of the Swedish electricity distribution system related to climate and weather related risks, such as extreme weather events like hurricanes for instance. How and to what extent the electricity sector is adapting to the risks are investigated. The analysis will be both quantitative and qualitative. Statistical data will be used to apprehend the extent of disturbances of the electricity distribution system and their causes. Interviews will be used in order to investigate different views among actors working within the electricity distribution system sector. This overall aim can be divided into the following sub themes containing more specific questions:

Disturbance

What do different actors in the Swedish electricity distribution sector perceive as disturbances for the electricity-system in Sweden and how often do disturbances appear?
What affects the size and extent of the disturbance?
How often do different actors apprehend the weather as being the cause of disturbance and is the electricity distribution system more sensitive to some weather-types than others?

Risk and Vulnerability

What do different actors perceive as vulnerability of the electricity distribution system in Sweden and how do different actors view weather related risks and vulnerability in a future climate change? Is it their belief that the risk and the vulnerability will increase or not?

Adaptation

What does adaptation mean to the different actors and how are they adapting to the weather related risks and the vulnerability that they have identified?
What future risks, vulnerability and possibilities are seen related to climate change adaptation?
What weather specific strategies and measures, for adapting to climate change and to the current extreme events, are formulated and implemented in order to reduce vulnerabilities?

3. Electricity- a part of the infrastructure in Sweden

This chapter will first put some focus on climate variation and climate change. A history of storms and losses of forests in Sweden will then shortly be described. After that the focus is to describe the electricity dependence in Sweden. The distribution of electricity in Sweden will then be described and also some big disturbances in the world and their consequences. Following this, the vulnerability of the electrical distribution system will be discussed and finally in this chapter there will be some words about adaptation.

3.1 Climate variations and climate change

Even if the storm in Sweden 2005 was very extreme, it is not a proof in itself that the climate is changing. A weather situation is nothing else but a description of temperature, air pressure, cloudiness, and other properties in the atmosphere at a specific moment. The climate describes the average properties of the weather in a specific area during a longer period, and also how the weather in average varies during a day, through a year or even several decades. The climate comprises extreme and rare weather situations (Bernes, 2003 p13).

A storm can cause a lot of disturbance and a lot of loss in the society. If we go back again to the storm Gudrun on the 8th of January 2005 , the average wind speed was measured to 33 m/s and the gust to 42 m/s. About 70 million m^3 forest fell which is more loss of forest than earlier storms in Sweden in total. Large parts of the infrastructure system were damaged; roads and the electrical system included. When looking at storm history in Sweden we have had some big storms with serious consequences. The wind speed of the storm on the 3rd of December 1999 was in Hanö measured to 33 m/s; the loss of forest was almost 2 million m^3. Another severe storm occured on the 22nd of September 1969. The wind speed was measured to 35 m/s at Örskär. About 10 million m^3 forests fell and 10 people were killed. Big storms do not occur very often. Before 1969 there was a storm in 1967 (wind speed 40 m/s), and one in 1954 (wind speed 36 m/s). There were also big storms in 1943 and 1902 but there is no detailed information about the wind speed in these events (Alexandersson, 2005).

The working group II of the IPCC conclude in their report *Climate Change 2001, The scientific basis* that over the 20th century the globally averaged surface temperature have increased by 0.6 ± 0.2° C. The scenarios published in the *IPCC Special Report on Emission Scenarios*, projected by models, state that the global average surface air temperature will increase from 1.4 to5.8° C by the year 2100 relative to 1990. The main cause is believed to be the increased emissions of greenhouse gases. These projections indicate changes in the variability of climate and changes in frequency and intensity of some extreme climate phenomena (IPCC, 2001). A more detailed scenario for Europe was made by the Swedish research programme SweClim. This scenario indicate that the current temperature in France will, within a hundred years from now, become the climate of the south of Sweden. In the middle of Sweden it might be the same temperature as the current one in Denmark or northern Germany. The northern Sweden might have the climate that the middle of Sweden has today (Bernes, 2003).

During the autumn 2004 the Swedish Meteorological and Hydrological Institute (SMHI) was given the task by the Swedish National Environmental Protection Agency to investigate what actors for the moment are analysing what effect a future climate change might have and what kind of adaptation is needed to deal with a possible change. Plans, achievements and protective measures for a feared climate change were also investigated. The result was presented in the report *Anpassningar till klimatförändringar* that was published in February 2005. It emerged in the report that there is an increasing awareness of the growing

consequences of blackouts in Sweden and there is a strategy for maintaining the electrical supply in the country, according to the threats we have today (SMHI, 2005 p 22). The report also brought up some reflections about where the responsibility for adapting to climate change lies. The effect on the electrical supply that might be caused by a possible climate change has not been analysed. Moreover, it was stated that the safety margin increases when lines are rebuilt. If it is possible technically and if the electrical companies finds it economically reasonable, the electrical companies take the risks from a climate change into consideration (SMHI, 2005 p 22-23).

3.2 Electricity dependence in Sweden

The use of electricity has increased a lot in Sweden since 1970. Today, we are using about 15 000 kWh per inhabitant/year. Only Norway, Canada and Iceland use more electricity. This is due to our cold climate and the fact that we have an energy demanding industry. The household has also changed, now having computers, more television sets and many other electrical equipments (Svensk Energi, 2005a). The access to electricity these days are taken for granted in our society. We have had it for so long in Sweden; since the 1870s. The information age is totally dependent on a constant supply of electricity (Svensk Energi, 2005b). The produced total amount of electricity in Sweden 2003 was 132 TWh and about 145 TWh was used by the Swedes. Some electricity was imported from other countries. The users of electricity are foremost the industrial sector and the household and service sector. Their combined use in 2003 was 127 TWh, and that is 88 % of the total use in Sweden (Statens Energimyndighet, 2004b). The total amount of electricity customers in Sweden is about 5.2 million; about 1.5 million customers in the countryside, and about 3.7 million customers in urban areas (Swedenergy, 2004). About 90 % of the Swedish electricity comes from waterpower and nuclear power. The rest is produced mainly with fossil fuel. Only a small part of the power comes from wind power (Svensk Energi, 2005c).

3.3 Distribution of electricity

The electric lanes in Sweden cover about 526 200 km. About 49 % are cables buried underground and 51 % are overhead (Svensk Energi 2005d). The electricity is transported and distributed from the producer through the national grid, the regional networks and finally through the fine-meshed local networks to the electricity consumer (Svensk Energi 2005d).

The national grid transports the electricity long distance and the tension in the line is very high, 400 kV and 220 kV. The owner of the national grid is the state-owned authority Svenska Kraftnät (Swedenergy 2004). The national grid runs parallel to another meshed net with a smaller voltage class, about 130-20 kV called the regional networks. Swedish regional net companies own and run the regional net and they are customers of the national grid. Some industries with high consumption of electricity often get electricity directly from the regional network (Swedenergy 2004). The local networks have more than 180 owners and within a certain area, every company distribute electricity to the final consumer which are smaller industries, household and other consumers. The electricity is being transformed step by step to 230 V and that is the voltage class we have in our homes. There are transmission connections between Sweden and Norway, Finland, Denmark, Germany and Poland (Svensk Energi 2005d).

3.4 Disturbance

In the autumn of 2003 there were three really big blackouts in the world, reminding us about what an important infra-structure the electricity distribution system really is. One blackout took place in northern America and another two occurred in Europe. In the centre of attention

of these blackouts was the enormous extent of the disturbances. The blackout in northern America affected about 50 million inhabitants in eight federal states and in the province Ontario in Canada. The blackout in Italy affected the whole population; 55 million inhabitants, and the blackout in southern Sweden and eastern Denmark affected about 5 million inhabitants. The cause of the blackouts was technical mistakes that started a domino effect through the lines. In Italy the cause was that the lanes for the networks had not been cleared. These were of course very extreme events which do not happen often. The fact that it could happen and that it could affect so many people is a reminder of the vulnerability of our new information society. These blackouts were also very costly. The disturbance in Sweden was later estimated to about 500 million SKr, and in Denmark to 135 million DKr.(Statens Energimyndighet, 2004). Auld and MacIver (2004b) state that there are increasing costs of the infrastructure losses in Canada, and they mean that the increasing costs are the result of increased vulnerability for weather related events.

3.5 Vulnerability

The work for reducing the vulnerability of the electrical distribution system to weather related disturbances will require overall planning. It will be important to understand the properties of this part of the infrastructure and where the system is vulnerable. Smithers and Smit (1997) have identified relevant properties or characteristics of human activity systems for understanding the sensitivity of an impacted region or system and identify the probability for adaptation to the climate variability and change. The system characteristics are: stability (the ability to remain unchanged from disturbance), resilience (ability to recover or the degree of experienced impact without moving the system from a previous equilibrium), vulnerability (the sensitivity of a human or economic system to disruption, wound or damage from environmental change), flexibility (the degree of manoeuvrability within the system), scale (individual, community, sector, region and so on) (Smithers and Smit, 1997 p.137-138).

The concept of vulnerability has been explained in the report Climate Change 2001: Impacts, Adaptation, and Vulnerability written by Working Group II of the Intergovernmental Panel on Climate Change (IPCC, 2001, p. 238)) as:

> The degree to which a system is susceptible to, or unable to cope with, adverse effects of climate change, including climate variability and extremes. Vulnerability is a function of the character, magnitude and rate of climate change and variation to which a system is exposed, its sensitivity, and its adaptive capacity.

The vulnerability to climate variability, weather extremes and climate change in Europe is according to IPCC different between the sub regions. The less wealthy areas will be less able to adapt. In this thesis adaptation and vulnerability of the electrical system in Sweden corresponding to current climate variability and the expected future climate change are in focus. The electrical system is one part of the infrastructure in Sweden that might be affected by climate effects. The vulnerability of this part of the infrastructure in Sweden is discerned at the last few years´ large blackouts, especially when the blackout strikes a larger area and lasts very long, for example as the latest storm in January 2005.

