Montana – Dakotas
Regional Transmission Study

WEST SIDE STUDIES
PROJECT 5

Western
AREA POWER
ADMINISTRATION

UPPER GREAT PLAINS REGION
Transmission Planning

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PROJECT 5 SUMMARY

Project 5 modeled a 600 MW wind generation project consisting of six geographically dispersed 100 MW projects in Montana. Three different power flow schedules were investigated to find their individual impacts on the power system. There were no other system improvements included in the model. The estimated substation and transmission costs associated with the six wind farms is $38 million.

System losses were evaluated for this Project. The increased losses indicated in Table 1 represent 18% to 25% of the new generation. This magnitude of additional losses is indicative of diminished system performance as a result of heavy line loading, and even line overloads, with the new generation added.

System intact analysis demonstrated that the wind generation scheduled to Spokane and Salt Lake City created minimal rating violations that were in known areas of constraint. Numerous voltage violations were introduced by all the power schedules.

The wind generation and schedules of this Project were shown to be non-viable due to multiple rating, voltage, and stability violations. The effect of adding new generation, even when dispersed throughout Montana, without the addition of sufficient transmission capacity is detrimental to the existing system. Reducing the sizes of some or all of the wind farms may be feasible, but the results of this study indicate that additional transmission facilities would provide the most viable solution. Transmission line alternatives studied in Projects 1 through 5 are not likely to meet the needs of the dispersed wind farms, with the exception of the line route to Denver. Further analysis is required to determine the transmission line sections necessary to fully integrate the six dispersed 100 MW wind farms into the existing system.

1. INTRODUCTION AND PROJECT SCOPE

Project 5 of the Montana Transmission Study investigates the effects of six dispersed 100 MW Wind Generation projects. The new generation was scheduled to Spokane, Denver, and Salt Lake City. The purpose of this Project was to illustrate the effect of attempting to export dispersed wind generation from Montana without adding new transmission facilities.

1.1 Scope

The Project simulated six 100 MW wind powered generation projects with a wind farm near each of the following locations: Blackfeet near Cut Bank, Great Falls, Billings, Yellowtail, Livingston near Clyde Park, and Fort Peck. The entire 600 MW Project output was scheduled to Spokane, Salt Lake City, or Denver separately.

Project maps illustrating the line routing for each of the transmission alternatives can be found in the Appendices. Figure 1 illustrates the locations of the six individual projects. Transmission line taps of 10-15 miles were used to connect the Blackfeet Wind Farm to Cut Bank, to connect the Livingston Wind Farm to Clyde Park, and to connect the other Wind Farm projects to the existing Great Falls, Billings, and Yellowtail, and Fort Peck buses.

2. DESCRIPTION OF THE BASE CASES

Two models obtained from the Western Electricity Coordinating Council (WECC) were used to build the Project models. From these, additional system models were established in order to study and compare the different schedules. In all cases, the additional Project generation was scheduled by reducing generation in the destination area.

2.1 Generation Scheduled to Spokane

Project generation scheduled to the Spokane area is represented by this system model. The model is based on the WECC 2002 Light Summer model, which represents heavy flows from Montana to Washington.

Area schedules were modified to reflect the additional 600 MW of generation. Due to increased losses, only 480 MW could be exported from the Project to the Northwest area. The swing generators in each of the areas experienced minimal changes in their swing megawatts, and therefore were permitted to adjust for the new system conditions. Shunt Capacitors were added as follows to the wind farm at Fort Peck and sections of the 161 kV Hiline to increase the transfer capability of the line:

- 5 MVAR at the 34.5 kV Fort Peck Wind Farm bus
- 16 MVAR at the Malta 161 kV bus
- 24 MVAR at the Havre 161 kV bus

2.2 Generation Scheduled to Salt Lake City

Based on the WECC 2002 Heavy Summer case, this model simulates power scheduled to Salt Lake City.

Area schedules were modified to reflect the additional 600 MW of generation. Due to increased losses, 480 MW was exported from the Project to the Salt Lake City area. The swing generators in each of the areas experienced minimal changes in their swing megawatts, and therefore were permitted to adjust for the new system conditions. Shunt Capacitors were added as follows to the wind farm at Fort Peck and sections of the 161 kV Hiline to increase the transfer capability of the line:

- 5 MVAR at the 34.5 kV Fort Peck Wind Farm bus
- 30 MVAR at the Malta 161 kV bus
- 24 MVAR at the Havre 161 kV bus

2.3 Generation Scheduled to Denver

Project generation scheduled to Denver is represented by this system model. This model is based on the WECC 2002 Heavy Summer model.

