



Bundesnetzagentur

Report

by the Federal Network Agency for Electricity, Gas,
Telecommunications, Post and Railways

on the disturbance in the German and European power system
on the 4th of November 2006

Bonn, February 2007

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1. The strategy of the Federal Network Agency

On the evening of 4 November 2006 at 22:10 hrs., some parts of Europe experienced a power cut. The outage originated in Elmsland where E.ON Netz GmbH (hereinafter referred to as E.ON Netz) switched off an extra-high voltage power line across the River Ems to enable a cruise ship from Papenburg to pass safely underneath. As a consequence, an interconnection line between Landesbergen and Wehrendorf tripped due to overloading, resulting in a cascade of line trippings from North to South throughout Europe resulting in the separation of the interconnected European grid into three areas with different frequencies. Approximately 15 million people throughout Europe were affected by this power cut. The power supply was fully restored after around 1.5 hours, the interconnection of the three grids was terminated at 23:47 hrs. E.ON Netz and other network operators have informed the Federal Network Agency about the power cuts.

Pursuant to Section 13 subsection 5 of the Energy Management Act (Energiewirtschaftsgesetz), transmission system operators (TSOs) are obliged to notify the Federal Network Agency immediately if the security or reliability of the electricity supply network is at risk, requiring the implementation of measures pursuant to Section 13 subsection 2 of the Energy Management Act.

Section 11 subsection 1 (1) of the Energy Management Act stipulates that TSOs are obliged to “develop a safe, reliable and efficient energy supply network in a non-discriminatory manner, to service it and, if need be, to expand it if it is financially reasonable to do so.” The Energy Management Act comprises some other obligations for the transmission and distribution network operators, that are aimed at safeguarding the electricity supply.

Pursuant to Section 12 subsection 3 of the Energy Management Act, relevant network transmission capacity and reliability are supposed to contribute to securing the electricity supply. Pursuant to Section 12 subsection 3 of the Energy Management Act, TSOs should draw up a report on the condition of the network and on plans for network expansion every two years. Furthermore they are obliged to conduct a weakpoint analysis every year in order to avoid serious supply disruptions and to implement relevant measures (Section 13 subsection 7 of the Energy Management Act). In addition, TSOs are obliged to notify the Federal Network Agency by 30 June of each year of any power cuts that have occurred in the previous calendar year (Section 52 of the Energy Management Act).

Pursuant to Section 65 of the Energy Management Act, the Federal Network Agency shall implement supervisory measures if a transmission network operator contravenes the provisions set forth in the Energy Management Act. In order to be able to avail itself comprehensively of this right, Section 69 of the Energy Management Act bestowed upon the Federal Network Agency comprehensive rights to request information. It can, for instance, when an appraisal is due on whether or not a transmission network operator is capable of operating a network securely in individual cases or in general request relevant information and details that are deemed necessary in order to assess the case at hand.

The Federal Network Agency began investigating the incident immediately after the blackout. It asked E.ON Netz to provide a detailed report, inter alia, outlining the cause and extent of the blackout. E.ON Netz sent a “Report on the Status of Investigations into the Cause and Extent of the Outage of the Continental European Transmission grid” to the Federal Network Agency on 14 November 2006¹. A day later, the Federal Network Agency discussed this report with E.ON Netz.

¹ <http://www.eon-netz.com/Ressources/downloads/BNetzABerichtundAnlage.pdf>

After receiving this report and having meanwhile become aware of the findings from communications by the UCTE and the press, all four German TSOs – namely E.ON Netz, RWE Transportnetz Strom GmbH (hereinafter referred to as RWE Transportnetz Strom), Vattenfall Europe Transmission GmbH (hereinafter referred to as Vattenfall Europe Transmission) and EnBW Transportnetze AG (hereinafter referred to as EnBW Transportnetze) – received comprehensive questionnaires from the Federal Network Agency. These questionnaires comprised questions on the blackout that occurred on the evening of 4 November 2006, but also on the investigations conducted by the UCTE and the weakpoint analyses which the TSOs are obliged to submit to the Federal Network Agency pursuant to Section 13 subsection 7 of the Energy Management Act.

The Federal Network Agency evaluated these questionnaires and discussed some of them with representatives of all German TSOs on 13 December 2006.

On 20 December 2006, representatives of the Federal Network Agency went to the network control station of E.ON Netz in Lehrte, and to the network control station of RWE Transportnetz Strom in Brauweiler on 22 January 2007.

In January 2007, all German TSOs received additional questions from the Federal Network Agency that had arisen after the incident had been evaluated. These questions referred to the technical facilities of the network control stations, staff training measures, network control and on the Operation Handbook on network control.

Furthermore, the Federal Network Agency evaluated the interim report by the UCTE² of 30 November 2006 (Interim Report: System Disturbance on 4 November 2006)³ and the final report of 30 January 2007 (Final Report: System Disturbance on 4 November 2006)⁴, the interim report by ERGEG⁵ of 20 December 2006 (ERGEG Interim Report on the lessons to be learned from the large disturbance in European power supply on 4 November 2006)⁶ and the summarised account by the German TSOs of 15 December 2006, taking note of information obtained through the press as well as unsolicited accounts sent in by experts and institutions.

² Union for the coordination of Transmission auf Electricity

³ <http://www.ucte.org/pdf/News/IC-Interim-Report-20061130.pdf>

⁴ <http://www.ucte.org/pdf/Publications/2007/Final-Report-20070130.pdf>

⁵ European Regulators' Group for Electricity and Gas

⁶ http://www.ergreg.org/portal/page/portal/ERGEG_HOME/ERGEG_DOCS/ERGEG_DOCUMENTS_NEW/ELECTRICITY_FOCUS_GROUP/E06-BAG-01-05_InterimReport.pdf

2. Facts

Having evaluated the reports by E.ON Netz, RWE Transportnetz Strom, Vattenfall Europe Transmission and EnBW Transportnetze, the Interim Report and Final Report by UCTE and the Interim Report and Final Report by ERGEG, the Federal Network Agency sees the sequence of events as follows:

On 18 September 2006, the shipyard (Meyerwerft) sent a request to E.ON Netz for a disconnection of the double circuit 380 kV line Conneforde-Diele for the transport of the ship "Norwegian Pearl" via the River Ems to the North Sea on 5 November at 01:00. The disconnection of this circuit is required regularly when ships of this size cross the river because the distance between the high voltage line and the ships' structure is too small to enable the ships to cross the river safely without disconnecting the line.

Since 1995, E.ON Netz has had to disconnect the double circuit 380 kV line Conneforde-Diele 14 times in order enable ships to cross the river. The River Ems is impounded in order to enable a large ship belonging to the shipyard (Meyerwerft) to cross and the ship sails into a sluice. The double circuit 380 kV line is then disconnected and E.ON Netz issues the so-called availability authorisation. This acts as confirmation to the shipyard Meyerwerft, that the line has been disconnected. Meyerwerft opens the sluice gates and the ship leaves the sluice. Depending on the case involved, the double circuit 380 kV line is disconnected for between two and four hours.

E.ON Netz provisionally approved the request by the shipyard on 27 October after E.ON Netz had previously carried out an analysis of the impact the switching off of the line would have on the network situation using standard planning data – the data record includes adequate, assumed values for environment variables for network calculation. This analysis did not show any violation of the N-1 criterion in its network. However, as there was no information available at this time on the injection and consumer conditions for 5 November 2006, the final approval was subject to a further analysis of the network situation being conducted just before the line was disconnected – a common procedure according to E.ON Netz.

Furthermore, E.ON Netz informed TenneT and RWE Transportnetz Strom about the provisional agreement, so they could carry out an N-1 analysis on their own networks. The results of those analyses confirmed that the grid would be highly loaded, but secure. As a result of co-ordination among TenneT and E.ON Netz for the outage of the Conneforde-Diele line, the TSOs agreed to reduce the cross border transmission capacity from E.ON Netz to TenneT by 350 MW for 5 November from 00:00 to 06:00 hrs.

On 4 November, TenneT decided to further reduce the capacity between Germany and the Netherlands for 5 November 2006 to take into account the wind forecast. As no wind feed-in was expected from E.ON Netz due to the planned outage of the Diele Conneforde line, the reduction of 159 MW was made only on the capacity from RWE Transportnetz Strom to TenneT.

