Protection System Faults – a Comparative Review of Fault Statistics

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***Abstract*—Correct operation of the protection system is of vital importance for the reliability and security of supply. Information of protection system faults is therefore important for different purposes such as quality of supply regulation and as input data to security and reliability analysis. This paper provides a comparative review of the Norwegian and Finnish fault statistics for line and transformer protection systems at the voltage levels 132 – 400 kV for the period 1999 – 2004. Unwanted operation is the major fault type, particularly for transformer protection. Human causes dominate by roughly 50 %, technical faults count for 20 – 30 % while there are large portions of faults where the cause is not identified. In Norway 20 % of the total energy not supplied at these voltage levels are caused by the protection. The corresponding portion in Finland is only 4 %.**

***Index Terms*—Energy not supplied, fault, human factors, power system protection, power system reliability**

I. Introduction

CORRECT operation of the protection system is of vital importance for the reliability and security of supply. Analyses of recent blackouts have shown that such incidents are usually caused by combinations of failures where incorrect operations of the protection system play important roles [1, 2]. Previous studies of the Norwegian fault statistics have shown that the protection system has a large number of incorrect operations and is a significant contributor to energy not supplied and thereby the customers' interruption costs [3, 4]. This problem might aggregate as the power systems are operated closer to their limits. The increased focus on reliability and security of supply has therefore brought increased attention to the protection and control systems.

Deregulation of the electricity sector and the pressure on cost reductions can weaken the quality of supply through less investments and reduced maintenance. Quality of supply regulation is therefore a growing area of interest in liberalized energy markets. Different mechanisms to provide quality incentives in the network monopoly are discussed in [5]. Examples are yardstick competition, performance standards and economic penalties such as the Norwegian CENS arrangement [6]. In this arrangement the network companies' revenue caps are adjusted in accordance with the customers' interruption costs (in principle). CENS is calculated as the product of average interruption cost rates and energy not supplied (ENS) caused by long interruptions (> 3 minutes). In Finland there is no system like the Norwegian CENS, but the distribution grid owners have to pay compensation to customers if the interruption time is more than 12 hours.

Finland and Norway both take part in the Nordic cooperation on fault statistics through the Nordel organisation. The Nordel statistics comprise faults during power system disturbances and there are some common classification guidelines [7]. These statistics provide limited information on protection system incorrect operations. However the information collected on each incident in the different countries and the data basis gives possibilities for more detailed exploration of such faults. This paper provides a comparative review on the Norwegian and Finnish fault statistics for line and transformer protection systems at the voltage levels 110 – 420 kV for the period 1999 – 2004. Differences in the power systems and external conditions, data collection and registration routines are commented.

The kind of information given in this paper is important for different purposes such as quality of supply regulation and as a basis for more detailed input data to security and reliability analysis methods. In both countries there are projects going on where the aim is to handle protection operations in such kinds of analyses.

Section II of the paper gives the main characteristics of the power systems in Norway and in Finland. It also introduces an overview of the disturbances and the disturbance data bases. In Section III major causes for protection incorrect operations are presented together with protection performance indicators. Section IV provides a comparative review of the protection system faults. The conclusions are presented in Section V.

II. Power System Disturbances – An Overview

A. *The power systems in Finland and Norway*

The Finnish transmission grid consists of 400 kV, 220 kV and 110 kV overhead lines. The grid is meshed, even though some 110 kV lines are operated as radial lines.

This study was financed by Fingrid Oyj (The Finnish Transmission System Operator), Statnett SF (The Norwegian Transmission System Operator), Norwegian Electricity Industry Association, the Research Council of Norway, network companies and SINTEF Energy Research.

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The Finnish 400 kV transmission line protection system consists of two separate main protection relays. These are most often different types of distance relays using permissive overreach transfer trip (POTT) scheme. In some lines the main protection consists of one distance and one differential relay. The main protection system of 400 kV is duplicated, since the dependability of the protection is essential due to stability reasons. High resistance earth faults are detected by the sensitive earth fault current relays. The protection of 220 kV and 110 kV lines has one main protection relay only, which usually is a distance relay. In most cases there is no telecommunication channel between the relays. As a back-up there is an overcurrent relay and for high resistance earth faults there is one earth fault relay. The earth fault relay is directional at 110 kV level.

