GUIDELINES FOR THE CLASSIFICATION OF GRID DISTURBANCES ABOVE 100 kV

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1 INTRODUCTION

These guidelines describe how HVAC transmission grid disturbances and faults are classified in the ENTSO-E Disturbance and Fault Statistics (EDFS) guidelines.

The ENTSO-E Disturbance and Fault Statistics is published by ENTSO-E Regional Group Nordic (RGN) while a subgroup to it, called Disturbance Statistics and Classification (DISTAC), collects the data, prepares the report and maintains these guidelines.

The guidelines were originally prepared by Nordel in 1971 and updated in 2009. Nordel was an organization for co-operation between the transmission system operators in the Nordic countries, whose objective was to create preconditions for a further development of an effective and harmonised Nordic electricity market. Nordel was discontinued and all operational tasks were transferred to ENTSO-E in July 2009.

These guidelines determine the definitions and instructions necessary to ensure uniform classification and calculation of the number of grid disturbances and faults for the statistics published by ENTSO-E Regional Group Nordic. 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 in the European countries. Chapter 2 sets the purpose of grid disturbance statistics. Chapter 3 describes the scope of the statistics and the limitations imposed. The necessary terms are defined in Chapter 4. Chapter 0 lists how and what to report about each grid disturbance. This is followed by several examples of different types of grid disturbances in Chapter 6. Chapter 0 explains how the number of components are calculated. The final Chapter 8 looks to the future and considers ideas for further developing the grid disturbance statistics.

2 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 transmission grid.

3 SCOPE AND LIMITATIONS OF THE STATISTICS

The statistics comprise:

- grid disturbances
- faults causing or aggravating a grid disturbance
- grid disturbances that disconnect end users from the network
- 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 4.1.1 shows which components in the network 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.

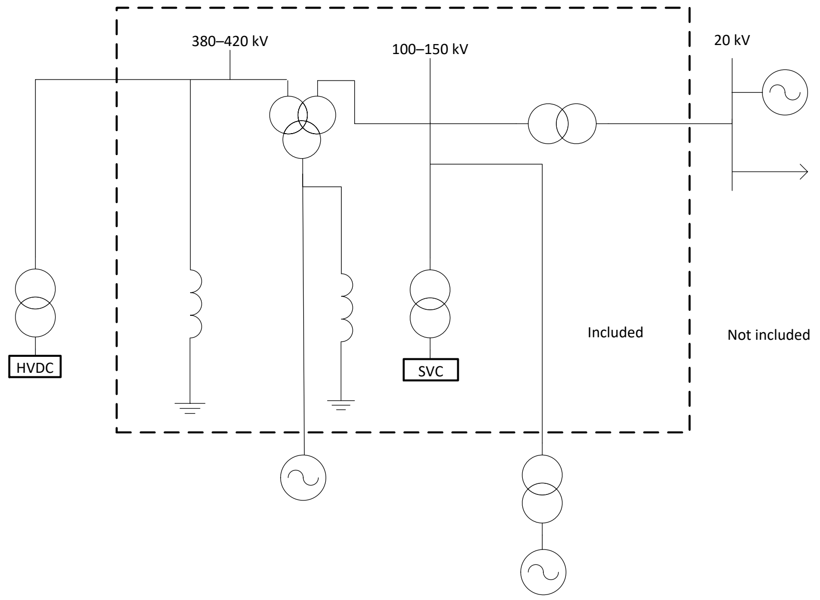

Figure 4.1.1 The dashed-line rectangle shows the types of components which are included in the statistics

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

4 DEFINITIONS

This chapter defines the central concepts of these guidelines. The definitions are of a general nature and do not in themselves indicate the scope of the statistics. The scope of the statistics is defined in Chapter 3.

First, a grid disturbance and a multiple fault situation is defined. Second, the different kinds of faults are defined. Third, an outage is defined. Finally, the other concepts are defined.

4.1 GRID DISTURBANCE

A grid disturbance is defined as:

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

A grid disturbance starts with a primary fault and may also consist of one or more secondary faults or latent faults.

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. However, permanent earth faults in compensated networks are reported as disturbances even though operations are restructured as the fault is sectioned off.

A failed manual connection is 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:

- a tripping of breaker because of lightning striking a line;
- a failed line connection when repairs or adjustments need to be carried out before the line can be connected to the network;
- an emergency disconnection due to fire;
- an undesired power transformer disconnection because of faults due to relay testing
- tripping with a successful high-speed automatic reclosing of a circuit breaker.

Each grid disturbance results in an outage affecting at least one system unit. See Section 4.3 about outages and system units.

4.1.1 Duration of a disturbance

The duration of a disturbance is the time between the start of the first outage and the end of the last outage.

4.1.2 Multiple fault situation

A multiple fault situation occurs when a grid disturbance has one or more secondary or latent faults. The cause of the grid disturbance is the same as the one indicated for the primary fault.

4.2 FAULTS

A fault is defined as:

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

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
- a system disturbance and fault in components.

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

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.

There are also different kinds of faults, which are described below.

4.2.1 Primary fault

A primary fault is defined as:

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 4.1, the cause of the primary fault is also considered as the cause of the grid disturbance.

4.2.2 Secondary fault

A secondary fault is defined as:

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

A secondary fault is a fault which is caused by a primary fault. An example of this is the breakdown of a voltage transformer because 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 the secondary fault can cause additional outages in the system units (see Section 4.3). 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, a disconnection due to a line fault may last longer in connection with a fault in a circuit breaker.

4.2.3 Latent fault

A latent fault is defined as:

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

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 4.2.2.

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 6.14. 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, these fault types are treated as equals in the statistics. In other words, they are simply summed up.

4.2.4 Permanent fault

A permanent fault is defined as:

> *A fault which means that the component or unit is damaged and cannot be restored to service until repair or replacement is completed [1].*

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

When determining if a fault is permanent or not, the duration of the disconnection is irrelevant.

4.2.5 Temporary fault

A temporary fault is defined as:

> *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].*

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

When determining if a fault is temporary or not, the duration of the disconnection is irrelevant. 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.

4.2.6 Intermittent fault

An intermittent fault is defined as:

> *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].*

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. A fault like this is considered as the beginning of a grid disturbance every time the fault occurs.

One example of an intermittent fault is galloping lines.

4.2.7 Fault in component

A fault in a component is defined as:

> *A fault which affects a specific component.*

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

Incorrect operation is considered a fault in a component, or in other words, the incorrect operation is attributed to the unit which has been operated incorrectly.

4.2.8 System disturbances

A system disturbance is defined as:

> *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].*

System disturbances have traditionally been termed system problems. Only system disturbances resulting in grid disturbances or aggravating a grid disturbance are 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).

4.2.9 Cause, primary cause and underlying cause

A cause of a fault is defined as:

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

A primary cause of a fault is defined as:

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

An underlying cause of a fault is defined as:

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

The cause of a fault must be indicated for each fault. All faults usually have a primary cause while some faults also have underlying causes. The primary cause is the cause that has the most significant impact on the fault.

If, for example, a tower collapses due to snow or strong winds and the weather conditions are above designed parameters of tower, the primary cause will be snow or wind. However, if the weather conditions were within the designed parameters of the tower, the primary cause could be lack of maintenance, lack of tower design or metal fatigue due to aging. 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 other circumstances appear.

In the statistics, only one cause is reported. 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".

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 to report the most likely cause as the cause instead of "unknown".

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

Table 4.2.1 shows the categorisation of causes applied in the HVAC statistics. Furthermore, Appendix A shows how the Nordic countries convert their own fault causes to the format of the fault categories in the HVAC statistics.

Table 4.2.1 Fault causes

Fault cause	Explanation
Lightning	The category Lightning is separated from the environmental causes because its impact is insignificant from a maintenance perspective. This is mainly because the Nordic grid is well protected against lightning.
Other environmental causes	Moisture, ice, low temperatures, earthquakes, pollution, salt, snow, vegetation, wind, heat, forest fires etc.
External influences	Fire due to a third party, 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	

4.3 OUTAGE AND SYSTEM UNITS

A system unit is defined as:

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

An outage is defined as:

> *The component or unit is not in the "in service" state. In other words, it is partially or fully isolated from the system [4].*

The concepts of outages and system units 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 [4].

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.

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The type of the system unit is determined by its dominant component and the categories are following:

- Power transformer
- Overhead line
- Cable
- 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 an outage. The system unit is unavailable after the outage has occurred.

A system unit may be unable to transport energy due to another system unit being disconnected depending on the grid configuration the system unit is in. If, for example, the line in Figure 4.3.1 is disconnected, the power transformer cannot transport energy. Both the line and the power transformer are then considered as having been affected by the 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 4.3.1–4.3.5 show different types of system units.

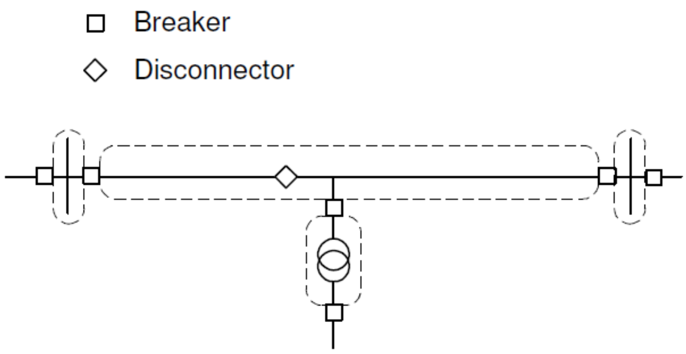


Figure 4.3.1 A system unit is delimited by circuit breakers as indicated by the dotted lines. Disconnectors do not delimit system units. This system unit must be defined as being of the line type.

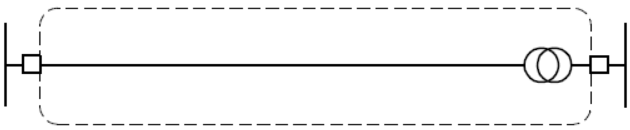


Figure 4.3.2 If there are no power transformer circuit breakers, the line and the power transformer are considered as one system unit. Whether the unit is considered a transformer or a line is determined by its primary function.

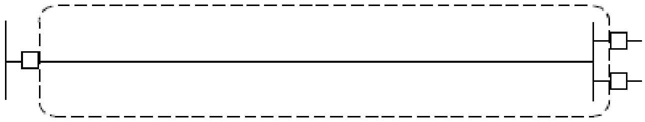


Figure 4.3.3 The busbar has no circuit breakers and together with the line it forms a system unit which, as was the case in Figure 4.3.2, is said to be defined as being of the line type.

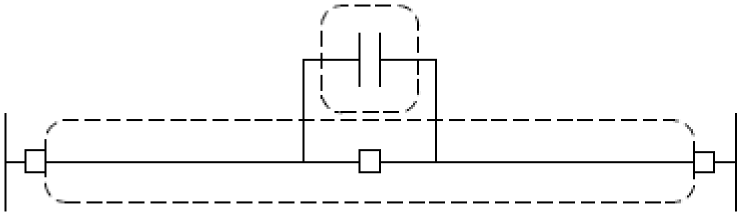


Figure 4.3.4 A series capacitor is not delimited by one or more circuit breakers according to the definition, but a series capacitor bypasses a circuit breaker, which does not agree with the definition. The delimitation of a system unit of the series capacitor type is selected in accordance with the above figure. If the line is affected by a grid disturbance, the series capacitor is also affected by outage.

4.3.1 Duration of a grid outage

The duration of an outage is defined as:

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

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

4.4 Other definitions

4.4.1 Delivery point

A delivery point is defined as:

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

The definition is a general definition and can in practice comprise all points, power transformers and busbars. In the statistics, the delivery point is on the boundary of the statistical area. Another term for delivery point is supply point.

4.4.2 End user

An end user is defined as:

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

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

4.4.3 End-user interruption

An end-user interruption is defined as:

> *Situation characterised by the failure to deliver electricity to one or more end users when the voltage constitutes less than 1 per cent of the contractually agreed voltage [5].*

End-user interruption concerns only end users. End-user interruption may or may not be notified. End-user interruption is of either long or short duration.