Also on 3 November 2006, the shipyard requested E.ON Netz by telephone to bring the disconnection of the line forward by three hours, to 4 November at 22:00 hrs. E.ON Netz considered the predicted loads for the earlier disconnection to be more favourable than the originally envisaged time. E.ON Netz expected a higher load and lower forecast wind feed-in, resulting in reduced exchanges in East-West direction and less network capacity. No N-1 analysis or simulations were carried out. At this time, RWE Transportnetz Strom and TenneT were not notified of the advanced timing. What is more, the DACF (Day Ahead Congestion

Forecast)⁷ of 3 November 2006 by E.ON Netz containing the forecast for 4 November 2006, 22:00 hrs. and beyond did not include any information indicating that the line was to be disconnected earlier than planned.

E.ON Netz did not inform RWE Transportnetz Strom and TenneT until 4 November 2006 between 18:00 hrs.⁸ and 19:00 hrs.⁹ about the new time for switching off the Diele-Conneforde line.

According to TenneT, it was no longer possible at this time to reduce the cross-border exchange programme as this would have contravened the auction rules. The daily auction is held before the close of the market, so that it would certainly have been impossible to reduce the daily capacity auctioned off on the evening of 4 November 2006. At the same time TenneT agreed with E.ON Netz and RWE Transportnetz Strom to change the tap position on the phase shifter in Meeden (TenneT) in order to reduce high flows expected for the coming hours on the Meeden – Diele line. Half an hour later, at 19:33 hrs., TenneT changed the tap positions of the phase shifter in Meeden.

It is worth underlining that, on 4 November 2006, due to construction work in the 380 kV Borken substation (E.ON Netz), the substation was operated in a two-busbar mode. The Borken substation is usually operated in only one-busbar mode. This configuration means that power flows were not possible from East to West in this region

The frequency in the area of the UCTE from 21:30 hrs. to 22:09 hrs. was very close to the nominal set point at 50 Hz according to the UCTE's final report.

At 21:29 hrs., according to E.ON Netz, a load flow calculation made by E.ON Netz did not indicate any violation of limit values. Based on an empirical evaluation of the grid situation which takes the exact situation in one's own grid into account as well as the networks of neighbouring transmission TSOs and model networks and provides information about the load flows in one's own network, E.ON Netz staff assumed, without numerical computation, that after switching of the Conneforde-Diele line the N-1 criterion would be met in the system.

At around 21:30 hrs., TenneT and RWE Transportnetz Strom confirmed to E.ON Netz that the flows between Germany and the Netherlands were high, however since TenneT and RWE Transportnetz Stromgrid would be secure, TenneT and RWE Transportnetz Strom gave its agreement to the switching operation of the Conneforde-Diele lines. Just before the opening of the Conneforde-Diele line, RWE Transportnetz Strom made a load flow calculation and an N-1 analysis with the outage of the Conneforde-Diele line.

At 21:38 hrs., E.ON Netz switched off the first circuit of the 380 kV line Conneforde-Diel which crosses the River Ems. The load flows from East to West were hence redirected to other lines that were further South.

At 21:39 hrs., after the switching operation, E.ON Netz received several warning messages about the high power flow on the lines Elsen-Twistetal and Elsen-Bechterdissen. Warning messages at E.ON Netz comprise an optical and acoustic signal and according to E.ON Netz is one of the entry variables for evaluation of a concrete situation by the network control station. The specific warning message indicated that the power limits were about to be reached. At E.ON Netz's grid control station, dispatchers were aware that under the inter-

⁷ Day Ahead Congestion Forecast (DACF) Data and files are prepared by each transmission network operator every day at around 18:00 hrs. for the coming day. UCTE is requiring 4 time stamps per day. E.ON Netz is providing 24 time stamps data for each hour and a half. These DACF files can be used by all UCTE TSOs to make security analyses on a larger basis than their "home" grid.

⁸ According to information provided by E.ON Netz.

⁹ According to information provided in the UCTE Final Report, p. 18

nal regulations at E.ON Netz, a temporary overload of operating system of 25 is permissible and they saw no need to take any immediate action.

At 21:41 hrs. the network control station of E.ON Netz phoned the network control station of RWE Transportnetz Strom in order to find out if everything was still ok. RWE said yes – the N-1 security criterion had been met in its own grid -, but pointed out the security margin¹⁰ of 1800 A for the Landesbergen – Wehrendorf line. This line is an interconnection line between E.ON Netz (Landesbergen) and RWE (Wehrendorf). Furthermore, the network control station of RWE Transportnetz Strom pointed out the limit values¹¹ von 1990 A at the substation in Wehrendorf. However, at this point of time the current on this line was still under the given limit (1 795 A), and the N-1 criterion was still met in the internal RWE Transportnetz Strom network.

At 21:42 hrs., dispatchers at E.ON Netz issued the so-called passage approval for the ship.

In additional telephone calls between dispatchers at E.ON Netz, and Vattenfall Europe Transmission at 21:46 hrs. and 21:52 hrs., the situation was considered to be tight.

After 22:05 hrs., according to E.ON Netz und RWE Transportnetz Strom the load on the 380 kV line Landesbergen-Wehrendorf increased by 100 MW (which corresponds to around 160 A). It was not clear what was causing the change in load flow. The power on the line Landesbergen – Wehrendorf increased to around 1900 A within two to three minutes, thereby exceeding the warning value of 1 800 A for RWE Transportnetz Strom for this line.

At 22:07 hrs. the warning value was exceeded which triggered an immediate reaction by RWE Transportnetz Strom which called E.ON Netz at 22:08 hrs. with the request for urgent intervention to restore safe grid operation.

The staff at the network control station of E.ON Netz made an empirical assessment of the situation and decided to couple the busbars in the substation of Landesbergen. The network control station at E.ON Netz thought this would lead to a reduction of the current by about 50 MW (which is equivalent to 80 A). No load flow calculations were made and no checks were carried out to see if the N-1 criterion had been met.

This manoeuvre was done at 22:10 hrs. without any further co-ordination with RWE Transportnetz Strom.

Two seconds later, namely at 22:10:13 hrs., the automatic protection device disconnected the line Landesbergen – Wehrendorf.

¹⁰ The security margin is a value that requires intervention if exceeded in order to restore secure operation of the grid and to avoid the risk of a line being automatically switched off.

¹¹ The security margin, also referred to as the voltage collapse boundary, must not be exceeded after a tripping value has been reached within a defined period in order to prevent a line from being automatically switched off.

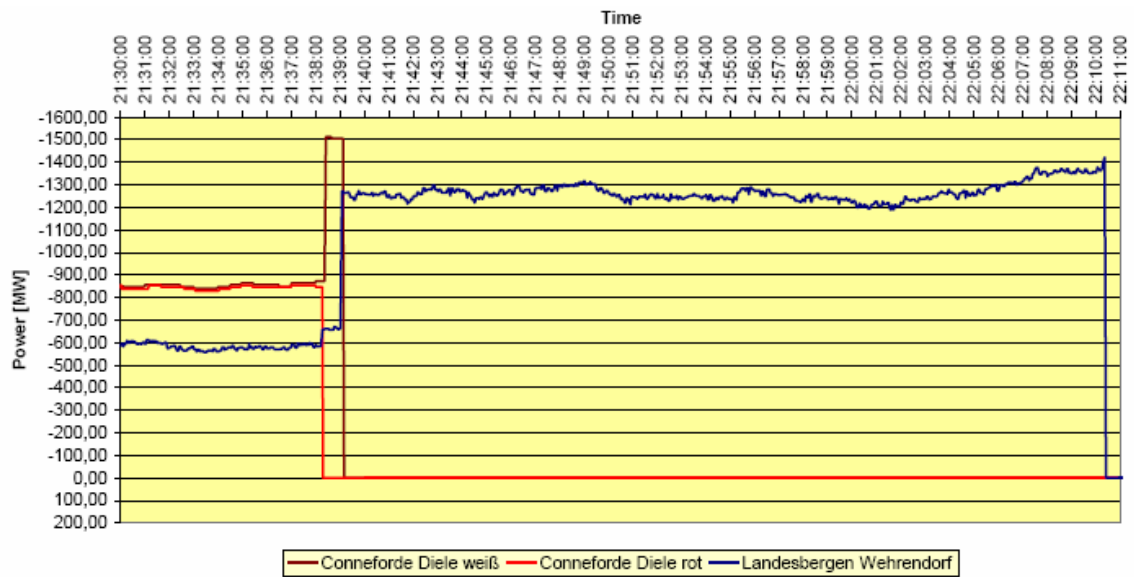


Figure 1: load flow on the Landesbergen – Wehrendorf line before and after the disconnection of the Conneforde – Diele line

Source: UCTE Final Report

This resulted in load deviations which led to the 220 kV Bielefeld/ East – Gütersloh being disconnected at 22:10:15 hrs.. At 22:10:19 hrs, the 380 kV Bechterdissen – Elsen line tripped. Other lines from North to South right across Germany, Austria, Croatia, Hungary and other countries subsequently tripped within the next few seconds.