Mirza (2004) states that power generation, transmission and distribution components of the energy sector in Canada are presently vulnerable to extreme weather events and will become more vulnerable unless adaptation measures are designed and implemented. It will require a varied and interconnected range of adaptive actions to reduce societal vulnerability to weather related disasters under current and changing climate conditions. A lot of actions are presented by Auld and MacIver and among them vulnerability identification and hazard assessment

(Auld and MacIver, 2004a). Vulnerability assessment is described by Auld and MacIver as a very critical part of a disaster reduction strategy: "vulnerability assessment identifies sources of hazards, vulnerable groups, risks likely and potential interventions". Physical vulnerability studies could analyze impacts on the infrastructure (Auld and MacIver, 2004a). A successful hazard assessment requires sufficient and defensible analyses by experienced scientific teams. Auld and MacIver mean that identification and prioritisation of hazards require documentation and studies. This needs to be done both at the probable location and about the severity of dangerous phenomena. High impact weather as well as information on the probability of their occurring within a specific time period in a given area should be included in such studies (Auld and MacIver, 2004a).

3.6 Adaptation

It is important to identify gaps in the current capacity for addressing climate variability and extremes as a first step in reducing risks according to Auld and MacIver (2004b). The concept of adaptive capacity is explained by IPCC (IPCC, 2001 p.238) as:

> The ability of a system to adjust to climate change, including climate variability and extremes, to moderate potential damages, to take advantage of opportunities, or to cope with the consequences.

In Europe the adaptive capacity is according to IPCC estimated as generally high for human system, because of the economic conditions. Europe has also well developed political, institutional, and technological support systems (IPCC, 2001 p.271). The report (IPCC, 2001) also states that if there is a well planned and anticipatory adaptation, the ecological and economical costs might decrease and also the adverse impact. According to Auld and MacIver (2004b) the transmission lines are designed with lower safety factors. This is because their failures are considered to bring economic losses rather than losses of lives. Hospitals or schools are designed with higher safety factors because their failures are considered to bring losses of lives. There is an increasing trend towards electronic and just in time delivery economies and Auld and MacIver mean that the losses from interruptions in electrical power now include large economic costs as well as losses of lives (Auld and MacIver, 2004b).

Adaptation options to climate change should be developed today and implemented as soon as possible because the infrastructure that has been built in current time is intended to survive for decades to come (Auld and MacIver, 2004b). Auld and MacIver claim that the infrastructure of today has been designed using values calculated from historical climate data. In the design of the infrastructure there has been an assumption about the climate that the average and extreme condition of the past will represent the future conditions of the structure, and that will no longer hold since the climate changes. Moreover, Auld and MacIver state that there is a need to increase the safety factors in use in codes and standards. This would reflect the growing uncertainties in climatic conditions over the lifespan of the structure, since societies become increasingly dependent on critical services and increasingly vulnerable to interruptions created by weather and climate extremes (Auld and MacIver, 2004b).

Social and economic systems are not likely to collapse by climatic changes according to Smithers and Smit (1997). The adaptation process to a changed environment is described as both a public policy and a spontaneous response. Smithers and Smit distinguish two reasons for estimating impacts of climate change. The first reason is to provide information about the climate change itself as a base for determining the severity of the problem. The second reason is a need to provide a bench mark for evaluating prospects and consequences of potential response strategies. A framework for human adaptation to environmental change has been suggested by Smithers and Smit. The framework contains three dimensions of adaptation to

climate stimuli: 1, The nature of the disturbance stimulus or force of change. 2, The properties of the system which may influence its sensitivity. 3, The type of adaptation which is undertaken (Smithers and Smit, 1997 p.142).
The electricity distribution system is an important part of the infra structure in Sweden. There is a need to learn more about vulnerability and adaptation to the climate change to prevent future losses of economies and life's.

4. Method

There are a number of methods to use when identifying the risk and vulnerability of a specific sector. For instance, a risk analysis could have been made in order to determine the size of the risks, and a vulnerability analysis could have brought forward the ability and resources to resist the identified risks, but that means that the risks would already need to be identified (Hallin et al., 2004). This study investigates the different views of some important actors in the electricity distribution system sector.

When attempting to answer the questions and analysing the vulnerability of the Swedish electricity distribution system and climate and weather related risks three different methods have been used.

- Review of the literature and reports about the vulnerability of the electrical system.
- Review of statistical data for understanding disturbances; how often they appear and their causes.
- Interviews of four important actors working in the electricity sector: The Swedish Energy Agency, The national grid - Svenska Kraftnät (SvK), The regional network, Sydkraft and the trade association Swedish Energy.

4.1 Reviewing literature and reports

SMHI and IPCC have been important sources when reviewing the climate effect. The report *Climate Change 2001: Impacts, Adaptation, and Vulnerability* (IPCC, 2001) by the working group II of IPCC has contributed with the base for understanding the questions about adaptation, vulnerability and impacts. Reports from Svenska Kraftnät, Swedenergy and Swedish Energy Agency are an empirical base and supplement to the interviews. They have not been collected systematically. However, some of these reports were provided by the respondents in the interviews and some were found on the homepage of the different representatives. The statistical data comes mainly from Swedish Energy -The Darwin report- (Swedenergy, 2003) that was provided by their respondent.

4.2 Interviews

4.2.1 Why interviews?

The use of interviews is often a qualitative method and as Kvale writes in his introduction in his book *Den kvalitativa forskningsintervjun* (1997): “If you want to know how people apprehend their world and their lives, why not talk to them?” (the authors translation). He also points out that you build up knowledge in the qualitative research interview. Interview as a method is an excellent tool when illustrating different aspects of the arena of the electrical system in Sweden. A lot of knowledge is to be found in different reports but what also needs to be collected is the experience and knowledge of the actors working on the arena. They are people who have a responsibility for the electricity distribution system and they are adapting the system according to the demands of other actors. Their perspective and point of view cannot be found in the reports.

4.2.2 Who?

The emphasis of the thesis is to analyse the vulnerability of the Swedish electricity distribution system in relation to climate and weather related risks. There are many actors on the electricity arena and after scanning and making a list of relevant actors suitable for investigating the aim of the thesis, the decision was made to interview four people. The

respondents are chosen for their knowledge of the Swedish electricity distribution system. They are relevant for this study since they are representatives of some major performers on the Swedish electricity distribution field:

- The Swedish Energy Agency is a very relevant actor with the responsibility for the energy supply in Sweden. The interviewed person Bengt Boström is head of The Climate Change Division at The Department for System Analysis.
- The national grid - Svenska Kraftnät (SvK) is relevant because this is the authority responsible for preparedness of the electricity in Sweden. SvK own the national grid and are responsible for the system. The interviewed person Folke Pärnerteg is head of staff at the emergency service. He co-ordinates SvK´s preparedness activity, the security and the preparedness within the whole power industry.
- The regional network, Sydkraft –having 624 000 customers in the south of Sweden (many of them affected by the hurricane Gudrun) makes Sydkraft a very relevant actor. Kurt Lindqvist was interviewed because he is head of staff at the Strategy and Analyse department. He is working with the long term questions about the security of deliverance and investment programme and he works as a part of the Industrial Liaison Council of the Swedish Emergency Management Agency.
- The trade association Swedish Energy was selected because the association is the united voice of the electricity market. The interviewed person Matz Tapper, Enhet Nät, works in cooperation with all the net-companies in Sweden. His main concern is questions about management and maintaining the net.

The aim of this thesis is cross scientific which makes it difficult to find one person who can answer all of the questions in a satisfactory way. This has been taken into account when deciding who to interview. At the Swedish Energy Agency another person, Andres Muld was after conducting the interview with Bengt Boström contacted for further information. Muld is head of the Department for Sustainable Energy Management at the Swedish Energy Agency and he provided the report about "Hel-projektet" (Muld, 2004) and gave further information about were to find other reports.

Representatives for local nets could have been of interest to interview but they are instead represented by Swedish Energy, the trade organisation.

4.2.3 Making contacts

The contact with the respondents was first taken by e-mail in which they were offered to see the interview questions in advance. Three of the four contacted persons took this opportunity and questions were sent to them by e-mail. In two cases the persons, after reading the questions, sent them forward to someone else in the organisation that had a better knowledge of the subject. After reading the questions it was decided when to conduct the interview.

4.2.4 The interview situation

An interview is a special form of conversation, Kvale (Kvale 1997 p123) means that:

> The interview is like a normal conversation but with a specific purpose and a specific structure characterized by a systematic form of questioning.

The questions (see appendix 1 and 2) were prepared before the interviews and sometimes followed by spontaneous questions. The answers were open, meaning that the respondent uses

his own words to answer the questions. The respondents who read the questions in advance may have had some time to reflect and to prepare themselves before the interviews.

Three of the interviews were made on telephone. One interview was a personal meeting with the respondent. All of the interviews have been recorded on a tape. A meeting for the interview might have given a better contact than interviewing on telephone. Using a microphone may have had some restraining influences to the answers. The material on the taped interview is however so much better from an analytical point of view than taking notes during the event and that was the reason for using a tape recorder.

The interviews were transcribed by the author of this thesis. Supporting feedback, that is words that did not contribute to the conversation more than just to show that one was listening was left out. A few times there were words that could not be heard from the tape. They were illustrated with three dots. The text was written in a table with three columns where the first represented the name of the speaker, the second represented the dialogue and finally the third column was left empty for the analysing part.

4.2.5 Analysing the interviews

As the first step, keywords had been chosen before the interviews to be picked out from the text. These were disturbance, risks, vulnerability, and adaptation. The words were pointed out in the text with different colours for each word. However, during the interviews more words came up describing the essence of the discussion. These were consequence, preparedness, responsibility, climate scenarios, demands, long-termed actions. These words were all written in the third column of the transcriptions and formed a categorization that framed the analysis. A couple of quotations have been selected to illustrate specific and general statements.

After the analysis of the interviews a copy was sent to each one of the respondents and they could fill in or correct if something had been misunderstood.