Area schedules were modified to reflect the additional 600 MW of generation. Due to increased losses, 475 MW was exported from the Project to the Denver area. The swing generators in each of the areas experienced minimal changes in their swing megawatts, and therefore were permitted to adjust for the new system conditions. Shunt Capacitors were added as follows to the wind farm at Fort Peck and sections of the 161 kV Hiline to increase the transfer capability of the line:

- 5 MVAR at the 34.5 kV Fort Peck Wind Farm bus
- 30 MVAR at the Malta 161 kV bus
- 24 MVAR at the Havre 161 kV bus

3. POWER FLOW ANALYSIS

Two power flow conditions were studied: Category A and Category B. The effect of the Project on the system was gauged by comparing pre-Project and post-Project rating and voltage violations. Additionally, power losses were studied for Category A conditions.

3.1 Category A Power Losses

Table 1 summarizes the change in system losses due to the Project. Losses are sorted by area, and are broken up into real power (MW) and reactive power (MVAR) losses. Please note that only those areas with significant changes are included in Table 1. Positive values in the table indicate an increase in system losses, whereas negative values indicate that losses decreased. Values in bold text indicate the area to which the Project has been scheduled.

Table 1 Project Effect on System Losses by Area

Schedule -->	Spokane		Denver		Salt Lake City	
	MW	MVAR	MW	MVAR	MW	MVAR
Total System	106	1191	143	1479	151	1561
Northwest	**21**	**238**	41	649	45	685
B.C. Hydro	3	35	2	21	2	23
Idaho	11	104	-1	-33	5	17
Montana	38	505	33	404	38	445
WAPA U.M.	11	97	16	149	15	138
PACE	11	107	9	15	**31**	**168**
Colorado	1	11	**15**	**89**	0	0
WAPA R.M.	10	96	27	185	13	87

As can be expected, significant changes occur in the export areas and the import areas (values in bold). Four wind farm projects were located in the Montana area, one wind farm at Yellowtail was located in the PACE area, and one wind farm at Fort Peck was located in the WAPA U.M. area. Due to the physical power flow paths, the Project can be seen to have some impact on surrounding areas. Overall system losses were increased for all schedules, but scheduling the Project to Spokane had the least increase. Total system losses in the schedules to Denver and Salt Lake City were 35% and 42% higher respectively than the schedule to Spokane.

The increase in losses indicated in Table 1 represents 18% to 25% of the new generation. Additional losses of this magnitude are indicative of diminished system performance as a result of the very heavy line loadings.

3.2 Category A Violations

Table 2 presents the number of Category A rating and voltage violations for the Project. The first results column gives the number of violations caused or worsened by the Project. The second results column gives the number of violations that were fixed or improved by the Project.

Table 2 - Category A Violations Summary

Schedule	Area Name	Violations caused or worsened by 5%		Violations fixed or improved by 5%	
		Ratings	Voltage	Ratings	Voltage
Spokane	Northwest	-	-	3	2
	Montana	1	-	-	1
	WAPA U.M.	-	2	-	-
Denver	Northwest	-	1	-	1
	B.C. Hydro	-	-	-	2
	Montana	-	4	-	1
	WAPA U.M.	-	9	-	-
	PACE	1	2	-	-
	Colorado	-	3	-	-
	WAPA R.M.	-	13	-	-
Salt Lake City	Northwest	-	-	-	1
	B.C. Hydro	-	-	-	3
	Montana	-	4	-	1
	WAPA U.M.	-	9	-	-
	PACE	3	2	-	1
	WAPA R.M.	-	2	-	-

3.2.1 Generation Scheduled to Spokane

As can be seen from Table 2, one new rating violation and two new voltage violations occurred for this case. The single rating violation occurred at Colstrip, where the COLSTP4 26-500 kV GSU transformer became marginally overloaded by 0.6% due to increased VAR output. The two voltage violations are located on the 161 kV Hiline. The 161 kV buses at Malta and Harlem fell from a nominal value of 1.00 per unit to 0.93 per unit and 0.92 per unit respectively. The Hiline is a weak system, as seen by the very large amount of VARS added at Malta and Havre buses, therefore it is not practical to attempt to export the full 100 MW wind farm Project at Fort Peck.

