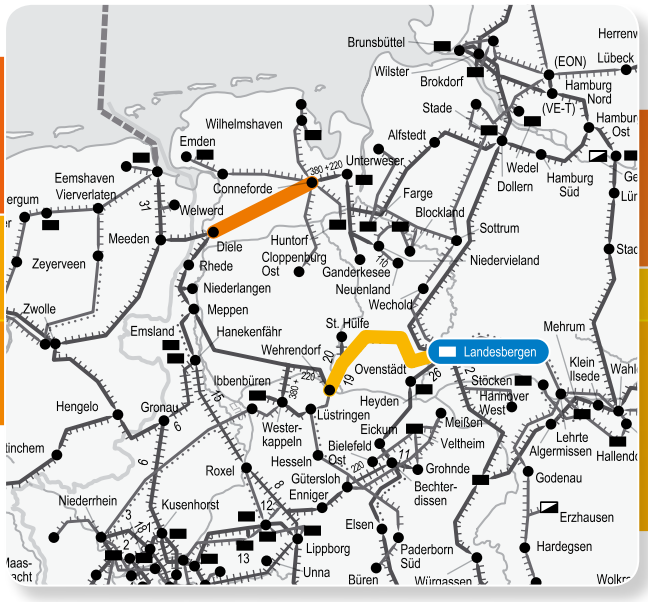
5 LESSONS LEARNT FROM THE DISTURBANCE ON 4 NOVEMBER 2006

Background

In the evening of 4 November 2006, at around 22:10 h, the UCTE interconnected grid was affected by a serious incident originating from the North German transmission grid that led to power supply disruptions for more than 15 million European households and a splitting of the UCTE synchronously interconnected network into three areas.

The immediate action taken by all Transmission System Operators (TSOs) according to the UCTE security standards prevented this disturbance to turn into a Europe-wide blackout. However, this event ranks among the most severe and largest disturbances in Europe.

Immediately after the disturbance, UCTE decided to set up a UCTE Investigation Committee charged to find out the root causes of the disturbance and propose recommendations to avoid a recurrence of such events. The UCTE Investigation Committee was led by Gerard Maas as Chairman of the UCTE Steering Committee assisted by three convenors (corresponding to the 3-fold split in the system).



21:38 h – double circuit line switched off by E.ON Netz (due to ship crossing)

21:38 h till 22:10 h – heavy loaded line between RWE TSO and E.ON Netz

22:10 h – manoeuvre in Landesbergen substation

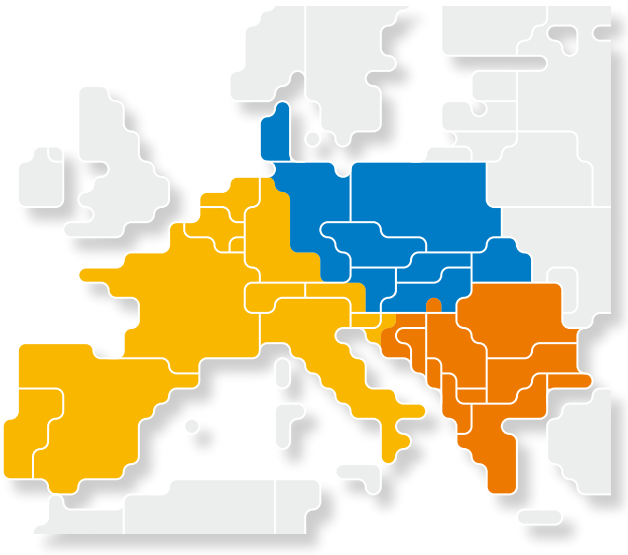
Sequence of events

In the evening of November 4, significant East – West power flows in the UCTE system resulted from international power trade and the obligatory exchange of wind feed-in inside Germany. At around 22:00 h, the consumption in the control area of E.ON Netz was about 13 500 MW with the injected wind power amounting to 3 300 MW. This situation was in itself normal.

At 21:38 h, both circuits of the 380-kV-line Conneforde-Diele were switched off in order to secure the passing of the Ems river by a ship. A routine simulation of the switching-off of the aforementioned line was computed in advance and did not bring up concerns about this switching manœuver. Following the switching-off of the said line, the energy flow was transferred to other lines in the South and this situation was still stable.