4.2.6 Translating the interviews

The respondents and the writer of this thesis are all Swedish and during the interviews the language spoken was Swedish. This means that for writing this thesis the contents of the interviews had to be translated to English. Some quotations from the interviews are presented in the thesis and they were translated from Swedish to English. When the quotations were translated to English the focus was to remain the contents of the sentence.

4.2.7 Frame

The frame here is to study the part of the Swedish electricity distribution system that concerns the distribution of the electricity. This means that the production and the use of electricity and also the distribution to and from other countries have been left out. This study concerns the experience and knowledge about climate and weather related risks of some actors working within the field of the Swedish electricity distribution sector. More specifically, vulnerability, adaptation and risks of the Swedish electricity distribution system are issues that are addressed.

5. Result

This chapter will describe the results of the interviews, the review of reports and literature. First there will be an introductory table presenting what emerged from the interviews concerning the respondents´ responsibility about preventing future problems. After that, the analysing keywords from the interviews: disturbance, risks and vulnerability and adaptation will function as headlines. At the end of every headline there will be conclusive remarks, with a short answer to the specific questions as they are described in the aim at page 7 of this thesis. The respondents will be referred to according to the actor they represent, Svenska Kraftnät, the Swedish Energy Agency, Sydkraft and Swedenergy.

5.1 Responsibility

The respondents have all a common responsibility for the electrical system but the responsibility is of course different depending on what level they represent. Table 1 describes the responsibility that the respondents emphasised in the interviews when discussing preventing future problems.

Table 1: the respondents view of their responsibility for the electrical system

respondent	**responsibility**
Sydkraft	The respondent emphasises their responsibility to build a robust and secure deliverance of electricity that can handle the weather strains.
Svenska Kraftnät (SvK)	The responsibility is the wires managing by Svenska Kraftnät - the national grid. Svenska Kraftnät is also the responsible authority for the system and responsible for sending directions to the companies about the technical security in the plants. SvK is also the responsible authority for preparedness of electricity and responsible for taking actions to increase the security in the electrical system.
Swedish Energy Agency	The responsibility is a safe supply of energy in the whole country. Working with different aspects, the department for sustainable use of energy, and the energy market inspection supervise the deregulated electricity market.
Swedenergy	The respondent is responsible for managing and maintaining the net in cooperation with all net-companies in Sweden. Swedenergy has also another department working with building and development of the net.

5.2 Disturbance

5.2.1 Identifying disturbance

In the interviews the respondents emphasised somewhat different aspects of what a disturbance is, but taken together the interviews indicate that a disturbance is foremost all types of cut-off that affect the customer and also cases when there is a deficiency in the quality of the electricity. It was stated that the disturbance can be long-term and short term, it can be planned and unplanned. If the disturbance is longer than 3 minutes, it will be reported to the Swedish Energy Agency and becomes part of the national statistics. One respondent (Svenska Kraftnät, 2005), made it clear that if the cut-off is planned it will not be counted as a disturbance but as normal activity. Anything beyond normal activity will be counted as a disturbance.

5.2.2 Frequencies of national and regional disturbances

Two of the respondents (Svenska Kraftnät, Sydkraft, 2005) distinguished between two different kinds of disturbances, national and regional. The national disturbances are disturbances that occur on the national grid and the regional concern the regional mains. Regarding national disturbances it was stated that we have had 2 disturbances on the national grid (400kV) during the last 2-3 decades (1983 and 2003). A national disturbance can affect half of the country. The disturbances of the regional mains however occur with a shorter frequency of 5 years (Svenska Kraftnät, Sydkraft, 2005). One respondent (Sydkraft, 2005) meant that the cities in Sweden have very few disturbances of the mains. The cut-offs are in average about 20 minutes per year, and they are only affected by the national disturbances. The countryside on the other hand has more frequent cut-offs, in average at least 200 minutes per year (Sydkraft, 2005). Thus, the vulnerabilities of the countryside seem larger than those of the cities, at least related to frequency.

For surveying the situation of disturbances, a data base called Darwin is being built up. It contains operational disturbance and interruption (longer than 3 minutes) statistics at the regional network (Swedenergy, 2005). The report *Darwin Driftstörnings- och avbrottsstatistik 2003* (Swedenergy, 2003) show the situation in the local net in Sweden 2003. 90 net companies are contributing with data for the data base that covers the year 2003. The data from these companies represent 71 % of the customers in Sweden. The distribution of the data of disturbances is even between the transmission lines in the cities and in the countryside. The goal for 2004 is to increase the co-operation and cover at least 90 % of the customers (Swedenergy, 2003). The respondent from Swedenergy (2005) explained in the interview that Darwin will cover the whole country in the future, but this process is still in progress. He meant that so far the priority has been quantity before quality and the next step is to educate everyone who will work with Darwin to increase quality. When reporting to The Swedish Energy Agency about disturbances longer than 3 minutes, a different kind of data is required. The Swedish Energy Agency demand a compulsory report about disturbances for their statistics but they want calculated ratio so Darwin needs different details (Swedenergy, 2005).

The Darwin report presents 21 identified different parts of the whole electric main establishment (Swedenergy, 2003 table 3.5). One identified part is cables buried underground. Cables buried underground had 5603 disturbances 2003. The total amount of the presented disturbances in the different parts of the electric main establishment was 40 738. There was one “unknown” post with 10 215 disturbances on unexplained parts of the system. The Darwin report shows 5 different types of wires overhead and altogether they had 11 792 disturbances. The underground cables were mentioned in one of the interviews (The Swedish Energy Agency, 2005) as often being damaged by excavators, but it seems as the wires overhead are more affected by disturbances. The regional disturbances presented in the Darwin report (Swedenergy, 2003 table 3.1) show that the lines of smaller voltage class 0.4 kV are the lanes with most unplanned interruptions (21 968) of deliverance. This can be compared with the unplanned interruptions of deliverance on the lanes of higher voltage class 24.12 and <10 kV. There were all together 19 213 of them. The total amount of unplanned interruptions in 2003 was 41 181. According to this statistics it seems like the lines of smaller voltage class 0. 4 kV are the most vulnerable lines of the regional network. Adding to this, the respondent from Svenska Kraftnät (2005) claimed that it is very rare that weather causes disturbances on their lines, the regional network. He meant that normally such disturbance happens with an interval of five years, but if there is a disturbance in the country side it will most likely depend on the weather. Another respondent (Sydkraft, 2005) also mentioned the five year interval and stated storms and hurricanes as the causes. It was emphasised in the

interviews that the network in forests is vulnerable for storms or watery snow making the trees fall or leaning on the lines. The biggest disturbance however, seems to be connected with a powerful wind and badly cleared lanes. There are big economical values that affect the badly cleared lanes (The Swedish Energy Agency, 2005). There were also other causes of disturbances mentioned in the interviews by one respondent: there have been fires in the electrical constructions in tunnels in Stockholm (The Swedish Energy Agency, 2005),

5.2.3 Factors affecting the size and extent of the disturbance

A couple of important technical factors that affect the frequency and the severity of disturbances could be distinguished from the interviews.

The technical lifecycle of the mains is at least 40 years so it depends a lot on where in this life cycle the disturbed main turns out to occur. The size of the damage on the mains, where and how the main is damaged are of course also crucial. A disturbance caused by thunder is often quite controlled, and the customer is soon connected again. National disturbances on the other hand are extensive, when the whole electrical system is being cut off for some technical reason (Sydkraft, 2005). Another important factor is the cleared lanes: are they newly cleared or not? The lanes are cleared within a certain interval of approximately five years. A shorter interval between clearings, such as four years, would make a difference (Swedenergy, 2005).

Since clearing of the lanes could make a difference it is also interesting to view the width of the lanes. This was mentioned by one of the respondents (Sydkraft, 2005).

The table below (table 2) presents the different types of lines overhead and the width of the lanes below them. There is a difference between the lanes of higher voltage class and the lanes of smaller voltage class. The lines of 130 and 400 kV have 40-50 metres wide lanes and the lines of 20 and 10 kV have 6-8 metres width of the lanes. There are a lot of lines overhead, Sydkraft have about 20 000 km lines in forest land (Sydkraft, 2005).

Table 2: the type of wires in the air and the width of the lanes below them (Sydkraft, 2005)

Type of line	**Width of the lanes**
130 kV and 400 kV	40-50 metres wide lanes
20 kV,10 kV	6-8 metres

A very important factor for the security of deliverance of electricity to the customer is if there is a redundancy in the network. The respondent from Swedenergy explained that the lines of higher voltage class (the national and regional network) have fine-meshed lines. Normally if one line is out of order it will not lead to a disturbance for the customer. More likely, a reconnection, often by remote control will then occur that gives the needed reserve power back to the customer. The fine-meshed net creates an alternative way for the electricity through the system. This is called redundancy. A transformer station can have two transformers instead of one and if there is a problem one can manage by overloading one of them (Swedenergy, 2005). When describing what is affecting the size and extent of disturbances of the electrical system it seems to concern the status of the mains, how recently the lane has been cleared and if there is redundancy in the network.

5.2.4 Causes of disturbances

The *Darwin* report from Swedenergy, 2003 (table 3.3) presents operational disturbances distributed on different causes; thunder, other weather conditions, personnel, overload,

material/ method, damage, returning load, fuse break and finally unknown causes. Figure 1 illustrate this.