Nr.	Zeit	kV	Leitung
1	22:10:13	380	Wehrendorf-Landesbergen
2	22:10:15	220	Bielefeld/Ost-Spexard
3	22:10:19	380	Bechterdissen-Elsen
4	22:10:22	220	Paderborn/Süd-Bechterdissen/Gütersloh
5	22:10:22	380	Dipperz-Großkrotzenburg 1
6	22:10:25	380	Großkrotzenburg-Dipperz 2
7	22:10:27	380	Oberhaid-Grafenrheinfeld
8	22:10:27	380	Redwitz-Raitersaich
9	22:10:27	380	Redwitz-Oberhaid
10	22:10:27	380	Redwitz-Etzenricht
11	22:10:27	220	Würgau-Redwitz
12	22:10:27	380	Etzenricht-Schwandorf
13	22:10:27	220	Mechlenreuth-Schwandorf
14	22:10:27	380	Schwandorf-Pleinting

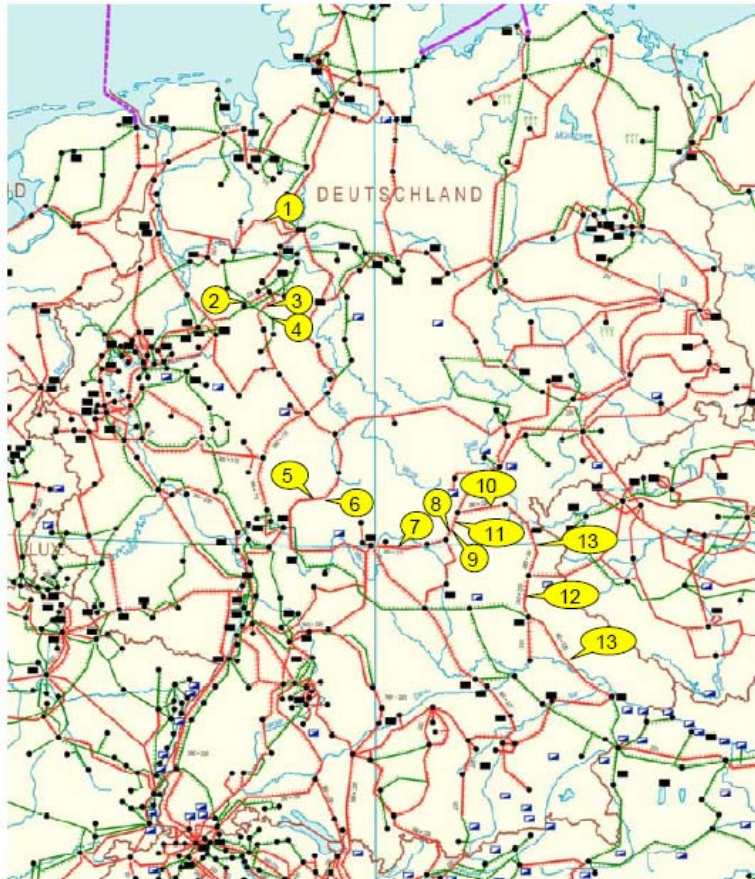


Figure 2: times when lines were automatically disconnected in the catchment area of E.ON Netz on 4 November 2006

Source: E.ON report on the stage of investigations of 14 November 2006

As a result of the failure of individual lines, the European transmission grid was split in three. The North-Eastern area had an over-frequency and encompassed the area of the German TSOs Vattenfall Europe Transmission and part of the network of E.ON.. In the Western area, the other part of E.ON's network including the areas of EnBW Transportnetze and RWE Transportnetz Strom and in the South-Easterly area, there was an under-frequency.

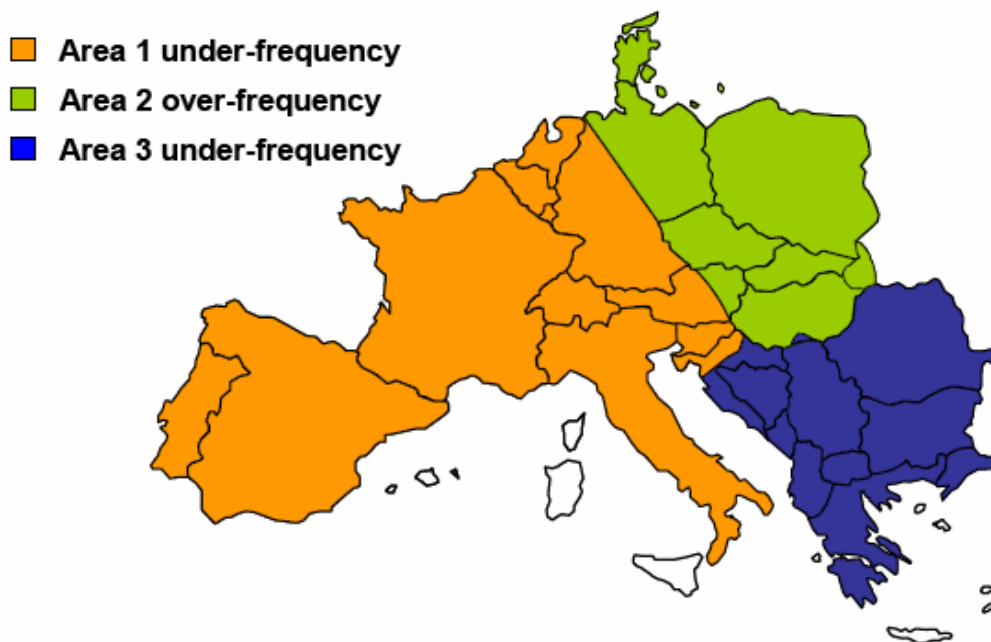


Figure 3: diagram of the UCTE grid which had split into three frequency areas

Source: UCTE Final Report

In the North-East, there was a surplus of generating power so that the frequency of 50 rose to around 51.4 Hz, gradually levelling out at around 50.4 Hz. In order to counteract the surplus of generating power, TSOs shed loads in this area at short notice or cut the power altogether. Pumps were also activated in the pump storage units.

In the West, frequency dropped to 49.0 Hz, in the South-East to around 49.7 Hz. In these areas, consumers were disconnected from the network, pump output in hydro generation plans was switched off and additional generation units were activated.

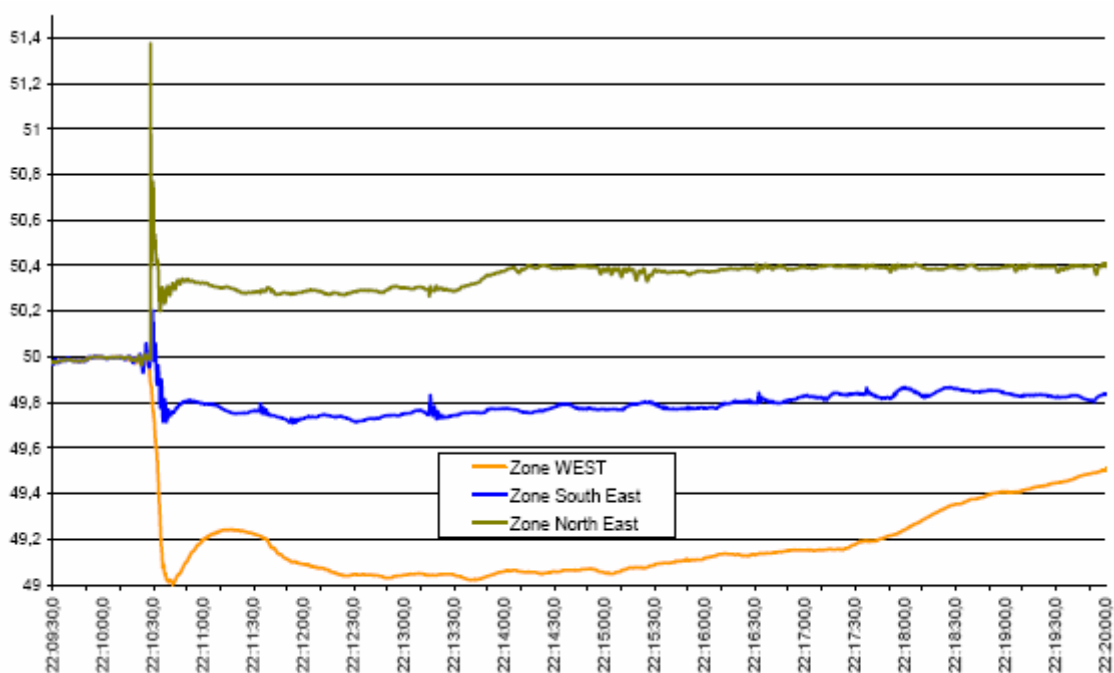


Figure 4: records of the frequencies following the split in the UCTE grid

Source: UCTE Final Report

According to the UCTE, it was relatively easy to stabilise the frequencies in the under-frequency areas (West and South-East), although it was more difficult to do so in the over-frequency area where there was a surplus of generation which was exacerbated by the automatic reconnection of wind generation units.

