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Nordel's Guidelines for the Classification of Grid Disturbances

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1. Introduction

The guidelines have been prepared by the Grid Disturbance Group (STÖRST), which has been organised under Nordel's Operations Committee.

The guidelines and the accompanying examples replace the guidelines and examples from 1971. New experience and assessments have been incorporated into the present guidelines. The greatest difference between these guidelines and those dating from 1971 when only faults were reported is that the concept of grid disturbances has been introduced. Grid disturbances may involve one or more faults.

The purpose of the guidelines is to lay down the definitions and instructions necessary to ensure uniform classification and calculation of the number of grid disturbances and faults for the statistics published by Nordel. Furthermore, instructions are included for the possible incorporation into national statistics with a view to facilitating the comparison of operating experience.

The guidelines are intended to form the basis of common grid disturbance statistics within Nordel. Chapter 3 sets out the purpose of Nordel's grid disturbance statistics. Chapter 4 describes the scope of the statistics and the limitations imposed. The necessary terms are defined in Chapter 5. Chapter 6 lists how and what to report in connection with each grid disturbance. This is followed by a number of examples of different types of grid disturbances in Chapter 7. Chapter 8 gives an account of how compilations of grid disturbances should be reported for a joint annual report. The final chapter of the document looks to the future and considers ideas for further developing the grid disturbance statistics.

The document was originally written in Swedish.

2. Scope of the guidelines

These guidelines came into effect on 1 January 2000. The year 2000 is, however, a transition year as the guidelines were to be applied to the extent possible.

3. Purpose of the guidelines

The purpose of the grid disturbance statistics is to compile data which can form the basis of:

- A correct assessment of the quality and function of the different components
- A calculation or assessment of the reliability of the transmission system
- An assessment of the quality of delivery points
- Studies of trends and comparisons of different parts of the Nordel grid

4. Scope and limitations of the statistics

The statistics comprise[1]:

- Grid disturbances
- Faults causing or aggravating a grid disturbance
- Disconnection of end users in connection with grid disturbances
- Outage in parts of the electricity system in conjunction with grid disturbances

The statistics do not comprise:

- Faults in production units
- Faults detected during maintenance
- Planned operational interruptions in parts of the electricity system
- Behaviour of circuit breakers and relay protection if they do not result in or extend a grid disturbance

The statistics are limited to transmission units in commercial operation with a voltage of at least 100 kV, including units for reactive compensation.

Figure 4.1 shows the extent to which power transformers, shunts, SVCs and HVDC units are included in the statistics. Power transformers for the transmission of energy to lower voltages are included in the statistics. On the other hand, generator step-up transformers are not included. Power transformers for HVDC are not registered separately, but as components in an HVDC unit.

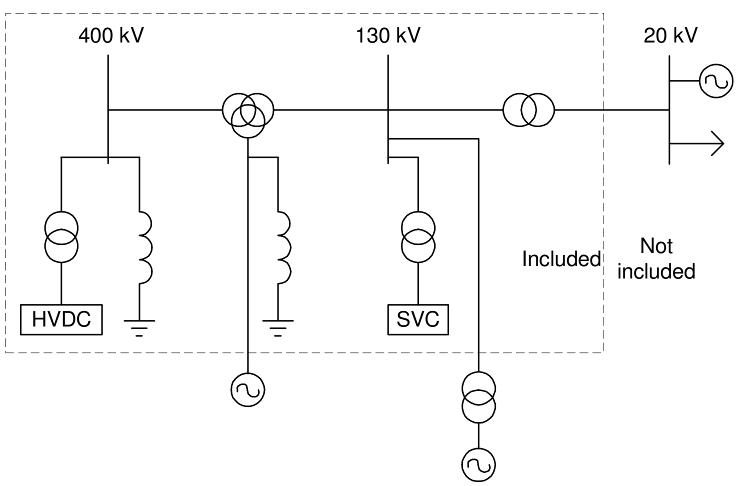


Figure 4.1 The dashed-line rectangle shows the types of components which are included in the statistics.

[1] Although the classification of grid disturbances and faults in HVDC systems is described in the guidelines, Nordel does not currently publish HVDC statistics. Please refer to the CIGRÉ HVDC statistics.

Units in trial operation whose warranty period have not yet commenced are also included in the statistics after connection to the Nordel network.

5. Definitions

Below follows a list of the definitions of central concepts. The definitions are of a general nature and do not in themselves indicate the scope of the statistics. The scope of the statistics is indicated above.

First, grid disturbance is defined, followed by fault and outage. Finally, the other concepts are defined.

5.1 Grid disturbance

Definition of a grid disturbance:

Outages, forced or unintended disconnection or failed re-connection as a result of faults in the power grid [1].

Comment:
A grid disturbance starts with a primary fault and may also consist of one or more secondary faults or latent faults. The cause of the grid disturbance is the same as the one indicated for the primary fault.

Faults may be caused by inadequate power system units, system disturbances or flawed routines.

A forced disconnection is not classified as a grid disturbance if preventive action can be taken before disconnection, for example through the restructuring of operations. An exception is remaining earth faults in compensated networks. Even though operations are restructured as the fault is sectioned off, this is considered to be a grid disturbance.

A failed manual connection is considered to be a grid disturbance if repairs are carried out before a possible new attempt at connection. Signal acknowledgement is not considered repair work.

A grid disturbance can, for example, be:

- Tripping of breaker as a result of lightning striking a line
- Failed line connection when repairs or adjustments need to be carried out before the line can be connected to the network
- Emergency disconnection due to fire
- Undesired power transformer disconnection as a result of faults in connection with relay testing

Each grid disturbance results in an outage affecting at least one system unit. See Section 5.3 on outage and system units.

5.2 Faults

Definition of a fault:

The inability of a component to perform its required function [2, 3].

Comment:
A fault is any defect or deviation resulting in a unit being incapable of fulfilling its intended function in the power system. A fault is:

- A primary fault or a secondary/latent fault
- Temporary or permanent
- Intermittent or non-intermittent
- System disturbance and fault in components

A fault which is intermittent and permanent is a fault which at first was intermittent, but subsequently became permanent. An example could be galloping lines which turn into phase failure.

5.2.1 Primary fault

Definition of a primary fault:

A fault which initiates a grid disturbance [1].

The fault initiating a grid disturbance is called a primary fault. Any subsequent faults are called secondary faults or latent faults. A grid disturbance is always started by a primary fault. According to Section 5.1, the cause of the primary fault is also considered as the cause of the grid disturbance.

5.2.2 Secondary fault

Definition of a secondary fault:

A fault which occurs as a consequence of a primary fault.

Comment:
A secondary fault can be a fault which is caused by the primary fault. An example of this is the breakdown of a voltage transformer as a result of high voltages in conjunction with an earth fault in a compensated network.

However, only secondary faults aggravating the grid disturbance should be included in the statistics. By aggravation is meant that if more faults occur in addition to the primary fault, more system units (see Section 5.3) are affected by outage than would have been the case if only the primary fault had occurred. Furthermore, the grid disturbance is considered as having been aggravated if faults other than the primary fault result in the disconnection of system units for longer than would have been the case if there had only been a primary fault. For example, disconnection may last longer in connection with a fault in a circuit breaker in conjunction with the disconnection of a line fault.

5.2.3 Latent fault

Definition of a latent fault:

A fault which was present before the primary fault, but which was only detected in connection with the occurrence of the primary fault.

Comment:
A latent fault is not directly related to the primary fault. An example would be a fault in the relay protection system.

As is the case with secondary faults, only latent faults aggravating the grid disturbance must be included in the statistics. See Section 5.2.2.

It should be noted that a defective redundant protection is normally not included in the statistics as this is often a latent fault which does not aggravate the grid disturbance.

In some cases a grid disturbance may be caused by a latent fault, in which case the latent fault should be included in the statistics. See the example in Section 7.15. Had it not been for the latent fault, the grid disturbance would not have happened in this example.

As it can be very difficult to distinguish between latent faults and secondary faults, no distinction is made between these fault types in the Nordel statistics. They are summed up.

5.2.4 Permanent fault

Definition of a permanent fault:
A fault which means that the component or unit is damaged and cannot be restored to service until repair or replacement is completed [1].

Comment:
A permanent fault requires repair or adjustment before the unit is ready for operation. Signal acknowledgement is not considered as repair work. The resetting of computers is considered repair work. A switch in the wrong position is considered a permanent fault.

5.2.5 Temporary fault

Definition of a temporary fault:
A fault which means that the unit or component is undamaged and is restored to service through manual switching operations without repair being performed, but possibly with on-site inspection [1].

Comment:
Faults which do not require measures other than the reconnection of circuit breakers, replacement of fuses or signal acknowledgement.

Whether a fault is temporary or permanent has nothing to do with the duration of the disconnection. If, for example, a fault results in long-term disconnection, and if an inspection is carried out without the fault being pinpointed, such a fault is considered a temporary fault as no repairs are carried out.

5.2.6 Intermittent fault

Definition of an intermittent fault:

A recurring fault in the same unit and in the same place and for the same reason which repeats itself before it becomes necessary to carry out any repairs or eliminate the cause [1].

Comment:
A fault which repeats itself after an inspection which did not result in the fault being pinpointed or repaired is not considered an intermittent fault. This is thus considered as giving rise to a grid disturbance every time the fault occurs.

One example of an intermittent fault is galloping lines.

5.2.7 Fault in component

Definition of a fault in a component:

A fault which affects a specific component.

Comment:
Unlike a system disturbance, a fault in a component is attributable to a specific component.

Maloperation is considered a fault in a component, i.e., the maloperation is attributed to the unit which has been operated incorrectly.

5.2.8 System disturbances

Definition of a system disturbance:

A forced outage which results from system effects or conditions and is not caused by an event directly associated with the component or unit being reported on [1].

Comment:
System disturbances have traditionally been termed system problems. Only system disturbances resulting in grid disturbances or aggravating a grid disturbance are to be included in the statistics.

The examples below are termed system disturbances:

- Overfrequency or underfrequency in a separate network
- Power fluctuations
- Overvoltage or undervoltage in parts of a network
- Harmonics
- Sub-synchronous resonance (SSR)
- Geomagnetically induced currents (GIC)

5.2.9 Cause, primary cause and hidden cause

Definition of a cause of a fault:

Cause relating to design, production, installation, operation or maintenance which results in a fault [1].

Definition of a primary cause of a fault:

Event or circumstance which leads to a fault [1].

Definition of an underlying cause of a fault:

Event or circumstance which is present before a fault occurs [1].

Comment:
The cause of a fault must be indicated for each fault. All faults usually have a primary cause. Some faults also have underlying causes.

If, for example, a tower collapses due to snow or strong winds, the primary cause is wind, while the underlying cause is metal fatigue. The underlying cause of the fault can thus be a condition which was present long before the occurrence of the grid disturbance, whereas the grid disturbance does not occur until a primary cause is present. Lack of maintenance is a typical example of an underlying cause.

In the Nordel statistics, only one cause is included. This is normally the primary cause, but if the primary cause is unknown or unidentified, the underlying cause is used. If, for example, an isolator explodes seemingly without any primary cause, the underlying cause is reported, which could be "technical equipment".

Table 5.1 below shows the categorisation of causes applied in Nordel.

In the event of many faults occurring in the power system, it can be difficult to identify the exact cause of the faults as there may be insufficient evidence. It is therefore recommended that the cause not be reported as “unknown” and that the most likely cause be reported instead.

All the countries or companies which provide data to the Nordel statistics have their own more detailed categorisation of causes. Appendix A contains a cross-reference list showing how the different causes are converted into the Nordel categories.

Table 5.1 Fault causes

Fault cause	**Explanation**
Lightning	
Other environmental causes	Moisture, ice, low temperatures, earthquakes, pollution, rain, salt, snow, vegetation, wind, heat, etc.
External influences	Fire, animals and birds, aircraft, excavation, collision, explosion, tree felling, vandalism
Operation and maintenance	Lack of monitoring, fault in settings, fault in connection plan, fault in relay plan, incorrect operation, fault in documentation, human fault
Technical equipment	Dimensioning, fault in technical documentation (e.g., guidelines, manuals), design, corrosion, materials, installation, production, vibration, ageing
Other	Operating problems, faults at customers', faults in other networks, problems in conjunction with faults in other components, system causes, other
Unknown	

5.3 Outage and system units

Definition of a system unit:

A group of components which are delimited by one or more circuit breakers [1].

Definition of an outage:

The component or unit is not in the "in service" state; that is, it is partially or fully isolated from the system [5].

Comment:
The concepts of outage and system unit have been introduced with the purpose of getting an idea of how grid disturbances affect the availability of different component types. The registration is based on an IEEE standard [5].

A system unit is often the same as a component. The system unit concept has been defined with a view to facilitating the calculation of availability. A system unit is delimited by circuit breakers. Individual components are not always delimited by circuit breakers, for which reason a system unit may contain more components. The circuit breakers are not included in the system unit. Table 5.2 shows the system units which make up the system.

Table 5.2 Types of system units used in the statistics. The dominant component determines the type of system unit.

Power system unit	Comment
HVDC system	
Power transformer	
Line	This type of power system unit includes overhead lines and cables.
Reactor	
Busbar	
Series capacitor	
Shunt capacitor	
SVC	

When a system unit is no longer transporting or supplying electrical energy, the system unit is affected by outage. After the occurrence of an outage, a system unit is unavailable.

There are grid configurations, meaning that a system unit cannot transport energy due to another system unit being disconnected; if, for example, the line in Figure 5.1 is disconnected, the power transformer cannot transport energy. Both the line and the power transformer are then considered as having been affected by outage.

The outage of a system unit may be caused by the failure of a component within the system unit, a fault in a circuit breaker between two system units or a system disturbance.

The system units are divided into different types according to the main functions they fulfil. Figures 5.1-5.5 show different types of system units.

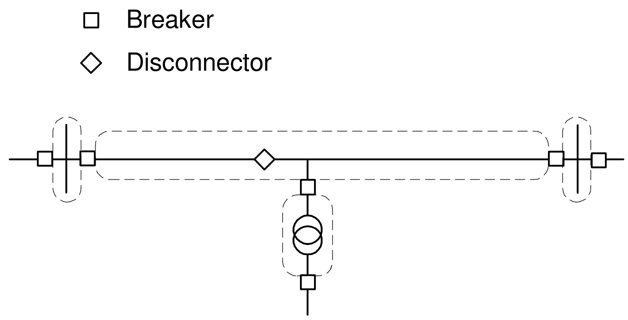


Figure 5.1 A system unit is delimited by circuit breakers as indicated by the dotted lines. Disconnectors do not delimit system units. This system unit must be defined as being of the line type.

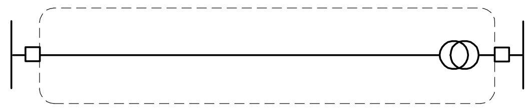


Figure 5.2 If there are no power transformer circuit breakers, the line and the power transformer are considered as one system unit. Whether the unit is considered a transformer or a line is determined by its primary function.

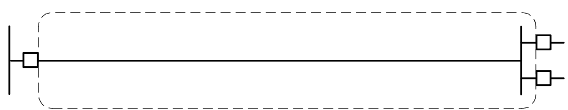


Figure 5.3 The busbar has no circuit breakers and together with the line it forms a system unit which – as was the case in Figure 5.2 – is said to be defined as being of the line type.

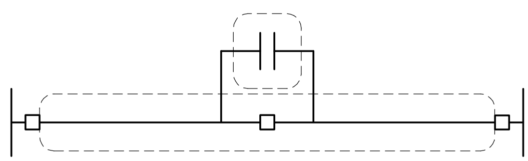


Figure 5.4 A series capacitor is not delimited by one or more circuit breakers according to the definition, but a series capacitor bypasses a circuit breaker, which does not agree with the definition. The delimitation of a system unit of the series capacitor type is selected in accordance with the above figure. If the line is affected by a grid disturbance, the series capacitor is also affected by outage.

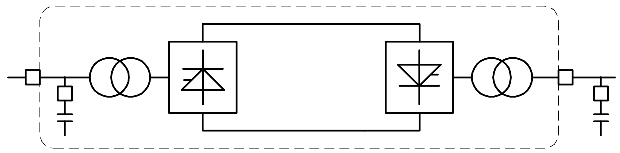


Figure 5.5 For an HVDC unit, the system unit ranges from circuit breaker to circuit breaker in the respective stations. If the shunt element is located within the outermost circuit breakers, as in the figure on the left side, the shunts are not considered to be system units in their own right.

