Darlingford, Boissevain, Killarney, & Minnedosa Wind Farms: Phase 1 Interconnection Evaluation Study

Performed by:

Manitoba Hydro
System Planning Department

Project Leader:
David Jacobson, P.Eng.

Principal Contributors:
Derek Collins
Rebecca Brandt

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Executive Summary

A Phase 1 Interconnection Evaluation Study (IES) has been performed to determine the transmission facilities necessary to connect wind farms ranging in size from 25 MW to 100 MW at four locations in Manitoba, including Darlingford (50-100 MW), Boissevain (25-75 MW), Minnedosa (25-100 MW) and Killarney (50-100 MW). The Customer has requested the proposed generation be considered a Manitoba Hydro (MH) network resource subject to negotiations with Power Supply. As a network resource, the impacts of scheduling to MH generation and load were evaluated. MH's load and generation are located entirely within the Province of Manitoba. Therefore, the wind generation will not require the need to increase transfer levels on the Manitoba to Ontario, Saskatchewan or U.S. boundaries. The Phase 1 IES determined the impact of the different wind generation sites on the existing MH transmission system by means of steady state power flow analysis.

There are several feasible connection points for each potential wind farm location, including voltage connection levels of 230 kV, 115 kV and 66 kV. Steady state power flow analysis was performed to determine the amount of wind generation that can be connected at any one of these locations.

Several thermal overloads are identified that require further investigation in an Interconnection Facility Study. All of the four proposed wind farm sites have similar impacts on Ridgeway transformer banks 1 and 2, 230 kV line D5R between Dorsey and Rosser, 110 kV line YV5 between Laverendrye and St. Vital, 110 kV line RS51 between Rosser and Inkster, 110 kV line XV39 between Mohawk and St. Vital, and 110 kV line BE3 between Brandon G.S. and Brandon-Victoria. These overloads are either base case problems, or occur due to an increase in load, however the impact of the wind farms may require mitigation sooner than would have been necessary due to normal load growth.

The Darlingford connection points include two 100 MW-230 kV options (A - tapping 230 kV line S60L, B- direct connection to St. Leon 230 kV bus) and two 50 MW-66 kV options (C- tapping radial 66 kV line L51, D- direct connection to St. Leon 66 kV bus). In addition to the impacts listed previously, the Darlingford wind farms impact 110 kV lines CB42 and CB1 between Brandon and Cornwallis. A 66 kV Option C wind farm greater than 41 MVA requires an increase in 66 kV line 51 thermal capacity. In addition, a 66 kV Option C or Option D wind farm greater than 93 MW requires a third 66-230 kV transformer at St. Leon (considering an outage of one of the two parallel banks).

The Boissevain connection points include one 100 MW-230 kV option (A - direct connection to 230 kV Souris East bus) and one 50 MW-66 kV option (B - direct connection to 66 kV Boissevain station). In addition to the impacts listed previously, the 100 MW farm impacts 110 kV lines CB42 and CB1 between Brandon and Cornwallis. The 50 MW farm impacts 110 kV line MR11 between Rapid City and Brandon. A 66 kV wind farm size greater than 26 MW requires an increase in 66 kV line 71 and line 72 thermal capacity (considering an outage of one of the two parallel lines). In addition, a 66 kV wind farm size greater than 40 MW requires a third 66-110 kV transformer at Brandon-Victoria (considering an outage of one of the two parallel banks).

The Killarney connection points include one 100 MW-230 kV option (A - tapping 230 kV line G82R) and one 50 MW-66 kV option (B - direct connection to 66 kV Killarney station). In addition to the impacts listed previously, the Killarney wind farms impact 110 kV lines CB42 and CB1 between Brandon and Cornwallis. The 100 MW farm also impacts 110 kV line MR11 between Rapid City and Brandon. A 66 kV wind farm size greater than 42 MW requires an increase in 66 kV line 44 thermal capacity. In addition, a 66 kV wind farm size greater than 100 MW requires a fourth 66-230 kV transformer at Glenboro South (considering an outage of one of the three parallel transformers).

The Minnedosa connection points include two 100 MW-115 kV options (A - tapping 110 kV line MR11, B - direct connection to the 110 kV Minnedosa station). In addition to the impacts listed previously, both options impact 110 kV line CB42 between Brandon and Cornwallis, 110 kV line MR11 between Rapid City and Brandon, 110 kV line MR11 between Raven Lake and MR11 tap, and 110 kV line NM10 between Neepawa and Minnedosa. The tapping option also impacts l10 kV line MR11 between Rapid City and MR11 tap. The direct connection option also impacts 110 kV line MR11 between Minnedosa and MR11 tap.

The approximate costs of the transmission facilities necessary to connect the wind farm to each connection point were calculated for planning purposes and are summarized below. A more detailed cost estimate will be developed in the Interconnection Facilities Study, which will include necessary Interconnection System and Network Upgrade costs.

100 MW	Darlingford	A	$ 12.58 M
100 MW	Darlingford	B	$ 7.95 M
100 MW	Minnedosa	A	$ 12.66 M
100 MW	Minnedosa	B	$ 5.56 M
100 MW	Killarney	A	$ 16.31 M
75 MW	Boissevain	A	$ 25.33 M
41 MW	Darlingford	C	$ 3.10 M
50 MW	Darlingford	D	$ 3.50 M
26 MW	Boissevain	B	$ 3.50 M
42 MW	Killarney	B	$ 2.90 M

The 66 kV connection options, especially Boissevain and Killarney, may require voltage control beyond the minimum requirements in order to control flicker, to prevent excessive 66-110 kV or 230 kV transformer tap changer action and to maintain acceptable operating voltages during wind power and local load fluctuations. In addition, adding the wind farm to a radial system reverses the normal power flow direction on the line and through the step-up transformers, which could require significant changes to and/or replacements of the existing protection. All of these issues would be further investigated in an Interconnection Facilities Study.

The preferred connection options are at the 115 kV and 230 kV voltage levels. However, as indicated by previous studies, it is likely that the Darlingford wind farms will require dynamic voltage control beyond the minimum requirements to prevent a voltage collapse scenario and/or transient voltage violations. A possible solution to avoid this extra requirement may be to swap several termination locations in the St. Leon 230 kV station ring bus to avoid the possibility of isolating more than 100 MW onto a single outlet line, which was the original cause of the voltage collapse scenario. The physical feasibility of swapping the terminations has not been investigated yet, nor has any stability analysis been performed. Swapping termination locations would also have cost implications that would need to be compared to the cost of dynamic voltage control in the Interconnection Facilities Study phase. The 230 kV Killarney wind farm taps a Manitoba – U.S. tie line, which impacts the HVdc reduction scheme, flows on two MAPP constrained paths, and the delta P relay on the Ontario ties, all of which would require further investigation. In addition, the 230 kV Killarney option requires an outage of tie line G82R to install the wind farm, costing up to $40/MWh for 200 MW for the length of time needed to install the wind farm. No previous stability studies have been performed for the Boissevain or Minnedosa locations.

The next phase of studies will include stability analysis, short circuit analysis, impacts on MAPP constrained interfaces, adequacy of reactive power facilities, detailed ring bus analysis and mitigation for reliability limitations, which could all impact the planning level cost estimates listed earlier. Further phases of studies will also determine a good faith cost estimate for all MH Interconnection Facilities, a good faith construction schedule estimate, any special protection requirements, communication requirements and will satisfy any requirements of the Regional Transmission Authority.

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1.0 Introduction

1.1 Background Information

This report documents the results of a Phase 1 Interconnection Evaluation Study for wind farms near the towns of Darlingford, Boissevain, Minnedosa and Killarney, all within the Province of Manitoba. The Customer is proposing one of the following wind farms, with an in-service date of Spring 2005:

- 50-100 MW near Darlingford
- 25-75 MW near Boissevain
- 50-100 MW near Killarney
- 25-100 MW near Minnedosa

The Customer has indicated land sections and corresponding Township-Range locations for each of the four wind farm sites at which the wind turbines could be installed. Please refer to Appendix A for maps depicting the four wind farm land locations.

There are several connection options for each of the four locations, including:

1. Darlingford
   A. Tapping 230 kV line S60L between St. Leon and Stanley stations
   B. Direct connection to the St. Leon 230 kV station bus
   C. Tapping 66 kV radial line L51 fed from St. Leon 66 kV station
   D. Direct connection to the St. Leon 66 kV station bus

2. Boissevain
   A. Direct connection to the 230 kV Souris East station
   B. Direct connection to the Boissevain 66 kV station bus

3. Killarney
   A. Tapping 230 kV line G82R between Glenboro and Rugby stations
   B. Direct connection to the Killarney 66 kV station bus

4. Minnedosa
   A. Tapping 110 kV line MR11 at Rapid City
   B. Direct connection to the Minnedosa 110 kV station bus

For all connection options, a single transmission line from the wind farm station to the Point of Interconnection (POI) is adequate from an operating reserve point of view. The MH network is designed to withstand loss of the largest unit under a single contingency, which today is two 133 MW Limestone units or 266 MW. The system can withstand loss of the largest HVdc valve group under maximum temperature conditions (i.e. greater than 28 deg. C), which corresponds to 500 MW. The probability of this event is ten times lower than loss of the Limestone unit. The single transmission line also assumes no energy delivery penalty during unscheduled outages of the line.

This report discusses specific connection options in terms of wind farm impacts on system reliability limitations and steady state voltage at the Points of Interconnection. Level 1 cost estimates are also provided for each connection option. These estimates do not include the cost for any Interconnection System or Network Upgrades.

1.2 Objectives

The Phase 1 Interconnection Evaluation Study objectives are to determine:

- the voltage level at the Point of Interconnection,
- MH Interconnection Facilities required to electrically connect the Generation Facility to the MH electrical system
- system reliability limitations (i.e. equipment overloads, voltage violations)
- planning level cost estimates of transmission facilities

1.3 MH Technical Requirements for Generator Interconnection

Please refer to the MH document titled, “Transmission System Interconnection Requirements” for more details.

2.0 General Study Information and Procedures

The PSS/E base cases were derived from the 2003 series of MAPP load flow models representing the year 2008 with summer peak loading.

2.1 Steady State Powerflow Analysis

In order to determine the steady state impacts of the wind generation on system reliability limitations, steady state dc powerflow analysis was performed. Linear dc powerflow analysis (PSS/E activity TLTG) is used to estimate import or export limits between a defined source and sink. The activity identifies a study system in which generation is increased and an opposing system in which generation is decreased (or load is increased). For this study, the source system or POR is defined as one of the potential wind sites at Darlingford, Boissevain, Killarney or Minnedosa. The opposing system or POD is defined as various combinations of Manitoba load or combinations of Manitoba generation.

Linear dc powerflows calculate thermal limitations caused by overloaded transmission lines or transformers. The method assumes sufficient reactive power reserves are available to hold voltages constant. This type of analysis confirms point-to-point transmission adequacy from the proposed wind sites to redispatched generation within Manitoba or due to a Manitoba load increase.

Power transfer distribution factors (PTDFs) relate the change in wind generator output to the change in specific line and interface flows. PTDF is sometimes referred to as Transmission Participation Factor (TPF) by MISO. Maximum transfer capabilities are calculated by extrapolating the line flows using the PTDF's and comparing them to specified ratings. Facilities identified in TLTG analysis are considered to be limiting elements if they have a PTDF greater than 3%.

To test the adequacy of the transmission system to transfer the additional wind generation and to search for worst-case contingencies, transfers between the wind sites and several Manitoba sinks were increased incrementally up to and beyond the desired maximum wind farm sizes. All single and common tower contingency outages within Manitoba and on ties to neighboring utilities were tested. The Manitoba sinks included Brandon, Dorsey DC, Grand Rapids and Winnipeg River generation as well as Manitoba load. The two critical sinks are considered to be Grand Rapids generation and Dorsey DC as these are the AGC plants for MH that would react to control net MH interchange for unscheduled variation in wind generation.

A number of insoluble contingencies can occur in the TLTG process. For the Manitoba area, they usually occur for a contingency that would normally result in a DC reduction, which is not modeled. These insoluble cases are ignored because it is assumed that the DC reduction will mitigate potential overloads. If a DC reduction does not occur and the case is insoluble, the problem is an existing base case or contingency overload not affected by the wind (i.e. PTDF much less than 3%).

2.2 Summary and Description of Limiting Facilities/Reliability Limitations

DC powerflow results identified several facilities that become overloaded and that are impacted by the wind generation. This section provides a brief description of the limiting elements of the overloaded lines and transformers.