The German TSOs were affected by the blackout due to their allocation to different frequency areas. In the control areas of RWE Transportnetz Strom, EnBW Transportnetze and Vattenfall Europe Transmission, the lines were not overloaded or disconnected in the grid as a result of the blackout. By contrast, the grid of E.ON was split down the middle as indicated in Figure 2.

The system disturbance meant that all German TSOs had to make adjustments pursuant to Section 13 subsection 2 of the Energy Management Act. This provision stipulates *mutatis mutandis* that the TSOs must adapt all power injections, transits and dispatching in their control areas to meet the requirement of secure and reliable operation of their transmission grid, if network-related measures (particularly network switching) and market-related measures are not sufficient to rule out risks to the security and reliability of the power supply network.

In order to obtain an overview of the situation, some TSOs made contact with each other after 22:10 hrs. They hence discovered that there was a disruption in the entire grid which resulted in the grid being split into three sub-systems.

An attempt was made after 22:34 hrs. to resynchronise the North-Eastern and Western sub-system. However, initial resynchronisation attempts were unsuccessful as the differences in frequency were too high.

At 22:47 hrs., the North-Eastern and Western sub-system were resynchronised. At around 22:47 hrs. lines that had tripped in Germany were switched back on. Attempts were made before this to switch lines back on but it became evident in individual cases that the lines could not be reconnected and they tripped again, causing a renewed blackout.

However, by 23:57 hrs. the European partial areas had been fully interconnected. It was around this time that the power supply was restored for consumers – according to the UCTE more than 15 million people throughout Europe had been affected by the blackout.

By 01:00 hrs. on 5 November 2006, according to the German TSOs, all the main interconnections in the German transmission grid had been completed in relation to the adjustment to generation and loads, thereby completing all the adjustments required under Section 13 subsection 2 of the Energy Management Act.

3. The reports by ERGEG

ERGEG¹² set up an ad hoc working group after the power supply disruption. This working group was asked to analyse the power cut in detail. On 20 December 2006, ERGEG published its Interim Report¹³, on 6 February 2007 its Final Report of the analysis.¹⁴ Two recommendations are made in the Final Report. There is a need for an improved legal and regulatory framework to minimise the risk of future interruptions. The second recommendation says that the TSOs themselves need to implement measures in order to secure effective coordination and cooperation among each other.

The recommendations were made under two broad headings which ERGEG holds responsible for the disruption in the European power grid:

- The N-1 criterion was not met.
- There was not sufficient coordination among TSOs.
- The behaviour of decentral generators cannot be sufficiently controlled or monitored by TSOs.

In relation to the N-1 criterion, ERGEG stated that it had not been met after the double 380 kV line had been disconnected over the River Ems. Investigations into the incident had shown that the individual TSOs interpret the requirements made in the UCTE Operation Handbook differently. They state that TSOs monitor at any time the N-1 criterion for their own system¹⁵. ERGEG considers that this requirement implies that all TSOs should perform N-1 security analysis in their own system every 15 minutes. It says that in order to allow sufficient time for these calculations, the order of procedures needs to be predefined as far as possible. ERGEG has stated that a more detailed and specific definition of the N-1 operational security criteria in the UCTE Operation Handbook should be considered.

ERGEG states that TSOs should also be obliged to enhance coordination and the exchange of information. To safeguard better, secure network management, TSOs should have access to real time data of power units connected to distribution grids.

The Final Report of ERGEG contains a large number of other recommendations. It says it should be analysed whether the UCTE philosophy of decentral responsibility should be developed more in the direction of a central and/or hierarchical system responsibility. It states that regulatory authorities, but also TSOs should examine whether the existing national operating rules are sufficient. Another important element is that the TSOs should have further-reaching tools than those currently available to control the use of decentral generation units in critical situations. Another important element could be the harmonisation of interconnection rules for any such generators.

In order to accomplish these goals, ERGEG proposes short and medium-term solutions. It says that amendments to the UCTE Operation Handbook could lead to immediate improve-

¹² European Regulator's Group for Electricity and Gas is an advisory group of European regulatory authorities which advises the European Commission on matters relating to energy regulation.

¹³ ERGEG Interim Report on the lessons to be learned from the large disturbance in European power supply on 4 November 2006. Published under http://www.ergreg.org/portal/page/portal/ERGEG_HOME/ERGEG_DOCS/ERGEG_DOCUMENTS_NEW/ELECTRICITY_FOCUS_GROUP/E06-BAG-01-05_InterimReport.pdf; ERGEG

¹⁴ Final Report: The lessons to be learned from the large disturbance in the European power system on the 4th of November 2006, E06-BAG-01-06, http://www.ergreg.org/portal/page/portal/ERGEG_HOME/ERGEG_DOCS/ERGEG_DOCUMENTS_NEW/ELECTRICITY_FOCUS_GROUP/

¹⁵For an explanation of the N-1 criterion in Operation Handbook cf. below, item 5.1.1.1.

ments. ERGEG lists a number of specific items in this context. However, the lack of a binding legal framework of the Operation Handbook and multilateral agreements is a major problem, as TSOs are unable to guarantee that the measures agreed are actually implemented. ERGEG therefore proposes that Operational Security Guidelines according to the Article 8 of the Regulation (EC) 1228/2003 be developed. Consequently, the short term effort may be focused on issues that relate directly to cross-border dispatching, such as the development of common planning standards or common emergency planning. It says the regulatory authorities should be commissioned with monitoring and enforcing these guidelines. ERGEG will develop the main elements of these guidelines within the framework of the work programme for 2007.

In the opinion of ERGEG, European considerations should play a role in national plans regarding the implementation of Security of Supply Directive 2005/89/EC. In order to ensure that amendments proposed by ERGEG are implemented in a comprehensive way in a secure legal framework, ERGEG thinks it is necessary to create a new legal framework in which the "European Grid" is defined, with TSOs having to develop a "European Grid Code". This code would have to be approved by the regulatory authorities and the latter would need to ensure it is implemented by the TSOs. All of this is conceivable, for instance, within the framework of enhanced competencies for the European Regulators Group for Electricity and Gas (ERGEGplus).

4. The reports by the UCTE

In its Final Report of 30 January 2007, the UCTE¹⁶ said the system disturbance of 4 November 2006 was one of the biggest and most serious disturbances that have ever occurred in Europe. In its Interim Report of 30 November 2006 and in its Final Report of 30 January 2007¹⁷, the UCTE established that there were two main causes of the power failure and the formation of partial networks, and hence network with different frequencies.

The first main cause was the non-fulfilment of the N-1 criterion.¹⁸ E.ON Netz did not check that the N-1 criterion was met before disconnecting the line. After manual disconnection of the double-circuit 380 kV Conneforde-Diele line (E.ON Netz), the N-1 criterion was not fulfilled in the E.ON Netz grid and on some of its tie-lines to the neighbouring TSOs.

UCTE considers the lack of coordination between the TSOs during the event to be the second main cause. The initial planning in relation to switching-off the double-circuit 380 kV Conneforde-Diele line scheduled for 5 November 2006 at 01:00 hrs. was duly prepared by the directly involved TSOs (E.ON Netz, RWE Transportnetz Strom und Tenne). However, the change in the time for this switching manoeuvre was communicated by E.ON Netz to the other directly involved TSOs at a very late stage.

The UCTE mentions additional factors in its Interim and Final Reports which it rates as critical.

The UCTE thinks it was critical that most of the TSOs do not have access to the real-time data of the power units connected to the distribution grids. Furthermore, in individual parts of the system, the uncontrolled reconnection of generation units induced very severe conditions and the need for additional time to recover secure system operation.

- Transmission network operators have certain possibilities under national regulations and internal procedures of averting disruptions and restoring secure operations. The Energy Management Act obliges the German TSOs to respond to emergency situations by implementing certain measures.¹⁹ The adequacy and effectiveness of such measures do not always support an adequate management of such specific conditions like the one on 4 November 2006.
- In some places the re-energisation was marked by poor coordination between the TSOs and DSOs.
- There was insufficient coordination between the TSOs regarding the resynchronisation of the sub-systems.
- The training of dispatchers needs to be improved.

