Climate Change Concerns and Finnish Electric Power Supply Security Performance

Sinan Küfeoğlu
Department of Electrical Engineering and Automation
Aalto University
Espoo, Finland
sinan.kufeoglu@aalto.fi

Niyazi Gündüz
Department of Electrical Engineering and Automation
Aalto University
Espoo, Finland
niyazi.gunduz@aalto.fi

Matti Lehtonen
Department of Electrical Engineering and Automation
Aalto University
Espoo, Finland
matti.lehtonen@aalto.fi

Abstract **– The significance of the continuous electric power service is getting higher and higher. Countries are developing policies to strengthen their electric power system infrastructure to sustain an acceptable level of supply security. The European electric power policies are guided by the climate and energy goals of the European Union. Climate change related extreme weather events pose a great threat against the power reliability. In terms of natural disasters and their impacts on electricity, Finland is among one of the most affected countries in Europe. This paper presents a detailed electric power reliability analysis for Finnish power system. The increasing influence of natural disasters on supply security is highlighted. The future plans of the Finnish authorities to further harden the power infrastructure and the policy changes to push the network operators to increase the customer satisfaction are also mentioned.**

Index Terms – reliability, climate, compensation, interruption, blackout,

I. INTRODUCTION

Continuous electric power has become a vital matter for the wellbeing of the societies. Almost all daily activities rely on electricity and hence in case of interruptions normal routine comes close to a halt. Finland is one of the developed countries that heavily depend on services which are provided by electricity. By being aware of the crucial impacts of power outages, the Finnish authorities have designed and constructed a robust electric power transmission and distribution infrastructure despite the harsh winter conditions the country is accustomed to experience. Nevertheless, what the country has not been used to is the increasing numbers of extreme weather conditions such as severe storms and thunderstorms. The Finnish electric power security has been under heavy criticism after the summer storms of 2010, winter storms of 2011, 2013 and 2015. This paper aims to analyze the reliability of the Finnish electric power system by paying special attention for the outcomes of the recent natural disasters which seriously threatened the wellbeing of the Finnish society.

II. THE STORMS AND BLACKOUTS

Finland has adapted its electric power system according to the tough winter conditions. Thanks to its robust infrastructure the country had been enjoying a high level of reliability until the recent years. However starting from the year 2010, the Finnish authorities have begun to realize that the electric power system is highly vulnerable against the extreme weather related natural disasters. During late July 2010, the country was hit by severe storms accompanied by thunders [1]. The storms caused excessive damage on forests. In addition, the thunderstorm activity reached a record high by 170 000 registered ground flashes, which was 20% higher than the long term average. The falling trees on the aerial distribution lines and excessive number of the thunders caused extensive blackouts throughout the country. From a total of 3.2 million electricity customers, about 481.000 had to experience power interruptions [2].

One year after the unusual storms activity of 2010, the country was shocked by another extreme weather event. During the Christmas time of 2011, the whole Baltic region was hit by Cyclone Dagmar. The storm caused devastating impacts around the region. In addition to the hazardous outcomes of the storm such as accidents, lack of fresh water and heating, interruptions in communication and transportation services, Finland experienced unusual long lasting blackouts [3]. About 18% of the whole customers suffered from interruptions which vary from minutes to several weeks [4]. The detailed information on the impacts of Cyclone Dagmar in Finland can be found at [3].

The year 2013 was another difficult year for the distribution system operators (DSO). The Storm Eino of October 2013 caused some 110 kV lines to trip and resulted in about 250.000 customer-outages [5]. According to Finnish transmission system operator (TSO) Fingrid, some transmission lines were disconnected due to the falling trees from the storm and the situation could be fixed within 40 minutes [6]. Major damage was seen at the distribution level. The DSO Elenia was the most affected company with 92.000 customer-outages [7].

The year 2015 was another unlucky year for Finland. By autumn, the storm Valio hit the country resulting in massive blackouts which left almost 170.000 households without electricity [8]. The extreme weather continued during winter and the snow storm caused long lasting blackouts especially around central-Finland [9]. The detailed statistics about the frequency and the duration of the interruptions due the snow storms have not been publicly shared yet.

