Variable Energy Resource Integration and Load Variability Study Final Report

Prepared for:

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DISCLAIMER

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EXECUTIVE SUMMARY

Variable Energy Resource Integration Study

Navigant's Variable Energy Resource (VER) Integration study was conducted for NorthWestern Energy to determine how much regulation and load following resources were needed to meet requirements for Reliability Based Control Standard BAL-001-2 as increasing amounts of wind and solar come online in NorthWestern's balancing area. The purpose of Reliability Based Control Standard BAL-001-2 is to control the interconnection frequency within defined limits. To comply with the standard, balancing authorities including NorthWestern Energy must:

(1) operate such that their Control Performance Standard 1 (CPS1)[1] score is greater than or equal to 100% for each preceding 12 consecutive calendar month period (evaluated monthly); and

(2) operate such that its clock-minute average of reporting ACE does not exceed its clock-minute Balancing Authority ACE Limit (BAAL)[2] for more than 30 consecutive minutes.

To comply with the standard, balancing authorities use a combination of regulation and load-following resources.

For the purposes of this study:

- Regulation is defined as the use of on-line generation equipped with Automatic Generation Control (AGC) which can change output quickly to track the minute-to-minute fluctuations in load.
- Load-following is the use of on-line generation to track the intra- and inter-hour changes in loads. It is split into INC (ramping up a resource) and DEC (ramping down a resource).

In Navigant's proprietary STORM model, which is used to simulate the sub-hourly operation of NorthWestern's system, a regulation resource is assumed to be capable of ramping up or down its full capacity in a minute, whereas a load following resource takes 15 minutes to ramp to its full INC or DEC capacity.

The Variable Energy Resource Integration study is divided into two Tasks: (1) a baseline analysis to determine the minimum amount of regulation and load following resources needed by NorthWestern to satisfy BAL-001-2 requirements during the test year (July 2016-June 2017), and (2) an analysis to determine the additional load following resources necessary to integrate higher levels of VER (both wind and solar PV) into the NorthWestern BA.

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[1] CPS1 assigns NorthWestern Energy a share of the responsibility for control of steady-state interconnection frequency and is calculated using the minute-by-minute interconnection frequency and NorthWestern's frequency bias and ACE.

[2] Balancing Authority ACE Limits (BAALs) are derived from NorthWestern's frequency bias and the measured & scheduled interconnection frequency in accordance with BAL-001-2.

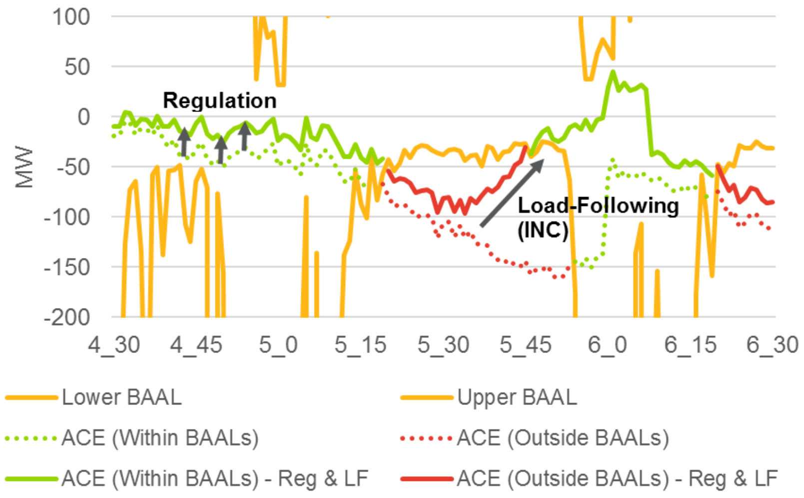
Baseline Analysis

Navigant's STORM model is a sub-hourly system operation model that simulates the system's ability to load follow and maintain frequency regulation on a minute-by-minute basis. In an iterative process, STORM can be used to determine the amount of regulation and load following resources needed in order to avoid NERC violations throughout the study period. Under the BAL-001-2 standard, a NERC violation occurs when the clock-minute average of NorthWestern's ACE exceeds its clock-minute Balancing Authority ACE Limit (BAAL) for more than 30 consecutive minutes.

The model uses two classes of units which are modeled generically, (1) regulation resources and (2) load following resources. The operation of the units is governed by a set of backward looking decision rules. These rules were developed with NorthWestern Energy such that they reflect how their system is actually operated in response to NERC events and changes in ACE.

The implementation of these rules is shown graphically in Figure 1. The dotted line is NorthWestern Energy's unadjusted ACE which does not take into account any of NorthWestern's corrective actions from regulation or load-following resources, and the solid line incorporates the STORM simulated corrective actions from regulation and load-following. From hours four to five, the regulation resource is dispatched to decrease the magnitude of ACE and return it to within established limits. In hour five, regulation is insufficient to keep the ACE from falling below the lower BAAL. After the 15-minutes below the lower BAAL, load-following resources are called upon to get NorthWestern out of the NERC event before the 30-minute limit is reached.

Figure 1. STORM Operation: NorthWestern Energy 11/8/16



Source: Navigant; data from NorthWestern Energy

Over the test year, the main criteria for the amount of needed regulation and load following resources is the minimum amount needed to avoid all NERC violations and maintain CPS1 scores at an acceptable level. However, this is not the only metric that should be monitored and maintained in order to maintain a reliable system. Navigant also monitored the number of times that a set of resources led to an event in which load following was required, the CPS1 score trend, and the amount of inadvertent generation[3], all metrics tracked by Navigant's STORM model. Maintaining these metrics is important for Northwestern to maintain a buffer so that reliability is not expectedly threatened if future events are more severe than what occurred in the test year.

For the baseline study, Navigant analyzed NorthWestern's system operation at 6 different levels of regulation capacity: 0MW, ±10MW, ±15MW, ±25MW, ±30MW and ±40MW. For each level of regulation capacity, Navigant determined the corresponding INC and DEC capacity needed to prevent a NERC violation throughout the test year by focusing analysis on the hardest INC and DEC events. Once the regulation capacity and corresponding INC and DEC capacities were determined, Navigant ran STORM for the entire test year to analyze the marginal benefits of adding regulation capacity.

The results of the test-year simulations are summarized in Table 1. Navigant recommends NorthWestern Energy procures ±25MW of regulation capacity given the aggregate benefits to CPS1 score, inadvertent generation, the number of INC/DEC calls, and the number of near-NERC violations.

With ±25MW of regulation capacity, there are significantly less INC/DEC calls needed, providing both an economic and systems operation benefit to NorthWestern Energy, and far fewer instances where NorthWestern exceeded the BAALs for 20 or 25 consecutive minutes, thus mitigating the risk of having a NERC violation. With ±25MW of regulation there is also a greater buffer between NorthWestern's CPS1 scores and the minimum allowable CPS1 under the BAL-001-02 standard. This is especially important as expected wind and solar additions on the system will likely put downward pressure on CPS1 scores.

Table 1. Test Year Results and Recommendation

	Regulation	±0 MW	±0 MW	±10 MW	±15 MW	±25 MW	±30 MW	±40 MW
	INC	0 MW	130 MW	115 MW	110 MW	120 MW	115 MW	105 MW
	DEC	0 MW	180 MW	170 MW	165 MW	155 MW	150 MW	140 MW
	NERC Violations	123	0	0	0	0	0	0
Outside BAALs	25 Min	218	12	14	12	10	7	7
	20 Min	385	135	107	78	46	45	34
	15 Min	700	687	469	393	263	217	141
	CPS1 Score	131%	149%	152%	154%	159%	162%	167%
	Inadvertent (MWh/hr)	32.9	31.9	24.5	21.6	16.8	15.0	12.1

Recommendation

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[3] Inadvertent is the net imbalance between NorthWestern Energy and the interconnection.

VER Integration Study (Future Scenarios)

Navigant conducted an analysis to determine the additional load following resources necessary to integrate higher levels of VER (both wind and solar PV) into the NorthWestern Energy balancing area. Navigant assessed three scenarios of renewable integration (A) 185MW of planned wind, (B) 185MW of planned wind & 320MW of new wind and (C) 185MW of planned wind & 100MW of new solar. These scenarios were chosen to reflect the near-term expected builds in NorthWestern Energy's balancing area and the potential for significant quantities of both wind and solar to be added to the system beyond that.

To study these scenarios with higher levels of VER than in the test year, Navigant used Monte Carlo methods to simulate hundreds of draws of alternate renewable operation with historical wind and solar data from NREL. Navigant analyzed a wide range of load-following events that required significant action by NorthWestern during the test year on which the impacts of additional variable generation could be layered. A key aspect of these draws is that they are real historical operation of the assumed resources including the impacts of regional weather and geographic diversity. This approach ensures that the cross-correlation of the variable generation is considered by randomizing the time period being drawn and pulling the operation of each resource from this period. The NREL datasets include over five years of historical 5-minute wind data (and corresponding estimated power production) at thousands of wind sites and one year of historical solar data from four sites in Montana. Wind sites were selected to be consistent with NorthWestern Energy's current wind generation portfolio and locations where proposed plants are expected to be built.

The Monte Carlo analysis results in 500 alternative scenarios of system operation simulated by STORM. For a given level of regulation/INC/DEC, the main output is the number of NERC violations that occur. An observation from the results is that there are diminishing returns from adding INC/DEC resources in terms of reducing the number of NERC violations. Over the 500 cases, it would be very expensive to have sufficient resources to guarantee no risk of a NERC violation. Instead, it is more appropriate to choose a threshold level of violations that results in a reasonable cost at a reasonable level of risk of a NERC violation to NorthWestern. Empirically, the recommended appropriate threshold is 1% of cases resulting in NERC violations (or 5 total NERC violations out of the 500 cases). Table 2 summarizes the approximate amount of INC and DEC capacity necessary to reach the 1% NERC violation risk threshold for each load-following event and degree of VER integration. Highlighted cells correspond to events in which the greatest amount of INC and DEC were necessary to reach the 1% NERC violation risk threshold.

Table 2. VER Integration Results Summary

	Load-Following Event Date Time	Test-Year INC/DEC Requirement	Load-Following Capacity Needed to Reach 1% NERC Violation Risk Threshold		
			Scenario A (185MW Planned Wind)	Scenario B (185MW Planned Wind & 320MW New Wind)	Scenario C (185MW Planned Wind & 100MW New Solar)
INC	11/1/16 Hours 18-19	120 MW	**180 MW**	195 MW	**180 MW ***
	12/18/16 Hours 17-18	55 MW	145 MW	140 MW	145 MW *
	9/17/16 Hours 18-19	60 MW	60 MW	115 MW	75 MW
	11/8/16 Hour 5	100 MW	105 MW	190 MW	100 MW
	10/22/16 Hours 17-18	65 MW	95 MW	135 MW	100 MW
	5/27/17 Hours 19-20	50 MW	45 MW	130 MW	45 MW *
	4/5/17 Hours 19-20	60 MW	130 MW	**200 MW**	130 MW *
	11/30/16 Hours 17-18	40 MW	80 MW	135 MW	90 MW
DEC	5/11/17 Hours 23-0	155 MW	**210 MW**	250 MW	**210 MW ***
	2/13/17 Hours 10-11	95 MW	0 MW	205 MW	0 MW
	8/31/16 Hours 22-23	115 MW	175 MW	200 MW	175 MW *
	7/25/16 Hours 22-23	90 MW	50 MW	90 MW	50 MW *
	9/23/16 Hours 16-18	60 MW	**210 MW**	**275 MW**	200 MW
	8/8/16 Hours 21-22	55 MW	165 MW	220 MW	165 MW *
	9/6/16 Hours 21-22	65 MW	60 MW	100 MW	60 MW *
	8/9/16 Hours 22-23	60 MW	160 MW	205 MW	160 MW *

Note: When necessary, linear interpolation and/or extrapolation was used to determine INC/DEC capacity at the 1% risk threshold
** Little to no solar variability during this period, assumed same results as Scenario A*

Due to the limitation of the Monte Carlo analysis to focus on individual INC/DEC events, the VER integration study was used only to determine the additional INC or DEC capacity needed to integrate higher levels of VER, not additional regulation capacity. Although this study does not draw conclusions for additional regulation capacity needed to integrate higher levels of VER, the recommended ±25MW from the Baseline Study took into account the impact that near-term renewable expansion would likely have on NorthWestern’s system. Navigant’s recommendations for the additional load following resources necessary to integrate higher levels of VER are provided in Table 3.

Table 3. Navigant Recommendation for INC and DEC Capacity for VER Integration

VER Integration Scenario	Additional INC Capacity	Additional DEC Capacity
Scenario A: 185MW Planned Wind	60 MW	55 MW
Scenario B: 185MW Planned Wind & 320MW New Wind	80 MW	120 MW
Scenario C: 185MW Planned Wind & 100MW New Solar	60 MW	55 MW

Using the recommended 1% risk threshold, Navigant recommends an additional 60MW INC capacity and 55MW DEC capacity for Scenarios A & C. Despite the added solar capacity in Scenario C, Navigant does not recommend any additional load-following capacity. Many of the most difficult events during the test-year occurred during times of little or no solar activity. Although solar contributes to the variability on the system and increases the need for INC and DEC capacity during certain events, it does not increase the load-following capacity necessary to reach the established risk threshold in the worst-case events from the test-year. However, with only one year of test data and limited historical solar operation in NorthWestern, this is a narrow finding. As more solar is added on the system, NorthWestern should continue to monitor their regulation and load-following needs. With increasing amounts of solar, Navigant expects solar variability will start to drive some of the hardest load-following events.

To integrate 185MW of planned wind and 320MW of new wind as in Scenario B, Navigant recommends an additional 80MW INC capacity and 115MW DEC capacity. In Scenario B, the results show that there is a lot of benefit from the geographic diversity that proportionally lessens the impact of the large amount of incremental wind.

Load Variability Study

Navigant's Load Variability Study allocates frequency regulation and load following generation requirements identified in the VER Baseline Study, described above, for three NorthWestern's customer classes. The allocation methodology complies with the Montana Public Service Commission ("MPSC") Order regarding the allocation of regulation capacity to NorthWestern's customer classes.[4]

The customer classes for which Navigant derived allocation factors include;

- Choice load (Wholesale and Rural Electric Cooperative)
- Non-Choice load (Retail)
- Generator (Wind and Solar)

All generation included in the Generator customer class is located in NorthWestern's BA and part of NorthWestern's resource supply portfolio.[5] Because all generation analyzed over the test-year evaluation period is comprised of wind, allocation factors that Navigant derived are based solely on the variability of wind output data collected during the June 2016 through May 2017 evaluation period. Data was not available for the small solar units located on NorthWestern's system. As such, the Generator class allocation factor should be updated when solar data becomes available. Choice load includes NorthWestern customers that have elected to procure electricity supply from third parties, and electric rural cooperatives. Non-Choice load includes residential, general service (demand and non-demand), street lighting and agriculture customer classes.

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[4] In Order No. 6943e, Docket No. D2008.8.95, the MPSC issued a decision ordering NorthWestern to perform a study to evaluate the allocation of the regulation capacity needs.