The external protection of power transformers consists of a differential relay, overcurrent relays, earth fault current relays and earth fault voltage relays. The transformer also has internal relays based on non-electrical phenomena, like a gas relay and oil thermometers.

The Norwegian transmission grid consists of 420, 300, 220, 132 kV overhead lines and there are a few km of cables at these voltage levels. The line protection on the voltage levels 220 – 420 kV consists of two separate main protection system, mainly two distance and in some lines one distance and one differential protection, with telecommunication channel and using POTT scheme. As in Finland there are high resistance earth fault protection systems. The protection of 132 kV lines has one main (mostly distance) protection, usually without communication. The power transformers at the highest voltage levels have two separate differential protection systems, overcurrent and earth fault current protection in addition to the internal protection for non-electrical phenomena.

The power systems in the Nordic countries are shown in Figure 1. The figure shows the main lines and power and transformer stations, while Table I gives an overview of the transmission grid included in the statistics and some key facts about Norway and Finland. For comparison purposes 400 kV, 220 kV and 132 kV are in this paper used as nominal voltages in accordance with Nordel (i.e. 420 = 400, 220 – 300 = 220, 110 = 132 kV).

TABLE I
THE TRANSMISSION GRID, AREA, POPULATION AND ELECTRICITY CONSUMPTION

	Norway	Finland
220 kV and 400 kV line length (2004)	8165 km	6400 km
132 kV line length (2004)	10114 km	15300 km
Number of transformers 132 – 400 kV (2004)	1056	74
Surface area	323802 km^2	338000 km^2
Population	4,6 million	5,2 million
Electricity consumpt. 2004	118 TWh	86,8 TWh

Table I brings out the fact that the total length of the two transmission grids is in the same order. There are remarkably higher numbers of power transformers in Norway (see also Fig.1). This is due to the fact that the settlements are more scattered in Norway and there are various power intensive industrial sites. The electricity consumption is about 35 % higher in Norway than in Finland, while the surface area and population are more in the same order.

Figure 1. The grid system in the Nordic countries. Red = 400 kV, blue = 300 kV, green = 220 kV, black = 132 kV. 110 kV lines are not presented in this figure.

B. *Overview of disturbances*

Table II presents the number of grid faults and disturbances and energy not supplied. Table III and IV gives the average annual fault frequencies for lines and power transformers respectively, according to the Nordel statistics [7].

TABLE II
NUMBER OF FAULTS, DISTURBANCES AND ENS, NORDEL, 2000 – 2004

	Norway	Finland
Number of grid faults, average per year 2000 – 2004	508	307
Number of grid disturbances, average per year 2000 – 2004	363	272
ENS (MWh) average 2000 - 2004	3710	125

TABLE III
FAULT FREQUENCIES PER 100 KM OF OVERHEAD LINES, NORDEL, 1995 – 2004

Network level	400 kV	220 kV	132 kV
Finland	0.37	1.0	2.54
Norway	1.33	0.91	1.34

TABLE IV
FAULT FREQUENCIES PER 100 POWER TRANSFORMERS, NORDEL, 1995 – 2004

Network level	400 kV	220 kV	132 kV
Finland	1.14	1.73	-
Norway	0.99	1.51	0.63

ENS is defined as the estimated quantity of energy that should have been delivered to the end-users if the failure in supply did not occur. In principle this variable is estimated on basis of the expected load curve for those end-users affected.

As can be seen from Table II the number of faults is about 65 % higher in Norway while ENS is thirty times more. These differences may partly be explained by geographical and structural differences: Norway is a long and narrow country with a long coastline, many fjords and mountains and the connection between the Northern and Southern Norway is quite weak. The faults at some locations at all voltage levels lead to interruptions to customers. In Finland the interruptions to customers are for the most part caused by faults at 110 kV or lower. However, it should be noted here that in this 5-year period there have been some unusual, still random, events in Norway leading to large amounts of ENS. The annual average ENS has therefore been higher in this period than previously. In Norway the estimation of ENS is coordinated with the network operators at lower voltage levels, keeping track of the total ENS caused by faults at the higher voltage levels. There may be differences in the estimation of this variable from company to company and between the two countries. Another reason may be the fact that the Finnish grid disturbance statistics cover all 400 and 220 kV lines but only 60 % of the 110 kV grid, while the Norwegian grid disturbance statistics covers all the 420, 300, 220 kV and 132 kV grid.

