ENERGY ADVISORY COMMITTEE

Loss of Electricity Supply Incident Affecting United States and Canada on 14 August 2003

This paper informs members of the investigation findings of the U.S.-Canada Power System Outage Task Force on the loss of electricity supply incident affecting extensive areas in the Midwest and Northeast United States and Ontario, Canada on Thursday, 14 August 2003[1].

Background

2. On 14 August 2003, a number of states in Midwest and Northeast U.S.A. together with Ontario in Canada suffered from a major power interruption, which was regarded as one of the largest power blackouts in the history of North America. The blackout affected the states of Michigan, Ohio, Pennsylvania, New York, New Jersey, Vermont, Massachusetts, Connecticut as well as the Ontario province in Canada. More than 200 power plants were shut down during the incident resulting in the loss of approximately 61,800 MW of customer load, affecting about 50 million people. Power was not restored for four days in some parts of the United States, while certain parts of Ontario suffered from rolling blackouts for more than a week before power was fully restored.

3. The U.S. President and the Canadian Prime Minister had directed the establishment of a joint U.S.-Canada Power System Outage Task Force (the Task Force) to investigate the causes of the blackout and the measures to reduce the possibility of future outages. The Task Force, under the co-chairmanship of the US Energy Secretary and the Canadian Minister of Natural Resources, issued an Interim Report, which focused on the causes of the blackout, on 19 November 2003 and the Final Report on 5 April 2004 which included recommendations to prevent or minimise the scope of future blackouts.

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[1] Based on the "Final Report on the August 14, 2003 Blackout in the United States and Canada" issued by the U.S.-Canada Power System Outage Task Force in April 2004.

The North American Power System

4. The power grid in North America is very complex. It includes over 320,000 kilometers of transmission lines (at 230 kV and above), with massive interconnection between different power companies crossing the boundaries between states, provinces, as well as countries including the United States, Canada and Mexico. The interconnected power grid delivers electricity supply from more than 950,000 MW of generation facilities amongst nearly 3,500 utility organisations, serving over 280 million people.

5. The system is divided into three distinct power grids, namely the Eastern Interconnection, the Western Interconnection and the ERCOT Interconnection (for Texas only). The three distinct power grids are independent from each other with only a few direct current links between them. The northeastern portion of the Eastern Interconnection (about 10% of the total load within that Interconnection) was affected by this blackout incident while the two other Interconnections were not affected at all.

6. In recent years, usage of the power grids in North America has expanded significantly, driven not only by growth in economy but also by increasing competition in the electricity supply sector. The transmission lines, which were built primarily for local supply and to interconnect neighbouring power companies and/or states and provinces for sharing of electricity supply resources, are now used for increasing regional power trading.

7. The North American Electric Reliability Council (NERC) and its ten Regional Reliability Councils (RCs) are the main organisations overseeing the reliability of the North American power grids. These are non-government owned organisations funded by utilities in the electricity supply sector. Since its inception in 1968, NERC has been operating as a voluntary organisation relying on peer pressure of all those involved in the electricity supply industry to ensure compliance with reliability requirements issued by NERC and its RCs.

The Incident

Before the Incident

8. On 14 August 2003, Northern Ohio was experiencing moderately high electricity demand. FirstEnergy (FE), one of the electricity suppliers in northern Ohio, was importing more than 2,000 MW into its service territory to support supply to about 12,000 MW of loads, which was within established

import capabilities. At 1:31 p.m., FE's generation unit 5 at Eastlake Power Station in northern Ohio tripped due to excitation system failure[2]. The loss of this unit did not put the power system into an unreliable state, but it required FE to import additional power to make up for the loss.

9. Around 2:14 p.m., unknown to the FE operators the alarm and logging system in FE's main system control room failed to operate due to failure of the computer software. FE's operators were hence not aware of any power system changes that followed. The system analysing tools of the reliability coordinator[3] for FE and the nearby areas – the Midwest Independent System Operator (MISO) – were out of service due to lack of real-time data from adjacent power systems. As a result, the operators involved lacked information on the power system for undertaking remedial actions even in the event of a system disturbance or emergency.

