NorthWestern Energy

EPA 111-D Clean Power Plan Consideration Study:

Retirement of All Coal-Fired Generation in Montana

November, 2015

Regional Electric Transmission Planning

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Executive Summary

The Environmental Protection Agency (EPA) is using its authority under Section 111 of the Clean Air Act to issue standards, regulations or guidelines that address carbon pollution from new and existing power plants, including modifications of those plants. NorthWestern Energy (NWE) performed a high-level analysis of the impacts to the transmission system should all coal-fired generation power plants in the NWE balancing authority be shut down. This is an update to similar study work and a report done by NWE in April 2015. The April report focused on the impact of the shutdown of Colstrip Units 1 and 2 only.

NWE studied six different configurations:

1. No coal-fired generation, no 500 kV.
    a. Scenario 1 with the addition of a 250 MW natural gas-fired generation plant modeled in Billings.
2. No coal-fired generation, no other system changes.
    a. Scenario 2 with the addition of a 250 MW natural gas-fired generation plant modeled in Billings.
3. No coal-fired generation, 2520 MW of wind added to the system
    a. Scenario 3 with the addition of a 250 MW natural gas-fired generation plant modeled in Billings.

The goals of the analyses were to discover if the local area can still be served reliably, whether it is possible to keep the 500 kV transmission system intact if there is no coal-fired generation, and what impacts to the path flows these different configurations have on the import and export capability of the external paths.

It is important to note that this is a transmission study only, performed for the purpose of understanding the potential physical or operational impacts to the transmission system of the shutdown of all coal generation in NWE's balancing authority area. Certain assumptions were required in order to test the critical operating scenarios under heavy and light loading situations. The economics, costs, or the viability of replacement generation from a supply perspective or other required infrastructure to develop these configurations that are key to actually seeing any of these to fruition are not considered in this analysis. In addition, assumptions regarding the future use of, or absence of, the Colstrip 500 kV Transmission System are approached from the technical perspective and the contractual perspective.

The high-level results of the analysis are as follows:

A. Coal-fired generation is a key component of the transmission system. Coal-fired generation provides power that is reliable, consistent, and predictable. The loss of coal-fired generation on the NWE transmission system severely inhibits NWE's ability to either export or move power through the system. The large coal-fired generators act as dampeners to stability events in that they help reduce the impacts of the stability event. Without coal-fired generation, there are fewer "dampeners" and the system has a reduced ability to reliably respond to events.

B. The Clean Power Plan could require a total shutdown of all the coal-fired generation in Montana. The coal-fired plants are listed in Table 1.

Table 1: Coal-Fired Generation Plants in Montana

Plant	**MW**
BGI	65
Colstrip	2306
Hardin	115
Montana One	41.5

If all the coal-fired generation in Montana were decommissioned, then additional resources would be needed. Natural gas-fired generation is a consistent, predictable, and reliable source of energy. Wind and other non-predictable renewable generation present complications such as the requirement of spinning and contingency reserves, conventional power sources to back up the variable resources and the need for other reactive devices for voltage control.

A consideration of replacing any generation with wind is the capacity factor. For example, if the decommissioned coal-fired generation was replaced with wind, and a conservative 33% capacity factor was assumed, then 7583 MW of wind would have to be installed to make up for the 2725 MW of coal-fired generation. Natural gas-fired generation can be configured as a one for one replacement to coal if natural gas infrastructure could be modified/expanded to accommodate new generation.

Without coal-fired generation, there are impacts to the Billings area. The coal-fired generation is an excellent source of Volt-Amp Reactive (VAR) power and the Billings area will need to replace the VARs supplied by the coal-fired generation. This replacement could be in the form of capacitors in the Billings area or by maintaining at least one high voltage line that feeds into the area. The high voltage line could be a 500 kV line or a new 230 kV line. The 500 kV line could be one of the existing 500 kV lines. A 500 kV line under light loading may actually cause too much capacitance (high voltage). Another area of interest in this scenario is the South of Great Falls cut plane. Without the 500 kV transmission system intact, reliability violations were found that would decrease the current South of Great Falls cut plane total transfer capability. If there were no 500 kV transmission system, then additional transmission from the Three Rivers area to Great Falls (likely a 230 kV line) would be needed to support current needs and obligations in that area.

Assuming a new 230 kV line between Great Falls and Three Rivers with routing along the existing 100 kV facilities, the length would be about 135 miles. A high-level estimate of $750,000 per mile yields a total line estimate of $101 million. In addition to the transmission line, a new 230 kV terminal at the Three Rivers Substation as well as a new 230 kV terminal at the Great Falls 230 kV Switchyard would be required which adds an additional $5 million to the estimate. Altogether, the total estimate for the line and associated facilities is $106 million.