In the Final Report, the UCTE makes recommendations that relate to technical and organisational aspects which should be implemented by UCTE or competent stakeholders at national or European level.

¹⁶ Union for the Coordination of Transmission of Electricity is the association of 23 transmission system operators in continental Europe, providing a reliable market base by efficient and secure electric "power highways".

¹⁷ UCTE also published a small presentation in relation to its Final Report which can be accessed at: http://www.ucte.org/pdf/Publications/2007/EC_MC_Penedos_v4.pdf

¹⁸ For detailed information about the N-1 criterion, compare below, item 5.1.1.1.

¹⁹ This refers to measures pursuant to Section 13 subsection 1 and 2 of the Energy Management Act.

The UCTE itself suggested that the Operation Handbook²⁰ be revised, while emphasising that the current regulations do not contain any fundamental deficiencies but that it required certain clarifications and supplements.

It specifically said the Operation Handbook needed clarification in Policy 3 regarding the application of the N-1 criterion and Policy 5²¹ needed to be extended by a master plan for emergency operations. Furthermore, it said that criteria on regional and supraregional coordination between TSOs that are aimed at regional security management need to be developed. Last but by no means least, it said that the UCTE should provide TSOs with a real time information system on the condition of the entire UCTE grid so that they could respond swiftly to major disturbances.

Another demand made by the UCTE focuses on the regulatory and legal framework which should ensure TSOs have more and more up-to-date data on generation units and enable them to switch generation units on and off themselves.

²⁰ For information on the Operation Handbook in general and the description of the N-1 criterion cf. below, item 5.1.1.1. Individual parts of the Operation Handbook have been published at:
http://www.ucte.org/ohb/cur_status.asp.

²¹ Policy 5 is overwritten with Emergency Procedures.

5. Findings and recommendations by the Federal Network Agency

The Federal Network Agency has arrived at the following findings and recommendations in relation to the following four aspects based on the information available to it:

- The N-1 security
- Cooperation and coordination between TSOs in general and specifically in respect of the exchange of data.

It hence agrees with ERGEG and the UCTE which see need for action regarding these two aspects.

5.1. N-1 security

The N-1 criterion requires that any single loss of transmission or generation element should not jeopardize the secure operation of the interconnected network. This means that there should not be any power supply disruption (blackout) or larger disruption, the voltage in the grid must not fall below or exceed limit values that is capable of triggering a cascade of line trippings or the loss of a significant amount of consumption.

5.1.1. Sets of rules

The N-1 criterion is specified in a number of regulations at national and international level.

5.1.1.1. The Operation Handbook of the UCTE

The Operation Handbook (OH) of the UCTE²² contains the technical and organisational standards that are intended to facilitate the exchange of power and at the same time to maintain a high level of supply security in the European transmission grid. The bulk of the Operation Handbook (seven of eight chapters, so-called “policies”) have meanwhile been completed. The Multilateral Agreement, which was drawn up in Belgian law and which makes the technical standards specified in the Operation Handbook binding for all members of the UCTE entered into force on 1 July 2005 after it was signed by all UCTE members. However, when the multilateral agreement was signed, each TSO was able to define some provisions as temporarily exempt from this European set of rules for their own area of responsibility.

Policy 3 “Operational Security” in Chapter A contains information about N-1 security. The UCTE rates the N-1 criterion as very importance for avoiding system disturbances.²³ It views the obligation of TSOs as follows: “TSOs monitor at any time the N-1-CRITERION for their own system through observation of the interconnected system (their own system and some defined parts of ADJACENT SYSTEMS) and carry out security computations for risk analy-

²² The individual parts of the Operation Handbook are published on the following website:
http://www.ucte.org/ohb/cur_status.asp.

²³ Chapter A, Introduction specifically says: “The N-1 CRITERION is of major importance to prevent disturbances.”

sis.”²⁴ The Operation Handbook does not contain any details, for instance, how frequently or in what situations the N-1 criterion should be considered. Rather, it says: “TSOs individually and jointly develop, maintain und implement procedures to comply with the N-1 CRITERION“.²⁵ It does not state either for what region the N-1 criterion should be considered.²⁶

5.1.1.2. The Transmission Code 2003

The rules of application of the N-1 criterion for German TSOs are specified in Transmission Code 2003 which was drawn up by the Association of German Network Operators (Verband der Netzbetreiber) (VDN²⁷). TransmissionCode 2003 specifies, among other things, the minimum technical requirements that should be met to maintain the security and reliability of the power supply system. Transmission Code 2003 implemented valid regulations set forth in the UCTE Operation Handbook (including the regulations on the N-1 criterion in Germany and describes what N-1 security means in a network. However, just like the Operation Handbook, Transmission Code 2003 does not specify how often TSOs should carry out an N-1 analysis on their network.

Pursuant to Transmission Code 2003, the N-1 criterion to assess the security of network operations in the 380/220 kV transmission grid and in 110-kV network groups with a transmission function, the simple failure of free lines, cable power circuits and network transformers are included. This means that in the event of fault-related outages of these network operating systems, violations of limit values of certain network factors (for instance, (operating voltage) and utilisation of operating systems (power load), interruptions in power supply, subsequent activation of other protective devices, the loss of stability of generation units and the need to change or, if applicable, interrupt transmission must be ruled out.

Pursuant to the rules of Transmission Code 2003, the N-1 criterion applies both within the framework of network planning and as part of operational planning.

The TSOs organise their network within the framework of planning in accordance with the N-1 criterion in order to ensure that the network functions are maintained for the forecast maximum transmission and supply tasks in the event of a disruption triggered by an incident. The minimum criteria that apply within the framework of the N-1 criterion (cf. above) represent the technical assessment scope for determining interconnection concepts of customer plans and network expansion.

As part of operational planning, network operation according to the N-1 criterion means that if there is a simple failure of operating facilities or of a generation unit with maximum impact on the supply security, the above-mentioned effects must be avoided. The basis of examination are all the already known scheduled reports and the scheduled network condition. The network condition includes planned disconnections of network operating facilities and generation units. When operational work and network modernisation are carried out, the TSOs may deviate temporarily from the N-1 secure supply (after network users have been duly notified in advance).

²⁴ Chapter A, Part R1.1

²⁵ Chapter A, Part P1

²⁶ UCTE Final Report, p. 49

²⁷ Association of German Network Operators (Verband der Netzbetreiber) (VDN beim VDEW

5.1.1.3. Operation Handbooks

At the individual TSOs, the rules set forth in the Operation Handbook and the Transmission Code 2003, the statutory provisions for the operation of electrical plants, the relevant regulations issued by the VDE-Bestimmungen²⁸ and the rules of the competent employers' liability insurance association should be included in the Operation Handbooks. Operation Handbooks comprise general specifications and hence provide the basis for organisation, the process and responsibility in operating the transmission grid. In relation to the obligation in the Operation Handbook and the TransmissionCode 2003 to operate networks securely, ensuring the N-1 security criterion is met, the Operation Handbooks should indicate that the technical facilities of the network control stations be taken into account, specifying precisely how the N-1 secure condition of the grid can be guaranteed.

5.1.2. The N-1 analysis at German TSOs in general

All German TSOs have network control tools at their disposal at their network control stations, that enable them to carry out an N-1 analysis and to check whether their network can be securely operated following the disconnection of operating facilities or a generation unit. However, there are major differences in how the TSOs can carry out an N-1 analysis and what functions the system have.

In general, TSOs carry out an N-1 analysis at regular intervals and automatically at specified intervals, as a rule every 15 minutes. In addition, it is possible to check the N-1 criterion manually at any time. It is at the discretion of staff to prompt initial analyses if they deem it necessary to do so. One TSO gives the example that an N-1 analysis was carried out prior to any switching.

At E.ON Netz, by contrast, it is currently not possible at the network control centre to carry out regular, automatic N-1 analysis. This can only be initiated manually. The network control centre does not have any analytical tools that could carry out any such analysis automatically using the latest data records. It is at the discretion of staff of the dispatchers at the network control centre whether and when an N-1 analysis is carried out.²⁹

The informative value of N-1 analyses also differs at German TSOs. The state of the art is that the complete network of the control area of a TSO including the first link of the neighbouring control area is included in the so-called outage variant analysis. As such, a number of outage variants are calculated and network security or part of the network are checked. The network control station of E.ON Netz does not provide this function at present, the informative value of an N-1 analysis is more limited. No automatic outage variant analysis is carried out here. Rather, after deciding what operating facility is to be approved for disconnection, the dispatchers at the network control centre have to decide on what other operating facilities security needs to be checked. This means the various outage variants have to be checked one-by-one. The result of the N-1 calculation is a simulated load flow image that refers to the control area managed by the network control centre including the interconnection lines with neighbouring networks as its only considers the outage of certain operating facilities for part of the grid.

