System Impact Study

109 MW Large Generator Interconnection
(115kV Transmission Interconnection between Hardin and Crossover)
Request #GI-0306
Hardin, MT Generation Project

August, 2005

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I. Background/Purpose

Western Area Power Administration (Western) Upper Great Plains Region (UGPR) received a large generator interconnection (LGI) request (#GI-0306) for 109 MW of net generation at connected at Western's Crossover 230kV Substation near Hardin, Montana. The requested in-service date was originally December 2005. The request includes a new 115kV transmission interconnection between the Hardin and Crossover substations, with a 115/230kV step-up transformer at Crossover.

Prior to this request, the Customer made a similar LGI request with NorthWestern Energy (NorthWestern) at NorthWestern's 115kV Hardin Auto Substation located approximately 4.5 miles from Western's 230kV Crossover Substation. That interconnection request was granted by NorthWestern and the Hardin Generation Project is expected to come on line in the fall of 2005. As a condition of the interconnection to NorthWestern's system, the Hardin Plant must be integrated into the Colstrip remedial action scheme (RAS) which will drop the Hardin Plant for at least two of NorthWestern's worst contingency events.

The primary purpose of this System Impact Study (Study) is to evaluate the steady state and transient stability impacts associated with injecting the proposed generation into the Western UGPR / Basin Electric Power Cooperative (BEPC) / Heartland Consumers Power District (HCPD) Integrated System (IS). This evaluation will determine any incremental adverse effects to the IS associated with the Hardin Plant's proposed alternate interconnection to Western via a new 115kV line from Hardin to Crossover, which would be operated in parallel with NorthWestern's interconnection or with the Hardin Plant connected radially to Western's Crossover substation.

Western UGPR provides administration of the IS Open Access Transmission Service Tariff (Tariff) on behalf of the other IS parties. Western is a member of the Western Electricity Coordinating Council (WECC) which operates within the Western Interconnected System (West System), and is required to observe WECC reliability policies and procedures when providing transmission services within the WECC operating region. Transmission service over the IS on both systems is posted and sold on the Mid-Contingent Area Power Pool (MAPP) OASIS.

The Hardin coal-fired plant will utilize a GE-197770 turbine and GE-316X252 generator. Net plant output is projected to be 109 MW. The generator step-up (GSU) transformer is specified as 13.8/115kV delta-wye, 81/108/135 MVA, 7% impedance. The Customer is constructing a new 115kV transmission line to NorthWestern's Hardin Auto 115-kV Substation. In addition, the Customer has proposed interconnecting its Hardin Plant via a 4.5 mile 115kV single circuit transmission to the Western Crossover Substation (to be constructed in parallel with NorthWestern's existing 230kV Hardin – Crossover circuit). The Crossover step-up autotransformer proposed is a 115/230kV wye-wye, 84/112/140 MVA, 4.39% impedance unit. This configuration would provide the Customer the ability to deliver the Hardin Plant output to Western, NorthWestern, or both.

Consequently this study is confined to the interconnection service requested and evaluates the incremental impact of this parallel interconnection. In effect, this study is a 'sensitivity analysis' to NorthWestern's System Impact Study issued March, 2002, and Co-existing System Impact Study issued April, 2002, along with additional NorthWestern sensitivity analysis performed January, 2004. The additional sensitivities performed by NorthWestern included up-to-date machine parameters provided by the Customer, an increase in the generator output from 100 MW to 109 MW and an associated increase in the transmission service provided by NorthWestern.

Western does not have any existing studies that can be utilized to determine if this request could be accommodated. Operation of the southeast Montana bulk transmission service is largely impacted by generation from the Colstrip and Yellowtail Plants along with schedules over Western's Miles City DC Converter Station (MCCS) and NorthWestern's parallel 500kV circuits that extend from Colstrip west to Bonneville Power Administration's (BPA) 500kV Garrison Substation located between Butte and Missoula, MT.

II. Study Models / Development

Base case models and the transient stability package utilized as a benchmark for this study were provided by NorthWestern. NorthWestern's models and package included the most current plant data provided by the Customer to NorthWestern as recent as April 2005. Primary impacts associated with the Hardin Plant itself as compared to the existing system were provided by NorthWestern's March, 2002 System Impact Study and January, 2004 sensitivity analysis. Within these studies, NorthWestern identified the worst case seasonal scenario as light autumn, high transfer. Therefore, this study considers only the 2004_LA1-S light autumn, high transfer model as conditioned and provided by NorthWestern. Prior to NorthWestern's conditioning, the 2004_LA1-S base case originated from WSCC (now WECC) and was posted for study purposes in early 2000. All analyses were performed with Power Technologies, Inc. PSS/E software and modeling format.

