# FEASIBILITY STUDY

[redacted] WIND POWER PROJECT
3x100 MW GENERATION INTERCONNECTION
LARAMIE RIVER STATION-STORY 345 KV

INTERCONNECTION CUSTOMER:
[redacted]

GI-002 (2008)
TI-08-0131A
TI-08-0131B

# **FINAL**

08\05\08

Basin Electric Power Cooperative
Transmission Services

## 0.0 Executive Summary

This is the feasibility study for [redacted] Large Generator Interconnection request for a total of 300 MW of wind generation on the Missouri Basin Power Project (MBPP) system. A 100 MW interconnection request has been made to Basin Electric and two 100 MW requests to Tri-State Generation and Transmission Association. Basin Electric and Tri-State are participants in the MBPP. The proposed project is located approximately 20 miles south of the MBPP Laramie River Station in Platte and Goshen Counties, Wyoming. The primary Point of Interconnection (POI) is a new substation on the LRS-Story 345 kV line. The LRS 230 kV substation has been identified as an alternate POI.

The study is performed as described in the Interconnection Feasibility Study Agreement dated March 26, 2008. The "Interconnection Customer" is [redacted]. The "Transmission Provider" is Basin Electric Power Cooperative and/or Tri-State Generation and Transmission Association through their respective tariffs. The Interconnection Customer requested that Network Resource Interconnection Service be studied, with the option for Energy Resource Interconnection. At this time a Transmission Service Request has not been submitted to the Transmission Provider, and there is no available firm transmission capacity on the MBPP system. The request for generation interconnection service in and of itself does not convey any right to deliver electricity to any specific customer or Point of Delivery. The Interconnection Customer has indicated interest in marketing the power in Colorado. For this reason the feasibility study analysis is performed on a summer peak load case with stressed TOT3 conditions.

The results indicate that the interconnection of the [redacted] wind project will require upgrades to the MBPP transmission system. The LRS-Stegall 230 kV is overloaded beyond its emergency rating for the forced outage of the LRS-Ault 345 kV line. This overload was observed during the initial 100 MW generation interconnection of the [redacted] wind project at both of the proposed POI. To relieve the LRS-Stegall 230 kV line loading, a new Archer tap on the LRS-Story 345 kV line, Archer 345\230 kV transformer, and Archer-Cheyenne 230 kV line is proposed. Initial cost estimates for these system improvements is $25,360,605. The full 300 MW of the generation interconnection request on the LRS-Story 345 kV line can be accommodated with these improvements to the MBPP system. This estimate does not include the cost of the [redacted] project interconnection facilities.

This study analyzed two of the 24 points on the TOT3 generation matrix. All 24 TOT3 generation scenarios will need to be analyzed in the future System Impact Study to insure there are no impacts to TOT3 transfer capabilities.

## 1.0 Introduction

[redacted] ("Interconnect Customer") has proposed the [redacted] wind power project. The project would consist of one hundred Vestas V90 3 MW turbines for a total of 300 MW of wind generation. The [redacted] project is to be interconnected into the Missouri Basin Power Project (MBPP) transmission system. The primary point of interconnection is 20 miles south of the MBPP Laramie River Station (LRS) on the existing LRS-Story 345 kV line. The alternate POI is the LRS 230 kV substation. The project site is located in Platte and Goshen Counties, Wyoming, and is located adjacent to the LRS-Story 345 kV line. The Feasibility Study Agreement for the Large Generator Interconnect request was signed on March 26, 2008. The project is expected to be completed in three 100 MW phases and in-service in 2010, 2011, and 2012.

## 2.0 Study Scope

This study will determine the impacts of generation interconnection request by analyzing the transmission system both pre- and post- interconnection of the [redacted] project. The study will include power flow, dynamic stability, and short circuit analysis at peak summer loads and high TOT3 transfers.

The proposed point of interconnection for the project is directly north of WECC Path 36, commonly known as TOT3. TOT3 defines the power transfer from southern Wyoming into northern Colorado.