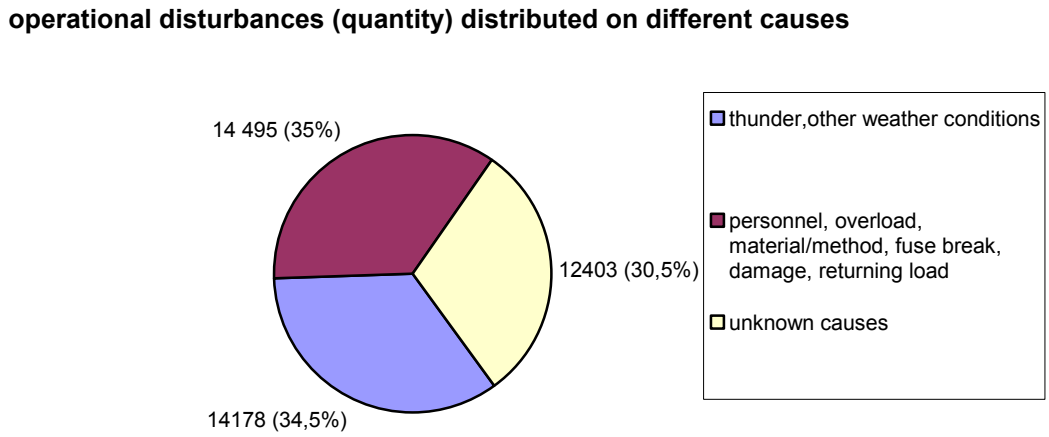

Figure 1: The operational disturbances distributed on different causes (Source: Swedenergy 2003)

It emerges that "thunder" and "other weather conditions" are together the cause of 34,5 % or 14 178 disturbances. The total amount of disturbances was 41 076. The rest of the causes represented together about 35 % of the total amount or 14 495 of disturbances. About 30 % of the disturbances has an unknown cause. Sometimes the reports come in to the Darwin data base uncompleted and the cause of the disturbance is not noted. In such cases the cause is marked unknown (Swedenergy, 2003). The respondents in the interviews seem to agree, with one exception; the weather being the dominating cause of electrical disturbances in the mains, especially in the countryside. Therefore a big part of the unknown 30 % (see figure 1) could be believed to have some weather related cause.

Svenska Kraftnät has performed a risk- and vulnerability analysis on the electrical system in Sweden. In the resulting report (Pärnerteg, 2005a) the identified threats, vulnerabilities and consequences are described. There are 11 different threats identified in the report and two of them are relevant here: events related to the nature and critical relation of dependence. About the events related to nature the report mentions high water flow and extensive rain as one risk. Thunder and wet snow are mentioned as being a risk for causing disturbances in the electrical system and a combination of wet snow and hard winds is identified as able to cause disturbances in the local and regional network The hurricane Gudrun was mentioned in the report as being an extreme nature related event. Concerning the critical relation of dependence of electricity, one important example came up: there is a mutual dependence relation between the electrical supply and the telecommunications. (Pärnerteg, 2005a). The risk and vulnerability report does not mention a future climate change as being a risk for the electricity distribution system in Sweden.

5.2.5 Viewing frequency of weather related disturbances

The weather can cause disturbance on the electrical system both directly and indirectly. For example, after a long cold period of time, there could be electrical shortage - as a consequence

when the need of electricity is increasing, because of the weather (The Swedish Energy Agency, 2005).

According to the respondent from Sydkraft (2005) 90 % of the long disturbances is related to the weather. In the interviews the respondents emphasised somewhat different aspects about how often the cause of the disturbances are weather related. There seems to be a diversity in storms that cause perturbations in the electrical system. Storms or bad weather can be seen as a part of a one-year disturbance, five-year disturbance or ten-to- fifty-year disturbance. The hurricane Gudrun was a fifty-year disturbance (Swedenergy, 2005).

One respondent (Swedenergy, 2005) meant that disturbances related to a powerful wind and badly cleared lanes do not happen very often, statistically, but that there has been a tendency of more powerful bad weather a little more regularly than earlier. Another respondent mentioned that earlier there were storms more seldom – with a time span of maybe ten to fifteen years between the storms (Sydkraft, 2005). It was also mentioned in one interview (Sydkraft, 2005) that it seems to be more watery snow in the south of Sweden today. Every second year for the past five years there has been watery snow. He also meant that storms and hurricanes seem to happen more often. There was a hurricane in1999 and one in 2001 and before that there was one in 1969.

5.3 Summary – Disturbance

- When identifying disturbances for the electricity distribution system in Sweden, the interviews indicate that a disturbance is all types of unplanned cut offs that affect the customers. If the disturbance is longer than 3 minutes, it will be reported to the Swedish Energy Agency and becomes part of the national statistics.
- The respondents distinguished between two different kinds of disturbances; national and regional. The vulnerabilities of the countryside seem larger than those of the cities, at least related to frequency. In the statistics of Darwin it emerges that the lines of smaller voltage 0,4 kV are the most vulnerable of the regional network and the lines overhead are most affected by disturbances.
- The interviews state that the status of the main and the cleared lanes, and if there is a redundancy in the network, are affecting the size and extent of the disturbance. The hurricane Gudrun was mentioned in a risk and vulnerability analysis as an extreme nature related event. Some risks, like ice storms are not dimensioned in the mitigations work.
- According to the interviews the dominating cause of electrical disturbances in Sweden in the mains is the weather. Weather conditions can affect both directly and indirectly. It appears that thunder, wet snow, storms and hurricanes are weather types that cause disturbance and that the biggest disturbance is connected with powerful wind and badly cleared lanes.

5.4 Risk and Vulnerability

5.4.1 The disturbance as a problem

One of the questions in the interviews was if all the disturbances were associated with risks or problems. One respondent (Swedenergy, 2005) indicated that the magnitude of the disturbance depends on where in the electric main the disturbance occurs - on what voltage class. On higher voltage class like the national or regional network, there is a way to switch over and the customer will not be affected. In such cases you might say that there has been a disturbance of the normal activity. The customer will not be affected. It will be less security in the electric main for a period when the reserve is being used. Should one more event occur at the same location, then there will be a problem and the customer will be affected.

In one interview the respondent (Sydkraft, 2005) emphasised the risk for disturbance for some industries e.g. the process industry. There might be problems in the process industry even if there is only a very short break for tenth of a second. He also meant that for society there will be a big problem if the disturbance is longer than 24 hours. Another point of view came up from one respondent (The Swedish Energy Agency, 2005) where it was claimed that the preparedness from the electrical companies might have deteriorated. He meant that the companies are working with less margins, now having less employees working as linemen. He meant that this is a chosen risk because disturbances happen rarely but he also indicated that maybe this is a strategy that needs to be reconsidered after the extent of the latest storm.

5.4.2 Risks related to future climate change

Risks related to future climate change were discussed in the interviews. The experiences among the respondents diverged slightly. One respondent (Swedenergy, 2005) mentioned that the identified risk of the lines through the forests is now being built away. Non isolated wires overhead are foremost replaced with cables buried underground. When that job is done the net can handle most types of weather. He explained that the new cables buried underground are not sensitive for moist, since they are waterproof. So if it would rain more in a future climate it would not affect the distribution of electricity. Even for thunder the risks of disturbances will decrease, when the cables are buried underground. Another respondent (Sydkraft, 2005) however meant that a changing climate can become a problem for the energy support:

> Yes, with more extreme weather situations and increased frequency of hurricanes it will become a problem.

He emphasised that the lines in the forests will have more disturbances, and the power lines in open terrain will have problems if the wind is really strong. It remains to be seen if all of the lines overhead in forests will be buried underground. If not, a future climate change can become a problem for the distribution of electricity in Sweden. One respondent (The Swedish Energy Agency, 2005) also mentioned the importance of keeping the airborne wires in good condition and maybe modernize them. He also mentioned another point of view; a changing climate might not be all for the worse for the electrical system:

> The climate change could lead to a change in the weather in Sweden, but if that causes increasing problems is uncertain (The Swedish Energy Agency, 2005).

He meant that they are calculating with a relatively high confidence that the precipitation will change. Rain and snow might fall during different parts of the year and that could lead to a changing (maybe increasing) supply of water power. It was stated by the respondent from Svenska Kraftnät (2005) that the calculated change of the precipitation is also that the water

flows will increase. He meant that we might have more extreme weather situations than before. Situations such as the one in January this year might occur more often. It seems like there is a divergence between the respondents on how and if a future climate change really is seen as a risk for the electricity distribution system. According to IPCC an increasing amount of extreme weather situations are very likely to happen in the tropics. The temperate zone here is more complex. An increasing amount of extreme weather might seem to be indicated but not with any certainty (IPCC 2001).

The Swedish Energy Agency was given the task by the government in Sweden in 2001 to start a project developing a general picture of the security and preparedness of the electric supply. The project runs under the name "HEL-projektet". In the progress report to the government from the 1 of November 2004 different threats and risks that ought to be the base for the societies security and preparedness had been identified: nature disasters and infection, extensive technical disturbances and antagonistic threat. Extreme nature related events like an ice storm over a big part of the country can not be dimensioned in the preparedness because of the low probability and the enormous consequences according to the progress report. The yearly storms however are mentioned as something that society should be able to trust the electrical deliverance to handle (Muld, 2004)

5.4.3 Reasoning about the vulnerability for disturbances of electricity in Sweden.
When discussing the vulnerability of the electrical system it is quite interesting that different kinds of answers came up from the respondents answering the same question. One of the respondents was discussing the vulnerability of the lines and two of them talked about the societal vulnerability. This might depend on how the question was asked, and of course how the earlier conversation had progressed in the interview. What kind of things that had been brought up just before this question came up could also influence the answers. Yet, the respondents seemed to make different associations when they were asked: "how vulnerable are we for disturbance of electricity in Sweden?" These associations might also depend on the institutional belongings of the electricity sector which the respondent represented.

The respondent from Swedenergy reasoned about the lines. He claimed that in general we are resilient. During the years however local networks have been built in such a way that they have become more sensitive to weather related disturbances. This is an identified field where an intensive effort of strengthening this part of the transmission lines is made, and that will take some years. The respondent from Swedenergy meant that there is a debate going on now about how many years this process may take (Swedenergy, 2005) .

Regarding societal vulnerability, one of the respondents (Sydkraft, 2005) emphasised that during the past 10-20 years the vulnerability for electricity disturbance in society has increased:

> I don't know exactly what that depends on. Computerisation is contributing, we have less houses warmed up by fires for example, we are another generation of people, the industry is more vulnerable, the agriculture is more dependent on electricity, people is working on distance.