4.4.4 Duration of end-user interruption

The duration of an end-user interruption is defined as:

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

4.4.5 Interruption

An interruption is defined as:

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

If an area has more than one delivery point from a transmission network, and an interruption occurs in one of these delivery points, the magnitude of the interruption is 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 the end-user interruption due to delivery via another delivery point.

4.4.6 Long-term interruption

A long-term interruption is defined as:

> *End-user interruption or interruption lasting more than three minutes [5].*

4.4.7 Short-term interruption

A short-term interruption is defined as:

> *End-user interruption or interruption lasting up to three minutes [5].*

4.4.8 Energy not supplied

Energy not supplied (ENS) is defined as:

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

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

Statistical data does not include disturbances inside installations owned by the end-users, even if they are over 100 kV. One example can be an aluminium smelting plant.

If an expected load curve is available, it is used to calculate ENS. If not, ENS is approximated as the load before the interruption multiplied by the duration of the failure. If it is not possible to determine how much energy the end customer did not receive, and the only available information is the measurement from the closest delivery point from the transmission grid, the term Energy Not Distributed (END) should be used instead of ENS.

To calculate the ENS, the end-user interruption must have lasted for longer than normal state operation time for control equipment. This has been established as the minimum duration so that, for example, automatic reclosing is not included.

In the calculation of ENS, the fact that some industries may experience a delay before production is back to normal is not considered. Figure 4.4.1 shows how ENS is calculated in this case.

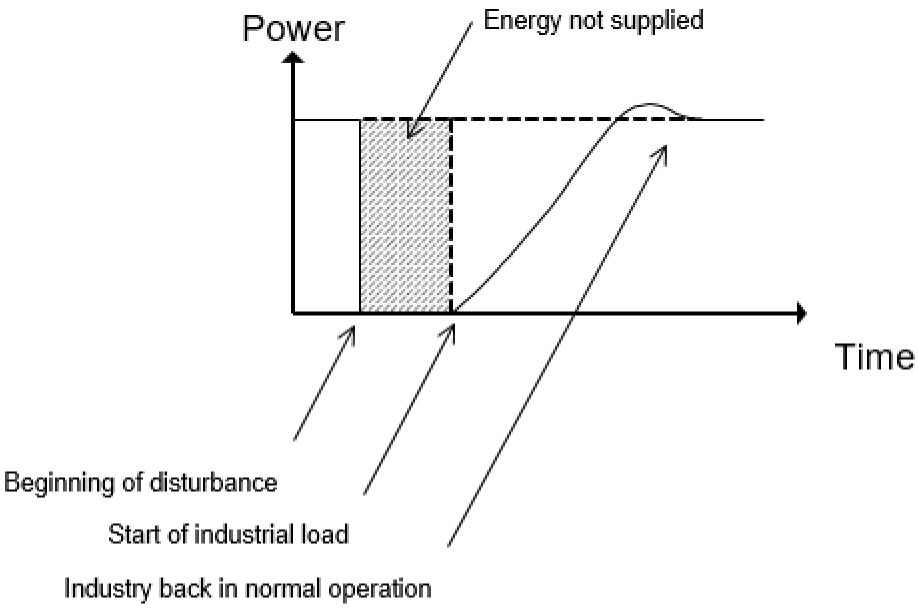


Figure 4.4.1 Grid disturbance with end-user interruption for industrial load.

However, if a grid disturbance affects different end users for different lengths of time, ENS is calculated as the shaded area in Figure 4.4.2.

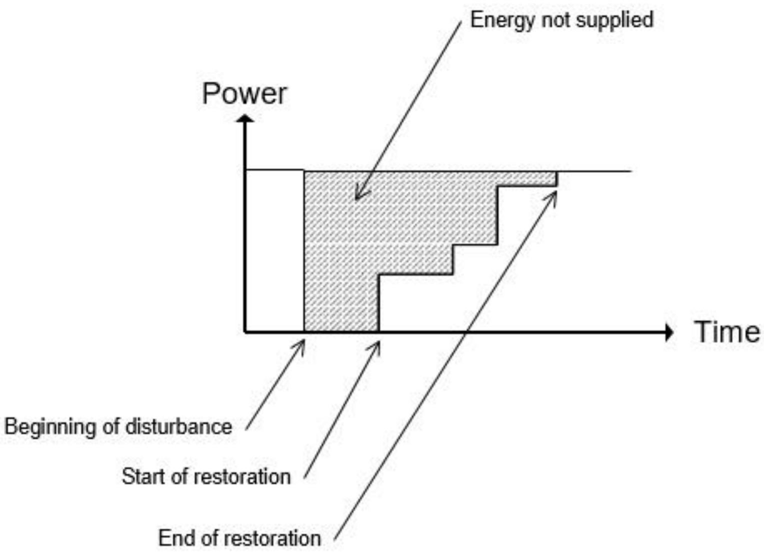


Figure 4.4.2 Grid disturbance with end-user interruption affecting several end users.

Per definition, energy not supplied also occurs when the energy output is limited due to transmission restrictions in the grid.

Figure 4.4.3 shows an example of this. One of the feeder lines to the transformer is disconnected due to a failure. The remaining line cannot supply the required output and results therefore in ENS because transmission must be restricted.

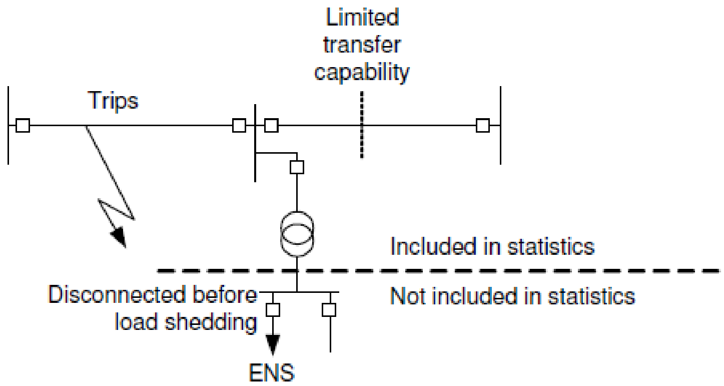


Figure 4.4.3 ENS due to transmission restrictions

In order for ENS to be registered, the interruption causing the ENS must affect a system unit within the statistical area. See Figures 4.4.4–4.4.7.

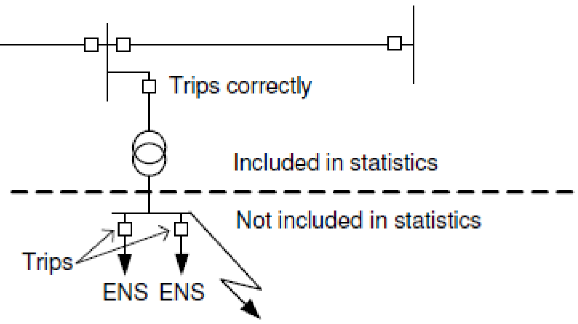


Figure 4.4.4 A failure in the downstream network causes an outage in a system unit within the statistical area resulting in ENS. As an outage causing ENS also occurs within the statistical area, this ENS must be included in the statistics with the fault cause other statistical area.

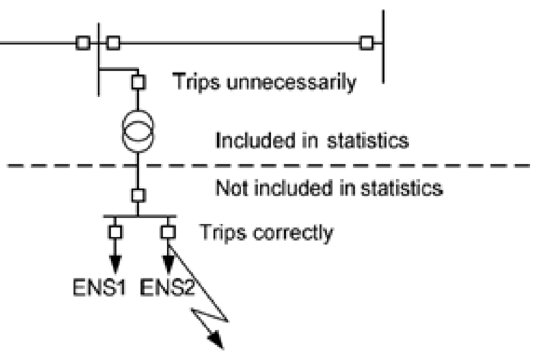


Figure 4.4.5 This scenario includes a breaker on the lower side of the transformer, in this case a breaker within the statistics trips unnecessarily. The ENS values should be separated If possible. The first ENS (ENS2) is for the line where the feeder tripped correctly (fault in another statistical area) and the other ENS (ENS1) is for the feeder where the breaker tripped unnecessarily.

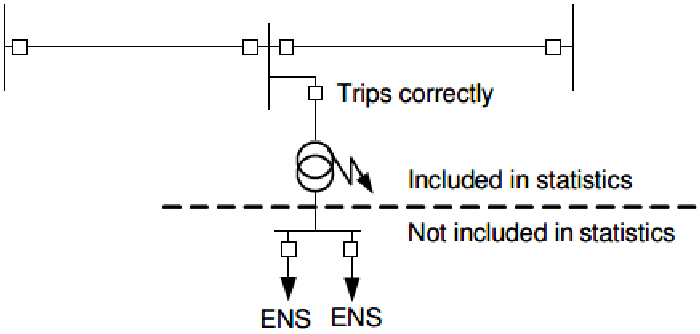


Figure 4.4.6 ENS must be recorded when the transformer is affected by a fault that causes an outage.

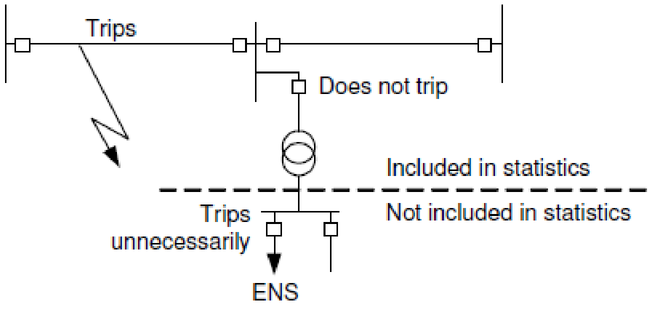


Figure 4.4.7 Incorrect settings in the protection system causes faults in the downstream network. The resulting ENS should not be registered because no system unit, that is transmitting to the downstream network, is affected by the outage.

4.4.9 Unit

A unit is defined as:

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

Main function means transmission, transformation, compensation, etc.

4.4.10 Component

A component is defined as:

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

See Section 4.3 for an explanation of the differences between system units and components.

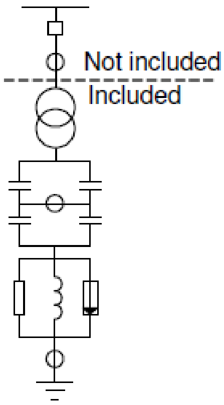
A fault must be associated with one of the components listed in the table below. However, if the fault is a system disturbance, it is not necessary to indicate the component. The table also shows which sub-components are included in each component to support in choosing the right component for a fault. It is important that faults are categorised identically in each country and company to attain comparable results.

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

<table>
<tr><th>Component</th><th>Sub-components included</th><th>Sub-components not included</th></tr>
<tr><td>Disconnectors and earth connectors</td><td>Disconnector contacts
Foundations Isolator(s)
Control equipment integrated in the disconnector
Operating mechanism
Support structure</td><td></td></tr>
<tr><td>Common ancillary equipment</td><td>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</td><td></td></tr>
<tr><td>Control equipment</td><td>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</td><td>Control equipment integrated in other components is not included. In connection with faults in integrated control equipment, the relevant component is indicated.</td></tr>
<tr><td>Power cables</td><td>Sensors
Cables
Cable boxes and joints
Oil expansion tank
End terminations</td><td></td></tr>
</table>

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	
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 • Reactor switch gear	

Component	**Sub-components included**	**Sub-components not included**
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
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. 	
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	

Component	Sub-components included	Sub-components not included
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		

4.4.11 Repair time

Repair time is defined as:

> *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].*

Repair time is reported only for permanent faults and does not include administrative delays (voluntary waiting time). However, any preparations necessary to carry out repairs, for example the collection or ordering of spare parts, waiting for spare parts or transport, are included in the repair time. The repair time is also considered to be zero if a fault is determined to be left unrepaired.

As of 2015, repair time is not mandatory to report because they are not included in the report anymore.

