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Reliability, Regions and RTOs

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On August 14, 2003, a cascading failure blacked out significant areas of the US and Canada. This incident was a fundamental failure to maintain system reliability, or "keep the lights on". With the interim report of the outage task force just released, some already apparent lessons are being re-affirmed. In a heavily interconnected system it is essential to manage reliability on a regional basis – rather than through a large number of disparate, utility-based control areas. Regional Transmission Organisations (RTOs), independent of individual utilities, are the logical entities to provide this management. The boundaries of these regions must be defined in accordance with the laws of physics, not politics. It is also becoming apparent that transmission under-investment – while remaining a serious problem – was not a direct cause of the blackout, nor was the existence of electricity markets in some of the impacted areas.

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First and Foremost, The Blackout Was A Reliability Issue

The chief goal of electricity system operations is to "keep the lights on", or in more technical parlance, to "ensure the reliability of electricity supply". On the afternoon of August 14, 2003, many systems across the North-East and Mid-West of North America cumulatively failed to achieve this goal. However, what was remarkable about this event was not that a blackout occurred in a single system, but that this led to a cascading failure, impacting much of the interconnected grid, and darkening large swathes of the US and Canada. To examine this better, it is important to understand a little about how the grid is managed.

Electricity supply cannot be guaranteed 100% of the time. Outages occur for many reasons – both avoidable and unavoidable – including storms, maintenance, component failure, etc. It is not possible to build a system to maintain service at all times and places, in all possible contingencies – the reason why critical facilities, such as hospitals, have always had their own backup supply. Instead, electricity systems are designed to keep the lights on under most conditions, including normal operations, and a range of contingencies, such as failure of a transmission line or a generation plant "tripping off". Events outside of these contingencies may result in load being shed – in a controlled manner – causing localised blackouts. This is done to save essential equipment from being damaged by potentially excessive currents and/or voltages.

The Eastern Interconnection of the US and Canada consists of many interconnected electricity systems[1] – representing the largest synchronous grid in the world. One of the key reliability objectives of this interconnected grid – both in its design and operation – is that should a serious event occur within a given system, that portion can be isolated, protecting the rest of the interconnection. In other words – Blackouts occur, cascading failures should not!

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Ensuring system reliability is a function of both planning and operational control.

Automated Response	**Operator Action**	**Planning**
• Because of the instantaneous nature of electricity flow, responses to system events often need to occur in the space of seconds[2]. • Many of the actions which must be taken in this timeframe are automated – under the control of complex Energy Management Systems (EMS), and various automatic protection devices, such as relays, installed remotely on the system.	• When there is sufficient prior indication of a potential system event, system operators have the ability to take action • This can include changes to network configuration, load shedding, generation re-dispatch, etc.. • These actions are usually taken in accordance with pre-established operational procedures.	• System operators and planners conduct extensive analyses and simulations of potential system contingencies, and the appropriate response to them. • The results of these analyses directly influence how automated systems are configured, and the procedures to be followed by the system operators.

[1] A geographical area which includes PJM, New York, New England, the Midwest, Ontario, Canadian Maritimes, South-Eastern US and Florida.

[2] For example, the final collapse of the system in the 2003 blackout occurred in around nine (9) seconds.

Therefore, at its most basic level, the 2003 Blackout was a reliability engineering issue – a result, at least in part, of both of the following:

- Adequate measures were in place to manage the event, but systems and/or operators failed to act as anticipated[3].
- Once the event reached a certain stage it was outside the range of planned-for contingencies[4], and therefore automated and operator responses were sub-optimal.

As stated by Spencer Abraham, US Energy Secretary, "One major conclusion of the interim report is that this blackout was largely preventable…However, the report also tells us that once the problem grew to a certain magnitude, nothing could have been done to prevent it from cascading out of control."[5]

What do you mean "responses were sub-optimal"? Nothing was working where I was!

There is no doubt that the response to the events of August 14th could have been better – with quick isolation of the problem areas from the rest of the grid – and that those stuck without power in cities such as New York, Toronto and Detroit would have been fairly unimpressed. However, some things also went right.

If you were in Philadelphia, Boston or Chicago, all on the same Eastern Interconnect, the lights stayed on. More importantly, in most locations which were blacked out, the direct cause was the automatic disconnection of protective relays. This occurred in order to prevent permanent physical damage to important system components, which are expensive and can take extended periods of time to replace. The result was that the system could be restarted fairly quickly – in most places within 24 hours. By way of contrast, in February 1998 all four major transmission lines into downtown Auckland, New Zealand – that country's largest city – burnt out, resulting in widespread blackouts lasting almost two months.