Between 22:05 h and 22:07 h, the load on the 380 kV line Landesbergen-Wehrendorf increased by 100 MW exceeding the warning value. E.ON Netz expected that coupling of the busbars in the substation of Landesbergen would end in a reduction of the current, however this manoeuvre implemented at 22:10 h resulted in immediate tripping of the line and consequent cascading line tripping throughout the UCTE area.

This led to a split of the European UCTE interconnected network into 3 separate islands. About 9 000 MW which came from the Eastern to the Western area was cut and those areas could not ensure the balance any more. Therefore, the frequency sharply dropped to about 49 Hz in the Western area due to the sudden lack of power. On the contrary, the North-Eastern area faced a surplus of generating power of the same magnitude which induced a high over-frequency reaching about 51.4 Hz in the peak. Just after the splitting, the South-Eastern area was missing an amount of power of around 750 MW which induced a slight under-frequency of about 49.7 Hz. <<<



Area 1 – under-frequency: 49.00 Hz

Area 2 – over-frequency: 51.40 Hz

Area 3 – under-frequency: 49.70 Hz

System status and defense actions in individual areas

In the Western area, the imbalance between supply and demand resulting from the splitting was further increased in the first moment due to a significant amount of tripped generation connected to the distribution grid (mainly windmills). The frequency drop activated defence plans in each TSO area and led to an automatic load shedding (meant as cut of the power to customers) and pump storage units' tripping. Finally, a total of about 17 000 MW of consumption and 1 600 MW of pumps was shed. All these actions occurred in a very short time (8 seconds during the frequency drop) and prevented the system collapse. The frequency was restored close to its nominal value in relatively short time upon manual starting of generation units (mainly hydro ones) by TSOs.

The North-Eastern area faced severe generation surplus leading to a situation of high over-frequency peaking up to about 51.4 Hz and then being reduced to the range of about 50.3 Hz by automatic pre-defined actions. In the first minutes after the disturbance the windmills, which tripped at 22:10 h, started being automatically reconnected to the power systems, thus gradually increasing generation resulting in slow but steady further frequency increase. Manual actions to decrease output of thermal units led in turn to significant changes in power flows within area 2. At that time, there was a real danger of further splitting of UCTE power systems. Fortunately, the cooperation between the control centres of involved TSOs allowed first to relieve the overload for some minutes, and then finally the successful resynchronization at 22:47 h decreased the flows in the region to acceptable levels within half an hour.

In the South-Eastern area, the frequency dropped down to 49.79 Hz, which was still significantly above the first threshold for load shedding. Thus, no other automatic actions or load shedding took place during the event. The area was N-1 secure during the whole event.

As a first step of a resynchronization process, the Western area was synchronized with the North-Eastern area in Germany and Austria and as a second step, the South-Eastern area was synchronized with those already interconnected areas through the tie-line between Romania and West Ukraine. Upon several unsuccessful attempts, the first successful reconnection of the tie-line between the Western and the North-Eastern area was carried out at 22:47 h, and the first tie-line between already connected areas and the South-Eastern area was switched on at 22:49 h. The TSOs were able to re-establish a normal situation in all European countries in less than 2 hours. <<<

Analysis of main causes and recommendations

The investigations identified two main causes of the disturbance as well as some critical factors which had significant influence on its course.

Two main causes

Non fulfilment of the N-1 criterion

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. Moreover, the resulting physical flow on the 380 kV Landesbergen (E.ON Netz) – Wehrendorf (RWE TSO) line – being in operation – was so close to the protection settings at the Wehrendorf substation (RWE TSO) that even a relatively small power flow deviation triggered the cascade of line tripping. This occurred when E.ON Netz did not undertake proper countermeasures to reduce the flow on this line.

Insufficient inter-TSO co-ordination

The initial planning for switching-off the double-circuit 380 kV Conneforde – Diele line scheduled for 5 November from 01:00 h to 5:00 h was duly prepared by the directly involved TSOs (E.ON Netz, RWE TSO and TenneT).