4.4.12 Consumption

Energy consumption is the total amount of energy consumed in the respective reporting country. It is used in the statistics to measure the severity of disturbances in relation to energy not supplied because regional and local grids rely on the transmission grid for power and frequency control. While a local grid can be almost self-supporting with its own production and consumption, a disturbance in the transmission grid could make the grid below fail.

4.4.13 Transmission

Transmission is defined as:

> *The transfer in bulk of electricity, from generating stations to areas of consumption [6].*

5 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.

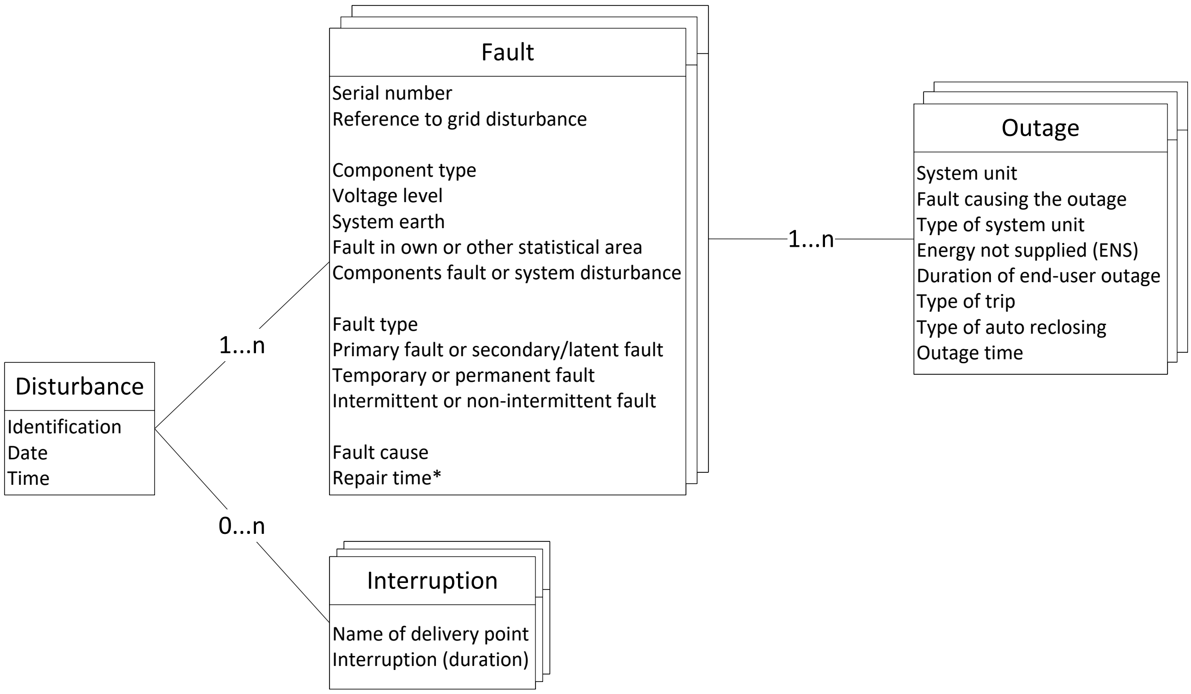


*Figure 4.4.1 A grid disturbance is caused by faults and a fault can result in several outages. Grid disturbances can also result in none, one or several supply interruptions. *Repair time is not mandatory to report but might be useful for internal use.*

Figure 4.4.1 shows that every grid disturbance has at least one fault. This also applies to outages; one fault causes one or more outages. A grid disturbance can even cause none or several interruptions.

5.1 CLASSIFICATION OF GRID DISTURBANCES

In the 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.

When a grid disturbance is registered, the definitions given in Section 4.1 must be fulfilled. Furthermore, at least one component with a minimum voltage level 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 5.1.1 Information to be registered for every grid disturbance

Category	Data
Identification *Usually in the form of a serial number counting from one every year. Not important for the statistical compilation.*	A serial number, for example, 2016-1, 2016-2.
Date	Date of grid disturbance, e.g., 2016-01-17
Time	Time of disturbance, e.g., 17:19:23.

5.2 Classification of Faults

These statistics only consider faults resulting in or aggravating grid disturbances. In case of a grid disturbance, faults can occur in several components. These faults are registered individually which in turn leads to the possibility of a grid disturbance having several faults, as were shown in Figure 4.4.1. 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.

If a fault occurs due to incorrect operation of circuit breakers and disconnectors, the fault must be related to the component that has been incorrectly operated. Thus, the primary cause is reported as operation and maintenance.

If an intermittent fault results in several faults in the same component and in the same place within a short period due to the same cause, only one fault is reported.

The following table describes the information that must be reported for every single fault.

Table 5.2.1 Information to be registered for every fault

Category	Data
Serial number The serial number counts from one for every grid disturbance.	1, 2, 3, etc.
Reference to grid disturbance	Identification of the disturbance, see Table 5.1.1
Component type	See Section 4.4.10. If the fault is a system disturbance, the component type is optional.

Category	Data
Voltage level The voltage level for power transformers, SVCs, rotating phase compensators and common ancillary equipment is determined in the following manner: • Power transformers: the rated voltage of the winding with the highest voltage. • SVCs, shunt capacitors, shunt reactors and rotating phase compensators: the voltage designed for regulation. • Common ancillary equipment: the highest voltage in the station.	• 100–150 kV • 220–330 kV • 380–420 kV
System grounding Whether the power system is directly earthed or compensated. This information is optional for faults in units with 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 more of the fault needs to be reported. The information can be filled in but must, however, be removed from the joint statistics.	• Own network • Other network
Component fault or system disturbance Only system disturbances causing or aggravating a grid disturbance needs to be registered. See sections 4.2.7 and 4.2.8.	• Component fault • System disturbance
Fault types One fault can consist of several fault types. If a fault consists of several fault types, the most significant fault type is used. In case of developing faults, that is in 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. (A broken conductor with an earth fault is referred to as a *single-phase earth fault* or *two or three-phased faults with or without an earth fault*) • Others, for example, geomagnetic currents, SSR, capacitor bank imbalances, bad contact,

Category	Data
Primary fault or secondary/latent fault The statistics do not distinguish between secondary and latent faults. See sections 4.2.2 and 4.2.3 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 4.2.6.	• Intermittent faults • Non-intermittent fault
Fault cause The fault cause must always be reported. If the fault cause is a combination of several fault causes, choose the most significant one.	See Section 4.2.9
Repair time	Not required but may be useful for internal use. Must be given in hours and minutes. Voluntary waiting time should not be included. See Section 4.4.11.

5.3 Classification of Outages

The following must be stated for every single outage.

Table 5.3.1 Information to be registered for every outage

Information	Choices
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.
Fault causing the outage If two faults occur within the same system unit (for example, wrecked surge arresters along with lightning faults) the fault causing the outage of the longest duration will be chosen.	Serial number of the fault which caused the outage according to Table 5.2.1.
Type of system unit	See Section 4.3.
Energy not supplied (ENS)	See Section 4.4.8. To calculate ENS the end-user outage must have lasted at least 2 seconds.
Duration of interruption	See Section 4.4.4.
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

Information	**Choices**
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 4.3.1.

5.4 Classification of interruptions

For every interruption, the data outlined in Table 5.4.1 must be reported.

Table 5.4.1 Information to be registered for every interruption

Category	**Data**
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.

However, it is only the delivery points in the own network that should be registered. Let us consider the system in Figure 5.4.1. If one company owns equipment on the 400 kV side and another company owns equipment on the 130 kV side and a fault occurs on the 400/130 kV transformer, only the 130 kV system registers an interruption.

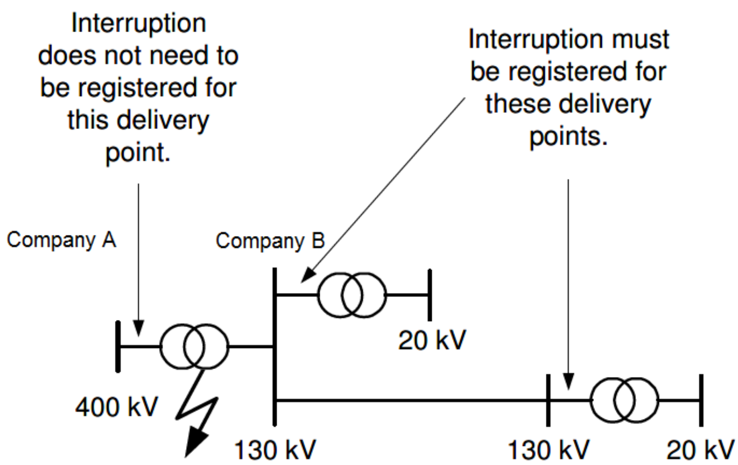


Figure 5.4.1 It is only the delivery points from the transmission network to low voltages that are registered

6 EXAMPLES OF CLASSIFICATION OF GRID DISTURBANCES, OUTAGES, FAULTS AND INTERRUPTIONS

This chapter presents examples of different kinds of grid disturbances which are designed to cover all possible kinds of disturbances. Most of the examples are constructed around the direct earthed network in Figure 6.1. The network consists of the following system units: line X-Y, line Y-Z, busbar X, busbar Y and power transformer Y. All the examples have the same date and time in order to make them clearer.

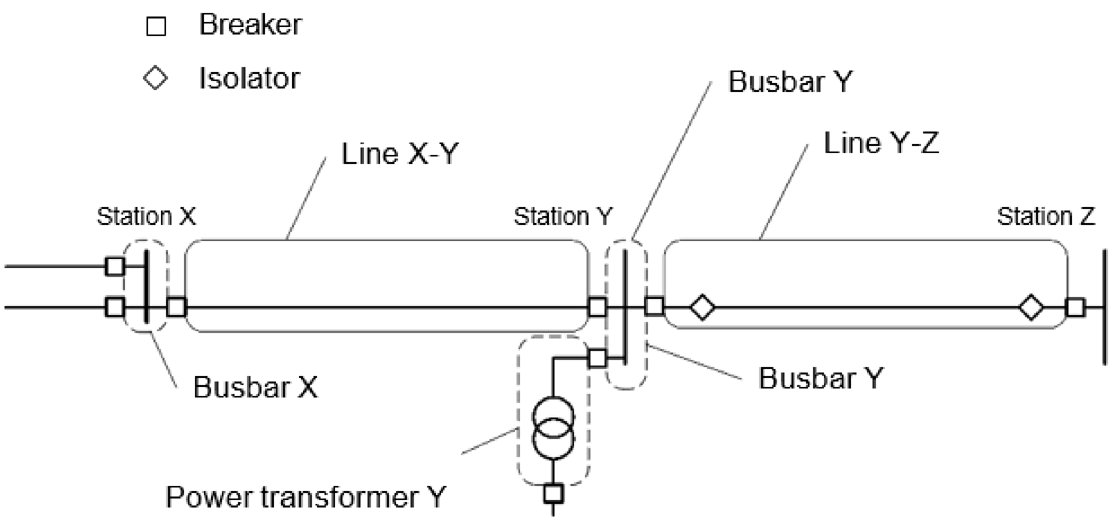


Figure 6.1 The network used in most of the examples

6.1 FLASHOVER ON POWER TRANSFORMER BUSHING DUE TO SALT

Along with heavy onshore wind, a flashover (or in other words a short to earth) occurred on a 220 kV isolator on the 220/60 kV power transformer Y. The transformer had been placed outdoors in a station close to the coast and investigations after the incident concluded that the isolator was covered with salt, which had dissipated completely along with the flashover. Furthermore, the transformer bushings were not designed for outdoor use. The power transformer was loaded with 50 MW before the fault occurred, and was operational again after half an hour. The downstream network was only fed by this transformer and resulted therefore in 25 MWh of energy not supplied.

The cause of the fault depends on already known or investigated conditions. The correct primary cause will be the one that is most significant. If the owner knew that the bushings were not designed for outdoor and still made the decision to place the transformer there due to a small probability of such weather conditions, the cause will be “other environmental causes”. If the transformer was placed outdoors by a mistake in planning or maintenance, the primary cause will be “operations and maintenance”.