The average line fault frequencies are about the same level except the fact that in Finland there are more 132 kV line faults and in Norway there are considerably more 400 kV line faults. Nature causes (lightning, wind etc), count for more than 40 % of the disturbances and more than 30 % of ENS in both countries. In Finland faults due to operation and maintenance constitute the next largest portion of ENS by 26 %. In Norway a large portion of ENS has technical causes (36 %). One third of the total ENS at these voltage levels is caused by the protection and control systems (P&C) in Norway, while the corresponding figure in Finland is 12 %. P&C is however the second largest contributor to ENS after overhead lines in both countries.

C. The Finnish data base

In Finland only the Finnish TSO, Fingrid Oyj collects a comprehensive disturbance statistics. Fingrid owns nearly all 400 and 220 kV lines but only about half of the 110 kV grid (7600 km). Therefore the statistics do not cover all the disturbances. In Finland it is not mandatory to collect grid disturbance data. The operator fills the following data for each grid disturbance into the database: Disturbance number, date and time, fault location, responsible operator, grid owner, faulted component, fault type (earth fault, short circuit, other), fault cause, involved phases, relay(s) that tripped, automatic reclosures and manual reconnections, fault class (line fault, busbar fault, other fault), nature of the fault (primary fault, secondary fault) as well as free text for comments and discussions. The energy not supplied at a delivery point and the cost of energy not supplied is also recorded. The latter is the validation of financial costs of the disturbance to society, not the energy not invoiced.

Additionally, Fingrid Oyj also has a protection failure data base that covers all relay failures discovered. Protection failures detected in a grid disturbance are manually linked to the disturbance report. In this case the following additional data is available: Protected object, faulted component of the relay, mode of incorrect operation (e.g. unwanted trip, missing trip), failure cause, relay manufacturer and type, relay class (e.g. distance, overcurrent relay), protection generation (electromechanical, static, processor).

D. The Norwegian data base

The fault analysis and disturbance statistics at the voltage levels 132 – 420 kV is performed by Statnett, the Norwegian TSO. It is mandatory and therefore the disturbance statistics cover 100 % of the network. The data collected for each disturbance are quite similar to the Finnish data. In addition to the disturbance statistics Statnett collects information about all protection trips and faults. The number of incorrect trips may be larger than the number of protection system faults since one fault may lead to more incorrect trips before it is identified or corrected. The information about each protection fault comprises the following: Date and time, fault number during the disturbance, the protected component, type of protection, voltage level, fault causes, fault type (unwanted, missing, i.e. the type of incorrect operations), repair time, energy not supplied and cost of energy not supplied (CENS).

III. PROTECTION SYSTEM FAULTS (INCORRECT OPERATIONS)

A. Incorrect operations of the protection system

Incorrect operations of the protection system comprise mainly unwanted and missing trips. In addition there are some delayed trips (not focused here). The numbers presented in this paper cover the main protection systems and to some extent the back-up protection systems. If the trip signal by the main protection system is missing or delayed, the signal is registered as incorrect even though the back-up protection would operate. Unwanted trip signals by the main or back-up protection are also registered. The unwanted trips are presented with one number only and are not further divided into unwanted spontaneous and unwanted unselective trips.

The transformer incorrect trips are classified in such a way that the number of unwanted trips depends on the number of transformers tripped by the unwanted trip signal. In Finland, some relays send the trip signal to both transformers and some relays to only one transformer. On the other hand the number of correct trips is one, if one transformer is tripped correctly regardless of the number of circuit breakers that trip. In some cases the correct operation is to trip circuit breakers on both voltage levels, sometimes only the lower voltage circuit breaker. Unwanted trips by the transformer protection relays based on non-electrical phenomena are included in the numbers presented.

Table V gives an overview of the protection system fault frequency measured in terms of number of incorrect operations per 100 circuit breakers. The table shows that Norway has considerably higher frequencies than Finland. This may partly be explained by differences in registration routines and policies. Another reason may be the higher number of primary faults is in Norway, as explained in Section II. Many of the protection system faults are discovered as a result of primary faults.