Primary generation and transfer limits of the local study area, as provided by NorthWestern in the base case, were set as follows:

Hardin Plant	= 109 MW
Colstrip Plant	= 2,290 MW
Yellowtail Plant	= 200 MW
Corette Plant	= 151 MW
Miles City DC Converter Station	= 136 MW East-to-West
Rimrock Phase Shifter	= 20-30 MW South-to-North
Billings Phase Shifter	= 46-56 MW South-to-North
Crossover Phase Shifter	= 38-42 MW North-to-South

The base case load flow and stability models without the Customer's interconnection to Western are designated as follows:

- Hardin109_nwe.sav

The base case load flow and stability models with the Customer's generation/transmission interconnection to Western are designated as follows:

- Hardin109_nwe_115gi.sav
  (interconnection tied in parallel with NorthWestern at the Hardin 115kV bus)
- Hardin109_nwe_115gi_splt.sav
  (interconnection split/sectionalized from NorthWestern at the Hardin 115kV bus)

NorthWestern identified the worst credible contingency events relative to WECC reliability criteria as follows:

1. Broadview-Garrison double-single (two simultaneous single-phase faults at first double circuit 500kV tower near Townsend, MT with single-pole tripping followed by unsuccessful reclosing on both circuits 1 and 2)
2. Broadview-Garrison circuits 1 and 2 (a three-phase fault at Broadview 500kV bus followed by loss of both circuits 1 and 2).

Both contingency events are stability limiting, rather than steady state limiting.

Based on the above base cases and worst credible contingency events, selective analysis was accomplished to evaluate the incremental impact of the Customer's interconnection to Western. These analyses included selective pre-contingent, post-contingent and prior-outage analyses, as described below. The specific areas monitored were Montana, WAPA Upper Missouri and WAPA Rocky Mountain, as specified in the WECC base case models.

Pre-contingent analyses represent the steady state system intact during normal operating conditions. All pre-contingent load flow analyses allow automatic phase-shift adjustments, load tap changer adjustments, switched shunt adjustments and disabled area interchange.

Post-contingent analyses represent the system immediately following a specified system outage, i.e. a transmission line, transformer, etc. All post-contingent load flow and dynamic stability analyses fix the phase-shifting taps, load tap changers and discrete shunt capacitors or reactors at the pre-disturbance value.

Prior-outage analyses represent the system's normal operating conditions with a known prior-outage that resulted from system operational requirements, e.g. equipment maintenance, etc. This also includes the system's return to a steady state condition following the post-contingent period of the prior outage. Similar to the pre-contingent analyses, all prior-outage analyses allows automatic phase-shift adjustments, load tap changer adjustments, switched shunt adjustments and disabled area interchange. All subsequent contingency events are then evaluated on a post-contingent basis, i.e. fixed

phase-shifting taps, load tap changers and discrete shunt capacitors or reactors at the pre-disturbance value.

III. Study Criteria

Transmission system voltages were monitored against the following WECC reliability criteria limits:

1. Normal (Category A): min.=0.95 p.u. max.=1.05 p.u.
2. Emergency (Category A): min.=0.90 p.u. max.=1.10 p.u.
3. Transient, (Category B, single*): max. V dip=0.25 p.u.
4. Transient, (Category C, double**): max. V dip=0.30 p.u.

*single circuit/element outage: maximum duration of V dip greater than 0.20 p.u. is 20 cycles (V dip referenced from pre-disturbance value).
**double circuit/element outage: maximum duration of V dip greater than 0.20 p.u. is 40 cycles (V dip referenced from pre-disturbance value).

Facility loadings were monitored against the following limits:

1. Normal: 100% of NORMAL for All Facilities = RATE A
2. Emergency: 110% of NORMAL for Transmission Lines = RATE B
   125% of NORMAL for Transformers = RATE B

These values may not apply to all WECC members as they may have a different basis or criteria for certain emergency limits. Emergency limits are short-term loading limits that may be allowed for up to 30 minutes. After 30 minutes, reliability criteria dictate that the system must be restored within Normal limits. Also, there is no WECC requirement for monitoring sub-transmission facilities (<115kV). However, voltage violations and overloads of the sub-transmission facilities were monitored throughout the analyses, based on the same limits.

