PROJECT #401

LARGE GENERATION

SYSTEM IMPACT STUDY

RESTUDY REVISION 4

SEPTEMBER 20, 2023

ELECTRIC TRANSMISSION PLANNING

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Introduction

The System Impact Study (SIS) report is an evaluation of the impact and cost of interconnecting the Generating Facility to the NorthWestern Energy's (NWE) transmission system.

This SIS has been revised to reflect updated study parameters. This restudy supersedes and revises the Project 401 Restudy Revision 3, report dated May 15, 2023.

Description of Project

The Interconnection Customer has proposed interconnecting a wind facility to the 100 kV bus at NWE's existing Roundup City substation. The interconnection request is for a total output of 70 MW at the Point of Interconnection (POI). The project is number 401 in NWE's interconnection queue. The requested commercial operation date (COD) is November 15, 2023. The Interconnection Customer has requested NRIS service.

Interconnection Data

Project

- **Interconnection Queue Position:** 401
- **Requested Output at Point of Interconnection:** 70 MW
- **Rated Size** 84 MW @ 1.0 pf, nameplate
- **Interconnection Service Requested:** NRIS
- **Requested Commercial Operation Date:** 11/15/2023

Point of Interconnection

- **Description of Location:** Roundup City substation
- **Location:** 46°26'24.56"N, 108°33'46.26"W
- **Nominal Voltage:** 100 kV

Equipment

- **Turbine Information:**
  - Number of Turbines: 14
  - Manufacturer: Vestas
  - Make/Model: V162-6.0
  - Turbine Type: Type 4
  - Nameplate Turbine Rating: 7.0MVA, 6.0MW
- **GSU Transformers:**
  - Number of transformers: 14
  - Size: 7 MVA
  - Voltage: 0.72/34.5 kV
  - Winding Connection: Wye-Gnd/Delta (Low/High)
  - Impedance: 9.9%, 19.2 X/R
  - Fixed or OLTC: Fixed
- **Main Transformers at POI:**
  - Number of transformers: 1
  - Size: 66/88/110 MVA transformers
  - Voltage: 34.5/100 kV
  - Winding Connections: Wye-Gnd/Wye-Gnd (Low/High)
  - Impedance: 8%; 35 X/R
  - Fixed or OLTC: Fixed
- **Storage:**
  - None

Change of Ownership:

See one-line diagram

Disclaimer

NWE cannot guarantee that future analysis (i.e. Transmission Service or Operational studies) will not identify additional problems or system constraints that require mitigation or reduce operation. Neither ERIS nor NRIS interconnection product conveys nor implies any type of transmission service. If there is a change in queue, a restudy of this project may be required.

Study Method

In analyzing the proposed Generating Facility, NWE utilized PSS®E software to conduct the study. NWE studied the Generating Facility as NRIS. The study simulated the interaction of the Generating Facility with other resources and loads on the transmission system. This study was conducted using a WECC case modified to include the projected 2024 heavy summer peak and light spring load as well as non-BES elements inside NWE's footprint. The System Impact Study includes the following types of analyses:

- Steady State Power Flow
- Fault Duty
- Short Circuit Ratio (SCR) Analysis
- Transient Stability
- Power Voltage Analysis

Existing generation dispatch and system load were varied as needed to emulate stress on the system for various scenarios. A complete list of senior queue projects can be found at:

http://www.oasis.oati.com/NWMT/index.html

Modeling Assumptions

- The Generating Facility was modeled (and will be expected) to provide 0.90 leading to 0.90 lagging power factor at full requested output at the high side of the generator substation.
  - The Generating Facility cannot meet NWE's power factor requirement given the current performance specifications provided by the Interconnection Customer. The Interconnection Customer must inform NWE how they intend to meet the power factor requirement prior to construction.
- The main transformer connection configuration must be approved by NWE prior to construction.
- The customer will be required to have a breaker on the Generating Facility side of the Change of Ownership.

Steady State Power Flow Analysis

The steady state power flow analysis examines steady state, system normal operating conditions with no elements out of service (i.e., P0 conditions) and with various elements out of service (i.e., P1-P7 conditions).

Method

A power flow simulation is completed before and after the addition of the Generating Facility to identify any unacceptable thermal overloads and voltage excursions the Generating Facility may cause. The local area contingencies were the primary focus, but major transmission line outages around the NWE system were also studied. The scheduled voltage at the POI was modeled at 1.00 pu voltage.