Table 1. Limiting Elements of Overloaded Lines/Transformers.

Limiting Facility	Limiting Element(s)
110 kV line CB42	120 MVA risers at Brandon which are being replaced in 2005. 133 MVA risers at Cornwallis may need re-rating or replacing.
110 kV line CB1	133 MVA risers at Cornwallis may need re-rating or replacing.
Raven Lake Bank 3	65.1 MVA overcurrent relay setting to protect line MR11. The bank itself is not being overloaded.
110 kV line MR11 (Rapid City-Brndn)	270 A CT at Brandon which is being replaced. Next limits are 356 A risers at both ends of the line, and 396 A line conductor (75 deg C sag).
110 kV line MR11 (MR11 tap-Rpd Cty	425 A line conductor (sagged to 75 deg C), which may need re-sagging to 100 deg C.
110 kV line MR11 (Rvn Lk-MR11 tap)	356 A risers at both ends of the line, which may need re-rating or replacing. Next limit is the 426 A line conductor (sagged to 75 deg C), which may need re-sagging to 100 deg C.
110 kV line MR11 (Minned.-MR11 tap)	356 A risers at both ends of the line, which may need re-rating or replacing. Next limit is the 426 A line conductor (sagged to 75 deg C), which may need re-sagging to 100 deg C.
110 kV line NM10	356 A risers at both ends of the line, which may need re-rating or replacing. Next limit is the 426 A line conductor (sagged to 75 deg C), which may need re-sagging to 100 deg C.
230 kV line S60L	HVDC reduction occurs for contingencies which cause this overload and therefore no additional mitigation should be required.
Ridgeway Bank 1(2)	125 MVA thermal limit of 230-66 kV banks at Ridgeway. Studies are underway to investigate expansion at Transcona 230-66 kV station in lieu of adding a third Ridgeway bank. Studies not yet completed.
Brandon Bank 5(6)	40 MVA thermal limit of 110-66 kV banks at Brandon-Victoria.
230 kV line D5R	645 A risers at Dorsey end of the line, which may need re-rating or replacing.
110 kV line YV5	3.15 km section of 110 MVA line conductor (sagged to 100 deg C) which may need re-conductoring.
110 kV line RS51	160 MVA section of underground cable that may require replacement. 180.6 MVA risers at both ends, which may require re-rating or replacing. 186.7 MVA line conductor (sagged to 100 deg C) which may need re-conductoring.
110 kV line XV39	110.1 MVA line conductor (sagged to 100 deg C), which may need re-conductoring. Risers at both ends of the line, which may need re-rating or replacing.
110 kV line BE3	81.2 MVA line conductor (sagged to 75 deg C), which may need re-sagging.

2.3 Steady State Voltage at the Point of Interconnection (POI)

In order to roughly assess how large an impact a wind farm will have on the voltage at the POI, steady state voltages are compared between the existing system before adding wind and after adding wind for each connection option. This provides a general idea if the minimum voltage regulation requirements will be sufficient to mitigate possible flicker and steady state voltage problems due to wind power and local load fluctuations, especially for wind farms connecting to longer radial lines. The voltages at the POI and at the wind turbine bus are noted for two scenarios of power factor / voltage control:

1. Full load PFC: slow switched capacitors totaling the full load Var consumption of the generator (i.e. if wind is producing full output, full-load PFC capacitors are on-line regardless of voltage).

2. Dynamic PFC: thyristor-switched capacitors/reactors always controlling the net Vars at the wind turbine bus to 0 MVAr for unity power factor control (or possibly some other desired power factor).

2.4 Reactive Power and Voltage Control Requirements

For Generator Facilities greater than 10 MW, the Generator is required to supply reactive power between 0.9 overexcited (leading) to 0.9 underexcited (lagging) as measured at the generator terminals. If the Generator Facility is comprised of induction type generators, such as may be connected to wind turbines, the reactive power requirements are 0.95 overexcited (leading) to 0.95 underexcited (lagging) as measured at the generator intermediate bus. The reactive supply must available over the full range of operating conditions. The use of mechanically-switched capacitors or reactors, static var compensators or similar devices may be acceptable alternatives for providing part of all of the supply, as further studies will verify. The Generator is responsible for providing any necessary reactive power facilities as determined by the Interconnection Studies.

A Generator Facility equipped with a continuously acting voltage regulator shall have the capability to maintain the steady state voltage within $\pm$0.5% of the set point at the Point of Interconnection (POI), or some other point as determined by the MH System Operator. The voltage response time will depend on Interconnection Studies but shall not be longer than 100 ms.

A Generator Facility relying on mechanically-switched shunt capacitors for steady-state voltage regulation shall have a voltage response time not greater than 15 seconds. Interconnection Studies will determine if this type of voltage regulation is permissible.

Please refer to MH Document “Transmission System Interconnection Requirements” for more detail.

2.5 Planning Level Unit Cost Estimates

Table 2 summarizes the Planning Level unit cost estimates that were used to develop the overall connection option cost estimates.

Table 2. Planning Level Unit Cost Estimates.

Equipment	Cost Estimate (in $1000)		
	230 kV	115 kV	66 kV
New Station	3,000	2,000	500
Termination	2,900 / breaker	2,300 / breaker	1,700 / breaker
Line to MH grid	275 / km	225 / km	100 / km

3.0 Darlingford Study Results

Four connection options were studied for the Darlingford wind site. Please refer to Appendix A for a map showing the land location of the proposed wind farm.

3.1 Connection Option A

Option A has a target size of 100 MW. The connection option requires tapping 230 kV line S60L between St. Leon and Stanley stations, as shown in Figure 1.

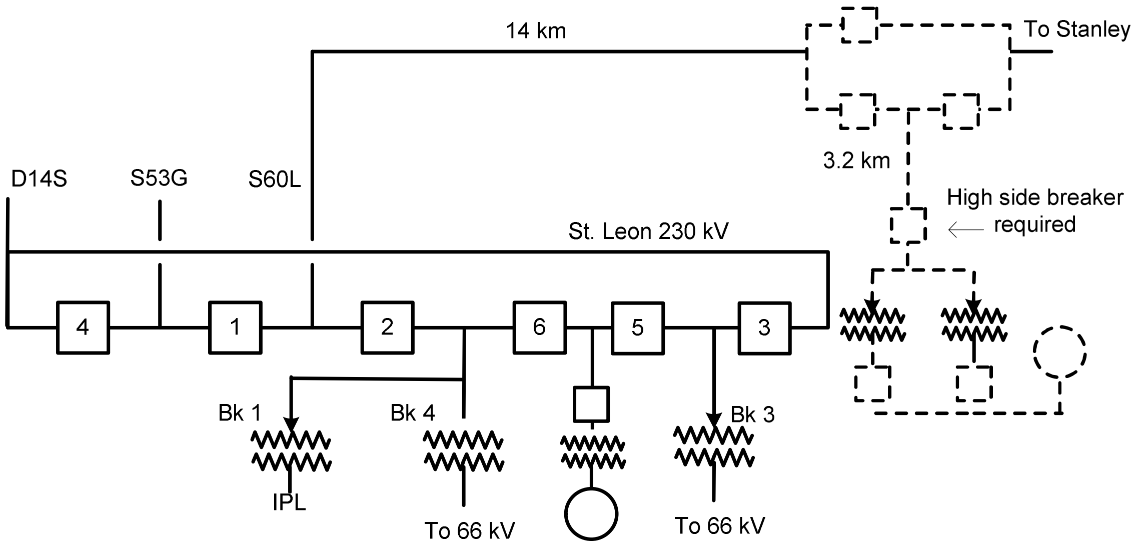


Figure 1. Darlingford Option A.

3.1.1 Impact on Reliability Limitations

Table 3 summarizes the impact of the wind generation on system reliability limitations. The incremental MW value refers to the size of wind farm at which the listed facility becomes overloaded if the contingency occurs. Please refer back to Table 1 for a description of the limiting elements.

Table 3. Darlingford Option A Impacts.

Limiting Facility	Contingency	Sink	Incremental MW
CB42	Cornwallis Bank 3	Brandon	5.8
CB1	Cornwallis Bank 3	Brandon	38.2
Raven Lake Bank 3	C28R	Brandon	1.1
S60L	Y51L	Dorsey DC	75.8
Ridgeway Bank 1(2)	Ridgeway Bank 1(2)	MH load	13.7
D5R	D13R+D16R	MH load	11.4
YV5	YX48+YX47	MH load	0
RS51	YX48+YX47	MH load	0
XV39	YX48+YX47	MH load	0
BE3	BE1+BE2	MH load	0

3.1.2 Impact on Steady State Voltage at the POI

Table 4 summarizes the voltage at the POI and at the wind turbine bus for several scenarios.

Table 4. Darlingford Option A – Voltage at POI.

	Voltage (pu)	
	POI	LV Wind Farm Bus
Before Wind	1.0224	n/a
Wind farm with full load PF caps	1.0154	0.9939
Wind farm with net MVAR = 0	1.0162	0.9690

3.1.3 Interconnection Facilities Cost Estimate

Table 5 provides the cost estimate for Darlingford Option A according to the facilities shown in Figure 1 and the cost assumptions provided in Table 2.

Table 5. Darlingford Option A – Cost Estimate.

Item	Quantity	Cost (in $1000)
New Station	1	3,000
Termination	3 breakers	8700
Line to MH grid	3.2 km	880
	Total	$12580

3.2 Connection Option B

Option B has a target size of 100 MW. The connection option is a direct connection to the 230 kV St. Leon station bus, as shown in Figure 2.

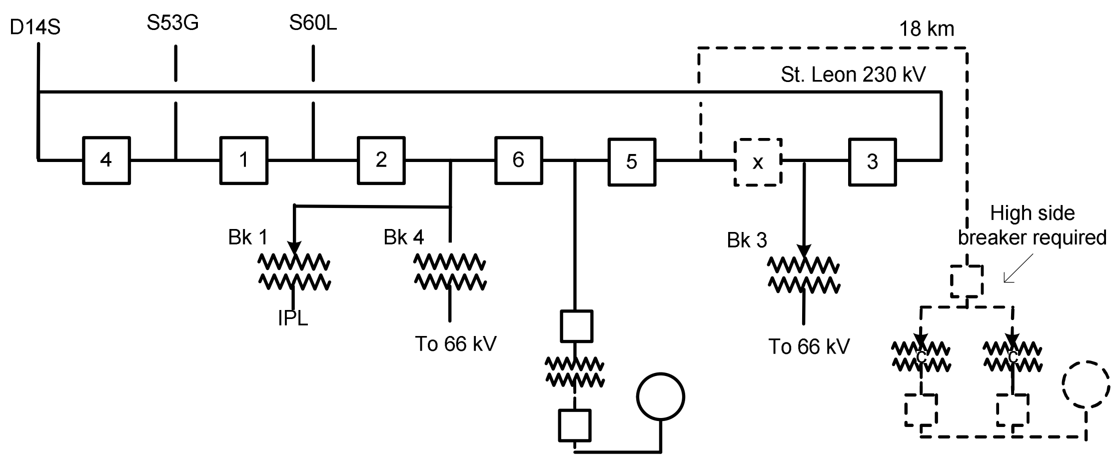


Figure 2. Darlingford Option B.

3.2.1 Impact on Reliability Limitations

Table 6 summarizes the impact of the wind generation on system reliability limitations. The incremental MW value refers to the size of wind farm at which the listed facility becomes overloaded if the contingency occurs. Please refer back to Table 1 for a description of the limiting elements.

Table 6. Darlingford Option B Impacts.

Limiting Facility	Contingency	Sink	Incremental MW
CB42	Cornwallis Bank 3	Brandon	5.8
CB1	Cornwallis Bank 3	Brandon	38.2
Raven Lake Bank 3	C28R	Brandon	1.1
S60L	Y51L	Dorsey DC	75.8
Ridgeway Bank 1(2)	Ridgeway Bank 1(2)	MH load	13.7
D5R	D13R+D16R	MH load	11.4
YV5	YX48+YX47	MH load	0
RS51	YX48+YX47	MH load	0
XV39	YX48+YX47	MH load	0
BE3	BE1+BE2	MH load	0

3.2.2 Impact on Steady State Voltage at the POI

Table 7 summarizes the voltage at the POI and at the wind turbine bus for several scenarios.

Table 7. Darlingford Option B – Voltage at POI.

	Voltage (pu)	
	POI	LV Wind Farm Bus
Before Wind	1.0274	n/a
Wind farm with full load PF caps	1.0226	0.999
Wind farm with net MVAR = 0	1.0234	1.0041

3.2.3 Interconnection Facilities Cost Estimate

Table 8 provides the cost estimate for Darlingford Option B according to the facilities shown in Figure 2 and the cost assumptions provided in Table 2.

