THE 2003 BLACKOUT: DID THE SYSTEM OPERATOR HAVE ENOUGH POWER?

Fernando L. Alvarado (alvarado@engr.wisc.edu) & Rajesh Rajaraman (rrajaraman@LRCA.com)
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The causes of the 2003 blackout are still being investigated and it is too soon to know what went wrong. From press accounts, it appears that the problems began somewhere in Ohio at least one hour before the blackouts when some major transmission lines began tripping out of service. (It is also possible that there may have been other contributing predisposing factors, such as oscillations among some generators in parts of the system or some other as yet undetermined conditions.) Among the many unanswered questions, we would like to add the following important questions for further investigation: Were the system operator's hands tied by rules that hindered the operator from taking the most appropriate corrective actions in a timely manner? Would rules such as those followed in the Pennsylvania-Jersey-Maryland (PJM) system have helped in preventing the blackout?[1]

To support the case for investigating whether PJM-style rules might have assisted system operators in enhancing system reliability, we provide a brief overview of these rules and comment on the possible actions that can be taken by a system operator under these rules in response to overloads or potential overloads. We contrast the PJM-style rules with the rules prevalent in some other regions of the country (specifically, in Ohio). Our intent is not to place blame; indeed, if anything, our thesis is that the system operators in all regions of the country are highly skilled, but that they must be entrusted with better rules in order for them to effectively perform their jobs. In addition, the PJM-style rules are also market-oriented; the PJM system operation enables a well-functioning power market with real-time prices for power posted every 5 minutes, and permits generators that would rather schedule themselves to do so in response to these prices.

First, we provide some background on the general functioning of the power system. A power system is not like the interstate highway network. For example, if you decide to go from Cleveland to New York City by road, you have a number of different combinations of highways that you can use; in other words, you have control of the route that you take. If you encounter congestion on the way, you can simply exit that highway and try to find an alternate route.

In an electrical network, if you generate power in Cleveland and someone in New York City takes out power, then the route of power flow is controlled by the laws of physics and not directly by you. The flows will go over many different lines, including, for example, around Lake Erie and through Mid-Atlantic States. In particular, some of this power flow could overload some transmission lines that could contribute to the unreliability of the power grid. In such a case, power has to be re-routed to other less loaded transmission lines, but unfortunately because of coordination and communication issues, it is not an easy task for market players (generators and traders) to accomplish.

However, it is relatively easy for any system operator to re-route transactions and re-dispatch generators to prevent overloads. Moreover, the system operator has all of the tools that are required to do this in the most economical way, thus saving power consumers money. For example, to relieve an overload in one transmission line, the system operator in PJM typically re-routes power by turning down generation in one location (upstream of the overload) and turning up generation at a different location (downstream of the overload) to maintain system reliability. Because the system operator is aware of all of the relevant dispatch

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[1] We do not discuss the system operators' actions in other regions as it appears that system operators in the various regions were in effective control of their systems until about a few minutes before the blackout. Things then began spiraling out of control. Problems in Michigan appear to have begun only a few minutes before the blackout, and Ontario, New York and the rest of the Northeastern U.S. did not report problems until a few seconds before the blackout, their system operators had almost no time to take any actions and were thus powerless to stop the blackouts.

costs, the re-routing is done at the most economical cost possible. By this action, the system operator sets the market prices for power everywhere in the system.

In other places, such as the regions neighboring PJM to the west (specifically, in Ohio), the system operator does not have the authority to follow the above (PJM-style) rules. Instead, the system operator ignores the economics and markets altogether and simply starts curtailing—rather than efficiently re-routing—many power transactions to relieve a transmission line overload. Therefore, to relieve a single overload, the system operator may have to make possibly tens or hundreds of phone calls to other parties to stop their power transactions. Apart from just bad economics (power transactions are curtailed without regard to cost, resulting in higher prices) and poor market design (market players whose transactions are cut are left on their own to get around transmission congestion), the system operator wastes precious time in curtailing more transactions than necessary in a critical situation. With PJM-style rules, the operator would simply re-dispatch a handful of generators to achieve the same goals, presuming sufficient reserves were available; this is much less time-consuming and can be done through electronic signals. In the box presented at the end of this paper, we present a scenario that demonstrates how PJM-style rules may have impacted system operations in the Ohio grid.