III. THE ELECTRIC POWER RELIABILITY IN FINLAND

System Average Interruption Duration Index (SAIDI) is a useful tool in assessing the reliability level of a certain region or customer segment. Fig. 1 illustrates the yearly change of SAIDI hours in Finland between 2007 and 2014 [10]. It also presents the main causes of the outages.

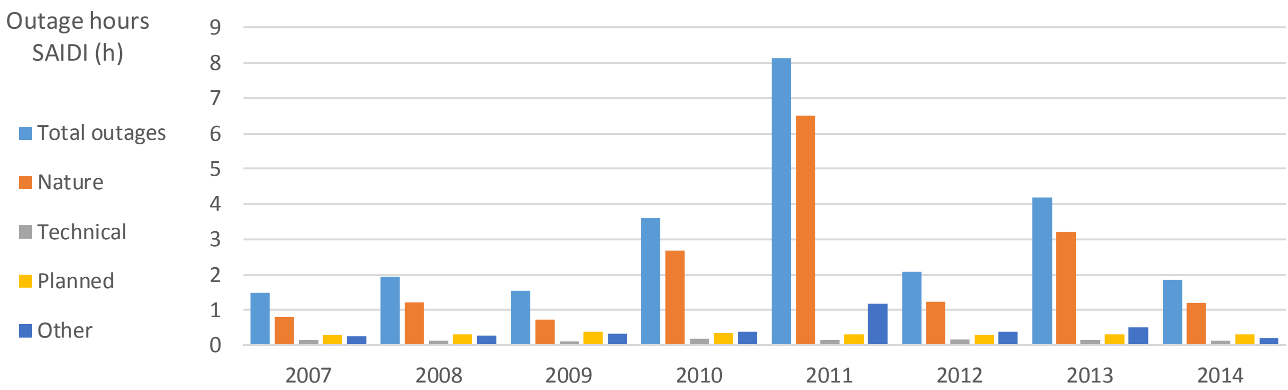

Fig. 1. SAIDI outage hours in Finland, 2007 - 2014

The power interruptions are mainly caused by natural effects such as storms, hurricanes, heavy snowfall, thunderstorms and etc. The other parameters are technical reasons, planned outages due to repair and maintenance and other causes. The impacts of the 2010, 2011 and 2013 storms on electric power security can easily be observed on the Fig 1. When these years are excluded, it is seen that the SAIDI outage hours is below 2 hours per year. This figure clearly shows that the main threat against the Finnish electric power security is the natural disasters. Fig. 2 indicates the distribution of the nature events in the outage hours [10].

The statistics show that even though Finland is famous with its cold and long lasting winters, the power infrastructure is durable against snow and ice. However the figure also shows the power system is not prepared and designed against the harsh winds and storms. This is understandable when the phenomenon of the climate change is highlighted. The true nature of the global warming is still debatable. However it is clear that both the number and the frequency of the extreme weather related natural disasters have increased noticeably for the last decade [11]. The authorities are now aware of this fact and hence to improve the electric power reliability against the natural disasters they initiated a vast transformation in the power systems. This struggle can be overviewed under two subtitles. The first one is the legislative attempts to protect electricity customers against long lasting interruptions. The second one is the direct investments in the infrastructure. Finland is a pioneer in providing standard customer compensations in case of excessive outages. To achieve this goal, the Energy Market Act of Finland introduced a legislation in 2003 which defined maximum allowable single event outage durations [12]. Different unallowable durations corresponded certain penalties. According to this legislation, in case the single event outage exceeds the allowable limit, the utility is supposed to pay the corresponding percentage of the annual electric power delivery fee back to the customer. Nevertheless, after the shocking events in 2010 and 2011, in 2013 an update in the standard customer compensations was made [13].

The compensation scheme accepted in 2003 and in 2013 are summarized on Table I and Table II respectively. In 2003 the maximum allowable penalty was set to be 700 €/year. However, after 2013 this amount was raised to 1200 €/year. In addition to this radical update, in 2012 the Finnish Ministry of Employment and the Economy introduced a change in the legislation.