Another respondent (Svenska Kraftnät, 2005) reasoned about the same question, in the sense that Sweden as a nation is very vulnerable and enormously dependent on a constant supply of electricity. He emphasised that there are not more disturbances today but they tend to become more noticed nowadays. The societal costs of the disturbances in 2003 were much higher than the costs of the disturbance in 1983. We have become more dependent on electricity during the past 20 years. The respondent emphasised that:

These are facts that are important to understand when discussing disturbances and their effect on society (Svenska Kraftnät, 2005).

The respondent from Svenska Kraftnät compared the storm in January 2005 with another storm in 1921 with freezing rain and wind of about 60-65 m/s. There was not any technical infrastructure then. The disturbance was severe but not the same as in January 2005. The same respondent also brought up the issue of the electric supply you need for telecommunication. There must be electricity in the exchange and people seem to have forgotten that. He also meant that when something happens it generally happens in the south of Sweden. The storm in January 2005 demonstrates how things are affected when the network become totally demolished. 2500 km of new wires had to be built up again and such destruction is of an enormous extent (Svenska Kraftnät, 2005).

5.5 Summary – Risk and Vulnerability

- All disturbances in the electrical system are not associated with risks or problems. This depends on where in the electric main the disturbance occurs - on what voltage class. Even a tenth of a second of disturbance can cause problems e.g. in the process industry. Society will have big problems if the disturbance is longer than 24 hours. The mitigation work from the electrical companies might have deteriorated since the companies are working with less margins. The mutual dependence relation between the electrical supply and the telecommunications seems to be a forgotten risk.
- It seems like there is a divergence between the respondents on how and if a future climate change really is a risk or not for the electricity distribution system
- Two fields were distinguished when the respondents were reasoning about the vulnerability for disturbances of electricity in Sweden: Vulnerability of the lines and societal vulnerability. The vulnerability has increased in the society during the past 10-20 years. So has the societal costs of the disturbances. It is stated that this is because of the increasing dependence on electricity. It emerged from the interviews that the south of Sweden is generally more often hit by storms than other parts of the country.

5.6 Adaptation

5.6.1 Adaptation to expectations

In the interviews the respondents were emphatic about the need for reducing the vulnerability. The respondent from The Swedish Energy Agency referred to the demands from society and the customers of electricity:

> I think that the demands from society are based on the expectations from the citizens that the society needs to be able to handle extreme situations.

The statement seems to indicate a trust and expectations from the citizens that the responsibility for a safe supply of electricity in extreme situations is with the society. The same respondent also compared the expectation of the Swedish citizens with the expectations of the citizens in the Baltic area. They were also hit by the storm Gudrun, almost as seriously as Sweden. The respondent from The Swedish Energy Agency meant that people in the Baltic were not at all as upset as in Sweden because of their different expectation on society to handle a situation like this. In addition, it was stated in another interview (Swedenergy, 2005) that the customers have different demands today. A customer in the countryside wants the same security of deliverance that a customer in the city has. This shows that there is an opinion in the Swedish society about this part of the infrastructure that it is supposed to function. Also, the regulation is supposed to follow the development in the society as well. Measures that are needed are regarded as part of a long term development by the respondents. The respondent from Svenska Kraftnät made a point that the climate change is not so quick either. One respondent (The Swedish Energy Agency, 2005) meant that the latest report of IPCC, Climate Change 2001: Impacts, Adaptation, and Vulnerability (IPCC, 2001) has really put the question of adaptation on the agenda.

5.6.2 Adaptations to increase the security of deliverance of electricity

According to the respondent from Sydkraft, the Energy Market Inspection is working on establishing propositions for legislations to the government about increasing the security of electricity in the countryside. He mentioned proposals of e.g. maximum cut offs of electricity for the customer of 24 hours. If there is a cut-off, there will be compulsory compensations to the customers from the electrical company per day for a couple of days. The same respondent said that there are plans for making a decision at Sydkraft that electrical blackouts should not be allowed to last longer than 24 hours. This promise can become real to 80 % of the population in the countryside within a five year period, the same respondent added. He said that this means investments of maybe 20-30 billions Skr. Another proposal from the Energy Market Inspection is an obligation to do risk and vulnerability analyses over the different areas that are most affected. The respondent from Sydkraft claimed that this assignment will be completed by the 31 of April. And quite right, during the work of this thesis the report "*En Leveranssäker Elöverföring*" was published (Energimyndigheten, 2005a). The Swedish Environment and Social Structure minister -Mona Sahlin also received the report from the Energy Market Inspection at the Swedish Energy Agency. The report presented 14 suggestions that will increase the security of deliverance of electricity, especially in the countryside. The suggestions will also lead to a decrease in the consequences of future storms and other difficult weather events. In a press release from the Swedish Energy Agency (Energimyndigheten 2005b) these suggestions explain briefly that there will be demands on the network owners that a disturbance will not last longer than 24 hours. There will also be a duty to pay compensation to the customers from the electrical company. There will be risk and vulnerability analysis and a better communication with the customers

(Energimyndigheten 2005b). Events not included in the responsibility are war, terror actions and nature disasters which were explained as earthquakes, earth slips and ice storms. It also emerges from the press release that recurrent weather events like thunder, snowstorms and storms are not nature disasters, and shall therefore be counted as a disturbance. It was emphasised that the storm Gudrun should be regarded as a recurrent event (Energimyndigheten 2005b).

5.6.3 Possible adaptation measures for the electrical companies

The electrical system needs to improve the security of deliverance to reduce the vulnerability for disturbances. The respondent from Swedenergy stated that we have a cable technique that makes it possible economically to upgrade the technique today. He stated that the traditional technique is not enough. The life cycle perspective of the network is important to use, he meant. A number of possible adaptation measures for reducing the vulnerability of the electrical system to the current and changing climate conditions were suggested in the interviews and from the reports:

- Cables buried underground - One respondent (Swedenergy, 2005) emphasised the life cycle perspective when building new wires for 10 kV and 20 kV distribution. The best alternative economically is to run a cable in the ground. He meant that during the whole life cycle there is no need for any maintenance. Of course the cost of investment is higher but looking on the whole life cycle the cost is lower. For the lines overhead there is a need to clear the lanes and control the poles regularly. He meant that there has been estimated within the local lines of smaller voltage (10 and 20 kV) that 55 000 km of lines need to be buried if possible. This work has started already and will continue during a period of the next ten years. It is the lines through the forest that will be attended to first according to the respondent from Swedenergy. For cables buried underground there is a completely new strategy according to the respondent from Sydkraft. Earlier there were isolated lines overhead (plastic wires), but if there is a very strong wind and trees are falling on the lines, both the lines and the poles will break. The new strategy is to bury all the cables underground where it is possible. Supporting this, it was also mentioned in the risk-and vulnerability report (Pärnerteg, 2005a) that non isolated lines overhead will be changed to isolated lines overhead or buried underground. The respondent from Sydkraft made a reservation against the burying actions of all the lines. He pointed to the fact that it might not be possible to bury all the lines underground. He meant that it is a question concerning national economy if 80 % or 100 % of the lines overhead shall be buried underground (Sydkraft, 2005).

- Break poles- According to the respondent from Sydkraft there is a new kind of poles today called break poles that are being used if it is not possible to bury the cables underground. If there would be a situation with a lot of trees on the wires, the pole will bend and the wire will fall to the ground, still functioning. The pole will still be intact and the lines are enclosed with metal. If the lines are lying on the ground, they are not dangerous for animals or humans (Sydkraft, 2005).

- Lanes- One respondent (Sydkraft, 2005) mentioned the need to broaden the lanes for the lines of higher voltage.

- Dimensioning of new wires- Svenska Kraftnät has also decided to look into the need of increasing the physical resistant power against high wind speed (Pärnerteg, 2005a).

This was also mentioned in the interviews by the respondent from Sydkraft. He stated that the Swedish network is dimensioned to handle a wind speed of 35 m/s and it might be a necessity to increase the dimension to 40-45 m/s. It seems like more than one respondent is emphatic about the need for increasing the physical resistant power.

- Risk- and vulnerability analysis- One way of viewing the different needs of reducing vulnerability is to do risk- and vulnerability analysis. The risk and vulnerability analysis by Svenska Kraftnät, mentioned earlier (Pärnerteg, 2005a) exemplifies measures for increasing the robustness of the electrical system. Actions for strengthening the national grid during the period of the next five years were mentioned in the report (Pärnerteg, 2005a).

5.6.4 Customers preparedness

When discussing the future risks, possibilities and vulnerability of the electrical system with the respondents it emerged that the durability in a region is affecting the risk and vulnerability. The consequences of a disturbance are affected by the customers preparedness to handle a break. The respondent from Svenska Kraftnät meant that people living in the cities generally have a low preparedness for electrical disturbances, since the cities are seldom affected. He emphasised that behind the electricity meters the responsibility is in the hand of the customer, and the community respectively. Customers can prepare themselves for disturbances and increase the durability in the region. In the interviews the respondents emphasised a couple of things which the customers could do to reduce the vulnerability for disturbances of the electricity:

- Keep a reserve power source. A small one might cost 10 000 Skr. The investment cost for the customer was compared by the respondent from Sydkraft to the investment cost of the electrical companies. When they are burying the lines underground it might cost 50 000-100 000 Skr/customer.
- Alternatives to electric heating in the houses, e.g. fires or LPG (liquid petroleum gas) are one important factor that was mentioned by the respondent from Sydkraft.
- The respondent from Sydkraft emphasised the need for the customers to make a plan for how to solve the water issue without electricity.
- All the citizens should do a risk analysis. One can prepare one self before a disturbance actually occurs. Just to think about the situation before it happens and how one can manage is a good thing according to the respondent from Sydkraft.
- Farmers and other customers in need of constant access to electricity could pay for "prima el" – an agreement with the electrical supplier according to the respondent from Svenska Kraftnät. The agreement assures the customer access to reserve power from the electrical companies if it is needed.

Future risks, possibilities and vulnerability of the electrical system seem to be a question that the persons behind the electricity meters can affect. One identified possibility is that if the preparedness for disturbance in the region increases the risks and vulnerability decrease.