²⁸ VDE: Verband der Elektrotechnik, Elektronik, Informationstechnik e.V. (Association for Electrical, Electronic & Information Technologies)

²⁹ E.ON Report of 14 November 2006, p. 14

5.1.3. Carrying out N-1 analyses in connection with the power failure of 4 November 2006

As manifested by the facts outlined above, N-1 analyses were only carried out in individual cases in preparation for the disconnection of the double circuit 380 kV line Conneforde-Diele. Specifically, the N-1 criterion was taken into account as follows:

- By 27 October 2006: E.ON Netz checked the N-1 security criterion was met after the shipyard Meyerwerfft requested that the Conneforde – Diele line be disconnected on 5 November 2006, by analysing the network load situation.
- On or after 27 October 2006: according to the UCTE's Final Report, TenneT and RWE Transportnetz Strom checked the N-1 security in their networks, the result showed that the networks were highly loaded but secure.
- 3 November 2006: the shipyard Meyerwerfft requested E.ON Netz to bring forward the disconnection of the extra-high voltage power line by three hours, to 4 November 2006. E.ON Netz agreed to do so, no N-1 analysis was carried out.
- 4 November 2006, 19 hrs.: E.ON Netz informed RWE Transportnetz Strom and TenneT about the new time for switching off the Diele-Conneforde line.
- 4. November 2006, 21:29 hrs: E.ON Netz carried out a simulation analysis, but no N-1 analysis. The simulation analysis did not indicate any violation of limit values.
- 4. November 2006, 21:30 hrs.: according to the UCTE Report, RWE Transportnetz Strom carried out an N-1 analysis based on the assumption that the Conneforde – Diele had been disconnected. This analysis showed that its own network was highly loaded but secure.
- 4. November 2006, 21:38 hrs.: E.ON Netz disconnected the extra-high voltage power line and subsequently received several warning messages. E.ON Netz did not check the network security by carrying out an N-1 analysis.

This overview shows that E.ON Netz did not carry out any N-1 analyses on 3 or 4 November 2006. At RWE Transportnetz Strom, the routine N-1 analyses were carried out at 21:20 hrs., 21:35 hrs., 21:50 hrs. and 22:05 hrs. taking into account that the Conneforde - Diele line had been disconnected with the result that the TSO's own network would be and was in N-1 secure condition after the disconnection of the extra-high voltage power line over the River Ems.

5.1.4. Assessment of the failure to carry out N-1 analyses at E.ON Netz

The sequence of events relating to the power failure as described above shows that the network of RWE Transportnetz Strom met the N-1 security criterion. After the Conneforde – Diele line was disconnected, the load flow on the interconnection line between Landesbergen and Wehrendorf increased. After this line had tripped – removing one element of the system in the grid of RWE Transportnetz Strom – the network of RWE Transportnetz Strom remained secure. However, this was not the case at E.ON Netz. Its grid was only secure up to the point when the 380 kV Conneforde – Diele line was disconnected. After this line had been switched off – which reduced the operating facilities of E.ON Netz³⁰ – the network was no longer secure. Rather, the tripping of the interconnection line Landesbergen –Wehrendorf caused a second tripping of lines, causing failure of E.ON's entire grid.

³⁰ In actual fact, the Conneforde – Diele line is a double circuit which is considered to be operating equipment here as the ship could not have passed through so long as one of the two lines was switched on.

If E.ON Netz had operated its own grid securely in line with the N-1 contingency on the evening of 4 November 2006, the Landesbergen-Wehrendorf line would not have failed. The failure of this line had a cascading effect that led to large-scale system disturbance. The Federal Network Agency does not understand why E.ON Netz failed to carry out an N-1 analysis before or after receiving numerous warning messages and phone calls once the 380 kV Conneforde – Diele line had been disconnected.

Having considered the sequence of events, the Federal Network Agency assumes that an N-1 analysis would certainly have revealed that E.ON Netz's grid was indeed not secure. In this regard, the Federal Network Agency finds the assessment of the UCTE logical. It explicitly mentions in its Final Report that ultimately even a relatively small power flow deviation could start the cascade of lines tripping. Between 22:00 hrs. and 22:10 hrs. the power flow on the Landesbergen-Wehrendorf line increased by around 130 MW – causing the line to trip.³¹

As outlined above, an N-1 analysis is not carried out automatically or cyclically at the network control station of E.ON Netz. On 4 November 2006, a simulation calculation was carried out at 21:29 hrs., indicating what load flow would be reached if the double circuit line above the River Ems was disconnected. The next step would have been to consider additional operational equipment as being disconnected and then to assess the security of the grid after new load flow calculations were available. In this case, the N-1 security computations would have been carried out.

As described above, E.ON Netz leaves it to the discretion of their dispatchers when to carry out N-1 analysis. The UCTE Final Report indicates that according to the rules in force at E.ON Netz, the dispatchers should have checked that the N-1 criterion was met before opening the 380 kV double circuit line Conneforde-Diele.³² This means the conclusion could be drawn that, to quote the words of E.ON Netz, “the situation was misread” and hence the disturbance was attributable to “human error”, namely “that the human factor played a crucial role” in the disturbance.³³

However, these conclusions are too one-sided and do not gauge the incident properly. Naturally, it must be taken into account that incorrect decisions were taken at the network control station of E.ON Netz above all on the evening of 4 November 2006. Generally speaking, it cannot be disregarded that even when optimum technical equipment is available, any wrong decision taken by a dispatcher can have consequences that could have been avoided had the situation been assessed carefully. To put it differently, an N-1 analysis (carried out cyclically or prompted manually) indicating a violation of network security would have been of no use whatsoever if the dispatchers at the network control station failed to take note of it or assessed the result incorrectly.

It is however particularly critical in this particular case, that E.ON Netz does not even have a technical sub-structure for checking the N-1 criterion that could have assisted the dispatchers with network control and limited their discretion. No N-1 analysis was carried out and no simulation computations were carried out automatically that automatically assist dispatchers with network control.

It is general practice at German TSOs to carry out N-1 analyses at regular intervals, as described above. Furthermore, additional N-1 analyses can be carried out at any time if required. Dispatchers are responsible in this case for making the following assessments and decisions:

³¹ UCTE Final Report, p. 48 ff.. Also ERGEG Final Report, p. 12, deals with the claim made by E.ON that there were sudden and unforeseeable movements in power flows. ERGEG does not think there is sufficient logical evidence to back up this claim.

³² UCTE Final Report, p. 19

³³ These quotations originate from the Inquiry Report by E.ON Netz of 14 November 2006, p. 19 ff.

- Assessing the result of cyclical N-1 analyses
- Exercising their discretion as to whether an additional N-1 analysis should be carried out (e.g. in preparation for switching)
- Assessing the result of the additional N-1 analysis if any such analysis has been carried out.

As each TSO is obliged to ensure that their grid is operated securely and meets the N-1 criterion at all times, special importance is attached to evaluating the result of N-1 analyses. As any such result is shown automatically and cyclically, the dispatchers at the network control station are specifically required to evaluate the condition of the grid as being either in N-1 secure condition or at risk. The discretion begins when dispatchers need to decide whether it is necessary to carry out an additional network security analysis.

The situation is different at E.ON Netz. Dispatchers here are responsible for taking the following decisions:

- Exercising their discretion as to whether an N-1 analysis should be carried out in the first place
- Assessing the result of the N-1 analysis.

In this case, discretion begins with the question when and whether an N-1 analysis should be carried out in the first place. The system does not help dispatchers at the network control station to assess the network condition as mandatory– whether the grid is in “N-1” secure conditions or is at risk.

By contrast, the statements which the German TSOs made to the Federal Network Agency that it is not possible to conclusively describe all critical situations but that special importance is attached to the experience and resulting from this experience the decisions made at dispatchers’ discretion at the network control stations in coping with critical situations. However, if there is a lack of technical equipment or if technical equipment no longer reflects the state of the art, this is instrumental in causing the serious consequences such as those seen on 4 November 2006, this proves that the TSOs failed to operate their grids in “N-1” secure conditions at all times.

The Federal Network Agency is aware that E.ON Netz is currently in the process of putting a technically modernised network control station into operation which provides, inter alia, for the cyclical, automatic implementation of outage variant computations to check that the N-1 security criterion is met.