The data that should be reported about the incident is shown in the tables below.

Table 6.1.1 The grid disturbance data to be reported

Identification	2016-1
Date	2016-01-10
Time	10:01

Table 6.1.2 The fault data to be reported

Serial number	1
Reference to grid disturbance	2016-1
Component type	Power transformer
Voltage level	220–330 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
Repair time	0 min

Table 6.1.3 The outage data to be reported

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

Table 6.1.4The interruption data to be reported

Name of delivery point	Transformer Y
Duration of interruption	30 min

6.2 OUTAGE OF A LINE WHEN WORK IS PERFORMED ON A CONTROL UNIT

A current circuit was opened to the differential protective relay while working on the relay protection system of the 400 kV Y-Z line which tripped the line, as seen in Figure 6.2.1. It took five minutes to solve the problem and reconnect the line. The power transformer load was 50 MW.

The fault is a permanent fault 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 network were affected by interruption.

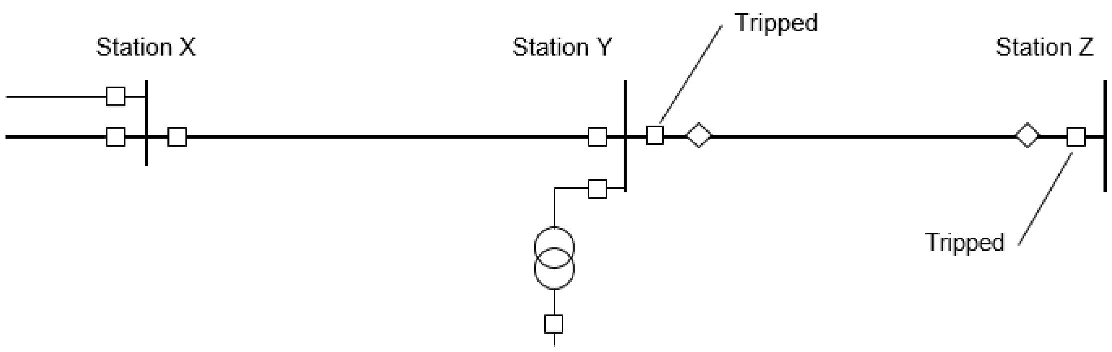


Figure 6.2.1 The scenario of an outage of line when work is performed on a control unit.

The data that should be reported about the incident is shown in the tables below.

Table 6.2.1 The grid disturbance data to be reported

Identification	2016-2
Date	2016-01-10
Time	10:01

Table 6.2.2 The fault data to be reported

Serial number	1
Reference to grid disturbance	2016-2
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

Table 6.2.3 The outage data to be reported

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

Table 6.2.4 The interruption data to be reported

Name of delivery point	-
Duration of interruption	-

6.3 TWO LINE FAULTS WITHIN A FEW SECONDS INTERVAL COMBINED WITH A CIRCUIT BREAKER FAULT RELATED TO THE PREVIOUS FAULT

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

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

Table 6.3.1 The grid disturbance data to be reported

Identification	2016-3
Date	2016-01-10
Time	10:01

Table 6.3.2 The fault data to be reported

Serial number	1
Reference to grid disturbance	2016-3
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

Table 6.3.3 The outage data to be reported

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 discon-	Automatically
Characterisation of reclosing	Automatically after less than 2
Duration of outage	0

Table 6.3.4

Name of delivery point	-
Duration of interruption	-

Imagine that the other disturbance is given the serial number 2016-4. 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. This disturbance is reported as shown in the tables below.

Table 6.3.5 The grid disturbance data to be reported

Identification	2016-4
Date	2016-01-
Time	10:01

Table 6.3.6 The fault data to be reported

Serial number	1	2
Reference to the grid disturbance	2016-4	2016-4
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

Table 6.3.7 The outage data to be reported

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

Table 6.3.8 The interruption data to be reported

Name of delivery point	-
Duration of interruption	-

6.4 INCORRECT CIRCUIT BREAKER OPERATION

Circuit breakers in station Y on the X-Y line were operated incorrectly while the other end of the line remained connected to the network, as demonstrated in Figure 6.4.1. The circuit breaker was manually reclosed after five minutes. No customers were affected by the outage because the network was meshed.

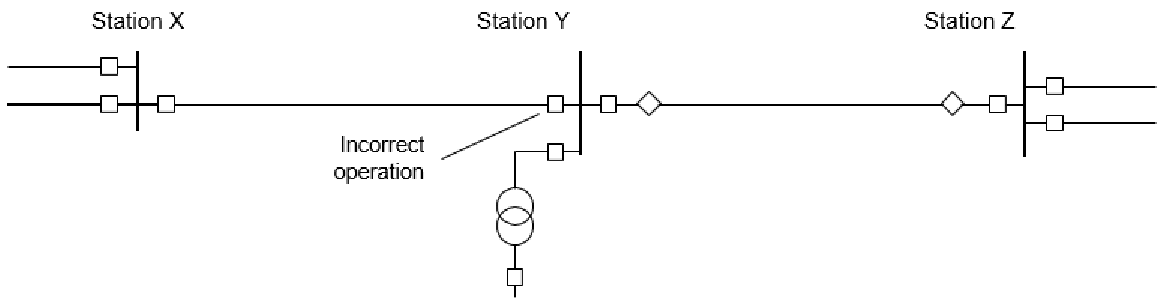


Figure 6.4.1 Incorrect circuit breaker operation.

The data that should be reported about the incident is shown in the tables below.

Table 6.4.1 The grid disturbance data to be reported

Identification	2016-4
Date	2016-01-10
Time	10:01

Table 6.4.2 The fault data to be reported

Serial number	1
Reference to grid disturbance	2016-4
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

Table 6.4.3 The outage data to be reported

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
Duration of outage	5 min

Table 6.4.4 The interruption data to be reported

Name of delivery point	-
Duration of interruption	-

6.5 LINE FAULT AND A CIRCUIT BREAKER MALFUNCTION

The 220 kV X-Y line was struck by lightning which caused a single-phase earth fault. Furthermore, the circuit breaker in station Y failed to trip. Therefore, the zone 2 protection in station Z tripped the Y-Z line and the feeding to the 220/70 kV power transformer in station Y was interrupted causing an interruption of load. Station Y was inspected and 45 minutes later the load could be rerouted 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. An overview of the incident can be seen in Figure 6.5.1.

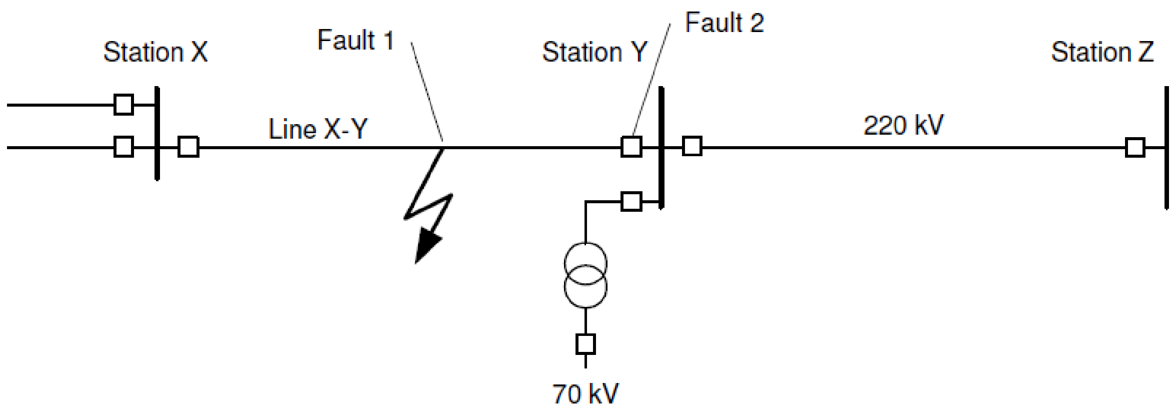


Figure 6.5.1 Line fault with a circuit breaker malfunctioning

The grid disturbance had two faults: a lightning fault and a circuit breaker fault. Four outages occurred: one in each line, one in the power transformer and one in the gathering strip. Interruption must be registered for the power transformer.

The data that should be reported about the incident is shown in the tables below.

Table 6.5.1 The grid disturbance data to be reported

Identification	2016-5
Date	2016-01-10
Time	10:01

Table 6.5.2 The fault data to be reported

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

Table 6.5.3 The outage data to be reported

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 dis-connection	Automatically	Automatically	Automatically	Automatically
Characterisation of re-closing	Manually after repair	Manually after inspection	Manually after inspection	Manually after in-spection
Duration of outage	48 h 0 min	0 h 45 min	0 h 45 min	0 h 45 min

Table 6.5.4 The interruption data to be reported

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

6.6 SVC OUTAGE WITH AN UNRECOGNISED FAULT

An SVC, with the indication SVC-X, used for regulating the 130 kV voltage tripped. While inspecting the SVC, no visible faults or indications of possible causes were discovered. The probable cause was a fault in the program assets in the control equipment for operating the SVC. The control computer was not restarted and thus no repair was carried out. The reclosing of the SVC was possible after 45 minutes.

For the report, check that the voltage level is set to 130 kV. Further instructions can be seen in Table 5.2.1. Also, if the control equipment is integrated into the SVC, state the component type as SVC and statcom, as in Table 6.6.2. If the control equipment is not integrated, the component type is stated as control equipment.

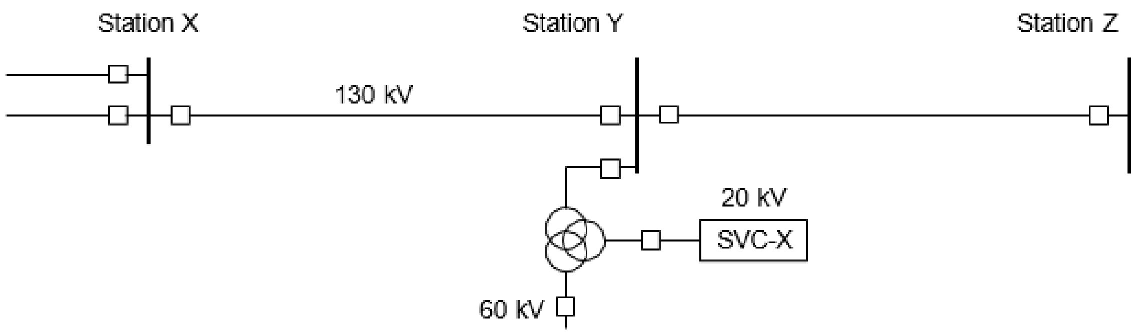


Figure 6.6.1 SVC outage without a recognised fault.

The data that should be reported about the incident is shown in the tables below.

Table 6.6.1 The grid disturbance data to be reported

Identification	2016-6
Date	2016-01-10
Time	10:01

Table 6.6.2 The fault data to be reported

Serial number	1
Reference to grid disturbance	2016-6
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

Table 6.6.3 The outage data to be reported

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

Table 6.6.4 The interruption data to be reported

Name of delivery point	-
Duration of interruption	-

6.7 MANUAL LINE DISCONNECTION DUE TO A FAULTY CURRENT TRANSFORMER

A 400 kV current transformer was discovered to have an increased pressure level during scheduled inspection of a station and was leaking oil, as shown in Figure 6.7.1. It was determined that there was a high risk of the transformer exploding so the X-Y line with the current transformer was immediately taken out of operation. The line and a replacement transformer was reconnected after 16 hours.

This is considered a grid disturbance as it is an emergency outage according to Section 4.1. If the outage could have been postponed, it would not have been a grid disturbance and should not have been registered.