TABLE V
FAULT FREQUENCIES*) FOR PROTECTION SYSTEM FAULTS, NORDEL, 1995 – 2004

Network level	400 kV	220 kV	132 kV
Finland	8,7	5,0	2,9
Norway	14,5	11,4	4,1

*) No of incorrect operations per 100 circuit breakers per year 1995 – 2004

B. Protection system fault causes

The causes for protection faults are in this paper grouped as follows:

1. Operation/testing
2. Incorrect setting
3. Design, installation etc
4. Technical equipment
5. Other, unknown

The first group covers faults introduced by human activities during testing and operation of the power system, the second group covers incorrect settings while putting into operation, while the third group covers faults introduced during manufacturing, design, installation and maintenance etc. The technical faults comprise ageing, wear, loose or damaged parts etc. The first three groups are human related causes, while the last group includes operational or environmental stress and faults where the cause is not identified.

C. Protection performance indicators

Performance indicators as defined in [8] are given below. The performance indicators measure the probability of not having a failure to operate (dependability), the ability of not having an unwanted operation (security) and the ability of not having an incorrect operation (reliability). The reliability is the combined ability of not having a failure to operate and not having an unwanted operation. These indices are defined as follows [8]:

Dependability:

$$D = \frac{N_c}{N_c + N_f} \quad (1)$$

Security:

$$S = \frac{N_c}{N_c + N_u} \quad (2)$$

Reliability:

$$R = \frac{N_c}{N_c + (N_f + N_u)} \quad (3)$$

Where

N_c = number of correct operations
N_f = number of failures to operate (missing operations)
N_u = number of false (unwanted) operations

The reliability (R) of a protection system is the probability that a protection can perform a required function under given conditions for a given time interval.

IV. A COMPARATIVE REVIEW

This section provides a comparative review of the protection system incorrect operations, fault causes and ENS due to protection system faults for the period 1999 – 2004. In general when comparing fault statistics one should keep in mind that the numbers may be affected by dissimilar interpretations, routines, philosophies and cultures related to fault registrations. This may also be the case in this paper in spite of the common Nordel guidelines for classification of disturbances.

A. Protection system incorrect operations

Tables VI and VII give the total number of protection trips for the period 1999 - 2004. The performance indicators of Norway and Finland are presented in Figures 2 and 3, respectively. In the Norwegian figures the number of correct trips includes all the protection units while the Finnish figures cover the protection system as a whole. This brings a difference in the performance indicators of those protected objects, where the main protection is duplicated. In Norway, after each trip, it is checked whether every protection unit that should have sent a trip signal has really done it. If both main units have sent the trip signal, the number of correct trips is 2, even though only one circuit breaker has tripped. In the Finnish statistics, if there is a correct trip, this is regarded as one correct trip regardless of the number of main protection units, since all we know is that at least one of the relays has sent a trip signal. This difference means that if for instance the Finnish dependability indicator of 400 kV line protection systems seems to be better than the Norwegian ones, the case is not necessarily so.

TABLE VI
NUMBER OF THE NORWEGIAN PROTECTION TRIPS 1999 – 2004

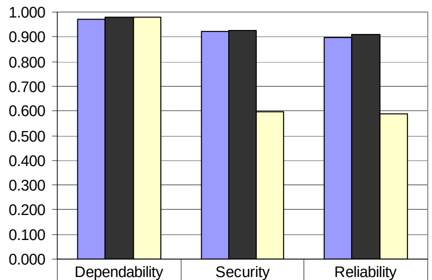
Protection	Correct	Unwanted	Missing	Other*)
132 kV line	1809	149	35	24
220-420 kV line	2267	196	63	102
132 – 420 kV transf.	662	445	15	47

*) Other = Delayed, not specified etc

TABLE VII
NUMBER OF THE FINNISH PROTECTION TRIPS 1999 – 2004

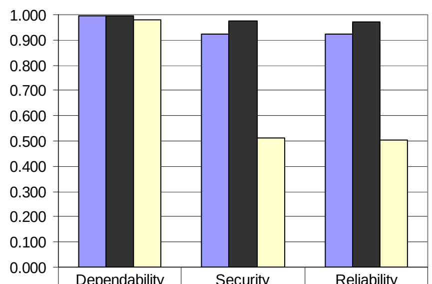
Protection	Correct	Unwanted	Missing	Other*)
132 kV line	3942	97	12	8
220-420 kV line	434	35	2	4
132 – 420 kV transf.	48	46	1	0

*) Other = Delayed, not specified etc



	Dependability	Security	Reliability
220 - 420 kV line prot	0.973	0.920	0.897
132 kV line prot	0.981	0.924	0.908
132 - 420 kV transf prot	0.978	0.598	0.590

Figure 2. The protection performance indicators of Norway.