5.1.5. Recommendations made by the Federal Network Agency

The Federal Network Agency makes the following recommendations on the basis of the facts and findings outlined above:

E.ON Netz should bring its network control stations up to the state of the art and implement cyclical, technical, automatic outage variant computations to ensure that the N-1 security criterion is met as soon as possible.

Until the network control stations of E.ON Netz have been brought up to the relevant technical standard, dispatchers should be made specially aware of the need to meet the N-1 criterion. Staff should be obliged to check the N-1 security criterion is met in certain situations to be described by carrying out an analysis. In addition, it seems to be necessary to draw up and describe in general the precise situations in which there is room for discretion regarding the carrying out of N-1 analyses.

All German TSOs should automatically check the N-1 security criterion is met at least every 15 minutes. The TSOs should also specify the cases in which dispatchers at network control

stations should be obliged to carry out additional N-1 computations. In order to take into account the fact that it is not possible to conclusively describe in particular each and every critical situation, the dispatchers at network control stations should also be made responsible for carrying out N-1 computations in addition to the network security checks above and beyond the cases described above. The dispatchers at network control stations should be made specifically aware of this requirement.

It is recommended that German TSOs exchange experiences on the application of the N-1 criterion. The TSOs should compare how the N-1 criterion applies at their grid control stations within the framework of this exchange of experience.

Just like the UCTE and ERGEG, the Federal Network Agency thinks it is necessary to define and specify Policy 3 “Operational Security” in relation to N-1 security in the Operation Handbook. It is, for instance, not clear what is currently meant when it says that TSOs monitor the N-1 criterion “at any time”³⁴ for their own system and how often, when precisely, for what area and using what operational equipment this should be done.

5.1.6. Training of dispatchers

In the explanations on N-1 analyses provided in the foregoing and on how to cope with critical situations, it was indicated that each and every German TSO leaves it up to their dispatchers to take decisions independently. The Federal Network Agency has no objection to dispatchers exercising discretion in their decision-making if situations require them to do so.

The Federal Network Agency asked the TSOs what qualifications the dispatchers operating the lines had. The documents they responded with do not provide any evidence of omissions or deficits. The requirements are similar and comparable with all German TSOs.

On the basis of a basic degree, generally a degree in engineering, dispatchers are taught the theory. Many dispatchers have already gained experience in other jobs. This is followed by on-the-job training under the supervision of existing switched circuit staff, with training lasting between several months and one year, depending on the person’s previous knowledge. This practical instruction is concluded with the issuing of switching authorisation.

After this, further training measures are implemented at regular intervals, for instance, through the system managers’ colloquium of Association of German Network Operators (Verband der Netzbetreiber) (VDN). Specially configured dispatcher training simulators that emulate network conditions and specific disturbances are used for training purposes.

In order to enhance the assessment of disturbances spanning several networks, exchanges of information and joint training measures are held with neighbouring TSOs.

However, the sequence of events in the splitting of the UCTE network into several sub-grids shows that this disturbance differs hugely from any scenarios assumed up to then. In particular, it was not obvious for some switched lines that one control area, namely that of E.ON Netz, had split into two partial sub-grids with different frequencies.

5.1.7. Recommendation

On the basis of a detailed evaluation of the system disturbance of 4 November 2006, the Federal Network Agency hence recommends that new scenarios be developed for re-

³⁴ Chapter A, Section R.1.1

sponses to disturbances and that training on these new scenarios be provided for German TSOs and for TSOs from neighbouring countries.

5.2. Cooperation and coordination between TSOs

The system disturbance of 4 November 2006 has highlighted the fact that there was indeed a lack of cooperation and coordination between TSOs. Fault is found with coordination regarding advance notification of line disconnection. Special aspects of this deficiency relate to the protection limits and data exchange with coordination staff.

5.2.1. Information on planned disconnection of lines

It had particularly serious consequences that E.ON Netz failed to notify the two other TSOs that were directly affected, namely RWE Transportnetz Strom und TenneT until the evening of 4 November 2006 at 19:00 hrs. that the double circuit line was to be disconnected three hours earlier than previously planned. E.ON Netz had already taken this decision on 3 November 2006. However, as this information was passed on so late, the precautions taken by TenneT later on (load flow reduction) proved to be futile.

The Federal Network Agency assumes that if the other TSOs had been notified earlier on by telephone, or even if E.ON Netz had provided a relevant DACF data record indicating that the Conneforde – Diele line was to be disconnected at 22:00 hrs. on 4 November 2006, the changed load flows in the grid would not have taken the other TSOs by surprise after 21:38 hrs. This could perhaps have meant that fewer phone calls would have been made to the grid control centre of E.ON Netz regarding the disconnection of the Conneforde – Diele line which tripped the Landesbergen – Wehrendorf a line and the situation there may well have been a lot more relaxed than it actually was.

It cannot be ruled out either that TenneT would have reduced the cross-border power dispatch and hence the load flows in the network as a whole.

5.2.2. Recommendation by the Federal Network Agency

The Federal Network Agency therefore deems it absolutely vital that TSOs that are aware of imminent congestion resulting from switching or any other activity notify the other TSOs accordingly (e.g. in the DACF) as soon as a decision has been taken to disconnect or connect a line.

5.2.3. Activation of protection equipment

The ultimate event which triggered the system disturbance in the UCTE transmission grid was the fact that the tripping current³⁵ set in the protection system at Wehrendorf network stations was exceeded which led to tripping of the interconnection line between Landesbergen (E.ON Netz) and Wehrendorf (RWE Transportnetz Strom) due to overloading.

³⁵ The tripping current/activation limit is the value of power that activates the protection equipment with a specified delay.

The protection in electrical equipment is intended to ensure the safety of persons and operating equipment in the event of an error. To this end, faulty elements must be disconnected swiftly, reliably and selectively when electrical faults occur. The protection equipment in meshed grids must be configured in such a way as to ensure that the network elements connected to the respective operating equipment are taken into account. For this reason, the settings of protection equipment are not necessarily identical at the various ends of transmission lines.

Even though the protection concepts differ for topology-related reasons and the German TSOs sometimes use different limit values, this does not mean that German TSOs basically have a different view of the various limit values. It is standard that

- An adequate safety margin always be kept from protection limit values³⁶ which must never be exceeded
- If the thermal capacities³⁷ fall below the protection limit values, overloading is possible in certain circumstances.

On 4 November 2006, the protection settings at the network stations Landesbergen and Wehrendorf were as follows:

	Limit values	E.ON (Landesbergen)	RWE (Wehrendorf)
1	Thermal capacity	2000 A	2000 A
2	Security limit value, warning (alarm) value	2000 A	1795 A (90% of 3)
3	Tripping current	2550 A (85% of 4 for max. 1h)	1995 A (95% of 4)
4	Tripping current	3000 A	2100 A

Table 1: protection settings in Landesbergen und Wehrendorf

Source: UCTE Final Report

The varying limit values for E.ON Netz and RWE Transportnetz Strom result from the different administrative rules on grid schedules and on the technology-based network topology.

RWE Transportnetz Strom points out that the departments affected (e.g. Protection Department, Network Planning Department) exchange the data on the latest network protection settings with the interconnectors in writing. It claims that E.ON Netz had been notified of the tripping current and security margin in Wehrendorf in a letter dated 19 September 2003. It says that the limit values had also been discussed on the evening of 4 November 2006 in direct telephone calls between the network control station of E.ON Netz and RWE Transportnetz Strom. Specifically, the network control station of RWE Transportnetz Strom issued a warning about the tight security margin in Wehrendorf shortly after switching-off the Conneforde-Diele line, RWE Transportnetz Strom contacted E.ON Netz once again at 22:07 hrs..

³⁶ The safety margin and security limit value are both limit values that warn the circuit engineer that the operating equipment is overloaded and that automatic activation is imminent, alerting him that intervention is required. The security limit value is a value that requires intervention in the event of overloading in order to continue to operate a grid securely and to avoid the risk of automatic line disconnection. The security limit value, also known as the voltage collapse boundary must not be exceeded after a tripping value has been reached within a defined period in order to prevent a line from being automatically switched off.

³⁷ The thermal capacity specifies the permanent, maximum power transmission of operating equipment.

The Federal Network Agency cannot explain how it was not possible to avert the system disturbance given that E.ON Netz had been notified of the tight security margin at the Wehrendorf substation on the evening of 4 November 2006, but that this information had not been taken into account. RWE Transportnetz Strom had to phone the grid control station of E.ON Netz twice that evening before E.ON Netz dispatchers realised that the interconnection line between Wehrendorf and Landesbergen was at risk of tripping.