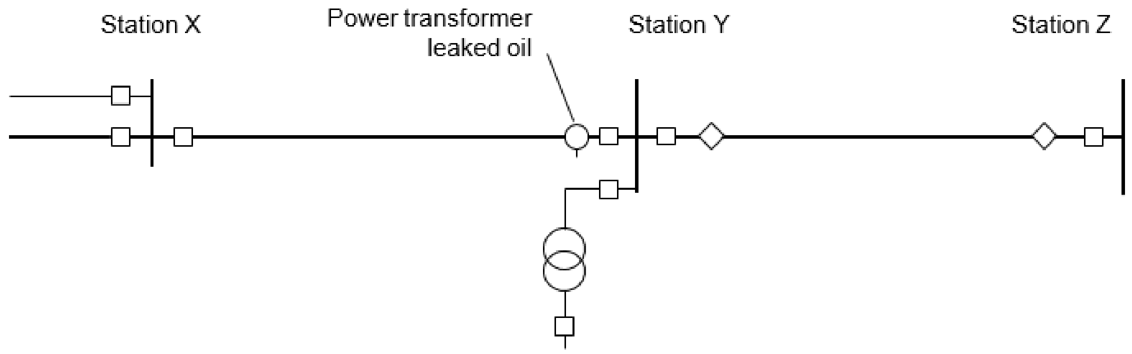


Figure 6.7.1 Manual line disconnection due to a faulty current transformer.

The data that should be reported about the incident is shown in the tables below.

Table 6.7.1 The grid disturbance data to be reported

Identification	2016-7
Date	2016-01-10
Time	10:01

Table 6.7.2 The fault data to be reported

Serial number	1
Reference to grid disturbance	2016-7
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

Table 6.7.3 The outage data to be reported

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

Table 6.7.4 The interruption data to be reported

Name of delivery point	-
Duration of outage	-

6.8 LINE DISCONNECTION CAUSED BY TEMPORARY EARTHING EQUIPMENT BEING LEFT ON LINE

Temporary earthing equipment had been left on the X-Y line in station Y after maintenance had been performed on the X-Y line, as shown in Figure 6.8.1. This 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.

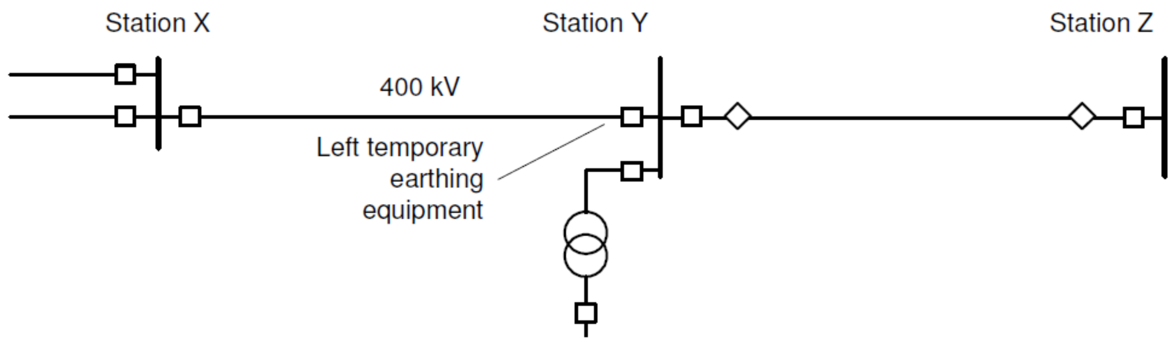


Figure 6.8.1 Line disconnection caused by temporary earthing equipment being left on the X-Y line in station Y.

The data that should be reported about the incident is shown in the tables below.

Table 6.8.1 The grid disturbance data to be reported

Identification	2016-8
Date	2016-01-10
Time	10:01

Table 6.8.2 The fault data to be reported

Serial number	1
Reference to grid disturbance	2016-8
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

Table 6.8.3 The outage data to be reported

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

Table 6.8.4 The interruption data to be reported

Name of delivery point	-
Duration of outage	-

6.9 LINE FAULT AND A FAULT IN THE HIGH SPEED AUTOMATIC RECLOSING EQUIPMENT

A single-phase earth fault occurred on the 400 kV Y-Z line due to lightning, as shown in Figure 6.9.1. High speed automatic reclosing was successful in station Y but failed to take place in station Z. Instead, the circuit breaker in station Z reclosed automatically after one minute. The high speed automatic reclosing was repaired after three days; the repair time being three hours.

This incident should be registered as a fault because the fact that the high speed automatic reclosing malfunctioned results in the grid disturbance being aggravated over time.

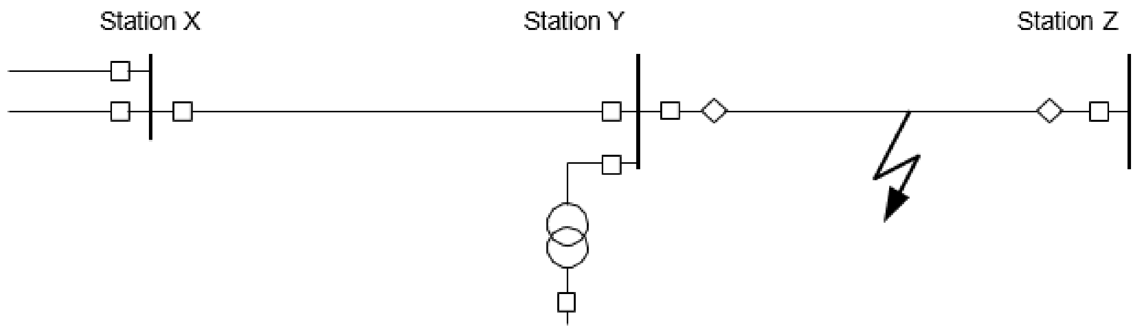


Figure 6.9.1 Line fault and fault in the high speed automatic reclosing equipment.

The data that should be reported about the incident is shown in the tables below.

Table 6.9.1 The grid disturbance data to be reported

Identification	2016-9
Date	2016-01-10
Time	10:01

Table 6.9.2 The fault data to be reported

Serial number	1	2
Reference to grid disturbance	2016-9	2016-9
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

Table 6.9.3 The outage data to be reported

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

Table 6.9.4 The interruption data to be reported

Name of delivery point	-
Duration of outage	-

6.10 Fault in a generator connected directly to the transmission network

A hydro-power unit connected directly to the 220 kV transmission network tripped, as shown in Figure 6.10.1. The frequency of the network decreased causing an interruption of load. No system unit above the voltage level 100 kV tripped.

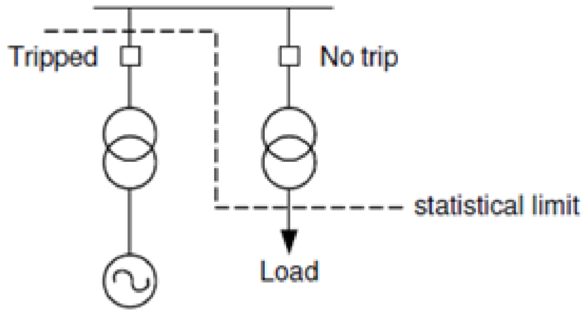


Figure 6.10.1 Fault in a generator connected directly to the transmission network

Faults in production units, such as aggregate power transformers and generators, are not included in the statistics. Neither is a network component with a voltage level lower than 100 kV. (See Chapter 3 for more information.) According to the definitions, this incident did not occur within the statistical area since the load did not trip.

6.11 Power oscillation in the power system

A change in the production evoked power oscillation in the power system. According to Section 4.1, 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.

6.12 Nuclear power station outage

A nuclear power station tripped which caused the frequency of the grid to decrease and the network load limits to be exceeded. The situation was resolved by starting gas turbines. This grid disturbance does not need to be registered as neither the aggregate power transformers nor the generators are included in the statistics, as explained in Chapter 3.

6.13 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 interruption was caused by switching-over voltages, which are normal when connecting capacitors.

This incident should not be reported as the grid disturbance took place in a network with a voltage level of less than 100 kV.

6.14 Operation of loaded disconnectors

Before beginning to work on any line, its circuit breaker and disconnector should be opened in consecutive order. However, while doing this on line Y-Z, the circuit breaker had not opened and when the line disconnector was opened the disconnector had a flashover, the line tripped and the high speed automatic reclosing failed to occur. This incident is demonstrated in Figure 6.14.1. 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 without damaging the line disconnector. It took one hour and five minutes to replace the fuse.

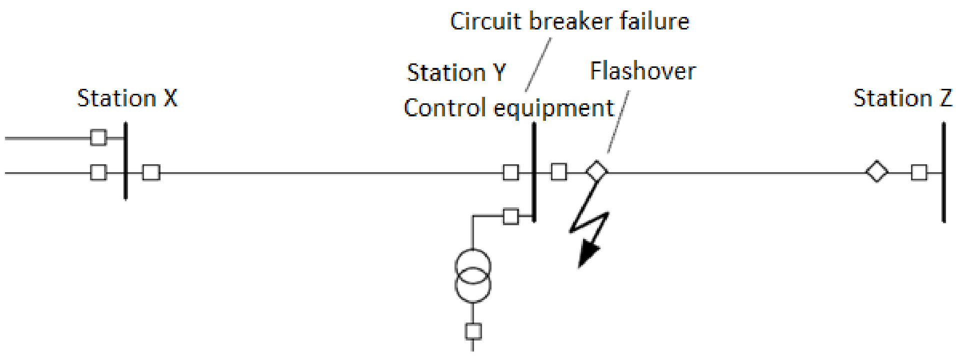


Figure 6.14.1 Operation of loaded disconnectors.

There are two options when registering this grid disturbance concerning the primary fault: it was either caused by the flashover on the disconnector or by the fault in the control unit. If the flashover on the disconnector was the primary fault, the fault in the control equipment should be registered as a latent fault in the control equipment category. A latent fault not aggravating the grid disturbance is normally not included in the statistics. However, the question now 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 Section 4.2.3 for more information. The duration of the outage is related to the repair time of the control equipment and not the work that was going to be performed on the line, so outage duration should be reported as an hour and five minutes.

On the other hand, if the control unit fault is registered as the primary fault, the fault in the disconnector is registered as a secondary fault.

The tables below show how the incident should be reported if the flashover on the disconnector was considered as the primary fault.

Table 6.14.1 The grid disturbance data to be reported

Identification	2016-15
Date	2016-01-10
Time	10:01

Table 6.14.2 The fault data to be reported

Serial number	1	2
Reference to grid disturbance	2016-15	2016-15
Component type	Disconnector	Control equipment
Voltage level	400 kV	400 kV
Fault within own or other statistical	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

Table 6.14.3 The outage data to be reported

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

Table 6.14.4 The interruption data to be reported

Name of delivery point	-
Duration of interruption	-

6.15 Unsuccessful power transformer energisation due to sensitive relay setting

A 400/130 kV power transformer had to be energised but tripped immediately as the protective relay settings of the transformer were too sensitive to the inrush current, as shown in Figure 6.15.1. The second attempt after inspection and relay adjustment 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 network were affected by interruptions, see Section 5.4.

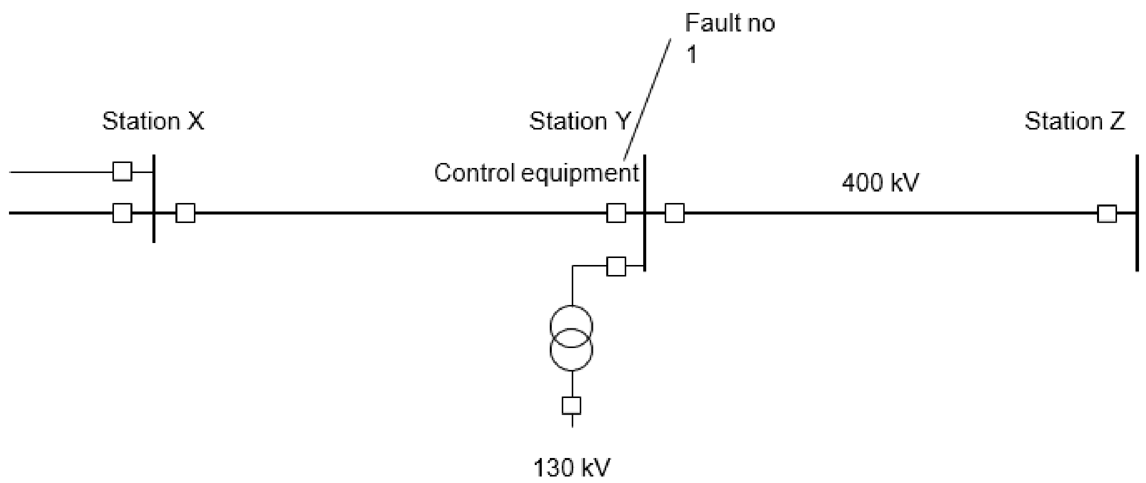


Figure 6.15.1 Unsuccessful power transformer energisation due to sensitive relay settings.