TOT3 is defined as the combined north to south flow on the following lines:

- Laramie River-Ault 345 kV
- Laramie River-Story 345 kV
- Archer-Ault 230 kV
- Sidney-Spring Canyon 230 kV
- Cheyenne-Ault 230 kV
- Cheyenne-Ault 115 kV
- Sidney-Peetz 115 kV

The transfer capabilities across TOT3 is dependant on the power schedule on the Stegall and Sidney DC ties, and the generation levels at the Laramie River Station, Pawnee, and Colorado Power Project (Brush) generation units. There are a total of 24 points on the TOT3 generation matrix. The scope of this study is to determine the impacts due to the interconnection of the [redacted] project at two of the 24 generation points and at the same TOT3 transfer. This study will include the generation scenario that allows for the maximum TOT3 transfer, that being 1680 MW. This generation point includes LRS=1140 MW, Pawnee=777 MW, CPP=66 MW, and the Sidney and Stegall DC ties scheduled at 300 MW east to west. The 1680 MW rating is a result of the LRS-Story 345 kV outage and LRS-Ault 345 kV line loading to its limit. The second scenario that will be analyzed has the same LRS, Pawnee, CPP generation, but the DC ties are scheduled west to east.

Western Area Power Administration (WAPA) is in Phase 3 of WECC Path Rating Process to increase the TOT3 capabilities to 1680 MW. Their Miracle Mile Project includes upgrading one of the Miracle Mile-Cheyenne 115 kV lines to 230 kV, and a new Cheyenne-Ault 230 kV line. This study will include WAPA's Miracle Mile Project.

First the benchmark results will be determined by increasing the TOT3 north to south transfers until the existing TOT3 limit is established. Area n-1 outages will then be simulated to assess the existing transmission system. Then the [redacted] wind project will be interconnected and generation north and south of TOT3 will be readjusted to achieve the same TOT3 transfer. The same n-1 outages will be simulated and the results will be compared to determine the interconnection impacts. This process will be completed with the [redacted] generation at 100 MW, 200 MW, and 300 MW.

The analysis is performed according to NERC/WECC requirements and includes system intact and contingent (n-1) analysis. Transmission facilities 69 kV and higher are monitored in the study area. PSSE version 29.4 is used.

## 3.0 Base Case

This study will utilize the heavy summer base case that WAPA created for accrediting their Miracle Mile Project through the WECC Path Rating Process. This 2010 HS case was originally created for the Wyoming Joint Queue Study. WAPA has updated this case and it has been reviewed by members of their Peer Review Group to ensure accurate representation of regional area loads, resources, and transmission system configurations.

## 4.0 Modeling

The [redacted] wind project is modeled with equivalent generator models provided by [redacted]. The one hundred 3 MW Vestas V90 wind turbine generators are modeled as three 100 MW generators at 100% of nameplate capacity. The wind turbine models include Vestas' "Advanced Grid Option 2". For the 345 kV POI, the 34.5\345 kV GSU transformers are modeled with an impedance of 10% on a 69 MVA base. At the point of interconnection on the LRS-Story 345 kV a three breaker ring substation is modeled with a fault clearing time of 4 cycles. For the LRS 230 kV POI, a radial 20 mile 230 kV line is modeled from the LRS 230 kV substation to the project 230 kV substation. The 34.5\230 kV GSU transformers are modeled with an impedance of 10% on a 69 MVA base.

## 5.0 Performance Criteria

**System Normal (NERC/WECC Category A):**
All bus voltages are within 0.95-1.05 per unit. All line and transformer loading is less than 100% of continuous rating.

**Outage Conditions (NERC/WECC Category B, C, and D):**

**Steady State:**
All bus voltages are within 0.90-1.10 per unit. All line and transformer loading is less than 100% of continuous rating or an established emergency rating. Solution calculation disables automatic transformer tap changing. Automatic shunt device switching is disabled.

**Transient Stability:**
First swing bus voltage dip is greater than 0.70 pu, generator rotor angles remain in synchronism and positive system damping occurs.

## 6.0 Steady State Powerflow Analysis Results

The purpose of the steady state power flow analysis is to determine the impacts that the [redacted] project has on the transmission system during peak load and high TOT3 north to south transfers. System intact and contingency (n-1) analysis is provided. The forced outage list and power flow summary reports are provided in Appendix A.

Previous power flow study results indicate that with LRS=1140 MW, Pawnee=777 MW, CPP=66 MW, and the DC ties 300 MW W-E, the existing system has a TOT3 limit of 1150 MW. During this generation and transfer scenario, and the forced outage of the LRS-Ault 345 kV line, the loading on the LRS-Stegall 230 kV line is 112% of 478 MVA. This is within the 30 minute emergency rating of 560 MVA, or 117% of 478 MVA. Current operating procedures curtail the LRS generation for the loss of the LRS-Ault 345 kV line. This generation curtailment would relieve this overload to within its continuous rating.