The results of this analysis are high-level and should only be used for informational purposes.

Study

Questions

1. Without coal-fired generation, can NWE reliably serve its local area load?
2. Without coal-fired generation, is the 500 kV transmission system useable and needed?
3. Can NWE replace coal-fired generation with wind or a combination of wind and natural gas-fired generation?
4. What are export and import impacts to the four external transmission paths?

Considerations

Currently, Montana has more generation than load and is typically considered an export state. With the loss of approximately 2520 MW of coal-fired generation on the system, Montana would have less generation than load during medium and heavy loading and would be faced with the routine import of power to serve native load. In addition to impact to NorthWestern's customers, the large choice customers would be faced with the same situation – significantly reduced in-state resources to meet their energy intensive needs.

The 500 kV transmission system was installed with the primary purpose of exporting power from the Colstrip coal-fired generation plant and to serve Montana customers through substations along the transmission lines. The 500 kV transmission system now also serves as a strong backbone to the overall transmission system. Without generation in excess of load, there may be diminished need for the 500 kV transmission system. Currently, 675 MW of load is designated to be served by coal-fired generation in the NWE Balancing Authority.

Study Assumptions/Process

NorthWestern Energy studied the following scenarios:

1. No coal-fired generation, no 500 kV.
    a. Scenario 1 with the addition of a 250 MW natural gas-fired generation plant modeled in Billings.
2. No coal-fired generation, no other system changes.
    a. Scenario 2 with the addition of a 250 MW natural gas-fired generation plant modeled in Billings.
3. No coal-fired generation, 2520 MW of wind added to the system. The introduced wind is modeled at 100% output (very optimistic and perhaps not realistic, but required to test the technical limits of the transmission system); all existing wind on the system was dispatched according to the "Dispatch Descriptions for all Scenarios" section.
    a. Scenario 3 with the addition of a 250 MW natural gas-fired generation plant modeled in Billings; this 250 MW replaced 250 MW of the introduced wind.

For all scenarios, both heavy and light loading was considered. NWE explored a 2015 Light Summer case and a 2015 Heavy Winter case. The results are steady-state only.

First, an exploration was made to see if the transmission planning cases solved given the six different scenarios. Next, contingency analysis was performed to discover any initial reliability violations. If the case had reliability violations, then the cases were modified to see if those violations could be alleviated through generation re-dispatch or modification to the path flows. Last, the path flows were increased to see if the transmission system could reliably handle being treated as a conduit for transmission service.

For the most part, once the case was solved and initial contingency violations were alleviated, NWE was not able to increase the path flows without creating new contingency violations.

Dispatch Descriptions for all Scenarios

While there are infinitely many combinations of path flows and generation dispatch levels, the two different dispatch levels selected for study are an attempt to study the "bookends" of the many different combinations that could result from these three scenarios.

Light Loading in the NorthWestern Balancing Authority (1140 MW): Heavy hydro and wind to simulate a spring runoff condition.
This extreme case is to analyze the ability to export power out of Montana.

Heavy Loading in the NorthWestern Balancing Authority (1750 MW): Light hydro and no existing wind dispatched.
This extreme case represents the worst-case scenario for importing power to serve native load. In the Heavy Loading cases under Scenario 3; the introduced wind was fully dispatched (again an optimistic view, but required to test the system).

High-Level Results

The loss of coal-fired generation presented some challenges to the transmission system.

Scenario 1, No Coal-Fired Generation, No 500 kV, Heavy System Loading: The 500 kV transmission line was required to be de-energized (taken out of service) east of Garrison which is the interconnection to the BPA system. In this scenario, Path 8 imports would have to be limited to approximately 850 MW which is down from the current import limit of 1350 MW. The initial critical outage is the loss of one of the 161/100 kV transformers at Mill Creek which caused cascading voltage collapse in the Butte area. If those transformers were upgraded, then the next critical contingency is the loss of the 230 kV South Butte to Three Rivers line which causes cascading voltages. Each of these scenarios is unacceptable.