	Dependability	Security	Reliability
220 - 420 kV line prot	0.995	0.925	0.921
132 kV line prot	0.997	0.976	0.973
132 - 420 kV transf prot	0.980	0.511	0.505

Figure 3. The protection performance indicators of Finland.

The dependability of the protection is high for lines and transformers in both countries. Therefore, the missing trip does not seem to be a major problem at any voltage level. The security indexes of the line protection are a bit lower than the dependability indexes, while the security of the transformer protection is only about 50 % in Finland and 60 % in Norway. The reliability of the protection almost equals the security of the protection.

Unwanted spontaneous trips seldom cause any problems to the system if the grid is planned and operated according to the n-1 criterion. Unwanted unselective trips can cause major problems for the stability at the highest voltage levels, but cause only local consequences at lower voltage levels. Even though there is no exact division between these two classes in this study, we know that most unwanted trips are spontaneous at the highest voltages and unselective in 110 kV level in Finland.

B. *Fault causes*

The causes for unwanted trips for lines and transformers are presented in Figures 4 and 5, respectively.

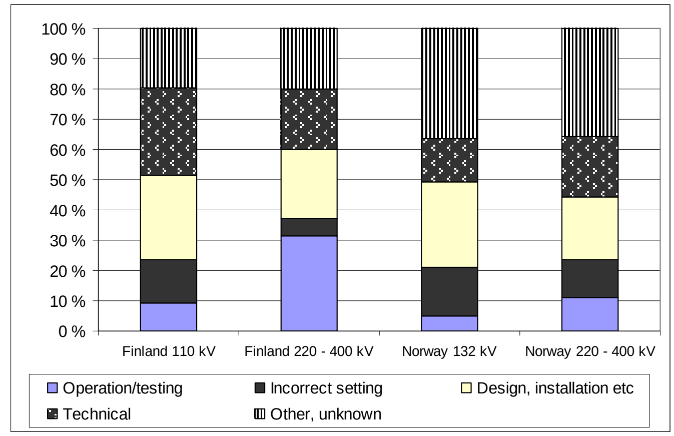


Figure 4. Percentage values of the causes of unwanted line trips.

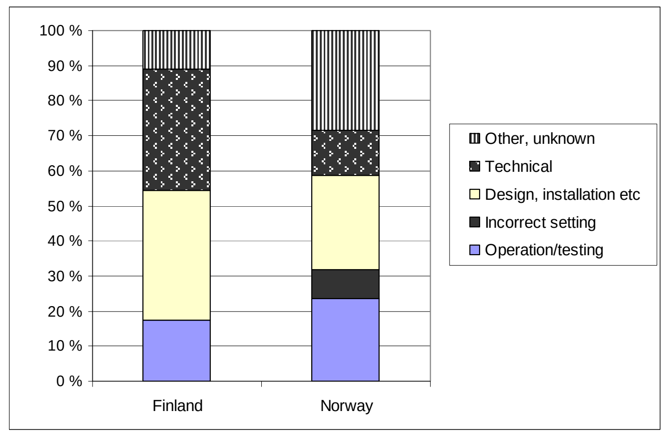


Figure 5. Percentage values of the causes of unwanted transformer trips.

As shown in Tables VI and VII unwanted trips occur more frequently than missing trips. In Norway the unwanted trips count for 60 % and 88 % of the total number of incorrect trips for lines and transformers respectively. Corresponding numbers in Finland are 84 % and 97 %. The causes for unwanted trips are roughly divided in half between human causes and technical/other/unknown causes. This is also the case for the rather limited number of the missing trips. Operation and testing together with failures introduced during design, installation etc. dominates the human causes rather than setting errors (except for missing trips in Norway). In principle, the grid company can try to reduce these errors with enhanced instructions and testing procedures. Technical failures, however, are more difficult to eliminate without replacing old relays with new ones to reduce the number of failures caused by ageing. The major challenge will be the faults introduced during manufacturing, design, installation and maintenance. Even though modern protection units have self-supervision to detect failures, they cannot send an alarm for all failures that can create problems. Incorrect settings, failures in wiring and other installation parts are examples of faults that the self-supervision cannot always detect.