The interconnection of the [redacted] project agitates this overload beyond its emergency rating for all three 100 MW increments at both of the proposed POI. A 90 MW wind project could be interconnected into the 345 kV system, or a 70 MW project interconnected at the LRS 230 kV substation, before system upgrades are required. During outage conditions, the [redacted] generation would have to be curtailed to insure that the LRS-Stegall line loading is within its continuous rating. Table 1 summarizes the LRS-Stegall 230 kV line loading, during the LRS-Ault 345 kV forced outage, for each of the [redacted] generation levels and point of interconnections.

| Case | [redacted] Generation | POI | LRS-Stegall 230 kV | TOT3 |
|---|---|---|---|---|
| 1A1C32 | Existing System | N\A | 112.0% OF 478.0 MVA | 1150 |
| 1A5C28 | 90 MW | 345 kV | 117.0% OF 478.0 MVA | 1151 |
| 1B6C29 | 70 MW | 230 kV | 116.8% OF 478.0 MVA | 1140 |
| 1A2C27 | 100 MW | 345 kV | 117.4% OF 478.0 MVA | 1146 |
| 1B2C28 | | 230 kV | 119.1% OF 478.0 MVA | 1152 |
| 1A3C23 | 200 MW | 345 kV | 123.2% OF 478.0 MVA | 1145 |
| 1B3C24 | | 230 kV | 126.0% OF 478.0 MVA | 1154 |
| 1A4C20 | 300 MW | 345 kV | 129.0% OF 478.0 MVA | 1154 |
| 1B4C21 | | 230 kV | 133.3% OF 478.0 MVA | 1150 |

Table 1

These results indicate that transmission upgrades are required to accommodate the 100 MW, 200 MW, and 300 MW generation interconnection requests for the [redacted] wind project. The LRS-Stegall line has a continuous rating of 478 MVA, or 1200 amps. This is based on the PLC wave traps, relays, and line disconnects at both the LRS and Stegall 230 kV substations. Approximately 55 miles of the LRS-Stegall line is constructed with 2306 MCIL conductor and has a rating of at least 640 MVA. The remaining 2.76 miles of the line is constructed with 1272 MCIL conductor and is rated at 520 MVA, or 1145 amps. One solution

that would allow the full 300 MW wind project to be interconnected into the MBPP system is to upgrade the terminal equipment at both LRS and Stegall, and re-conductor the 2.76 miles of 1272 MCIL line to accommodate the required emergency rating of 640 MVA, or 1605 amps.

| **Estimated Cost** | |
|---|---|
| LRS-Stegall 230 - Reconductor with 2306 MCM ASCR | $250,000 |
| LRS & Stegall Relays | $300,000 |
| LRS & Stegall PLC Wave Traps | $40,000 |
| LRS Line\Ground Disconnect | $22,000 |
| **Total** | **$612,000** |

This cost estimate assumes that the existing structures can accommodate the heavier conductors and substation terminal equipment. Additional research can be completed in the Facilities Study to determine the required structural steel and foundation upgrades.

Although there are several options that could relieve the LRS-Stegall 230 kV overload, this study will consider a new Archer tap on the LRS-Story 345 kV line, a new Archer 230\345 kV transformer, and a new Archer-Cheyenne 230 kV line. The system upgrade is estimated to cost $25,360,605. This estimate does not include the cost of the [redacted] project interconnection facilities. Previous studies have indicated that this system upgrade also has potential to increase TOT3 transfers capabilities. During the System Impact Study, when all TOT3 generation scenarios are analyzed, a more appropriate solution may become apparent to accommodate any additional transmission impacts.

| **Estimated Cost** | |
|---|---|
| Archer Substation Additions | $14,345,000 |
| Cheyenne Substation Additions | $1,498,000 |
| Archer-Cheyenne 230kV TL | $9,517,605 |
| **Total** | **$25,360,605** |

A higher queue interconnection request requires the upgrade of the LRS-Ault 345 kV line and an additional LRS 230\345 kV transformer. In the event that this higher queue project is abandoned, a restudy of the [redacted] interconnection request will be required to determine at what generation level these improvements are required. These improvements will be required to accommodate the full 300 MW request.

The remainder of this report will summarize the results with these transmission upgrades and the full 300 MW of generation interconnected.