Scenario 1, No Coal-Fired Generation, No 500 kV, Light System Loading: In this analysis, South of Great Falls total transfer capability would have to be reduced unless a new 230 kV line between Great Falls and Three Rivers could be built. The loss of the 230 kV line between Judith Gap South and Broadview is the critical contingency that causes cascading outages in the Harlowton area. This is not only a reliability concern, but commitments made to third parties for wholesale transmission service would be significantly impacted. Currently, the southbound Total Transfer Capability (TTC) is 495 MW, of which 360 MW is designated as firm transmission. The northbound TTC is 468 MW, of which 374 MW is designated as firm transmission. Both the northbound and the southbound directions are often fully designated if both firm and non-firm designations are considered.

Scenario 2, No Coal-Fired Generation, 500 kV In Service, Heavy System Loading: Though the 500 kV transmission system was considered "in service", one of the parallel 500 kV lines between Broadview and Garrison had to be de-energized to maintain voltage limits on the transmission system; if both lines remained in service, then their combined capacitance would make it such that reactors would have to be installed to offset their capacitance (reduce voltage). This case presents a loading and generation condition that solved and maintained N-1 reliability.

Scenario 2, No Coal-Fired Generation, 500 kV In Service, Light System Loading: Though the 500 kV transmission system was considered "in service", one of the parallel 500 kV lines between Broadview and Garrison had to be de-energized to maintain voltage limits on the transmission system. This case presents a loading and generation condition that solved and maintained N-1 reliability.

Scenario 3, No Coal-Fired Generation, 500 kV In Service, 2520 MW Wind, Heavy System Loading: With 2520 MW of wind at 100% dispatch, there are no violations seen on the heavy loading condition and the system demonstrated N-1 reliability.

Scenario 3, No Coal-Fired Generation, 500 kV In Service, 2520 MW Wind, Light System Loading: With 2520 MW of wind at 100% dispatch, there were violations seen for loss of 230 kV and 161 kV segments in the Broadview/Billings areas caused by the introduction of a very large wind farm at Broadview/Billings area.

All scenarios with the addition of a 250 MW natural gas combined cycle plant in the Billings area:

- In general, the gas plant helped alleviate voltage issues in the Billings area. The gas plant was modeled at the Steam Plant Substation, but voltage support beyond the capability of the gas plant would still be necessary. If a 250 MW natural gas plant were to be built in Billings, then the Billings Steam 230 kV Substation would benefit from being re-configured to a breaker-and-a-half scheme. With the current configuration and with the addition of a 250 MW natural gas plant, a single breaker failure or stuck breaker in the Billings Steam 230 kV Substation could lead to voltage collapse in the Billings area.
    - Additional capacitor banks in Judith Gap area are approximately $1 million based on historical costs.
    - Replacement of the existing Steam Plant 230 kV bus with a new 230 kV breaker-and-a-half scheme configuration would cost approximately $25 million.

Discussion

Using wind as a resource presents complications. Wind, by its very nature, is variable and not inherently predictable. Wind is not always available when it is needed most. Every MW of wind added to any transmission system has to have corresponding balancing reserves for the inevitable time when wind generation is scheduled and then the wind dies out.

Transmission systems are often described using a "spring-mass" comparison; the transmission lines themselves are the "springs" and the generators are the "masses". A coal-fired generator has the most "mass" and as such, responds well to contingencies.

Wind farms have much less “mass” using this analogy and provide little to no response to contingencies.

Table 2 details the observed path flows for the scenarios described above. All values are in MW. A positive value indicates an export; a negative value indicates an import.

Table 2: Interchange Values for the Different Scenarios

Loading	Scenario	Path 8 (MW)	Path 18 (MW)	Path 80 (MW)	Path 83 (MW)	Total Dispatched Generation (MW)	Generation minus Load (MW)	Net Path Interchange, Pre-Contingency (MW)
Light, 1140 MW	No Coal, no 500 kV	61	27	-421	185	1056	-84	-148
	No Coal, no 500 kV, 250 MW at Billings	157	44	-325	214	1310	170	90
	No Coal, 500 kV In Service	-179	-131	128	140	1178	38	-42
	No Coal, 500 kV In Service, 250 MW at Billings	-1	-113	177	150	1428	288	213
	No Coal, 500 kV In Service, 2520 MW Wind	1785	287	325	173	3903	2763	2570
	No Coal, 500 kV In Service, 2270 MW Wind, 250 MW at Billings	1801	280	326	170	3908	2768	2577
Heavy, 1750 MW	No Coal, no 500 kV	-851	-97	-341	-300	276	-1474	-1589
	No Coal, no 500 kV, 250 MW at Billings	-851	-94	-90	-300	526	-1224	-1335
	No Coal, 500 kV In Service	-1272	-34	-49	64	557	-1193	-1291
	No Coal, 500 kV In Service, 250 MW at Billings	-1160	-28	-51	194	820	-930	-225
	No Coal, 500 kV In Service, 2520 MW Wind	631	167	123	37	2863	1113	958
	No Coal, 500 kV In Service, 2270 MW Wind, 250 MW at Billings	666	158	116	35	2871	1121	975

During heavy loading and low generation output, NWE can expect to have to import significant power in order to serve load. Because only “bookends” were studied for this analysis, NWE may expect to have to import power during light loading as well.