Greater Regional Coordination Is Needed

One of the key actions which can be taken to reduce the likelihood of such incidents in the future is better regional coordination of the grid, under the auspices of strong regional system operators.

System control, and management of system reliability is based upon "control areas", each of which is run as its own electricity system, generally with minimal coordination of planning and operations with other control areas. The coordination that does exist is achieved through voluntary compliance with guidelines published by the North American Electricity Reliability Council (NERC).

"Right now, different functions that relate to the stability and reliability on the grid are handled by different entities."

Stephen G. Kozey,
VP & General Counsel,
Midwest ISO

Source: New York Times, Aug. 22, 2003.

[3] The interim report of the Outage Task Force pointed to "inadequate situational awareness", including a failure of both procedures and systems, as being important contributors to the spread of the blackout.

[4] As stated in the Task Force Interim Report, "Major blackouts are rare, and no two blackout scenarios are the same."

[5] Source: Reuters, November 19, 2003. Comments by Spencer Abraham on release of the Interim Report of the US-Canada Power System Outage Task Force.

In a number of regions, these control areas are still aligned with the transmission footprint of major vertically-integrated utilities. For example in the Midwest, where the blackout started, there are 37 control areas. Electricity flows between these control areas are substantial, making them heavily interdependent, such that events in one area may have a significant impact upon reliability in adjacent areas. Rather than being considered as separate systems, these networks should more appropriately be treated as part of a larger interconnected region. Currently, however, each is managed in a semi-autonomous manner. In the case of the Midwest, MISO plays a coordinating role, but with no authority to compel individual control areas to act. In the words of the Outage Task Force, "MISO was hindered because it lacked clear visibility, responsibility, authority, and ability to take the actions needed in this circumstance."[6]

A number of system functions would benefit from a more regional approach, including:

Automatic Protection	**System Operations/Control**	**Planning**
• Relay setting and coordination is currently performed by transmission owners, with limited coordination beyond control area boundaries[7]. • Performing this function on a regional basis would allow a better response to large-scale events, such as the blackout. • Additionally, relay setting and coordination is a dying art. A regional approach would allow for better use of these scarce resources.	• Multiple control areas, operated by different organisations, do not often work seamlessly together. • This occurs for reasons of both practical difficulty (e.g. establishing information links) and commercial advantage (e.g. unwillingness to share competitively useful information). • Consolidating system operations under a single entity with no financial stake in the market eliminates this problem. • Solutions which maintain separate control centres while overlaying some regional structures do not address these issues, and may simply serve to add another layer to the communication and decision making process.	• System planning at a regional, rather than a local, level allows a more holistic assessment to be made of requirements for system augmentation – not just for transmission lines, but also protection equipment, new generation, etc.. • On a more immediate timeframe, a regional approach allows for better planning of maintenance, and development of more appropriate operational procedures for normal and contingency operation.

Suggestions by some that these problems would be solved by reducing the level of transmission interconnection are ludicrous. Interconnection between regions generally serves to improve system reliability. For example, generation lost in one region can be replaced by electricity from other regions, with reserves shared. This level of reliability would be prohibitively expensive if each utility system were its own island, which is the reason many utilities interconnected their systems in the first place. The trade-off to this benefit is that larger interconnected systems are more complicated to manage.

[6] US-Canada Power System Outage Task Force, *Interim Report: Causes of the August 14th Blackout in the United States and Canada*, November 2003.

[7] The blackout report pointed to improper relay coordination as an important contributor to previous blackouts. It has not been identified as a key contributor to the August 14th blackout.

RTOs Are The Logical Entities To Provide This Coordination

Instead of the current patchwork quilt of responsibilities, there is a need for mandatory regional coordination of both planning and operations. Experience, both overseas and in successful North-American markets, has shown that this coordination role is best played by strong central system operators – whether they be known as ISOs, RTOs, ITPs or some other acronym.

The fewer of these organisations, and hence the larger their geographic footprint, the better. Initially, though, the constraints of realpolitik are likely to result in a greater number than optimal. This can be seen in the recent failure of some mergers, which can be attributed more to issues of politics and parochialism than of engineering or economics.

In additional to broad coordination within a region, there remains a need for inter-regional coordination. This can probably be best achieved through the enforcement of mandatory national (or potentially international) reliability standards – a logical extension of existing NERC responsibilities.

> *"The cascading nature of this blackout offers an object lesson of how the electricity grid requires regional coordination and planning, a challenge the nation is still striving to meet."*
>
> Pat Wood III,
> Chairman, FERC
>
> Source: FERC,
> Aug. 22, 2003.