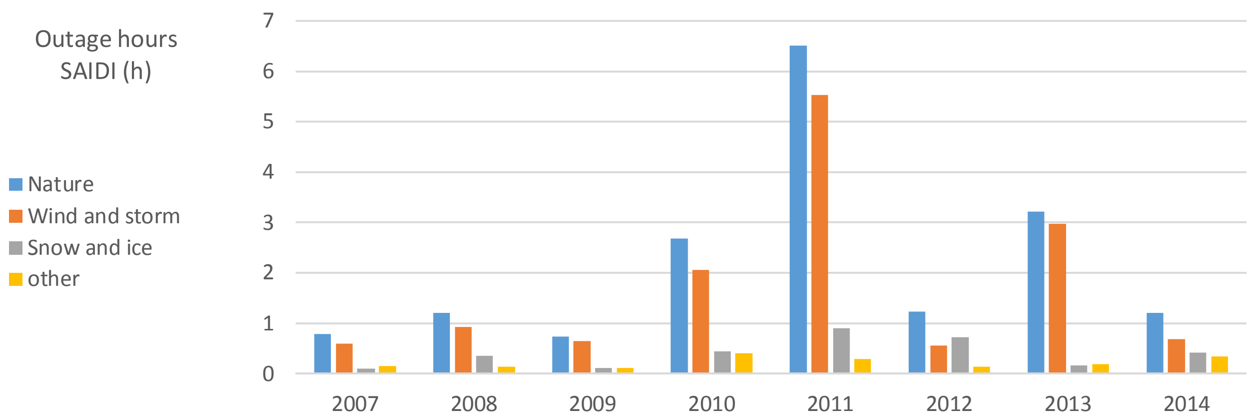

Fig. 2. Nature SAIDI outage hours in Finland, 2007 - 2014

TABLE I. THE STANDARD CUSTOMER COMPENSATIONS ACCORDING TO THE LEGISLATION ACCEPTED IN 2003

Standard Customer Compensation (2003)	
Outage time (h)	*Compensation (%)*
12 - 24	10
24 - 72	25
72 - 120	50
>120	100

TABLE II. THE STANDARD CUSTOMER COMPENSATIONS ACCORDING TO THE LEGISLATION ACCEPTED IN 2013

Standard Customer Compensation (2013)	
Outage time (h)	*Compensation (%)*
12 - 24	10
24 - 72	25
72 - 120	50
120 - 192	100
192 - 288	150
>288	200

According to the addition to the electricity market act, paragraph 51, for urban distribution regions the longest acceptable single time interruption event is set to 6 hours whilst it is defined to be 36 hours for the rural distribution regions [13]. The utilities are supposed to comply with these new time caps by the end of 2028 [13]. Fig. 3 shows the yearly change in both amount of customer compensations and the number of customers eligible to receive these [14].

It is obvious that the years 2011 and 2013 were not satisfactory years for the DSOs. The amount that paid back to the customers as outage compensations reaches 47 M€ in 2011. And it is more than 20 M€ in 2013. The distribution of the standard compensations per outage duration in M€ and the distribution of the number of customers received standard compensations per outage duration in 1k are shown in Fig 4 and Fig 5 respectively [14].

From Fig 4 and Fig 5 it is seen that the main challenge for the utilities is the interruptions lasting up to 72 hours. The longer ones might be regarded as exceptional events excluding the year 2011. The utilities found the remedy for avoiding such interruptions in increasing the degree of cabling in their distribution network. This is a part of the second main discussion in boosting the level of reliability, which is the direct investments in the electric power infrastructure. The focus is on the increasing the degree of cabling in the low voltage (LV) and medium voltage (MV) networks.

In 2012, the percentage of underground cables in MV and LV networks were 12% and 38% respectively [15]. In 2014 these

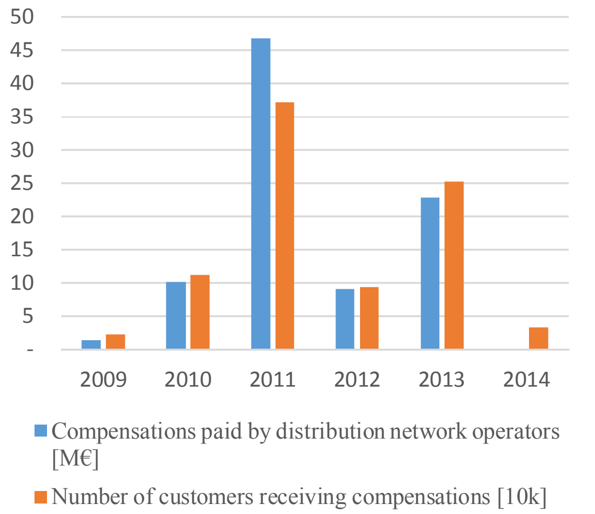

Fig. 3. Compensations and number of compensated customers in Finland from 2009 to 2014*