Initial Stage of the Incident

10. At 3:05 p.m., one of FE's 345 kV transmission lines located in northern Ohio tripped as a result of a line-to-tree contact[4]. This increased the loading on two other key 345 kV transmission lines in northern and central Ohio. These lines tripped subsequently at 3:32 p.m. and 3:41 p.m. respectively, also due to line-to-tree contacts. Thereafter, more transmission lines tripped due to overloading. This eventually led to the complete shut down of the 345 kV transmission path from southeastern Ohio to northern Ohio at 4:06 p.m., and triggered the start of a cascading blackout.

Cascade Stage of the Incident

11. The shut down of this 345 kV path caused FE's power import to flow through other routes, which placed a major and unsustainable burden in the adjacent areas including eastern Michigan. The remaining transmission lines and generating units in and around northern Ohio were automatically removed from service by their protective devices, largely due to consequential overloading and frequency/voltage fluctuations. This set off a cascade of

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[2] One main function of the excitation system of a generator is to maintain the voltage level at the generator's output terminal. During this incident, the excitation system of Eastlake generating unit 5 had tried to increase the voltage by drawing in a higher current when the voltage dropped, but why this had became excessive and led to the tripping was not mentioned in the Task Force's report.

[3] A reliability coordinator is an organisation with the main duty of preparing reliability assessment and coordinating emergency operation for the power systems within its region.

[4] Transmission line gets hotter as the power flowing through it increases, and its line conductors will begin to sag as the conductor metal expands under heat. This reduces the clearance between the conductors and nearby trees, if any. Vegetation management is therefore crucial to all power companies that operate overhead transmission lines. If overgrown trees are not adequately trimmed, they may touch the lines or cause a flashover from the lines, resulting in short-circuit faults.

power interruptions on adjacent power systems, and within about 7 minutes, the blackout rippled from northern Ohio and eastern Michigan, across northeast United States, into Ontario, Canada.

Investigation findings

12. The Task Force had identified four main causes for the blackout incident as follows –

(a) FE and its RC (the East Central Area Reliability Coordination Agreement, ECAR) failed to assess and understand the inadequacies of FE's system, particularly with respect to voltage instability and vulnerability of concerned areas. FE did not operate its system with appropriate voltage criteria;

(b) Inadequate Situation Awareness at FE. FE did not recognise or understand the deteriorating condition of its system;

(c) FE failed to manage adequately tree growth in its transmission rights-of-way; and

(d) Failure of the interconnected grid's reliability organisations to provide effective real-time diagnostic support.

Investigation Recommendations

13. The Task Force made a number of recommendations with regard to preventing or minimising the scope of future blackouts. These recommendations, which emphasised comprehensiveness, monitoring, training and enforcement of compliance with reliability standards, are as follows –

(a) Government bodies and related organisations should commit themselves to high reliability standards. Where conflicts arise between reliability and commercial objectives, reliability should take precedence;

(b) Maintaining reliability requires ongoing investments and operational expenditures, driven by regulatory assurance of cost recovery in the case of regulated markets and by profitability consideration in the case of liberalised markets;

(c) Successful implementation of the recommendations required performance monitoring, accountability of management, and enforcement of compliance with standards; and

(d) Although the blackout was not caused by malicious acts, a number of security-related actions are needed to enhance reliability.

Observations

14. The incident demonstrates, among other things, that in extensively interconnected power systems like that of the North America, when major transmission lines or generating facilities fail, the effects may not be confined locally but may have widespread impacts across the interconnected regions. Interconnected power systems offer many merits, such as facilitating mutual assistance and economic power exchanges between different systems for long-term reliability and economic benefits. However, there is also the inherent risk that power disturbances occurred in one system may propagate to other systems through the interconnection, a 'trade-off' that needs to be assessed and addressed when interconnecting power systems.

15. Major blackout incidents are rare, and no two incidents are the same. The events leading to the incident vary, ranging from human actions or inactions, system topology, load/generation balances, power system characteristics and status and capability of protective devices. Effective coordination and communication amongst relevant parties in power system planning, design and operation, as well as conformity to sound operating practices in containing and minimising the adverse impacts of local power disturbances is essential and of particular importance in the case of interconnected systems.

Advice Sought

16. Members are invited to note the content of the paper.

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