5.3.1 Duration of grid outage

Definition of duration of an outage:

The period from the onset of an outage occurrence until the component or unit is returned to the "in service" state [1].

Comment:
Administrative delays (voluntary waiting time) should not be included in the duration of the outage.

5.4 Other definitions

5.4.1 Delivery point

Definition of a delivery point:

Point, power transformer or busbar in the grid where electricity is exchanged.

Comment:
The definition is a general definition and can in practice comprise all points, power transformers and busbars. In the Nordel statistics, the supply point is on the boundary of the Nordel statistical area.

5.4.2 End user

Definition of end users:

Buyers of electrical energy who do not resell all the energy [1].

Comment:
A buyer who resells some of the power is considered an end user.

5.4.3 End-user interruption

Definition of an end-user interruption:

Situation characterised by the failure to deliver electricity to one or more end users when the voltage constitute less than 1 per cent of the contractually agreed voltage [4].

Comment:
End-user interruption concerns only end users. End-user interruption may be notified or unnotified. End-user interruption is of either long or short duration.

5.4.4 Duration of end-user interruption

Definition of duration of an end-user interruption.

The period from when the end-user interruption commences until voltage is supplied to end users again [1].

5.4.5 Interruption

Definition of an interruption:

Situation characterised by the discontinuation of the delivery of electrical power to one or more delivery points.

Comment:
If an area has more than one delivery point from a transmission network, and interruption occurs in one of these delivery points, the magnitude of the interruption is considered to be the electrical energy which was exchanged in the delivery point prior to the interruption.

The interruption must be included even if no end users are affected by end-user interruption due to delivery via another delivery point.

5.4.6 Long-term interruption

Definition of a long-term interruption:

End-user interruption or interruption lasting more than three minutes [4].

5.4.7 Short-term interruption

Definition of a short-term interruption:

End-user interruption or interruption lasting up to three minutes [4].

5.4.8 Energy not supplied

Definition of energy not supplied (ENS):

The estimated energy which would have been supplied to end users if no interruption and no transmission restrictions had occurred [1].

Comment:
The estimated magnitude is based on the expected load curve throughout the duration of the interruption. Load remaining out after supplies to end users have been resumed should not be included in ENS.

Statistical data does not include disturbances in installations of more than 100 kV owned by the end-users. One example is an aluminium smelting plant. On the other hand, the statistical data must include transmission grid disturbances affecting similar installations

If an expected load curve is available, this is used. If not, ENS is approximated as the load before the interruption multiplied by the duration of the failure.

In order for ENS to be calculated, the end-user interruption must have lasted for at least two seconds. Two seconds have been established as the minimum duration so that fast automatic reclosing is not included.

In the calculation of ENS, no account is taken of the fact that some industries may experience some delay before production is back to normal. Figure 5.6 shows how ENS is calculated in this case.

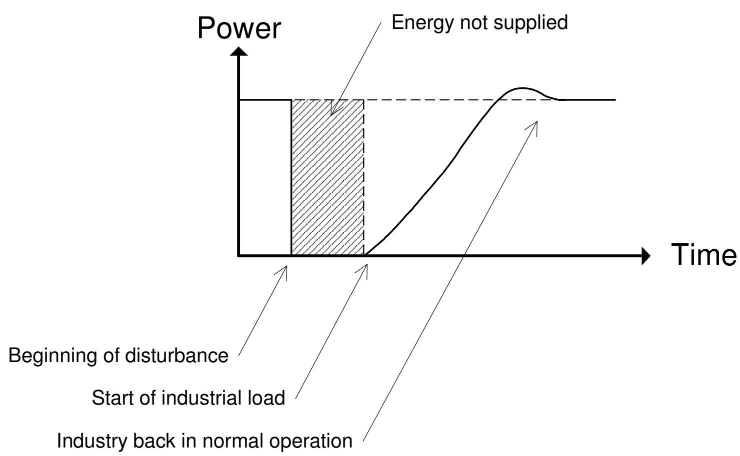


Figure 5.6 Grid disturbance with end-user interruption for industrial load.

If, on the other hand, a grid disturbance affects different end users for different lengths of time, ENS is calculated as the shaded area in Figure 5.7.

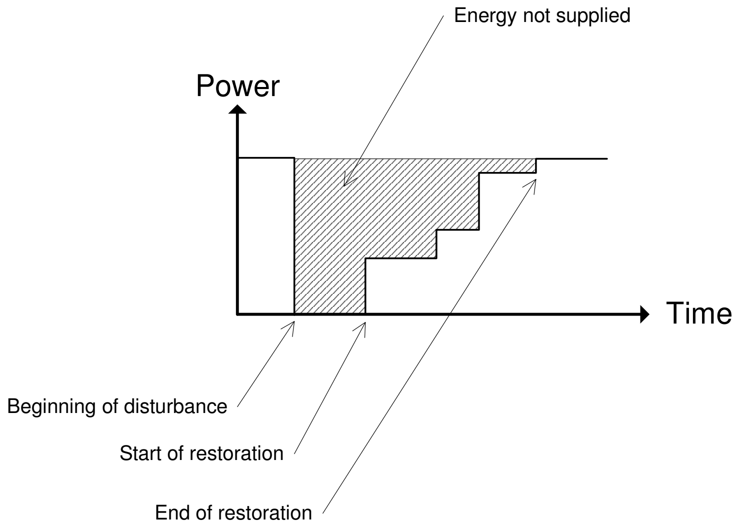


Figure 5.7 Grid disturbance with end-user interruption affecting several end users.

According to the definition, energy not supplied also occurs when the energy output must be limited due to transmission restrictions in the grid.

Figure 5.8 shows an example of this. One of the feeder lines to the transformer is disconnected due to failure. The remaining line cannot supply the required output, for which reason the transmission must be restricted, and ENS occurs.

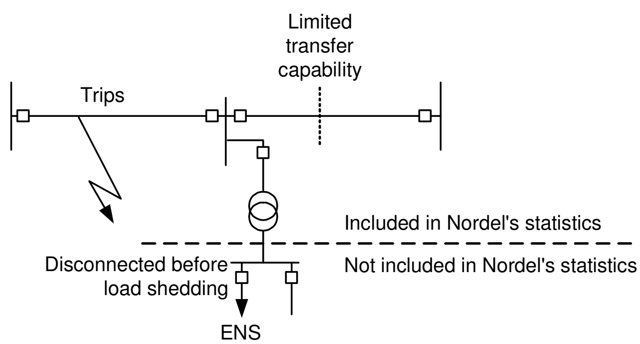


Figure 5.8 ENS due to transmission restrictions

In order for ENS to be registered, the interruption causing ENS must affect a system unit within the Nordel statistical area. See figures 5.9-5.12.

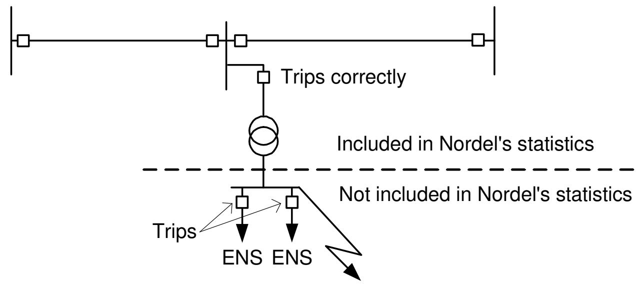


Figure 5.9 A failure in the downstream network causes an outage in a system unit within the Nordel statistical area resulting in ENS. As the outage causing ENS occurs within the Nordel statistical area, this ENS must be included in the statistics.

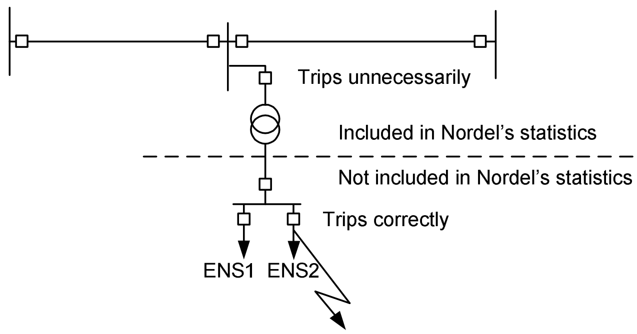


Figure 5.10 This constellation includes a breaker on the transformer low voltage side. In this case, ENS must be registered as the outage causing ENS occurs within the Nordel statistical area. Two ENS values should be registered. The first one is in the feeder which tripped correctly and the other one is in the feeder where the breaker did not react.

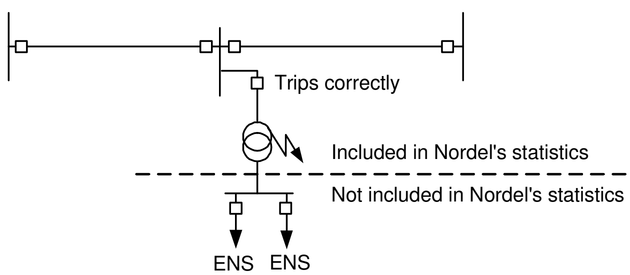


Figure 5.11 The transformer is affected by a fault which causes outage; ENS must be recorded.

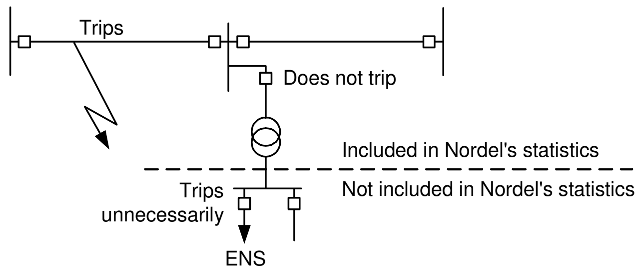


Figure 5.12 Due to incorrect setting of the protection system in a downstream network, ENS occurs in conjunction with faults in the Nordel system. As no system unit transmitting to the downstream network is affected by outage, ENS should not be registered in the Nordel statistics.

5.4.9 Unit

Definition of a unit:

A group of components which fulfils a main function in the power system [1].

Comment:
Main function means transmission, transformation, compensation, etc.

5.4.10 Component

Definition of a component:

Equipment which fulfils a main function in a unit [1].

Comment:
See Section 5.3 for an explanation of the difference between system unit and component.

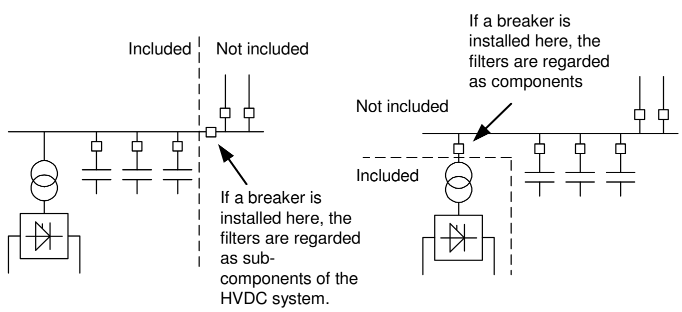
In order to compare the number of faults between countries and companies, it is important that faults be attributed to the same types of components.

One of the components listed in the table below must be selected. In order to avoid uncertainty as to which component should be selected, the table also shows the components forming part of the respective components.

If the fault is a system disturbance, it is not necessary to indicate the component.

Table 5.3 Classification of components

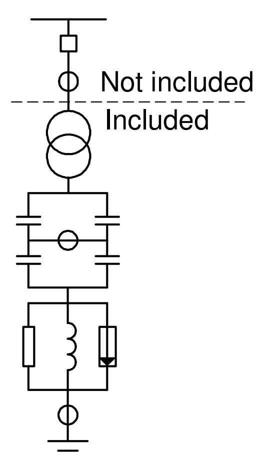
Component	**Sub-components included**	**Sub-components not included**
Surge arresters and spark gaps	*Active element* Foundations Sensors Isolators Counters Support structure	Arresters and spark gaps on series capacitor
Circuit breakers Disconnecting circuit breakers (DCB) are considered circuit breakers	Breaking elements Foundations Isolators Control equipment integrated in the circuit breaker Operating mechanism Support structure	External compressed-air system
Disconnectors and earth connectors	Disconnector contacts Foundations Isolator(s) Control equipment integrated in the disconnector Operating mechanism Support structure	

Component	**Sub-components included**	**Sub-components not included**
Common ancillary equipment	Local power Compressed-air system Buildings Fencing Direct-current rectifiers Direct-current system Diesel unit Distribution Other equipment which is not high-voltage equipment and which cannot be attributed to any of the components indicated	
HVDC	The HVDC system includes everything located within the circuit breakers as indicated in the figure below. The control equipment and the HVDC cables are also included in the HVDC system. 	

Component	**Sub-components included**	**Sub-components not included**
Control equipment	Alarm system Automatics, such as synchronous and phasing devices, interlocking devices, sequential controls (DUBA), voltage controls Remote control (SCADA) Control cables Installation cabinets Local control Grid protection Optic cables Signal transmission (data communication) Protection, including communication Control cables Reclosing	Control equipment integrated in other components is not included. In connection with faults in integrated control equipment, the relevant component is indicated.
Power cables	Sensors Cables Cable boxes and joints Oil expansion tank End terminations	

Component	Sub-components included	Sub-components not included
Power transformers	Foundations, including oil sumps Bushing Sensors, gas, temperature and pressure guards, oil level sensors Cooling, including integrated automatics for cooling Core Windings Tap changers and control equipment, including integrated automatics Instrument transformers if integrated in power transformer Tank	
Overhead lines An overhead line terminates at the first component in a station	Foundations Isolators Terminals Conductors, phase and earth Arc horn Joint Loop Guy wires Towers Vibration dampers	Control cables and optic cables are included under control equipment
Instrument transformers	Foundations Isolators Core Winding Voltage diverters Support structure Breaker, if integrated in instrument transformer	

Component	**Sub-components included**	**Sub-components not included**
Reactors inclusive of neutral point reactors	Foundations, including oil sumps Bushing Sensors, gas, temperature and pressure guards, oil level sensors Cooling, including integrated cooling automatics Core Windings Tap changers, including control equipment Instrument transformers, if integrated in reactor Tank	
Synchronous compensators	Ancillary equipment Integrated control equipment Excitation equipment Machinery including all electrical and mechanical parts Starting equipment	
Busbars The busbar includes connection to the first other component connected to the busbar. No distinction is made between air and gas-insulated distribution plants or indoor or outdoor distribution plants.	Density guard for GIS (gas insulated substations) Foundations Insulation medium for GIS Enclosure for GIS Bar Loop Support structures Support isolator Pressure guard for GIS	Earth connectors

Component	**Sub-components included**	**Sub-components not included**
Series capacitors	Surge arresters and varistors Spark gap Capacitor Resistor Instrument transformer if integrated in shunt capacitor battery or filter Reactor Support isolator	
Shunt capacitor batteries and filters	Capacitor Reactor Resistor Support isolator Power capacitor if power transformer is designed exclusively for shunt capacitor or filter Surge arresters if integrated in shunt capacitor battery or filter Instrument transformer if integrated in shunt capacitor battery or filter 	

Component	Sub-components included	Sub-components not included
SVC and statcom	Ancillary equipment Capacitor Integrated control equipment Cooling Reactor Power capacitor, if power capacitor is exclusively designed for SVC or statcom Valves, i.e., semiconductors such as GTO and IGTB	
Other high-voltage components in stations	Other high-voltage equipment which cannot be attributed to any of the components indicated Carrier frequency coils Foundations Connections between components in a station Bushings, though not integrated in other components Loop Stand Support isolators which are not included under other components	
Unknown		

5.4.11 Repair time

Definition of repair time:

Time from when repair commences, including necessary trouble-shooting, until the unit's function(s) has (have) been resumed and the unit is ready for operation [1].

Comment:
Repair time to be stated for permanent faults only. Repair time does not include administrative delays (voluntary waiting time). Any preparations necessary to carry out repairs are, however, included in the repair time, for example the collection or ordering of spare parts, waiting for spare parts, transport.

In connection with faults which we decide not to repair, the repair time is zero.

6. Classification of grid disturbances, faults, outages and interruptions

This chapter outlines the information to be registered for grid disturbances and how the material should be classified into different groups. The figure below describes the information to be registered for every grid disturbance.

