Blackout in the power system

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Abstract

This paper is focused on severe disturbances analysis which led to a blackout in the power system. In this paper we analyze causes of the blackouts in the power system and we indicate some possible measures to avoid such severe disturbances in the power system operation.

Key words: blackout, power system, transmission system, "N-1"criterion

Introduction

A blackout = a power outage. This state means the loss of the electricity supply to a part of the power system or to whole power system.
The blackout in the power system can cause:
- power system equipment damage,
- heavy economical losses,
- jeopardy of economy functioning,
- life paralysis in stricken parts of country.

It is necessary to notice that everyone is dependent on reliable and quality power supply.
Several power system blackouts became in the world of late years. Causes of these disturbances were various – technical, bad weather, human failing.
Some blackouts became in 2003 (during six weeks), in the northeastern USA and central Canada and in Europe, which affected more than 100 million people:

On August 14 – the northeastern USA and central Canada:
- 62 GW power outage, affected 50 million people,
- power supply restoring took some days.

On August 14 – London
- 724 MW power outage, affected 410 thousand people,
- power supply restoring took 40 minutes.

On September 2 – the southern Malaysia
- affected 5 states (out of 13) in Malaysia, including the capital Kuala Lumpur,
- power supply restoring took 5 hours.

On September 5 – Birmingham
- 250 MW power outage, affected 220 thousand people,
- power supply restoring took 11 minutes.

On September 19 – nine US states and parts of Ontario, Canada
- affected 4.3 million people,
- cause - hurricane Isabel.

On September 23 – Denmark and Sweden
- affected 5 million people,
- power supply restoring took 4 hours.

On September 28 – Italy
- affected 57 million people,
- power supply restoring took 4 hours.

1. Blackout in Italy – on September 28, 2003

The situation in the Italian power system before blackout was not exception.
- total load of Italy was 27 444 MW,
- 3 487 MW – pump load,
- 6 951 MW – physical import to the Italian power system,
- some transmission lines in neighboring power systems were out of service by reason of scheduled maintenance,
- the Italian power system was connected to neighboring power systems via 15 transmission lines.

1.1 Sequence of events of the blackout in Italy

The initial event was the 380 kV line tripping in Switzerland. Fewer than 25 minutes after this event the Italian power system ceased to operate synchronized to the UCTE system.

03:01:42 – the 380 kV line tripping in Switzerland (Lavorno – Metlen) – line was heavy loaded at 86%,
- the cause of tripping – a wire contacted to a tree,
- the attempts of single-phase auto-reclosing and also the attempt of the operators to put this line back into operation were not successful and the line was disconnected by its protection device, due to high phase angle (42°),
- after the Lavorno – Metlen line tripping, the other 380 kV line in Switzerland (Sils – Soaza) became overloaded.

03:11 – the Swiss dispatch ETRANS asked the Italian dispatch GRTN to reduce the import of Italy by 300 MW (on scheduled value),

03:25:21 – the second overloaded 380 kV line tripping in Switzerland ((Sils – Soaza),

03:25:25 – the third overloaded 380 kV line tripping in Switzerland,

03:25:26 – the interconnection line Austria – Italy (Lienz – Soverenze) tripping

03:25:33 – the Italian power system started to disconnect from the UCTE system

After disconnection Italy from the UCTE system the frequency in the Italian power system dropped abruptly, caused by the negative imbalance between power injection to the system and system load. The blackout in the Italian power system became within fewer than 3 minutes.

21:40 – official announcement about emergency cancellation in whole power system of Italy.

1.2 Main causes of the blackout in Italy

The initial event was the 380 kV line tripping in Switzerland in consequence of the wire – the tree contact. The attempts of single-phase auto-reclosing and also attempt of the operators to put this line back into operation were not successful and the line was disconnected by its protection device, because phase angle was too high.

We can see two causes:
- insufficient protective zone under the transmission lines,
- overloaded lines.

After the first 380 kV line tripping in the Swiss power system other power lines became overloaded. That means that the safety "N-1"criterion was non fulfillment in the Swiss power system.

We can see other cause:
- violation of basic safety "N-1"criterion.

Additional causes of the blackout:
- high import to Italy,
- incomplete information about neighboring power system,
- pump load was stopped too late, by automatics.

2. System disturbance in the UCTE system - on November 4, 2006

The system disturbance in the UCTE system on November 4, 2006 was the most serious incident in the UCTE system within an interconnected Europe history.
The system disturbance started in the German transmission system on November 4 2006, around 10 p.m. Result of this disturbance was a splitting the UCTE system into three separate areas (West, North-East and South-East). More than 15 million households were affected by an interruption of electricity supply.
Full resynchronization of the UCTE system was completed 38 minutes after the splitting.

2.1 What happened?

On 18 September 2006, the shipyard (Meyerwerft) sent a request to E.ON Netz for a disconnection of two 380 kV line Conneforde-Diele for the transport of the ship via the Ems River to the North Sea on 5 November at 01:00. Such a switching was done several times during the last years.
The E.ON Netz operator did a power flow calculation and verified fulfillment of safety "N-1"criterion using numerical computation. Analysis did not show any problem and so the operator provisionally approved the request of the shipyard and informed neighbouring transmission system operators (RWE – Germany and TenneT - Niederland).
On 3 November (around 12.00) came a new request to E.ON Netz for a time change of two power lines Conneforde-Diele switching – on 4 November at 22:00. A provisional agreement was given by E.ON Netz after a new analysis. But RWE and TenneT operators were not informed about this change at the same time. Only at 19:00 on 4 November E.ON Netz informed TenneT and RWE TSO about the new time for switching off the Diele-Coneforde line.
At 21:29 according to the load flow calculation made by E.ON Netz did not indicate any violation of limit values. But "N-1"criterion was checked without numerical computation, was checked based on an empirical evaluation of the grid situation only.