## 6.1 DC Ties East to West

### 6.1.1 Existing System

The current TOT3 rating with LRS=1140 MW, Pawnee=777 MW, CPP=66 MW, and DC ties east to west is 1680 MW. A higher queue request required the upgrade of the LRS-Ault 345 kV line and an additional LRS 230\345 kV transformer. With these system improvements the current system meets study criteria.

### 6.1.2 300 MW [redacted] Wind Project

The same scenario is created with the addition of the [redacted] wind project at 300 MW, the Archer tap transmission upgrades, and TOT3 at 1680. It is concluded that with the Archer tap transmission upgrades the 300 MW [redacted] wind project can be interconnected on the LRS-Story 345 kV line and meet study criteria. If the LRS 230 kV POI is desired additional system improvements maybe required. Results show that the Sidney-Peetz-Sterling 115 kV system loads to 100% of its 109 MVA rating during a forced outage along the Sidney-Spring Canyon-North Yuma 230 kV line.

## 6.2 DC Ties West to East

### 6.2.1 Existing System

The current TOT3 limit with LRS=1140 MW, Pawnee=777 MW, CPP=66 MW, and DC ties 300 MW west to east is 1150 MW. As noted in Section 6.0 the existing system meets study criteria. It is observed that the loading on the LRS-Stegall 230 kV, during the LRS-Ault 345 kV outage, is 112% of 478 MVA. This is within its emergency rating of 117%, or 560 MVA.

### 6.2.2 300 MW [redacted] Wind Project

The same scenario is created with the addition of the [redacted] Wind project at 300 MW, the Archer tap transmission upgrades, and TOT3 at 1150 MW. The loading on the LRS-Stegall 230 kV line, during the LRS-Ault 345 kV forced outage, is relieved due to the Archer tap transmission upgrades. It is concluded that with the Archer tap transmission upgrades the 300 MW [redacted] wind project can be interconnected on the LRS-Story 345 kV line and meet study criteria.

## 7.0 Transient Stability Analysis Results

The heavy summer transient stability analysis is performed at the same TOT3 generation points and TOT3 flows as the steady state analysis.

LRS=1140, Pawnee=777, CPP=66, DC Ties=300 E-W, TOT3=1680
LRS=1140, Pawnee=777, CPP=66, DC Ties=300 W-E, TOT3=1150

The wind turbines are modeled to include Vestas' "Advanced Grid Option 2". This option greatly improved the transient stability performance of the transmission system. If the [redacted] project proceeds with different wind turbine technology, or with Vestas V90 turbines without this option, additional studies will be required to ensure that the transient stability response is acceptable.

The transient stability analysis included the following disturbances:

- 4 cycle 3-phase fault at the Laramie River 345 kV bus and loss of the LRS-Ault 345 kV line
- 4 cycle 3-phase fault at the Laramie River 345 kV bus and loss of the LRS-Q1WND 345 kV line
- 4.25 cycle 3-phase fault at the Laramie River 230 kV bus and loss of the LRS-Dave Johnston 230 kV line
- 4.25 cycle 3-phase fault at the Laramie River 230 kV bus and loss of the LRS-Stegall 230 kV line
- 4.25 cycle 3-phase fault at the Laramie River 230 kV bus and loss of the LRS-[redacted] 230 kV line

The transient stability plots and summaries are provided in Appendix B.

## 7.1 DC Ties East to West

### 7.1.1 Existing System

Transient stability is analyzed with LRS=1140 MW, Pawnee=777 MW, CPP=66 MW, DC ties=300 MW E-W, and TOT3 at 1680 MW. The 3-phase fault at the LRS 345 kV bus and loss of the LRS-Ault 345 kV line creates the greatest disturbance to the transmission system. This fault results in a voltage dip of 0.7223 pu on the Stegall to Sidney 115 kV system. The existing system satisfies study criteria.

### 7.1.2 300 MW [redacted] Wind Project

The same scenario is created with the addition of the [redacted] wind project at 300 MW, the Archer tap transmission upgrades, and TOT3 at 1683. The transient stability analysis indicates that, with the Archer tap transmission upgrades, the 300 MW [redacted] wind project can be interconnected on the LRS-Story 345 kV line, or the LRS 230 kV substation. All disturbances meet study criteria. The system stability margin is improved due to the new Archer tap on the LRS-Story 345 kV line. The voltage dip for the 3-phase LRS 345 kV fault and loss of the LRS-Ault 345 kV line is improved to 0.8037 pu at the Skyline 115 kV bus.