Reductions in the steady state voltages at buses along the existing 500 kV corridor in Montana also occurred as a result of the increased flows to the Northwest area. Although they do not represent changes greater than 5% of their base case operating values, voltages at buses Garrison 500 kV and Bell BPA 500 kV were shown in the model to be significantly lower than the 1.08 pu nominal operating value. The Garrison 500 kV steady state voltage was reduced from 1.06 pu to 1.04 pu, and voltage at Bell BPA was reduced from 1.05 pu to 1.04 pu.

Three rating violations in the Northwest area were fixed for the schedule to Spokane. The two “CHIEFJO” Generator Step-Up (GSU) transformers, and the “COUGAR T” GSU experience 3% and 1% decreases respectively in their loading. This decrease is due to a reduction of generator output due to the scheduling method, and cannot be considered an improvement brought about by the Project.

Three insignificant overvoltage violations on 115 kV buses in the Northwest area were corrected when compared to the base case power flows.

3.2.2 Generation Scheduled to Denver

For this case, Table 2 shows that one new rating violation was caused, 32 voltage violations were caused, and only four voltage violations were fixed by the Project. There are 24 of the 32 voltage violations which are marginal, and may be resolved by adding reactive power compensation to the appropriate buses, particularly in the WAPA UM and WAPA RM areas. For these 24 cases, the voltage levels with the Project were just under the 0.95 per unit level (0.93 to 0.95) while the levels without the Project were just over the 0.95 per unit level (0.95 to 0.98). Of the remaining eight voltage violations which are more serious, seven are in the WAPA U.M. area on the 161 kV buses between Richardson/Coulee and Havre, where the voltage fell from the nominal levels of 1.02 and 1.03 per unit to 0.86 to 0.91 per unit. This confirms that the 161 kV Hiline cannot support the 100 MW wind farm at Fort Peck without additional reactive power support.

The new rating violation occurred on the 161 kV Jefferson phase shifting transformer in the PACE area. The transformer reached 114% of its 100 MVA rating, indicating that increased flows are present on the Amps 230 kV and Big Grassy 161 kV transfer paths from Montana to PACE.

3.2.3 Generation Scheduled to Salt Lake City

All three of the rating violations caused by the schedule to Salt Lake City are in the known constraint area around Amps in Idaho. The Jefferson 161 kV phase shifting transformer in Idaho reached 118% of its rating, and two 161 kV lines out of Fish Creek reached 108% and 105% of their ratings. For this schedule, 17 voltage violations were caused and 6 violations were fixed. Twelve of the seventeen voltage violations are marginal. For these twelve cases, the voltages levels with the project were just under the 0.95 per unit level (0.92 to 0.95) while the levels without the project were just over the 0.95 per unit level (0.95 to 0.98). However, the remaining five violations in the WAPA U.M. area are on the 161 kV buses between Richardson/Coulee and Havre, where the voltage fell from the nominal levels of 1.02 and 1.03 per unit to levels ranging from 0.87 to 0.91 per unit. This confirms that the 161 kV Hiline cannot support the 100 MW wind farm at Fort Peck even with additional reactive power support.

3.3 Category B Violations

Table 3 shows the number of rating and voltage violations affected by the Project for Category B power flow. For each schedule, 722 single-outage contingencies were analyzed.

Table 3 - Category B Violations Summary

Schedule	Area Name	Violations caused or worsened by 5%		Violations fixed or improved by 5%	
		Ratings	Voltage	Ratings	Voltage
Spokane	Northwest	19	29	-	-
	Montana	2	39	-	-
	WAPA U.M.	-	7	-	-
	Colorado	-	3	-	-
Denver	Northwest	8	17	-	-
	Idaho	1		-	-
	Montana	2	38	2	3
	WAPA U.M.	3	3	-	-
	PACE	-	3	1	2
	WAPA R.M.	4	1	-	-
Salt Lake City	Northwest	10	8	-	-
	Idaho	1		-	-
	Montana	2	38	2	3
	WAPA U.M.	-	3	-	-
	PACE	6	3	-	2
	WAPA R.M.	5	2	-	-

3.3.1 Generation Scheduled to Spokane

As shown in Table 3, 21 rating violations were caused or worsened by the Project scheduled to Spokane. There were no rating violations fixed for this case. The vast majority of the violations occurred in the Northwest area or in Montana. The most serious new rating violation occurred on the BURKE to HECLA 115 kV line, which reached 106% of its rating for the BURKE to LUCKYFTP 115 kV line contingency. Another serious new rating violation occurred on the BELL BPA 500 kV to the BELL SO 230 kV transformer, which reached 106% of its rating for the Dworshak to Taft 500 kV line outage. This same outage caused 29 new voltage violations in the Northwest that ranged from 0.93 per unit to 0.949 per unit. The Fort Peck to Richardson/Coulee 161 kV line outage caused the most serious voltage violation, 0.67 per unit, on the Havre 161 kV bus. An additional 20 voltage violations ranging from 0.73 per unit to 0.96 per unit were caused in the Montana area by this 161 kV outage. There were a total of 78 voltage violations caused or worsened for this generation schedule and no voltage violations fixed.