5.6.5 Changing conditions

The respondent from The Swedish Energy Agency mentioned a couple of future possibilities: If it becomes warmer less energy will be required. If there will be more rain it will increase the production of water power. He also mentioned the access to renewable energy, like bio fuel and wind that might change but there are no studies to support that according to the respondent. The negative part is of course the extreme weather situations. Moreover, he

claimed that if the weather conditions would change this might affect the variety of trees growing in Sweden:

> We calculate that it will not be possible to grow spruce with success in the south of Sweden (The Swedish Energy Agency, 2005).

He explained that the hurricane Gudrun most of all affected the spruce. This could happen because of the silviculture in Sweden and the spruces ground root system. He meant that the well-managed forests were mostly affected because it they were not sheltered from the wind.

5.6.6 Increasing the knowledge

It emerged from the interviews that the issue of adapting the electrical system to weather related risks is being dealt with at different levels;

- The respondent from The Swedish Energy Agency mentioned a big parliamentary investigation about vulnerability with some connections to the climate issue that will now take place.
- There is some research going on regarding the issue of vulnerability in communities according to the respondent from The Swedish Energy Agency. It emerged that research is conducted in about a number of vulnerable communities in the country e.g. Kristianstad.

One measure for adapting to weather events is to view situations abroad. The respondent from Sydkraft stated that there is useful information that comes from abroad. He mentioned that France is increasing the dimension of the physical resisting power for really high wind speed. This information from abroad is of course widening the knowledge about how to solve problems. France had a nasty experience, reported in a Bulletin at Svenska Kraftnät (Svenska Kraftnät, 2000). There were two hurricanes in France the night after Christmas day in 1999. As soon as the order was back to normal again after the first hurricane the second hurricane occurred totally unannounced leaving chaos in the society. About 3 million customers had a blackout. After a while with help from reserve aggregates, about 4 % of the need of electricity in society was provided for. The head of the net is normally the manager of 140 men but over this particularly night he all of a sudden had 2000 more men from other countries who came to help with the repair work. One problem was that communications did not work in a satisfactory way. The lines overhead were not repaired until 15 of May! The government stated new rules because of this event. The new poles in the coastal areas must be able to handle harder winds and all the wires in forests must be buried underground. There are also new goals for the electric supply about how long a disturbance is allowed to last. All this will be paid by the customers in France (Svenska Kraftnät, 2000).

5.6.7 The future

The respondent from Svenska Kraftnät wanted to see more of a changeover to a small scale system with the production of the energy near the consumer. He meant that there should soon be new technique concerning solar cells and other such systems. This can create a society with less need of distribution of the energy from the production source to the consumer. Modern technique can be used when building new houses that need less energy for warming up the houses the respondent added. He thought that new technique might start a local support of energy. The respondent also stated that money is a key issue when the costumer decides to look for another solution giving less need for electricity. He referred to the cheap electricity in Sweden: “We are among the cheapest countries in the world when it comes to electricity- on the fourth place if one counts from the bottom”. It seems to be the price and not the security

that decides if one buy security or not. This is interesting as we tend to go the opposite direction with a long distance distribution instead of having the production of energy near the consumer. Does that mean that we are increasing our vulnerability?

5.7 Summary- Adaptation

- Measures that are needed to adapt to expectations from the citizens in society and from the customers are regarded as part of a long term development by the respondents. The Energy Market Inspection is working on establishing propositions for legislations to the government about increasing the security of electricity in the countryside. Recurrent weather events like thunder, snowstorms and storms are not nature disasters, and shall therefore be counted as a disturbance. The issue of adapting the electrical system to weather related risks is being dealt with at many different levels. Research is going on about a number of vulnerable communities. There will be a big parliamentary investigation regarding vulnerability. One measure for adapting to weather events is to view situations abroad. France is one example that was mentioned by one respondent. It emerged in the interviews that a number of possible strategies can be performed by the electric companies for reducing the vulnerability. For instance bury the cables underground, using new kinds of poles, maybe even increase the dimension of physical resisting power in the air wires.
- One identified possibility is that if the preparedness for disturbance in the region increases the risks and vulnerability decrease. The customers can prepare themselves and reduce the consequences of a blackout by having reserve power, alternatives to electricity for heating the houses, plans for the water issue, make a risk analysis etc. One respondent wanted a more small scale system. According to the interviews a warmer climate will require less energy; the negative part is of course the extreme weather situations. There might be an affect on the variety of trees growing in Sweden, and the spruce which was severely affected by the hurricane Gudrun might not grow in the south of Sweden in the future.
- The respondent from Svenska Kraftnät wanted to see more of a changeover to a small scale system with the production of the energy near the consumer.

6. Discussion and Conclusions

The electricity distribution system is an important part of our infrastructure in society. It appears plausible to carefully plan in advance from all threatening aspects and analyse how to make the electrical system safe from disturbances from the climate variability and change. The identified properties of human activity system suggested by Smithers and Smit, 1997 (see chapter 3.5) can help us to illustrate the sensitivity and the probability for adaptation of the electrical system to climate change and extreme climate events. In this discussion the system characteristics has been subdivided into the basic structure of this report. They will be found under the headlines; disturbance (stability), risk and vulnerability (resilience, vulnerability and flexibility) and adaptation (scale). When discussing the adaptation to climate change and variability the framework for human adaptation suggested by Smithers and Smit, 1997 (see chapter 3.6) will be used. In the end of the discussion there will be some conclusive remarks describing the essence of the discussion

6.1 Disturbance

The first characteristics that will be discussed here is the stability of the electrical distribution system in Sweden. The respondents claimed that the electricity distribution system is stable and that there are very few disturbances. According to the result of the interviews, the national grid is more stable than the lines of smaller voltage class. Disturbances of the national grid seem to occur with a frequency of ten years. Disturbances of the regional mains happen with a shorter frequency of five years. As the result shows, the dominating cause of disturbances in the electrical network in Sweden is the weather, giving most hours of breaks in Sweden. The countryside has more often disturbances and it also emerges that it is the lines overhead that are most affected by disturbances. Thunder, wet snow and hurricanes are weather types considered to cause disturbances but the stability of the system seems to be most threatened by a combination of high wind and badly cleared lanes in the forests. It seems like there is a diversion between the respondents on how and if a future climate change really is a risk or not for the electricity distribution system. This seems to depend on what kind of adaptation strategy that will be accomplished, for instance burying cables underground or modernize the lines overhead.

When looking at storm frequencies in Sweden it emerges from the interviews that some of the respondents seem to discern that storms seems to occur more often recently. This is something that has been investigated by a group of scientists at Lunds University. In the paper *Skogseko* there is an interesting article about the storm frequency in Sweden (Nilsson et al., 2005). The article emphasises that the amount of storm is not increasing according to their analysis of the 20:th century. The damages of the forests at high wind speed are however increasing a lot. It seems like it is not the frequency but the vulnerability that increases. Nilsson et al 2005, mean that there is more forest in the south of Sweden today than earlier and especially spruce which is sensitive for storm because of its ground root system. Another reason for sensitivity for storm is according to the article if there is frost in the ground or not, and the latest storm damage has been in the winter or the late autumn (Nilsson et al., 2005). It did emerge in the interviews that the silviculture is a contributing factor to the damages from the last hurricane Gudrun. It was mentioned by one respondent that the south of Sweden is generally more often hit by storms. That seems to threat the stability of the electrical system. Maybe that is something that might change in the future since the interviews show that the spruce might be affected by the climate change and may not be able to grow in the south of Sweden in the future. Vulnerability of the electricity distribution system is a much wider issue than burying cables underground.

6.2 Risk and vulnerability

The interviews stated that the electrical system is vulnerable to weather related events. However, all disturbances in the electrical system are not associated with risks or problem. This depends on where in the electric main the disturbance occurs - on what voltage class. The system is flexible. If one line is disturbed the electricity can be distributed using another line (redundancy). There is a dependency in society of a constant supply of electricity in Sweden; tenths of a second of disturbance can cause problems. Society will have big problems if the disturbance is longer than 24 hours. Vulnerability are explained by Smithers and Smith (Smithers and Smit, 1997 p.137-138) as:

> The sensitivity of a human or economic system to disruption, wound or damage from environmental change.

The vulnerability in society has increased during the past 10-20 years along with the costs for a disturbance since we tend to increase the dependence on electricity in society. It is important to notice that according to the interviews there is an expectation on society from the citizens. We tend to trust society to handle extreme situations. One respondent made an interesting remark about the difference of expectations in the Baltic countries compared to Sweden since they were also hit by the hurricane Gudrun. He meant that they were not as upset about the fact that society did not function properly after the hurricane. They are used to it. Is it possible that because the Swedish society and the electric system seem stable, and we do not have problems with electricity very often, we tend to forget to prepare ourselves for the fact that a disturbance may occur? Ulrich Beck writes in the book Risk, Environment & Modernity (Lash et al, 2000) about society and the development of society. He introduces the term *risk society*. Beck claims that the control and protective institutions in the industrial society are threatened by the development towards a modern society. This concerns political, ecological and individual risks according to Beck (Lash et al, 2000). Is the development moving to fast for us? How could we have become more vulnerable the last 20 years as suggested in the interviews? In modern society there are different demands from the citizens. For instance, it is nowadays very important for us to feel that we always are reachable for other people e.g. by telephone, fax or through the computer. One risk that emerged in the interviews is the mutual dependence relation between the electrical supply and the telecommunications. In modern society we do not calculate with the fact that we might not be reachable all the time. We do not take any actions or make plans for how to handle the situation if the communication system do not have any electricity. Is it possible that we feel so safe in modern society about having electricity in the lines that we forget our own responsibility to prepare ourselves? One aspect that might have lead to this is also the fact that you are not allowed to fix the problem yourself if there is a problem with the electricity. You must find an electrician to do the job for you. Electricity is a forbidden area, if you are not authorised. So everything about electricity is someone else's responsibility. It might be hard to see exactly when the responsibility is no longer with the electricity companies. The result from the interviews made it clear that the responsibility of the electricity companies ends by the electricity meters and that the durability in the region depends on how the customers are prepared for a possible blackout. This shows that also the resilience in a region depends on the consequences of the impact. Smithers and Smit (1997) explain the concept of resilience as the:

> Ability to recover or the degree of experienced impact without moving the system from a previous equilibrium.