As can be seen in some of the detailed power flow study results provided in Exhibit 2 of this report, a number of bus voltages outside the normal operation limits exist for the pre-contingent normal operation scenarios. These apparent voltage violations are attributed to a number of issues. For example, NorthWestern typically operates it's 500kV system around 1.08 p.u. for voltage reliability purposes of the underlying transmission. Others voltage and loading violations may be due to modeling errors/omissions or incorrect rating values in the models. All are outside the Southeastern Montana region area of study. In addition, manual transformer tap adjustments and sub-transmission regulation likely are not accounted for. Consequently, numerous sub-transmission over-voltages are indicated that would not actually be experienced during operation. Therefore, the apparent voltage violations in the base case without the Customer's request for interconnection to Western were noted, and the incremental impacts of the Customer's request documented.

IV. Heavy Loading Analyses

Prior study work by NorthWestern and Western has consistently shown that worst-case system operating conditions for eastern Montana occur during periods of high generation transfer and light load demand. This applies to both the steady state load flow analyses and the dynamic stability analyses. NorthWestern's System Impact Study provided this verification.

V. Light Loading Analyses

Based on NorthWestern's prior studies, Western performed selective high transfer light loading analyses for this system impact study.

Steady State Analysis:

All steady state models and analysis included minor impedance and rating corrections to the Customer's proposed GSU transformer and Crossover auto transformer (based on transformer data provided in the Customer's LGI request, provided in Exhibit 1 (Note: included in Customer version of study report ONLY)).

As noted in Section II, the base cases received from NorthWestern included an East-to-West transfer of 136 MW across Western's Miles City DC Converter Station. However, at times the Miles City Converter Station will experience firm point-to-point transaction at the Converter Station's maximum transfer capacity of 200 MW East-to-West or 150 MW West-to-East. Therefore sensitivities were also performed with the Converter Station at maximum transfer capability.

Of primary interest was evaluation of the bulk transmission system with and without a parallel connection to the NorthWestern 115kV bus at the Hardin Auto Substation, i.e. Hardin Plant interconnected to both Western and NorthWestern versus interconnection to Western only.

A. Pre-Contingent Steady State Results:

This section summarizes the pre-contingent steady state analysis for the Study. The base cases utilized are as described in Section II of this report.

Pre-contingent (Category A) sensitivities that were considered in these analyses, along with specific file naming designations, are summarized as follows:

Case File Name	Description
Hardin109_nwe	NorthWestern interconnection only *(Miles City @ 136 EW)*
Hardin109_nwe_115gi	Parallel NorthWestern and Western interconnection *(Miles City @ 136 EW)*
Hardin109_nwe_115gi_200ew	Parallel NorthWestern and Western interconnection

	(Miles City @ 200 EW)
Hardin109_nwe_115gi_150we	Parallel NorthWestern and Western interconnection *(Miles City @ 150 WE)*
Hardin109_nwe_115gi_splt	Western interconnection only – Hardin bus split *(Miles City @ 136 EW)*
Hardin109_nwe_115gi_splt200ew	Western interconnection only – Hardin bus split *(Miles City @ 200 EW)*
Hardin109_nwe_115gi_splt150we	Western interconnection only – Hardin bus split *(Miles City @ 150 WE)*

No incremental pre-contingent system overloads or voltage violations resulting from the Customer's interconnection to Western were discovered within the local study area or across NorthWestern's bulk 500kV transmission system. As expected, a slight improvement of system performance is seen with parallel interconnection to both NorthWestern and Western, as compared to interconnection to NorthWestern or Western only.

Associated pre-contingent steady state system one-lines, overload and voltage violation screening outputs generated from PSS/E are provided in Exhibit 2 of this report.

B. Post-Contingent Steady State Results:

This section summarizes the post-contingent steady state analysis for the Study. The base cases utilized are as described in Section II of this report.