*The data for the amount of standard compensations paid by the DSOs during 2014 are not publicly available yet.

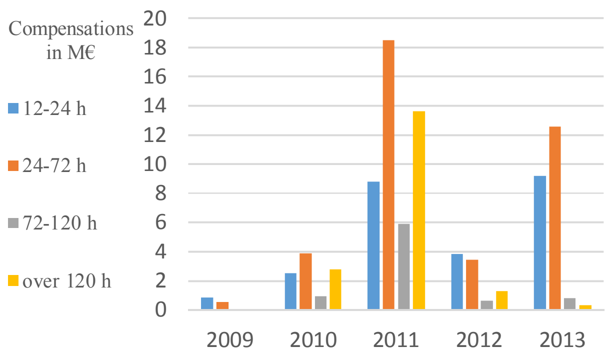

Fig. 4. Distribution of standard compensations per outage duration

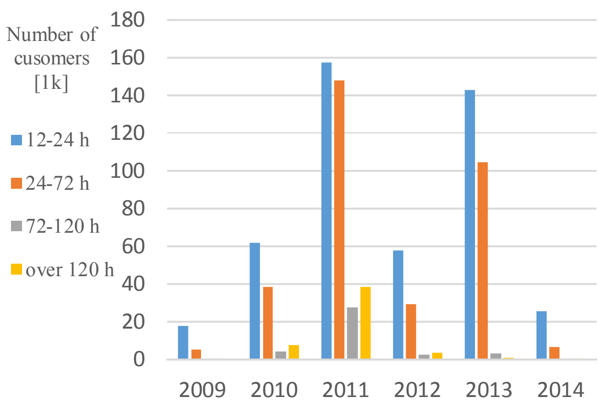

Fig. 5. Distribution of number of customers received standard compensations per outage duration

figures reached 16% in MV network and 42% in LV network [15]. In addition to the cabling efforts, the Finnish TSO Fingrid plans to invest about 1.2 billion euros from the year 2015 to 2025 to construct 3000 km of new transmission lines and 30 new substations [16].

IV. Discussion & Conclusions

Thanks to the increasing number of the natural disasters the time that the Finnish electricity customers enjoyed high level of supply security is over. An annual average of 2 hours of interruption is regarded to be acceptable for the Finnish authorities. However statistics show that this figure is easily exceeded in case of severe storms, heavy snowfalls and large thunderstorms. When compared to the rest of the European Union (EU), before the year 2010 the Finnish reliability indices show a relatively satisfactory performance [17]. Nonetheless, after 2010 the situation deteriorates. Fig. 6 summarizes the comparison of the SAIDI hours of Finland, the EU (excluding Slovenia and Malta), Denmark and Germany [17].

The authorities and the network operators are aware of this worsening performance. When compared to the high performing countries such as Denmark and Germany, the main problem for Finland is the sparsely distributed population. This necessitates the aerial distribution lines to pass through forests to feed relatively small populations. And falling trees on the lines are the number one foes against the supply security. The Finnish Ministry of Employment and the Economy proposes to build new overhead lines to the road sides instead of passing those through forests [12]. In addition cutting of the vegetation and enlarging the line corridors is another step to improve the supply security. The ultimate goal is to assure that no customer will experience a single time outage even lasting longer than 6 hours in the city regions and 36 hours in the rural regions [18].