The data that should be reported about the incident is shown in the tables below.

Table 6.15.1 The grid disturbance data to be reported

Identification	2016-16
Date	2016-01-10
Time	10:01

Table 6.15.2 The fault data to be reported

Serial number	1
Reference to grid disturbance	2016-16
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

Table 6.15.3 The outage data to be reported

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

Table 6.15.4 The interruption data to be reported

Name of delivery point	-
Duration of interruption	-

6.16 Exploded power transformer bushing

A bushing on the 400 kV side of a 400/130 kV power transformer exploded which in turn caused a short circuit that tripped the power transformer, as shown in Figure 6.16.1. The power transformer was replaced by a spare power transformer after seven days (or 168 hours). 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.

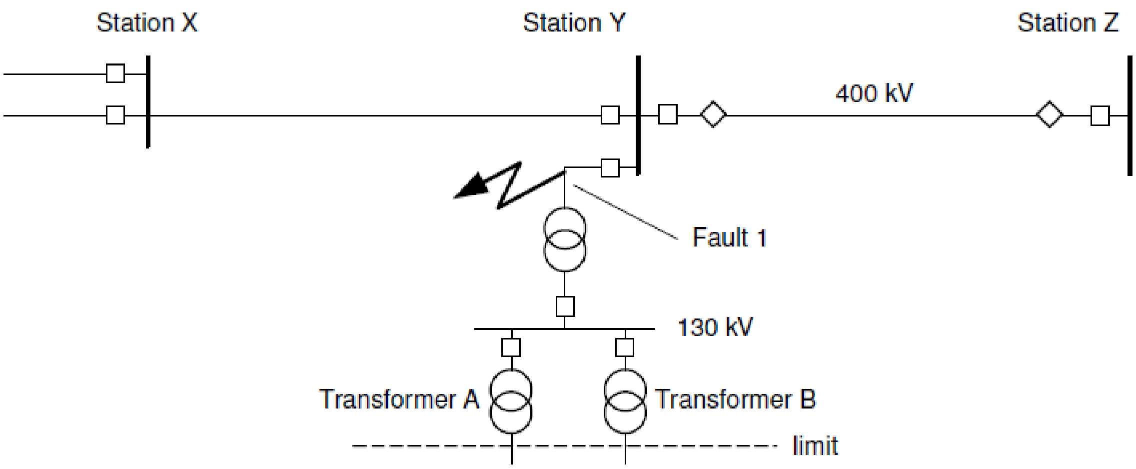


Figure 6.16.1 Exploded power transformer bushing.

The cause of the fault was determined to have been caused by moisture that had penetrated the bushing or by a poor contact in the bushing connections that allowed the oil to heat. The fault was attributed to ageing and the fault cause was thus reported as technical equipment, see Table 4.2.1.

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

The data that should be reported about the incident is shown in the tables below.

Table 6.16.1 The grid disturbance data to be reported

Identification	2016-17
Date	2016-01-10
Time	10:01

Table 6.16.2 The fault data to be reported

Serial number	1
Reference to grid disturbance	2016-17
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 con-
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

Table 6.16.3 The outage data to be reported

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

Table 6.16.4 The interruption data to be reported

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

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

Lightning struck a 400 kV line just outside an outdoor station causing a single-phase earth fault that blew up the line's valve surge arresters, as shown in Figure 6.17.1. The fragments from the explosion also damaged an isolator in one of the phases in the circuit breaker which caused three-phase short circuits 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. The repair time for the circuit breaker was eight hours and nine hours for the surge arrester. End users experienced no energy supplied as station Y was fed from both station X and station Z before the fault.

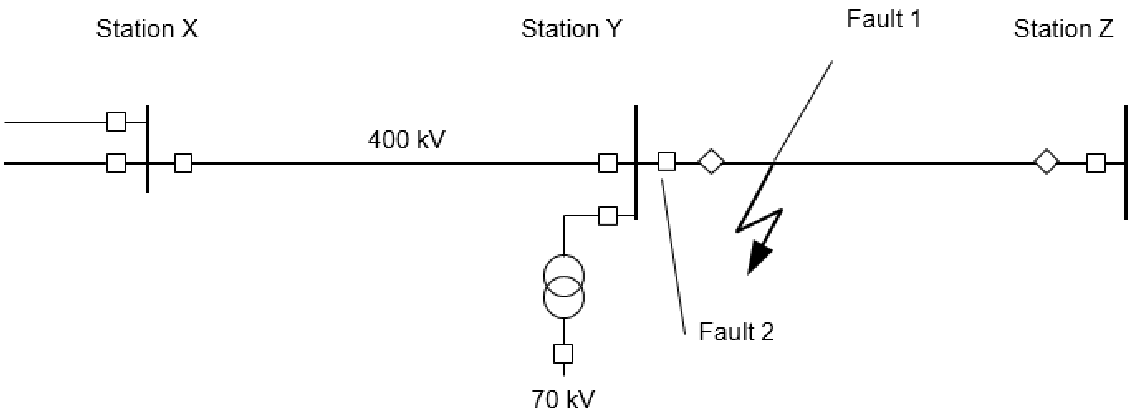


Figure 6.17.1 Line fault with simultaneous faults in surge arresters and circuit breaker.

Three faults occurred in connection with this disturbance: the lightning, the fault in the surge arrester and the fault in the circuit breaker. The fault in the circuit breaker and the surge arrester should be registered as they expanded the disconnected part of the network, or in other words, aggravated the disturbance. 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, that is, other fault causes, as seen in Table 4.2.1.

Interruption must be registered for power transformer Y.

The data that should be reported about the incident is shown in the tables below.

Table 6.17.1 The grid disturbance data to be reported

Identification	2016-18
Date	2016-01-10
Time	10:01

Table 6.17.2 The fault data to be reported

Serial number	1	2	3
Reference to grid disturb-	2016-18	2016-18	2016-18
Component type	Line	Surge arrester	Circuit breaker
Voltage level	400 kV	400 kV	400 kV

Fault within own or other	Own	Own	Own
Component fault or system	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	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

Table 6.17.3 The outage data to be reported

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

Table 6.17.4 The interruption data to be reported

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

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

Lightning struck a 132 kV overhead line located in a compensated network and caused a single-phase short circuit (earth fault). This also tripped the Y-Z line due to a relay fault. The line could be reconnected after 30 seconds and the relay fault was repaired after a week. The total repair time with travel time was 4 hours. The scenario is shown in Figure 6.18.1.

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.

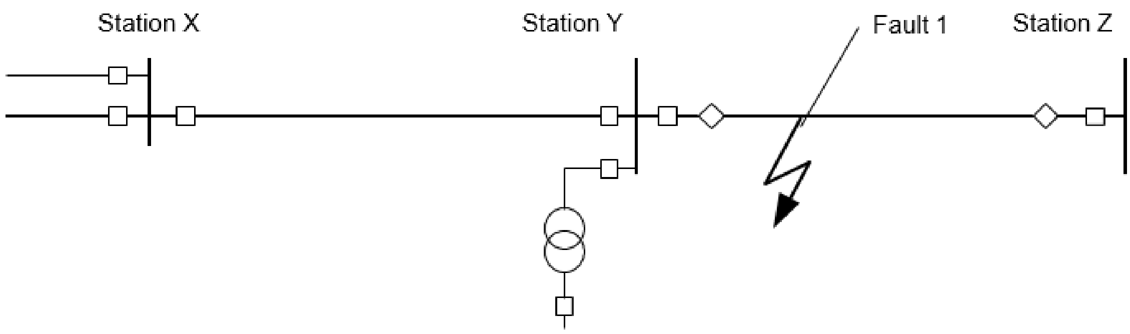


Figure 6.18.1 Earth fault in a compensated network with latent relay fault.

The data that should be reported about the incident is shown in the tables below.

Table 6.18.1 The grid disturbance data to be reported

Identification	2016-19
Date	2016-01-10
Time	10:01

Table 6.18.2 The fault data to be reported

Serial number	1	2
Reference to grid disturbance	2016-19	2016-19
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

Table 6.18.3 The outage data to be reported

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 disconnec-	Automatically
Characterisation of reclosing	Manually without either inspection, repair or restructuring of opera-
Duration of outage	30 secs

Table 6.18.4 The interruption data to be reported

Name of delivery point	-
Duration of interruption	-

6.19 Fault in a radial network with a circuit breaker failing to trip

Station X fed a radial, direct earthed network through a 132 kV line. Furthermore, this line fed two 132/20 kV transformer stations: stations Y and Z, as seen in Figure 6.19.1. The line between stations Y and Z sustained a three-phase earth fault due to a fallen tree during a severe storm. However, the Y-Z line's circuit breaker failed to trip because its tripping mechanism had frozen. Instead, the circuit breaker in power station X tripped.

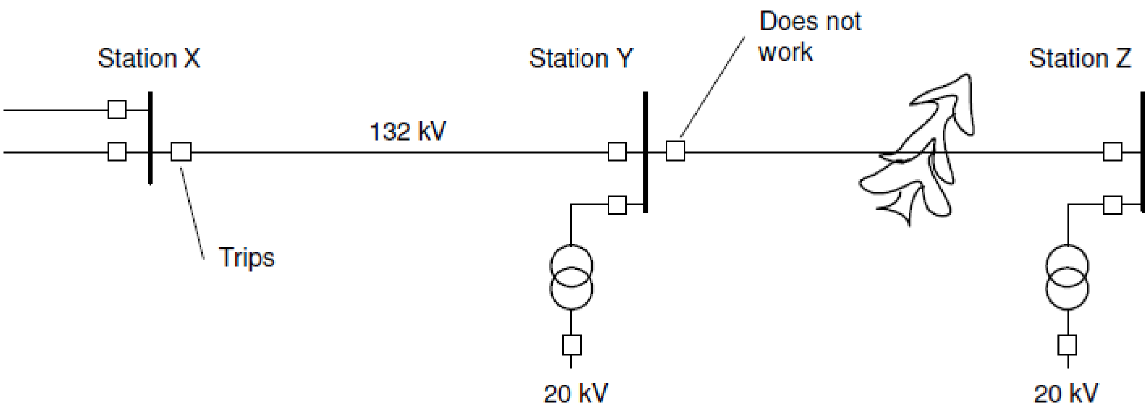


Figure 6.19.1 Fault on a radial feeder line with circuit breaker failing to trip.

The defective circuit breaker was isolated manually after 25 minutes, after which station Y could be energised via the X-Y line. The circuit breaker was repaired after two hours and 35 minutes later the tree was removed.

Energy not supplied amounted to 25 MWh in station Y and to 17 MWh in station Z. Interruptions for the respective transformers must be registered.

The data that should be reported about the incident is shown in the tables below.

Table 6.19.1 The grid disturbance data to be reported

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

Table 6.19.2 The fault data to be reported

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
Repair time	2 h 35 min	2 h

Table 6.19.3 The outage data to be reported

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

Table 6.19.4 The outage data to be reported

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

Table 6.19.5 The interruption data to be reported

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

6.20 Line fault with unexpected relay trip

A station fed from two 400 kV lines was interrupted because of lightning that struck and short circuited the Y-Z line. Furthermore, the X-Y line tripped unexpectedly because it was equipped with an old relay type that had a tendency to trip while transitioning from a single-phase earth fault to a three-phased short circuit, as shown in Figure 6.20.1. Fortunately, the condition of the relay on the X-Y line was known by the staff. Line Y-Z reclosed rapidly and automatically after less than two seconds while line X-Y reconnected after five minutes.