Post-contingent (Category B or C) sensitivities that were considered in these analyses, along with specific file naming *extensions* are summarized as follows (applied to the case file names listed above):

Case File Name Extension	Contingency Description
(file name)_bv1.col500	Broadview-Colstrip 500kV Circuit 1
(file name)_bv12.col500	Broadview-Colstrip 500kV Circuits 1 & 2
(file name)_cro.cu230	Crossover-Custer 230kV Circuit
(file name)_cro.hnt230	Crossover-Huntley 230kV Circuit
(file name)_cro.auto	Crossover 230/115kV Autotransformer
(file name)_hrd.cro230	Hardin-Crossover 230kV Circuit
(file name)_hrd.cro115	Hardin-Crossover 115kV Circuit
(file name)_hrd.auto	Hardin 230/115kV Autotransformer

No incremental post-contingent overloads or voltage violations resulting from the Customer's interconnection to Western were discovered within the local study area or across NorthWestern's bulk 500kV transmission system. As expected, a slight improvement of system performance is seen with parallel interconnection to both NorthWestern and Western, as compared to interconnection to NorthWestern or Western only.

Associated post-contingent steady state system one-lines, overload and voltage violation screening outputs generated from PSS/E are provided in Exhibit 3 of this report.

C. Prior-Outage Steady State Results:

This section summarizes the prior-outage steady state analysis for the Study. The base cases utilized are as described in Section II of this report.

Prior-outage sensitivities (Category B or C) were considered for each of the post-contingent events listed above (Section V.B). This corresponds to a prior-outage of each post-contingent event, followed by a contingency loss of each of the remaining contingencies.

Initial screening indicated two prior outages of primary concern. They were evaluated in full detail. All associated WECC reliability criteria violations are noted as follows:

1. <u>Broadview-Colstrip 500kV circuits 1 and 2</u>. This prior outage assumes the ability of NorthWestern to return Colstrip Unit 2 to 330 MW output (approx 306 MW net output at the Colstrip 230kV bus).
    - *MCCS @ 200 MW East-to-West:* Prior to a subsequent contingency, this prior outage scenario induces a 114% overload to the Crossover-Huntley 230kV circuit (545 MVA). Comparatively, a 117% overload (559 MVA) is observed with the Customer's Hardin Plant interconnected to NorthWestern only.
    - *MCCS @ 200 MW East-to-West:* A steady state load flow solution is not attainable with the subsequent loss of the Crossover-Huntley 230kV circuit.
    - *MCCS @ 150 MW West-to-East:* Prior to a subsequent contingency, this prior outage scenario induces overvoltages in excess of 1.08 p.u on NorthWestern's Colstrip to Hardin 115kV loop.

2. <u>Hardin-Crossover 230kV circuit.</u>
    - *MCCS @ 200 MW East-to-West:* A steady state load flow solution is not attainable with the subsequent loss of the Crossover-Custer 230kV circuit and the Hardin 115kV bus split, i.e. interconnection to Western only. Transfer on the Crossover-Custer circuit is 252 MW, prior to its subsequent loss in this scenerio.
    - *MCCS @ 150 MW West-to-East:* Prior to a subsequent contingency, this prior outage scenario induces a 125% overload to the Customer's proposed Crossover autotransformer (174 MVA). This overload increases to 134% with the subsequent loss of the Crossover-Huntley 230kV circuit (187 MVA).

No incremental prior-outage overloads or voltage violations resulting from the Customer's interconnection to Western were discovered within the local study area or across NorthWestern's bulk 500kV transmission system. During prior outages, considerable improvement of system performance is seen with parallel interconnection to both NorthWestern and Western, as compared to interconnection to NorthWestern or Western only.

At minimum, operational guides will be required for prior outages of the Hardin-Crossover 230kV circuit to address issues on the IS.

Associated pre-contingent steady state system one-lines, overload and voltage violation screening outputs generated from PSS/E are provided in Exhibit 4 of this report.

Stability Analysis:

The purpose of the no-disturbance analysis is to verify that the system is stable prior to any contingency events, i.e. the system is not slowly drifting out of synchronization. It should be noted that prior to evaluation of the new interconnection to Western, an initial run (execution) of the stability package, as provided by NorthWestern, was accomplished on the model to assure a clean stable benchmark for further analysis. It should also be noted that all analyses included in this Section of the Study, include the Miles City DC Converter Station set to 136 MW East-to-West, as provided in the original model package.

Limited stability sensitivity analysis was performed in this Study. NorthWestern's automated UNIX-shell based study package, which includes integration of the Acceleration Trend Relay (ATR) model, was not utilized. The ATR is an integral part of the Colstrip Plant remedial action tripping scheme (RAS) and initiates the necessary unit tripping to maintain acceptable stability results following a given contingency disturbance. In lieu of full implementation of the automated UNIX-shell based study package, NorthWestern provided the resulting disturbance/tripping sequence previously determined by their System Impact Study (including ATR actions). This was provided in the form of a PSS/E idev routine, and included the necessary Colstrip remedial actions for interconnection of the Hardin unit to their system.