NRIS Results

The study showed that the addition of the Generation Facility at full output to NWE's transmission system as an NRIS project does cause/contribute to the following thermal violations:

- Overloads on Crooked Falls – Wayne Pump Tap – North Raynesford Pump Tap – Spion Kop Wind Tap 100 kV lines caused by,
  - Loss of Great Falls 230 kV Switchyard – Highwood Switchyard 230 kV line
  - Loss of Highwood Switchyard – Spion Kop 230 kV line
  - Opening of Spion Kop – Judith Gap Auto 230 kV line without a fault
  - A 230 kV breaker failure at Great Falls 230 Switchyard or Highwood Switchyard
- Overloads on Spion Kop Wind Tap – Raynesford Pump Tap – Stanford Auto – Benchland – Utica Pump Tap – Utica-Front Range Tap – Judith Gap Auto 100 kV line caused by,
  - A 230 kV breaker failure at Great Falls 230 Switchyard
- Overloads on Judith Gap Auto – Judith Gap Tap – Harlowton 100 kV lines caused by,
  - Opening of Judith Gap Auto – Project 360 POI 230 kV line without a fault
- Overloads on Painted Robe – Harlowton 100 kV line caused by,
  - Loss of Broadview Switchyard 230/100 kV bank 1 or 2
  - Any breaker failure that removes the Broadview Switchyard 230/100 kV banks

Discussion

The following transmission upgrades are required prior to NRIS interconnection. The transmission upgrades are broken into two groups: Contingent Facilities required for this project but triggered by senior queued projects and required upgrades for newly identified overloads related to the addition of Project 401.

Contingent Facilities:

- Upgrade Crooked Falls – Wayne Pump Tap – North Raynesford Pump Tap – Spion Kop Wind Tap 100 kV line (34.1 miles) (triggered by Project 335)
- Upgrade Benchland – Stanford Auto 100 kV line (9.5 miles) (triggered by Project 335)
- Upgrade Spion Kop Wind Tap – Raynesford Pump Tap – Stanford Auto 100 kV line (24.2 miles) (triggered by Project 347)

- Judith Gap Auto – Benchland 100 kV 100 kV line (29.7 miles) (triggered by Project 347)
- Upgrade Harlowton – Judith Gap Tap – Judith Gap Auto 100 kV line (16.8 miles) (triggered by Project 335)

Mitigation for newly identified overloads:

- Rebuild Broadview Switchyard substation to accomplish the following:
  - Breaker and a half for the 100 kV bus
  - Independent protection so that the 230/100 kV banks can fault independently leaving the other parallel bank in service

Fault Duty Analysis

When a fault occurs on a power line, protective relaying equipment detects the fault current flowing and signals the associated circuit breakers to open. When the circuit breakers open, they must be capable of interrupting the fault current. If the magnitude of the fault current exceeds the interrupt rating of the circuit breakers, the fault may not be cleared and damage to system equipment and voltage collapse may result.

Method

To perform the fault duty analysis, substations at or near the POI are faulted in the power flow model to determine the fault current magnitude with the Generating Facility in service. The results of this analysis determine whether standard circuit breaker fault duty ratings would be exceeded with the addition of the Generating Facility.

Results

A typical breaker interrupt rating is 40,000 amps. The fault current observed at the POI was approximately 3,510 amps. The addition of the Generating Facility did not cause any breakers in the local area to exceed their interrupt rating. The Generating Facility can interconnect without needing to replace or upgrade any existing breakers.

Short Circuit Ratio (SCR) Analysis

A low SCR area ("weak system") indicates high sensitivity of voltage (magnitude and phase angle) to changes in active and reactive power injections or consumptions. High SCR ("stiff") systems have a low sensitivity and are predominantly unaffected by changes in active and reactive power injection. The ability to identify "weak" systems helps to reliably plan and operate the Bulk Electric System (BES) by understanding potential areas where weak grid issues could arise[1].

Method

SCR is defined as the ratio between short circuit apparent power (SCMVA) from a fault at a given location in the power system to the rating of the inverter-based resource connected to that location. Since the numerator of the SCR metric is dependent on the specific measurement location, this location is usually stated along with the SCR number.

$$SCR_{POI} = \frac{SCMVA_{POI}}{NW_{VER}}$$

Where $SCMVA_{POI}$ is the short circuit MVA level at the POI without the current contribution of the inverter-based resource, and MW_{VER} is the nominal power rating of the inverter-based resource being connected at the POI[1].

Results

Table 1 shows the SCR at the POI for an N-0 and N-1 (strongest source out-of-service) condition for Project 401. It is recommended that the Customer work with their generator manufacturer to ensure that the system they are procuring is capable of operating in a potentially "weak" system. As part of the construction sequence, an electromagnetic transient (EMT) study will be performed to verify the project does not have any negative impact on the rest of the system. The EMT study will be performed by contract engineering services once we have received a deposit and received updated data based on the actual equipment being procured by the Customer.

Table 1: SCR at the POI

System Condition	Without #401's Contingent Facilities or Required Mitigation	With #401's Contingent Facilities	With #401's Contingent Facilities & New Required Mitigation (Broadview Rebuild)
N-0	7.51	7.54	7.54
N-1	1.69	1.73	4.22

Transient Stability Analysis

When a fault occurs on the system protective relaying will respond by opening circuit breakers to remove the affected transmission elements from service. This switching action causes a system

[1] "Integrating Inverter-Based Resources into Low Short Circuit Strength Systems" Reliability Guide, NERC, December 2017

disturbance. Faults are simulated to determine if the transmission system will recover to acceptable steady state operating conditions after a system disturbance. Events that were studied include single phase and three phase faults causing either single or multiple branch outages and/or generator outages. The simulations are intended to assess the how the Generation Facility interacts with the rest of the system.