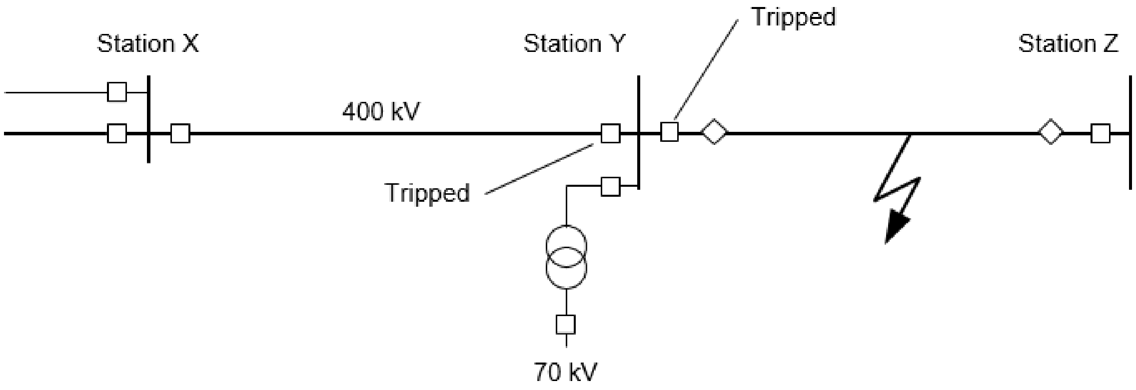


Figure 6.20.1 Line fault with unselective relay trip.

For the reporting, no ENS needs to be calculated because the end-user outage lasted less than two seconds, as explained in Section 4.4.8. Furthermore, the relay protection system fault is permanent. There is also normally a repair time associated with a permanent fault, but since the relay protection system was known to be flawed, it is evaluated as zero.

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

The data that should be reported about the incident is shown in the tables below.

Table 6.20.1 The grid disturbance data to be reported

Identification	2016-21
Date	2016-01-
Time	10:01

Table 6.20.2 The fault data to be reported

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

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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

Table 6.20.3 The outage data to be reported

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 secs	Manually
Duration of outage	0 min	5 min

Table 6.20.4 The outage data to be reported

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

Table 6.20.5 The interruption data to be reported

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

6.21 Intermittent line fault due to wind

Wind caused the phase leads in the 132 kV X-Y line to gallop, which resulted in five successive trips and a high speed automatic reclosing shortly after each one. 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 the possibility to eliminate the cause, as explained in Section 4.2.6.

For the report, one fault per component should be registered. If the interval between the disconnections is longer, one fault per component and disconnection should be registered. Furthermore, five outages must be registered.

The data that should be reported about the incident is shown in the tables below.

Table 6.21.1 The grid disturbance data to be reported

Identification	2016-22
Date	2016-01-10
Time	10:01

Table 6.21.2 The fault data to be reported

Serial number	1
Reference to grid disturbance	2016-22
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	-

Table 6.21.3 The outage data to be reported

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 out-	0 min	0 min	0 min
Characterisation of discon-	Automatically	Automatically	Automatically
Characterisation of reclos-ing	Automatically after less than 2 seconds	Automatically after less than 2 seconds	Automatically after less than 2 seconds
Duration of outage	0	0	0

Table 6.21.4 The outage data to be reported

System unit	Line X-Y	Line X-Y
Fault causing the outage	20016-9	2016-9
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	Automatically after
Duration of outage	0	0

Table 6.21.5 The interruption data to be reported

Name of delivery point	-
Duration of delivery point	-

6.22 FAULT IN OTHER STATISTICAL AREA CAUSING OUTAGE IN OWN STATISTICAL AREA

An unknown cause short-circuited the Y-Z line in company B's grid. Furthermore, a relay fault in station X caused the overhead line X-Y in company A's grid to also trip. The lines were reconnected manually after all affected stations had been inspected; the X-Y line was reconnected after 30 minutes and the Y-Z line after 45 minutes. This network, which is also shown in Figure 6.22.1, was fed from both directions and the lines had no capabilities for automatic reclosing. It took four hours and 45 minutes to repair the relay fault and energy not supplied for the transformer in station Y amounted to 10 MWh.

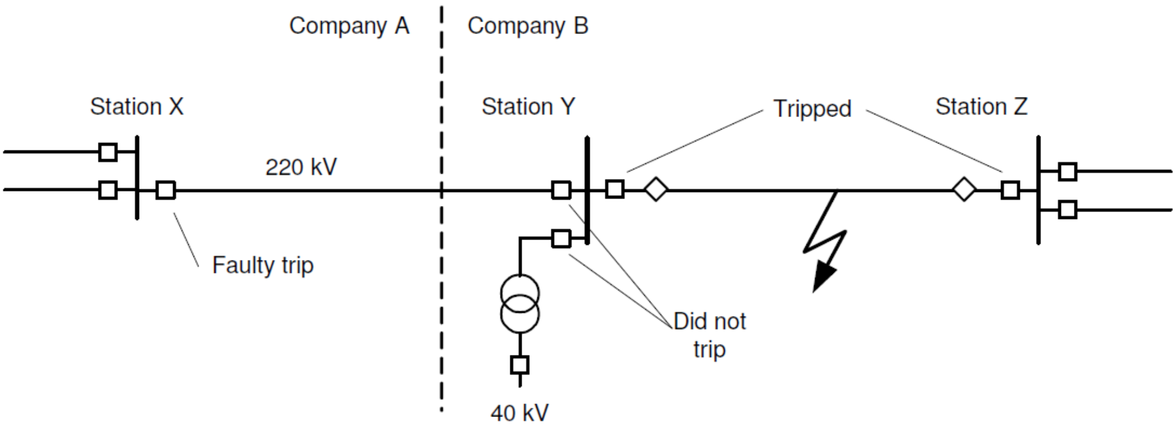

Figure 6.22.1 A fault in one company's network causing outage in another company's network.

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, as explained in Section 4.4.11. 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.

Company A with the relay fault prepares the report according to the tables below.

Table 6.22.1 The grid disturbance data to be reported

Identification	2016-23
Date	2016-01-10
Time	10:01

Table 6.22.2 The fault data to be reported

Serial number	1	2
Reference to grid disturbance	2016-23	2016-23
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	Other	Technical equipment
Repair time		4h 45min

Table 6.22.3 The outage data to be reported

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	30 min

Table 6.22.4 The interruption data to be reported

Name of delivery point	-
Duration of interruption	-

Company B with the line fault prepares the report according to the tables below.

Table 6.22.5 The grid disturbance data to be reported

Identification	2016-23
Date	2016-01-10
Time	10:01

Table 6.22.6 The fault data to be reported

Serial number	1	2
Reference to grid disturbance	2016-23	2016-23
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	
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

Table 6.22.7 The outage data to be reported

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

Table 6.22.8 The interruption data to be reported

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

6.23 DOUBLE EARTH FAULT IN A COMPENSATED NETWORK

A falling tree caused an earth fault in the R phase of the Y-Z line which in turn caused high phase voltages in the two other phases and damaged the S phase of a voltage transformer in station X, as seen in Figure 6.23.1. Thus, a double earth fault had occurred and line X-Y had tripped correctly in both ends. The earth fault in the Y-Z line disappeared automatically after the tree had been burned down and the X-Y line could be reconnected after the voltage transformer had been replaced, which took 24 hours.

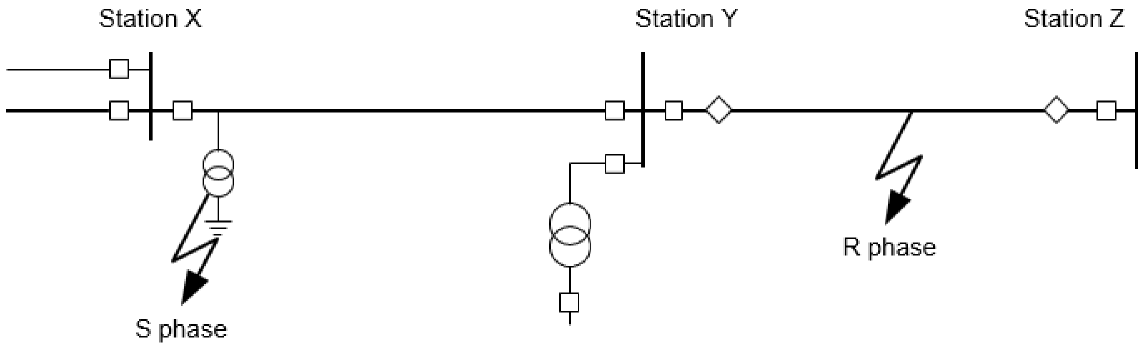

Figure 6.23.1 Double earth fault in a compensated network.

The data that should be reported about the incident is shown in the tables below.

Table 6.23.1 The grid disturbance data to be reported

Identification	2016-24
Date	2016-01-10
Time	10:01

Table 6.23.2 The fault data to be reported

Serial number	1	2
Reference to grid disturbance	2016-24	2016-24
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	Other
Repair time	-	24 h

Table 6.23.3 The outage data to be reported

System unit	Line X-Y
Fault causing the outage	1

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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

Table 6.23.4 The interruption data to be reported

Name of delivery point	-
Duration of interruption	-

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

The 400/130 kV power transformer T1 tripped because the tap changer was in the middle position. The main spring in the tap changer mechanism of one of the phases was broken. This overloaded the power transformer T2 and consecutively tripped it. The 130 kV level load was adjusted and 10 minutes later the power transformer T2 was reinstated without inspection. An overview of the scenario is presented in Figure 6.24.1.

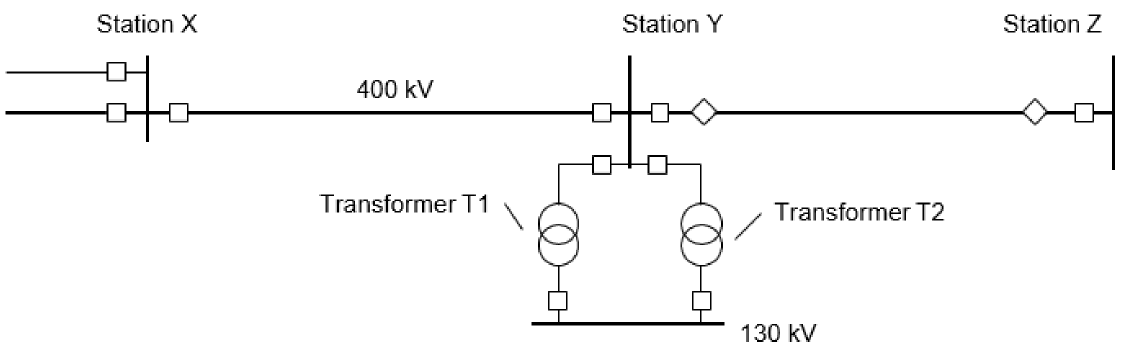

Figure 6.24.1 Outage of parallel power transformers due to tap changer fault and overload.

The power transformer T1 was operational again after five days even though 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 network were affected by the interruption, as explained in Section 5.4.

The data that should be reported about the incident is shown in the tables below.

Table 6.24.1 The grid disturbance data to be reported

Identification	2016-25
Date	2016-01-
Time	10:01

Table 6.24.2 The fault data to be reported

Serial number	1	2
Reference to grid disturbance	2016-25	2016-25
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

Table 6.24.3 The outage data to be reported

System unit	Power transformer	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 discon-	Automatically	Automatically
Characterisation of reclosing	Manually after repair	Manually without inspection, repair or restructuring of operation
Duration of outage	120 h	10 min

Table 6.24.4 The interruption data to be reported

Name of delivery point	-
Duration of interruption	-

6.25 LINE FAULT WITH AN END-USER OUTAGE IN THE DOWNSTREAM NETWORK

Lightning caused a single-phase earth fault on the 130 kV X-Y line which disconnected the 20 kV downstream network. Furthermore, the 20 kV downstream network was only fed via the X-Y line because the Y-Z line was under maintenance, as seen in Figure 6.25.1.