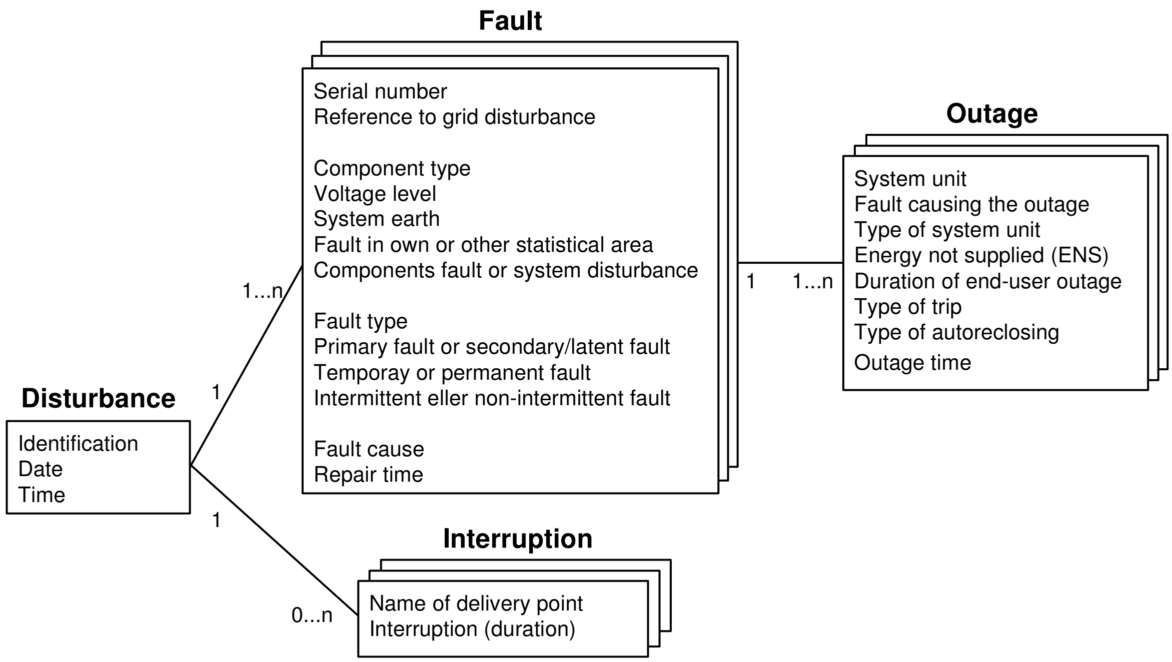


Figure 6.1 A grid disturbance is caused by faults; a fault can result in several outages; grid disturbances can result in none, one or several supply interruptions.

It is apparent from the indication ”1...n” in Figure 6.1 that every grid disturbance has at least one fault, and that more faults can be related to one grid disturbance. This also applies to outages; one fault causes one or more outages, and more outages can be the cause of one fault. A grid disturbance can even cause several interruptions.

6.1 Classification of grid disturbances

In Nordel’s grid disturbance statistics the date, time and classification of every single grid disturbance are registered. Identification could, for example, be in the form of a serial number counting from one every new year.

To register a grid disturbance, the definitions given in Section 5.1 must be fulfilled. Furthermore, at least one component with a minimum voltage of 100 kV or a component with reactive compensation must have been disconnected in one’s own statistical area.

The table below describes the information to be registered for every grid disturbance.

Table 6.1 Information to be registered for every grid disturbance.

Information/comment	**Options**
Identification *Usually in the form of a serial number counting from one every year. Not important for the statistical compilation.*	*For example 2000-1, 2000-2 etc.*
Date	Date of grid disturbance, e.g., 2000-01-17
Time	Time of disturbance, e.g., 17:19:23.

6.2 Classification of fault

These statistics only classify faults resulting in or aggravating grid disturbances. In case of a grid disturbance, faults can occur in several components. These faults are registered individually; thus a grid disturbance may have several faults. However, only one fault is registered if the fault aggravates within the component. Moreover, a grid disturbance is always caused by at least one fault.

In case of maloperation of circuit breakers and disconnectors, the fault must be related to the component that has been incorrectly operated, and the primary cause is stated as operation and maintenance.

If, in case of an intermittent fault, the same cause results in several faults in one component and in the same place within a short period, only one fault is registered.

The following information must be stated for every single fault.

Table 6.2 Information to be registered for every fault.

Information / comment	**Options**
Serial number The serial number counts from one for every grid disturbance.	1, 2, 3, etc.
Reference to grid disturbance	Identification of the disturbance, cf. Table 6.1
Component type	See Section 5.4.10. If the fault is a system disturbance, the component type need not be stated.

Information / comment	Options
Voltage level For the power transformer the rated voltage of the winding with the highest voltage is stated. For SVCs and rotating phase compensators the voltage designed for regulation is stated. For common ancillary equipment the highest voltage in the station is set. For faults occurring in a voltage lower than 100 kV, voltage level ”< 100 kV” is stated. For HVDC systems the voltage level ”HVDC” is stated.	• <100 kV • 132 kV Nominal voltages between 110 and 150 kV are included in this voltage level. • 220 kV Nominal voltages between 220 and 300 kV are included in this voltage level. • 400 kV • HVDC Only for HVDC components
System grounding Here it is stated whether the power system is directly earthed or compensated. This information is not necessary to provide in case of faults in units for reactive compensation with voltages lower than 100 kV.	• Directly earthed • Compensated (resonant earthed)
Fault in own or other statistical area A component fault that occurs either in a component within your own statistical area or within another area. If the fault occurs in another statistical area, nothing further needs to be registered on the fault. If information on faults in another statistical area is available, obviously this can be filled in. However, this information must be eliminated from the joint statistics.	• Own network • Other network

Information / comment	Options
Component fault or system disturbance Only system disturbances causing or aggravating a grid disturbance needs to be registered. See sections 5.2.7 and 5.2.8	• Component fault • System disturbance
Fault types One fault can consist of several fault types. If a fault consists of several fault types, the fault type most important for the purpose of the statistics is stated. In case of developing faults (i.e., faults changing from one type to another) the final type is given.	• Single-phase earth fault • Two or three-phase with or without earth fault • Function failing to occur • Undesired function; is only stated if the component is a circuit breaker, disconnector or control system • Oscillation • Overload • Broken conductor without earth contact (Broken conductor with earth fault is referred to as ”single-phase earth fault” or ”two or three-phased faults with or without earth fault”) • Others, e.g., geomagnetic currents, SSR, capacitor bank imbalances, bad contact, overheating
Primary fault or secondary /latent fault The statistics do not distinguish between secondary and latent faults. See sections 5.2.2 and 5.2.3 respectively for explanations of secondary and latent faults.	• Primary fault • Secondary/latent fault
Temporary or permanent fault See sections 5.2.4 and 5.2.5.	• Permanent fault • Temporary fault
Intermittent or non-intermittent fault See Section 5.2.6.	• Intermittent faults • Non-intermittent fault

Information / comment	Options
Fault cause The fault cause must always be stated. The fault cause may be a combination of several fault causes. It is thus not always possible to make an exact description of the cause by stating one fault cause only. If it is possible to choose from several causes, choose the one most important for the purpose of the statistics. See Section 5.2.9.	See Section 5.2.9
Repair time	Must be given in hours and minutes. Voluntary waiting time should not be included. See Section 5.4.11.

6.3 Classification of outage

The following must be stated for every single outage.

Table 6.3 Information to be registered for every outage.

Information / comment	Options
System unit The name of the system unit is used to calculate how often the same system unit is affected by outage. See Table 8.11.	Identification of the system unit affected by outage.
Faults causing the outage If two faults occur within the same system unit (e.g., wrecked surge arresters along with lightning faults) the fault causing the outage of the longest duration will be chosen.	Serial number for the fault which according to Table 6.2 causes the outage.
Type of system unit	See Section 5.3.
Energy not supplied (ENS)	See Section 5.4.8. To calculate ENS the end-user outage must have lasted at least 2 seconds.

Information / comment	Options
Duration of interruption	See Section 5.4.4.
Characterisation of the disconnection In case of a fault in the reclosing automatics resulting in lack of reclosing, ”Automatically” should be chosen as an alternative.	• Automatically • Automatically with unsuccessful automatic reclosing (fault current must have occurred twice) • Manually
Characterisation of reclosing If high speed automatic reclosing is successful at one end of a line, but the line needs to be reclosed manually at the other end, choose manual reclosing. In this document ”high speed automatic reclosing” refers to automatic reclosing after less than 2 seconds.	• Automatically after less than 2 seconds (successful high speed reclosing) • Automatically after more than 2 seconds (delayed reclosing) • Manually after restructuring of operation • Manually after inspection • Manually after repair • Manually without either inspection, repair or restructuring of operation • Unknown • Others
Duration of outage	See Section 5.3.1.

6.4 Classification of interruption

For every interruption, the information outlined in Table 6.4 must be registered. It is merely the delivery points in the Nordel network that should be registered. Delivery points from one Nordel network to another need not be registered, e.g., the voltage from 400 kV to 130 kV, see Figure 6.2. If one company owns equipment on the 400 kV side, and another company owns equipment on the 130 kV side (in Figure 6.2), the company on the 400 kV side does not register interruption. If, for example, a fault occurs in the 400/130 kV transformer in the figure, the 130 kV system only registers interruption.

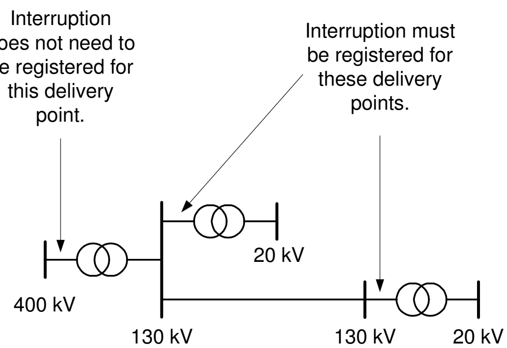


Figure 6.2 It is only the delivery points from the Nordel network to low voltages that are registered.

Table 6.4 Information to be registered for every interruption.

Information / comment	Options
Name of delivery point Not relevant to the compilation of statistics.	Name of the delivery point affected by outage.
Duration of interruption	The time the interruption lasts.

7. Examples of classification of grid disturbances, outages, faults and interruptions

This chapter presents a number of examples of different kinds of grid disturbances. The examples are numerous in order to cover all possible kinds of disturbances. The direct earthed network in Figure 7.1 has been used for most of the examples. The network consists of the system units line X-Y, line Y-Z, busbar X, busbar Y and power transformer Y. In the interest of simplicity, date and time are the same in all examples.

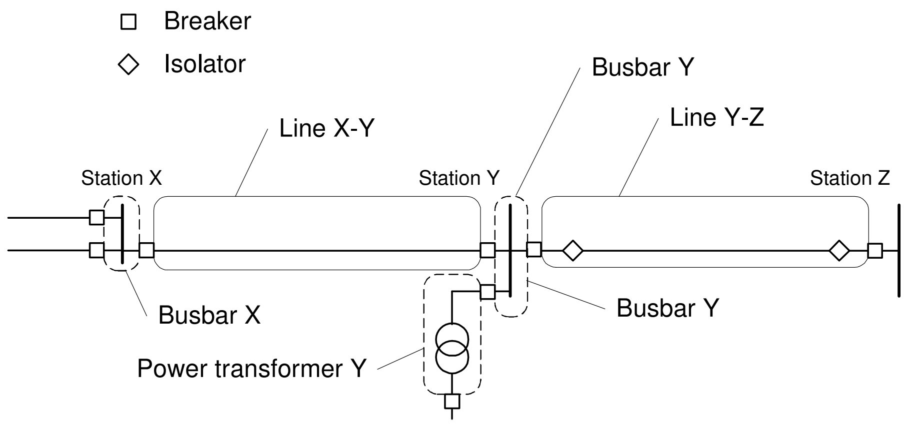


Figure 7.1 This network is used for most examples.

7.1 Flashover on power transformer bushing due to salt

Along with heavy onshore wind, flashover (short to earth) occurred on a 220 kV isolator on the 220/60 kV power transformer Y placed outdoors in a station close to the coast. When examining the power transformer, it became apparent that the isolator was covered with salt. The power transformer was placed temporarily in the station as its bushings were not designed for outdoor use. The salt disappeared completely simultaneously with the flashover. The staff checked that the power transformer was in an acceptable condition before it was put back in operation again. The power transformer was loaded with 50 MW before the fault occurred, and it was operational again after half an hour. The downstream network was only fed by this transformer, for which reason the energy not supplied rose to 25 MWh.

The cause of the fault was that the power transformer was not designed for outdoor use. However, in accordance with Section 5.2.9., the primary cause should normally be included in the Nordel statistics. The primary cause of the fault was salt, i.e., other environmental causes, cf. Table 5.1.

Grid disturbance

Identification	2000-1
Date	2000-01-10
Time	10:01

Fault

Serial number	1
Reference to grid disturbance	2000-1
Component type	Power transformer
Voltage level	220 kV
Fault in own or other statistical area	Own
Component fault or system disturbance	Component
System earth	Direct earthed
Type of fault	Single-phase earth fault
Primary fault or secondary/latent fault	Primary
Temporary or permanent fault	Temporary
Intermittent or non-intermittent fault	Non-intermittent
Fault cause	Other environmental causes
Repair time	0 min

Outage

System unit	Power transformer Y
Fault causing the outage	1
Type of system unit	Power transformer
Energy not supplied	25 MWh
Duration of end-user outage	30 min
Characterisation of disconnection	Automatically
Characterisation of reclosing	Manually after inspection
Duration of outage	30 min

Interruption

Name of delivery point	Transformer Y
Duration of interruption	30 min

7.2 Outage of a line when work is performed on control unit

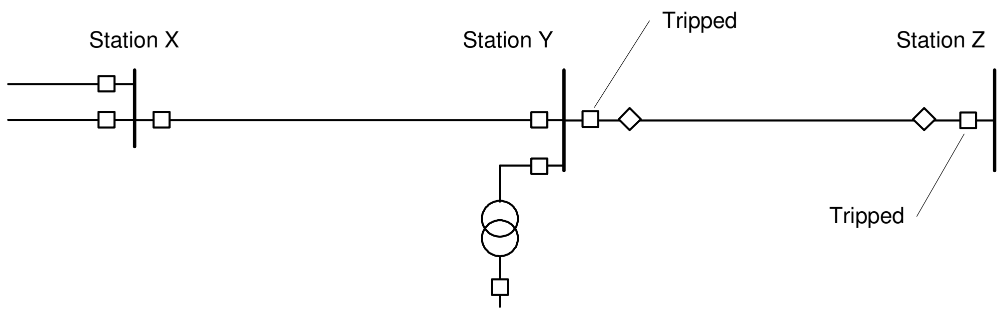


Figure 7.2 Outage of line when work is performed on control unit.

In connection with work being performed on the relay protection system of the 400 kV Y-Z line, a current circuit was opened to the differential protective relay. As a result, the Y-Z line tripped. It took five minutes to solve the problem and reconnect the line. The power transformer load was 50 MW.

The fault is characterised as permanent because the current circuit to the differential protective relay had to be reconnected before the line could be reclosed manually.

Energy not supplied is 0 MWh as the power transformer was fed via the X-Y line. Interruptions should not be registered since no delivery points in the Nordel network were affected by interruption.

Grid disturbance

Identification	2000-2
Date	2000-01-10
Time	10:01

Fault

Serial number	1
Reference to grid disturbance	2000-2
Component type	Control equipment
Voltage level	400 kV
Fault within own or other statistical area	Own
Component fault or system disturbance	Component fault
System earth	Direct earthed
Fault type	Undesired function
Primary fault or secondary/latent fault	Primary
Temporary or permanent fault	Permanent
Intermittent or non-intermittent fault	Non-intermittent
Fault cause	Operation and maintenance
Repair time	5 minutes

Outage

System unit	Line Y-Z
Fault causing the outage	1
Type of system unit	Line
Energy not supplied	0 MWh
Duration of end-user outage	0 min
Characterisation of disconnection	Automatically
Characterisation of reclosing	Manually after repair
Duration of outage	5 min

Interruption

Name of delivery point	-
Duration of interruption	-

7.3 Two line faults with a few seconds' interval combined with circuit breaker fault related to the latest fault

As a result of lightning, a single-phase earth fault occurred in the X-Y line, causing high speed automatic reclosing. Four seconds later, the line tripped again due to lightning. This time, high speed automatic reclosing failed to occur due to a fault in the circuit breaker in station Y. The faulty circuit breaker was repaired after eight hours.