Method

NWE simulated an extensive set of faults. The term “fault” refers to a short circuit between either a single-phase conductor to ground, or a short circuit between all three phases.

NRIS Results

The study showed that the addition of the Generation Facility at full output to NWE’s transmission system as an NRIS project does not cause any transient stability violations.

Power Voltage Analysis

The System Impact Study examines the reactive margin at critical buses on NWE's transmission system. In addition, the Power Voltage (PV) analysis identifies potential voltage collapse issues under maximum operating conditions. Voltage security margins were evaluated using PV analysis. For this type of study, the security margin (distance to the voltage collapse) is defined by the amount of additional power transfer that can occur before voltage collapse is reached on a predefined bus. Voltage collapse occurs at the "knee point" of the PV curve where the voltage drops rapidly with an increase in the transfer power flow. Operation at or near the stability limit is impractical and a satisfactory operation condition must be ensured to prevent voltage collapse.

Method

The output of the Generation Project was increased 5% more than the requested output. The additional generation was offset by reducing generation at Colstrip. Each of the N-1 and N-2 contingencies analyzed for the Steady State Power Flow Analysis were analyzed to ensure the "knee point" of the PV curve was not reached.

Results

For every contingency analyzed, it was found that there is adequate reactive margin with the addition of the Generation Facility.

Study Results

The results of the System Impact Study indicate that the addition of the Generating Facility as an NRIS project will cause new thermal violations and exacerbate existing thermal violations to multiple elements described in the Steady State Power Flow Analysis section.

The Generating Facility may be subject to re-study should any senior queued projects change their status. The customer will be responsible for mitigating any thermal overloads or voltage violations that may be identified in further System Impact Studies or the Transmission Service Request studies.

Required Modifications

The Generating Facility and collector/ step up substation are to be located north of Roundup, Montana. The requested Point of Interconnection (POI) is the Roundup City 100k kV bus. The Generating Facility and POI substation will be connected with an Interconnection Customer designed, built and owned 100 kV generation tie line, approximately 19 miles in length.

Based on the conclusions presented above, the following Generating Facility modifications, system modifications and Contingent Facilities will be required for the requested service.

Generating Facility Modifications

The Generating Facility is to be connected to the POI substation with a 100 kV generation tie line.

- The Generating Facility will be required to provide two (2) 24 count fiber optic cables, either single mode OPGW fiber optic cables or ADSS fiber optic cables. The purpose of these fiber facilities are to provide a primary and back up path for communications supporting line relaying and SCADA RTU communications from the Collector substation RTU to NWE's Tie Point RTU in the POI substation. It is assumed this will be provided by OPGW on the generator tie line. The Interconnection Customer is responsible for installation, testing, and splicing this cable.
- NWE requires the Generating Facility main transformer configuration to be approved by NWE.
- The Customer will be required to have a main breaker on the project side of the Change of Ownership.
- The Generating Facility will be required to bring the new generation tie line into the POI substation. Design exhibits showing proper clearances will be required if there are any crossings of NWE power lines. A path for the lines entering the POI substation that is satisfactory to all parties involved will have to be defined by the Developer. The Customer will work with NWE's right of way representatives as encroachment documents will be needed if the Generating Facility tie line crosses over any part of existing line easements.

System Modifications (POI)

This project is requesting 70 MW interconnection to the existing 100 kV bus at the Roundup City substation.

Substation Modifications:

This request requires 100 kV bus expansion of the Roundup City substation to add a line breaker and metering units.

- Four (4) three phase 100 kV ABSW
- One (1) 100 kV breakers
- Three (3) Single phase 100 kV CT/PT metering units
- Protective relaying equipment

This request requires a yard expansion. The Roundup City substation is land-locked. If it has to expand, the estimate in Table 2 includes a theoretical land budget. Will need to encounter willing neighbors who will sell their land for the expansion.

Transmission Lines Modifications:

The customer will route their interconnection line to a new bay at the substation. No line crossing or relocation of transmission lines to accommodate this interconnection is expected.

Communications Modifications:

Install a conduit at Roundup City substation from the Control House to the substation dead-end structure and provide ADSS fiber optic cable to terminate to the customer's OPGW fiber optic cable on the generation tie line.

Install a multi-mode fiber optic cable from the control house to the high side generation point of receipt meter in the Roundup City yard along with a network switch for Ethernet communications to the GPOR meter for MV-90 meter data.