[5] All wind facilities except for Spion Kop, which is owned by NorthWestern, are owned by third parties and under long-term contracts with NorthWestern to serve Non-Choice customers. Further, Choice loads in NorthWestern's BA are served by third parties, but these do not include any wind generators in the BA

Methodology and Sample Selection

Navigant allocated load following and frequency regulation requirements derived in the VER Integration Study based on the degree to which each customer class contributes to total BA load variability. For frequency regulation, each of the three class loads was measured via 1-minute intervals and compared to total BA 1-minute changes in load. For load following, class load data was collected and aggregated on a rolling basis over 15-minute intervals to align with the 30-minute INC and DEC events identified in Navigant's analysis of NorthWestern's system between June 2016 and May 2017. All allocation factors are based on Navigant's test-year recommendation for assigning regulation (±25MW) and load-following capacity (120MW INC & 155MW DEC) from Table 1 of the VER Baseline Study.

Because of the availability of a significant amount of 1-minute SCADA pi interval load data, Navigant was able to develop a robust representative load sample for each customer class. The SCADA pi data includes substations that serve Choice and Non-Choice customers located throughout NorthWestern's service territory, thereby accounting for differences in load patterns associated with geographic diversity. Choice load includes a broad mix of customer load types, which ensures the sample captures differences in load patterns and customer demand.

Table 4 presents the percentage of 1-minute data that was available from the data sample collected for each customer class. The sample coverage is based on average class loads collected during the test year. The generation sample is 100 percent as SCADA pi data is collected for all wind generation. The Choice sample is large due to the large number of customers, Choice and REA, that are served directly from transmission substations where SCADA pi data is collected. The Non-Choice sample is smaller due to the elimination of distribution feeders that serve both Choice and Non-Choice and Choice load, and the fewer number of substations serving Non-Choice load that are equipped with SCADA.

Table 4. Load Composition by Customer Class

Load Type	Average MW of Class Load	Percent of BA Load	Average MW of Sample	Sample Coverage
Balancing Area	1,270	100%	1,270	100%
Choice	501	39%	282	56%
Non-Choice	683	54%	183	27%
Generator (Wind and Solar)	90	7%	90	100%

Table 5 presents the Non-Choice sample in terms of the amount of energy consumption for each rate class (Navigant combined NorthWestern's demand and non-demand commercial rate classes). Results confirm the Non-Choice sample composition closely matches total Non-Choice load, thereby ensuring the 1-minute and 15-minute loads contained in load variability readings for the sample is comparable to the total Non-Choice rate class load.

Table 5. Non-Choice Sample Size by Rate Class

	Commercial	Residential	Irrigation	Lighting
Overall System	56%	41%	2%	1%
Non-Choice (Retail) Sample	52%	46%	1%	1%

Class Allocation Factors

Table 6 presents Navigant's allocation of generation assigned to frequency regulation and load following requirements based on recommendations from the Baseline Study for each of the three customer classes. Results indicate that Non-Choice customer load is assigned the largest percentage of regulation capacity, while Generation is assigned the highest percentage of INC and DEC load following capacity. Choice is assigned the least amount of load following and frequency regulation due to the relatively minor change in 1-minute and 15-minute load or output (wind) compared to other customer classes.

Table 6. Class Allocation Factors

Customer Class	Frequency Regulation	Load Following (INC)	Load Following (DEC)
Choice	8%	8%	8%
Non-Choice	55%	38%	34%
Generator (Wind and Solar)	38%	54%	58%

Table 7 presents results from Table 6 when Non-Choice and Generator class data is combined as required for retail cost allocation. Composite allocation factors frequency regulation and load following each exceed 80 percent for the combined Non-Choice and Generator class.

Table 7. Composite Allocation Factors

Customer Class	Frequency Regulation	Load Following	Load Following

Choice	8%	8%	8%
Non-Choice + Generator	92%	92%	92%

1. VARIABLE ENERGY RESOURCE INTEGRATION STUDY

Navigant's Variable Energy Resource (VER) Integration study was conducted for NorthWestern Energy to determine how much regulation and load following resources were needed to meet requirements for Reliability Based Control Standard BAL-001-2 as increasing amounts of VER come online in NorthWestern's balancing area. The purpose of Reliability Based Control Standard BAL-001-2 is to control the interconnection frequency within defined limits. To comply with the standard, balancing authorities including NorthWestern Energy must:

(3) operate such that their Control Performance Standard 1 (CPS1) score is greater than or equal to 100% for each preceding 12 consecutive calendar month period (evaluated monthly); and

(4) operate such that its clock-minute average of reporting ACE does not exceed its clock-minute Balancing Authority ACE Limit (BAAL)[6] for more than 30 consecutive minutes.

To comply with the standard, balancing authorities use a combination of regulation and load-following resources.

For the purposes of this study:

- Regulation is defined as the use of on-line generation equipped with Automatic Generation Control (AGC) which can change output quickly to track the minute-to-minute fluctuations in load.
- Load-following is the use of on-line generation to track the intra- and inter-hour changes in loads. It is split into INC (ramping up a resource) and DEC (ramping down a resource).

In Navigant's proprietary STORM model, a regulation resource is assumed to be capable of ramping up or down its full capacity in a minute, whereas a load following resource takes 15 minutes to ramp to its full INC or DEC capacity.

The Variable Energy Resource Integration study is divided into two Tasks: (1) a baseline analysis to determine the minimum amount of regulation and load following resources needed by NorthWestern to satisfy BAL-001-2 requirements during the test year (July 2016-June 2017), and (2) an analysis to determine the additional load following resources necessary to integrate higher levels of VER (both wind and solar PV) into the NorthWestern BA. To complete Tasks 1 & 2, Navigant used its proprietary STORM model to simulate the sub-hourly operation of NorthWestern's system.

1.1 Methodology for Baseline Study on Test Year

1.1.1 STORM Model Operation

Navigant's STORM model is a sub-hourly system operation model that simulates the system's ability to load follow and maintain frequency regulation on a minute-by-minute basis. In an iterative process, STORM can be used to determine the amount of regulation and load following resources needed in order to avoid NERC violations (in accordance with BAL-001-2) throughout the study period. The model uses

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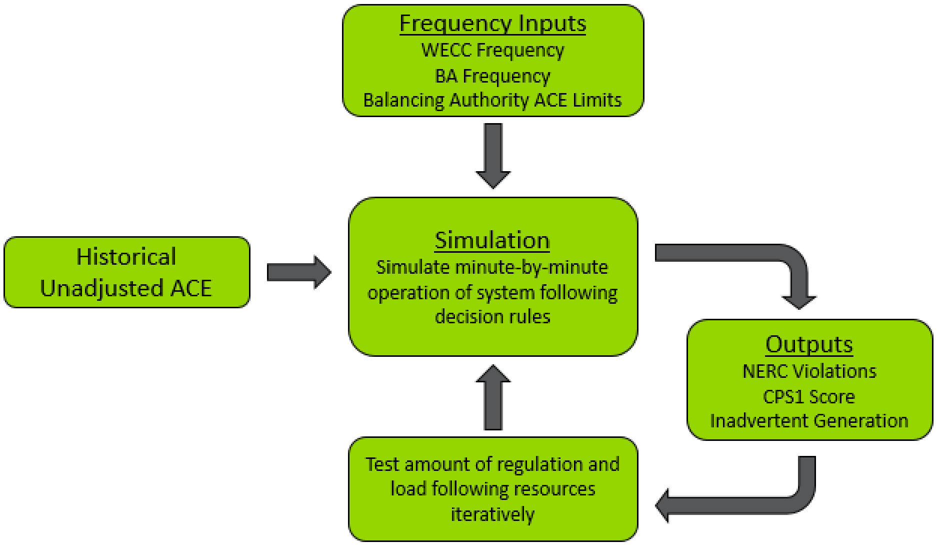
[6] Balancing Authority ACE Limits (BAALs) are derived from NorthWestern's frequency bias and the measured & scheduled interconnection frequency in accordance with BAL-001-2.

two classes of units which are modeled generically, (1) regulation resources which are on automatic generation control (AGC) and are used to balance rapid shifts in ACE, and (2) load following resources which are called upon within 15 minutes of being needed.

A schematic of the STORM model is shown in Figure 2. The inputs to the STORM model include the historical unadjusted ACE as described in Section 1.1.2, the WECC Interconnection frequency, and the Balancing Authority ACE Limits (BAALs). The BAALs are determined according to BAL-001-2 and are derived from the frequency bias for the BA, the measured interconnection frequency, the scheduled interconnection frequency, and the targeted frequency bounds for the Western Interconnection.

Figure 2. STORM Model Schematic

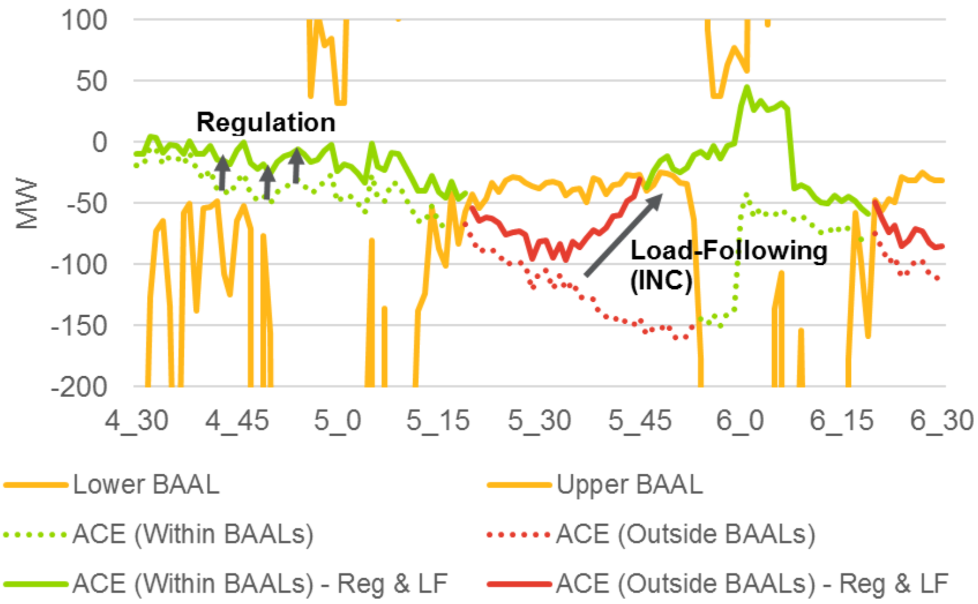


The operation of the generic regulation and load following units is governed by a set of backward looking decision rules. These rules were developed with NorthWestern Energy such that they reflect how their system is actually operated in response to NERC events and changes in ACE.

- If the ACE is within a “dead-zone” defined as ±10MW, no regulation is dispatched.
- If the ACE is outside the dead-zone, regulation resources are used to keep the system within the dead-zone.
- If the ACE is outside the BAALs for 15 consecutive minutes then load following resources are dispatched.
    - Load following resource can ramp to full output in 15 minutes.
    - The amount of load following called for a given event is the minimum of (a) the amount of load-following resources available and (b) the amount needed to return the ACE to the halfway point between the BAAL and the dead-band.
    - Load following event is terminated 20 minutes after the ramp is completed.

The implementation of these rules is shown graphically in Figure 3. The dotted line is NorthWestern Energy’s unadjusted ACE which does not take into account any corrective actions from regulation or load-following resources, and the solid line incorporates the STORM simulated corrective actions from regulation and load-following. From hours four to five, you can see how the regulation resource is dispatched to decrease the magnitude of ACE and return it to within the dead-band of +10MW. In hour five, regulation is insufficient to keep the ACE from falling below the lower BAAL. After the 15-minutes below the lower BAAL, load-following resources are called upon to get NorthWestern out of the NERC event before the 30-minute limit is reached.

Figure 3. STORM Operation: NorthWestern Energy 11/8/16



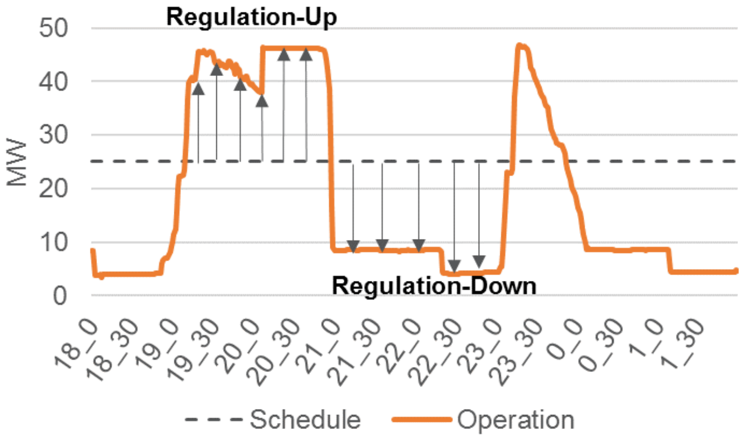
Source: Navigant; data from NorthWestern Energy

1.1.2 Model Input: Unadjusted ACE

NorthWestern Energy provided Navigant with historical ACE data for the test year on a 1-minute basis. This ACE, however, already accounted for the corrective actions taken by NorthWestern Energy including those from regulation and load-following resources. These corrective actions had to be “backed-out” of the ACE, so that Navigant’s STORM model could simulate how different levels of regulation and load-following resources correct the ACE in accordance with the decision rules outlined in Section 1.1.1.

Regulation was backed-out of the ACE using the historical operation and schedule of NorthWestern’s regulation resource, Dave Gates Generating Station (DGGS). The difference between the operation and the schedule was assumed to be the regulation output of DGGS. As shown in Figure 4 the schedule for DGGS on the last few hours of May 6, 2016 was 25MW, while the output fluctuated between approximately 5MW and 45MW. The amount of regulation, ranging from -20MW to +15MW, was then subtracted from the ACE on a minute-by-minute basis resulting in an ACE prior to corrective actions from regulation.

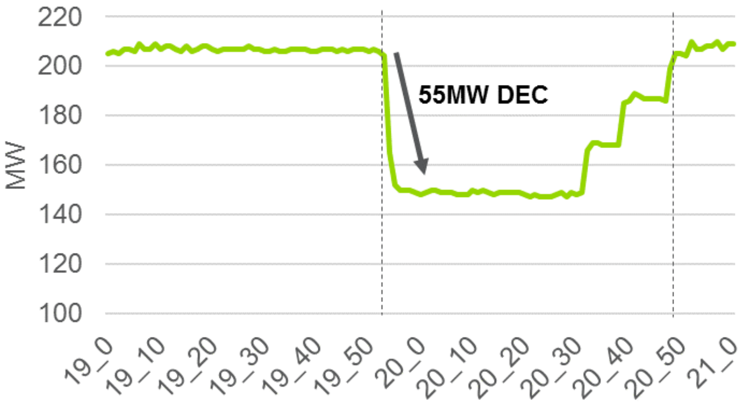
Figure 4. DGGS Operation and Schedule (5/6/2017-5/7/2017)



Source: Navigant; data from NorthWestern Energy

Load-following was backed-out of the ACE using the historical operation of NorthWestern's load-following resources in a similar manner. NorthWestern provided Navigant with a log describing all instances throughout the test year where control operators called on load-following resources to correct the ACE. One such event is depicted in Figure 5, which shows hydro resource Crooked Falls DEC approximately 55MW over the course of an hour on May 5, 2017. If Crooked Falls was not called to ramp down its output, it can be assumed that generation would have remained stable at approximately 205MW as seen on either side of the vertical dotted lines. Within the bounds of the dotted-lines, Crooked Falls output was subtracted from the baseline generation of 205MW and subsequently added back into the ACE on a minute-by-minute basis. This gives the ACE prior to corrective actions from load-following.