2.1.1 Sequence of events

- At 21:38 a 21:39 – power lines Conneforde-Diele were disconnected.
- At 21:39, after the switching operation, two 380 kV lines was overloaded.
- At 21:41, RWE dispatcher informed E.ON Netz about the safety limit value on the line Landesbergen-Wehrendorf (an interconnection line between E.ON Netz and RWE TSO). Later investigation uncovered different protections setting on this line.
- Between 22:05 and 22:07, the load on the 380 kV line Landesbergen-Wehrendorf increased and an immediate reaction of RWE operator that called E.ON Netz at 22:08 with the request for urgent intervention to restore safe grid operation.
- E.ON Netz made an empirical assessment of corrective switching measures without any load flow calculations for checking the "N-1"criterion. E.ON Netz expected that coupling of the busbars in the substation of Landesbergen would reduce of load on the 380 kV line Landesbergen-Wehrendorf. But this line was overload more than 100% and so was tripped and the other lines became overloaded.

Dispatcher could execute other possible measures. But according to the German law (German Energy Industry Act of 13 July 2005) and E.ON Netz internal procedures this would only be possible if topology changes were not effective to bring back the security of the network.

> German TSO dispatchers have to examine the following possibilities in case they have to manage congestion in the following order:
> 1. Grid-related measures which are non-cost measures:
>   - all possible topology changes
>   - full utilization of the operational limits (e.g. lowest acceptable voltage level)
> 2. Market-related measures which are cost measures based on contracts with third parties:
>   - re-dispatching
>   - counter trading
>   - activating of tertiary reserve
>   - switching of special loads
>   - capacity reduction (only in day-ahead)
>   - activating of additional reserves (e.g. from neighboring power system)
> 3. If all measures of 1 and 2 are fully utilized or time is too short:
>   - shortening of already confirmed exchanges schedules
>   - load shedding
>   - voltage reduction beyond acceptable limits
>   - direct order to all kinds of power plants including wind generation.

- At 22:10:28 – the UCTE system splitted to three area after the power lines switching in E.ON Netz, RWE, the Austrian power system and after disconnection of interconnection lines: Croatia – Hungary and Marocco – Spain.

The initial event of the system disturbance in the UCTE system was scheduled switching off two power lines.

2.2 Main causes

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

- non fulfillment of the "N-1"criterion or verified its fulfillment without numerical computation,
- insufficient co-ordination between the transmission system operators,
- dissatisfied power plant operation in emergency: tripping of generation units (particularly wind power plants) during disturbance and uncontrolled reconnection of generation units,
- limited range of action available to dispatchers,
- insufficient training of dispatchers,
- problem of co-ordination in the context of defense and restoration plans.

3. Blackout in the Northeastern USA and Central Canada – August 14 2003

The initial event was the power line tripping caused by the short circuit to ground due to tree contacts.

Other critical factors before blackout:

- power plant unit tripping – a small reactive power reserve,
- functionless monitor system in part of the power system,
- real-time date for State Estimate missing,
- insufficient co-ordination and communication between the transmission system operators.

Blackout in the northeastern USA and central Canada was investigated by NERC and some violation of safety and reliability standards was identified:

- following the outage of the first 345-kV line, dispatcher of the power system did not take the necessary actions to return the system to a safe operating state within 30 minutes to fulfillment of "N-1"criterion,
- dispatchers of neighboring transmission system were not informed about this situation,
- power system analysis based on real-time date was not performed, dispatcher did not use the State Estimator and tools for on-line contingency analysis,
- insufficient training of dispatchers,
- functionless monitor system in part of the power system,

4. Reliable and safety operation of the power system

The North American Electric Reliability Council (NERC) have developed system operating and planning standards for ensuring the reliability of a transmission grid that are based on seven key concepts:

- Balance power generation and demand continuously
- Balance reactive power supply and demand to maintain scheduled voltages
- Monitor flows over transmission lines and other facilities to ensure that thermal (heating) limits are not exceeded
- Keep the system in a stable condition.
- Operate the system so that it remains in a reliable condition even if a contingency occurs, such as the loss of a key generator or transmission facility (the "N-1"criterion).
- Plan, design, and maintain the system to operate reliably.
- Prepare for emergencies.

Conclusion

The short description and analysis of three serious disturbances in the power system operation hint at some common features of this contingencies, mainly non fulfillment of the "N-1"criterion, insufficient co-ordination and communication between the transmission system operators, disregard of disturbance seriousness.

The power system is complicated and complex system, therefore it is obvious that it is not possible to avoid all type of disturbances, but the most important task is to avoid cascading failures which can jeopardize whole power system or the other neighboring systems.

Therefore the main task in power engineering should be ensuring technical safety and reliability of the power system.

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