This same disturbance/tripping sequence was then applied manually for the critical disturbances to determine if there was any negative incremental impact to the system performance as a result of the additional 115kV transmission interconnection between the Hardin and Crossover substations. No change was made to the ATR actions as determined by NorthWestern's System Impact Study and sensitivities (MW's tripped or unit tripping times). Tripping of the Hardin unit at 10 cycles was an integral requirement by NorthWestern for the worst credible contingency events. Prior to the study being run, no significant change to system performance was expected. The study approach assumed further detailed analysis with the full NorthWestern study package if necessary, depending upon the results of this incremental sensitivity analysis.

D. Pre-Contingent Stability Results (No-Event):

This section summarizes the dynamic stability analysis for the pre-contingent system intact, no-disturbance (no-event). The base cases utilized are as described in Section II of this report. Of primary interest was evaluation of the bulk transmission system with and without a parallel connection to the NorthWestern 115kV bus at the Hardin Auto Substation, i.e. Hardin Plant interconnected to both Western and NorthWestern versus interconnection to Western only.

Three pre-contingent stability runs were initialized for No-Event. They are listed and described as follows:

Pre-Contingent Stability Run	Description
NWE (NO-EVENT)	NorthWestern Interconnection only
115GI (NO-EVENT)	Parallel Western and NorthWestern Interconnect
115GI_SPLT (NO-EVENT)	Western Interconnection only

Oscillographic output channel quantities that were plotted and monitored throughout this and subsequent stability analyses, covered in this report, are as follows:

- P & Q of the Colstrip-Broadview 500kV Circuit 1
- P & Q of the Colstrip-Broadview 500kV Circuit 2
- P & Q of the Broadview-Garrison 500kV Circuit 2
- POWR of Colstrip Units 1 thru 4
- ANGL of Colstrip Units 1 thru 4
- SPD of Colstrip Units 1 thru 4
- V & A at Colstrip 500kV bus
- V & A at Broadview 500kV bus
- V & A at Clyde Park 161kV bus
- V & A at Miles City 230kV bus
- V & A at Crossover 230kV bus
- V & A at Rosebud 230kV bus

Relative Global Voltage Report (RGLVRPT) outputs were generated for each stability run. The RGLVRPT is a NorthWestern screening tool that monitors relative voltages below 0.8 p.u. occurring between 0.1 and 2.0 seconds immediately subsequent to the disturbance event. Minimum relative low voltages and associated durations are summarized as follows for each stability run (system configuration).

Stability Run	Relative Low Voltage	Duration Below 0.8 pu	Bus
NWE (NO-EVENT)	0.9965	n/a	BARRIER 13.2
115GI (NO-EVENT)	0.9965	n/a	BARRIER 13.2
115GI_SPLT (NO-EVENT)	0.9965	n/a	BARRIER 13.2

Select output channel quantities were then plotted comparatively to evaluate the incremental system response changes that result from the Customer's interconnection to Western. These plots are named and described as follows:

Comparable Stability Plots	Compares
CMPR NO-EVENT W/BUS TIED	NWE (NO-EVENT) and 115GI (NO-EVENT)
CMPR NO-EVENT W/BUS SPLIT	NWE (NO-EVENT) and 115GI_SPLT (NO-EVENT)

Output channel quantities compared and monitored throughout this and subsequent comparable analyses covered in this report are as follows:

- P of the Colstrip-Broadview 500kV Circuit
- POWR of Colstrip Unit 1
- ANGL of Colstrip Unit 1
- SPD of Colstrip Unit 1
- V & A at Colstrip 500kV bus
- V & A at Crossover 230kV bus

As expected, and can be seen with all comparable channels plotted, there is no measurable difference between interconnection to NorthWestern, Western or both in parallel. Complete results with channels plotted, as referenced, are provided in Exhibit 5 of this report.