Figure 5. Load Following by Crooked Falls (5/5/2017)



Source: Navigant; data from NorthWestern Energy

1.2 Test Year Baseline Results

1.2.1 Results

Over the test year, the main criteria for the amount of needed regulation and load following resources is the minimum amount needed to avoid all NERC violations and maintain CPS1 scores at an acceptable level. However, this is not the only metric that should be monitored and maintained in order to maintain a reliable system. Navigant also monitored the number of times that a set of resources led to an event in which load following was required, the CPS1 score trend, and the amount of inadvertent generation. Maintaining these metrics is important for Northwestern to maintain a buffer so that reliability is not expectedly threatened if future events are more severe than what occurred in the test year.

For the study, Navigant analyzed NorthWestern's system operation at 6 different levels of regulation capacity: 0MW, ±10MW, ±15MW, ±25MW, ±30MW and ±40MW. For each level of regulation capacity, Navigant determined the corresponding INC and DEC capacity needed to prevent a NERC violation throughout the test year by focusing analysis on the hardest INC and DEC events. Once the regulation capacity and corresponding INC and DEC capacities were determined, Navigant ran STORM for the entire test year to analyze the marginal benefits of adding regulation capacity. The regulation capacity and corresponding INC and DEC capacities for each of the simulation runs is shown in Table 8.

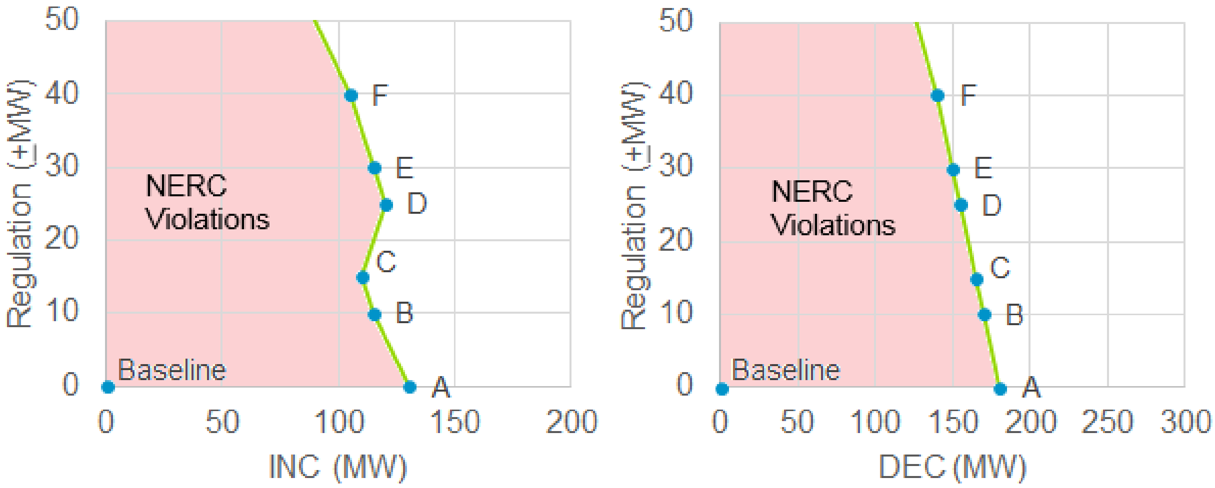
Table 8. STORM Regulation and Load Following Parameters

Case	Regulation Capacity	INC Capacity	DEC Capacity
Baseline	±0 MW	0 MW	0 MW
A	±0 MW	130 MW	180 MW
B	±10 MW	115 MW	170 MW
C	±15 MW	110 MW	165 MW
D	±25 MW	120 MW	155 MW
E	±30 MW	115 MW	150 MW
F	±40 MW	105 MW	140 MW

Note: ±X MW of regulation capacity suggests X MW regulation-up and X MW regulation-down

The amount of regulation capacity and the amount of load-following capacity necessary to avoid NERC violations throughout the test year are dependent on each other and are governed by the most difficult NERC events during the test-year. As the amount of regulation capacity increases, the amount of load-following necessary to avoid NERC violations tends to decrease, however, there are non-linearities which arise due to the irregular shape of the BAALs in the NERC events analyzed. Figure 6 shows the results given in Table 8 graphically. It shows the INC (left) and DEC (right) capacity needed to avoid NERC violations during the test-year at different levels of regulation capacity. Any combination of INC/DEC and regulation capacity that falls within the red zone on the plots would result in at least 1 NERC violation.

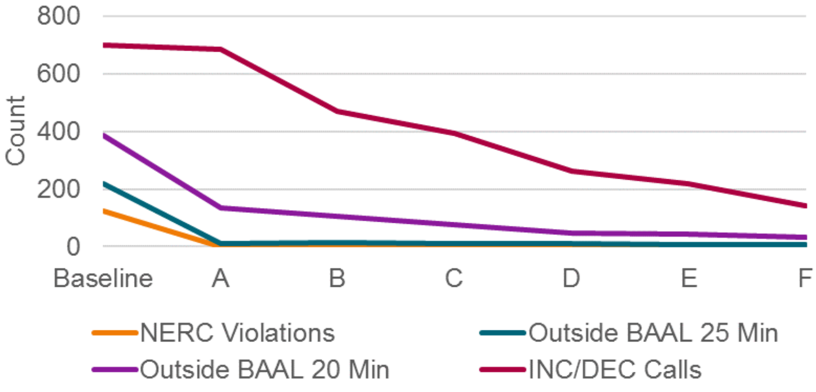
Figure 6. Load-Following Capacity Needed to Avoid NERC Violations During Test-Year at Different Levels of Regulation Capacity



Source: Navigant's NorthWestern Energy STORM Results

For each simulation of the test-year, STORM outputs the number of NERC violations (which by design is zero in every case except the Baseline), the number of INC/DEC calls, and the number of near-NERC violations, defined as instances when the ACE was outside the BAALs for 20 or 25 consecutive minutes. As can be seen in Figure 7, the number of INC/DEC calls decreases dramatically with increasing regulation capacity. The risk of choosing a level of regulation with significantly higher INC/DEC calls is that it means that there is overall higher risk to Northwestern of a NERC violation if a response to an event has an issue.

Figure 7. NERC Violations, Near-NERC Violations and INC/DEC Calls by Case



Source: Navigant's NorthWestern Energy STORM Results

STORM also outputs NorthWestern Energy’s CPS1 score. CPS1 assigns NorthWestern Energy a share of the responsibility for control of steady-state interconnection frequency and is calculated using the minute-by-minute interconnection frequency and NorthWestern’s frequency bias and ACE:

$$CPS1 = (2 - CF) * 100\%$$

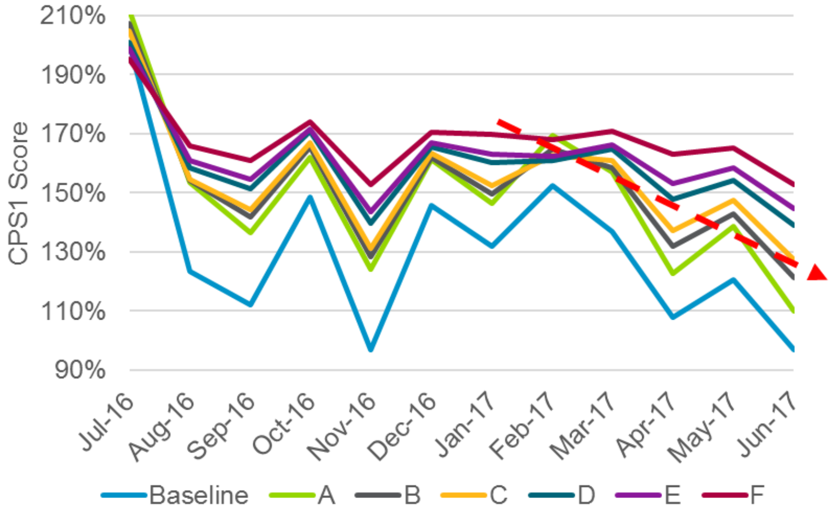
$$CF = \frac{CF_{12-month}}{\varepsilon_1^2}$$

$$CF_{clock-minute} = \left[\left(\frac{ACE}{-10B} \right)_{clock-minute} \times \Delta F_{clock-minute} \right]$$

where
CF is the compliance factor;
ε_1 is the targeted frequency bound for the Western Interconnection;
B is the balancing authority frequency bias; and
ΔF is the difference between the actual and scheduled interconnection frequency

The monthly simulated CPS1 scores for NorthWestern Energy are shown in Figure 8 for each case. NorthWestern Energy’s actual 2017 CPS1 scores exhibit the same degradation observed in the simulated CPS1 scores lending confidence to STORM’s ability to reflect actual system operation. The lesser the amount of regulation capacity the steeper the decline in CPS1 scores. Although this trend occurs at all levels of regulation, it is especially pronounced in cases with less than ±25MW of regulation capacity (cases A-C), where NorthWestern may soon be at risk of violating the CPS1 requirements under BAL-001-2 if these trends continued.

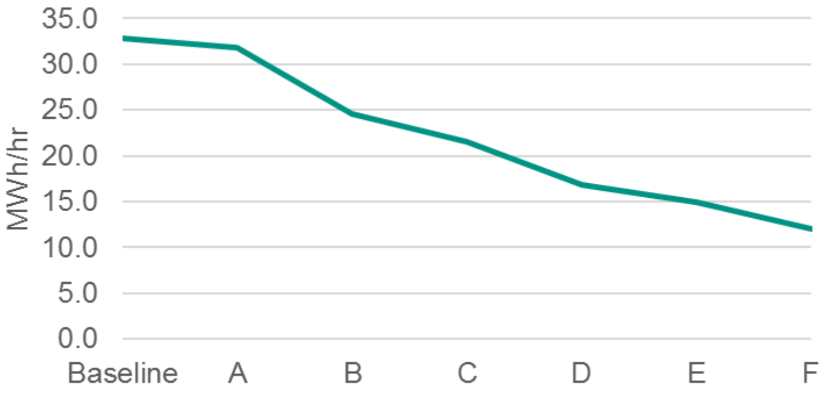
Figure 8. STORM Simulated Monthly CPS1 Scores by Case



Source: Navigant’s NorthWestern Energy STORM Results

Lastly, STORM outputs the inadvertent interchange, which is the net imbalance between NorthWestern Energy and the interconnection. As expected, the amount of inadvertent decreases with increasing regulation capacity as shown in Figure 9.

Figure 9. Inadvertent by Case



Source: Navigant's NorthWestern Energy STORM Results

1.2.2 Recommendation

Navigant recommends NorthWestern Energy procures +25MW of regulation capacity given the aggregate benefits to CPS1 score, inadvertent generation, the number of INC/DEC calls, and the number of near-NERC violations.

As shown in Table 9, with +25MW of regulation capacity, there are significantly less INC/DEC calls needed, providing both an economic and systems operation benefit to NorthWestern Energy. There are also far fewer instances where NorthWestern exceeded the BAALs for 20 or 25 consecutive minutes, thus mitigating the risk of having a NERC violation.

Table 9. Test Year Results and Recommendation

	Regulation	±0 MW	±0 MW	±10 MW	±15 MW	±25 MW	±30 MW	±40 MW
	INC	0 MW	130 MW	115 MW	110 MW	120 MW	115 MW	105 MW
	DEC	0 MW	180 MW	170 MW	165 MW	155 MW	150 MW	140 MW
	NERC Violations	123	0	0	0	0	0	0
Outside BAALs	25 Min	218	12	14	12	10	7	7
	20 Min	385	135	107	78	46	45	34
	15 Min	700	687	469	393	263	217	141
	CPS1 Score	131%	149%	152%	154%	159%	162%	167%
	Inadvertent (MWh/hr)	32.9	31.9	24.5	21.6	16.8	15.0	12.1

Recommendation

The degradation in CPS1 scores at ±25MW of regulation is much less severe, creating a greater buffer between NorthWestern's CPS1 scores and the minimum allowable CPS1 under BAL-001-02. This is especially important as expected wind and solar additions on the system will likely put downward pressure on CPS1 scores. The regulation capacity also provides the added benefit of contributing toward NorthWestern Energy's Frequency Response Reserve (FRR) requirements.

To realize these benefits to CPS1 score, inadvertent generation, the number of INC/DEC calls, and the number of near-NERC violations, it is necessary for NorthWestern to procure both 25MW of regulation-up and 25MW of regulation-down capacity. Regulation resources, which are on automatic generation control (AGC), are used to balance rapid shifts in ACE and are intended to prevent the ACE from drifting either too positive or too negative. This minute-to-minute variability is relatively symmetric, and if only regulation-up capacity were procured to balance these minute-to-minute shifts in ACE, CPS1 scores would fall, inadvertent would increase and there would be significantly more instances when NorthWestern would need to call upon its DEC capacity.

1.3 Methodology for VER Integration Study

For Task 2, Navigant conducted an analysis to determine the additional load following resources necessary to integrate higher levels of VER (both wind and solar PV) into the NorthWestern Energy balancing area. Navigant assessed three scenarios of renewable integration (A) 185MW of planned wind, (B) 185MW of planned wind & 320MW of new wind and (C) 185MW of planned wind & 100MW of new solar. These scenarios, which are summarized in Table 10, were chosen to reflect the near-term expected builds in NorthWestern Energy's balancing area and the potential for significant quantities of both wind and solar to be added to the system beyond that.