POI Metering Modifications:

NWE, as the Transmission Provider, shall install metering equipment at the POI prior to any operation of a Large Generating Facility and shall own, operate, test and maintain such metering equipment. Power flows to and from the Large Generating Facility shall be measured at the POI. Any additional metering that is required to accommodate allocating an interconnection project into multiple phases, multiple interconnection projects behind a single POI or any other market arrangements, shall be installed behind the POI by the Customer and its cost, operation, testing and maintenance shall be the responsibility of the Customer. The Customer will be responsible for any and all allocations behind the POI meter generated by such additional metering, and shall provide information of the allocations as requested by the Transmission Provider.

Install a 100 kV metering unit consisting of three (3) single phase 100 kV PT/CT combination metering units and associated equipment at the POI substation. Only high side metering is required.

POI EMS Data Modifications:
Update energy management system data bases and displays to incorporate the new POI substation and generating facility operational signals.

Additional System Modifications
In addition to the POI modifications, the following additional system modifications have been identified for NRIS service request to remove limitations in the system that arise from the addition of the 70 MW of wind generation.

Substation Modifications:
Broadview Switchyard requires a rebuild of the 230 kV and 100 kV busses for increased capacity.

Transmission Lines Modifications:
None identified

Communications Modifications:
None identified

Metering and EMS Data Modifications:
None identified

Contingent Facilities
The systems analysis above has identified the upgrades below as necessary prior to the operation of the proposed Generating Facility under NRIS conditions. These upgrades have been previously identified by senior queue interconnection projects and are also required by this project. As a result, they are identified as GIA Network Upgrades in Table 2. Should any of these projects change status, elements of this cost estimate will need to be reviewed and revised. The full cost of GIA Network Upgrades has been shown in Table 2 to provide a worst case estimate of potential project costs.

- Crooked Falls – Wayne Pump Tap – North Raynesford Pump Tap – Spion Kop Wind Tap 100 kV re-conductor (Project 335)
- Benchland – Stanford Auto 100 kV re-conductor (Project 335)
- Spion Kop Wind Tap – Raynesford Pump Tap – Stanford Auto 100 kV re-conductor (Project 347)
- Judith Gap Auto – Benchland 100 kV re-conductor (Project 347)
- Harlowton – Judith Gap Tap – Judith Gap Auto 100 kV re-conductor (Project 335)

Cost Estimate

Non-binding cost estimates to interconnect the Generating Facility as an NRIS project are summarized in **Error! Reference source not found.**2. A one-line diagram of the interconnection substation is included in Appendix 1: One-line Diagram of the Interconnection Substation.

Table 2: High-level, non-binding estimates of the costs for interconnection as an NRIS project.

	Cost
System Modifications	
POI substation modifications	$ 1,784,000
Broadview Switchyard 230 kV bus rebuild	$ 4,648,000
Broadview Switchyard 100 kV bus rebuild	$ 6,500,000
Total NRIS Cost Estimate	**$ 12,964,000**
Contingent Facilities	
GIA Network Upgrades	
Crooked Falls – Wayne Pump Tap – North Raynesford Pump Tap – Spion Kop Wind Tap 100 kV re-conductor (Project 335)	$ 13,885,000
Benchland – Stanford Auto 100 kV re-conductor (Project 335)	$ 5,021,000
Spion Kop Wind Tap – Raynesford Pump Tap – Stanford Auto 100 kV re-conductor (Project 347)	$ 11,643,000
Judith Gap Auto – Benchland 100 kV re-conductor (Project 347)	$ 15,283,000
Harlowton – Judith Gap Tap – Judith Gap Auto 100 kV re-conductor (Project 335)	$ 8,571,000
Total NRIS and Contingent Facilities Cost Estimate	**$ 54,403,000**

Notes

- All costs shown are fully loaded. Costs are in 2022 dollar values and are subject to change due to inflationary cost escalation and supply chain issues. The Interconnection Project will pay all actual charges required for the interconnection of the Project.
- Contingent Facilities are required to be in place before the Project can interconnect under system normal operating conditions and configurations. This assumes that the Contingent Facilities have already been constructed and are in service. If not, this Project will be required to construct the Contingent Facilities prior to interconnection and will incur costs up to the total estimated cost listed in appropriate cost table.

Estimate Assumptions

- Assumes neighbor(s) are willing to sell their land for the Roundup City substation expansion.

Construction Schedule

Design and construction of the POI upgrades is anticipated to required 18-24 months once adequate property has been secured. Based upon this expectation, the COD of 11/15/2023 is not feasible.