However, the change of the time for this switching manoeuver was communicated by E.ON Netz to the other directly involved TSOs at a very late moment; it was also not sufficiently prepared and checked in order to ensure the secure operation of the system in this area after the switching-off. No specific attention was given by E.ON Netz to the fact that the protection devices have different settings on both sides of the Landesbergen – Wehrendorf line although this information was critical due to the very high flow on this line. <<<

Critical factors

Generator-related issues

During the disturbance, a significant amount of generation units tripped due to the frequency drop in the Western area of the UCTE system. This contributed to the deterioration of system conditions and to the delay for restoring secure normal conditions. In addition, most of the TSOs do not have access to the real-time data of the power units connected to the distribution grids. This prevented them from performing a better evaluation of the system conditions. Furthermore, in the North-Eastern area, the uncontrolled reconnection of generation units induced very severe conditions and the need for additional time to recover secure system operation.

Limited range of action available to dispatchers for handling grid congestions

In Germany, TSOs have to take different kinds of measures during congestions and emergency situations as stated in the Energy Industry Act and transposed into internal procedures: grid-related measures, market-related measures and other adjustments for the management of emergency situations. The adequacy and effectiveness of such measures are not always supporting an adequate management of such specific conditions like the one on 4 November 2006.

TSO/DSO co-ordination in the context of defence and restoration plans

In some control areas, re-energization of customers was started by DSOs without proper knowledge of the situation in the overall UCTE system; some of them started reconnecting customers without coordination with their TSOs. This worsened the conditions for TSOs' action to restore normal system conditions in a controllable way.

Resynchronization process

Actions taken by TSOs during the resynchronization process were not fully coordinated. There have been several unsuccessful attempts to put tie-lines back into operation and to resynchronize the three different areas with only a partial view of the status of the whole grid.

Training of dispatchers

Although training of dispatchers has been well developed for a couple of years for situations related to TSOs' internal control area conditions, incidents originating from external networks and affecting a TSO's own grid are not always trained. Joint simulation training with neighbouring TSOs is not yet a common practice.

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In terms of security standards, the Investigation Committee proposed the following recommendations:

Recommendation #1

The application of the N-1 criterion in Policy 3 of the UCTE Operation Handbook has to be reviewed in terms of the following aspects:

- Definition of the relevant part and specific conditions in the adjacent systems which have to be taken into account in TSOs' security analyses.
- Simulation of contingencies (tripping of power system elements) located outside the TSO's own control area.
- Mandatory and regular online contingency analysis (N-1 simulations) connected to the alarm processing system.
- Preparation and regular check of the efficiency of remedial actions through numerical simulations.

Recommendation #2

Policy 5 (»Emergency Operations«) has to be extended to a »Master Plan« defining principles of operation and TSOs' responsibilities to manage UCTE-wide or regional disturbances. Additionally the following aspects have to be considered:

- TSOs have to reconsider their defence plans and load-shedding philosophy and rating taking into account significant amounts of generation tripped during disturbances with large frequency deviation.
- The restoration and re-energization process has to be explicitly coordinated by TSOs regarding DSOs actions, and the related responsibilities and duties of the parties involved must be clarified within a national framework.

Recommendation #3

UCTE has to develop standard criteria for regional and inter-regional TSOs' co-ordination approach aiming at regional security management, from operational planning to real time, in terms of joint training, enhancement of exchanges of data, results of security analyses and foreseen remedial actions.

Recommendation #4

UCTE has to set up an information platform allowing TSOs to observe in real time the actual state of the whole UCTE system in order to quickly react during large disturbances.

Recommendation #5

The regulatory or legal framework has to be adapted in terms of the following aspects:

- TSOs should have the control over generation output (changes of schedules, ability to start/stop the units).
- Requirements to be fulfilled by generation units connected to the distribution grid should be the same in terms of behaviour during frequency and voltage variations as for the units connected to the transmission network. These requirements should be applied also to units already connected to transmission and distribution grids.
- Operators of generation units connected to the transmission grid must be obliged to inform the TSO about their generation schedules and intra-day changes of programs prior to their implementation.
- TSOs should receive on-line data of generation connected to DSOs grids (at least 1-minute data).

The final report of the Investigation Committee on the disturbances of 4 November 2006 is available on the UCTE website.