There are two disturbances. The first disturbance is reported below.

Grid disturbance

Identification	2000-3
Date	2000-01-10
Time	10:01

Fault

Serial number	1
Reference to grid disturbance	2000-3
Component type	Line
Voltage level	400 kV
Fault within own or other statistical area	Own
Component fault or system disturbance	Component fault
System earth	Direct earthed
Fault type	Single-phase earth fault
Primary fault or secondary/latent fault	Primary
Temporary or permanent fault	Temporary
Intermittent or non-intermittent fault	Non-intermittent
Fault cause	Lightning
Repair time	0 min

Outage

System unit	Line X-Y
Fault causing the outage	1
Type of system unit	Line
Energy not supplied	0 MWh
Duration of end-user outage	0 min
Characterisation of disconnection	Automatically
Characterisation of reclosing	Automatically after less than 2 seconds
Duration of outage	0

Interruption

Name of delivery point	-
Duration of interruption	-

Imagine that the other disturbance is given the serial number 2000-4. This grid disturbance is affected by two faults. The first fault is lightning, and the second fault is in the circuit breaker. In this case, the fault in the circuit breaker is included as the disturbance is aggravated over time.

Grid disturbance

Identification	2000-4
Date	2000-01-10
Time	10:01

Fault

Serial number	1	2
Reference to the grid disturbance	2000-4	2000-4
Component type	Line	Circuit breaker
Voltage level	400 kV	400 kV
Fault within own or other statistical area	Own	Own
Component fault or system disturbance	Component fault	Component fault
System earth	Direct earthed	Direct earthed
Fault type	Single-phase earth fault	Function failed to occur
Primary fault or secondary/latent fault	Primary	Secondary/latent fault
Temporary or permanent fault	Temporary	Permanent
Intermittent or non-intermittent fault	Non-intermittent	Non-intermittent
Fault cause	Lightning	Technical equipment
Repair time	0 min	8 h

Outage

System unit	Line X-Y
Fault causing the outage	1
Type of system unit	Line
Energy not supplied	0 MWh
Duration of end-user outage	0 min
Characterisation of disconnection	Automatically
Characterisation of reclosing	Manually after repair
Duration of outage	8 h

Interruption

Name of delivery point	-
Duration of interruption	-

7.4 Incorrect circuit breaker operation

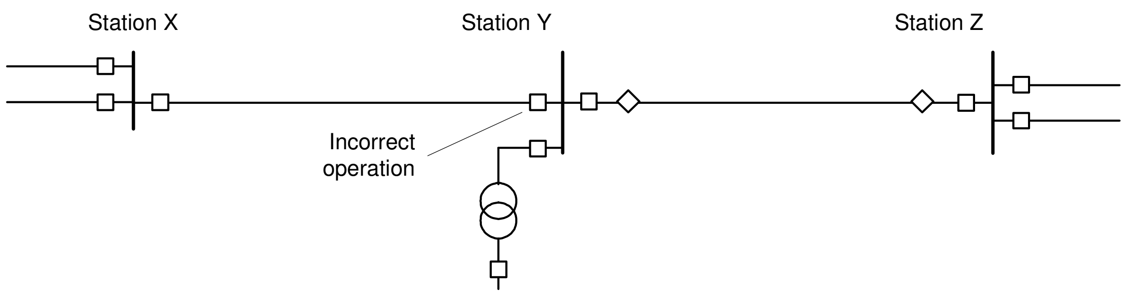


Figure 7.3 Incorrect circuit breaker operation.

Circuit breakers in station Y on the X-Y line were operated incorrectly. The other end of the line remained connected to the network. Because of the meshed network, no customers were affected by the outage. The circuit breaker was manually reclosed after five minutes.

Grid disturbance

Identification	2000-4
Date	2000-01-10
Time	10:01

Fault

Serial number	1
Reference to grid disturbance	2000-4
Component type	Circuit breakers
Voltage level	400 kV
Fault within own or other statistical area	Own
Component fault or system disturbance	Component fault
System earth	Direct earthed
Fault type	Undesired function
Primary fault or secondary/latent fault	Primary fault
Temporary or permanent fault	Temporary
Intermittent or non-intermittent fault	Non-intermittent
Fault cause	Operation and maintenance
Repair time	0 min

Outage

System unit	Line X-Y
Fault causing the outage	1
Type of system unit	Line
Energy not supplied	0 MWh
Duration of end-user outage	0 min
Characterisation of disconnection	Manually
Characterisation of reclosing	Manually without either inspection, repair or restructuring of operation
Duration of outage	5 min

Interruption

Name of delivery point	-
Duration of interruption	-

7.5 Line fault without circuit breaker operation

A single-phase earth fault occurred in the 220 kV X-Y line due to lightning, see Figure 7.4. The circuit breaker in station Y failed to trip. Therefore, the zone 2 protection in station Z tripped Y-Z line. The feeding to the 220/70 kV power transformer in station Y was interrupted, which caused an interruption of load. Following the inspection of station Y, the load could be reconnected after 45 minutes through feeding via the Y-Z line. Energy not supplied increased to 7 MWh. High speed automatic reclosing took place in X-Y line. The circuit breaker was repaired after two days.

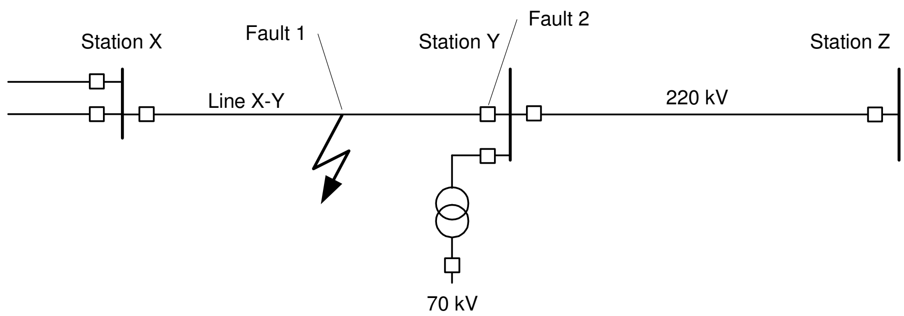


Figure 7.4 Line fault without circuit breaker function

Two faults are involved in this grid disturbance; a lightning fault and a circuit breaker fault. Four grid disturbances occurred; one in each line, one in the power transformer and one in the gathering strip.

Interruption must be registered for the power transformer.

Grid disturbance

Identification	2000-5
Date	2000-01-10
Time	10:01

Fault

Serial number	1	2
Reference to grid disturbance	2000-5	2000-5
Component type	Line	Circuit breakers
Voltage level	400 kV	400 kV
Fault within own or other statistical area	Own	Own
Component fault or system disturbance	Component	Component
System earth	Direct earthed	Direct earthed
Fault type	Single-phase earth fault	Function failing to occur
Primary fault or secondary/latent fault	Primary	Secondary/latent fault
Temporary or permanent fault	Temporary	Permanent
Intermittent or non-intermittent fault	Non-intermittent	Non-intermittent
Fault cause	Lightning	Technical equipment
Repair time	0 min	48 h 0 min

Outage

System unit	Line X-Y	Line Y-Z	Busbar Y	Power transformer Y
Fault causing the outage	1	2	2	2
Type of system unit	Line	Line	Busbar	Power transformer
Energy not supplied	0 MWh	0 MWh	0 MWh	7 MWh
Duration of end-user outage	0 min	0 min	0 min	45 min
Characterisation of disconnection	Automatically	Automatically	Automatically	Automatically
Characterisation of reclosing	Manually after repair	Manually after inspection	Manually after inspection	Manually after inspection
Duration of outage	48 h 0 min	0 h 45 min	0 h 45 min	0 h 45 min

Interruption

Name of delivery point	Power transformer Y
Duration of outage	0 h 45 min

7.6 SVC outage without a recognised fault

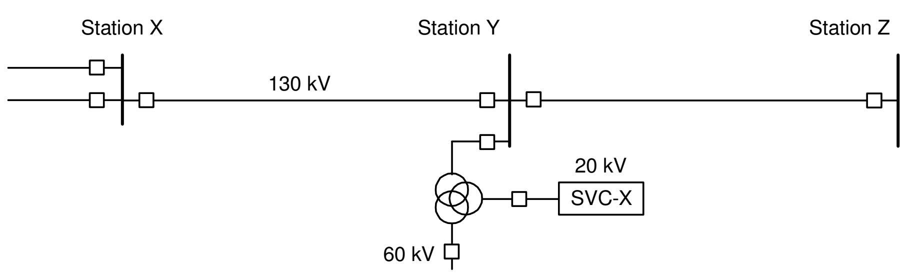


Figure 7.5 SVC outage without a recognised fault.

A SVC with the indication SVC-X connected to 20 kV tripped. The SVC is used for regulating the voltage of 130 kV. During inspection, no visible faults or indications hereof were ascertained. The probable cause was a fault in the program commodity in the control equipment for the operation of the SVC. No restart of the control computer was executed, thus no repair was carried out. The reclosing of the SVC was possible after 45 minutes.

Check that the voltage level is set to 130 kV, cf. Table 6.2.

If the control equipment is integrated into the SVC, state the component type as SVC and statcom, cf. Table 5.3. If the control equipment is not integrated, the component type is stated as control equipment.

Grid disturbance

Identification	2000-6
Date	2000-01-10
Time	10:01

Fault

Serial number	1
Reference to grid disturbance	2000-6
Component type	SVC and statcom *or* control equipment
Voltage level	130 kV
Fault within own or other statistical area	Own
Component fault or system disturbance	Component fault
System earth	Direct earthed
Fault type	Undesired function
Primary fault or secondary/latent fault	Primary
Temporary or permanent fault	Temporary
Intermittent or non-intermittent fault	Non- intermittent
Fault cause	Unknown
Repair time	0 min

Outage

System unit	SVC-X
Fault causing the outage	1
Type of system unit	SVC
Energy not supplied	0 MWh
Duration of end-user outage	0 min
Characterisation of disconnection	Automatically
Characterisation of reclosing	Manually after inspection
Duration of outage	45 min

Interruption

Name of delivery point	-
Duration of interruption	-

7.7 Manual line disconnection due to a faulty current transformer

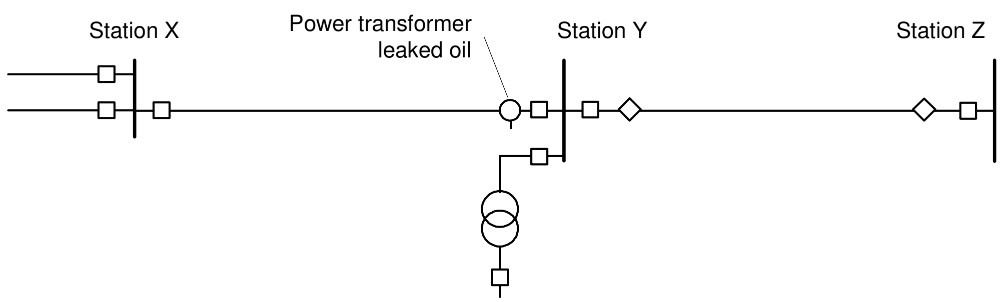


Figure 7.6 Manual line disconnection due to a faulty current transformer

During the inspection of a station, it was discovered that the pressure in a 400 kV current transformer had increased and that there was a high risk of it exploding. The X-Y line with the current transformer was immediately taken out of operation. After replacing the current transformer, the line was connected after 16 hours.

This is considered a grid disturbance as it is an emergency outage according to Section 5.1. If the outage could have been postponed, it would not have been a grid disturbance and should thus not be registered.

Grid disturbance

Identification	2000-7
Date	2000-01-10
Time	10:01

Fault

Serial number	1
Reference to grid disturbance	2000-7
Component type	Instrument transformer
Voltage level	400 kV
Fault within own or other statistical area	Own
Component fault or system disturbance	Component fault
System earth	Direct earthed
Fault type	Other
Primary fault or secondary/latent fault	Primary
Temporary or permanent fault	Permanent
Intermittent or non-intermittent fault	Non-intermittent
Fault cause	Technical equipment
Repair time	16 h

Outage

System unit	Line X-Y
Fault causing the outage	1
Type of system unit	Line
Energy not supplied	0 MWh
Duration of end-user outage	0 min
Characterisation of disconnection	Manually
Characterisation of reclosing	Manually after repair
Duration of outage	16 h

Interruption

Name of delivery point	-
Duration of outage	-

7.8 Line disconnection caused by temporary earthing equipment being left on X-Y line in station Y

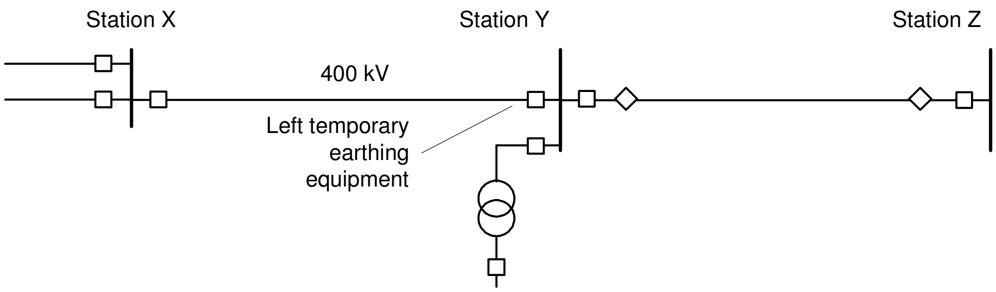


Figure 7.7 Line disconnection caused by temporary earthing equipment being left on the X-Y line in station Y.

Maintenance had been carried out on the X-Y line. Temporary earthing equipment left on the X-Y line in station Y caused the line to trip directly after the line was energized. The temporary earthing equipment was removed 20 minutes later, and it was possible to use the line again.

Grid disturbance

Identification	2000-8
Date	2000-01-10
Time	10:01

Fault

Serial number	1
Reference to grid disturbance	2000-8
Component type	Line
Voltage level	400 kV
Fault within own or other statistical area	Own
Component fault or system disturbance	Component fault
System earth	Direct earthed
Fault type	Single-phase earth fault
Primary fault or secondary/latent fault	Primary
Temporary or permanent fault	Permanent
Intermittent or non-intermittent fault	Non-intermittent
Fault cause	Operation and maintenance
Repair time	20 min

Outage

System unit	Line X-Y
Fault causing the outage	1
Type of system unit	Line
Energy not supplied	0 MWh
Duration of end-user outage	0 min
Characterisation of disconnection	Automatically
Characterisation of reclosing	Manually after repair
Duration of outage	20 min

Interruption

Name of delivery point	-
Duration of outage	-

7.9 Line fault and fault in the high speed automatic reclosing equipment

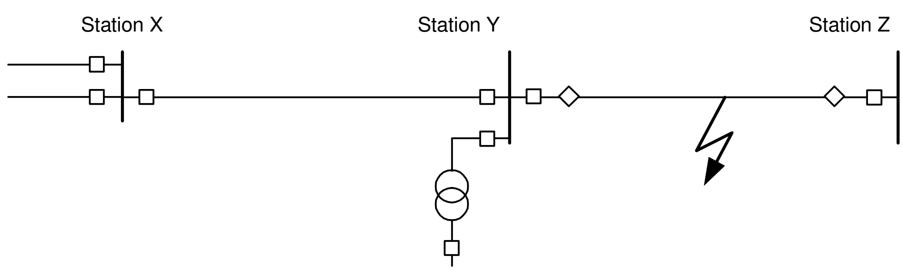


Figure 7.8 Line fault and fault in the high speed automatic reclosing equipment.

In the 400 kV Y-Z line, a single-phase earth fault occurred due to lightning. In station Y, high speed automatic reclosing was performed successfully. In station Z, high speed automatic reclosing failed to occur. Instead of being closed by means of high speed automatic reclosing, the circuit breaker was closed via automatically reclosed after one minute. The high speed automatic reclosing was repaired after three days; the repair time being three hours.

The fact that high speed automatic reclosing did not work in Z results in the grid disturbance being aggravated over time, and it should therefore be registered as a fault.