This case had eight new non-converged outages that were all related to the 500 kV sections from Colstrip through Broadview, Townsend, and Garrison to Taft. This indicates that the Project schedule is critically dependent on that particular 500 kV transmission corridor. When a section of this transmission path is out of service, the surrounding system cannot support the transfer of the Project generation.

Due to the number of new rating and voltage violations during contingencies, including the eight new non-converged outages, it is immediately clear that the Project does not benefit the western transmission system. New transmission

facilities are necessary to export additional power from Montana. With the exception of the wind farm at Fort Peck, the steady state and contingency analyses indicate that the other wind farm Projects did not cause rating and voltage violations near the wind farm locations, but in the load center area and along the 500 kV corridor. These observations suggest that a new transmission line route to Spokane similar to the viable alternatives studied in Projects 1 through 4 could provide the transfer capacity necessary to reach the Spokane market.

3.3.2 Generation Scheduled to Denver

This schedule caused or worsened 18 rating violations. Three rating violations were fixed. The most serious rating violations were caused by the YELOWTLP to YELLOWBR 230 kV line outage. The loading on the BASIN to GREYBULL 115 kV line and the CARTERMT to THERMOPL 115 kV line were both raised to 106 %.

There were 62 voltage violations caused or worsened by this generation schedule, while five voltage violations were fixed. The most serious voltage violations were caused in the Montana area by the Richardson/Coulee to Malta UM 161 kV line outage. A total of 18 new voltage violations ranging from 0.625 per unit to 0.967 per unit were caused by this 161 kV outage. An additional 11 voltage violations, ranging from 0.900 per unit to 0.988 per unit, were caused in the Montana area by the outage of the Garrison 500 kV to 230 kV transformer. The Dworshak to Taft 500 kV line outage caused 16 new voltage violations in the Northwest area ranging from 0.891 per unit to 0.949 per unit.

This case had nine new non-converged outages for this study. Eight of the non-converged outages are related to the 161 kV sections from Fort Peck to Great Falls through Richardson/Coulee and Havre and to the 161 kV transformers at Havre, Great Falls, and Rainbow. The other non-convergent outage was for the 230 kV line outage from Antelope to Amps. This is a known area of constraint.

The number and severity of contingency violations indicate that the schedule to Denver is not feasible without the addition of new transmission facilities. Contrary to the contingency analysis of the model scheduled to Spokane, the geographically widespread issues of this model are not likely to be solved by choosing a Denver-route transmission line alternative from one of the other Projects of this Study. Additional transmission sections would be required in several areas to address the widespread impact to the system. These additions would likely include pathways along the existing transfer constraints, and sections which run parallel to the existing 500 kV corridor.

3.3.3 Generation Scheduled to Salt Lake City

Twenty-four new rating violations were caused or worsened by this schedule and two rating violations were fixed. The most serious rating violations occurred on the Dillon to Big Grassy and the Big Grassy to Jefferson 161 kV transmission lines, 106 % and 104 % respectively, for Dworshak to Taft 500 kV line outage.

This generation schedule caused or worsened 54 voltage violations and fixed 5 voltage violations. The worst voltage violation was at the new Blackfeet 115 kV bus and was 0.674 per unit for Richardson/Coulee to Malta UM 161 kV line outage. This outage caused a total of 19 voltage violations in the Montana area ranging from 0.674 per unit to 0.963 per unit. An outage of the Garrison 500 kV to 230 kV transformer caused 15 voltage violations in the Montana area ranging from 0.903 per unit to 0.986 per unit. An outage of the Dworshak to Taft 500 kV line (circuit 1) caused 8 voltage violations in the Northwest area ranging from 0.946 to 0.949 per unit.