E. Post-Contingent Stability Results (Broadview-Garrison Double Single):

This section summarizes the dynamic stability analysis for the post-contingent Broadview-Garrison Double-Single outage (two simultaneous single-phase faults at the first double circuit 500kV tower near Townsend, MT with single-pole tripping followed by unsuccessful reclosing on both Circuits 1 and 2). The base cases utilized are as described in Section II of this report. Of primary interest was evaluation of the bulk transmission system with and without a parallel connection to the NorthWestern 115kV bus at the Hardin Auto Substation, i.e. Hardin Plant interconnected to both Western and NorthWestern versus interconnection to Western only.

Three post-contingent stability runs were initialized for the Broadview-Garrison Double Single outage. They are listed and described as follows:

Post-Contingent Stability Run	Description
NWE (BV-GR.DS-TG.HRD@10)	NorthWestern Interconnection only
115GI (BV-GR.DS-TG.HRD@10)	Parallel Western and NorthWestern Interconnect
115GI_SPLT (BV-GR.DS-TG.HRD@10)	Western Interconnection only

Oscillographic output channel quantities that were plotted and monitored are as listed previously (Section V.D).

Relative Global Voltage Report (RGLVRPT) outputs were generated for each stability run. The RGLVRPT is a NorthWestern screening tool that monitors relative

voltages below 0.8 p.u. occurring between 0.1 and 2.0 seconds immediately subsequent to the disturbance event. Minimum relative low voltages and associated durations are summarized as follows for each stability run (system configuration).

Stability Run	Relative Low Voltage	Duration Below 0.8 pu	Bus
NWE (BV-GR.DS-TG.HRD@10)	0.7213 pu	0.2542 sec	GRANTVLG 50.0
115GI (BV-GR.DS-TG.HRD@10)	0.7203 pu	0.2542 sec	GRANTVLG 50.0
115GI_SPLT (BV-GR.DS-TG.HRD@10)	0.7214 pu	0.2542 sec	GRANTVLG 50.0

Select output channel quantities were then plotted comparatively to evaluate the incremental system response changes that result from the Customer's interconnection to Western. These plots are named and described as follows:

Comparable Stability Plots	Compares
CMPR BV-GR.12 W/BUS TIED	NWE (BV-GR.DS-TG.HRD@10) and 115GI (BV-GR.DS-TG.HRD@10)
CMPR BV-GR.12 W/BUS SPLIT	NWE (BV-GR.DS-TG.HRD@10) and 115GI_SPLT (BV-GR.DS-TG.HRD@10)

Output channel quantities that were compared and monitored as listed previously (Section V.D).

As expected and can be seen with all comparable channels plotted, there is no measurable difference between interconnection to NorthWestern, Western or both in parallel. Complete results with channels plotted, as referenced, are provided in Exhibit 6 of this report.

F. Post-Contingent Stability Results (Broadview-Garrison Circuits 1 & 2):

This section summarizes the dynamic stability analysis for the post-contingent Broadview-Garrison Circuits 1 & 2 outage (a three-phase fault at Broadview 500kV bus followed by loss of both Circuits 1 and 2). The base cases utilized are as described in Section II of this report. Of primary interest was evaluation of the bulk transmission system with and without a parallel connection to the NorthWestern 115kV bus at the Hardin Auto Substation, i.e. Hardin Plant interconnected to both Western and NorthWestern versus interconnection to Western only.

Three post-contingent stability runs were initialized for the Broadview-Garrison Double Circuits 1 & 2 outage. They are listed and described as follows:

Post-Contingent Stability Run	Description
NWE (BV-GR.12-TG.HRD@10)	NorthWestern Interconnection only
115GI (BV-GR.12-TG.HRD@10)	Parallel Western and NorthWestern Interconnect
115GI_SPLT (BV-GR.12-TG.HRD@10)	Western Interconnection only

Oscillographic output channel quantities that were plotted and monitored are as listed previously (Section V.D).

Relative Global Voltage Report (RGLVRPT) outputs were generated for each stability run. The RGLVRPT is a NorthWestern screening tool that monitors relative voltages below 0.8 p.u. occurring between 0.1 and 2.0 seconds immediately subsequent to the disturbance event. Minimum relative low voltages and associated durations are summarized as follows for each stability run (system configuration).