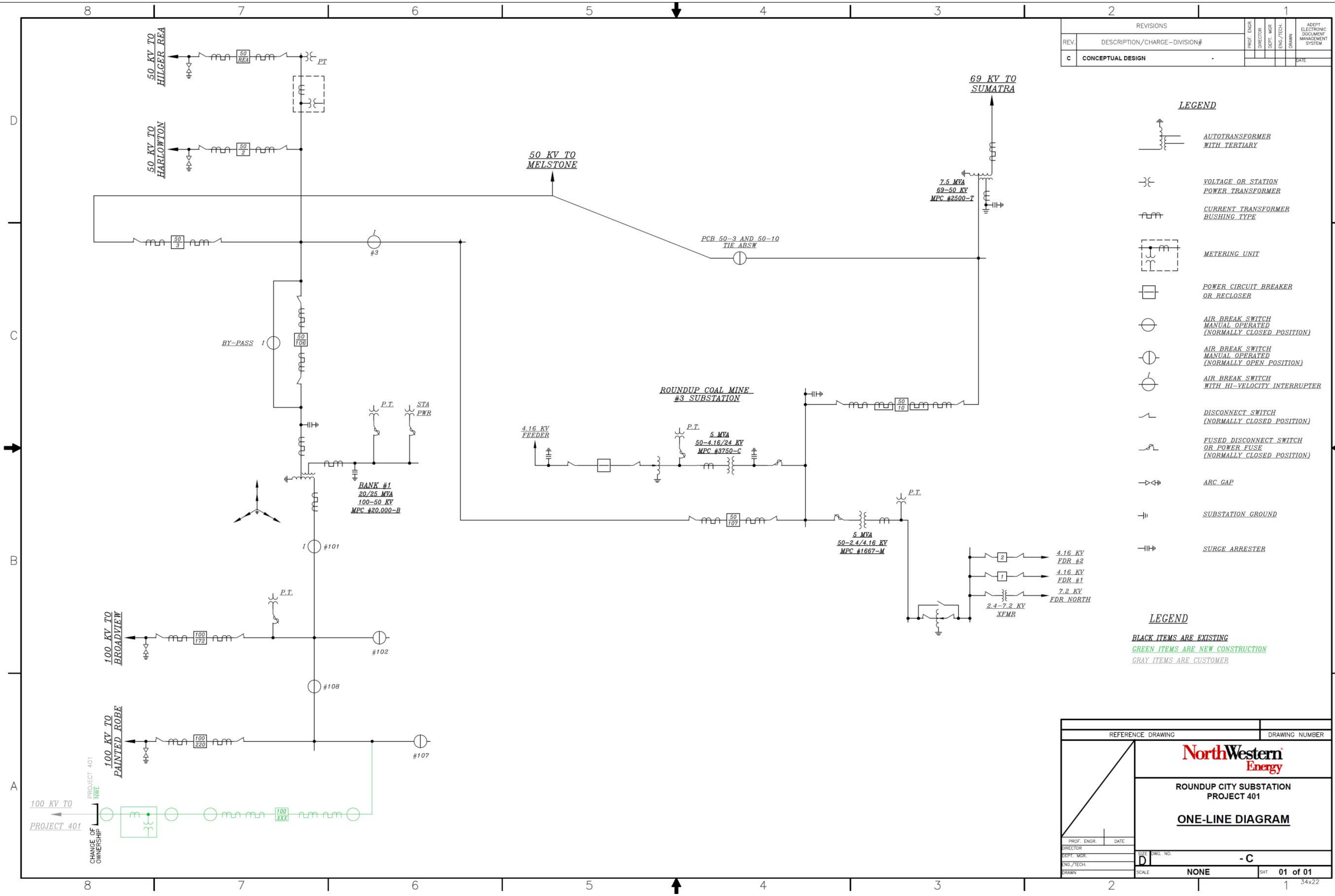
Design and construction of the Broadview substation upgrades is expected to require 24-30 months to complete. Construction of the 100 kV buss could likely proceed independently, however, reconfiguration of the existing 230 kV bus and cutover of 100 kV lines to the new 100 kV bus would need to be coordinated with other system requirements.