Grid disturbance

Identification	2000-9
Date	2000-01-10
Time	10:01

Fault

Serial number	1	2
Reference to grid disturbance	2000-9	2000-9
Component type	Line	Control system
Voltage level	400 kV	400 kV
Fault within own or other statistical area	Own	Own
Component fault or system disturbance	Component fault	Component fault
System earth	Direct earthed	Direct earthed
Fault type	Single-phase earth fault	Function failing to occur
Primary fault or secondary/latent fault	Primary	Secondary/latent fault
Temporary or permanent fault	Temporary	Permanent
Intermittent or non-intermittent fault	Non- intermittent	Non-intermittent
Fault cause	Lightning	Technical equipment
Repair time	0 min	3 h

Outage

System unit	Line Y-Z
Fault causing the outage	1
Type of system unit	Line
Energy not supplied	0 MWh
Duration of end-user outage	0 min
Characterisation of disconnection	Automatically
Characterisation of reclosing	Manually after repair
Duration of outage	1 min

Interruption

Name of delivery point	-
Duration of outage	-

7.10 Fault in a generator connected directly to the transmission network

A hydro-power unit connected directly to the 220 kV transmission network tripped. The frequency in the network decreased, causing an interruption of some load. No system unit with a voltage higher than 100 kV tripped.

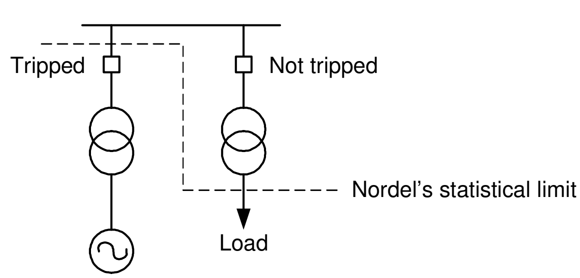


Figure 7.9 Fault in a generator connected directly to the transmission network.

This grid disturbance need not be registered as neither aggregate power transformers, generators nor network components with a voltage lower than 100 kV are included in the statistics, see Chapter 4. According to the definitions, no grid disturbances have occurred within Nordel's statistical area.

7.11 Commutation fault in a HVDC terminal

A commutation fault occurred in a HVDC terminal due to a fault in the control system. According to Section 5.1, a disconnection of a component is required for a situation to be considered a grid disturbance, and therefore nothing should be registered in this case.

7.12 Power oscillation in the power system

Power oscillation occurred in the power system in relation to the change in production. According to Section 5.1, a disconnection of a component is required in order for a situation to be considered a grid disturbance, and therefore nothing should be registered in this case.

7.13 Nuclear power station outage

A nuclear power station tripped, the frequency of the grid decreased, and the network load limits were exceeded. The situation was resolved by starting gas turbines. This grid disturbance need not be registered as neither aggregate power transformers nor generators are included in the statistics, see Chapter 4.

7.14 Interruption of a paper mill in a downstream network

A paper mill connected to a 40 kV network tripped when a capacity battery was energised in the 130 kV network. The cause of the interruption of the paper mill is switching-over voltages, which are normal when connecting capacitors.

This is not a grid disturbance in a network with a voltage of at least 100 kV and should therefore not be included in the Nordel statistics.

7.15 Operation of loaded disconnectors

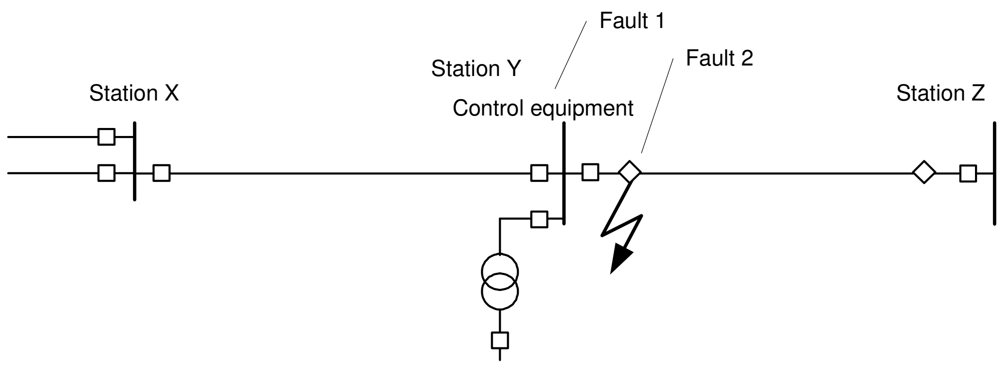


Figure 7.10 Operation of loaded disconnectors.

Before setting to work on Y-Z line, the line should be disconnected, and a line disconnector opened. Prior to latter, a circuit breaker should be operated. However, the staff was not aware that the circuit breaker had not opened in spite of the command. The line disconnector was given a command to open, which resulted in a flashover of the disconnector and the trip of the line and, subsequently, in unsuccessful high speed automatic reclosing. The circuit breaker did not open because the fuse had been removed from the control equipment. Trip coil 2 tripped the circuit breaker after the short circuit. The line disconnector was not damaged. It took one hour and five minutes to replace the fuse.

There are two options when registering this grid disturbance; either the flashover on the disconnector or the fault in the control unit is the primary fault. If the flashover on the disconnector was the primary fault, the fault should be registered in the control equipment as a latent fault. A latent fault not aggravating the grid disturbance is normally not included in the statistics. However, in this case, the question is whether the grid disturbance would have taken place if the latent fault had not occurred. Therefore fault number 2 is the fault in the control equipment, see also Section 5.2.3. The Y-Z line was supposed to be disconnected before the job was performed, and thus some time may pass before it is operational again. Therefore, it would be more relevant to set the duration of the outage to the time spent on repairing the control equipment, i.e., an hour and five minutes.

On the other hand, if you choose to register the control unit fault as the primary fault, the fault in the disconnector is registered as a secondary fault. Below it is shown how the registration should be carried out if the flashover on the disconnector is the primary fault.

Grid disturbance

Identification	2000-15
Date	2000-01-10
Time	10:01

Fault

Serial number	1	2
Reference to grid disturbance	2000-15	2000-15
Component type	Disconnector	Control equipment
Voltage level	400 kV	400 kV
Fault within own or other statistical area	Own	Own
Component fault or system disturbance	Component fault	Component fault
System earth	Direct earthed	Direct earthed
Type of fault	Two or three-phased fault with or without earth contact	Function failing to occur
Primary fault or secondary/latent fault	Primary fault	Secondary/latent fault
Temporary or permanent fault	Temporary	Permanent
Intermittent or non-intermittent fault	Non-intermittent	Non-intermittent
Fault cause	Operation and maintenance	Operation and maintenance
Repair time	0 min	1 h 5 min

Outage

System unit	Line Y-Z
Fault causing the outage	2
Type of system unit	Line
Energy not supplied	0 MWh
Duration of end-user outage	0 min
Characterisation of disconnection	Automatically, unsuccessful automatic reclosing
Characterisation of reclosing	Manually after inspection
Duration of outage	1 h 5 min

Interruption

Name of delivery point	-
Duration of interruption	-

7.16 Unsuccessful power transformer energisation due to sensitive relay setting

A 400/130 kV power transformer had to be energised but immediately tripped as the protective relay settings were too sensitive to the inrush current. After inspection and relay adjustment, another attempt to connect was successful.

The cause is stated as operation and maintenance as the relay was set to be too sensitive. No energy not supplied arose in relation to the disturbance as the downstream 130 kV network was meshed.

The repair time was one hour and 30 minutes, and the outage lasted one hour and 40 minutes.

No interruption should be registered as no delivery points in the Nordel network were affected by interruptions, see Section 6.4

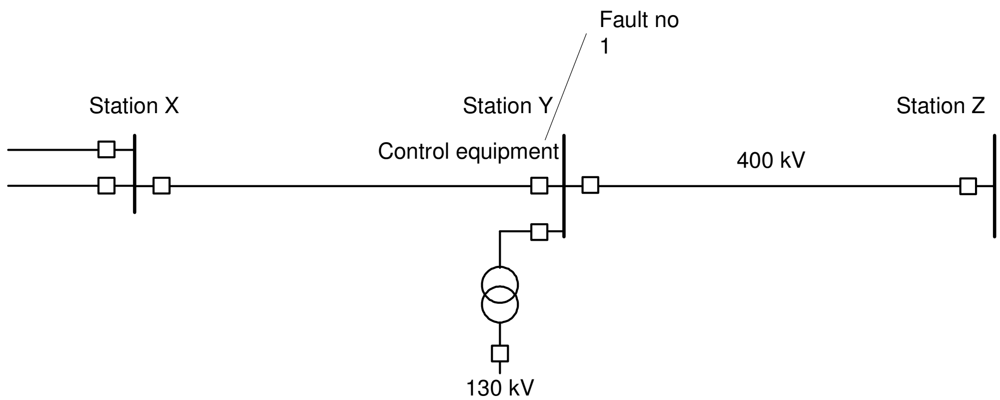


Figure 7.11 Unsuccessful power transformer energisation due to sensitive relay setting.

Grid disturbance

Identification	2000-16
Date	2000-01-10
Time	10:01

Fault

Serial number	1
Reference to grid disturbance	2000-16
Component type	Control equipment
Voltage level	400 kV
Fault within own or other statistical area	Own
Component fault or system disturbance	Component fault
System earth	Direct earthed
Fault type	Undesired function
Primary fault or secondary/latent fault	Primary
Temporary or permanent fault	Permanent
Intermittent or non-intermittent fault	Non-intermittent
Fault cause	Operation and maintenance
Repair time	1 h 30 min

Outage

System unit	Power transformer Y
Fault causing the outage	1
Type of system unit	Power transformer
Energy not supplied	0 MWh
Duration of end-user outage	0 min
Characterisation of disconnection	Automatically
Characterisation of reclosing	Manually after repair
Duration of outage	1 h 40 min

Interruption

Name of delivery point	-
Duration of interruption	-

7.17 Exploded power transformer bushing

A bushing on the 400 kV side exploded on a 400/130 kV power transformer resulting in flying fragments damaging the other bushings. A short circuit occurred, and the power transformer tripped. The power transformer was replaced by a spare power transformer after seven days (7 * 24 h = 168 h). The downstream 130 kV network was fed via the defective transformer before the fault occurred. Therefore, energy not supplied increased to 25 MWh before the load could be supplied by means of spare feeders after 30 minutes. Station Y was being fed from stations X and Z.

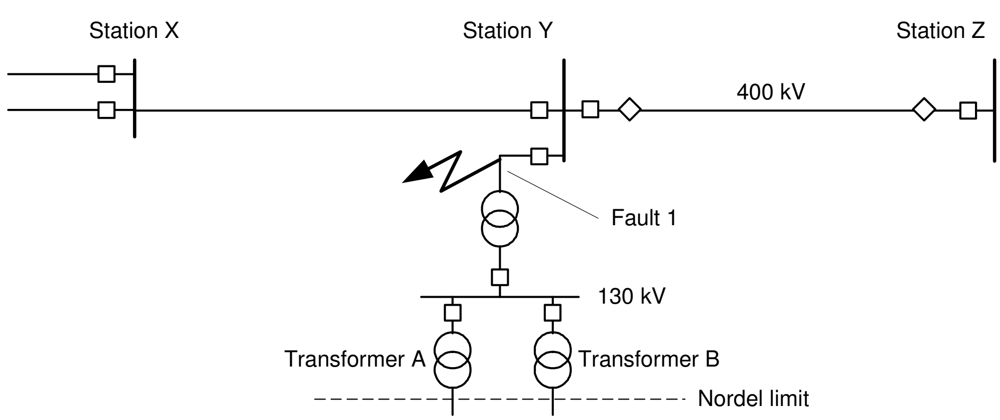


Figure 7.12 Exploded power transformer bushing.

One possibility was that moisture had penetrated the bushing. Another possibility was that poor contact between the bushing connections had resulted in the oil being heated. The fault was attributed to ageing, and the fault cause was thus set to be 'technical equipment', cf. Table 5.1.

Interruptions were registered for the delivery points Transformer A and Transformer B.

Grid disturbance

Identification	2000-17
Date	2000-01-10
Time	10:01

Fault

Serial number	1
Reference to grid disturbance	2000-17
Component type	Power transformer
Voltage level	400 kV
Fault within own or other statistical area	Own
Component fault or system disturbance	Component fault
System earth	Direct earthed
Fault type	Two or three-phased fault with or without earth contact
Primary fault or secondary/latent fault	Primary
Temporary or permanent fault	Permanent
Intermittent or non-intermittent fault	Non-intermittent
Fault cause	Technical equipment
Repair time	168 h

Outage

System unit	Power transformer Y
Fault causing the outage	1
Type of system unit	Power transformer
Energy not supplied	25 MWh
Duration of end-user outage	30 min
Characterisation of disconnection	Automatically
Characterisation of reclosing	Manually after restructuring of operation
Duration of outage	168 h

Interruption

Name of delivery point	Transformer A	Transformer B
Duration of interruption	30 min	30 min

7.18 Line fault with simultaneous faults in surge arresters and circuit breaker

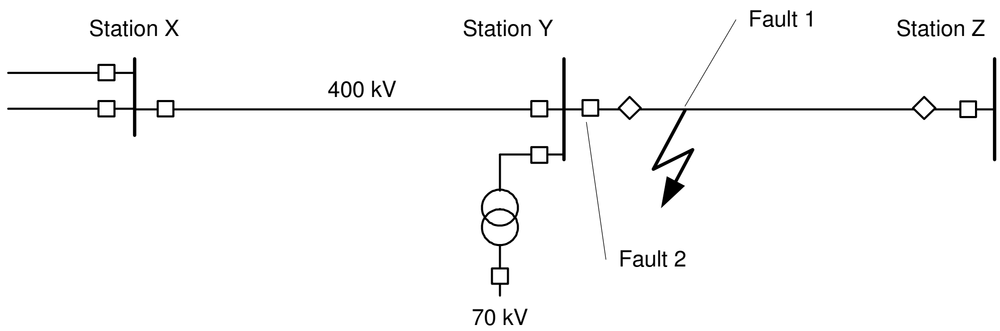


Figure 7.13 Line fault with simultaneous faults in surge arresters and circuit breaker.

A lightning strike resulting in a single-phase earth fault in a 400 kV line just outside an outdoor station caused the valve surge arresters of the line to explode. An isolator in one of the phases in the circuit breaker was damaged by fragments from the surge arresters, and three-phase short circuits occurred on the circuit breaker. The fault was disconnected by the circuit breakers of the power transformer and by the circuit breaker of the X-Y line in station Y. The defective circuit breaker was isolated manually after 50 minutes, after which station Y could be energised via line X-Y. It took eight and nine hours respectively to repair the circuit breaker and the surge arrester. No end users experienced having no energy supplied. Before the fault, station Y was fed from both station X and station Z.

Three faults occurred in connection with this disturbance: the lightning, the fault in the surge arrester and the fault in the circuit breaker. The faults in the circuit breaker and the surge arrester should be registered as they expand the disconnected part of the network. The fault cause for the surge arrester is set to be lightning. If the surge arrester had broken down due to ageing or fault dimensioning, the fault cause would have been technical equipment. The fault cause for the circuit breaker is stated as fault in conjunction with a fault in another component, i.e., Other fault causes, cf. Table 5.1.

Interruption must be registered for power transformer Y.

Grid disturbance

Identification	2000-18
Date	2000-01-10
Time	10:01

Fault

Serial number	1	2	3
Reference to grid disturbance	2000-18	2000-18	2000-18
Component type	Line	Surge arrester	Circuit breaker
Voltage level	400 kV	400 kV	400 kV
Fault within own or other statistical area	Own	Own	Own
Component fault or system disturbance	Component fault	Component fault	Component fault
System earth	Direct earthed	Direct earthed	Direct earthed
Fault type	Single-phase earth fault	Single-phase earth fault	Two or three-phased fault with or without earth contact
Primary fault or secondary/latent fault	Primary fault	Secondary/latent fault	Secondary/latent fault
Temporary or permanent fault	Temporary	Permanent	Permanent
Intermittent or non-intermittent fault	Non-intermittent	Non-intermittent	Non-intermittent
Fault cause	Lightning	Lightning	Other
Repair time	0 min	9 h	8 h

Outage

System unit	Line Y-Z	Busbar Y	Power transformer Y
Fault causing the outage	1	3	3
Type of power unit	Line	Busbar	Power transformer
Energy not supplied	0 MWh	0 MWh	0 MWh
Duration of end-user outage	0 min	0 min	0 min
Characterisation of disconnection	Automatically	Automatically	Automatically
Characterisation of reclosing	Manually after repair	Manually after inspection	Manually after inspection
Duration of outage	9 h	50 min	50 min

Outage continued

System unit	Line X-Y
Fault causing the outage	3
Type of system unit	Line
Energy not supplied	0 MWh
Duration of end-user outage	0 min
Characterisation of disconnection	Automatically
Characterisation of reclosing	Manually after inspection
Duration of outage	50 min

Interruption

Name of delivery point	Power transformer Y
Duration of interruption	50 min

7.19 Earth fault in a compensated network with a latent relay fault

During lightning, a single-phase short circuit (earth fault) occurred in an overhead line in a 132 kV compensated network. Due to a relay fault, the Y-Z line tripped. After 30 seconds, the line could be reconnected. The relay fault was repaired after a week. Travel time inclusive of repair time was 4 hours.