Stability Run	Relative Low Voltage	Duration Below 0.8 pu	Bus
NWE (BV-GR.12-TG.HRD@10)	0.7292 pu	0.2500 sec	BGTMBERA 161
115GI (BV-GR.12-TG.HRD@10)	0.7408 pu	0.2125 sec	BGTMBERA 161
115GI_SPLT (BV-GR.12-TG.HRD@10)	0.7298 pu	0.2500 sec	BGTMBERA 161

Select output channel quantities were then plotted comparatively to evaluate the incremental system response changes that result from the Customer's interconnection to Western. These plots are named and described as follows:

Comparable Stability Plots	Compares
CMPR BV-GR.12 W/BUS TIED	NWE (BV-GR.12-TG.HRD@10) and 115GI (BV-GR.12-TG.HRD@10)
CMPR BV-GR.12 W/BUS SPLIT	NWE (BV-GR.DS-TG.HRD@10) and 115GI_SPLT (BV-GR.12-TG.HRD@10)

Output channel quantities that were compared and monitored as listed previously (Section V.D).

As expected and can be seen with all comparable channels plotted, there is no measurable difference between interconnection to NorthWestern, Western or both in parallel. Complete results with channels plotted, as referenced, are provided in Exhibit 6 of this report.

VI. Short Circuit Analysis

Initial short circuit analysis was performed to determine if the proposed 115kV interconnection between the Hardin and Crossover Substations, which will increase the fault current levels at both substations, will require any terminal upgrades at those substations or at the substations in the immediate vicinity. The following table documents the single-line-to-ground (SLG) and three-phase (3-PH) fault levels with and without the new interconnection.

Fault Location (kV)	**Case**	**SLG Fault (Amps)**	**3-PH Fault (Amps)**
Hardin 115	No Hardin Plant, and no 115kV int.	5543.5	5125.8
" "	Hardin Plant radial to NWE only	8861.3	7712.3

Fault Location (kV)	Case	SLG Fault (Amps)	3-PH Fault (Amps)
“ “	Hardin Plant AND 115kV int.	11576.5	10133.9
Crossover 230	No Hardin Plant, and no 115kV int.	6138.9	7426.8
“ “	Hardin Plant radial to NWE only	6663.5	7987.8
“ “	Hardin Plant AND 115kV int.	7899.5	8338.5
“ “	Hardin Plant AND 115kV int. AND Crossover Phase Shifter bypassed	8129.8	8568.6
“ “	Hardin Plant radial to Crossover	7804.7	8327.1
“ “	Hardin Plant radial to Crossover AND Crossover Phase Shifter bypassed	8035.6	8556.5
Yellowtail 230	Hardin Plant radial to NWE only	7788.2	7271.0
“ “	Hardin Plant AND 115kV int.	7839.3	7301.6
Custer 230	Hardin Plant radial to NWE only	3049.8	3472.8
“ “	Hardin Plant AND 115kV int.	3180.3	3537.4
Hardin 230	Hardin Plant radial to NWE only	6569.1	7870.8
“ “	Hardin Plant AND 115kV int.	7275.1	8029.5
Hardin 13.8	Hardin Plant radial to NWE only	62770.2	61641.9
“ “	Hardin Plant AND 115kV int.	65821.0	66309.7
Colstrip 230	Hardin Plant radial to NWE only	27949.9	20131.4
“ “	Hardin Plant AND 115kV int.	27953.2	20133.1
Sarpy Crk 115	Hardin Plant radial to NWE only	3403.0	4600.9
“ “	Hardin Plant AND 115kV int.	3479.6	4785.9
Billings 230	Hardin Plant radial to NWE only	11020.7	11824.3
“ “	Hardin Plant AND 115kV int.	11109.4	11920.8

These initial short circuit results indicate that the impact of the new interconnection is confined to the Crossover and Hardin buses, and only small changes in fault current levels are observed at other substations in the vicinity. The impact to the Western substations should be within existing equipment fault interrupting ratings.

Additional review of the short circuit impacts (such as the Crossover 115kV bus), and impacts on the protective relaying will be required in the subsequent Facilities Study, if the Customer elects to proceed with the request. It should also be noted that many of the substations listed above are owned by NorthWestern and they will

need to review and concur that the impacts to their substation equipment are acceptable. It should also be noted that the Customer should review the fault level increases at their Hardin Plant 13.8kV bus to ensure that they are acceptable.