Table 8. Darlingford Option B – Cost Estimate.

Item	Quantity	Cost (in $1000)
New Station	0	0
Termination	1 breaker	2900
Line to MH grid	18 km	4950
Other	Expansion of St.Leon relay bldg	100
	Total	$7950

3.3 Connection Option C

Option C has a target size of 50 MW. The connection option is a tap of 66 kV line L51 which is radially fed from St. Leon 66 kV station, as shown in Figure 3.

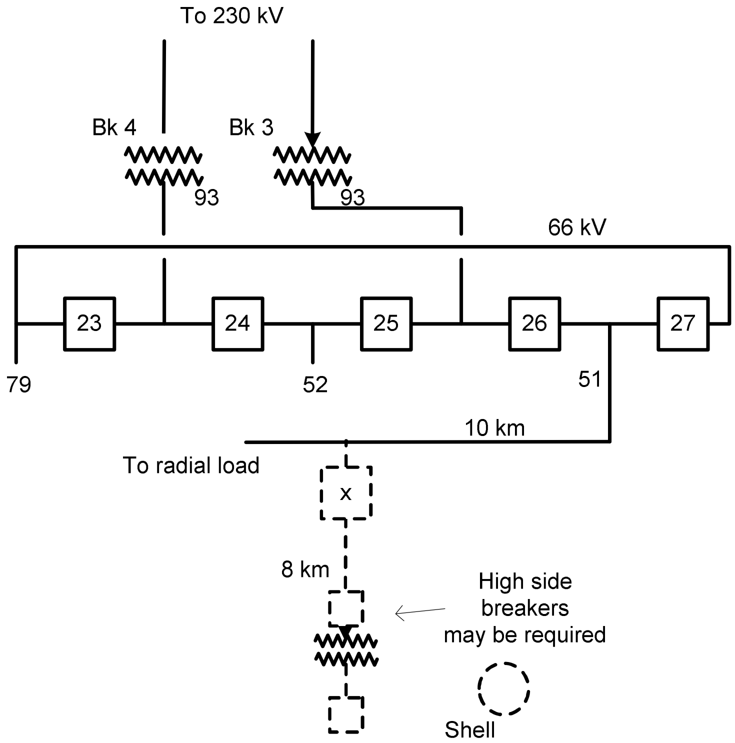


Figure 3. Darlingford Option C.

3.3.1 Impact on Reliability Limitations

Table 9 summarizes the impact of the wind generation on system reliability limitations. The incremental MW value refers to the size of wind farm at which the listed facility becomes overloaded if the contingency occurs. Please refer back to Table 1 for a description of the limiting elements.

Table 9. Darlingford Option C Impacts.

Limiting Facility	Contingency	Sink	Incremental MW
66 kV line 51	None (base case)	All	41
CB42	Cornwallis Bank 3	Brandon	5.8
CB1	Cornwallis Bank 3	Brandon	38.2
Raven Lake Bank 3	C28R	Brandon	1.1
Ridgeway Bank 1(2)	Ridgeway Bank 1(2)	MH load	13.7
St. Leon Bank 3(4)	St. Leon Bank 3(4)	All	93.0
D5R	D13R+D16R	MH load	11.4
YV5	YX48+YX47	MH load	0
RS51	YX48+YX47	MH load	0
XV39	YX48+YX47	MH load	0
BE3	BE1+BE2	MH load	0

3.3.2 Impact on Steady State Voltage at the POI

Table 10 summarizes the voltage at the POI and at the wind turbine bus for several scenarios.

Table 10. Darlingford Option C – Voltage at POI.

	Voltage (pu)	
	POI	LV Wind Farm Bus
Before Wind	1.0534	n/a
Wind farm with full load PF caps	1.0608	1.0674
Wind farm with net MVAR = 0	1.0507	1.0347

3.3.3 Interconnection Facilities Cost Estimate

Table 11 provides the cost estimate for Darlingford Option C according to the facilities shown in Figure 3 and the cost assumptions provided in Table 2.

Table 11. Darlingford Option C – Cost Estimate.

Item	Quantity	Cost (in $1000)
New Station	1	500
Termination	1 breaker	1700
Line to MH grid	8 km	800
Other	Expansion of St.Leon relay bldg	100
	Total	$3100

3.4 Connection Option D

Option D has a target size of 50 MW. The connection option is a direct connection to the St. Leon 66 kV station bus, as shown in Figure 4.

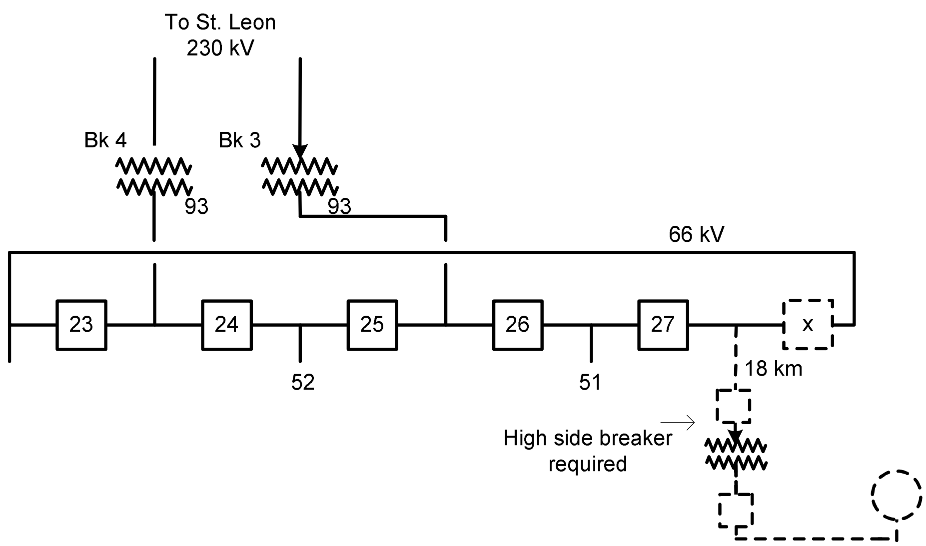


Figure 4. Darlingford Option D.

3.4.1 Impact on Reliability Limitations

Table 12 summarizes the impact of the wind generation on system reliability limitations. The incremental MW value refers to the size of wind farm at which the listed facility becomes overloaded if the contingency occurs. Please refer back to Table 1 for a description of the limiting elements.

Table 12. Darlingford Option D Impacts.

Limiting Facility	Contingency	Sink	Incremental MW
CB42	Cornwallis Bank 3	Brandon	5.8
CB1	Cornwallis Bank 3	Brandon	38.2
Raven Lake Bank 3	C28R	Brandon	1.1
Ridgeway Bank 1(2)	Ridgeway Bank 1(2)	MH load	13.7
St. Leon Bank 3(4)	St. Leon Bank 3(4)	All	99.0
D5R	D13R+D16R	MH load	11.4
YV5	YX48+YX47	MH load	0
RS51	YX48+YX47	MH load	0
XV39	YX48+YX47	MH load	0
BE3	BE1+BE2	MH load	0

3.4.2 Impact on Steady State Voltage at the POI

Table 13 summarizes the voltage at the POI and at the wind turbine bus for several scenarios.

Table 13. Darlingford Option D – Voltage at POI.

	Voltage (pu)	
	POI	LV Wind Farm Bus
Before Wind	1.0523	n/a
Wind farm with full load PF caps	1.0544	1.0787
Wind farm with net MVAR = 0	1.0560	1.0577

3.4.3 Interconnection Facilities Cost Estimate

Table 14 provides the cost estimate for Darlingford Option D according to the facilities shown in Figure 4 and the cost assumptions provided in Table 2.

Table 14. Darlingford Option D – Cost Estimate.

Item	Quantity	Cost (in $1000)
New Station	0	0
Termination	1 breaker	1700
Line to MH grid	18 km	1800
	Total	$3500

3.5 Darlingford Conclusions

Several thermal overloads are identified that require further investigation in an Interconnection Facility Study. All of the four connection options have similar impacts on Ridgeway transformer banks 1 and 2, 230 kV line D5R between Dorsey and Rosser, 110 kV line YV5 between Laverendrye and St. Vital, 110 kV line RS51 between Rosser and Inkster, 110 kV line XV39 between Mohawk and St. Vital, and 110 kV line BE3 between Brandon G.S. and Brandon-Victoria. These overloads are either base case problems, or occur due to an increase in load, however the impact of the wind farms may require mitigation sooner that would have been necessary due to normal load growth. In addition, all four options impact 110 kV lines CB42 and CB1 between Brandon and Cornwallis.

For 66 kV option C, to reach the MH network, all power generated from the wind farm must flow from the farm through radial line 51 and up through the two 93 MVA St. Leon 66-230 kV transformers. According to SCADA data, the total lightest loads on this line is in the order of 2 MVA, and the thermal limit of the line is 41 MVA in some line sections and 59 MVA in the rest of the line sections. The maximum permissible wind farm size is therefore 41 MVA. If the 41 MVA line sections were upgraded to match the 59 MVA rating of the rest of the line, this maximum size limit would increase to 59 MVA. A wind farm greater than 59 MVA would require a further increase in line 51 thermal capacity. The next limiting element would be one of the 93 MVA St. Leon transformers. It may also be possible increase the maximum size limit of the wind farm by networking lines 51 with other 66 kV line(s) in the area by closing a normally open switch(es). This networking option has not been studied and there may be protection and operating impacts that would not allow this.

Both 66 kV wind farm options may require voltage control beyond the minimum requirements in order to control flicker, to prevent excessive St. Leon 66-230 kV transformer tap changer action and to maintain acceptable operating voltages. In addition, the 66 kV wind farms reverse the normal power flow direction through the transformers and on part of line 51, which could require significant changes and/or replacements to the existing protection. All of these issues would be further investigated in an Interconnection Facilities Study.

As indicated by previous studies, it is possible that all of the Darlingford wind farms will require dynamic voltage control beyond the minimum requirements to prevent a voltage collapse scenario and/or transient voltage violations. However, of all Darlingford options, Option B would be the most likely not to require the extra dynamic VArs if its termination point in the St. Leon 230 kV ring bus could be swapped with the termination point of line S53G (refer to Figure 2). This would avoid isolating any generation onto a single outlet line, which was the original cause of the stability issues. As for Options A, C and D it may be possible to swap line D14S or S53G termination with the existing generator termination (refer to Figure 1). This would ensure the maximum amount of generation that could become isolated onto any single outlet line does not exceed 100 MW, as opposed to 200 MW for the terminations currently shown in Figures 1 and 2.

These scenarios have not been investigated at all in terms of physical feasibility of swapping terminations in the station. Further stability studies with these configurations would also be required to ensure all stability criteria would still be met. Swapping line terminations would have cost implications that would need to be compared to the cost of installing dynamic voltage control beyond the minimum connection requirements.

4.0 Study Results: Boissevain

Two connection options were studied for the Boissevain wind site. Please refer to Appendix A for a map showing the land location of the proposed wind farm.

4.1 Connection Option A

Option A has a target size of 75 MW. The connection option is a direct connection to the 230 kV Souris East station bus, as shown in Figure 5.

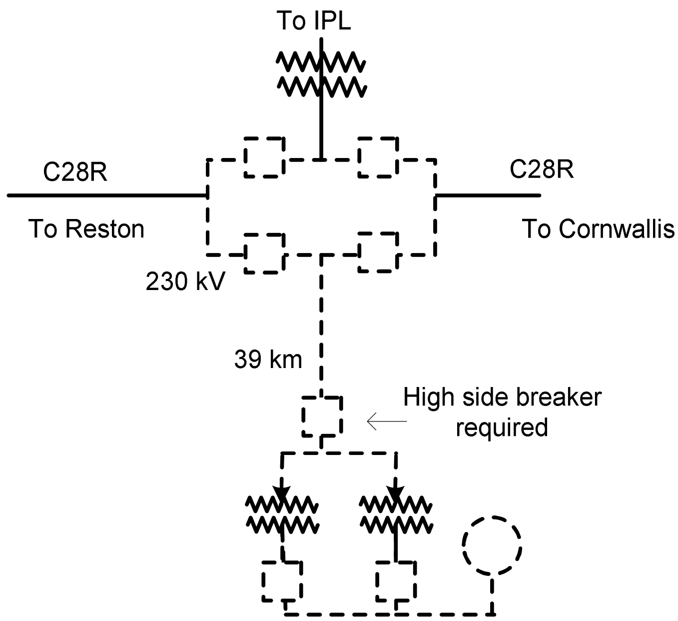


Figure 5. Boissevain Option A.