A temporary single-phase earth fault in a compensated network is normally not registered. However, in this case the earth fault tripped a circuit breaker and must thus be included.

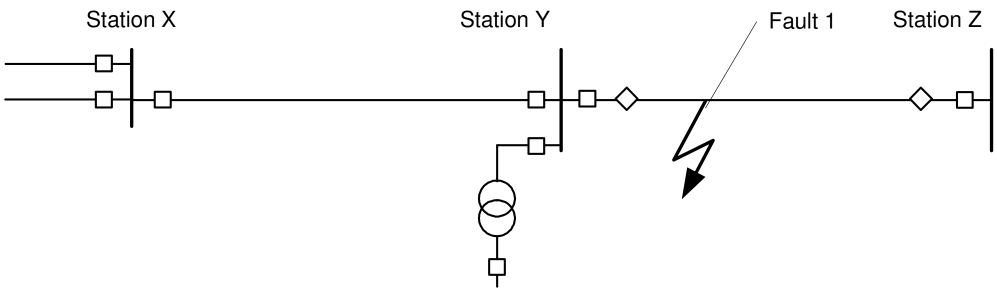


Figure 7.14 Earth fault in a compensated network with latent relay fault.

Grid disturbance

Identification	2000-19
Date	2000-01-10
Time	10:01

Fault

Serial number	1	2
Reference to grid disturbance	2000-19	2000-19
Component type	Line	Control equipment
Voltage level	132 kV	132 kV
Fault within own or other statistical area	Own	Own
Component fault or system disturbance	Component fault	Component fault
System earth	Compensated	Compensated
Fault type	Single-phase earth fault	Undesired function
Primary fault or secondary/latent fault	Primary	Secondary/latent fault
Temporary or permanent fault	Temporary	Permanent
Intermittent or non-intermittent fault	Non-intermittent	Non-intermittent
Fault cause	Lightning	Technical equipment
Repair time	0 min	4 h

Outage

System unit	Line Y-Z
Fault causing the outage	1
Type of system unit	Line
Energy not supplied	0 MWh
Duration of end-user outage	0 min
Characterisation of disconnection	Automatically
Characterisation of reclosing	Manually without either inspection, repair or restructuring of operation
Duration of outage	30 sec

Interruption

Name of delivery point	-
Duration of interruption	-

7.20 Fault on a radial feeder line with circuit breaker failing to trip

A 132 kV radial line fed two 132/20 kV transformer stations, stations Y and Z, in a direct earthed network, see Figure 7.15. Station X fed the system. During a severe storm, some trees fell down on the part of the line that was placed between stations Y and Z. A three-phase earth fault occurred.

Because of severe cold, the tripping mechanism had frozen in the circuit breaker of the outgoing line from station Y, and therefore the circuit breaker did not trip. Instead, the circuit breaker in power station X tripped. The defective erroneous circuit breaker was isolated manually after 25 minutes, after which station Y could be energised via line X-Y. The function of the circuit breaker was repaired after two hours. After another 35 minutes, the tree was removed and the operation could be fully reclosed.

Energy not supplied increased to 25 MWh in station Y and 17 MWh in station Z.

Interruptions for the respective transformers must be registered.

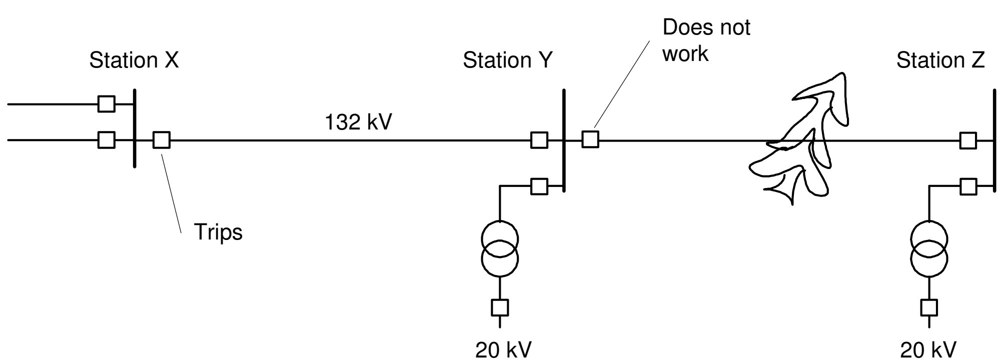


Figure 7.15 Fault on a radial feeder line with circuit breaker failing to trip.

Grid disturbance

Identification	2000-20
Date	2000-01-10
Time	10:01

Fault

Serial number	1	2
Reference to grid disturbance	2000-20	2000-20
Component type	Line	Circuit breakers
Voltage level	132 kV	132 kV
Fault within own or other statistical area	Own	Own
Component fault or system disturbance	Component fault	Component fault
System earth	Direct earthed	Direct earthed
Fault type	Two or three-phased fault with or without earth contact	Failed to occur
Primary fault or secondary/latent fault	Primary	Secondary/latent fault
Temporary or permanent fault	Permanent	Permanent
Intermittent or non-intermittent fault	Non-intermittent	Non-intermittent
Fault cause	Other environmental causes	Other environmental causes
Repair time	2 h 35 min	2 h

Outage

System unit	Line Y-Z	Power transformer	Line X-Y
Fault causing the outage	1	1	2
Type of system unit	Line	Power transformer	Line
Energy not supplied	0 MWh	17 MWh	0 MWh
Duration of end-user outage	0 min	2 h 35 min	0 min
Characterisation of disconnection	Automatically	Automatically	Automatically
Characterisation of reclosing	Manually	Manually	Manually
Duration of outage	2 h 35 min	2 h 35 min	25 min

Outage

System unit	Power transformer	Busbar Y	Busbar Z
Fault causing the outage	2	2	2
Type of system unit	Power transformer	Busbar	Busbar
Energy not supplied	25 MWh	0 MWh	0 MWh
Duration of end-user outage	25 min	0 min	0 min
Characterisation of disconnection	Automatically	Automatically	Automatically
Characterisation of reclosing	Manually	Manually	Manually
Duration of outage	25 min	25 min	2 h 35 min

Interruption

Name of delivery point	Power transformer Z	Power transformer Y
Duration of interruption	2 h 35 min	25 min

7.21 Line fault with unselective relay trip

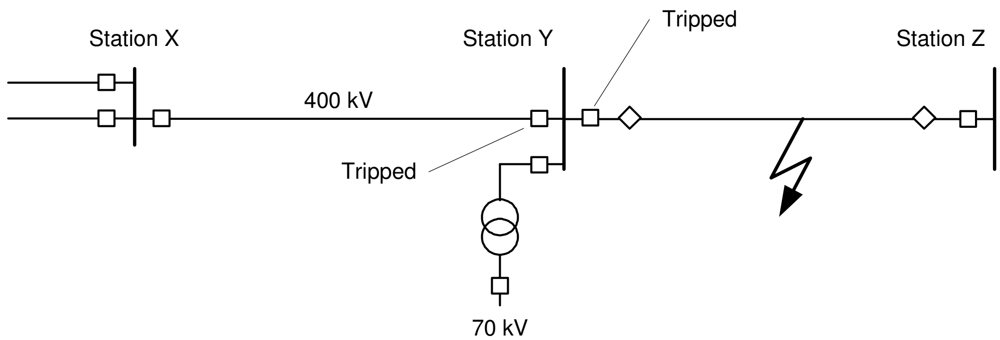


Figure 7.16 Line fault with unselective relay trip.

A station fed from two 400 kV lines was interrupted because of a short circuit caused by the lightning in Y-Z line and an unselective trip of X-Y line. The staff knew that line X-Y in station Y was equipped with an old relay type with a tendency to trip in the transition from a single-phase earth fault to three-phased short circuits. Line Y-Z was rapidly and automatically reclosed after less than two seconds. Line X-Y was reconnected after five minutes.

Thanks to the high speed automatic reclosing, the duration of the end-user outage was less than two seconds, and therefore no ENS need to be calculated, cf. Section 6.3.

The fault in the relay protection system is permanent. Normally, there is always repair time associated with a permanent fault, but since it is accepted that the protection is flawed, repair time is zero.

Interruption for the transformer must be registered. The duration of the interruption is set to 0 minutes.

Grid disturbance

Identification	2000-21
Date	2000-01-10
Time	10:01

Fault

Serial number	1	2
Reference to grid disturbance	2000-21	2000-21
Component type	Line	Control equipment
Voltage level	400	400
Fault within own or other statistical area	Own	Own
Component fault or system disturbance	Component fault	Component fault
System earth	Direct earthed	Direct earthed
Fault type	Two or three-phased fault with or without earth contact	Undesired function
Primary or secondary/latent fault	Primary	Secondary/latent fault
Temporary or permanent fault	Temporary	Permanent
Intermittent or non-intermittent fault	Non-intermittent	Non-intermittent
Fault cause	Lightning	Technical equipment
Repair time	0	0

Outage

System unit	Line Y-Z	Line X-Y
Fault causing the outage	1	2
Type of system unit	Line	Line
Energy not supplied	0 MWh	0 MWh
Duration of end-user outage	0 min	0 min
Characterisation of disconnection	Automatically	Automatically
Characterisation of reclosing	Automatically after less than 2 sec	Manually
Duration of outage	0 min	5 min

Outage (continued)

System unit	Busbar Y	Power transformer Y
Fault causing the outage	2	2
Type of system unit	Busbar	Power transformer
Energy not supplied	0 MWh	0 MWh
Characterisation of disconnection	Automatically	Automatically
Characterisation of reclosing	Automatically	Automatically
Duration of outage	0 min	0 min

Interruption

Name of delivery point	Power transformer Y
Duration of interruption	0 min

7.22 Intermittent line fault due to wind

Wind caused galloping lines of the phase leads in the 132 kV line X-Y. This resulted in five successive trips with high speed automatic reclosing within a short time.

This is an example of an intermittent fault as short circuiting in the same place within a short period of time causes more trips without it being possible the possibility to eliminate the cause, cf. Section 5.2.6.

A fault per component should be registered. In case of longer intervals between disconnections, a fault per component and disconnection should be registered. Furthermore, five outages must be registered.

Grid disturbance

Identification	2000-22
Date	2000-01-10
Time	10:01

Fault

Serial number	1
Reference to grid disturbance	2000-22
Component type	Line
Voltage level	132
Fault within own or other statistical area	Own
Component fault or system disturbance	Component fault
System earth	Direct earthed
Fault type	Two or three-phased fault with or without earth contact
Primary fault or secondary/latent fault	Primary
Temporary or permanent fault	Temporary
Intermittent or non-intermittent fault	Intermittent
Fault cause	Other environmental causes
Repair time	-

Outage

System unit	Line X-Y	Line X-Y	Line X-Y
Fault causing the outage	1	1	1
Type of system unit	Line	Line	Line
Energy not supplied	0 MWh	0 MWh	0 MWh
Duration of end-user outage	0 min	0 min	0 min
Characterisation of disconnection	Automatically	Automatically	Automatically
Characterisation of reclosing	Automatically after less than 2 seconds	Automatically after less than 2 seconds	Automatically after less than 2 seconds
Duration of outage	0	0	0

Outage continued

System unit	Line X-Y	Line X-Y
Fault causing the outage	2000-9	2000-9
Type of system unit	Line	Line
Energy not supplied	0 MWh	0 MWh
Duration of end-user outage	0 min	0 min
Characterisation of disconnection	Automatically	Automatically
Characterisation of reclosing	Automatically after less than 2 seconds	Automatically after less than 2 seconds
Duration of outage	0	0

Interruption

Name of delivery point	-
Duration of delivery point	-

7.23 A fault in one company's network causing outage in another company's network

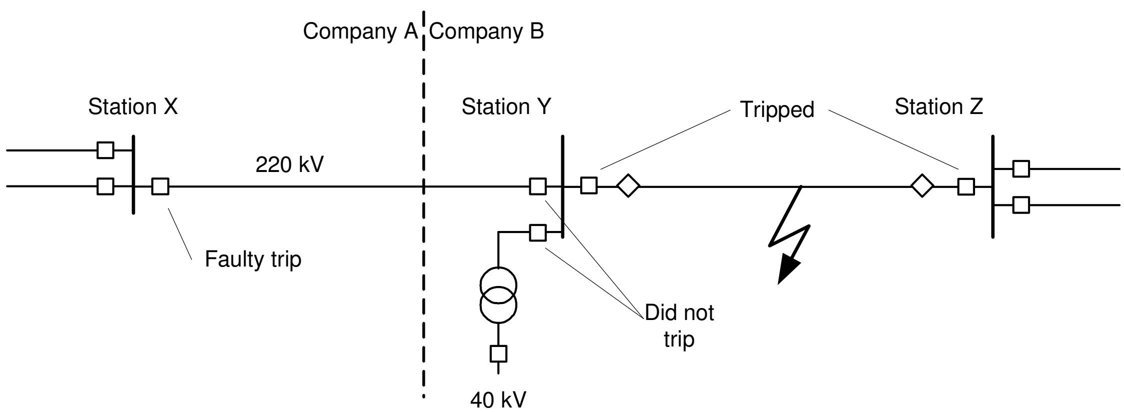


Figure 7.17 A fault in one company's network causing outage in another company's network.

Due to a short circuit of unknown cause in Y-Z line in company B's grid, the overhead line X-Y in company A's grid also tripped due to a relay fault. The lines were reconnected manually after all affected stations had been inspected; X-Y line after 30 minutes and Y-Z line after 45 minutes. Energy not supplied from the transformer in station Y increased to 10 MWh. The network in Figure 7.17 was fed from both directions. There is no autoreclosing for the line. It took four hours and 45 minutes to repair the relay.

Company A with the relay fault prepares the report below.

Even if the line is reclosed, the relay fault is permanent until the relay has been repaired. Voluntary waiting time should not be included in the repair time, see Section 5.4.11. A possible planned outage to repair the relay should not be included in the statistics as it is a planned outage. Company A does not need to do any other classifications than the ones shown below for fault number 1, which was the primary fault in company B's area.

Grid disturbance

Identification	2000-23
Date	2000-01-10
Time	10:01

Fault

Serial number	1	2
Reference to grid disturbance	2000-23	2000-23
Component type		Control equipment
Voltage level	220	220
Fault within own or other statistical area	Other statistical area	Own
Component fault or system disturbance		Component fault
System earth		Direct earthed
Fault type		Undesired function
Primary or secondary/latent fault	Primary	Secondary/latent fault
Temporary or permanent fault		Permanent
Intermittent or non-intermittent fault		Non- intermittent
Fault cause		Technical equipment
Repair time		4h 45min

Outage

System unit	Line X-Y
Fault causing the outage	2
Type of system unit	Line
Energy not supplied	0 MWh
Duration of end-user outage	30 min
Characterisation of disconnection	Automatically
Characterisation of reclosing	Manually
Duration of outage	0 min

Interruption

Name of delivery point	-
Duration of interruption	-

Company B with the line fault prepares the following report.