To summarize: in the course of ongoing investigations to determine the cause of the blackout, we encourage the investigators to examine whether the inefficiencies of overload relief rules contributed to the blackout, and to also examine whether PJM-style rules could have assisted in avoiding the blackout.

What might have happened had the rules been different?

To be a little more specific, we list the sequence of probable events that has been made available by the North American Electric Reliability Council (NERC) (http://www.nerc.com/pub_doc/PreliminaryDisturbanceReport.pdf). However, after each "event" in the timeline we comment as to the possible role that PJM-style rules could have had. Notice how the market prices in the Ohio grid might have reacted to each "event" under PJM-style rules; large congestion charges would have been applied to power transactions flowing over congested transmission lines, thus giving the market incentives to reduce transmission overloads. (Under the non-PJM rules in effect in Ohio, power transactions flowing over congested transmission lines were not assessed any congestion charges, and thus the market did not have any financial incentive to reduce transmission overloads.) We cannot at this time be more specific than a "qualitative plausibility" analysis, because a truly correct analysis will require much more data and more time than we have at hand; such analysis may also come to very different conclusions than ours.

Note: NERC gives all times as Eastern Standard Times, which is the same as Central Daylight Time. The prevailing Eastern Daylight Time is one hour ahead of this time.

14:06 Chamberlain – Harding 345 Kv line tripped – cause not reported
At this time the PJM-style rules would have recognized that this line outage would result in either the immediate congestion or the contingency-constrained congestion of any of a number of the lines that would have been forced to carry the flow from the Chamberlain-Harding line. In all probability, this would have resulted in an increase in generation downstream from the Hanna-Juniper line and a decrease in generation upstream to prevent the overload. (The result of this dispatch would also have been low market prices upstream of the constraint and high market prices downstream of the constraint.)

14:32 Hanna – Juniper 345 Kv line sagged and tripped.
As in the case of the previous trip, the outage of this line would have almost immediately resulted in further generator re-dispatch with PJM-style rules. (This could also have resulted in dramatic and drastic price differentials upstream and downstream of the constraint. This would have forced even those generators outside of the system operator's control to start lowering their output upstream of the constraint and increase their output downstream of the constraint, thus contributing to the reliability of the system. Power transactions flowing over the congested lines would have faced very high congestion charges.) Thus, overload relief of the Star-S. Canton line and the Tidd-Canton line may have well occurred prior to their tripping.

14:41 Star – S. Canton 345 Kv line tripped
14:46 Tidd - Canton Ctrl 345 Kv line tripped
If sufficient reserves were available downstream of the congestion, it is possible that we would not have reached this stage with PJM-style rules. However, even after these outages, PJM-style rules would likely have automatically lowered almost all possible generation upstream of the major transmission congestion constraints and increased generation downstream of these constraints. (The price differentials in the Ohio grid upstream and downstream of the congestion by now would have been dramatic and the congestion charges for power transactions flowing over the congested lines would have been very high.)

15:06 Sammis – Star 345 Kv line tripped and recolsed [*sic*]
(the preceding lines are located in the vicinity of Cleveland, Ohio)
With PJM-style rules, it is possible that we would not have reached this point because the necessary generation re-dispatch prior to this would have had a significant impact on overload relief. If we had reached this stage nonetheless, properly designed and activated demand shedding that is not based on frequency drop could have still saved the day. Since this did not happen, true rapid cascading occurred and no system operator in the world could have saved the system.

15:08 Power swings noted in Canada and Eastern US.
15:10 Campbell # 3 tripped ??
15:10 Hampton – Thetford 345 Kv line tripped
15:10 Oneida – Majestic 345 Kv line tripped
15:11 Avon Unit 9 tripped
15:11 Beaver – Davis Besse
15:11 Midway – Lemoyne – Foster 138(?) Kv line tripped
15:11 Perry Unit 1 tripped
15:15 Sammis – Star 345 Kv line tripped and reclosed
15:17 Fermi Nuclear tripped
15:17 - 15:21 Numerous lines in Michigan tripped

The Northeastern United States and Canada did not report significant outages prior to 15:11 CDT (or 16:11 EDT).