4.1.1 Impact on Reliability Limitations

Table 15 summarizes the impacts of the wind generation on system reliability limitations. The incremental MW value refers to the size of wind farm at which the listed facility becomes overloaded if the contingency occurs. Please refer back to Table 1 for a description of the limiting elements.

Table 15. Boissevain Option A Impacts.

Limiting Facility	Contingency	Sink	Incremental MW
CB42	Cornwallis Bank 3	Brandon	5.4
CB1	Cornwallis Bank 3	Brandon	35.5
Raven Lake Bank 3	C28R	Brandon	1.7
Ridgeway Bank 1(2)	Ridgeway Bank 1(2)	MH load	13.7
D5R	D13R+D16R	MH load	16.9
YV5	YX48+YX47	MH load	0
RS51	YX48+YX47	MH load	0
XV39	YX48+YX47	MH load	0
BE3	BE1+BE2	MH load	0

4.1.2 Impact on Steady State Voltage at the POI

Table 16 summarizes the voltage at the POI and at the wind turbine bus for several scenarios.

Table 16. Boissevain Option A – Voltage at POI.

	Voltage (pu)	
	POI	LV Wind Farm Bus
Before Wind	1.0404	n/a
Wind farm with full load PF caps	1.0415	1.0528
Wind farm with net MVAR = 0	1.0386	1.0406

4.1.3 Interconnection Facilities Cost Estimate

Table 17 provides the cost estimate for Boissevain Option A according to the facilities shown in Figure 5 and the cost assumptions provided in Table 2.

Table 17. Boissevain Option A – Cost Estimate.

Item	Quantity	Cost (in $1000)
New Station	1	3,000
Termination	4 breakers	11600
Line to MH grid	39 km	10725
	Total	$25325

4.2 Connection Option B

Option B has a target size of 50 MW. The connection option is a direct connection to the 66 kV Boissevain station bus which is radially fed from Brandon 110 kV station, as shown in Figure 6.

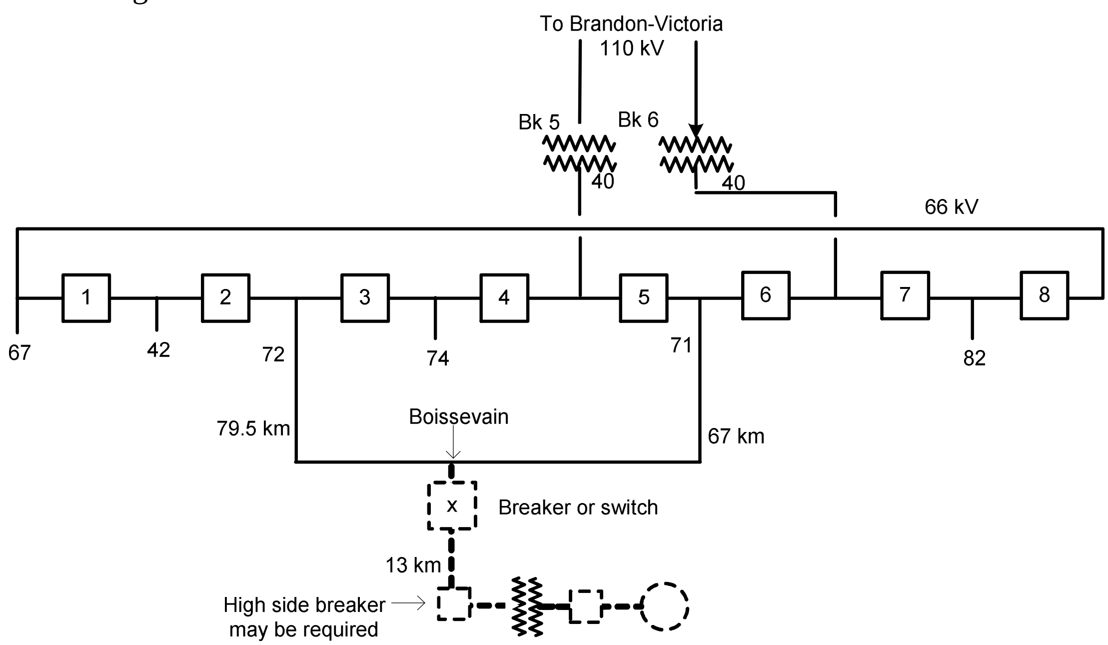


Figure 6. Boissevain Option B.

4.2.1 Impact on Reliability Limitations

Table 18 summarizes the impacts of the wind generation on system reliability limitations. The incremental MW value refers to the size of wind farm at which the listed facility becomes overloaded if the contingency occurs. Please refer back to Table 1 for a description of the limiting elements.

Table 18. Boissevain Option B Impacts.

Limiting Facility	Contingency	Sink	Incremental MW
66 kV line 71(72)	66 kV line 72(71)	All	26.0
Ridgeway Bank 1(2)	Ridgeway Bank 1(2)	MH load	14.3
Brandon Bank 5(6)	Brandon Bank 6(5)	All	50.0
MR11(Rpd Cty-Brndn)	C28R	MH load	40.9
D5R	D13R+D16R	MH load	13.4
YV5	YX48+YX47	MH load	0
RS51	YX48+YX47	MH load	0
XV39	YX48+YX47	MH load	0
BE3	BE1+BE2	MH load	0

4.2.2 Impact on Steady State Voltage at the POI

Table 19 summarizes the voltage at the POI and at the wind turbine bus for several scenarios. The wind farm has a large impact on steady state voltages.

Table 19. Boissevain Option B – Voltage at POI.

	Voltage (pu)	
	POI	LV Wind Farm Bus
Before Wind	0.9615	n/a
Wind farm with full load PF caps	1.2635	1.3723
Wind farm with net MVAR = 0	0.9619	0.9690

4.2.3 Interconnection Facilities Cost Estimate

Table 20 provides the cost estimate for Boissevain Option B according to the facilities shown in Figure 6 and the cost assumptions provided in Table 2.

Table 20. Boissevain Option B – Cost Estimate.

Item	Quantity	Cost (in $1000)
New Station	1	500
Termination	1 breaker	1700
Line to MH grid	13 km	1300
	Total	$3500

4.3 Boissevain Conclusions

Both connection options have similar impacts on Ridgeway transformer banks 1 and 2, 230 kV line D5R between Dorsey and Rosser, 110 kV line YV5 between Laverendrye and St. Vital, 110 kV line RS51 between Rosser and Inkster, 110 kV line XV39 between Mohawk and St. Vital, and 110 kV line BE3 between Brandon G.S. and Brandon-Victoria. These overloads are either base case problems, or occur due to an increase in load, however the impact of the wind farms may require mitigation sooner that would have been necessary due to normal load growth. In addition, the 100 MW farm impacts 110 kV lines CB42 and CB1 between Brandon and Cornwallis. The 50 MW farm impacts 110 kV line MR11 between Rapid City and Brandon.

To reach the MH network, all power generated from the wind farm must flow from the farm through parallel radial lines 71 and 72 and up through the two 40 MVA Brandon-Victoria 66-230 kV transformers. According to SCADA data, the total lightest loads on these lines are in the order of 2 MVA, and the thermal limit of the lines are 26 MVA in some line sections and 42 MVA in the rest of the line sections. To accommodate for an outage of either one of lines 71 or 72, the maximum permissible size of the 66 kV wind farm is 26 MVA. If the 26 MVA line sections were upgraded to match the 42 MVA rating of the rest of the line, this maximum size limit would increase to 40 MVA, also to respect the 40 MVA transformer limits with an outage of one of the parallel banks. A wind farm greater than 40 MVA would require increased line capacity as well as a third 66-230 kV transformer at Brandon-Victoria. It may also be possible increase the maximum size limit of the wind farm by networking lines 71 and 72 with other 66 kV line(s) in the area by closing a normally open switch(es). This networking option has not been studied and there may be protection and operating impacts that would not allow this.

The 66 kV wind farm is connected near the end of two parallel long radial lines (71 and 72), and may require voltage control beyond the minimum requirements in order to control flicker, to prevent excessive Brandon-Victoria 66-230 kV transformer tap changer action and to maintain acceptable operating voltages. In addition, adding the wind farm reverses the normal power flow direction on the line, which could require significant changes and/or replacements to the existing protection. All of these issues would be further investigated in an Interconnection Facilities Study.

No previous studies have been performed at the Boissevain location.

5.0 Study Results: Minnedosa

Two connection options were studied for the Minnedosa wind site. Please refer to Appendix A for a map showing the land location of the proposed wind farm.

5.1 Connection Option A

Option A has a target size of 100 MW. The connection option is tapping 110 kV line MR11 at Rapid City, as shown in Figure 7.

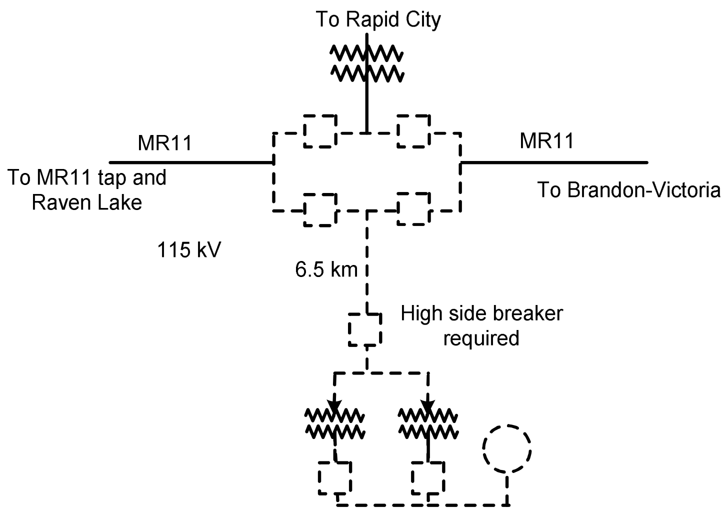


Figure 7. Minnedosa Option A.

5.1.1 Impact on Reliability Limitations

Table 21 summarizes the impacts of the wind generation on system reliability limitations. The incremental MW value refers to the size of wind farm at which the listed facility becomes overloaded if the contingency occurs. Please refer back to Table 1 for a description of the limiting elements.

Table 21. Minnedosa Option A Impacts.

Limiting Facility	Contingency	Sink	Incremental MW
CB42	Cornwallis Bank 3	Brandon	27.3
MR11 (Rpd Cty-Brndn)	C28R	all	46.0
MR11 (MR11 tap-Rpd Cty)	C28R	all	77.2
MR11 (Rav Lk-MR11 tap)	C28R	all	84.5
NM10	MR11	all	86.8
Ridgeway Bank 1(2)	Ridgeway Bank 1(2)	MH load	14.3
D5R	D13R+D16R	MH load	22.4
YV5	YX48+YX47	MH load	0
RS51	YX48+YX47	MH load	0
XV39	YX48+YX47	MH load	0
BE3	BE1+BE2	MH load	0

5.1.2 Impact on Steady State Voltage at the POI

Table 22 summarizes the voltage at the POI and at the wind turbine bus for several scenarios.

Table 22. Minnedosa Option A – Voltage at POI.

	Voltage (pu)	
	POI	LV Wind Farm Bus
Before Wind	1.0362	n/a
Wind farm with full load PF caps	1.0391	1.0264
Wind farm with net MVAR = 0	1.0381	1.0222

5.1.3 Interconnection Facilities Cost Estimate

Table 23 provides the cost estimate for Minnedosa Option A according to the facilities shown in Figure 7 and the cost assumptions provided in Table 2.

Table 23. Minnedosa Option A – Cost Estimate.

Item	Quantity	Cost (in $1000)
New Station	1	2000
Termination	4 breakers	9200
Line to MH grid	6.5 km	1462.5
Other	-	
	Total	$12662.5

5.2 Connection Option B

Option B has a target size of 100 MW. The connection option is a direct connection to Minnedosa 110 kV station bus, as shown in Figure 8.