Have you ever considered making a risk or vulnerability analysis concerning how you will manage in your home without electricity if there would be a blackout for a couple of days? If there is a blackout in your home, which lines are disturbed? How big is the risk that this particular line will be disturbed? Have you thought about what will function or not in your home and are you clear about how to get water without electricity? It does not help much knowing that you have an insurance that will cover the damages or that the electrical company might compensate you for the mess when you are actually in the mess. It is always nice and safe to have a plan to follow and to have the necessary equipment around in case of an electricity blackout. Auld and MacIver (2004a) state that sources of hazards, vulnerable groups, risks likely and potential interventions can be identified in vulnerability assessments (see chapter 3.5). Physical vulnerability studies could analyze impacts on the infrastructure (Auld and MacIver, 2004a).

Reducing the consequences of a weather related impact on the electrical system will make society more resilient and less vulnerable. Maybe that is why the people in the Baltic area were not as upset as we were in Sweden after Gudrun. Maybe they had a plan and were not confused and worried? A persons background and knowledge contribute to how the person solves problems. It might be a good thing to look into what exactly we learn in school about electricity and blackouts. Per Gyberg has been studying how energy is being treated as a topic in the schools in Sweden. Energy is a cross disciplinary subject connecting to problem issues outside school and according to Per Gyberg the schools tend to prefer the scientific and supply discourse (Gyberg, 2003). It appears that there is a belief that technology will solve any problem and this view is being supported by the schools. If there is any civilisation-critical discourses they are not taken seriously by the schools according to Gyberg. Thus the western way of living would then have been questioned. The understanding in schools about what a risk means is according to Gyberg used in school as something a scientist is calculating. Maybe that contributes to a belief that a risk analysis can only be conducted by authorised people in scientific contexts. Maybe it needs to be emphasised starting already in school how citizens can make their own risk analyses about their own personal way of living, in order to reduce the vulnerability. The durability for a possible climate change in a region can be increased if the customers are well prepared. So is the resilience in a region. The result states that it is not necessary to use only one source of energy as many people do today. Maybe if the price of electricity was higher, as it is in other countries we would be more willing to consider alternative sources.

There are different ways to reduce vulnerability in the electricity distribution system and technical solutions are one way of dealing with this important issue. Another angle when working with this issue should be to reduce the dependency of electricity in society. This is not a question the electrical companies can be expected to drive since they are dependent on our electrical dependency. When discussing the reduce of vulnerability and adaptation capacity with the respondents, only one respondent questioned the electricity dependence in society. The respondent from Svenska Kraftnät wanted to see more of a changeover to a small scale system with the production of the energy near the consumer. This is a technical alternative for adaptation that might be a valid solution since the distribution net seems vulnerable for weather related events. It seems to be a point in reducing vulnerability instead of trying to reduce the risk. In fact, Sarewitz et al. (2003) claim that it is important to focus on vulnerability reduction since reduced vulnerability leads to reduced risk. Unfortunately it does not seem to be a commutative relation between vulnerability and risk so reducing risk does not always leads to reducing vulnerability (Sarewitz et al, 2003). The need and dependency of electricity in society will remain even if the emissions that might cause the changing

climate decline and leads to a reduced risk in climate scenarios for further climate change. However if the need and dependence for a constant supply of electricity is being reduced in society, then the vulnerability for a sudden blackout will be less.

Another important matter is the joint starting point. It is important that all the actors have the same interpretation of the difference between a recurrent event and a nature disaster. It seems to be some uncertainty among the actors about how to separate a nature disaster from a frequent event. A risk and vulnerability analysis (Pärnerteg, 2005a) stated that the hurricane Gudrun was an extreme nature event. In the report from the Swedish Energy Agency, (Energimyndigheten 2005b) it was emphasised that storms, snowstorms and thunder are not nature disasters and the storm Gudrun should be regarded as a recurrent event. The report stated that events not included in the responsibility are war, terror actions and nature disasters which were explained as earthquakes, earth slips and ice storms. It seems to be a question of interpretation. One important step is to clarify exactly what to be counted as a recurrent event and that the different actors share this interpretation.

6.3 Adaptation

6.3.1 The nature of the disturbance or force of change

When discussing adaptation of the electrical system it emerges to be a very complex issue, with a lot of actors involved. The scale dimension of adaptation is represented here. This involves individual, community, sector, regions and so on; it seems to involve the whole of society. For the lines in forests it has been stated that the network needs a cleared lane and that seems to be a problem. Also the width of the lane can affect if disturbances will occur because of weather related events. If there is a storm, the trees might fall on the lines because the lane is not wide enough. A grown tree is about 20 meters high and the lanes in forests are at some locations not more than 6-8 metres wide according to the result. It was stated in the interviews that it is not very easy to just broaden the lanes, because there are about 20 000 km of lines in the forest land. That would lead to a lot of land needing to be cleared for broadening the lanes if one considers the height of the trees standing on each side of the lane. The width of the lane would need to be at least 40 metres. This is a very costly operation. And a very complex problem that involve a lot of actors. What does the owner of the forest think about the potential loss of that large a part of his land? On the other hand it also emerges in the interviews that the mitigation work from the electrical companies has deteriorated since the companies are working with less margins and they have fewer employees. It appears to be a chosen risk because the companies apprehend that disturbances occur rarely. In the investigation made by SMHI (SMHI, 2005) about adaptation to a future climate change it emerged that the effect on the electrical supply that might be caused by a possible climate change has not been analysed. The investigation stated that there is some uncertainty about where the responsibility for adapting to the climate change lies.

The Energy Market inspection have established propositions for legislations to the government about increasing the security of electricity in the countryside. The 14 suggestions from the report *En leveranssäker elöverföring* (Energimyndigheten, 2005a) are supposed to increase the security of electrical deliverance. It seems as the electric sector thinks that the rules are hard according to a press release from Swedenergy (Källstrand, 2005). Källstrand states that the new demands will lead to big costs for the companies and the level of that cost is unreasonable. He meant that this will lead to increasing costs for the customers in the countryside distribution. Anders Richert (2005) from Swedenergy wondered in some comments to the 14 suggestions if the customers are willing to pay for protection of the

network against events that only occur once every century (he referred to the hurricane Gudrun). The customers in France are paying their adaptation for reducing the vulnerability. The responsibility issue appears to be a question that needs to be thoroughly cleared. Who is responsible and who will pay for the adaptation? Is it the electrical companies or the land owner? Is it the customers? Maybe this is a question about national economy? There are a lot of actors involved in this complex issue and there are a big economical interests involved that will influence the national economy e. g. the forest industry.

6.3.2 The system's properties might influence its sensitivity

The complex responsibility issue and all affected actors influence the sensitivity of the electrical system. Not much will be done until it is clear who is responsible and who will pay.

Muld states in the progress report of the project that runs under the name "HEL-projektet" by the Swedish Energy Agency (see result, 5.4.2) that it is not possible to completely prevent blackouts when the security of the network is increasing. There are factors that the electricity sector can not have any influence on.

The Swedish Emergency Management Agency has been analysing the experiences after the hurricane Gudrun. Pärnerteg, 2005 states in a PM that it is established that this event is not alone a reason to make the conclusion that the electrical distribution system is not correctly dimensioned regarding physical resisting power. Pärnerteg means however that the experiences about how the storm affected the new types of wires are important to use. Furthermore, the need for establishing lines buried underground where it is possible is supported here as well. This report picks up another important point of view and that is the societal preparedness. It seems like there is a lot of reserve aggregates around but not any control over where they are. Pärnerteg means that there is a need to establish a registry over them (Pärnerteg, 2005). Muld emphasised in his report (Muld, 2004) the need for the local ability to reduce the consequences of important societal users.

The question of priority of some important customers came up in the interviews and the respondents pointed to the fact that at this point such priorities are against the law. No customers have any right to be prioritised if there is lack of electricity in society. Not even hospitals. There seems to be many things the electrical sector can do and it is a good thing to learn from experiences from events that have occurred. It would be useful to learn more about how the electrical system properties influence the sensitivity in society. We can not determine how the weather should behave, but we can try to make scenarios of a possible future climate as SweClim did (Bernes, 2003). What if the current climate in France really becomes the climate of the south of Sweden? It seems to be a reason to continue to look at France and learn about their weather events and consequences and most of all about their strategy to avoid problems.

6.3.3 The future

It emerged in the interviews that a number of possible strategies can be carried out by the electrical companies to reduce the vulnerability. And there are a lot of work going on to increase the security of deliverance of electricity. For instance burying the cables underground, using new kinds of poles, maybe even increase the dimension of physical resisting power in the air wires. There seems to be a need for the electricity sector to invest more money to mitigate the effect that a future climate change might cause. These technical actions will reduce the vulnerability of the electrical system for more extreme weather situations and an increased frequency of hurricanes. But to reduce the vulnerability of society

there is a need to further investigate the dependency of electricity. The big parliamentary investigation about vulnerability, mentioned by the respondent from the Swedish Energy Agency in the interview, might be one way of comprehending this complex issue. Sarewitz et al. (2003) states however that there is a political problem to justify vulnerability reduction economically. It is not easy to capture the political benefits of reducing vulnerability and prevent future economical losses (Sarewitz et al., 2003). The future costs are unpredictable. It is important to investigate exactly where to put the money today to prevent catastrophic losses in the future. Smithers and Smit (1997) are discussing the risk of social and economical system that are adapting to political, cultural and economic stimuli so thoroughly that they become decoupled from the natural environment. It is stated that the consequences might be an increasing vulnerability to climatic extremes even if the future climate does not change (Smithers and Smit, 1997). The adaptive capacity in Europe is according to IPCC generally high because of the economic conditions (see chapter 3.6). The well developed political, institutional and technological support system are estimated to contribute to increase the adaptive capacity in Europe. This means that there is a good chance to decrease the impact of a future climate change. The most important thing is to investigate where the vulnerability in society lies and find a valid solution to reduce the vulnerability. Sarewitz et al, 2003 states that: "vulnerability reduction is a human right issue". Modern society are obliged to protect the citizens from the threat of disasters. Since the interviews clearly states that society has developed the past 20 years so it has become more vulnerable than before, it is clear that the future development can not continue as before. There is a need for a change. Adaptation of the electrical system to the future climate change and to current extreme events involve the whole of society. We can all contribute to this because we are all involved in the development of society.