One fortunate matter for the future grid planners is that the country's electric energy consumption per capita is not increasing [19]. On the contrary Fig. 7 shows that the trend line tends to decrease due to stable population and the ongoing recession in the Finnish economy. Surely this will help to avoid extra investments to meet the increasing electric energy demand. Another positive impact will come by the extensive usage of smart devices. Finland is aiming to transform its ageing power system into a smart grid by providing attractive incentives to the network operators. The cost of all direct and indirect impacts of the power interruptions during 2011 reaches 890 M€ [20]. One criticism however could be brought to the ten year development plan. After the global financial crisis in 2007, the Finnish economy has been struggling with recession fears. The Ministry of employment and the economy prepared a national energy and climate report in 2013 [21]. This report includes a future energy mix scenario which is based on the decisions made by the end of 2010. According to the plans the nuclear power plant Olkiluoto was expected to be completed by the year 2015. However, the plant is still under construction in 2016. The future plans of carrying a substantial portion of the aerial lines to underground, constructing 3000 km of new transmission lines and 30 new substations and replacing the ageing infrastructure with smarter ones might be questionable. On the other hand one can claim that the Finnish electric power supply is already secure and the natural disasters are rare events.

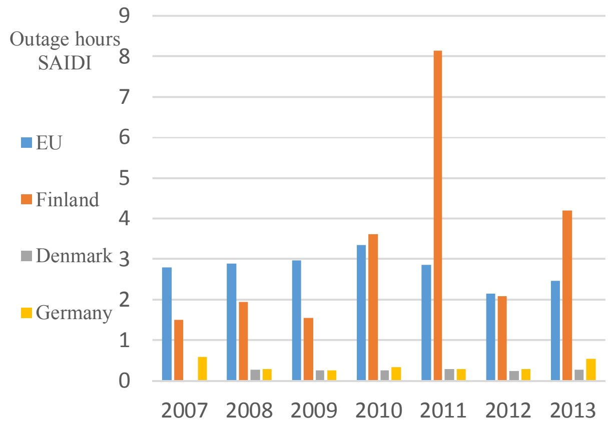

Fig. 6. Comparison of outage hours between Finland, the EU, Denmark and Germany

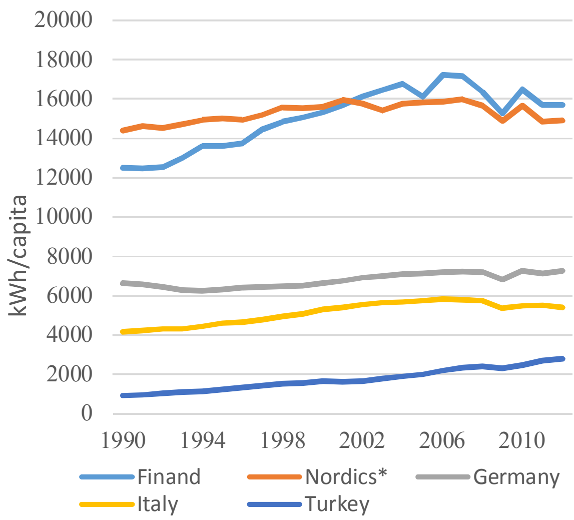

Fig. 7. Yearly change of electric energy consumption** per capita in several countries

*Finland, Sweden, Norway and Denmark (Iceland excluded)

** Electric power consumption measures the production of power plants and combined heat and power plants less transmission distribution and transformation losses and own use by heat and power plants.

Acknowledgment

This paper has been prepared as a part of the Smart Control Architecture for Smart Grids (SAGA) project at the Department of Electrical Engineering and Automation, School of Electrical Engineering, Aalto University, Espoo, Finland.

REFERENCES

[1] Finnish meteorological institute, Press release archive: 2011, 2010 – a year of weather extremes, available at: http://en.ilmatieteenlaitos.fi/press-release/125205, last visited on 22.02.2016.

[2] K. Hanninen, J. Naukkarinen, 570 000 customers experienced power losses at the end of the year, (Loppuvuoden sähkökatkoista kärsi 570 000 asiakasta, in Finnish), Finnish Energy Industries's press release in 19th January 2012, November 25th, 2012, available at: http://energia.fi, last visited on 22.02.2016.

[3] S. Kufeoglu, M. Lehtonen, Cyclone Dagmar of 2011 and its impacts in Finland, Innovative Smart Grid Technologies Conference Europe (ISGT-Europe), 2014 IEEE PES, pp. 1-5, Istanbul, Turkey.