Regions Are Defined By Physics, Not Politics

Regional boundaries are dictated by the flow of electricity, which in turn is determined by network topology and the laws of physics. However, in a legal sense electricity transmission is governed by an overlay of federal and state regulation (and legislation), with each having its own rules and agenda. It is not unknown for these regulations to expect electricity to flow differently because it has crossed a state border – the electricity industry equivalent of trying to legislate the value of pi[8].

Some of these fictions are also entrenched in existing technical solutions. For example, the OASIS system for "physical" transmission reservation, mandated by FERC Order 888, is based upon a deemed "contract path". However, this is a crude approximation to physical reality, which fails to recognise parallel and loop flows – an inherent result of Kirchoff's laws – and therefore becomes increasingly invalid as the system becomes more meshed. This fiction can be increasingly dispensed with as the number of separate system operators shrinks, and the size of the systems they operate grows. For example, as PJM expands, participants in the new service territory no longer need to make OASIS reservations to move electricity within PJM, but instead participate directly in PJM's internal scheduling.

> *"When you do this stuff state by state, it doesn't work. It's like having an air traffic control system state by state."*
>
> Craig Glazer,
> VP, Government Policy,
> PJM Interconnection.
>
> Source: New York Times,
> Aug. 23, 2003.

Action needs to be taken to establish a clear set of ground rules to govern electricity transmission – respecting the realities of transmission physics. As wholesale electricity tends to cross a number of state borders, and it is not realistic to expect a fifty-state consensus, this action must be taken at a federal level. To the extent that FERC's authority is ambiguous in these matters, Congress should act to establish certainty. It is worth noting that every successful electricity market established outside the US has had a clear legislative mandate for market restructuring, accompanied by a concerted effort to establish robust market infrastructure.

[8] At least one State has also tried this. See "House Bill No. 246, Indiana State Legislature, 1897".

But What About Transmission Investment?

The current lack of transmission investment in the US has been suggested by some pundits as a key cause of the blackout. Transmission under-investment is a critically important issue, which must be addressed to meet the steady-state needs of transferring power between major load and supply centres. It is not clear, however, that it had any major influence in causing the blackout. August 14th was not an unusually high demand day anywhere on the system, and there is no indication that the transmission system was under any particular transmission strain prior to the cycle of events commencing.

The main evidence of a lack of transmission capacity in a given area is real-time congestion. However, the first lines to trip were not operating at full capacity, and tripped due to a set of non-congestion related causes. This then caused the re-routing of power, which led to overloading, and additional power lines being tripped. It is arguable that if systems had worked as expected, and people had noticed the rerouting of power, then steps could have been taken to handle the overloading problem resulting from the initial trips.

It is equally important to note that the day-to-day management of system reliability is based upon the system the operators have, not the system they would like to have. In the event that insufficient transmission is available to get supply to load, this should result in orderly shut-down of some facilities, rather than instantaneous blackouts.

…And Isn't This All Just The Fault Of Markets?

The 2003 Blackout has been used to promote a number of agendas which have little or nothing to do with the actual event. One of the most absurd of these is the claim that the blackout came about because of markets and deregulation. The obvious implication seems to be that if the industry was run by regulated monopolies then this couldn't happen. Only, it did happen – in 1965 and 1977!

Many of the arguments which have been advanced fly in the face of fact. These include:

- *The blackout occurred in only those regions with markets*: Just plain wrong. The Midwest ISO does not yet operate an electricity market. On the other hand, the region where the blackout was stopped, PJM, has the most mature electricity market in the US, and is the poster-child for FERC's Standard Market Design (SMD).
- *Markets have led to changes in inter-control-area flows, which are severely straining the system*: Generation and load are fairly much where they have always been. Additionally, electricity works by displacement[9]. So, while financial flows between regions may have increased, the pattern of physical electricity flows is not impacted on the same scale. More importantly, system operators continue to ensure the system is operated within pre-established reliability constraints.

[9] Imagine throwing a bucket of water in a pool, at the same time someone at the other end removes a bucket. As long as the water is all the same, it doesn't matter that they don't get the exact bucket you threw in. Electricity works in a similar way – it's not necessarily your physical power that is delivered, it just replaces the power that your customer does use.

- *Markets have caused inadequate investment in transmission*: Transmission remains a fully regulated business, not subject to market competition. The lack of transmission investment is generally driven by issues such as siting and permitting, allowed rate-of-return, etc.
- *Electricity markets don't work*: This wantonly ignores hard evidence to the contrary – both within the US (e.g. PJM) and outside of it (e.g. Nord Pool).
- *Electricity is too important to trust to markets*: This is a political/philosophical argument, not a practical one. The same arguments were advanced during the deregulation of oil, natural gas, telecommunications, and other industries.

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