5.2.4. Recommendations

In view of the fact that the protection settings may differ at each end of the line, the Federal Network Agency advises the TSOs to compare the protection settings of the interconnected lines with the neighbouring TSOs at home and abroad. Once the settings have been compared, it should be ensured that the grid control stations have access to the very latest values.

Furthermore, each TSO needs to check what it considers to be a tolerable network load.

The TSOs should exchange experiences on the network capacity limits, in which they must decide, among other things, whether it is possible to standardise the load and the protection settings.

The Federal Network Agency also suggests that it is checked in the UCTE transmission grid whether it is meaningful to establish a uniform limit value for network capacity that could be declared binding by the national regulatory authorities if need be. The Federal Network Agency also proposes investigating whether it is possible to standardise the protection settings and whether this would be beneficial in terms of network security.

5.2.5. Data exchange at interconnectors

Another aspect of cooperation between TSOs relates to data exchange at interconnectors.

5.2.5.1. Data exchange between TSOs

Interconnectors in the power network create the electrical link between two neighbouring networks and enable interconnection both at national or European level. The neighbouring TSOs have to coordinate network links and ensure there is a relevant data exchange. The calculations made by the control stations include the first link with the neighbouring network.

The exchange of the relevant measurement data is usually implemented online at regular intervals by the stations at the grid control centres. As such it is crucial for data exchange that the measurement values are transmitted fault-free and redundantly so that network calculations can be made fault-free, facilitating an accurate assessment of the network situation. The TSOs record the measured data and make the data available to their own control system and the neighbouring TSOs via communications equipment.

The documents available to the Federal Network Agency indicate that differences exist regarding the exchange of data, e.g. regarding the transmission cycle of values recorded at the network control stations, but also regarding the scope of data transmitted.

5.2.5.2. Recommendation

The Federal Network Agency therefore recommends that the TSOs agree on a scope and quality of data as well as their transmission frequency in order to enable them to make network topology calculations using the applications and tools available at the network control centres. The aim should not be to find the smallest common denominator but to assess the situation realistically and to subsequently implement what data is necessary in order to achieve an optimum exchange of information. It is absolutely vital that agreement and data matching be implemented not just at national level, but also at international level in view of the existing European transmission grid.

5.2.5.3 Data exchange between the TSOs and distribution network operators

Network links not only exist between TSOs, but also between TSOs and distribution network operators. After the separation of the transmission grid resulting from the lines being switched off in E.ON Netz's grid, the TSOs had to implement stabilisation, network restoration as well as resynchronisation measures. Resynchronisation of partial areas requires that physical network factors such as frequency, voltage and phase shifters be within certain tolerance areas.

As indicated in the UCTE report of 31 January 2007, the measures taken to stabilise the partial networks and the subsequent attempts at resynchronisation have shown that there is a need to improve data exchange and communication between TSOs and the distribution network operators.

As a result of the underfrequency caused by the incident on 4 November 2006, a large number of decentral generation units at distribution network level were automatically disconnected from the network. At distribution network level, generation units were subsequently activated within the framework of network stabilisation without any information being exchanged or any coordination between TSOs. Another critical factor was that restoration of the grid was hampered by the uneven absorption of the initial surplus of generation capacity in this area, mainly due to automatic reconnection of wind generation units.

5.2.5.4. The factor wind

The feed-in forecasts of wind energy involves many uncertainties. They are taken into account in the simulation computations of TSOs and are taken into account and managed by network control stations during operational management.

The above-mentioned load flow from North-East to South-West is a situation that occurs frequently. The load on the network area of E.ON Netz on the evening of 4 November 2006 was not unusual. Extraordinarily high wind feed-in on that evening can be ruled out as the cause of the overloading of the Landesbergen – Wehrendorf line.

As a result of the impermissible frequency drop, depending on which partial area is being considered, it was logical that the loads and generation units tripped during the disturbance. About 40% of the total generated power (4,100 MW) which tripped during the incident was

accounted for by wind generation units. Moreover, 60 % of the wind generation connected to the grid tripped just after the frequency drop.³⁸

The stabilisation of the individual network areas and the subsequent resynchronisation did not run smoothly. Wind generation units are usually connected at distribution network level. Wind generation units are automatically disconnected from the network if the network frequency is less than 49.5 Hz. In the Western partial network, network frequency was 49 Hz immediately after the disturbance occurred. A large number of wind generation units automatically disconnected from the grid. This further exacerbated the frequency drop in the Western area.

In the North-Eastern partial area, wind generation units also disconnected from the grid as a result of the impermissible drop in frequency. While the network frequency was stabilising, the wind generation units reconnected to the power grid automatically after a short space of time. This reconnection hampered stabilisation of the grid area. It was not possible to make up for the additional energy by load shedding of conventional power generators in the control area of Vattenfall Europe Transmission, as it was already being operated close to its generation minimum. Finally, the surplus frequency was absorbed when the CENTREL control block leader decreased generation by the Polish dispatcher PSE-O.

The automatic reconnection of wind generation units took place without being monitored by the TSOs and distribution network operators. It needs to be mentioned in this context that the TSOs did not have any real time data on the decentral generation units connected to the distribution grid levels. This uncontrolled reconnection greatly hampered stabilisation of network areas.

System stability above all in fault-related operations depends, inter alia, on how detailed the information on downstream network levels is to which TSOs have access. As such, it is important for TSOs to be familiar with real time data of the decentral generation units connected in the distribution grid. The transmission of the necessary data gives the TSOs an exact overview of the feed-in situation in their control area and hence also to assess in detail what measures need to be taken.

5.2.5.5. Recommendation

The TSOs involved should exchange the necessary real time data in particular regarding the generation units connected to the grid in order to give the TSOs a detailed picture of the system condition.

³⁸ The UCTE Final Report contains several figures that emphasise the wind feed-in and failure of wind generation units, p. 27, 30ff., 33 ff., 36.

6. Summary

TSOs are obliged to operate their grid securely and reliably. In order to fulfil this obligation, the Federal Network Agency considers two of many factors to be particularly important for secure network operations and which TSOs should focus on. They are N-1 security on the one hand and cooperation and coordination on the other. At least these are the conclusions drawn from the system disturbance of 4 November 2006.

The Federal Network Agency is fully aware that nowadays network management faces a whole new range of requirements than those of a few years ago. Due to decentral generation and increased trade, networks tend to be busier. Wind power which is marked by inaccuracies anyway, does not make network management any easier.

All the stakeholders agree fully that network expansion measures are needed when congestion occurs and that these measures need to be pressed ahead with. However, they also agree that even a grid that is operating at maximum capacity should not break down.

The Federal Network Agency is exercising the powers assigned to it in the Energy Management Act to ensure that TSOs meet their statutory obligations. It is prompted by special events such as the system disturbance of 4 November 2006 to examine whether a TSO has been operating its network securely and is capable of doing so in the future.

The Federal Network Agency will continue to meet its monitoring and supervisory obligations in future and will do everything in its power to assist with the secure operation of power supply networks and hence reliable power supply without intending to relieve TSOs of their statutory obligation to operate secure networks. This begins with the careful, critical evaluation of reports and alerts it receives under the Energy Management Act, includes engaging in an intensive dialogue with the TSOs but also with associations and ends specifically with issuing instructions and implementing measures if violations of the Energy Management Act come to its attention.

The activities of the Federal Network Agency are not confined to national level. At European level, it is represented in a number of working groups on system and supply security and is a member of ERGEG. The incident of 4 November 2006 highlighted the need for close cooperation between European regulatory authorities. The Federal Network Agency will therefore be actively involved in implementing the recommendations made in the Final Report of ERGEG. However, it has yet to be examined to what extent closer cooperation between European regulatory authorities needs to be formalised by extending ERGEG's competencies (ERGEGplus).

One goal of the Federal Network Agency's activities is to develop terms of reference at national and international level for secure, fault-free network operation. However, the Federal Network Agency does not see any need at present to take immediate action to create an additional legal framework at national level. The obligations of TSOs, but also the rights of the Federal Network Agency ensuing from the Energy Management Act, have been outlined above. Nonetheless, the Federal Network Agency checks on an ongoing basis whether in general an additional legal framework or specifications are needed and whether in individual cases, measures to enhance power supply security are required. This explains why the Federal Network Agency's activities in connection with the system disturbance of 4 November 2006 will not end with the drawing up of this report. Rather, the Federal Network Agency intends to take this incident as an op-

portunity to press ahead with the harmonisation of network security and system standards both for its own benefit and for the benefit of the TSOs.