Discussion

These results assume no other elements out of service. Much consideration will be required of the transmission system if there are any unplanned or planned outages on the system. Transient stability was not performed because there were already reliability violations present in steady-state. A transient stability analysis will be necessary when there is a clear understanding of the landscape surrounding these issues.

Considerations

Frequency

The large mass of the coal-fired generation units allows the units to respond to transient stability events with a positive dampening effect. The coal-fired generation units effectively dampen oscillations that occur during transient stability events and that dampening helps to improve response time and to protect the transmission system. While renewables have some damping capability, they are hardly comparable with the dampening power of coal-fired generation. The transmission system will be more susceptible to oscillations during transient stability events if coal-fired generation were shut down and either not replaced or replaced with only renewable energy. If a 250 MW natural gas-fired generation plant were built in the Billings area, it would help maintain system frequency both during steady-state and during contingency.

Total Transfer Capability, Path Capacity

The capacity of a line does not decrease when a resource is removed much like a garden hose’s capacity does not disappear when the water spigot is shut off. However, it is possible that the path rating/transmission capability might have to be reduced due to resource limitations depending on the possible resulting scenario.

The 500 kV transmission system is critical to Path 8. Without the 500 kV transmission system, there will be significant limitations on both the import and export capability of the path. If renewables, or a combination of renewables and natural gas-fired generation, were to replace all the coal-fired generation on the system, then analysis will have to be done to determine new values for the total transfer capability on any of the affected paths.

Local Area

Any time generation is added or removed from the system, extensive study work is required to assess any impact to loads and transmission near the generation. If the alternate generation resources are at or near Colstrip, there may be no change in the Colstrip area, but if not, system improvements may be required. While high-level impacts to the local area were analyzed, the study did not focus on load growth or future local area projects. This analysis did identify a need for VAR support in the Billings area. That VAR support may be in the form of a gas-fired generator in the Billings area or as a high-voltage transmission line into the area.

Voltage Support with the 500 kV Transmission System Intact

The Colstrip facility currently provides important voltage support to the transmission system in eastern Montana, and is vital in keeping the Montana 500 kV system within its voltage limits. Any replacement alternate generation would need to be capable of providing equal voltage support capability so that there is no negative affect to the system or stress on nearby generation. If a variable alternate generation resource such as solar or wind was chosen, additional dynamic and/or static VAR devices may be necessary to maintain adequate voltage on the 500 kV system. In general, the alternate generation resource will need to boost voltage under heavy generation output and suppress voltage under low generation output. As a side note, capital investments in devices to provide voltage support in the Billings area were planned and installed recently, in large part due to the known closure of the Corette coal-fired generation plant in Billings. That facility traditionally provided significant voltage support in the Billings area. The installation of capacitor banks in the Billings area over the last few years totaled $1.9 million (five switched banks totaling 80 MVAR).

Voltage Support without the 500 kV Transmission System

The voltage profile of the entire NWE transmission system will change without the 500 kV transmission system intact. The 500 kV transmission system supplies necessary VARs to both the Billings area and the Mill Creek area. Without the 500 kV transmission system, voltage support will be required. That voltage support may be in the form of dynamic VAR devices, capacitors or new generation that supplies the required VARs.

Remedial Action Scheme (RAS)

Currently, the Colstrip units are protected by the ATR which senses acceleration on the four coal-fired units and trips a combination of the units in order to maintain stability on the transmission system. While the ATR itself would no longer be required if all of the Colstrip facility is taken out of service, a RAS or multiple RASs will be necessary to protect the transmission system during outage and contingency events. Any RAS can only be developed once the state of the system is known.

Impact to Import Capability

The 500 kV transmission system acts as a strong "backbone" for the entire transmission system. Without it, the transmission system has lessened capability to both import and export power. The 500 kV transmission system is vital to the import capability on Path 8 as well as the capability of through flows on the South of Great Falls cut plane. Impacts to the import capability of Path 8 are of particular interest and concern. Without coal-fired generation and without the 500 kV transmission system, there is a significant need to import power to serve local load, but the import capability on Path 8 is lessened which will stress the other paths. Without building new transmission lines internal to the NWE transmission system, there will be lessened opportunities to move power through the transmission system to serve our internal customers and to meet current obligations for transmission service to wholesale customers.