C. Conventional versus numerical distance protection

For line distance protection it is possible to make a distinction between faults due to conventional protection (electromechanical and static) and numerical protection. The fault causes are shown in Figure 6 for the two types of generations.

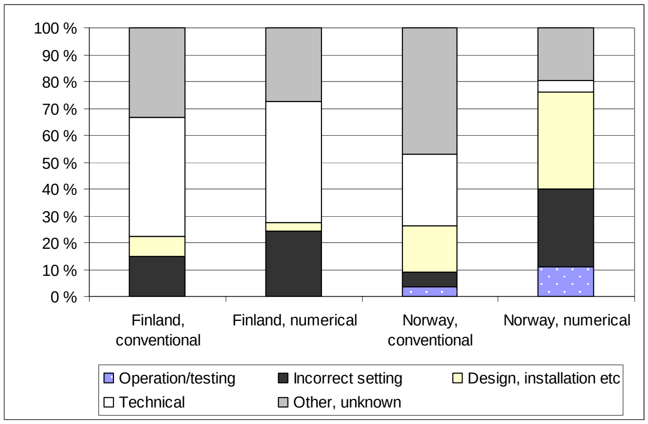


Figure 6. Failure causes of the line distance protection.

In Finland technical faults dominate for both types of distance protection, while in Norway more than 70 % of the faults on numerical protection have human causes, where incorrect settings and faults during design and installation etc dominate. Such differences in the distribution of failure causes may be explained by dissimilar interpretations. For conventional distance protection in Norway the cause is unknown or not specified for as much as nearly 50 % of the faults. In Finland the numerical units as well have more incorrect settings than the conventional. At least one conclusion is clear and coherent: It seems more difficult to define or feed the correct settings for numerical than for conventional protection. The setting and configuring of the modern microprocessor units is a complicated task and sometimes the protection engineers talk about the "setting jungle". The manufacturers develop new versions of the protection more and more quickly. The new versions tend to have more features that, in principle, can help to create better and more tailor-made settings for different grid circumstances. On the other hand, the risk of making mistakes with parameter setting and configuration has increased. One should remember that Figure 6 only presents failures discovered during grid disturbances. Self-supervision sends an alarm of some failures but not of incorrect settings, which often are detected during disturbances only.

D. Impact on the reliability of supply

Protection and control incorrect operations may initiate power system disturbances and thereby customer interruptions and/or extend the consequences. Table VIII gives an overview of energy not supplied (ENS) due to protection failures on different voltage levels.

In Norway the amount of energy not supplied due to protection system faults is larger than in Finland. This may partly be explained by the larger amount of ENS in this period in Norway (see Section II, B) and partly by differences in the registration routines and policies. For instance in Norway, if a disturbance wouldn't have resulted in an interruption unless there was an incorrect protection operation, ENS as a whole is allocated to the secondary fault. One should also note that this review comprises all 400 kV, 220 kV and about 60 % of the 110 kV in Finland, whereas the Norwegian figures cover completely the voltage levels under study.

TABLE VII
ENERGY NOT SUPPLIED (ENS) DUE TO PROTECTION FAULTS 1999 – 2004

MWh	Finland 1999 - 2004	Norway 1999 - 2004
220 - 400 kV lines	5.6	1489
132 kV lines	26.3	1201
Transformers	11.5	1731
All protection failures	43.4	4393
All ENS	1043	21716
Percentage value of protection of total ENS	4.2 %	20.2 %

V. CONCLUSIONS

This paper provides a comparative review of the Norwegian and Finnish fault statistics for line and transformer protection systems at the voltage levels 132 – 400 kV for the period 1999 – 2004. The Norwegian data on faults and disturbances cover 100 % of the network at these levels, while the Finnish data cover 100 % of the 220 – 400 kV, but only 60 % of the 110 kV network. Some similarities are found, like the fact that the main problem with protection is the unwanted trips (protection security) rather than missing trips (protection dependability). Human causes count for about 50 % of the unwanted trips. Operation and testing together with failures introduced during design, installation etc dominates the human causes. Technical faults count for 20 – 30 %, while there are large portions where the fault cause is not identified. The dependability values of protection are high in both countries for all protected objects under study. On the other hand the security of protection is not as high as the dependability for lines, even though it is over 90 %. In both countries the lowest reliability values were counted for the transformers, where the security (and the reliability) was only about 50 or 60 %. The transformers have more protection units than lines and therefore more unwanted trips, due to all kinds of reasons. Transformers are the most expensive single components of the grid and therefore the dependability is more important than the security.