[4] I. Horelli, The Tapani Day, 26.12.2011, storm damage in south – western Finland, (Tapaninpäivän 26.12.2011 myrskytuhot Lounais- Suomessa, I. Horelli, Lounais – Suomen aliehallintovirasto, Pelastustoimi ja varautuminen, Lounais-Suomen aluehallintoviraston julkaisuja Publikationer från Regionförvaltningsverket i Sydvästra Finland, 2:2012, Raportti), ISSN (PDF) 1798-8292.

[5] Yle.fi press release, Einon katkomia sähköjä korjattu urakalla - yli 300 vielä sähköttä, available at: http://yle.fi/uutiset/einon_katkomia_sahkoja_korjattu_urakalla_-_yli_300_viela_sahkotta/6945413, last visited on: 22.02.2016.

[6] [6] Fingrid, Eino-myrsky vaikutti myös Fingridin 110 kV kantaverkkoon, available at: http://www.fingrid.fi/fi/ajankohtaista/tiedotteet/Sivut%2FEino-myrsky-vaikutti- my%C3%B6s-110-kV-kantaverkkoon-.aspx, last visited on 22.02.2016.

[7] Elenia, Hyvitykset ja korvaukset automaattisesti 6 kk kuluessa – Eino-myrsky faktoina ja lukuina, available at: http://www.elenia.fi/uutiset/hyvitykset-ja-korvaukset-automaattisesti-6-kk-kuluessa-%E2%80%93-eino-myrsky-faktoina-ja-lukuina, last visited on 22.02.2016.

[8] Finland times, press release, Massive blackout as Valio hits country, available at: http://www.finlandtimes.fi/weather/2015/10/03/20956/Massive-blackout-as-Valio-hits- country, last visited on 22.02.2016.

[9] Finland times, press release, Snow storm causes massive power outage, available at: http://www.finlandtimes.fi/weather/2015/11/22/22580/Snow-storm-causes-massive- power-outage, last visited on 22.02.2016.

[10] Finnish Energy Industries, 2013, Outage statistics 2007 – 2014, available at: http://energia.fi/tilastot-ja-julkaisut/sahkotilastot/sahkon-keskeytystilastot, last visited on 22.02.2016.

[11] S. Kufeoglu, S. Prittinen, M. Lehtonen, "A Summary of the Recent Extreme Weather Events and Their Impacts on Electricity", In International Review of Electrical Engineering, vol.9, no. 4, pp. 821-828, 2014.

[12] Report on Electricity Security of Supply 2012, (Kertomus sähkön toimitusvarmuudesta 2012, in Finnish), Energy Market Authority, Finland, available at: http://www.energiamarkkinavirasto.fi/files/

[13] Electricity Market Act, (Sähkömarkkinalaki, in Finnish), Ministry of Trade and Industry, Finland, available at: http://www.finlex.fi

[14] Energy Authority, Electricity network the key figures, available at: http://www.energiavirasto.fi/muut-tilastot, last visited on 22.02.2016

[15] Energia, Statistics and Publications, available at: http://energia.fi/tilastot-ja-julkaisut, last visited on 22.02.2016.

[16] Fingrid, Finnish power systems, 2016, available at: http://www.fingrid.fi/fi/voimajarjestelma, last visited on 22.02.2016

[17] Council of European Energy Regulators, CEER Benchmarking Report 5.2 on the Continuity of Electricity Supply Data update, 2015, available at: http://www.ceer.eu/portal, last visited on 19.2.2016.

[18] Finlex, The Electricity Market Act, Sähkömarkkinalaki, 588/2013, available at: www.finlex.fi, last visited on 22.02.2016.

[19] The World Bank, Electric power consumption (kWh per capita), available at: http://data.worldbank.org, last visited on 22.02.2016.

[20] S. Kufeoglu, S. Prittinen, M. Lehtonen, "Customer interruption costs calculation of finnish electricity customers", 12th International Conference on the European Energy Market (EEM), Lisbon, Portugal, 2015.

[21] Ministry of employment and the economy, Kansallinen energia – ja ilmastostrategia Taustaraportti, Helsinki, Finland, 2013, available at: http://www.tem.fi