Grid disturbance

Identification	2000-23
Date	2000-01-10
Time	10:01

Fault

Serial number	1	2
Reference to grid disturbance	2000-23	2000-23
Component type	Line	
Voltage level	220	220
Fault within own or other statistical area	Own	Other statistical area
Component fault or system disturbance	Component fault	
System earth	Direct earthed	
Fault type	Two or three-phased fault with or without earth contact	
Primary fault or secondary/latent fault	Primary	
Temporary or permanent fault	Temporary	
Intermittent or non-intermittent fault	Non-intermittent	
Fault cause	Unknown	Technical equipment
Repair time	0 min	4h 45min

Outage

System unit	Line Y-Z	Power transformer Y	Busbar Y
Fault causing the outage	1	2	2
Type of system unit	Line	Power transformer	Busbar
Energy not supplied	0 MWh	10 MWh	0 MWh
Duration of end-user outage	45 min	30 min	30 min
Characterisation of disconnection	Automatically	Automatically	Automatically
Characterisation of reclosing	Manually	Manually	Manually
Duration of outage	45 min	30 min	30 min

Interruption

Name of delivery point	Power transformer Y
Duration of interruption	30 min

7.24 Double earth fault in a compensated network

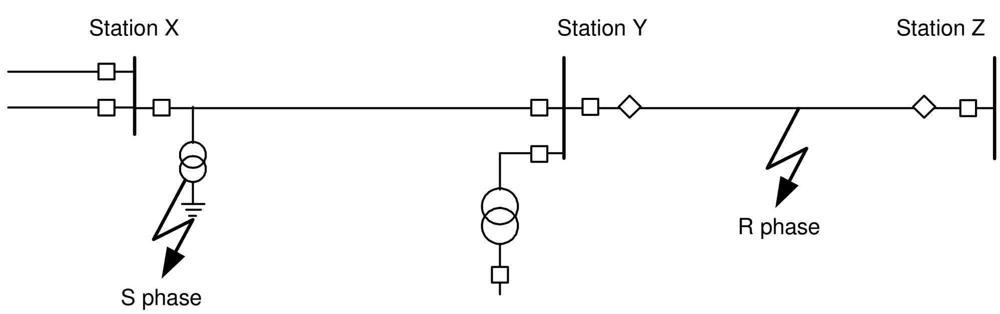


Figure 7.18 Double earth fault in a compensated network.

An earth fault occurred in the R phase in the Y-Z line as a result of a tree falling down on the line. The earth fault caused high phase voltages in the two other phases, and a voltage transformer was damaged in the S phase in station X. Thus a double earth fault occurred, and line X-Y tripped correctly in both ends. The earth fault in the Y-Z line disappeared automatically after the tree had been burned. Line X-Y could be reconnected after 24 hours after the voltage transformer was replaced.

Grid disturbance

Identification	2000-24
Date	2000-01-10
Time	10:01

Fault

Serial number	1	2
Reference to grid disturbance	2000-24	2000-24
Component type	Line	Voltage transformer
Voltage level	132 kV	132 kV
Fault within own or other statistical area	Own	Own
Component fault or system disturbance	Component fault	Component fault
System earth	Compensated	Compensated
Fault type	Single-phase earth fault	Single-phase earth fault
Primary fault or secondary/latent fault	Primary	Secondary/latent fault
Temporary or permanent fault	Temporary	Permanent
Intermittent or non-intermittent fault	Non-intermittent	Non-intermittent
Fault cause	Other environmental causes	Other
Repair time	-	24 h

Outage

System unit	Line X-Y
Fault causing the outage	1
Type of system unit	Line
Energy not supplied	0 MWh
Duration of end-user outage	0 min
Characterisation of disconnection	Automatically
Characterisation of reclosing	Manually after repair
Duration of outage	24 h

Interruption

Name of delivery point	-
Duration of interruption	-

7.25 Outage of parallel power transformers due to a tap changer fault and overload

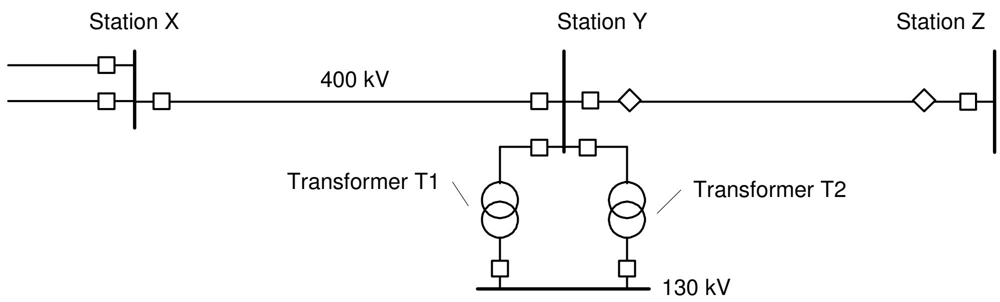


Figure 7.19 Outage of parallel power transformers due to tap changer fault and overload.

In a transformer station, a 400/130 kV power transformer T1 tripped because the tap changer was in a middle position. The main spring in the tap changer mechanism of one of the phases was broken. After interruption of T1, the power transformer T2 also tripped due to overload. After restructuring the 130 kV level load, T2 was put into operation after 10 minutes without inspection.

The power transformer was operational again after five days, but the repair only took 40 hours. The 130 kV network is meshed, and therefore no end-user outage occurred.

No interruption should be registered as no delivery points in the Nordel network were affected by the interruption, see Section 6.4.

Grid disturbance

Identification	2000-25
Date	2000-01-10
Time	10:01

Fault

Serial number	1	2
Reference to grid disturbance	2000-25	2000-25
Component type	Power transformer	Power transformer
Voltage level	400 kV	400 kV
Fault within own or other statistical area	Own	Own
Component fault or system disturbance	Component fault	Component fault
System earth	Direct	Direct
Fault type	Other	Overload
Primary fault or secondary/latent fault	Primary	Secondary/latent fault
Temporary or permanent fault	Permanent	Temporary
Intermittent or non-intermittent fault	Non-intermittent	Non-intermittent
Fault cause	Technical equipment	Other
Repair time	40 h	0 min

Outage

System unit	Power transformer T1	Power transformer T2
Fault causing the outage	1	2
Type of system unit	Power transformer	Power transformer
Energy not supplied	0 MWh	0 MWh
Duration of end-user outage	0 min	0 min
Characterisation of disconnection	Automatically	Automatically
Characterisation of reclosing	Manually after repair	Manually without inspection, repair or restructuring of operation
Duration of outage	120 h	10 min

Interruption

Name of delivery point	-
Duration of interruption	-

7.26 Line fault with an end-user outage in the downstream network

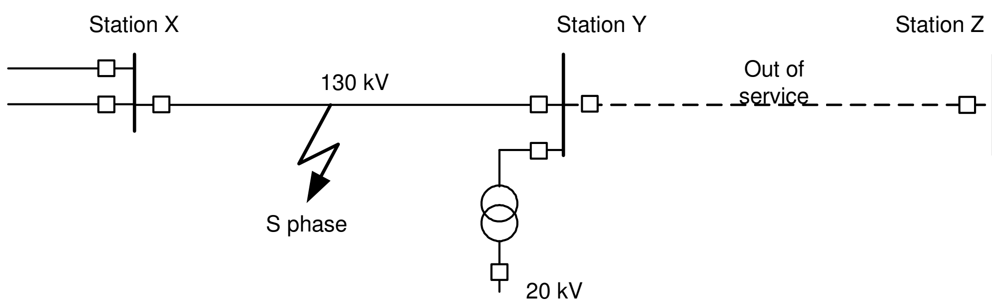


Figure 7.20 Line fault with an end-user outage in the downstream network.

A 20 kV network was fed by the 130 kV network only via X-Y line and from a local power plant. Due to lightning, a single-phase earth fault occurred in the 130 kV network, after which the feeder line was disconnected.

The total load in the 20 kV network was 50 MW before the disturbance. The X-Y line and the power transformer Y were both reconnected 30 minutes after having been inspected, and it was possible to reclose 20 MW of the load directly. After another 20 minutes, the rest of the load was reclosable.

According to Section 5.4.8, energy not supplied is calculated as the energy that should have been delivered, had the outage not occurred. In this case, it is recommended that the energy be calculated as 30/60 * 50 + 20/60 * 30 = 35 MWh. However, in practice the procedure for calculating in this case may be different in another company.

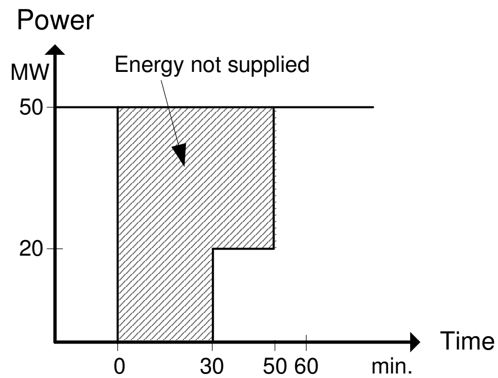


Figure 7.21 Energy not supplied.

Grid disturbance

Identification	2000-26
Date	2000-01-10
Time	10:01

Fault

Serial number	1
Reference to grid disturbance	2000-26
Component type	Line
Voltage level	130 kV
Fault within own or other statistical area	Own
Component fault or system disturbance	Component fault
System earth	Direct earthed
Fault type	Single-phase earth fault
Primary fault or secondary/latent fault	Primary
Temporary or permanent fault	Temporary
Intermittent or non-intermittent fault	Non-intermittent
Fault cause	Lightning
Repair time	0 min

Outage

System unit	Line X-Y	Power transformer Y
Fault causing the outage	1	1
Type of system unit	Line	Power transformer
Energy not supplied	0 MWh	15 MWh
Duration of end-user outage	50 min *)	50 min *)
Characterisation of disconnection	Automatically	Automatically
Characterisation of reclosing	Manually after inspection	Manually after inspection
Duration of outage	30 min	30 min

*) The end-user outage lasting the longest is stated.

Interruption

Name of delivery point	Power transformer Y
Duration of interruption	30 min

7.27 Outage of a line with a series capacitor

400 kV X-Y line with a series capacitor tripped because of a two-phased earth fault after which the series capacitor bypassed automatically. The high speed automatic reclosing of the line was successful. The series capacitor was back in operation after one and a half hours after having been inspected.

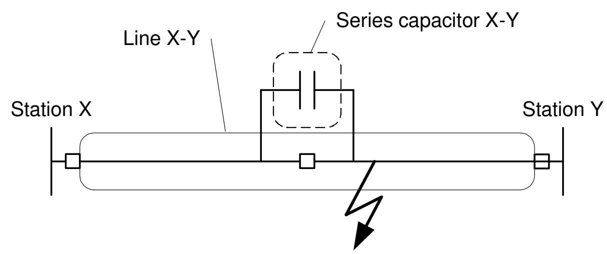


Figure 7.22 Outage of line with series capacitor.

Grid disturbance

Identification	2000-27
Date	2000-01-10
Time	10:01

Fault

Serial number	1
Reference to grid disturbance	2000-27
Component type	Line
Voltage level	400 kV
Fault within own or other statistical area	Own
Component fault or system disturbance	Component fault
System earth	Direct earthed
Fault type	Two or three-phased with or without earth contact
Primary fault or secondary/latent fault	Primary
Temporary or permanent fault	Temporary
Intermittent or non-intermittent fault	Non-intermittent
Fault cause	Lightning
Repair time	0 min

Outage

System unit	Line X-Y	Series capacitor X-Y
Fault causing the outage	1	1
Type of system unit	Line	Series capacitor
Energy not supplied	0 MWh	0 MWh
Duration of end-user outage	0 min	0 min
Characterisation of disconnection	Automatically	Automatically
Characterisation of reclosing	Automatically after less than 2 sec	Manually after inspection
Duration of outage	0 min	1 h 30 min

Interruption

Name of delivery point	-
Duration of outage	-

8. Reporting of the basis for the annual report

8.1 Reporting form

In Table 8.1, the number of grid disturbances and the amount of energy not supplied distributed on the causes for the primary fault of the grid disturbances are reported. The cause of the disturbance is the same as the cause of the primary fault.

Table 8.1

Cause of primary fault	Number of grid disturbances	No. of grid disturbances causing ENS	ENS (MWh)
Lightning			
Other environmental causes			
External influences			
Operation and maintenance			
Technical equipment			
Other			
Unknown			

In Table 8.2, the number of grid disturbances and ENS per month is reported. Check that the total number of grid disturbances and the sum of ENS correspond to those given in Table 8.1.

Table 8.2

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Number of grid disturbances												
ENS (MWh)												

In Table 8.3, the number of faults classified according to the cause of the fault is reported. Moreover, it is registered how many faults that have caused ENS, and how much ENS the faults caused. Include faults both in your own grid and other grids resulting in system disturbances. Note the difference between Table 8.1 and Table 8.3. Table 8.1 shows grid disturbances while Table 8.3 shows faults. A grid disturbance may contain several faults, see sections 5.1 and 5.2.

Table 8.3

Fault cause	Number of faults	Number of faults with ENS	ENS (MWh)
Lightning			
Other environmental causes			
External influences			
Operation and maintenance			
Technical equipment			
Other			
Unknown			

In Table 8.4, the number of faults in lines and cables divided by cause is reported. Moreover, the numbers of single-phase faults and permanent faults are reported. In the last column, the cause of the ENS fault is reported. Include faults in your own grid only.

Table 8.4

Component	Number of km	Number of faults	Number of faults divided by cause							Number of single-phase earth faults	Number of permanent faults	ENS (MWh)
			Lightning	Other environmental causes	External influences	Operation and maintenance	Technical equipment	Other	Unknown			
Overhead lines 132 kV compensated												
132 kV direct earthed												
220 kV direct earthed												
400 kV direct earthed												
Cables 132 kV compensated												
132 kV direct earthed												
220 kV direct earthed												
400 kV direct earthed												

In Table 8.5, the number of faults in other components divided into causes is reported. In the last column, the cause of the ENS fault is reported. Include faults in your own grid only.

Table 8.5

Component	Number	Number of faults	Number of faults divided by cause							ENS (MWh)
			Lightning	Other environmental causes	External influences	Operation and maintenance	Technical equipment	Other	Unknown	
Power transformers 132 kV										
220 kV										
400 kV										
Instrument transformers 132 kV										
220 kV										
400 kV										
Circuit breakers 132 kV										
220 kV										
400 kV										
Busbars										
Synchronous compensators										
SVC and statcom										
Shunt capacitor batteries and filters										
Reactors inclusive of neutral point reactors										
Series capacitors										
Control equipment 132 kV										
220 kV										
400 kV										

Component	Number	Number of faults	Number of faults divided by cause							ENS (MWh)
			Lightning	Other environmental causes	External influences	Operation and maintenance	Technical equipment	Other	Unknown	
Disconnectors and earth connectors										
Surge arresters and spark gaps										
Common ancillary equipment										
HVDC										
Other high voltage appliances										

In Table 8.6 the number of disturbances caused by faults in other statistical areas and the number of system faults are reported. In the last column, the cause of the ENS fault is reported.

Table 8.6

	Number of faults	**ENS (MWh)**
Faults in adjoining statistical area		
System disturbances		

In Table 8.7, ENS divided by voltage level is registered. The voltage level must concern the primary fault. Check that the sum of ENS equals the sum in Table 8.1.

Table 8.7

Voltage level for primary faults	**ENS (MWh)**
< 100 kV	
132 kV	
220 kV	
400 kV	

In Table 8.8 the number of faults in own grid by voltage level is reported.

Table 8.8

Fault voltage levels	**No. of faults in own grid**
< 100kV	
132 kV	
220 kV	
400 kV	

In Table 8.9, the total amount of consumption of every country is reported. Furthermore, the total energy not supplied of every company is reported, and this should correspond to the sum of ENS in Table 8.1.

Table 8.9

Total consumption showed per country (GWh)	
The sum of ENS (MWh)	

In Table 8.10, the total numbers of system units are reported. In addition, the numbers of system units with different numbers of outages are reported. Check that the total sums of the columns from ”0” to ”>5” correspond to the figures in the column ”Number of system units”.

Table 8.10

System unit	**Number of system units**	**Number of system units grouped by number of outages**						
		No outages	**1 outage**	**2 outages**	**3 outages**	**4 outages**	**5 outages**	**>5 outages**
HVDC system								
Line								
Reactor								
Busbar								
Series capacitor								
Shunt capacitor								
SVC								
Power transformer								

In Table 8.11, the numbers of system units with different outage durations are reported. First, for every system unit, the total duration of the outage is summed up. After this, the number of system units for every time interval is summed up and reported in Table 8.11. Note that the administrative delay (voluntary waiting time) should not be included in the duration of the outage, see Section 5.3.1. Check that the sum of all columns for every kind of system unit in Table 8.11 equals the figure in the column ”Number of system units” in Table 8.10.