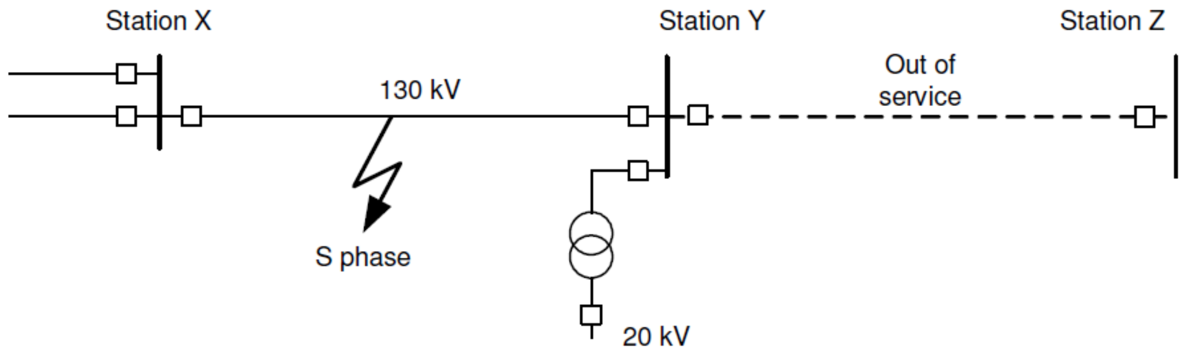

Figure 6.25.1 Line fault with an end-user outage in the downstream network.

The total load before the disturbance was 50 MW in the 20 kV network. Both the X-Y line and the power transformer Y were inspected and 30 minutes after the disturbance they were also reconnected with a 20 MW load. The rest of the 50 MW load was reclosed 20 minutes later.

Energy not supplied is calculated as the energy that should have been delivered had the outage not occurred, as explained in Section 4.4.8,. In this case, it is recommended to calculate the energy not supplied as $\frac{30}{60} \cdot 50\ MWh + \frac{20}{60} \cdot 30\ MWh = 35\ MWh$, as shown in Figure 6.25.2. However, the method for calculating the energy not supplied may differ for another company in practice.

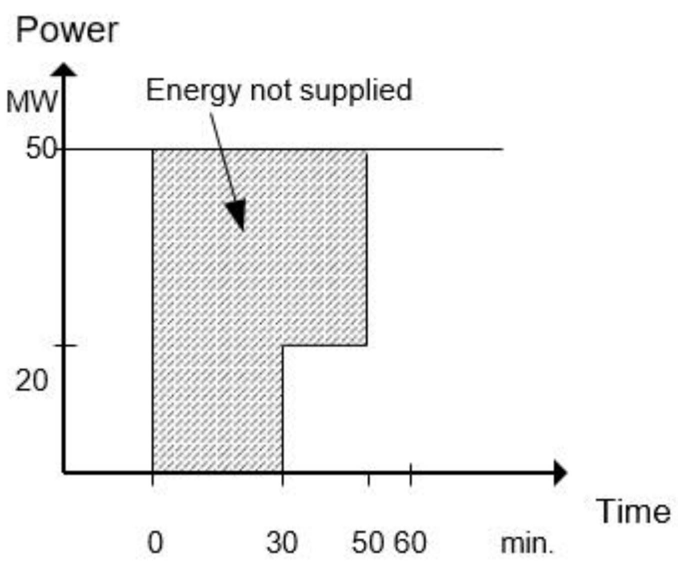

Figure 6.25.2 A visual representation of how to calculate the energy not supplied in the example of Section 0.

The data that should be reported about the incident is shown in the tables below.

Table 6.25.1 The grid disturbance data to be reported

Identification	2016-26
Date	2016-01-10
Time	10:01

Table 6.25.2 The fault data to be reported

Serial number	1
Reference to grid disturbance	2016-26
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

Table 6.25.3 The outage data to be reported

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.

Table 6.25.4 The interruption data to be reported

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

6.26 OUTAGE OF A LINE WITH A SERIES CAPACITOR

A two-phased earth fault tripped the 400 kV X-Y line and its series capacitor X-Y, as shown in Figure 6.26.1. The high speed automatic reclosing of the line was successful and the series capacitor was also bypassed automatically. The series capacitor was inspected and 1.5 hours after the incident it was put back into operation.

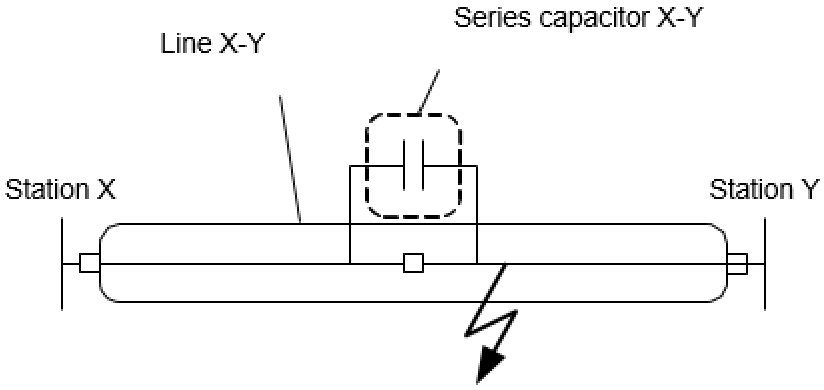

Figure 6.26.1 Outage of line with series capacitor.

The data that should be reported about the incident is shown in the tables below.

Table 6.26.1 The grid disturbance data to be reported

Identification	2016-27
Date	2016-01-10
Time	10:01

Table 6.26.2 The fault data to be reported

Serial number	1
Reference to grid disturbance	2016-27
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

Table 6.26.3 The outage data to be reported

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 secs	Manually after inspection
Duration of outage	0 min	1 h 30 min

Table 6.26.4 The interruption data to be reported

Name of delivery point	-
Duration of outage	-

6.27 Fault in under 100 kV network

A component on the lower side of the transformer's bushing tripped and caused ENS on the downstream network, as shown in Figure 6.27.1. The fault is also situated on the lower side of the transformer. The transformer trips correctly on the 100 kV side. Therefore, no faults or ENS is to be reported in the statistics.

Contrarily, a fault and ENS would be reported if the fault had been on the transformer.

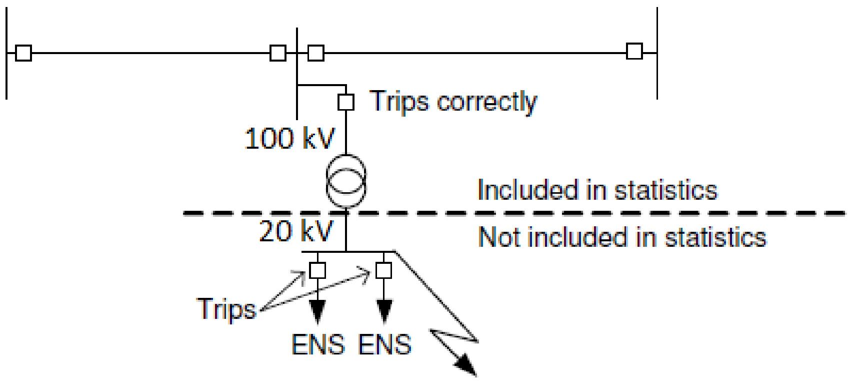

Figure 6.27.1 Fault on the lower side of a 100/20 kV transformer

7 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 6.27.1 shows how the number of the various components is calculated.

Table 6.27.1 How to calculate the number or length of various components

Component	Calculation of number and kilometres
Overhead lines	Is calculated as total length per kilometre and voltage level.
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.
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.
Instrument transformers	Instrument transformers are counted as individual components. One component for one-phased units and three components for three-phased units. This was changed in 2018 to simplify the calculations and to make the comparison between countries more factual.
Circuit breakers	Circuit breakers are considered as one component per three-phased unit. Disconnecting circuit breakers (DCB) are considered circuit breakers.
Control equipment	The number of control equipment should equal the number of circuit breakers
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.
Common ancillary equipment	The number of common ancillary equipment should equal the number of stations.
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.
Reactors inclusive of neutral point reactors	Reactors inclusive of neutral point reactors are considered as one component per three-phased connection organ.
Series capacitors	Series capacitors are considered as one component per three-phased connection
Shunt capacitor batteries and filters	Shunt capacitor batteries and filters are considered as one component per three-phased connection organ.
Surge arresters and spark gaps	Surge arresters and spark gaps are counted as individual components. One component for one-phased units and three components for three-phased units. This was changed in 2018 to simplify the calculations and to make the comparison between countries more factual.
SVC and statcom	SVCs and statcom are considered as one component per unit.
Synchronous compensators	Rotating phase compensators are considered as one component per unit.
Other high voltage appliances	The number of other high voltage appliances should equal the number of stations.

8 FUTURE WORK

While these guidelines were prepared, suggestions were presented as to how to develop the HVAC statistics. Also, common solutions must be found, and questions within certain areas need to be answered.

One idea could be to introduce the concept energy not delivered (END). It could be defined as the *calculated amount of energy that should have been delivered by a delivery point if the outage had not occurred*. However, there is 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 END 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?

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 TSO's 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.

9 REFERENCES

[1] The Energy Concern's National League, The Norwegian Water Supply and Energy Department, Statnett and Sintef Energy Research, "Definisjoner knyttet til feil og avbrudd i det elektriske kraftsystemet – Versjon 2 (In English: Definitions in relation to faults and outages in the electrical power system – Version 2)," 2001. [Online]. Available: http://www.energy.sintef.no/Prosjekt/KILE/.

[2] IEC 50(191-05-01), *International Electrotechnical Vocabulary, Dependability and Quality of Service..*

[3] EN 13306, Maintenance terminology.

[4] IEEE, *Standard Terms for Reporting and Analyzing Outage Occurrence and Outage States of Electrical Transmission Facilities.*

[5] EN 50160, Voltage Characteristics of Electricity Supplied by Public Distribution Systems.

[6] "IEC 60050: International Electrotechnical Vocabulary," 2018. [Online]. Available: http://www.electropedia.org/.

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APPENDIX A: CROSS REFERENCE LIST FOR FAULT CAUSES

The tables below state how different fault causes and subcauses for various countries and companies categorised according to the fault causes presented in Table 4.2.1.

Table A. 1 Fault causes in Denmark

Fault cause in Denmark	**Fault cause in the HVAC 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 cause in Finland	**Fault cause in the HVAC 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

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Fault cause in Finland	Fault cause in the HVAC statistics
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 cause in Iceland	Fault cause in the HVAC 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 cause in Norway	Subcause in Norway	Fault cause in the HVAC 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

Fault cause in Norway	Subcause in Norway	Fault cause in the HVAC statistics
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 compo-nent	Technical equipment
Technical equipment	Crack/break	Technical equipment
Technical equipment	Decay	Technical equipment
Technical equipment	Pollution/impurities	Technical equipment
Technical equipment	Blocking	Technical equipment
Technical equipment	Other	Technical equipment
Design/installation	Design/dimensioning fault	Technical equipment
Design/installation	Production fault	Technical equipment

Fault cause in Norway	Subcause in Norway	Fault cause in the HVAC statistics
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 cause for Svenska Kraftnät	Subcause for Svenska kraftnät	Fault cause in the HVAC 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 documenta-tion/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

Fault cause for Svenska Kraftnät	Subcause for Svenska kraftnät	Fault cause in the HVAC statistics
	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 E.ON

Fault causes for E.ON	Subcauses for E.ON	Fault cause in the HVAC 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

Fault causes for E.ON	Subcauses for E.ON	Fault cause in the HVAC statistics
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	Fault cause in the HVAC 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

Fault causes for Vattenfall	Subcauses for Vattenfall	Fault cause in the HVAC statistics
	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

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