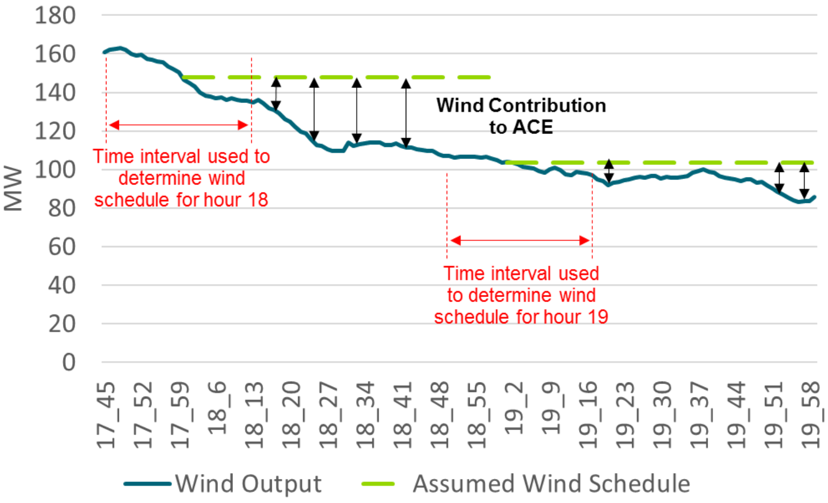
Table 10. VER Integration Scenarios

Scenario	Description
A	259 MW of existing wind + 185 MW of planned wind
B	259 MW of existing wind + 185 MW of planned wind + 320 MW of new wind
C	259 MW of existing wind + 185 MW of planned wind + 100 MW of new solar

To study these scenarios with higher levels of VER than in the test year, Navigant used Monte Carlo methods to simulate hundreds of draws of alternate renewable operation with historical wind and solar data from NREL. The draws of alternate renewable operation were layered on top of (1) the three hardest INC and DEC events per season, and (2) the next five hardest INC and DEC events regardless of season during the test year. This set of events was chosen to give a wide range of events that required significant action by NorthWestern during the test year on which the impacts of additional variable generation can be layered. It was necessary to capturing both the worst-case scenarios and any potential impacts of seasonality.

For each INC and DEC event analyzed, the wind contribution to NorthWestern's ACE is first backed-out from the unadjusted ACE described in Section 1.1.2. The wind contribution to ACE is the difference between wind output and schedule. Navigant assumes the schedule to be the average wind output for the 15 minutes prior to and 15 minutes following the start of the hour, as depicted in the INC event on November 1, 2016 shown in Figure 10.

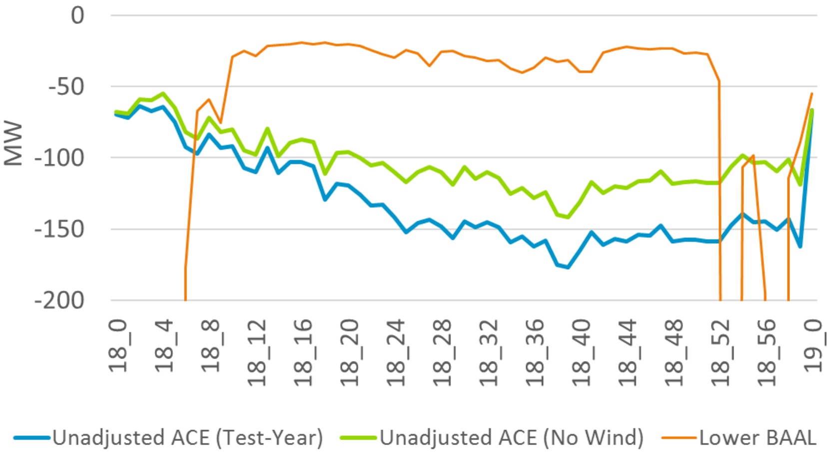
Figure 10. NorthWestern Wind Operation (11/1/2016)



Source: Navigant; data from NorthWestern Energy

For this event, wind had a significant and quick decline in generation, and subsequently was contributing to increases in the ACE magnitude during this period. Figure 11 shows the unadjusted ACE with (blue) and without (green) the contribution from NorthWestern's wind plants during the test-year. As expected, when NorthWestern's wind variability is removed, the magnitude of the unadjusted ACE is smaller.

Figure 11. Wind Contribution to ACE (11/1/2016)



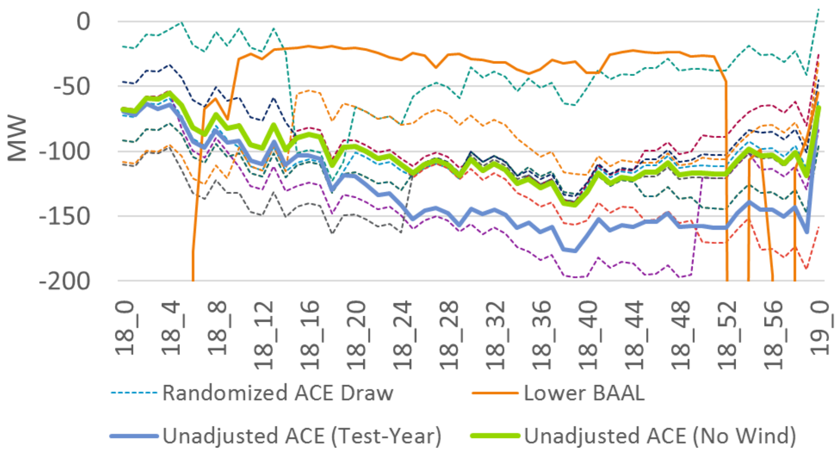
Source: Navigant; data from NorthWestern Energy

Once the contribution from renewables is backed-out from the test-year unadjusted ACE, NREL Wind and Solar Integration Data Sets are used to simulate hundreds of draws of alternate renewable operation. A key aspect of these draws is that they are real historical operation of the assumed resources including the impacts of regional weather and geographic diversity. This approach ensures that the cross-correlation of the variable generation is considered by randomizing the time period being drawn and pulling the operation of each resource from this period.

Although the time period is randomized in each draw, it is limited to the same season as the INC/DEC event when layering on wind, and limited to the same season and hour as the INC/DEC event when layering on solar. This is done to ensure that the draw is a reasonable representation of potential operation of the unit. For example, if an event occurs at night, it is not reasonable to allow any solar generation or variability.

For each alternate draw of renewable operation, the ACE contribution from the renewables is determined using the process depicted in Figure 10. Each alternate draw consists of 259MW of existing wind capacity in addition to the incremental renewable capacity depending on the Scenario. The ACE contribution from the alternate draw of renewable operation is then layered on top of the unadjusted ACE (no wind) shown in Figure 12. In some draws, wind is contributing less to ACE than it had during the test-year, and in others, wind is contributing more to the ACE than it had during the test-year.

Figure 12. Randomized Draws of Alternate Wind Operation (11/1/2016)



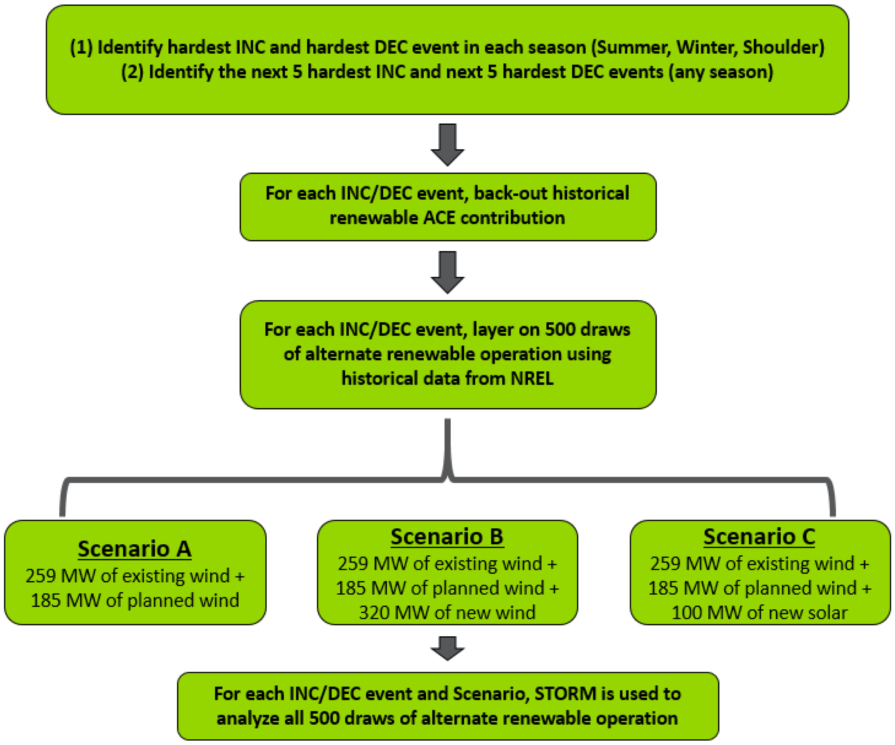
Source: Navigant; data from NREL Wind Integration Data Sets and NorthWestern Energy

The NREL datasets include over five years of historical 5-minute wind data (and corresponding estimated power production) at thousands of wind sites and one year of historical solar data from four sites in Montana. Wind sites were selected to be consistent with NorthWestern Energy's current wind generation portfolio and locations where proposed plants are expected to be built as shown in Table 11. A schematic summarizing Navigant's VER Integration study approach is shown in Figure 13.

Table 11. NREL Data Summary for Scenario Analysis of VER Integration

<table>
<tr><th colspan="4">Scenario</th><th>NREL Data Site Latitude/Longitude</th><th>MW</th><th>Plant Notes</th></tr>
<tr><td rowspan="5">Existing Wind</td><td rowspan="8">Scenario A</td><td rowspan="11">Scenario B</td><td rowspan="8">Scenario C</td><td>(46.59, -109.77)</td><td>165</td><td>Judith Gap, Musselshell 1 & 2, Two Dot</td></tr>
<tr><td>(47.34, -110.63)</td><td>40</td><td>Spion Kop</td></tr>
<tr><td>(47.67, -112.33)</td><td>35</td><td>Fairfield, Greenfield</td></tr>
<tr><td>(46.41, -110.33)</td><td>10</td><td>Gordon Butte</td></tr>
<tr><td>(47.50, -111.43)</td><td>9</td><td>Horseshoe Bend</td></tr>
<tr><td></td><td>(45.72, -110.28)</td><td>80</td><td>Crazy Mountain</td></tr>
<tr><td></td><td>(45.87, -109.48)</td><td>80</td><td>Stillwater</td></tr>
<tr><td></td><td>(45.91, -110.12)</td><td>25</td><td>Big Timber</td></tr>
<tr><td></td><td></td><td></td><td>(45.87, -109.48)</td><td>160</td><td>Project 300, Project 327-328</td></tr>
<tr><td></td><td></td><td></td><td>(47.13, -106.89)</td><td>80</td><td>Project 164</td></tr>
<tr><td></td><td></td><td></td><td>(46.40, -109.12)</td><td>80</td><td>Project 335</td></tr>
<tr><td></td><td></td><td></td><td rowspan="4">Scenario C</td><td>(45.05, -104.65)</td><td>25</td><td>Generic Solar 1</td></tr>
<tr><td></td><td></td><td></td><td>(45.25, -104.15)</td><td>25</td><td>Generic Solar 2</td></tr>
<tr><td></td><td></td><td></td><td>(45.25, -104.65)</td><td>25</td><td>Generic Solar 3</td></tr>
<tr><td></td><td></td><td></td><td>(45.35, -104.15)</td><td>25</td><td>Generic Solar 4</td></tr>
</table>

Figure 13. VER Integration Study: Task 2 Flow Diagram



(1) Identify hardest INC and hardest DEC event in each season (Summer, Winter, Shoulder)
(2) Identify the next 5 hardest INC and next 5 hardest DEC events (any season)

For each INC/DEC event, back-out historical renewable ACE contribution

For each INC/DEC event, layer on 500 draws of alternate renewable operation using historical data from NREL

Scenario A
259 MW of existing wind +
185 MW of planned wind

Scenario B
259 MW of existing wind +
185 MW of planned wind +
320 MW of new wind

Scenario C
259 MW of existing wind +
185 MW of planned wind +
100 MW of new solar

For each INC/DEC event and Scenario, STORM is used to analyze all 500 draws of alternate renewable operation

The Monte Carlo analysis results in 500 alternative scenarios of system operation simulated by STORM. For a given level of regulation/INC/DEC, the main output is the number of NERC violations that occur. An observation from the results is that there are diminishing returns from adding INC/DEC resources in terms of reducing the number of NERC violations. Over the 500 cases, it would be very expensive to have sufficient resources to guarantee no risk of a NERC violation. Instead, it is more appropriate to choose a threshold level of violations that results in a reasonable cost at a reasonable level of risk of a NERC violation to NorthWestern. Empirically, the recommended appropriate threshold is 1% of cases resulting in NERC violations (or 5 total NERC violations out of the 500 cases).

1.4 VER Integration Results

1.4.1 Results

Due to the limitation of the Monte Carlo analysis to focus on individual INC/DEC events, the VER integration study was used only to determine the additional INC or DEC capacity needed to integrate higher levels of VER, not additional regulation capacity. Although this study does not draw conclusions for additional regulation capacity needed to integrate higher levels of VER, the recommended ±25MW from Task 1 took into account the impact that near-term renewable expansion would likely have on NorthWestern's system.

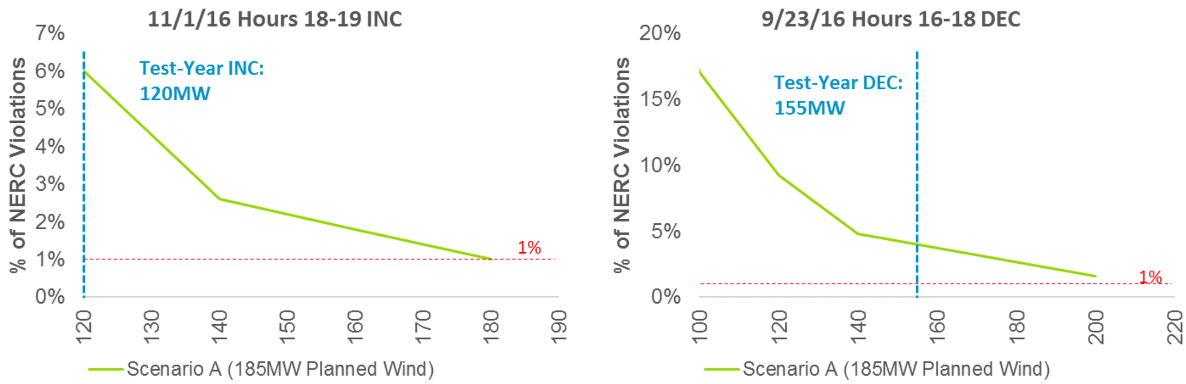
For each VER scenario and INC/DEC event shown in Table 12, STORM was used to analyze 500 draws of ACE and output the percent of NERC violations (per 500 draws) at different levels of INC or DEC capacity with the amount of regulation capacity being held constant at the Navigant recommended level of ±25MW. Detailed results for all Scenarios and events are provided in APPENDIX A.

Table 12. VER Integration INC/DEC Events Analyzed

Description	INC Event Date Time	DEC Event Date Time
Hardest Test-Year Shoulder Season Event	11/1/16 Hours 18-19	5/11/17 Hours 23-0
Hardest Test-Year Winter Season Event	12/18/16 Hours 17-18	2/13/17 Hours 10-11
Hardest Test-Year Summer Season Event	9/17/16 Hours 18-19	8/31/16 Hours 22-23
Next 5 Hardest Test-Year Events Regardless of Season	11/8/16 Hour 5	7/25/16 Hours 22-23
	10/22/16 Hours 17-18	9/23/16 Hours 16-18
	5/27/17 Hours 19-20	8/8/16 Hours 21-22
	4/5/17 Hours 19-20	9/6/16 Hours 21-22
	11/30/16 Hours 17-18	8/9/16 Hours 22-23

Figure 14 shows the Scenario A (185MW planned wind) results for the INC and DEC event in which the probability of NERC violations was greatest. A reference line is provided at the 1% probability threshold for a NERC violation. During the test-year, 120MW INC capacity was needed to avoid all NERC violations. As can be seen in Figure 14, 180MW INC was needed to reduce the probability of a NERC violation to the 1% threshold.