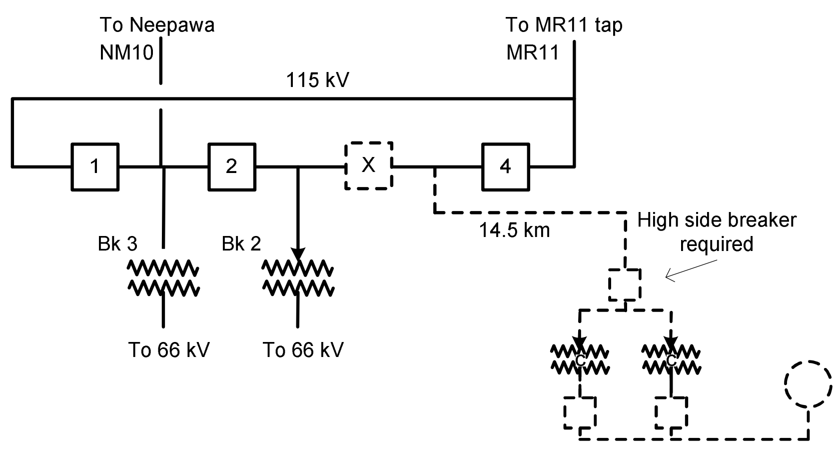


Figure 8. Minnedosa Option B.

5.2.1 Impacts on Reliability Limitations

Table 24 summarizes the impacts of the wind generation on system reliability limitations. The incremental MW value refers to the size of wind farm at which the listed facility becomes overloaded if the contingency occurs. Please refer back to Table 1 for a description of the limiting elements.

Table 24. Minnedosa Option B Impacts.

Limiting Facility	Contingency	Sink	Incremental MW
CB42	Cornwallis Bank 3	Brandon	20.1
MR11 (Rpd Cty-Brndn)	C28R	all	47.7
MR11 (Rav Lk-MR11 tap)	C28R	all	84.4
MR11 (Minned-MR11 tap)	MR11	all	72.7
NM10	MR11	all	73.0
Ridgeway Bank 1(2)	Ridgeway Bank 1(2)	MH load	14.5
D5R	D13R+D16R	MH load	26.1
YV5	YX48+YX47	MH load	0
RS51	YX48+YX47	MH load	0
XV39	YX48+YX47	MH load	0
BE3	BE1+BE2	MH load	0

5.2.2 Impacts on Steady State Voltage at the POI

Table 25 summarizes the voltage at the POI and at the wind turbine bus for several scenarios.

Table 25. Minnedosa Option B – Voltage at POI.

	Voltage (pu)	
	POI	LV Wind Farm Bus
Before Wind	1.0427	n/a
Wind farm with full load PF caps	1.0380	1.0076
Wind farm with net MVAR = 0	1.0388	1.0097

5.2.3 Interconnection Facilities Cost Estimate

Table 26 provides the cost estimate for Minnedosa Option B according to the facilities shown in Figure 8 and the cost assumptions provided in Table 2.

Table 26. Minnedosa Option N – Cost Estimate.

Item	Quantity	Cost (in $1000)
New Station	0	0
Termination	1 breakers	2300
Line to MH grid	14.5 km	3263
	Total	$5563

5.3 Minnedosa Conclusions

Both connection options have similar impacts on Ridgeway transformer banks 1 and 2, 230 kV line D5R between Dorsey and Rosser, 110 kV line YV5 between Laverendrye and St. Vital, 110 kV line RS51 between Rosser and Inkster, 110 kV line XV39 between Mohawk and St. Vital, and 110 kV line BE3 between Brandon G.S. and Brandon-Victoria. These overloads are either base case problems, or occur due to an increase in load, however the impact of the wind farms may require mitigation sooner that would have been necessary due to normal load growth. In addition, both options impact 110 kV line CB42 between Brandon and Cornwallis.

Depending on the connection option, outlet lines MR11 and NM10 reach riser and possible line conductor thermal limits. The outlet lines impacted by both options are 110 kV line MR11 between Rapid City and Brandon, 110 kV line MR11 between Raven Lake and MR11 tap, and 110 kV line NM10 between Neepawa and Minnedosa. The tapping option also impacts l10 kV line MR11 between Rapid City and MR11 tap. The direct connection option also impacts 110 kV line MR11 between Minnedosa and MR11 tap. Please refer to Table 2 for details on the limiting elements.

No previous studies have been performed at the Minnedosa location.

6.0 Study Results: Killarney

Two connection options were studied for the Killarney wind site. Please refer to Appendix A for a map showing the land location of the proposed wind farm.

6.1 Connection Option A

Option A has a target size of 100 MW. The connection option is tapping 230 kV line G82R between Glenboro and Rugby stations, as shown in Figure 9.

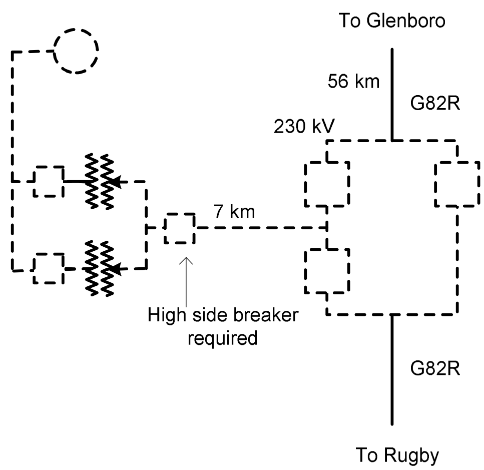


Figure 9. Killarney Option A.

6.1.1 Impact on Reliability Limitations

Table 27 summarizes the impacts of the wind generation on system reliability limitations. The incremental MW value refers to the size of wind farm at which the listed facility becomes overloaded if the contingency occurs. Please refer back to Table 1 for a description of the limiting elements.

Table 27. Killarney Option A Impacts.

Limiting Facility	Contingency	Sink	Incremental MW
CB42	Cornwallis Bank 3	Brandon	5.6
CB1	Cornwallis Bank 3	Brandon	37.1
Raven Lake Bank 3	C28R	Brandon	1.2
MR11 (Rpd Cty-Brandon)	C28R	MH load	90.5
Ridgeway Bank 1(2)	Ridgeway Bank 1(2)	MH load	13.7
D5R	D13R+D16R	MH load	12.5
YV5	YX48+YX47	MH load	0
RS51	YX48+YX47	MH load	0
XV39	YX48+YX47	MH load	0
BE3	BE1+BE2	MH load	0

6.1.2 Impact on Steady State Voltage at the POI

Table 28 summarizes the voltage at the POI and at the wind turbine bus for several scenarios.

Table 28. Killarney Option A – Voltage at POI.

	Voltage (pu)	
	POI	LV Wind Farm Bus
Before Wind	1.0272	n/a
Wind farm with full load PF caps	1.0207	1.000
Wind farm with net MVAR = 0	1.0214	1.003

6.1.3 Interconnection Facilities Cost Estimate

Table 29 provides the cost estimate for Killarney Option A according to the facilities shown in Figure 9 and the cost assumptions provided in Table 2.

Table 29. Killarney Option A – Cost Estimate.

Item	Quantity	Cost (in $1000)
New Station	1	3000
Termination	3 breakers	8700
Line to MH grid	7.0 km	1925
Other	$40/MWh – 2-wk G82R line outage to install wind farm.	2688
	Total	$16313

6.2 Connection Option B

Option B has a target size of 50 MW. The connection option is a direct connection to the Killarney 66 kV station which is radially fed from Glenboro 230 kV station, as shown in Figure 10.

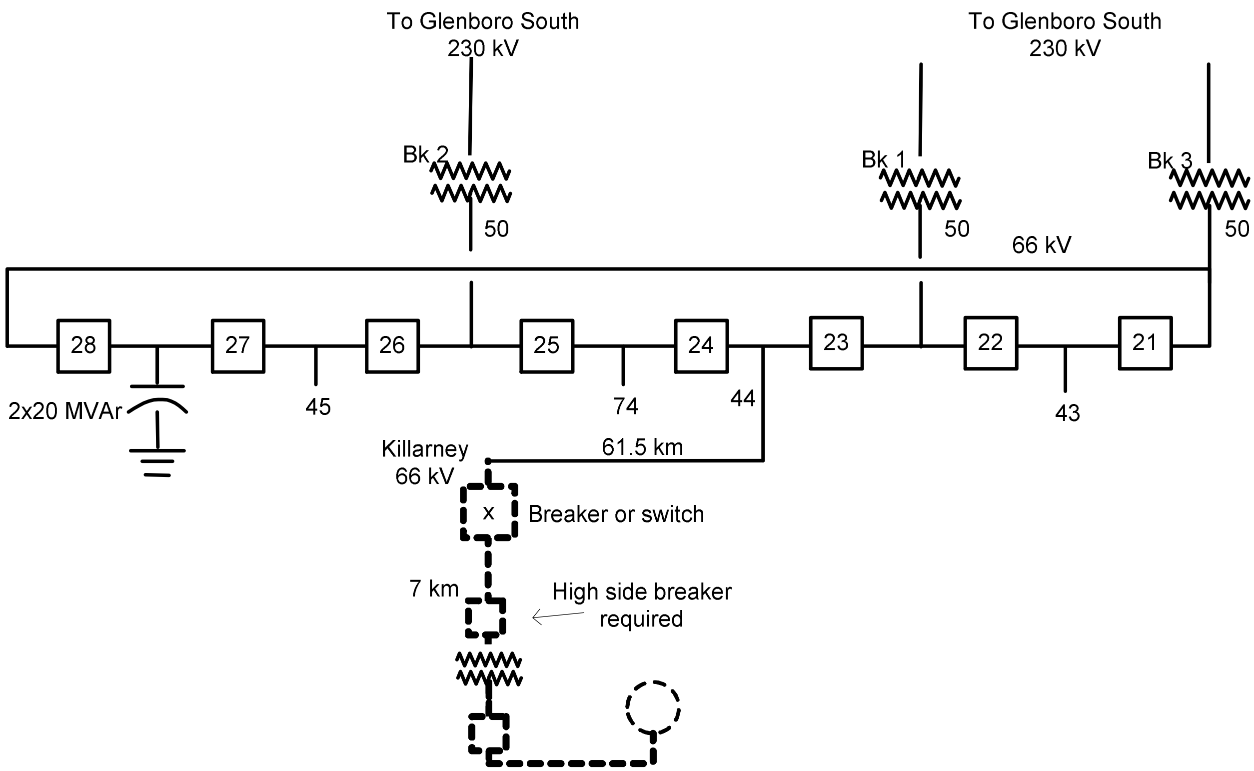


Figure 10. Killarney Option B.

6.2.1 Impact on Reliability Limitations

Table 30 summarizes the impacts of the wind generation on system reliability limitations. The incremental MW value refers to the size of wind farm at which the listed facility becomes overloaded if the contingency occurs. Please refer back to Table 1 for a description of the limiting elements.

Table 30. Killarney Option B Impacts.

Limiting Facility	Contingency	Sink	Incremental MW
66 kV line 44	None (base case)	All	42.0
Glenboro Bk 1/2/3(2/3/1)	Glenboro Bk 1/2/3(2/3/1)	All	100.0
CB42	Cornwallis Bank 3	Brandon	8.8
CB1	Cornwallis Bank 3	Brandon	39.7
Raven Lake Bank 3	C28R	Brandon	0
Ridgeway Bank 1(2)	Ridgeway Bank 1(2)	MH load	11.9
D5R	D13R+D16R	MH load	0
YV5	YX48+YX47	MH load	0
RS51	YX48+YX47	MH load	0
XV39	YX48+YX47	MH load	0
BE3	BE1+BE2	MH load	0

6.2.2 Impact on Steady State Voltage at the POI

Table 31 summarizes the voltage at the POI and at the wind turbine bus for several scenarios. The wind farm has a large impact on steady state voltages.

Table 31. Killarney Option B – Voltage at POI.

	Voltage (pu)	
	POI	LV Wind Farm Bus
Before Wind	1.0015	n/a
Wind farm with full load PF caps	1.1303	1.1823
Wind farm with net MVAR = 0	1.0428	1.0508

6.2.3 Interconnection Facilities Cost Estimate

Table 32 provides the cost estimate for Killarney Option B according to the facilities shown in Figure 10 and the cost assumptions provided in Table 2.

Table 32. Killarney Option B – Cost Estimate.

Item	Quantity	Cost (in $1000)
New Station	1	500
Termination	1 breakers	1700
Line to MH grid	7.0 km	700
	Total	$2900

6.3 Killarney Conclusions

Both connection options have similar impacts on Ridgeway transformer banks 1 and 2, 230 kV line D5R between Dorsey and Rosser, 110 kV line YV5 between Laverendrye and St. Vital, 110 kV line RS51 between Rosser and Inkster, 110 kV line XV39 between Mohawk and St. Vital, and 110 kV line BE3 between Brandon G.S. and Brandon-Victoria. These overloads are either base case problems, or occur due to an increase in load, however the impact of the wind farms may require mitigation sooner that would have been necessary due to normal load growth. In addition, the Killarney wind farms impact 110 kV lines CB42 and CB1 between Brandon and Cornwallis. The 100 MW farm also impacts 110 kV line MR11 between Rapid City and Brandon.