The short circuit results are based upon the following initial modeling estimates: Crossover 230/115kV transformer Y-Y-D; Zps = 0.00356 + j0.05843, Zpt = 0.00444 + j0.11992, Zst = 0.00356 + j0.05321 (100 MVA base); Crossover-Hardin 115kV line; 4.5 miles, Z+ = 0.0034 + j0.0251, Z0 = 0.0163 + j0.0844 (100 MVA base); Hardin Plant GSU 115/13.8 transformer Y-D; Z = 0.00361 + j0.08634 (same for zero) (100 MVA base), and Hardin Plant; X'' = 0.117, X' = 0.165, X=1.697, Zneg = 0.013 + j0.111, Z0 = 0.006 + j0.072 (109 MVA base). The analysis was performed using Western's UGPR Aspen short circuit model "WAPA-UGP-042505.olr" model.

VII. Conclusions

Pre & Post-Contingent Analysis:

No incremental pre or post-contingent overloads or voltage violations resulting from the Customer's interconnection to Western were discovered within the local study area or across NorthWestern's bulk 500kV transmission system. A slight improvement of system performance is seen with parallel interconnection to both NorthWestern and Western, as compared to interconnection to NorthWestern or Western only.

Prior-Outage Steady State Analysis:

No incremental prior-outage overloads or voltage violations resulting from the Customer's interconnection to Western were discovered within the local study area or across NorthWestern's bulk 500kV transmission system. During prior outages, considerable improvement of system performance is seen with parallel interconnection to both NorthWestern and Western, as compared to interconnection to NorthWestern or Western only.

At a minimum, operating guides will be required for a prior outage of the Hardin-Crossover 230kV circuit. It is assumed that NorthWestern will address any required operating guides for their system.

With the Miles City Converter Station (MCCS) set to maximum East-to-West transfer of 200 MW during a prior outage of both Broadview-Colstrip 500kV circuits 1 & 2, the Crossover-Huntley 230kV circuit will experience overloading in excess of 114% prior to any subsequent contingencies (114% with the Customer's Hardin Plant interconnected to both NorthWestern and Western, 117% with interconnection to NorthWestern only). These results are based upon the Colstrip tripping assumed, and further analysis of this issue may be required. In addition, a steady state load flow solution is not attainable with the subsequent loss of the Crossover-Huntley 230kV circuit.

With the Miles City Converter Station (MCCS) set to maximum West-to-East transfer of 150 MW during a prior outage of both Broadview-Colstrip 500kV circuits 1 & 2, overvoltages in excess of 1.08 p.u. are seen on NothWestern's Colstrip to Hardin 115kV loop, prior to any subsequent contingencies. These results are also based upon the Colstrip tripping assumed, and further analysis of this issue may be required.

With the Miles City Converter Station (MCCS) set to maximum East-to-West transfer of 200 MW during a prior outage of the Hardin-Crossover 230kV circuit, a steady state load flow solution is not attainable with the subsequent loss of the Crossover-Custer 230kv circuit and the Hardin 115kV bus split, i.e. interconnection to Western only. An operating guide will be required to address this condition.

Pre-Contingent Stability Analysis (No-Event):

As expected, there are no measurable differences between interconnection to NorthWestern, Western or both in parallel prior to a disturbance (no-event).

Post-Contingent Stability Analysis (Broadview-Garrison Double Single):

As also expected, there are no measurable differences between interconnection to NorthWestern, Western or both in parallel during Northwestern's worst credible event (two simultaneous single-phase faults at first double circuit 500kV tower near Townsend, MT with single-pole tripping followed by unsuccessful reclosing on both circuits 1 and 2). This conclusion is based on NorthWestern's proposed remedial action tripping scheme (RAS) as provided to Western and submitted to WECC for approval.

As expected, there are no measurable differences between interconnection to NorthWestern, Western or both in parallel during Northwestern's second worst credible event (a three-phase fault at Broadview 500kV bus followed by loss of both circuits 1 and 2). This conclusion is based on NorthWestern's proposed remedial action tripping scheme (RAS) as provided to Western and submitted to WECC for approval.

The results of the Study indicate no incremental degradations to the IS as a result of RMP's parallel 115kV interconnection to Western and/or interconnection of the new Hardin Plant directly to Western only. However, operating guidelines and restrictions specific to Western's system will be required during a prior outage of the Hardin-Crossover 230kV circuit, and these will be developed during the subsequent study process.

A subsequent Facilities Study will be required to identify the required facility additions at Crossover and remote end of the proposed 115kV line, the cost of those additions, the Customer's share of those costs, and the schedule for installing the required additions. In addition, any outstanding issues from this study (e.g. operating guide requirements, protection and short circuit issues, coordination with neighboring Transmission Providers, etc) will need to be resolved during the Facilities Study.