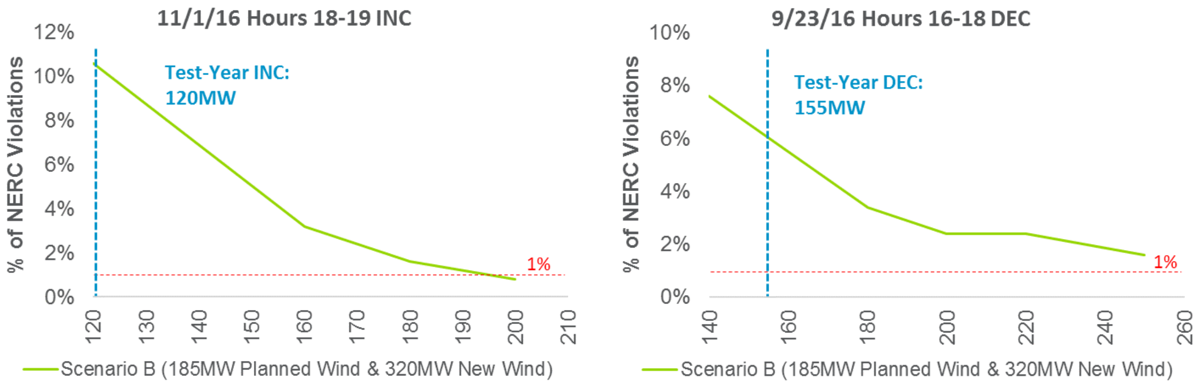
Figure 14. Scenario A VER Integration Results – Percent NERC Violations



Source: Navigant STORM Results

Figure 15 shows the Scenario B (185MW planned wind & 320MW new wind) results for the same two load-following events. As expected, with additional wind on the system there is a higher percentage of NERC violations at the same levels of INC and DEC. For example, at the level of INC needed during the test-year to avoid all NERC violations (120MW), there is a 6% chance of a NERC violation in Scenario A compared to a 10% chance of a NERC violation in Scenario B. The increase in NERC violations, however, is slightly less evident at higher levels of INC and DEC. Although there is 320MW more wind capacity in Scenario B relative to Scenario A, the added geographical diversity of wind resources lessens the impact on the ACE and subsequently the percentage of NERC violations.

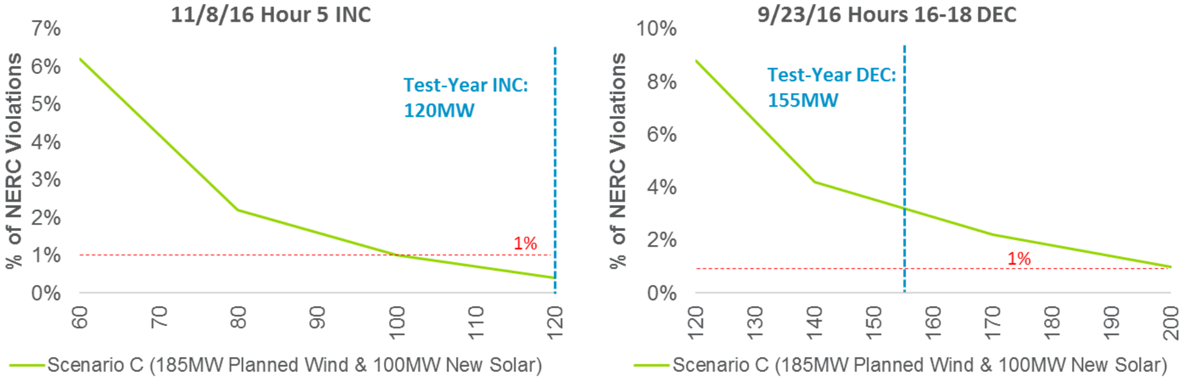
Figure 15. Scenario B VER Integration Results – Percent NERC Violations



Source: Navigant STORM Results

The results for two load-following events in Scenario C (185MW planned wind & 100MW new solar) are provided in Figure 16. The additional solar capacity in Scenario C relative to Scenario A had no impact on the levels of INC and DEC capacity needed to reach the 1% threshold. In many cases, the load-following events analyzed occurred at night when solar variability would be a non-issue. The added solar, however, is still contributing to the overall variability on the system and increases the need for INC and DEC capacity during certain load-following events.

Figure 16. Scenario C VER Integration Results – Percent NERC Violations



Source: Navigant STORM Results

Table 13 summarizes the approximate amount of INC and DEC capacity necessary to reach the 1% NERC violation risk threshold for each load-following event and degree of VER integration. Highlighted cells correspond to events in which the greatest amount of INC and DEC were necessary to reach the 1% NERC violation risk threshold.

Table 13. VER Integration Results Summary

	Load-Following Event Date Time	Test-Year INC/DEC Requirement	Load-Following Capacity Needed to Reach 1% NERC Violation Risk Threshold		
			Scenario A (185MW Planned Wind)	Scenario B (185MW Planned Wind & 320MW New Wind)	Scenario C (185MW Planned Wind & 100MW New Solar)
INC	11/1/16 Hours 18-19	120 MW	**180 MW**	195 MW	**180 MW ***
	12/18/16 Hours 17-18	55 MW	145 MW	140 MW	145 MW *
	9/17/16 Hours 18-19	60 MW	60 MW	115 MW	75 MW
	11/8/16 Hour 5	100 MW	105 MW	190 MW	100 MW
	10/22/16 Hours 17-18	65 MW	95 MW	135 MW	100 MW
	5/27/17 Hours 19-20	50 MW	45 MW	130 MW	45 MW *
	4/5/17 Hours 19-20	60 MW	130 MW	**200 MW**	130 MW *
	11/30/16 Hours 17-18	40 MW	80 MW	135 MW	90 MW
DEC	5/11/17 Hours 23-0	155 MW	**210 MW**	250 MW	**210 MW ***
	2/13/17 Hours 10-11	95 MW	0 MW	205 MW	0 MW
	8/31/16 Hours 22-23	115 MW	175 MW	200 MW	175 MW *
	7/25/16 Hours 22-23	90 MW	50 MW	90 MW	50 MW *
	9/23/16 Hours 16-18	60 MW	**210 MW**	**275 MW**	200 MW
	8/8/16 Hours 21-22	55 MW	165 MW	220 MW	165 MW *
	9/6/16 Hours 21-22	65 MW	60 MW	100 MW	60 MW *
	8/9/16 Hours 22-23	60 MW	160 MW	205 MW	160 MW *

Note: When necessary, linear interpolation and/or extrapolation was used to determine INC/DEC capacity at the 1% risk threshold
** Little to no solar variability during this period, assumed same results as Scenario A*

As expected, in nearly all events, more INC or DEC capacity was needed in Scenario B than in Scenario A to reach the 1% threshold of NERC violation risk due to the added wind variability. Relative to the 120MW INC needed to avoid all NERC violations during the test-year, 60MW more INC capacity is needed in Scenario A to reach the 1% threshold. Despite an additional 320MW of new wind in Scenario B, only an additional 20MW INC was necessary to reach the same risk threshold.

The explanation is that geographic diversity lessened the impact of the large amount of incremental wind. To confirm this, Navigant analyzed a scenario in which the 320MW of new wind in Scenario B is all located near Judith Gap, NorthWestern's largest wind plant, rather than at the locations specified in Table 11. As expected, a significant amount more INC capacity was necessary to reach the 1% NERC violation risk threshold in the three load-following events analyzed, as shown in Table 14.

Without the geographical diversity, 320MW, or 200MW more INC capacity than that needed in the test-year to avoid all NERC violations, was needed to reach the same risk threshold as in Scenario A. This is more in line with proportional scaling as Scenario B has almost three times the incremental wind capacity than that of Scenario A (505MW incremental wind vs. 185MW incremental wind) and needs approximately three times the incremental INC capacity above the test-year baseline to reach the 1% risk threshold (+200MW INC vs. +60MW INC).

Table 14. Geographical Diversity Impact Results Summary

Date Time	Test-Year INC/DEC Requirement	Load-Following Capacity Needed to Reach 1% NERC Violation Risk Threshold	
		Scenario B	Scenario B No Geographical Diversity
11/1/16 Hours 18-19	120 MW	195 MW	260 MW
11/8/16 Hour 5	100 MW	190 MW	270 MW
4/5/17 Hours 19-20	60 MW	200 MW	320 MW

Note: When necessary, linear interpolation and/or extrapolation was used to determine INC/DEC capacity at the 1% risk threshold

1.4.2 Recommendation

Navigant's recommendations for the additional load following resources necessary to integrate higher levels of VER are provided in Table 15.

Table 15. Navigant Recommendation for INC and DEC Capacity for VER Integration

VER Integration Scenario	Additional INC Capacity	Additional DEC Capacity
Scenario A: 185MW Planned Wind	60 MW	55 MW
Scenario B: 185MW Planned Wind & 320MW New Wind	80 MW	120 MW
Scenario C: 185MW Planned Wind & 100MW New Solar	60 MW	55 MW

In order to develop our recommendation, we first identified 1% as a reasonable percent threshold for the acceptable risk of having a NERC violation. NorthWestern Energy should assume some risk, however, setting the threshold much lower would result in unrealistic levels of INC/DEC. Also, the incremental benefit in the reduction of NERC violation risk tends to drop-off around 1%.

In Scenario B, the results show that there is a lot of benefit from the geographic diversity that proportionally lessens the impact of the large amount of incremental wind. This is not unexpected, however integrating 320MW of new wind in addition to the 185MW of planned wind deviates from the current system much more significantly than in Scenario A. Navigant believes this gives greater uncertainty to the impact the renewables will have on system reliability and further justifies the use of a conservative 1% threshold.

Using the recommended risk threshold, Navigant recommends an additional 60MW INC capacity and 55MW DEC capacity for Scenarios A & C. Despite the added solar capacity in Scenario C, Navigant does not recommend any additional load-following capacity. Many of the most difficult events during the test-year occurred during times of little or no solar activity. Although solar contributes to the variability on the system and increases the need for INC and DEC capacity during certain events, it does not increase the load-following capacity necessary to reach the established risk threshold in the worst-case events from the test-year. However, with only one year of test data and limited historical solar operation in NorthWestern, this is a narrow finding. As more solar is added on the system, NorthWestern should continue to monitor their regulation and load-following needs. To integrate 185MW of planned wind and 320MW of new wind as in Scenario B, Navigant recommends an additional 80MW INC capacity and 115MW DEC capacity.

2. LOAD VARIABILITY STUDY

The Load Variability phase of the Study allocates frequency regulation and load following generation requirements identified in the Baseline Study to three of NorthWestern's customer classes within its balancing area (BA). Navigant's allocation methodology complies with the Montana Public Service Commission ("MPSC") Order regarding the allocation of regulation capacity to NorthWestern's customer classes.[7]

The customer classes for which Navigant derived allocation factors include;

- Choice load (Wholesale and Rural Electric Cooperatives)
- Non-Choice load (Retail)
- Generator (Wind and Solar)

All generation included in the Generator class is located in NorthWestern's BA and part of NorthWestern's supply portfolio.[8] All Generator data is wind as no solar data was available for the small solar units located on NorthWestern's system. Because all generation analyzed over the test-year evaluation period is comprised solely of wind generation, allocation factors that Navigant derived are based on the variability of wind output data collected during the June 2016 through May 2017 evaluation period. However, results presented in this study are intended to apply to all third-party generators located within NorthWestern's BA.[9]

Choice load includes NorthWestern customers that have elected to procure electricity supply from third parties, and electric rural cooperatives - each must obtain these services under NorthWestern's wholesale tariffs for frequency regulation and load following.

2.1 Load Variability Study Methodology

Navigant allocated load following and frequency regulation requirements based on the degree to which each customer class contributes to total BA load variability. For frequency regulation, class load was measured via 1-minute intervals and compared to total BA 1-minute changes in load. For load following, class load data was collected and aggregated on a rolling basis over 15-minute intervals to align with the 30-minute INC and DEC events identified in Navigant's STORM simulation analysis of NorthWestern's system. All allocation factors presented in this section are based on Navigant's test-year recommendation for regulation (±25MW) and load-following capacity (120MW INC & 155MW DEC) from the Baseline Study.

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[7] In Order No. 6943e, Docket No. D2008.8.95, the MPSC issued a decision ordering NorthWestern to perform a study to evaluate the allocation of the regulation capacity needs.

[8] All wind facilities except for Spion Kop, which is owned by NorthWestern, are owned by third parties and under long-term contracts with NorthWestern to serve Non-Choice customers. Further, Choice loads in NorthWestern's BA are served by third parties, but these do not include any wind generators in the BA

[9] The Generator class allocation factor should be updated when solar data becomes available.

2.1.1 Allocation Methodology

Navigant developed load following and frequency regulation allocation factors based on the load variability for Choice, Non-Choice and Generation customer classes. Choice load includes mostly large industrial and commercial customers that purchase power supply from third parties, plus Rural Electric Cooperative load. Non-Choice includes customers taking full retail service from NorthWestern; mostly residential and commercial customers taking service under NorthWestern's primary and secondary General Service tariffs. Non-Choice load also includes customers receiving service under NorthWestern's Agricultural and Street Lighting tariffs.

Navigant allocated NorthWestern's regulating resources based on the relative contribution of load variability from each customer class, in percent, during 1-minute and 15-minute intervals when frequency regulation and load following service is required. For frequency regulation, all hours of the year, except for intervals when INC or DEC events occurred, were analyzed, as frequency regulation service is needed on a continuous basis. For load following, only those intervals when INC or DEC were predicted to be needed by Navigant's STORM model (262 events throughout the test-year) to meet RBC requirements were analyzed.

Navigant derived 1-minute and 15-minute load variability by obtaining a representative sample of loads and generation output for each customer class. The Choice and Non-Choice samples include a wide dispersion of loads across NorthWestern's service territory to ensure they account for geographic diversity. The load samples were then scaled to represent the entire class load. Navigant developed class allocation factors based on the percent contribution of the scaled load variability to the total balancing 1-minute and 15-minute load variation over the test-year evaluation periods. The resulting percentages were then applied to the recommended levels of regulation and load-following capacity from the Baseline Study to determine the amount of generation capacity allocated to each customer class in MW for frequency regulation and load following.

2.1.2 Load Variability by Customer Class

For each of the three customer classes, Navigant determined 1-minute and 15-minute load variability using SCADA data collected at NorthWestern substations that exclusively serve only Choice, Non-Choice or Generation load. Virtually all transmission substations and several distribution substations are equipped with SCADA communications, which provide one-minute interval load data that NorthWestern downloads daily to its central database management system (Pi Historian); often referred to as "pi" data and referenced as such herein.[10]

2.1.3 Allocation of Load Following and Regulation Service by Customer Class

Navigant developed allocation factors to assign generation capacity for load following and frequency regulation derived in the Baseline Study to each customer class. The approach we applied to develop allocation factors for each component is summarized below.