South of Great Falls Cut Plane

The South of Great Falls (SOGF) cut plane is a uniquely situated portion of the NWE transmission system. Due to the mountain ranges in Montana and the location of the natural load pockets, there is a grouping of transmission lines that are sited between the north and south portions of the state, with the center-point being the city of Great Falls. Any transmission service in the north-south or south-north direction through NWE has to go through this cut plane, which makes it inherently valuable from a transmission service perspective. The SOGF Cut Plane will be impacted with the loss of the 500 kV transmission system. Without the "backbone" of the transmission system, the reliable limit through the SOGF, either north or south, will be reduced. Currently, the southbound Total Transfer Capability (TTC) is 495 MW, of which 360 MW is designated as firm transmission. The northbound TTC is 468 MW, of which 374 MW is designated as firm transmission. Both the northbound and the southbound directions are often fully designated if both firm and non-firm designations are considered. While a full-blown Total Transfer Capability analysis was not done for this report, it was shown in Scenario 1 that reductions to the SOGF are in order and that reliable flows may be in the 300 MW to 350 MW range for northbound flows – a reduction in the range of 120 to 170 MW.
Economic Impact

The analysis above does not consider the economics, viability or other infrastructure requirements associated with a large build out of wind generation or gas generation in eastern Montana as potential replacement to Colstrip generation. NWE does not take a position regarding the economics of wind generation in Montana and ability to find a customer, presumably outside of Montana, for a large wind resource. With regard to gas generation, if Colstrip generation was shut down, presumably transmission capacity would be available on the Colstrip 500 kV transmission system for replacement generation. There is multi-party ownership of this transmission capacity. However, significant consideration would be required of gas transportation and gas supply for large scale gas generation in eastern Montana.

Currently, NWE spends approximately $2.26 million on property taxes for the 500 kV transmission system between Colstrip and Garrison, of which, approximately $0.6 million is the property tax paid due to NWE's beneficial use of the portion of 500 kV transmission system owned by the Bonneville Power Administration (BPA).

The Montana Intertie Agreement between BPA and the Colstrip Transmission Owners covers the responsibilities of the parties for the facilities and transmission service across the Montana Intertie. The contract is tied to the output of the Colstrip generation. If the Colstrip generation is removed, then BPA has the option to remove the 500 kV facilities from Townsend to Garrison for its salvage value. If this happened, then the Broadview-Townsend line would not tie to anywhere and the transmission system from Colstrip to Townsend would become a stranded asset for the Colstrip Transmission Owners. The Colstrip Transmission Owners have the option to remove their transmission facilities if the Colstrip Generation Project stops production per the Colstrip Transmission Agreement. Removal of these facilities will have a significant impact on the property taxes and Beneficial Use Taxes collected on these facilities.

Conclusions

The loss of coal-fired generation would be a huge change to the planning and operation of the transmission system. With the transmission system "as-is" and the only change being the loss of coal-fired generation, the transmission systems ability to export power is drastically impacted and import capability is also greatly impacted.

NWE is uniquely situated in the Western Interconnection and currently not only serves its native/local customers, but also is a transmission conduit for other parties seeking to move power through the NWE transmission system. With a full shutdown of coal-fired generation in the state there would need to be very significant infrastructure changes.

The South of Great Falls Cut Plane would need to be reinforced to handle increased flows caused by the loss of the 500 kV system. This cut plane is heavily used to serve customers, move hydro generation and coal fired generation and also to move significant wind generation to and through the state. In the Scenario 1 study, it was found that in today's system, the South of Great Falls cut plane flows would have to be reduced down to approximately 300 to 350 MW in the northbound direction, a reduction of up to 170 MW, if the only changes are the loss of coal-fired generation and the loss of the 500 kV transmission system east of Garrison.

At the very least, a new 230 kV line between Three Rivers and Great Falls would be required to simply maintain the Total Transfer Capability rating of 495 MW under the no coal-fired generation, no 500 kV transmission scenario. Under any of the scenarios, a new 230 kV line and perhaps other significant infrastructure changes would be required to increase the capacity through the cut plane and alleviate the congestion caused by power movement through the NWE system.

The results of this analysis are high-level and should only be used for informational purposes.