6.4 Conclusive remarks- discussion

- According to the result the national grid is more stable than the lines of smaller voltage class. The countryside has a larger need for preparedness since they have more often disturbances than cities.
- Storms in the south of Sweden seem to threat the stability of the electrical system. Maybe that is something that might change in the future since the interviews show that the spruce might be affected by the climate change and may not be able to grow in the south of Sweden in the future.
- The system is somewhat flexible. If one line is disturbed on the higher voltage class, the electricity can be distributed using another line (redundancy).
- Reducing the consequences of a weather related impact on the electrical system will make society more resilient and less vulnerable.
- All the actors should have the same interpretation of the difference between a recurrent event and a nature disaster.
- It is important to clarify where the responsibility for adapting the electrical sector to the possible climate change lies. This complex responsibility issue with all affected actors influences the sensitivity of the electrical system.
- There is a need to learn more about how the electrical system properties influence the sensitivity and vulnerability in society. There are a lot of technical solutions but maybe there is a need also to change our lifestyle. There is a need to investigate the dependency of electricity.

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Interview respondents

1. Svenska Kraftnät, Folke Pärnerteg, 24 february, 2005
2. Energimyndigheten, Swedish Energy Agency, Bengt Boström. Eskilstuna, 15 mars, 2005
3. Sydkraft, Kurt Lindqvist. 22 mars, 2005
4. Svensk Energi –Swedenergy-AB, Matz Tapper. 21 april, 2005

Appendix 1- Questions for Svenska Kraftnät, the Swedish Energy Agency and Sydkraft

Introduktion/Introduction
Berätta kort om din roll och dina arbetsuppgifter på Svenska Kraftnät.
(Give a short introduction about your role and your assignment at Svenska Kraftnät/The Swedish Energy Agency/Sydkraft)

Syn på störningar och sårbarhet i elsystemet/ viewing disturbances and vulnerability in the electrical system
Jag är intresserad av detta med störningar i elsystemet. Vad räknar du/ni som störningar i vårt elsystem? *(I am interested in disturbances in the electrical system. What do you count as a disturbance in our electrical system?)*

Är alla störningar förknippade med risker/problem? *(Are all disturbances associated with risks/problems?)*

Hur ofta inträffar större störningar i elsystemet i Sverige? *(How often do bigger disturbances occur in the electrical system in Sweden?)*

Hur ofta inträffar större störningar i södra Sverige? *(How often do bigger disturbances occur in the south of Sweden?)*
Hur sårbara är vi för elstörningar i Sverige enligt din uppfattning*?(How vulnerable do you think that we are to electrical disturbances in Sweden?)*

Hur sårbara är vi för elstörningar i södra Sverige enligt din uppfattning? *(How vulnerable do you think that we are to electrical disturbances in the south of Sweden?)*

Vad påverkar enligt din uppfattning hur stor omfattning och hur stora konsekvenser störningen får i en viss region*?(According to your opinion, what influences the extent and the size of the consequences from a disturbance in a certain region?)*

Vilka faktorer är mest betydelsefulla i detta avseende? *(What are the most significant factors concerning this issue?)*

Störningarnas orsaker och betydelsen av väderrelaterade störningar/ The causes of disturbances and the significance of weather related disturbances

Hur ofta uppfattar du att störningen beror på vädret*?(How often, according to your opinion does the disturbance depend on the weather?)*

Vilka andra orsaker kan urskiljas? *(What other reasons can be distinguished?)*

Är elsystemet enligt din uppfattning mer känsligt för vissa typer av väder, i så fall vilka*?(Is the electrical system more sensitive to specific sorts of weather types in your opinion, if that is the case- what weather types?)*

Är den vädertypen vanligt förekommande idag? *(is that weather type common today?)*

Är det din uppfattning att den vädertypen blir vanligare/inte vanligare framöver, exempelvis med tanke på klimatförändringarna? *(is it your opinion that the weather type becomes more frequent/not more frequent in the future, e.g. concerning the climate change?)*

Klimatförändringar och framtida anpassning av elsystemet? / The climate change and future adaptation of the electrical system?

Kan klimatförändringen bli ett problem för energiförsörjningen/elförsörjningen i Sverige? *(Can the climate change become a problem for the energy/electrical supply in Sweden?)*

Vilka risker för elsystemet ser du vid en framtida klimatförändring med stigande medeltemperatur och ökade antal extrema vädersituationer? *(What kind of risks do you see if the climate changes results in a rising average temperature and an increasing amount of extreme weather situations?)*

Vilka krav kommer att ställas på elsystemet med tanke på de scenarier som pekar på mer extrema vädersituationer) *(What demands will the electrical system face concerning the scenarios that indicate more extreme weather situations?)*

Vilka möjligheter och svårigheter för elsystemet ser ni med en klimatförändring? *(What kind of possibilities and difficulties do you see if the climate changes?)*

Vilket ansvar har ni att förebygga och motverka framtida problem och sårbarhet? *(What is your responsibility to mitigate and counteract future problem and vulnerability?)*

Har dagens klimatscenarier föranlett några särskilda strategier, åtgärder eller liknande för ert långsiktiga planerings- och utvecklingsarbete? *(Have the recent climate scenarios caused any special strategies, measures or similar options for your long term plans and development work?)*

Genomför ni särskilda åtgärder med fokus på minskad sårbarhet och anpassning till framtida klimatförändringar? Om ja: I så fall vilka? Om nej: varför inte? *(Do you take any special measures focusing on reduced vulnerability and adaptation to future climate change? If yes: which? If no: why not?)*

Genomför ni särskilda åtgärder osv. med tanke på nuvarande sårbarhet, risker och störningar? I så fall vilka? *(Do you take any special measures concerning present vulnerabilities, risks and disturbances?)*

Appendix 2-Questions for Svensk Energi

Introduktion/Introduction
Berätta kort om din roll och dina arbetsuppgifter på Svensk Energi.
(Give a short introduction about your role and your assignment at Swedenergy)

Syn på störningar och sårbarhet i elsystemet/viewing disturbances and vulnerability in the electrical system
Jag är intresserad av detta med störningar i elsystemet. Vad räknar du/ni som störningar i vårt elsystem? *(I am interested in disturbances in the electrical system. What do you count as a disturbance in our electrical system?)*

Är alla störningar förknippade med risker/problem? *(Are all disturbances associated with risks/problems?)*

Hur sårbara är vi för elstörningar i Sverige enligt din uppfattning? *?(How vulnerable do you think that we are to electrical disturbances in Sweden?)*

Störningarnas orsaker och betydelsen av väderrelaterade störningar/The causes of disturbances and the significance of weather related disturbances
Är elsystemet enligt din uppfattning mer känsligt för vissa typer av väder, i så fall vilka? *?(Is the electrical system more sensitive to specific sorts of weather types in your opinion, if that is the case- what weather types?)*

Är den vädertypen vanligt förekommande idag? *(Is that weather type common today?)*

Är det din uppfattning att den vädertypen blir vanligare/inte vanligare framöver, exempelvis med tanke på klimatförändringarna? *(Is it your opinion that the weather type becomes more frequent/not more frequent in the future, e.g. concerning the climate change?)*

Klimatförändringar och framtida anpassning av elsystemet?/ The climate change and future adaptation of the electrical system?
Kan klimatförändringen bli ett problem för energiförsörjningen/elförsörjningen i Sverige? *(Can the climate change become a problem for the energy/electrical supply in Sweden?)*

Vilka risker för elsystemet ser du vid en framtida klimatförändring med stigande medeltemperatur och ökade antal extrema vädersituationer? *(What kind of risks do you see if the climate changes resulting in a rising average temperature and an increasing amount of extreme weather situations?)*

Vilka krav kommer att ställas på elsystemet vid en klimatförändring? *(What demands will the electrical system face concerning a climate change?)*

Vilka möjligheter och svårigheter för elsystemet ser ni med en klimatförändring? *(What kind of possibilities and difficulies do you see if the climate changes?)*

Vilket ansvar har ni att förebygga och motverka framtida problem? *(What kind of possibilities and difficulies do you see if the climate change?)*

Har dagens klimatscenarier föranlett några särskilda strategier, åtgärder eller liknande för ert långsiktiga planerings- och utvecklingsarbete? *(Have the recent climate scenarios caused any special strategies, measures or similar options for your long term plans and development work?)*

Genomför ni särskilda åtgärder med fokus på anpassning till framtida klimatförändringar? Om ja: I så fall vilka? Om nej: varför inte? *(Do you take any special measures focusing on reduced vulnerability and adaptation to future climate change? If yes: which? If no: why not?)*

Genomför ni särskilda åtgärder osv. med tanke på nuvarande risker och störningar? I så fall vilka? *(Do you accomplish any special measures concerning present vulnerabilities, risks and disturbances?)*

Efter att ha läst rapporten har jag några frågor knutna till den/ After reading the report I have some questions about it
Vad betyder redundans? *(What does redundance mean?)*

Påverkas en kabel i marken av översvämningar? Fuktkänslighet? *(Does a cable buried underground become affected by flooding? Sensitivity for moist?)*

Betalar man lika mycket för el på landsbygden och i stan? *(Do the customers pay the same for electricity in the city and electricity in the countryside?)*

Prioriteringar av leveranser till vissa kunder verkar vara en svår fråga där den nuvarande lagstiftningen inte tar tydlig ställning till hur frågan ska hanteras, görs det något för att tydliggöra ansvarsförhållanden? *(Priority of deliverance to certain customers seem to be a difficult question where the current legislation does not clearly take up a definite position about how to handle the issue, is something being done to clarify the responsibility?)*