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[10] NorthWestern's SCADA system polls loads at each substation over 4 to 10-second intervals and downloads the data to the Pi Historian system. NorthWestern aggregated the data over 1-minute intervals for use in this study. Navigant aggregated the 1-minute data to create 15-minute interval data.

a) **Frequency Regulation** – Allocation factors were derived based on the contribution of each customer class 1-minute load variability to NorthWestern's total BA 1-minute load variability for each minute over the test-year evaluation period June 2016 through May 2017, except during load following events (i.e. 519,190 total intervals for one year). Navigant subtracted wind generation from the BA load to derive frequency regulation allocation factors. For each 1-minute interval, the upward or downward change in load for each customer class is compared to the total upward or downward change in net load for NorthWestern's BA, minus the wind generation. If the 1-minute change in class load is in the same direction (e.g. both BA and class load moves upward), the change in class load for the interval is assigned a positive value equal to the absolute value of the 1-minute change in load. Conversely, if the change in 1-minute class load is in the opposite direction as the BA 1-minute change in load, the class load is assigned a negative value for that interval. The summation of class 1-minute contribution to changes in BA 1-minute load, positive or negative, over the 519,190 intervals for each load class represents the average contribution to frequency regulation requirements, from which allocation factors are developed for each load class.

b) **Load Following** – Allocation factors for load following are derived in a similar manner to frequency regulation. The primary difference is that changes in class load are measured on a 15-minute basis, consistent with how load-following resources are dispatched to comply with the RBC NERC standard. Further, the contribution from customer class 15-minute load is only compared to total BA load during intervals when generation is ramped-up (INC) or ramped-down (DEC) to avoid a NERC violation. The number of INC and DEC events during the STORM simulated test-year with ±25MW of regulation capacity is approximately 130 for each; hence, there are far fewer intervals analyzed for load-following than for frequency regulation. Another distinction in the way class load is tracked during each interval is the assignment of positive or negative values based on whether the event is INC (unscheduled generation ramped-up) or DEC (generation ramped-down). All changes in 15-minute class load during INC and DEC events is tracked and summarized separately to recognize the difference in cost of provided INC or DEC generation services per NorthWestern's wholesale tariff.

Navigant then allocated the Navigant recommended levels of frequency regulation and load following capacity based on the percent contribution of each classes load variability to total BA load variability.

2.2 Load Variability Study Results

2.2.1 Sample Selection

Because of the availability of a significant amount of 1-minute SCADA pi interval load data, Navigant was able to develop a robust representative load sample for each customer class. The SCADA pi data we obtained from NorthWestern includes substations that serve Choice customers located throughout NorthWestern's service territory, thereby accounting for differences in load patterns associated with geographic diversity. For Choice load, most of which is large commercial and industrial, Navigant included a broad mix of customer load types to ensure the sample captured differences in load patterns and customer demand.

Table 16 presents the percentage of 1-minute data that was available from the data sample collected for each customer class. The derivation of each sample size and reasons for different percentages are presented in sections that follow.

Table 16. Load Composition by Customer Class

Load Type	Average MW of Class Load	Percent of BA Load	Average MW of Sample	Sample Coverage
Balancing Area	1,270	100%	1,270	100%
Choice	501	39%	282	56%
Non-Choice	683	54%	183	27%
Generator	90	7%	90	100%

2.2.1.1 Choice Load Sample

Most Choice customers are large commercial and industrial entities whose loads are individually metered for both demand and energy via MV90 meters that record 15-minute interval demand. Many large Choice customers are served exclusively by higher voltage transmission lines and substations; that is, no other customers are served by these lines and substations. Several REA delivery points also record SCADA data. Thus, Navigant was able to develop 1-minute and 15-minute load samples based solely on SCADA pi data obtained from substations that serve industrial and large commercial load, and REA loads.[11]

The sample excludes 643 Choice customers served via secondary distribution voltages on lines that also serve Non-Choice load. Choice customers that are excluded from the sample are not metered for demand, and 1-minute data is unavailable. However, total load for the 643 Choice customers is very small compared to those connected to higher voltages lines. Thus, the percent of Choice load that we were able to include in the sample is high, approximately 56 percent, thereby ensuring accuracy in the derivation of allocation factors presented in subsequent sections of this report.

As noted, Choice load includes Rural Electric Cooperative wholesale load. Because a portion of Electric Cooperative load is metered using MV90 devices, only 15-minute interval data is available at some delivery points. However, several. Several of the Electric Cooperative delivery points are equipped with SCADA, which enabled Navigant to collect sufficient data needed to derive 1-minute interval demand needed to derive allocation factors for frequency regulation.

2.2.1.2 Non-Choice Load

Non-Choice load is the largest of the three customer classes, with an average load of just under 700MW. Non-Choice load is mostly a mix of residential and small commercial load, with much smaller amounts of lighting and other minor rate classes (in terms of connected load). Because individual Non-Choice loads are not equipped with meters that record 1-minute interval demand – most customers are residential or non-demand commercial - Navigant used SCADA pi data obtained from substations that only serve Non-Choice customer load in its sample.

As noted above, virtually all NorthWestern transmission substations are equipped with SCADA communications. In contrast, a smaller percentage of distribution substations (that serve Non-Choice

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[11] Several substation SCADA readings were derived based on recorded data from two or more transmission lines. For these substations, Navigant derived 1-minute SCADA data based on the net deliveries from all incoming lines.

load) is equipped with SCADA. (The distribution substations where SCADA pi data is available and that Navigant included in the sample are listed in APPENDIX B (Table B-1)). The percentage of Non-Choice load with 1-minute load data is lower than Choice, as most retail load is served from distribution substations - approximately 27 percent of these substations record sub-minute load data via SCADA.

While lower than Choice, Navigant concludes that the Non-Choice sample is sufficiently given the geographically diversity of the SCADA readings and consistent percent in customer mix between the Non-Choice sample versus all NorthWestern's Non-Choice BA load. Table 17 presents the Non-Choice sample in terms of the amount of energy consumption for each rate class (Navigant combined demand and non-demand commercial rate classes). Results confirm the Non-Choice sample composition closely matches total Non-Choice load based on a comparison of energy usage by rate class, thereby ensuring the 1-minute and 15-minute load variability readings for the sample is comparable to the total Non-Choice rate classes.

Table 17. Non-Choice Sample Size by Rate Class

	Commercial	Residential	Irrigation	Lighting
Overall System	56%	41%	2%	1%
Non-Choice (Retail) Sample	52%	46%	1%	1%

2.2.1.3 Generation Sample

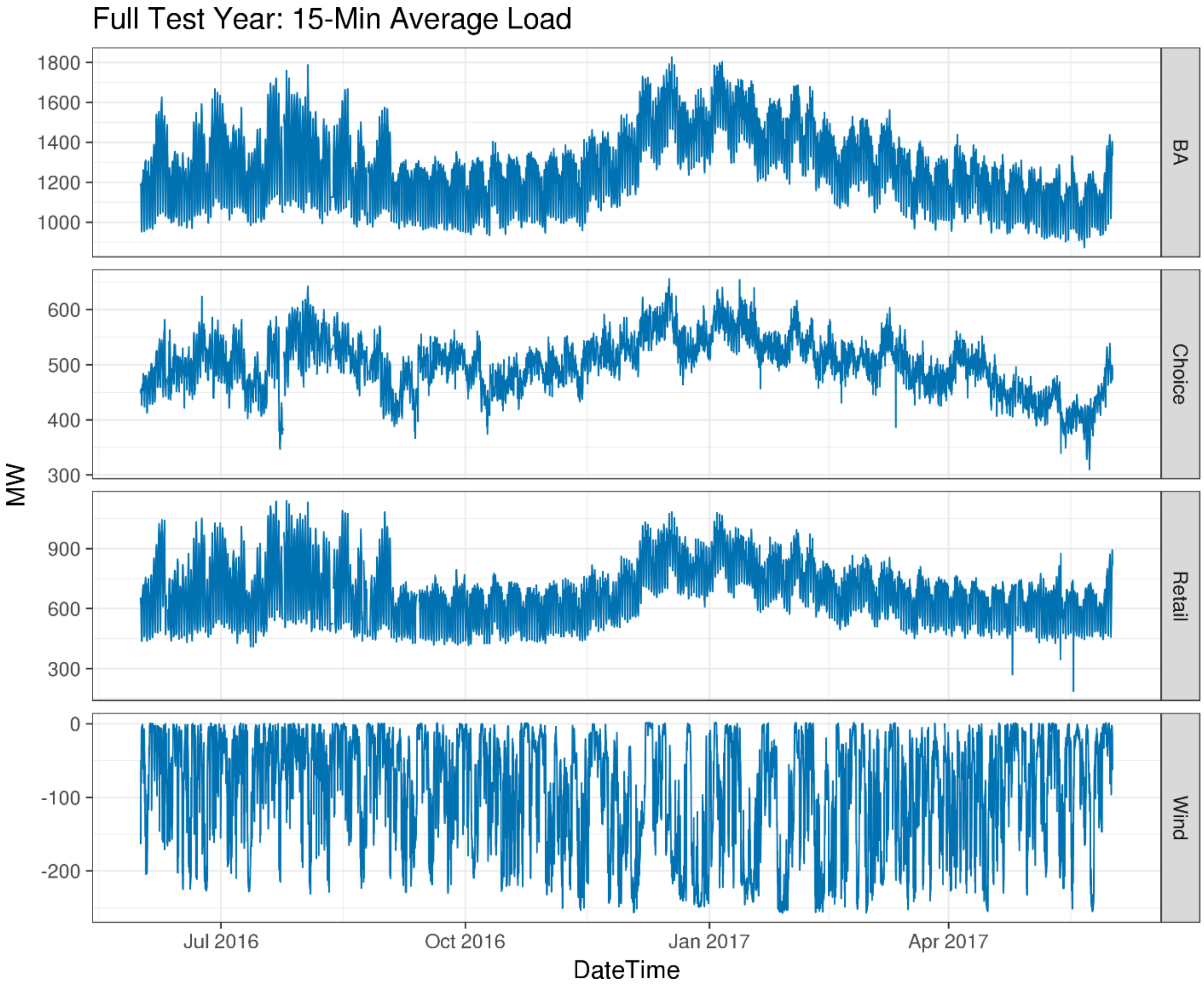
All large wind generators are equipped with SCADA communications that enable NorthWestern to collect pi data. Thus, 1-minute output data is available for 100 percent of generators that receive service under NorthWestern's wholesale tariff. The substations where SCADA pi data was obtained for existing wind generators and that are included in the Generation sample are listed in APPENDIX B (Table B-2).

2.2.2 Customer Class Load Variability

Navigant tracked upward and downward changes in load for 1-minute and 15-minute intervals for each customer class based on SCADA pi data measurements at each substation where pi data is available. The 15-minute intervals were derived by summing consecutive 1-minute pi data on a rolling, quarter-hour basis for each substation. The 1-minute and 15-minute readings were then obtained for each substation that exclusively serves either Choice or Non-Choice load. All substations connected to wind generators are equipped with SCADA communications. Further, all substations connected to wind generators do not serve other Retail or Choice load, which enabled Navigant to obtain interval readings for 100 percent of generators.

Figure 17 displays total BA and scaled 15-minute loads by customer class over the one-year evaluation period. The change in BA 15-minute load typically ranges between 200MW and 400MW; whereas the change in Choice and Non-Choice 15-minute loads varies between 100MW and 300MW, respectively. Generator output tends to have greater variability relative to maximum generator capability, as output continually varied from zero to its maximum rated capability of just over 250MW.

Figure 17. Customer Class Load Variability

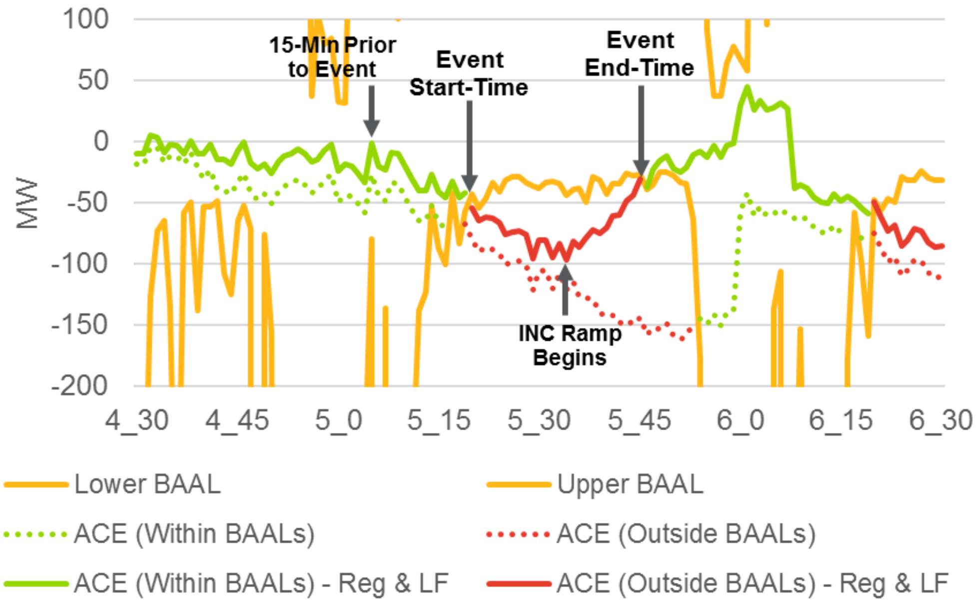


Navigant applied the 1-minute and 15-minute scaled loads described in Section 2.2.3 to derive allocation factors for frequency regulation and load following components for each of NorthWestern's three customer classes. The approach and rationale Navigant applied to allocate generation assigned to frequency regulation and load following is described in the sections that follow.

2.2.2.1 Load Following Intervals (INC and DEC Events)

Although class load consistently shows variability throughout all hours of the year, only those intervals when INC and DEC events occurred (i.e. NorthWestern Control Center staff increased or decreased generation to avoid a 30-minute BAAL violation) were analyzed to determine load following requirements and the allocation of these requirements to each customer class. From the Baseline Study, the STORM model predicted 262 INC and DEC events over the test-year evaluation period given ±25MW of regulation capacity. As shown in Figure 18, the analyzed time interval for each event consists of three phases: 1) the 15 minutes prior to the ACE first exceeding the BAALs; 2) the following 15 minutes in which the ACE exceeds the BAALs, before INC or DEC is called; and 3) the INC or DEC ramp time until the event ends, which varies in duration.

Figure 18. Time Interval Analyzed for INC/DEC Events



STORM operation of NorthWestern Energy's system on 11/8/2016

Figure 19 presents the number of INC and DEC events for increasing levels of event size (in MW). While the maximum absolute size is 155MW, the total number of INC and DEC events is nearly equal, with a large concentration of INC events between 20MW and 40MW.