For the 66 kV wind farm, to reach the MH network, all power generated from the wind farm must flow from the farm through radial 66 kV line 44 and up through the three 50 MVA Glenboro 66-230 kV transformers. According to SCADA data, the total lightest loads on line 44 are in the range of 2 to 5 MVA, and the thermal limit of the line is 42 MVA. Therefore, the maximum permissible wind farm size is 42 MVA, unless more line capacity is added to accommodate the wind farm. The next limit would be 100 MVA to accommodate for an outage of one of the 66-230 kV transformers.

The 66 kV wind farm is connected near the end of a long radial line (44), and may require voltage control beyond the minimum requirements in order to control flicker, to prevent excessive Glenboro 66-230 kV transformer tap changer action and to maintain acceptable operating voltages. In addition, adding the wind farm reverses the normal power flow direction on the line, which could require significant changes and/or replacements to the existing protection. All of these issues would be further investigated in an Interconnection Facilities Study.

As indicated by previous studies, the 230 kV Killarney wind farm taps a Manitoba – U.S. tie line, which will impact the HVdc reduction scheme, the delta P relay on the Ontario ties and possibly flows on MAPP constrained paths. It also requires an outage of line G82R to installed the wind farm. This can cost up to $40/MWh for loss of 200 MW of Manitoba-U.S. transfer capability for the duration of the outage.

Appendix A:

Manitoba Maps –
Proposed Wind Farm Locations

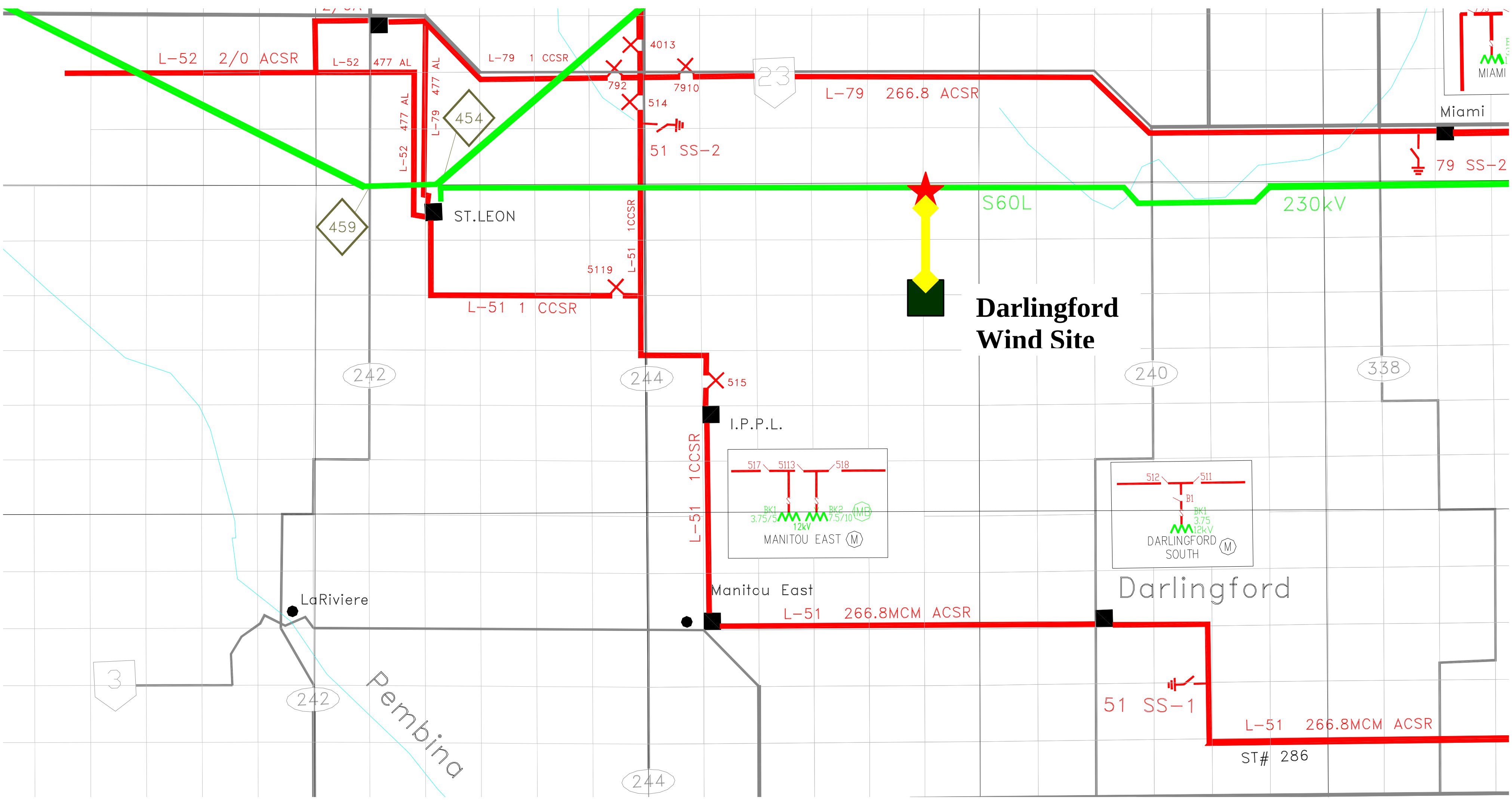
Darlingford Option A

100 MW 230 KV 3.2 KM tap @ S60L

New 230 KV line

Wind Site

Termination Point



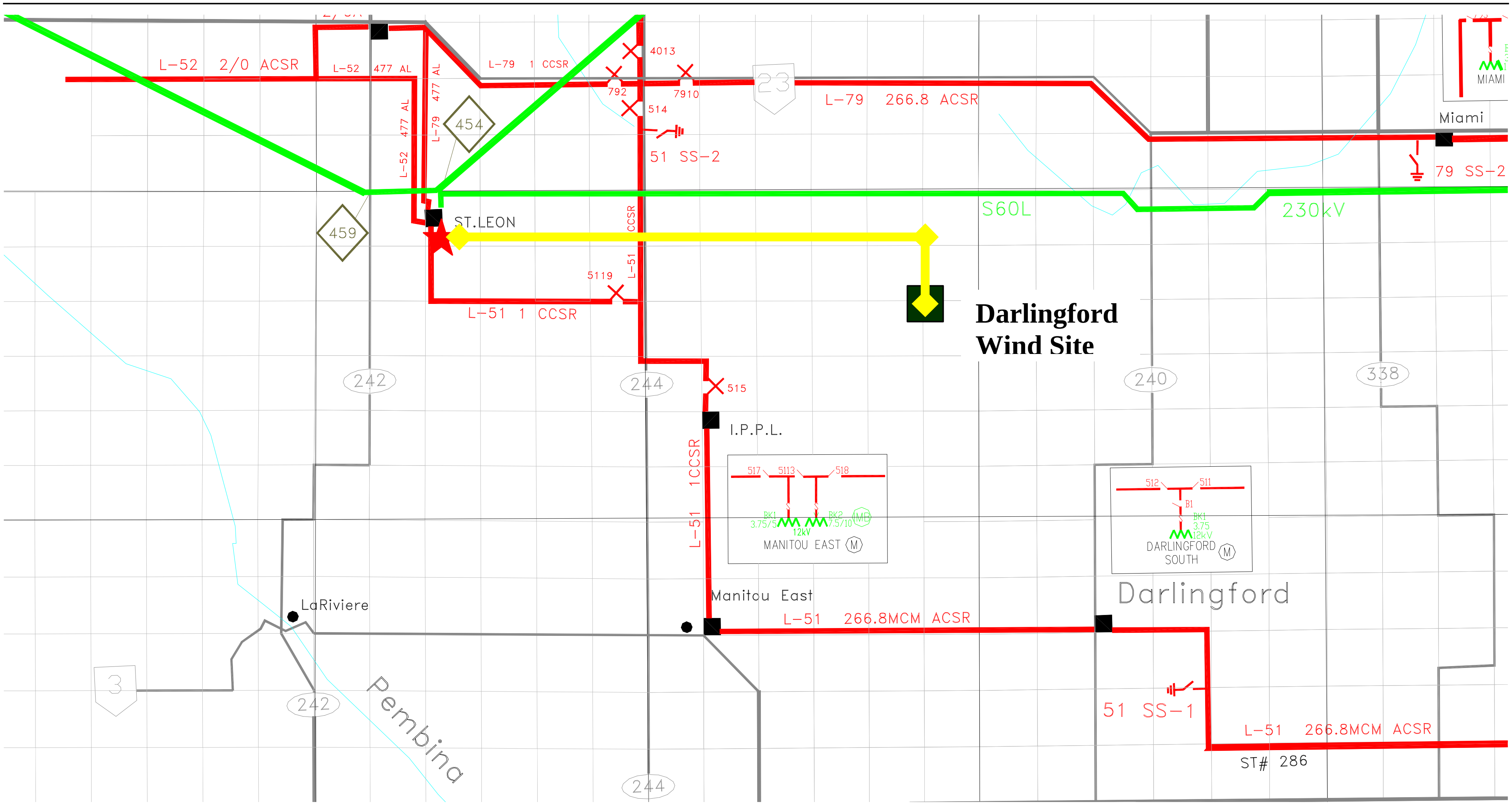
Darlingford Option B

100 MW 230 KV 18 KM termination @ St. Leon Station

New 230 KV line

Wind Site

Termination Point



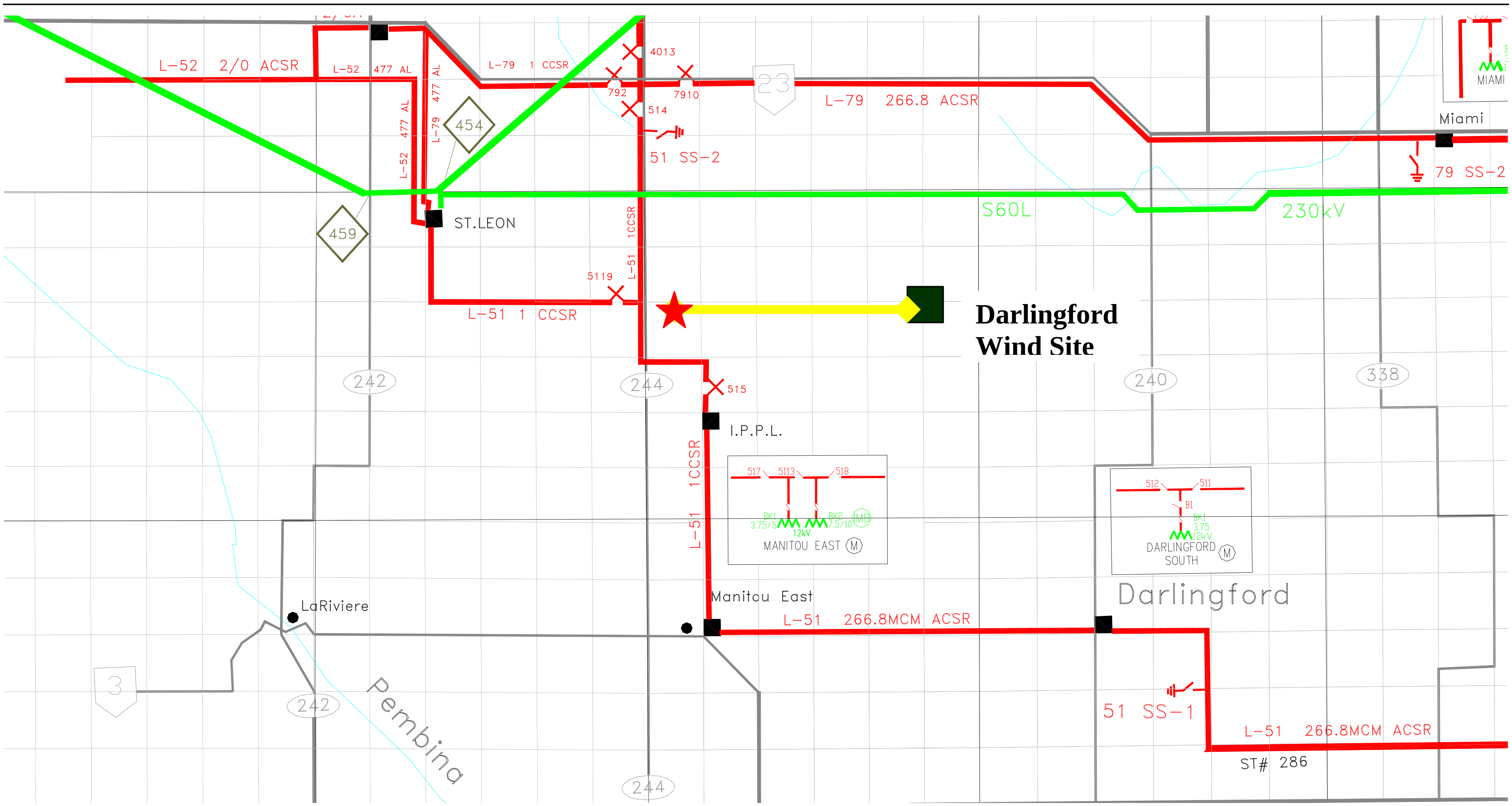
Darlingford Option C

50 MW 66 KV 8 KM tap @ L51

New 66 KV line

Wind Site

Termination Point



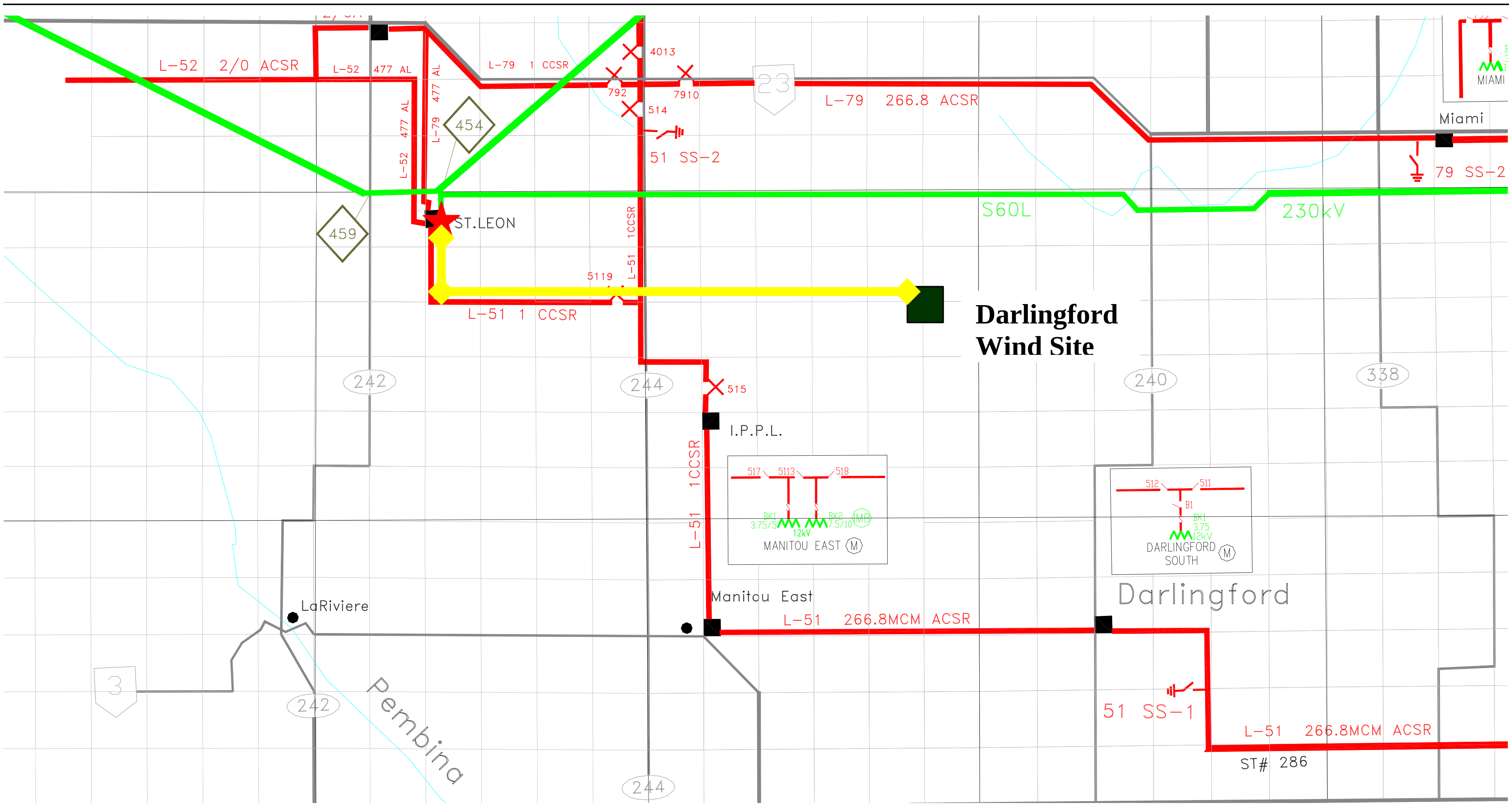
Darlingford Option D

50 MW 66 KV 18 KM termination @ St. Leon Station

New 66 KV line

Wind Site

Termination Point



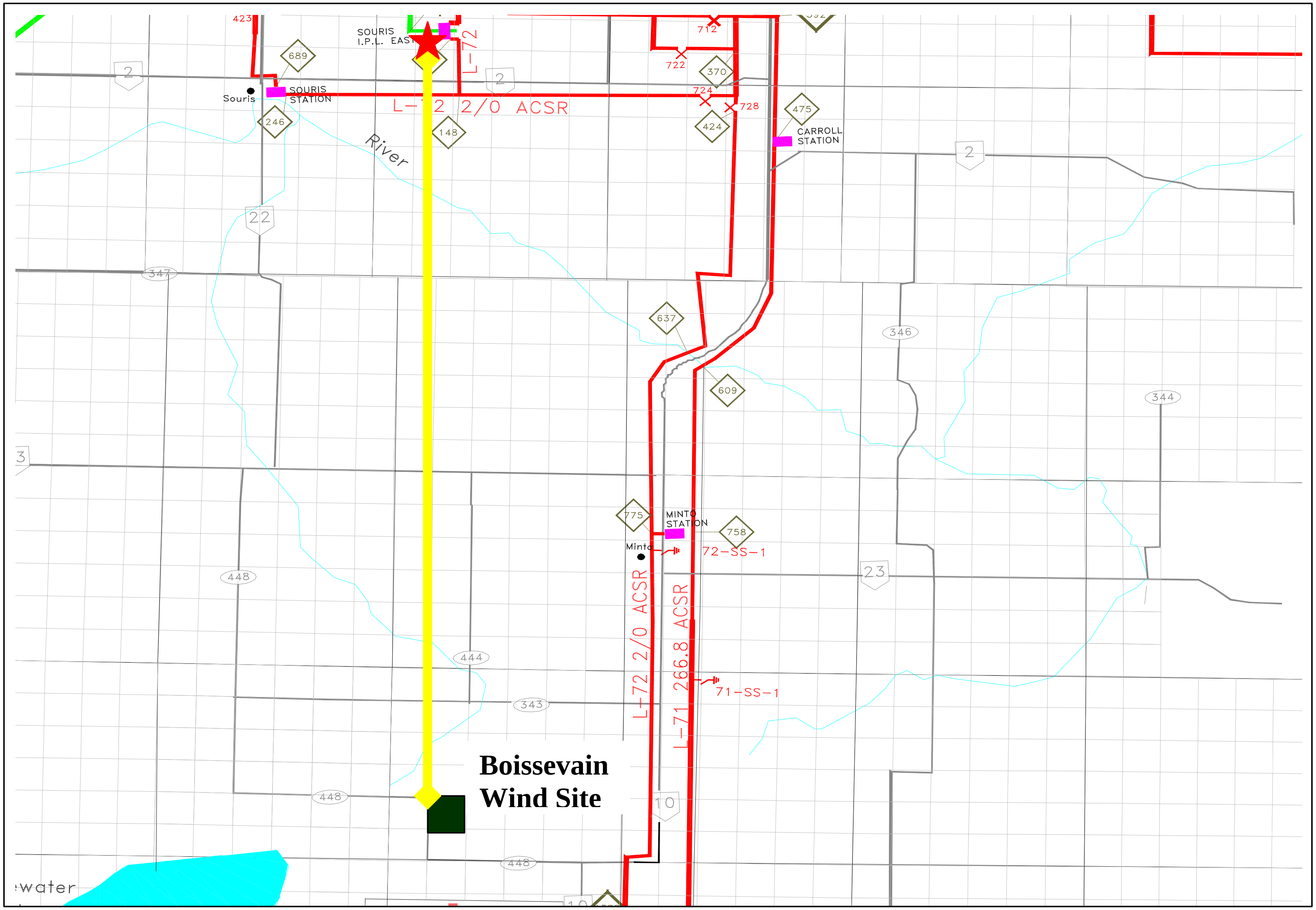
Boissevain Option A

75 MW 230 KV 39 KM termination @ Souris East Station

New 230 KV line