Table 8.11

	Number of system units grouped by total outage duration time								
System unit	**No outages**	**0 -3 min**	**3-10 min**	**10-30 min**	**30-60 min**	**60-120 min**	**120-240 min**	**240-480 min**	**>480 min**
HVDC system									
Line									
Reactor									
Busbar									
Series capacitor									
Shunt capacitor									
SVC									
Power transformer									

8.2 Guidelines for calculating the number of components

To be able to calculate fault frequencies for components, it is imperative to know the number of individual components. Table 8.12 shows how the number of the various components is calculated.

Table 8.12

Component	***Calculation of number and kilometres***
Surge arresters and spark gaps	Surge arresters and spark gaps are considered as one component per three-phased unit.
Circuit breakers	Circuit breakers are considered as one component per three-phased unit. Disconnecting circuit breakers (DCB) are considered circuit breakers.
Disconnectors and earth connectors	Disconnectors and earth connectors are considered as one component per three-phased unit. Earth connectors and disconnectors are considered as two components.
Common ancillary equipment	The number of common ancillary equipment should equal the number of stations.
HVDC	HVDC systems are considered as one per pole.
Cables	Cable length is considered as the cable distension multiplied by the number of parallel cable connections. Thus, if there are two parallel cable connections, the cable length is twice the distance between the connection points of the cable.

Component	***Calculation of number and kilometres***
Control equipment	The number of control equipment should equal the number of circuit breakers
Power transformers	A power transformer with a separate regulating transformer is considered as one component. A power transformer consisting of three single-phase units is considered as one component.
Overhead lines	Is calculated as total length per kilometre and voltage level.
Instrument transformers	An instrument transformer is considered as one component per three-phased unit. If only a single-phase unit is installed, this is also considered as one component.
Reactors inclusive of neutral point reactors	Reactors inclusive of neutral point reactors are considered as one component per three-phased connection organ.
Synchronous compensators	Rotating phase compensators are considered as one component per unit.
Busbars	The number of busbars is considered as one per voltage level and station. A, B and C busbars are not considered as separate bars.
Series capacitors	Series capacitors are considered as one component per three-phased connection organ.
Shunt capacitor batteries and filters	Shunt capacitor batteries and filters are considered as one component per three-phased connection organ.
SVC and statcom	SVCs and statcom are considered as one component per unit.
Other high voltage appliances	The number of other high voltage appliances should equal the number of stations.

9. Future work

While these guidelines were prepared, suggestions were presented as to how to develop Nordel's statistics. Also, common solutions have to be found, and questions within certain areas need to be answered.

One idea could be to introduce the concept energy not transmitted (ENT). A definition may be: ”Calculated amount of energy that should have been delivered by a delivery point if the outage had not occurred.” There is, however, a degree of uncertainty attached to this definition. What applies to a downstream network with several feeders? If the production in the downstream network releases simultaneously with an outage occurring, and this leads to the transmitted effect in the downstream network being greater than before the outage, then how is ENT calculated?

It is difficult to find a model for calculating energy not supplied (ENS) that will always work. How do you treat the cases in which the downstream generation is simultaneously connected to load? Can end-user outage be calculated on the basis of the total load within the area or from the power supplied to the area before the fault?

Faults never come singly, and it would therefore be interesting to create a basis for common mode faults.

The reliability and the behaviour of the relay protection system during grid disturbances have great influence on the development of grid disturbances. Here a comparison within the Nordic countries would be interesting.

It should be possible to develop the statistics report to also contain non-grid disturbance related material, such as data on frequency quality, use of internal sections and international connections and planned outages.

A further parameter being discussed in relation to the work on these guidelines is production loss. It would be interesting to see statistics of this.

References

1. The Energy Concern's National League, The Norwegian Water Supply and Energy Department, Statnett and Sintef Energy Research – Definitions in relation to faults and outages in the electrical power system - Version 2, 2001
2. IEC 50(191-05-01): International Electrotechnical Vocabulary, Dependability and quality of service
3. EN 13306: Maintenance terminology
4. EN 50160 Voltage Characteristics of Electricity Supplied by Public Distribution Systems
5. IEEE Standard Terms for Reporting and Analyzing Outage Occurrence and Outage States of Electrical Transmission Facilities (IEEE Std 859-1987)

Appendix A: Cross reference list for fault causes

The tables below state how the division of fault causes and subcauses for various countries and companies are converted into Nordel's division of fault causes according to Table 5.1.

Table A.1 Fault causes in Denmark

Fault causes in Denmark	Conversion into fault cause in the Nordel statistics
Lightning	Lightning
Meteorological conditions	Other environmental causes
Wind (storm)	Other environmental causes
Ice and snow coverings	Other environmental causes
Pollution, salt, etc.	Other environmental causes
Low temperature	Other environmental causes
Heat	Other environmental causes
Rain and moisture	Other environmental causes
Flood, storm surge	Other environmental causes
Other external influences	External influences
Vandalism	External influences
Tree felling and rock blasting	External influences
Flying objects	External influences
Fire	External influences
Birds or other animals	External influences
Earthwork	External influences
Collision	External influences
Stray current	External influences
Work on plant excl. staff	External influences
Staff	Operation and maintenance
Maloperation local control	Operation and maintenance
Maloperation remote control	Operation and maintenance
Influences during work or testing	Operation and maintenance
Lack of monitoring	Operation and maintenance
Other	Other
Coupling overvoltages, induction etc.	Other
Switching on of a fault during fault search	Other
Switching off of component during fault search	Other
No immediate cause	Other
Influenced by another fault in another unit	Other
Unknown	Unknown

Table A.2 Fault causes in Finland

Fault causes in Finland	Conversion into fault causes in the Nordel statistics
Lightning	Lightning
Natural phenomena in general	Other environmental causes
Wind	Other environmental causes
Rain or moisture	Other environmental causes
Snow or ice	Other environmental causes
Temperature (high or low)	Other environmental causes
Pollution and salt	Other environmental causes
Animals	External influences
External influences in general	External influences
Vandalism	External influences
Tree felling	External influences
Accidents, external	External influences
Switching voltage or current	Operation and maintenance
Maintenance in general	Operation and maintenance
Power line maintenance	Operation and maintenance
Protection maintenance	Operation and maintenance
Equipment maintenance	Operation and maintenance
Mistake in investments	Operation and maintenance
Switching mistake	Operation and maintenance
Device in general	Technical equipment
Production	Technical equipment
Ageing	Technical equipment
Design	Technical equipment
Operation in general	Technical equipment
Other	Other
Secondary fault	Other
Fault in other network	Other
System cause	Other
Unknown	Unknown

Table A.3 Fault causes in Iceland

Fault causes in Iceland	Conversion into fault causes in the Nordel statistics
Nature	Other environmental causes
Felling	External influences
Fault in material and production	Technical equipment
Ageing	Technical equipment
Installation	Operation and maintenance
Lack of line passage	Technical equipment
Fault in relay plan	Operation and maintenance
Design/dimensioning	Operation and maintenance
Lack of monitoring	Operation and maintenance
Lack of maintenance	Operation and maintenance
Unknown	Other
Other	Other

Table A.4 Fault causes in Norway

Fault causes in Norway	Subcauses in Norway	Conversion into fault causes in the Nordel statistics
Surroundings	Lightning	Lightning
Surroundings	Wind	Other environmental causes
Surroundings	Snow/ice	Other environmental causes
Surroundings	Frost/frozen earth	Other environmental causes
Surroundings	Water/precipitation/moisture	Other environmental causes
Surroundings	Salt/pollution	Other environmental causes
Surroundings	Contaminant	External influences
Surroundings	Birds/animals	External influences
Surroundings	Vegetation	Other environmental causes
Surroundings	Displacements	Other environmental causes
Surroundings	Avalanche	Other environmental causes
Surroundings	Fire/explosion	External influences
Surroundings	Other	Other
Humans/staff	Maloperation	Operation and maintenance
Humans/staff	Work/testing	Operation and maintenance
Humans/staff	Tree felling	External influences
Humans/staff	Excavation/explosion	External influences
Humans/staff	Component work	Operation and maintenance
Humans/staff	Traffic damage	External influences
Humans/staff	Vandalism/sabotage	External influences
Humans/staff	Other	Operation and maintenance
Humans/external staff	Maloperation	Operation and maintenance
Humans/external staff	Work/testing	Operation and maintenance
Humans/external staff	Tree felling	External influences
Humans/external staff	Excavation/explosion	External influences
Humans/external staff	Component work	Operation and maintenance
Humans/external staff	Traffic damage	External influences
Humans/external staff	Vandalism/sabotage	External influences
Humans/external staff	Other	Operation and maintenance
Humans/others	Maloperation	External influences
Humans/others	Work/testing	External influences
Humans/others	Tree felling	External influences
Humans/others	Excavation/explosion	External influences
Humans/others	Component work	External influences
Humans/others	Traffic damage	External influences
Humans/others	Vandalism/sabotage	External influences
Humans/others	Other	External influences
Operational problems	Overload	Other
Operational problems	High/low voltage	Other
Operational problems	High/low level	Other
Operational problems	High/low pressure	Other
Operational problems	Vibration	Other
Operational problems	Permanent load increase	Other
Operational problems	Other	Other
Technical equipment	Ageing	Technical equipment
Technical equipment	Abrasion	Technical equipment
Technical equipment	Corrosion	Technical equipment
Technical equipment	Cavitation	Technical equipment
Technical equipment	Erosion	Technical equipment
Technical equipment	Poor contact	Technical equipment
Technical equipment	Electrical discharges	Technical equipment
Technical equipment	Leak	Technical equipment
Technical equipment	Loose parts	Technical equipment
Technical equipment	Damaged/defective component	Technical equipment
Technical equipment	Crack/break	Technical equipment
Technical equipment	Decay	Technical equipment
Technical equipment	Pollution/impurities	Technical equipment
Technical equipment	Blocking	Technical equipment

Fault causes in Norway	Subcauses in Norway	Conversion into fault causes in the Nordel statistics
Technical equipment	Other	Technical equipment
Design/installation	Design/dimensioning fault	Technical equipment
Design/installation	Production fault	Technical equipment
Design/installation	Installation	Technical equipment
Design/installation	Faulty settings/adjustment	Operation and maintenance
Design/installation	Lack of instructions/routines	Technical equipment
Design/installation	Lack of maintenance	Operation and maintenance
Design/installation	Defective relay	Technical equipment
Design/installation	Fault in relay plan	Operation and maintenance
Design/installation	Other	Technical equipment
Former fault		Other
No primary cause		Other
Cause not defined		Unknown

Table A.5 Fault causes for Svenska Kraftnät

Fault causes for Svenska Kraftnät	Subcauses for Svenska Kraftnät	Conversion into fault causes in the Nordel statistics
Lightning		Lightning
Other nature	Low temperature	Other environmental causes
	Frost	Other environmental causes
	Pollution/salt	Other environmental causes
	Rain/moisture/snow	Other environmental causes
	Vegetation	Other environmental causes
	Wind	Other environmental causes
	Heat	Other environmental causes
	Other	Other environmental causes
	Unknown	Other environmental causes
External influences	Fire	External influences
	Animals	External influences
	Flying objects incl. kites etc.	External influences
	Excavation/explosion	External influences
	Collision	External Influences
	Tree felling	External influences
	Vandalism	External influences
	Other	External influences
	Unknown	External influences
Operation and maintenance	Fault in documentation/foundation	Operation and maintenance
	Maloperation/connection plan	Operation and maintenance
	Fault in settings	Operation and maintenance
	Fault earthing	Operation and maintenance
	Erroneous work	Operation and maintenance
	Fault coupling/maloperation	Operation and maintenance
	Other staff fault	Operation and maintenance
	Unknown	Operation and maintenance
High voltage equipment	Poor contact	Technical equipment
	Fault in design/installation	Technical equipment
	Leak	Technical equipment
	Material break	Technical equipment
	Optic fault	Technical equipment
	Program fault	Technical equipment
	Abrasion	Technical equipment
	Other fault in high voltage component	Technical equipment
	Unknown	Technical equipment
Control equipment	Poor contact	Technical equipment
	Fault in design/installation	Technical equipment
	Fault in electronic component	Technical equipment
	Program fault	Technical equipment
	Optic fault	Technical equipment
	Abrasion	Technical equipment
	Lack of communication	Technical equipment
	Other	Technical equipment
	Unknown	Technical equipment
Subsynchronous resonance		Other
Other	Overload	Other
	Power hunting	Other
	Fault in other network	Other
	Low transmission	Other
	Other	Other
Unknown		Other

Table A.6 Fault causes for Sydkraft

Fault causes for Sydkraft	Subcauses for Sydkraft	Conversion to fault causes in the Nordel statistics
Weather and environment	Lightning	Lightning
	Wind	Other environmental causes
	Rain and moisture	Other environmental causes
	Snow, ice bark, galloping lines	Other environmental causes
	Salt, pollution	Other environmental causes
	Low temperature	Other environmental causes
	Heat	Other environmental causes
	Resetting of waterways	Other environmental causes
	Other	Other environmental causes
Vandalism on surroundings	Digging, collision	External influences
	Outrageous act	External influences
	Explosion, splintering	External influences
	Tree felling	External influences
	Flying or buoyant objects	External influences
	Fire, explosion	External influences
	Animals, birds	External influences
	Foreign objects in turbine	External influences
	Other	External influences
Staff	Maloperation	Operation and maintenance
	Lack of monitoring and maintenance	Operation and maintenance
	Neglected or erroneous deregistration or changing of protection and monitoring equipment	Operation and maintenance
	Unsuitable setting of protection and monitoring equipment, wrongly chosen fuse	Operation and maintenance
	Fault in relation to testing and monitoring	Operation and maintenance
	Lack of monitoring	Operation and maintenance
	Other	Operation and maintenance
Equipment and material	Faulty manufacture or material	Technical equipment
	Defective design or appliance	Technical equipment
	Insufficient dimensioning, aged plants	Technical equipment
	Exhaustion, abrasion, ageing, corrosion	Technical equipment
	Temporary	Technical equipment
	Defective installation	Technical equipment
	Insufficient line section passages. If the line passage is tree proof, it should be classified as "Lack of monitoring and maintenance" if lack of maintenance is the case.	Technical equipment
	Other	Technical equipment
Other causes	Influence in conjunction with fault in another component during the same grid disturbance	Other
	Decreased mechanical or electrical strength due to earlier problems.	Other
	Known insufficiencies in the equipment	Other
	Coupling overload etc.	Other
	Other	Other

Table A.7 Fault causes for Vattenfall

Fault causes for Vattenfall	Subcauses for Vattenfall	Conversion to fault causes in the Nordel statistics
Natural circumstances	Lightning	Lightning
	Wind	Other environmental causes
	Rain and moisture	Other environmental causes
	Low temperature, snow and ice bark	Other environmental causes
	Salt cover	Other environmental causes
	Birds and other animals	Other environmental causes
	Heat	Other environmental causes
	Resetting of waterways	Other environmental causes
	Other	Other environmental causes
Vandalism	Outrageous act	External influences
	Explosion and such causes	External influences
	Tree felling	External influences
	Other personnel	External influences
	Aircraft etc.	External influences
	Fire	External influences
	Excavation, collision etc.	External influences
	Foreign objects	External influences
	Other	External influences
Staff	Maloperation	Operation and maintenance
	Lack of monitoring and maintenance	Operation and maintenance
	Erroneously reconnected protection equipment	Operation and maintenance
	Erroneously set protection equipment	Operation and maintenance
	Fault in relation to testing	Operation and maintenance
	Other	Operation and maintenance
Equipment and material	Defective material	Technical equipment
	Unsuitable design	Technical equipment
	Insufficient dimensioning	Technical equipment
	Unexpected problems	Technical equipment
	Temporary	Technical equipment
	Defective installation	Technical equipment
	Lack of line passage	Technical equipment
	Other	Technical equipment
Other causes	Coverings on dampened surfaces	Other
	Coverings on surfaces in contact with gas	Other
	Oil pollution etc.	Other
	Unsuitable fuel	Other
	Coupling over voltage etc.	Other
	Other	Other
Own system disturbance	Interruption of connection lines	Other
	Interruption due to local overload	Other
	Own system disturbance	Other
	Other	Other
Not own system disturbance	Fault in other company	Other
	Not own system disturbance	Other
	Deficient selectivity	Other
	Other	Other