Next Steps

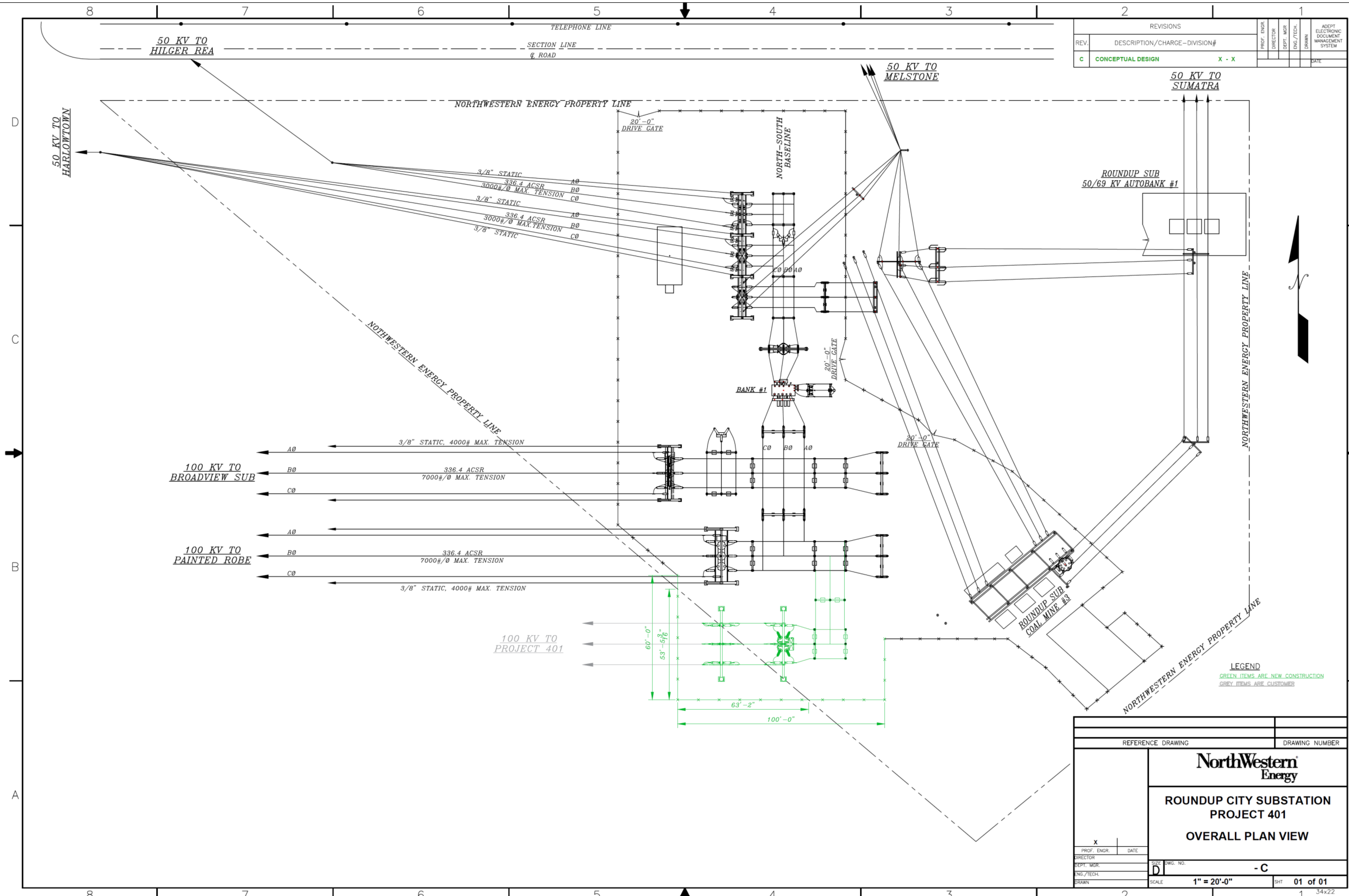
NWE has used the results of this Systems Impact Study in conducting the Facilities study with the same date. NWE will schedule a meeting to discuss the findings of the System Impact Study and Facilities study with the customer.

This study does not constitute a request for transmission service. The study examined the physics of the electrical system and does not imply transmission rights of the Generating Facility. The customer must follow the procedures described in the transmission tariff available on http://www.oasis.oati.com/NWMT/index.html to request and/or receive transmission service.