Wind Site

Termination Point



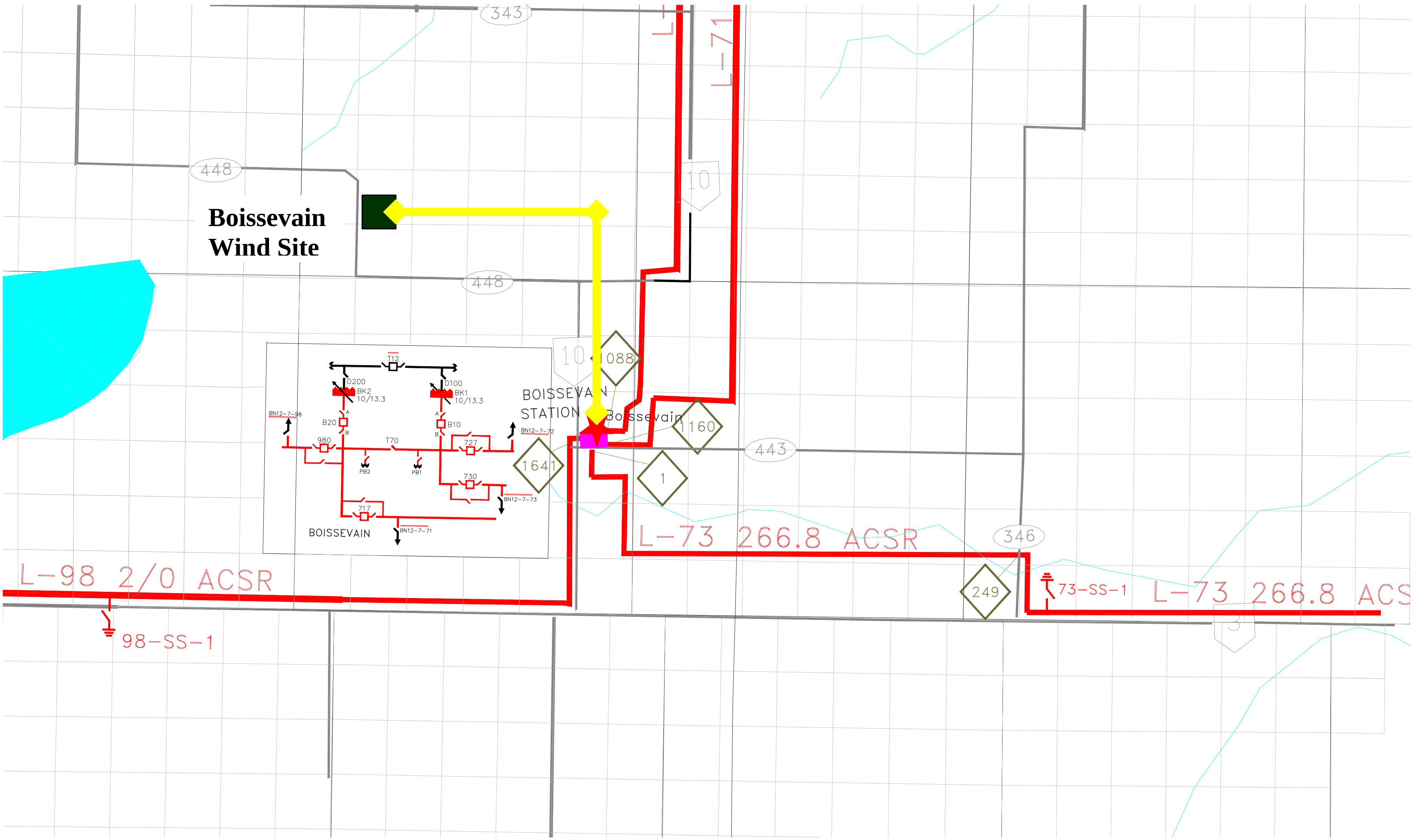
Boissevain Option B

50 MW 66 KV 13 KM termination @ Boissevain Station

New 66 KV line

Wind Site

Termination Point



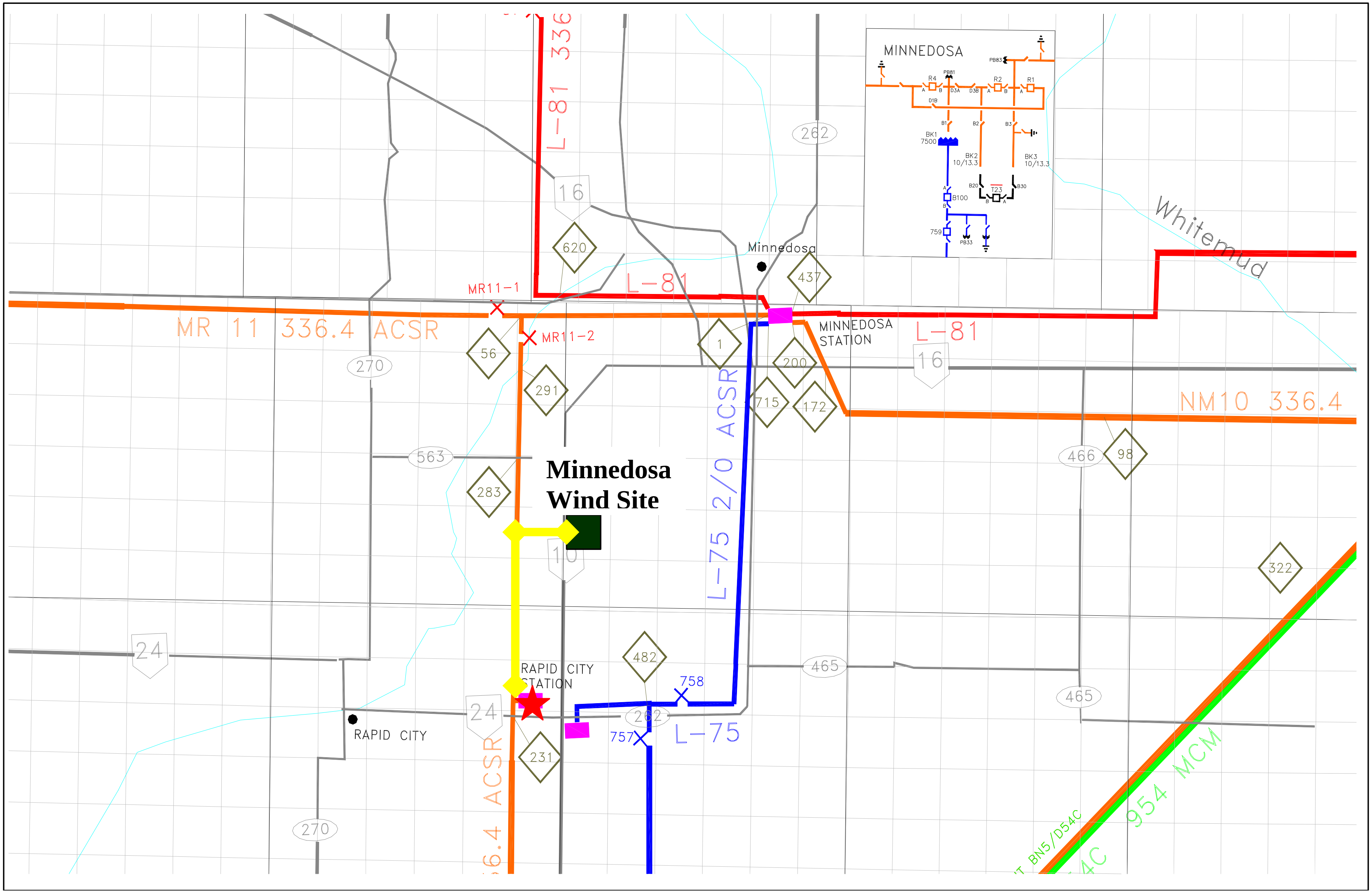
Minnedosa Option A

100 MW 110KV 6.5 KM tap of MR11 at Rapid City

New 110KV T-Line

Wind Site

Termination Point



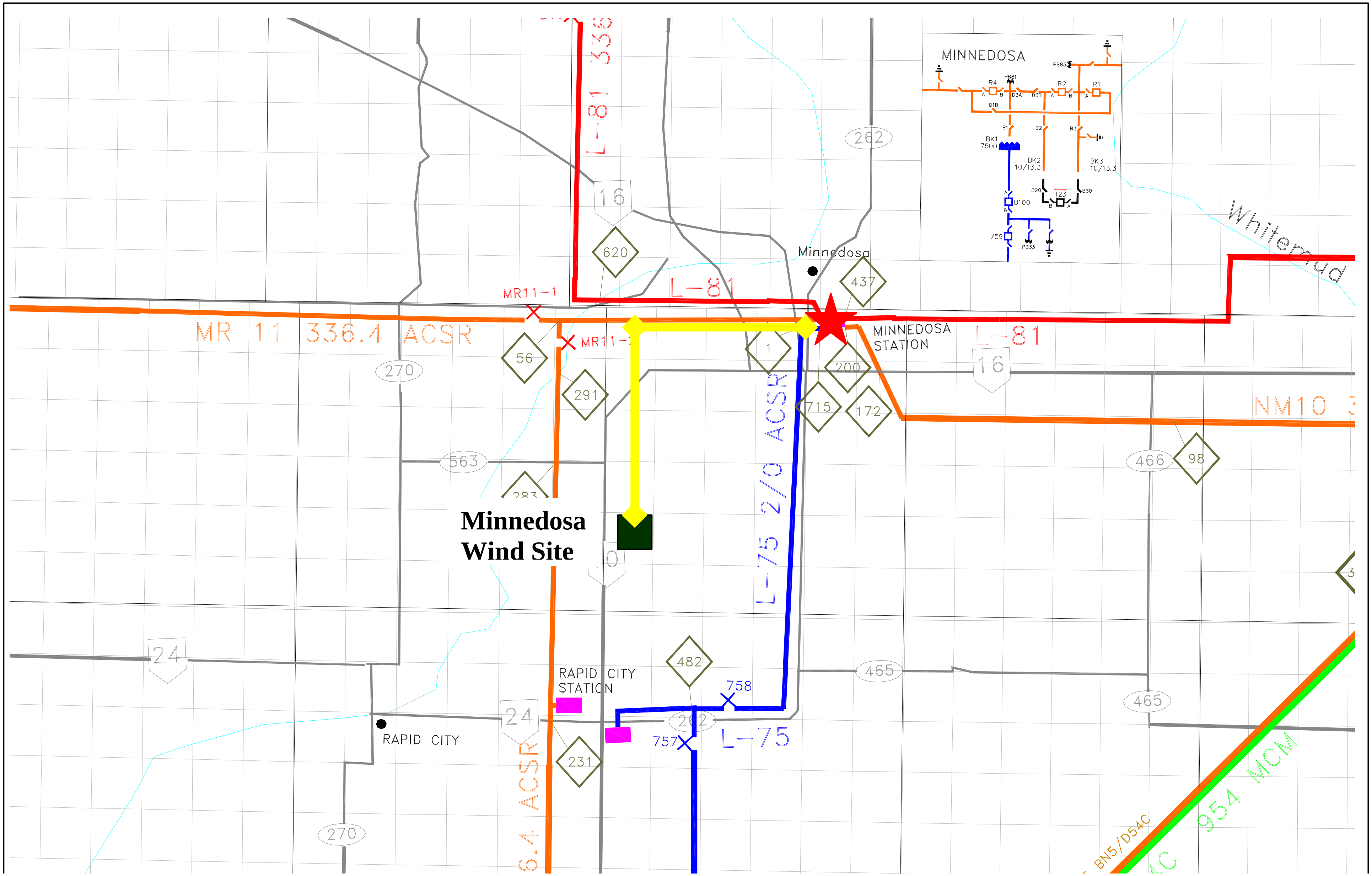
Minnedosa Option B

100 MW 110KV 14.5 KM termination @ Minnedosa Station

New 110KV T-Line

Wind Site

Termination Point



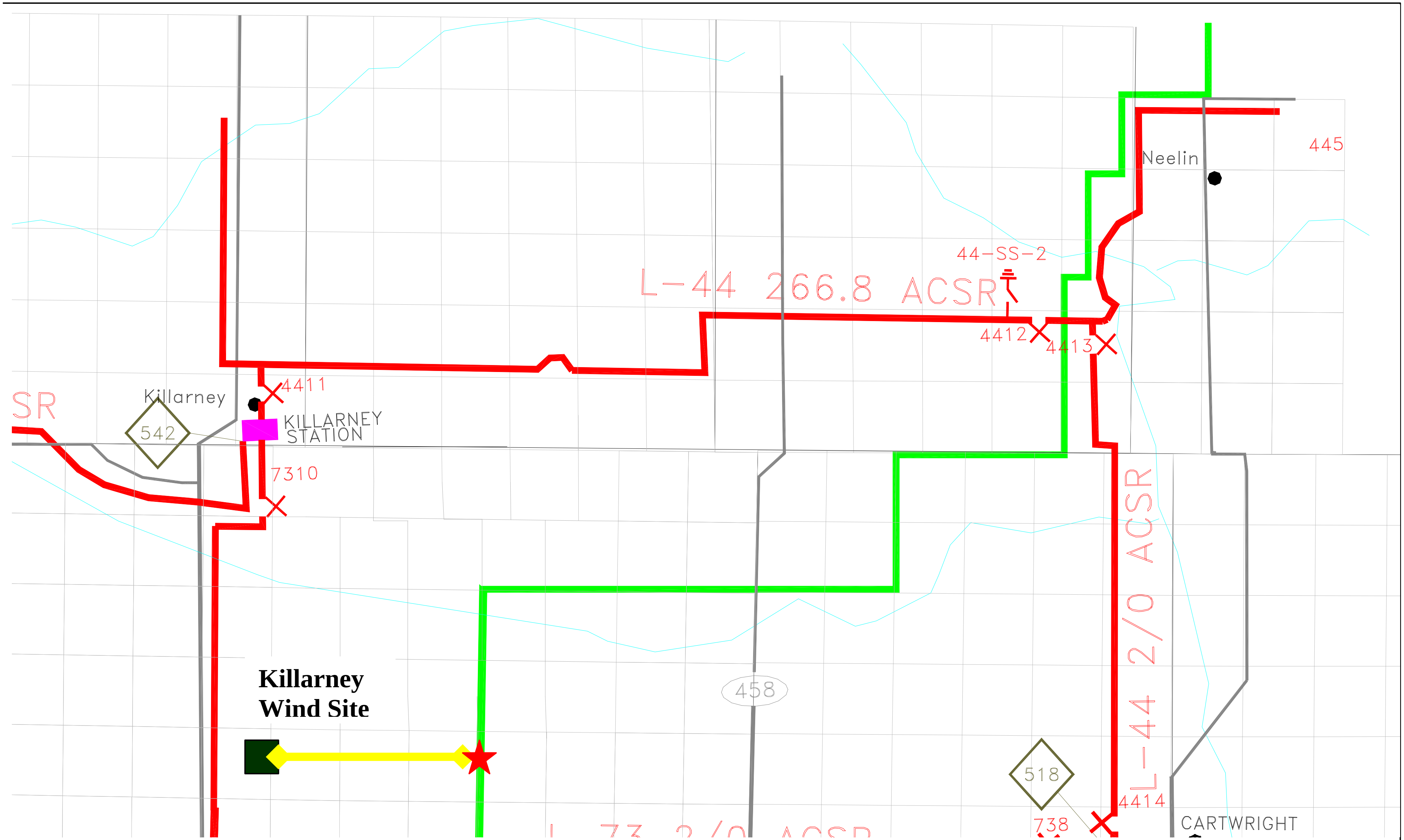
Killarney Option A

100 MW 230 KV 7 KM tap @ G82R

New 230 KV line

Wind Site

Termination Point



Killarney Option B

50 MW 66 KV 7 KM termination @ Killarney Station

New 66 KV line

Wind Site

Termination Point