Figure 19. 15-Minute INC/DEC Events

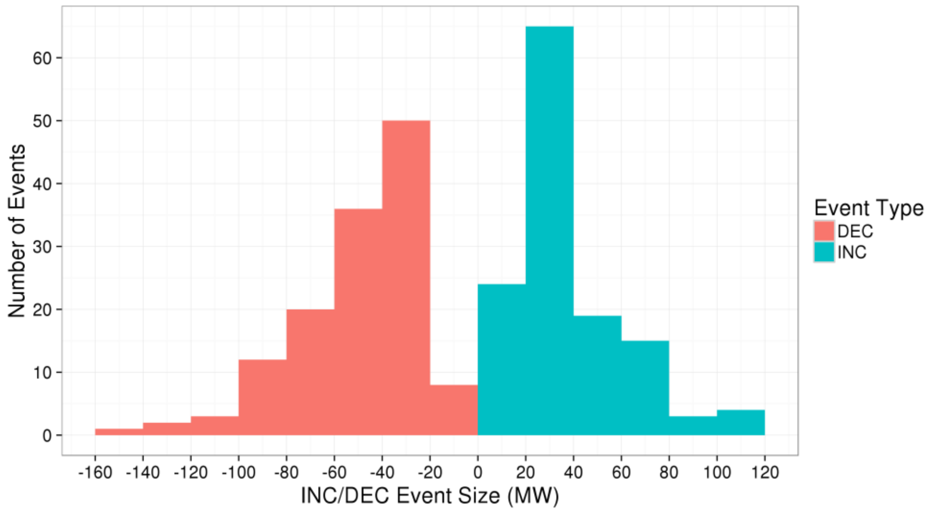


Figure 20 presents maximum INC and DEC (absolute size in MW) by month, which ranges between 40MW to just above 150MW. For most months (8), maximum DEC size is higher than average INC. However, the average event size tends to be consistent for most months, with winter monthly maximum event size slightly lower than that of summer months.

Figure 20. Average Monthly INC/DEC Size

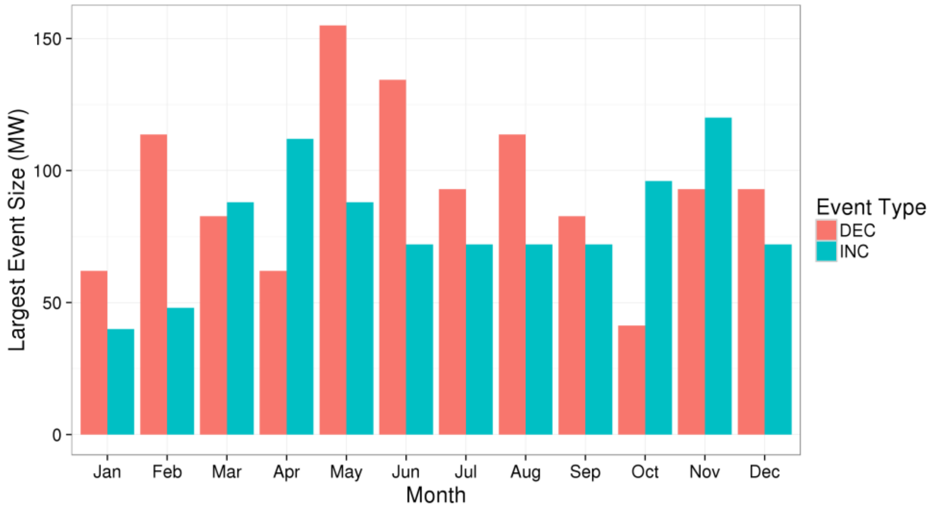
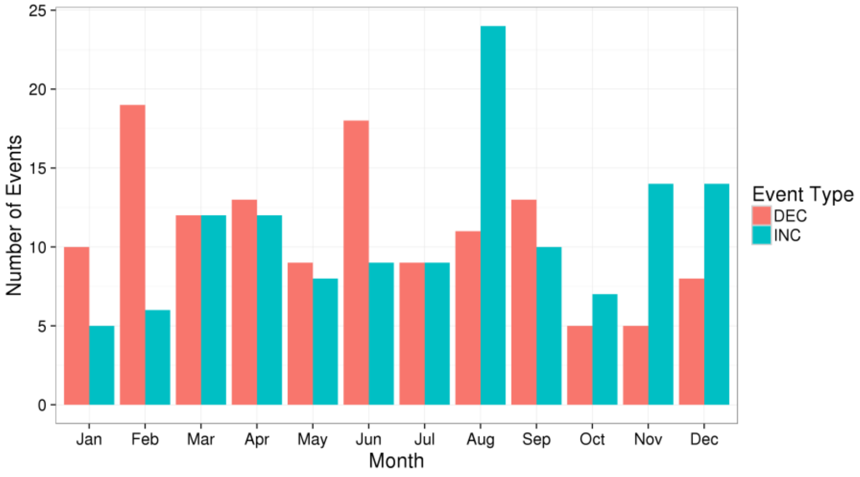


Figure 21 presents the number of INC and DEC events per month. Similar to average INC and DEC size, the number of INC and DEC events tends to be consistent for most months, with the fewest occurring in October and the most in August. Because both the average event size and number of INC and DEC events are mostly consistent throughout the year, the likelihood of bias or uneven weighting of class allocation factors is low. Further, because 15-minute class load variability tends to be consistent throughout the year (Figure 17), the potential for bias or error in deriving class allocation factors is further reduced. Lastly, the relatively large number of INC and DEC events (262) confirms that the sample size is sufficiently large to virtually eliminate potential bias and improper averaging of interval data used to derive allocation factors for the three customer classes.

Figure 21. Number of Monthly INC and DEC Events



2.2.2.2 Average Load Variability (INC and DEC Events)

The following 3 charts present the 15-minute change in load at the time of each INC and DEC event over the one-year evaluation period for each customer class. (The sign convention is reversed for wind generation to illustrate the reduction in BA load when generation output increases and vice-versa for decreases in wind output).

These charts indicate that class load sometimes is in the opposite direction of INC or DEC event (e.g. 15-minute class load increases during a DEC event). However, the charts also show a clear correlation between the change in class load (or generation output) for each corresponding INC and DEC event; particularly for generation.

Figure 22. 15-Minute Change in Load During INC/DCE Events (Choice)

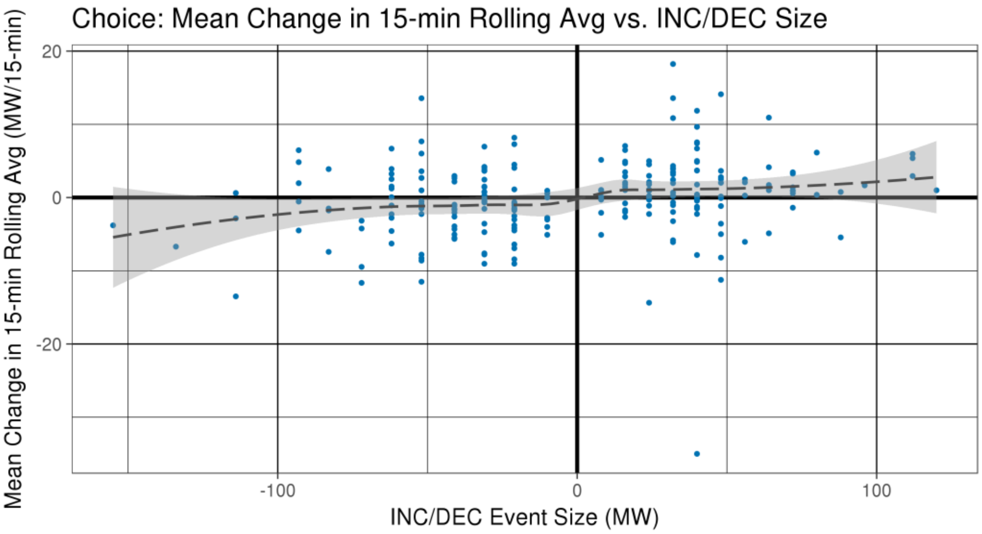


Figure 23. 15-Minute Change in Load During INC/DCE Events (Non-Choice)

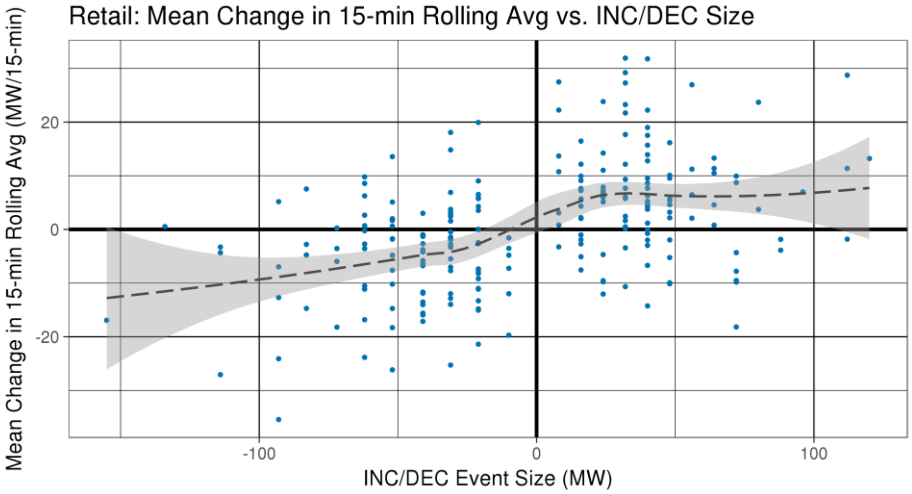
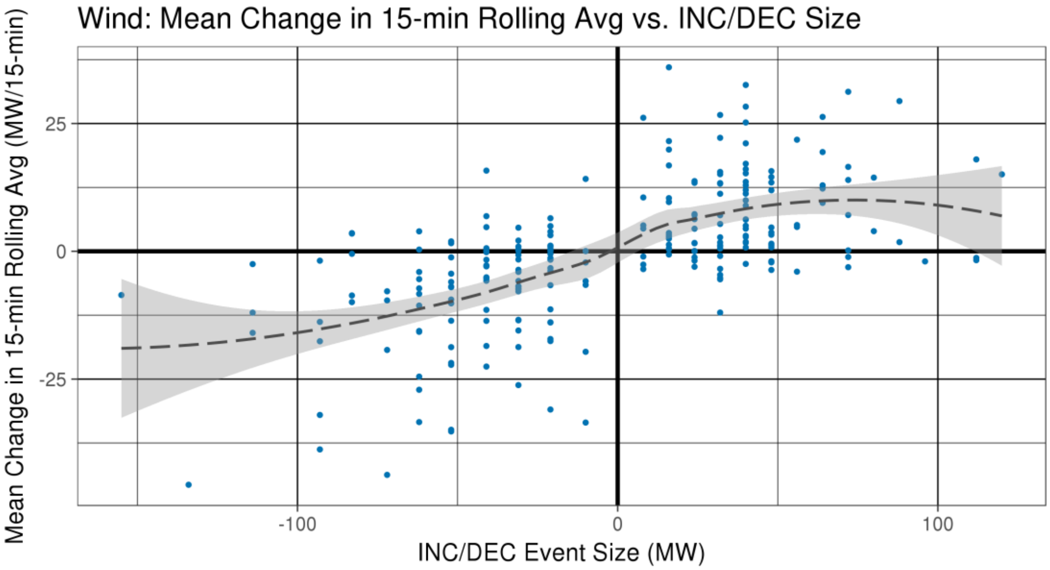


Figure 24. 15-Minute Change in Load During INC/DCE Events (Generation)



2.2.3 Allocation Factors

The results outlined in the preceding charts and tables were used by Navigant to derive allocation factors for frequency regulation and load following. Allocation factors for frequency regulation were derived based on the average 1-minute change in load or generator output for each of the three customer classes. Allocation factors for load following were derived based on the 15-minute average change in load or generator output for the 262 INC and DEC events identified in the Baseline Study. Separate allocation factors were prepared for both INC and DEC events, as the average change in 15-minute load or generator output differs for these two event categories.

2.2.3.1 Frequency Regulation

Table 18 presents the average 1-minute change in load for each customer class over the one-year evaluation period. (A total of 519,190 intervals were analyzed, as Navigant subtracted wind generation from the BA load to derive frequency regulation allocation factors.) Results indicate that Non-Choice retail load has the highest minute-by-minute variability: 55 percent of the total average change in 1-minute load, which is close to the corresponding 54 percent of total BA average load. Conversely, the 8 percent of total change in 1-minute load for Choice load is well below the corresponding 39 percentage of total BA load.

Although generation output is small (7 percent) compared to total BA load, the corresponding percent change in 1-minute variability in output is much higher (38 percent). However, the diversity in output from multiple generators in different locations likely causes coincident 1-minute shifts in load to be smaller as function of total generation output that otherwise would be obtained from a single generator. The higher percent allocation of generation to load following appears to confirm this premise.

Table 18. Average 1-Minute Change in Load or Output

Class Load	Annual Average Load (MW)	Percent of BA Average Load (%)	Average 1-Minute Variability (MW)	Percent of Total
Balancing Area	1270	100%	2.27	**-**
Choice	501	39%	0.16	**8%**
Non-Choice	683	54%	1.14	**55%**
Generator	-90	-7%	0.79	**38%**

2.2.3.2 Load Following

Table 19 presents the average 15-minute change (increase) in load for each customer class over the test-year evaluation period (130 intervals). Results indicate that Generation has the highest 15-minute variability: 54 percent of the total average change in 15-minute load even though it represents just 7 percent of total BA average load. Similar to frequency regulation, Choice load has much lower 15-minute load variability during INC events compared to Non-Choice customers.

Table 19. Average 15-Minute Change in Load or Output (INC Events)

Class Load	Annual Average Load (MW)	Percent of BA Average Load (%)	Average 15-Minute Variability (MW)	Percent of Total
Balancing Area	1270	100%	16.89	**-**
Choice	501	39%	1.29	**8%**
Non-Choice	683	54%	5.88	**38%**
Generator	-90	-7%	8.31	**54%**

Table 20 presents the average 15-minute change (decrease) in load for each customer class over the test-year evaluation periods (132 intervals). Similar to INC, results indicate that Generation has the highest 15-minute variability: 58 percent of the total average change in 15-minute output even though it represents 7 percent of total BA average load. Similar to frequency regulation, Choice load also has much lower 15-minute load variability during DEC events compared to Non-Choice customers and Generation.

Table 20. Average 15-Minute Change in Load or Output (DEC Events)

Customer Class	Annual Average Load (MW)	Percent of BA Average Load (%)	Average 15-Minute Variability (MW)	Percent of Total
Balancing Area	1270	100%	-20.22	**-**
Choice	501	39%	-1.52	**8%**
Non-Choice	683	54%	-6.31	**34%**
Generator	-90	-7%	-10.98	**58%**

2.2.3.3 Class Allocation Factors

Table 21 presents Navigant's allocation of frequency regulation and load following requirements based on recommendations from the Baseline Study for each of the three customer classes. The table lists the total generation capacity assigned to NorthWestern's BA for each component – INC and DEC are listed separately – and the allocation of these values to each customer class is based on the percentages derived in Table 18, Table 19 and Table 20.[12] Results indicate that Non-Choice customer load is assigned the largest percentage of regulation capacity, while Generation is assigned the highest percentage of INC and DEC load following capacity. Choice is assigned the least l amount of frequency regulation and load following due to the relatively minor change in 1-minute and 15-minute load or output (wind) compared to other customer classes.