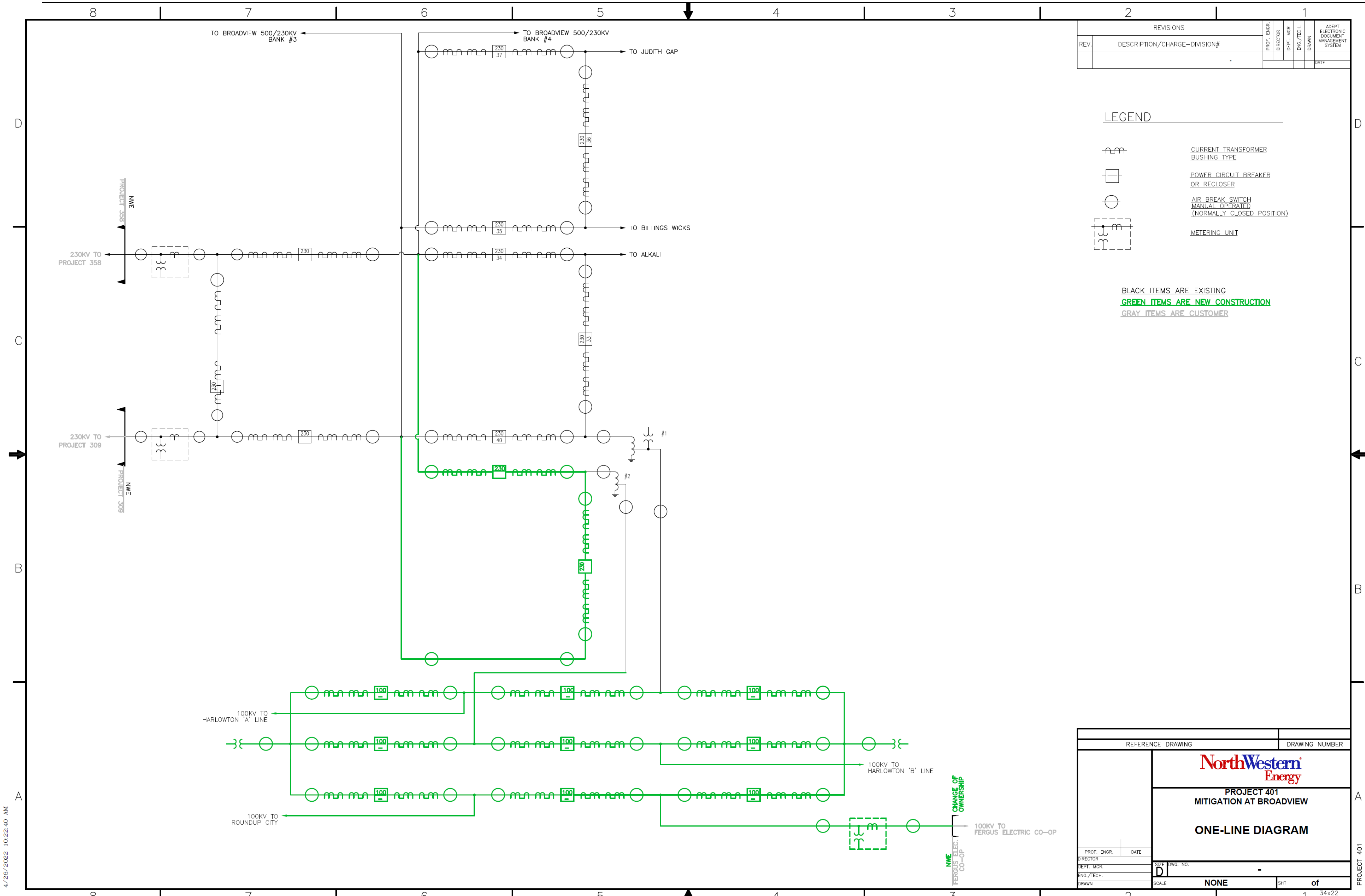
Appendix 1: One-line Diagram of the Interconnection Substation



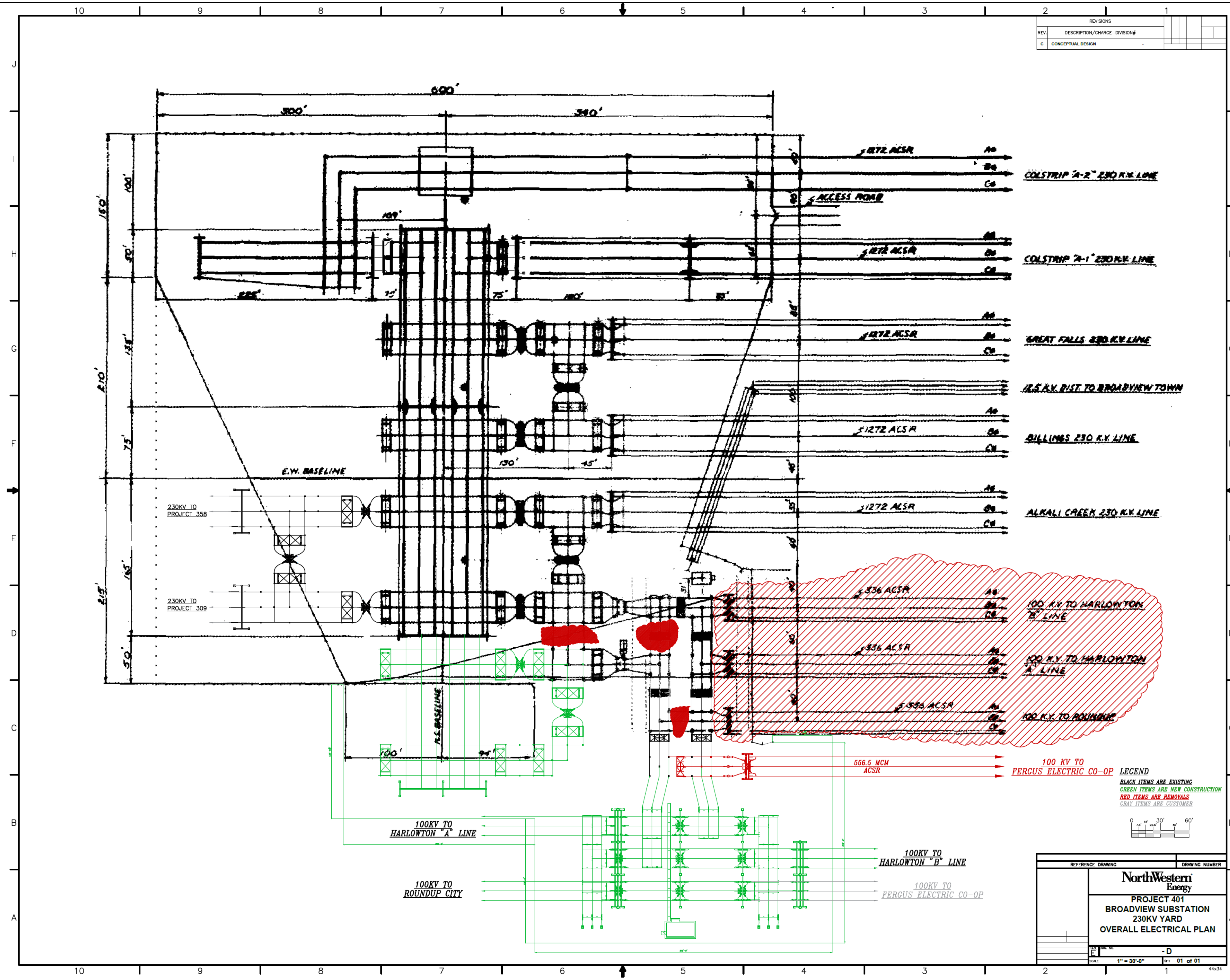
Appendix 2: General Arrangement Diagram of the Interconnection Substation