When comparing the different generations of line distance protection it was found that in both countries there were more failures due to setting of modern microprocessor protection than the conventional. Many protection engineers share the opinion that it is more difficult to calculate the settings and to plan the configuration of the processor units since they have so many features and setting possibilities.

Protection and control system faults in total are the second largest contributors to ENS after overhead lines in both countries at these voltage levels. It is observed that in Norway there are more grid faults and far more ENS than in Finland in total as well as a larger portion caused by incorrect protection operations. Such differences can partly be explained by geographical and structural differences between the countries and their power systems and partly by different registration routines. In general when comparing fault statistics one should keep in mind that the numbers may be affected by dissimilar interpretations, routines, philosophies and cultures related to fault registrations. However, the Nordic cooperation in these matters steadily leads to increased quality and harmonization of the fault and disturbance data in general and the protection system fault data in particular.

VI. References

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VII. Biographies

Gerd H. Kjølle was born on February 25 1958 in Oslo, Norway. She received her MSc and PhD degrees in electrical engineering from the Norwegian University of Science and Technology (NTNU, former NTH), in 1984 and 1996 respectively. She has been with SINTEF Energy Research since 1985 interrupted by a couple of periods at NTNU, Department of Electrical Power Engineering. She is presently a senior research scientist at SINTEF Energy Research, Department of Energy Systems, working mainly with reliability and interruption cost assessment, energy systems planning and risk analyses.

Oddbjørn Gjerde was born on May 16 1970 in Volda, Norway. He received his MSc and PhD degrees in electrical engineering from the Norwegian University of Science and Technology (NTNU, former NTH), in 1993 and 1999 respectively. He has been with SINTEF Energy Research, Department of Energy Systems, as a research scientist since 2000. Main fields of work are within reliability assessment and protection and control.

Bjørn T. Hjartsjø was born on February 6 1970 in Porsgrunn, Norway. He received his MSc degree in electrical engineering from the Norwegian University of Science and Technology (NTNU, former NTH) in 1995. He has been with Statnett SF, the Norwegian transmission system operator, since 1996. In 1996-2003 he worked mainly with fault analysis, fault statistics and reliability of supply. Since 2003 he has been working as an operator in the regional control center for the main grid in the southern part of Norway.

Haakon Engen was born on June 15 1979 in Lillehammer, Norway. He received his MSc in electrical engineering from the Norwegian University of Science and Technology (NTNU) in 2004. He has been with Statnett SF, the Norwegian transmission system operator, since 2004, working mainly with fault analysis, fault statistics and CENS.

Liisa Haarla (formerly Pottonen) was born on October 16 1956 in Eno, Finland. She has received M.Sc. and Dr. Tech degrees in Electrical Engineering from Helsinki University of Technology in 1982 and 2005, respectively. She has been in Imatran Voima Oy (1982-1997), in the Finnish transmission system operator Fingrid Oyj (1997-2002, and 2005), in VTT (2002-2003) and in Helsinki University of Technology (2004). She has mainly worked on various system engineering, relay protection and reliability issues. From January 2006 she has been professor of Power Transmission Systems in Helsinki University of Technology.

Lauri Koivisto is a senior specialist and has been working on relay protection issues since 1974. He started in Imatran Voima Oy as a relay test engineer. After that he has been working on protection planning issues, calculating the relay settings, and developing the relay protection database. Now he works in the relay protection team of Fingrid Oyj and his main responsibility is relay setting calculation.

Patrik Lindblad is M.Sc. (El.Eng.) and started in Imatran Voima Oy in 1989 working with control and protection system planning and specification issues. He has worked in Fingrid since 1995 both as substation project manager and as team leader for Fingrid's relay protection specialist team. His main responsibilities are overall co-ordination of relay protection work in Fingrid and control and protection specifications.