Table 21. Class Allocation Factors

Customer Class	Frequency Regulation (%)	Load Following (INC)	Load Following (DEC)	Frequency Regulation (MW)	Load Following (INC MW)	Load Following (DEC MW)
Balancing Area	**-**	**-**	**-**	**50**	**120**	**155**
Choice	8%	8%	8%	3.8	10.0	12.5
Non-Choice	55%	38%	34%	27.3	45.6	52.0
Generator	38%	54%	58%	18.9	64.4	90.5

Table 22 presents results from Table 21 when Non-Choice and Generator class data is combined as required for retail cost allocation. Composite allocation factors frequency regulation and load following each exceed 80 percent for the combined Non-Choice and Generator class.

Table 22. Choice Versus Non-Choice + Generator Allocation Factors

Customer Class	Frequency Regulation	Load Following (INC)	Load Following (DEC)
Choice (MW)	3.8	10.0	12.5
Choice (%)	8%	8%	8%
Non-Choice + Generator (MW)	46.2	110.0	142.5
Non-Choice + Generator (%)	92%	92%	92%

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[12] Generation capacity assigned to frequency regulation is equal to 50 MW, as generation capacity must be able to increase or decrease output by 25 MW. Thus, 50 MW of generation capacity must be held in reserve to respond to rapid changes in load and meet NorthWestern's RBC standard.

APPENDIX A. **VER INTEGRATION STUDY RESULTS**

Table A-1. Scenario A – 185 MW New Wind

Event Date Time	INC or DEC	INC/DEC (MW)	Number of NERC Violations per 500 draws	% NERC Violations
9/17/2016 Hours 18-19	INC	20	38	7.6%
	INC	40	15	3.0%
	INC	60	4	0.8%
	INC	80	2	0.4%
12/18/2016 Hours 17-18	INC	55	365	73.0%
	INC	75	93	18.6%
	INC	100	37	7.4%
	INC	140	7	1.4%
11/1/2016 Hours 18-19	INC	120	30	6.0%
	INC	140	13	2.6%
	INC	160	9	1.8%
	INC	180	5	1.0%
11/8/2016 Hour 5	INC	60	37	7.4%
	INC	80	16	3.2%
	INC	100	6	1.2%
	INC	120	2	0.4%
10/22/2016 Hours 17-18	INC	25	33	6.6%
	INC	45	17	3.4%
	INC	65	11	2.2%
	INC	85	7	1.4%
5/27/2017 Hours 19-20	INC	10	14	2.8%
	INC	30	7	1.4%
	INC	50	4	0.8%
	INC	70	4	0.8%
4/5/2017 Hours 19-20	INC	60	71	14.2%
	INC	80	36	7.2%
	INC	100	8	1.6%
	INC	120	6	1.2%
11/30/2016 Hours 17-18	INC	40	41	8.2%
	INC	60	17	3.4%
	INC	80	4	0.8%
	INC	100	1	0.2%
8/31/2016 Hours 22-23	DEC	115	34	6.8%
	DEC	135	21	4.2%

Event Date Time	INC or DEC	INC/DEC (MW)	Number of NERC Violations per 500 draws	% NERC Violations
	DEC	155	12	2.4%
	DEC	175	5	1.0%
2/13/2017 Hours 10-11	DEC	0	4	0.8%
	DEC	25	4	0.8%
	DEC	75	1	0.2%
	DEC	95	1	0.2%
5/11/2017 Hours 23-0	DEC	155	38	7.6%
	DEC	175	22	4.4%
	DEC	195	13	2.6%
	DEC	215	2	0.4%
7/25/2016 Hours 22-23	DEC	30	8	1.6%
	DEC	50	5	1.0%
	DEC	70	5	1.0%
	DEC	90	3	0.6%
9/23/2016 Hours 16-18	DEC	60	372	74.4%
	DEC	80	176	35.2%
	DEC	100	85	17.0%
	DEC	120	46	9.2%
	DEC	140	24	4.8%
	DEC	170	16	3.2%
	DEC	200	8	1.6%
8/8/2016 Hours 21-22	DEC	55	375	75.0%
	DEC	75	119	23.8%
	DEC	95	71	14.2%
	DEC	115	40	8.0%
	DEC	160	9	1.8%
9/6/2016 Hours 21-22	DEC	5	24	4.8%
	DEC	25	18	3.6%
	DEC	45	11	2.2%
	DEC	65	3	0.6%
8/9/2016 Hours 22-23	DEC	60	307	61.4%
	DEC	80	75	15.0%
	DEC	100	34	6.8%
	DEC	120	21	4.2%
	DEC	160	5	1.0%

Table A-2. Scenario B – 505 MW New Wind

Event Date Time	INC or DEC	INC/DEC (MW)	Number of NERC Violations per 500 draws	% NERC Violations
9/17/2016 Hours 18-19	INC	60	25	5.0%
	INC	80	16	3.2%
	INC	100	7	1.4%
	INC	120	4	0.8%
12/18/2016 Hours 17-18	INC	75	87	17.4%
	INC	100	19	3.8%
	INC	120	15	3.0%
	INC	140	5	1.0%
11/1/2016 Hours 18-19	INC	120	53	10.6%
	INC	160	16	3.2%
	INC	180	8	1.6%
	INC	200	4	0.8%
11/8/2016 Hour 5	INC	80	31	6.2%
	INC	100	24	4.8%
	INC	120	14	2.8%
	INC	160	12	2.4%
	INC	180	12	2.4%
	INC	200	0	0.0%
10/22/2016 Hours 17-18	INC	65	24	4.8%
	INC	85	10	2.0%
	INC	105	8	1.6%
	INC	125	6	1.2%
5/27/2017 Hours 19-20	INC	50	19	3.8%
	INC	70	12	2.4%
	INC	90	7	1.4%
	INC	110	6	1.2%
4/5/2017 Hours 19-20	INC	100	31	6.2%
	INC	120	13	2.6%
	INC	140	10	2.0%
	INC	160	10	2.0%
	INC	200	5	1.0%
11/30/2016 Hours 17-18	INC	60	51	10.2%
	INC	100	15	3.0%
	INC	120	7	1.4%
	INC	140	4	0.8%
8/31/2016 Hours 22-23	DEC	135	21	4.2%
	DEC	155	12	2.4%

Event Date Time	INC or DEC	INC/DEC (MW)	Number of NERC Violations per 500 draws	% NERC Violations
	DEC	175	9	1.8%
	DEC	195	6	1.2%
2/13/2017 Hours 10-11	DEC	0	30	6.0%
	DEC	30	30	6.0%
	DEC	95	8	1.6%
	DEC	115	8	1.6%
	DEC	145	7	1.4%
5/11/2017 Hours 23-0	DEC	175	43	8.6%
	DEC	215	12	2.4%
	DEC	235	7	1.4%
	DEC	255	4	0.8%
7/25/2016 Hours 22-23	DEC	30	16	3.2%
	DEC	50	13	2.6%
	DEC	70	9	1.8%
	DEC	90	5	1.0%
9/23/2016 Hours 16-18	DEC	140	38	7.6%
	DEC	180	17	3.4%
	DEC	200	12	2.4%
	DEC	220	12	2.4%
	DEC	250	8	1.6%
8/8/2016 Hours 21-22	DEC	115	56	11.2%
	DEC	160	24	4.8%
	DEC	200	8	1.6%
	DEC	220	5	1.0%
9/6/2016 Hours 21-22	DEC	45	18	3.6%
	DEC	65	12	2.4%
	DEC	85	9	1.8%
	DEC	105	4	0.8%
8/9/2016 Hours 22-23	DEC	120	33	6.6%
	DEC	140	22	4.4%
	DEC	180	9	1.8%
	DEC	200	6	1.2%

Table A-3. Scenario C – 185 MW New Wind & 100 MW New Solar

Event Date Time	INC or DEC	INC/DEC (MW)	Number of NERC Violations per 500 draws	% NERC Violations
9/17/2016 Hours 18-19	INC	20	54	10.8%
	INC	40	25	5.0%
	INC	60	9	1.8%
	INC	80	4	0.8%
11/8/2016 Hour 5	INC	60	31	6.2%
	INC	80	11	2.2%
	INC	100	5	1.0%
	INC	120	2	0.4%
10/22/2016 Hours 17-18	INC	25	73	14.6%
	INC	45	36	7.2%
	INC	65	17	3.4%
	INC	85	10	2.0%
11/30/2016 Hours 17-18	INC	40	52	10.4%
	INC	60	31	6.2%
	INC	80	9	1.8%
	INC	100	2	0.4%
2/13/2017 Hours 10-11	DEC	0	5	1.0%
	DEC	25	5	1.0%
	DEC	75	1	0.2%
	DEC	95	1	0.2%
9/23/2016 Hours 16-18	DEC	120	44	8.8%
	DEC	140	21	4.2%
	DEC	170	11	2.2%
	DEC	200	5	1.0%

APPENDIX B. **LOAD VARIABILITY STUDY RESULTS**

Table B-1. Non-Choice Customer Load Assigned to Load Following and Frequency Regulation

Substation	PI Tag	Annual Average Load (MW)
Bellrock	BELLROCK.XFMR.BK1H.MW	10.7
	BELLROCK.XFMR.BK2H.MW	9.0
	TOTAL	**19.7**
Big Timber City	BGTIMB_C.LINE.BIG_TMBR_A.MEAS.MW	6.6
	BGTIMB_C.LINE.LIV_CITY_A.MEAS.MW	-4.8
	TOTAL	**1.8**
Billings 8th Street	EIGHTHST.XFMR.BK1L.MEAS.MW	6.3
	EIGHTHST.XFMR.BK2L.MEAS.MW	9.8
	EIGHTHST.XFMR.BK3L.MEAS.MW	9.3
	TOTAL	**25.4**
Bozeman Westside	BOZ_WS.XFMR.BK1L.MEAS.MW	5.3
	BOZ_WS.XFMR.BK2L.MEAS.MW	11.0
	TOTAL	**16.4**
Butler Creek	BUTLER_C.XFMR.BK1H.MEAS.MW	5.0
	TOTAL	**5.0**
Colstrip	COLSTRIP.LD_SH.LOAD_SHED.MWC1	-6.1
	COLSTRIP.XFMR.BK1H.MW	9.9
	TOTAL	**3.8**
Cora	CORA.XFMR.BK1L.MEAS.MW	2.3
	TOTAL	**2.3**
East Gallatin Auto	E_GALL.CBWORE.050-042.MW	12.1
	TOTAL	**12.1**
East Helena	E_HELENA.CBWORE.100-133.MW	3.1
	HELNA_ES.XFMR.BK1H.MEAS.MW	7.4
	TOTAL	**10.5**
Gardiner	GARDINER.LINE.EMIGRANT_1.MW	1.5
	GARDINER.LINE.EMIGRANT_2.MW	3.8
	GARDINER.LINE.MAMMOTH_A.MW	-3.6
	TOTAL	**1.7**
Harlowton	HARLOTWN.LINE.GLENGARY_A.MW	1.5
	HARLOTWN.LINE.LAVINA_A.MW	0.6
	HARLOTWN.XFMR.BK1H.MW	3.4
	TOTAL	**5.6**

Substation	PI Tag	Annual Average Load (MW)
Helena Valley	E_HELENA.LINE.HOLTER_A.MW	-12.6
	HOLTER.LINE.E_HELENA_A.MW	21.9
	TOTAL	**9.3**
Industrial Park	MONT_ST.LINE.IND_PARK_A.MW	-1.8
	S_BUTTE.LINE.MONT_ST_A.MW	5.7
	TOTAL	**3.9**
King Ave	KING_AVE.LOAD.MPC_LD1.MEAS.MW	2.9
	KING_AVE.LOAD.MPC_LD2.MEAS.MW	2.9
	KING_AVE.LOAD.MPC_LD3.MEAS.MW	1.6
	KING_AVE.LOAD.MPC_LD4.MEAS.MW	2.4
	TOTAL	**9.8**
LaDuke	EMIGRANT.LINE.GARDINER_2.MW	4.1
	GARDINER.LINE.EMIGRANT_2.MW	-3.8
	TOTAL	**0.3**
Landers Fork	GF_FALLS.LINE.LNDRS_FK_A.MEAS.MW	82.3
	OVANDO.CBWRE.230-004.MW	-79.3
	TOTAL	**2.9**
Mammoth	GARDINER.LINE.MAMMOTH_A.MW	3.6
	MAMMOTH.CBWRE.069-083.MPCR.MW	2.5
	TOTAL	**6.1**
Meadow Village	MDOW_VLG.XFMR.BK1L.MEAS.MW	4.4
	TOTAL	**4.4**
Meridian	MERIDIAN.LOAD.MPC_LD1.MEAS.MW	2.3
	MERIDIAN.LOAD.MPC_LD2.MEAS.MW	0.0
	MERIDIAN.LOAD.MPC_LD3.MEAS.MW	2.3
	TOTAL	**4.6**
Plains	KERR.LINE.T_FALLS_A.MW	1.7
	T_FALLS.LINE.KERR_A.MW	2.7
	TOTAL	**4.4**
Shiloh Road	SHILOH.XFMR.BK1H.MW	11.4
	TOTAL	**11.4**
Sourdough	SOURDGH.XFMR.BK1L.MEAS.MW	8.8
	TOTAL	**8.8**
St Regis	ST_REGIS.LINE.SALTESE_A.MW	11.2
	ST_REGIS.LINE.WALDORF_A.MW	-9.1
	TOTAL	**2.1**
White Sulphur Springs Southside	LOWETH.LINE.WHITS_SS_A.MW	1.3

Substation	PI Tag	Annual Average Load (MW)
	TOTAL	**1.3**
Wicks Lane	BLGS_STM.LINE.WICKS_LN_A.MW	-73.0
	BRDVIEW.LINE.WICKS_LN_A.MW	82.4
	TOTAL	**9.3**
Grand Total		**683**

Table B-2. Generation Load Assigned to Load Following and Frequency Regulation

PI Tag	Annual Average Load (MW)
ICCP_FRFLD_WD_FRFW_MW	3.6
ICCP_FRFLD_WD_GRFW_MW	5.6
ICCP_GORDBUTP_GORD_MW	4.2
ICCP_HORSESHU_HRSU_MW	2.6
ICCP_JUDGAP_S_INVG_MW	50.0
ICCP_MSSHL100_MSG1_MW	2.7
ICCP_MSSHL100_MSG2_MW	3.2
ICCP_SPNKPCOL_SPKG_MW	14.5
ICCP_TWODOTWD_TWDW_MW	3.7
Grant Total	**90.0**