## 7.2 DC Ties West to East

### 7.2.1 Existing System

Transient stability is analyzed with LRS=1140 MW, Pawnee=777 MW, CPP=66 MW, DC ties=300 MW W-E, and TOT3 at 1150 MW. For the existing system all disturbances meet study criteria.

### 7.2.2 300 MW [redacted] Wind Project

The same scenario is created with the addition of the [redacted] Wind project at 300 MW, the Archer tap transmission upgrades, and TOT3 at 1150. The transient stability analysis indicates that, with the Archer tap transmission upgrades, the 300 MW [redacted] wind project can be interconnected on the LRS-Story 345 kV line, or the LRS 230 kV substation. All disturbances meet study criteria.

## 8.0 Short Circuit Analysis

The short circuit analysis is performed on the existing transmission system to determine the base case fault duties. The [redacted] wind project is then set in service and the fault duties are recalculated. The fault duty impacts are presented in Tables 3 and 4.

| Fault | Fault Current w/o Project | Fault Current w/ Project |
|---|---|---|
| LRS 345 kV 3-phase | 14,000 amps | 15,200 amps |
| LRS 345 kV SLG | 16,900 amps | 18,100 amps |
| Q1Wind 345 kV 3-phase | 9,500 amps | 11,400 amps |
| Q1Wind 345 kV SLG | 8,200 amps | 9,000 amps |
| [redacted] 345 kV 3-Phase | | 10,000 amps |
| [redacted] 345 kV SLG | | 6,700 amps |

**Table 3: POI LRS-Story 345 kV Short Circuit Results**

| Fault | Fault Current w/o Project | Fault Current w/ Project |
|---|---|---|
| LRS 345 kV 3-phase | 14,000 amps | 15,200 amps |
| LRS 345 kV SLG | 16,900 amps | 18,100 amps |
| LRS 230 kV 3-phase | 13,100 amps | 14,900 amps |
| LRS 230 kV SLG | 14,100 amps | 15,500 amps |
| [redacted] 230 kV 3-Phase | | 7,200 amps |
| [redacted] 230 kV SLG | | 4,400 amps |

**Table 4: POI LRS 230 kV Short Circuit Results**

Existing equipment at the LRS 230\345 kV substation can accommodate these fault duties.

## 9.0 Conclusions

This analysis considers the generation interconnection of the [redacted] wind project into the LRS-Story 345 kV line, and the LRS 230 kV substation. Steady state and transient stability analysis is performed on two of the 24 points in the TOT3 generation matrix.

The power flow results indicate that transmission additions are required to accommodate the [redacted] Wind Project with 100 MW, 200 MW, and 300 MW of generation interconnected. The LRS-Stegall 230 kV line becomes overloaded beyond its 30 minute emergency rating during the LRS-Ault 345 kV outage. Although there are several options that could relieve the LRS-Stegall 230 kV overload, this study considered a new Archer tap on the LRS-Story 345 kV line, a new Archer 230\345 kV transformer, and a new Archer-Cheyenne 230 kV line. The initial estimated cost for these system improvements is $25,360,605. This estimate does not include the cost of the [redacted] project interconnection facilities. With these system improvements the full 300 MW of wind generation could be interconnected into the MBPP system on the LRS-Story 345 kV line. If the LRS 230 kV POI is desired additional system upgrades maybe required. The Sidney-Peetz-Sterling 115 kV line is loaded to 100% of its rating during a forced outage along the Sidney-Spring Canyon-North Yuma 230 kV line.

The transient stability and short circuit analysis indicate the full 300 MW of the generation interconnection request can be accommodated with the proposed Archer tap, Archer 230\345 kV transformer, and Archer-Cheyenne 230 kV line.

In the System Impact Study all 24 TOT3 generation points will be analyzed to determine if the [redacted] wind project impacts the remaining TOT3 limits and to ensure that the existing TOT3 transfer rights are not affected.

The Interconnection Customer has not submitted a Transmission Service Request to the Transmission Provider. The request for Generation Interconnection service in and of itself does not convey any right to deliver electricity to any specific customer or Point of Delivery. Before proceeding with the System Impact Study the Interconnecting Customer may want to consider submitting a Transmission Service Request as no firm transmission capacity is available on the MBPP system.