This case had nine non-converged outages for this study. Seven of the non-converged outages are related to the 161 kV sections from Fort Peck to Great Falls through Richardson/Coulee and Havre and to the 161 kV transformers at Havre, Great Falls, and Rainbow. This indicates that the Project schedule is critically dependent on that particular 161 kV transmission corridor and transformers. The other non-convergent outages were for the 230 kV line outage from Antelope to Amps, and for the 230 kV line outage from Anaconda to Peterson Flats. These non-converged outages are in the known area of constraint.

The quantity and severity of contingency issues indicate that this generation schedule is not feasible. Additionally, the dispersal of the rating and voltage violations geographically indicates that additional transmission sections would be required in several areas to address the widespread impact to the system. These additions would likely include pathways along the existing transfer constraints, and sections which run parallel to the existing 500 kV corridor.

4. DYNAMIC STABILITY ANALYSIS

4.1 Fault Scenarios

The following outage scenarios, both pre- and post-Project, were simulated for a study period of 10 seconds to determine if the Project creates any system instability, or violation of WECC criteria, during these line and generator outages.

4.1.1 Fault Location 1

A single-circuit three-phase fault near the Cut Bank 115 kV bus was cleared by tripping the faulted project line in normal 5-cycle total clearing time.

A single-circuit single-phase-to-ground fault near the Cut Bank 115 kV bus was cleared by tripping the faulted project line in delayed 25-cycle total clearing time.

In both the three-phase and single-line-to-ground scenarios, the 100 MW wind farm at Blackfeet was tripped due to the loss of its tap line. These studies were made with the Project generation scheduled to Spokane that is based on the

WECC Light Summer model and represents heavy flows to Spokane and the Northwest area. The pre-Project fault scenarios were run on the corresponding base case.

4.1.2 Fault location 2

A single-circuit three-phase fault near the Great Falls 100 kV bus was cleared by tripping the faulted project line in normal 5-cycle total clearing time.

A single-circuit single-phase-to-ground fault near the Great Falls 100 kV bus was cleared by tripping the faulted project line in delayed 25-cycle total clearing time.

In both the three-phase and single-line-to-ground scenarios, the 100 MW wind farm at Great Falls was tripped due to the loss of its tap line. These studies were made with the Project generation scheduled to Salt Lake City, which is based on the WECC Heavy Summer model and represents additional heavy flows to Salt Lake City due to the Project generation schedule. The pre-Project fault scenarios were run on the corresponding base case.

4.1.3 Fault Location 3

A single-circuit three-phase fault near the Fort Peck 161 kV bus was cleared by tripping the faulted project line in normal 5-cycle total clearing time.

A single-circuit single-phase-to-ground fault near the Fort Peck 161 kV bus was cleared by tripping the faulted project line in delayed 25-cycle total clearing time.

In both the three-phase and single-line-to-ground scenarios, the 100 MW wind farm at Fort Peck was tripped due to the loss of its tap line. These studies were made with the Project generation scheduled to Spokane, which is based on the WECC Light Summer model and represents heavy flows to Spokane and the Northwest area. The pre-Project fault scenarios were run on the corresponding base case.

4.1.4 Fault Location 4

A single-circuit three-phase fault near the Clyde Park 161 kV bus was cleared by tripping the faulted project line in normal 5-cycle total clearing time.

A single-circuit single-phase-to-ground fault near the Clyde Park 100 kV bus was cleared by tripping the faulted project line in delayed 25-cycle total clearing time.

In both the three-phase and single-line-to-ground scenarios, the 100 MW wind farm at Livingston was tripped due to the loss of its tap line. These studies were made with the Project generation scheduled to Salt Lake City, which is based on the WECC Heavy Summer model and represents additional heavy flows to Salt Lake City due to the Project generation schedule. The pre-Project fault scenarios were run on the corresponding base case.

4.1.5 Fault Location 5

A single-circuit three-phase fault near the Billings 100 kV bus was cleared by tripping the faulted project line in normal 5-cycle total clearing time.

A single-circuit single-phase-to-ground fault near the Billings 100 kV bus was cleared by tripping the faulted project line in delayed 25-cycle total clearing time.

In both the three-phase and single-line-to-ground scenarios, the 100 MW wind farm at Billings was tripped due to the loss of its tap line. These studies were made with the Project generation scheduled to Denver, which is based on the WECC Heavy Summer model and represents additional heavy flows to Denver. The pre-Project fault scenarios were run on the corresponding base case.

4.1.6 Fault Location 6

A single-circuit three-phase fault near the Yellowtail 230 kV bus was cleared by tripping the faulted project line in normal 5-cycle total clearing time.

A single-circuit single-phase-to-ground fault near the Yellowtail 230 kV bus was cleared by tripping the faulted project line in delayed 25-cycle total clearing time.

In both the three-phase and single-line-to-ground scenarios, the 100 MW wind farm at Yellowtail was tripped due to the loss of its tap line. These studies were made with the Project generation scheduled to Denver, which is based on the WECC Heavy Summer model and represents additional heavy flows to Denver. The pre-Project fault scenarios were run on the corresponding base case.

4.2 Dynamic Stability Study Results

The results indicate that the six dispersed wind farms of did not meet stability criteria with no new transmission lines added to the system. The 161 kV Hiline cannot support the transfer of additional generation. Consequently, the Fort Peck hydro unit was shown to be unstable. When the scheduled generation at the Fort Peck wind farm was reduced from 100 MW to 50 MW, there were no stability violations for any of the fault locations 1 through 6.

Further investigation showed that the new Blackfeet wind farm was unstable for contingencies as remote as Great Falls when all six wind farms remained online after the disturbance. Project 5 could be made functional by reducing the size of wind generation at Fort Peck and Blackfeet, and by installing reactive power support on several buses. However, increased system losses and additional stress on existing transfers limit the feasibility of Project 5.

As suggested by the 500 kV Hiline upgrade of Project 4, proper transmission line upgrades of the Hiline would provide sufficient capacity for a 100 MW wind farm at Fort Peck. Similar transmission improvements in the Blackfeet area would be necessary to support 100 MW of new generation at Blackfeet. These results suggest that a 100 MW wind installation may be feasible at the other sites, but further detailed analysis of each site is necessary.

As a side note, the geographical dispersal of the six wind farm sites, coupled with the fact that the availability of wind energy cannot be predicted, makes it unlikely that all six sites would be operating simultaneously at their maximum power output. Therefore, the dynamic analysis presented in this study represents the worst case conditions however improbable.

5. COST ANALYSIS

Transmission and substation estimated costs for the individual projects are shown in Table 4. The generation substations do not include any distribution equipment. The estimated costs began at the low side bushings of the Wind Generation Substation transformer and went through to the designated transmission tie-in buses.

Table 4 - Transmission and Substation Costs - Project 5

Project Location / Tie-In Location	Line Length and Voltage	Line Cost (thousands)	Gen Sub Costs (thousands)	Tie-In Sub Costs (thousands)	Total Costs (thousands)
Blackfeet / Cut Bank	10 miles; 115 kV	$2,154	$2,500	$1,046	$5,700
Great Falls / Great Falls	10 miles; 100 kV	$2,154	$2,500	$1,046	$5,700
Fort Peck / Fort Peck	10 miles; 161 kV	$2,279	$2,700	$1,335	$6,314
Livingston / Clyde Park	15 miles; 115 kV	$3,419	$2,700	$1,335	$7,454
Billings / Billings	10 miles; 100 kV	$2,154	$2,500	$1,046	$5,700
Yellowtail / Yellowtail	10 miles; 230 kV	$2,755	$3,000	$1,816	$7,571
Total Project Costs					**$38,439**

6. VIABILITY SUMMARY

The wind generation and schedules of this Project were shown to be non-viable due to multiple rating, voltage, and stability violations. The effect of adding new generation, even when dispersed throughout Montana, without the addition of sufficient transmission capacity is detrimental to the existing system. Reducing the sizes of some or all of the wind farms may be feasible, but further analysis would be required.

7. CONCLUSIONS

This study shows the different impacts on the system depending on the power flow schedule and system conditions. Each of the three generation schedules results in increased system losses and widespread low voltages, indicating that the performance of the system is reduced. Power scheduled to Spokane introduces the least increase in losses, while power scheduled to Denver has only slightly lower losses than power scheduled to Salt Lake City.

System intact analyses indicated that numerous voltage violations were introduced by all the power schedules, but may be corrected by adding shunt capacitors to the affected buses.

There were few new rating violations which all occurred on known constraint paths. These overloads and undervoltages would need to be addressed for any of the wind farm projects.

Contingency analyses indicated a large quantity of rating and voltage violations. The results of the contingency analysis demonstrate the need for additional transmission paths. The Projects did not meet dynamic stability criteria when all six sites were online simultaneously. Some of the 100 MW wind sites may still be feasible, but further study is necessary.