Appendix 3: One-line Diagram of the Broadview Switchyard substation



Appendix 4: General Arrangement Diagram of the Broadview Switchyard substation



Appendix 5: Definitions

Contingent Facilities shall mean those unbuilt Interconnection Facilities and Network Upgrades upon which the Interconnection Request's costs, timing, and study findings are dependent, and if delayed or not built, could cause a need for Re-Studies of the Interconnection Request or a reassessment of the Interconnection Facilities and/or Network Upgrades and/or costs and timing.

Distribution Upgrades shall mean the additions, modifications and upgrades to the Transmission Provider's Distribution System at or beyond the Point of Interconnection to facilitate interconnection of the Generating Facility and render the transmission service necessary to affect Interconnection Customer's wholesale sale of electricity in interstate commerce. Distribution Upgrades do not include Interconnection Facilities.

Energy Resource Interconnection Service (ERIS) allows the Interconnection Customer to connect its Generating Facility to the Transmission Provider's Transmission System and to be eligible to deliver the Generating Facility's electric output using the existing firm or non-firm capacity of the Transmission Provider's Transmission System on an as available basis. Firm or non-firm service must be requested through the transmission service process. Energy Resource Interconnection Service in and of itself does not convey transmission service. As an ERIS, the Interconnection Customer will be responsible for any required upgrades necessary for connection to the POI. The ERIS findings included in this study do not assure the Interconnection Customer that the planned Generating Facility will be allowed to operate at full or reduced capacity under any or all operating conditions.

Generating Facility shall mean Interconnection Customer's device for the production of electricity identified in the Interconnection Request, but shall not include the Interconnection Customer's Interconnection Facilities.

Interconnection Facilities shall mean the Transmission Provider's Interconnection Facilities and the Interconnection Customer's Interconnection Facilities. Collectively, Interconnection Facilities include all facilities and equipment between the Generating Facility and the Point of Interconnection, including any modification, additions or upgrades that are necessary to physically and electrically interconnect the Generating Facility to the Transmission Provider's Transmission System. Interconnection Facilities are sole use facilities and shall not include Distribution Upgrades, Stand Alone Network Upgrades or Network Upgrades.

Interconnection Customer's Interconnection Facilities shall mean all facilities and equipment owned, controlled, or operated by the Interconnection Customer, that are located between the Generating Facility and the Point of Change of Ownership, including any modification, addition or upgrades to such facilities and equipment necessary to physically and electrically interconnect the Generating Facility to the Transmission Provider's Transmission System. Interconnection Customer's Interconnection Facilities are sole use facilities.

Network Resource Interconnection Service (NRIS) allows the Interconnection Customer to be designated as a Network Resource, up to the Large Generating Facility's full output, on the same basis as existing Network Resources interconnected to the Transmission Provider's Transmission System. NRIS identifies all system upgrades necessary for the project to operate at the full requested output. NRIS does not convey reservation of transmission service nor does it convey any right to deliver electricity to any specific customer or Point of Delivery.

Network Upgrades shall mean the additions, modifications, and upgrades to the Transmission Provider's Transmission System required at or beyond the point at which the Interconnection Facilities connect to the Transmission Provider's Transmission System to accommodate the interconnection of the Generating Facility to the Transmission Provider's Transmission System.

Point of Change of Ownership between NorthWestern Energy's transmission system and the Interconnection Customer's Interconnection Facilities is the point where the Interconnection Customer's overhead or underground line meets the NWE bus connecting to the NWE disconnects and metering set.

Point of Interconnection is the point where the Interconnection Customer's Interconnection Facilities tap a NWE Transmission or Distribution line or connects to an existing NWE substation.

Transmission Provider's Interconnection Facilities shall mean all facilities and equipment owned, controlled, or operated by the Transmission Provider from the Point of Change of Ownership to the Point of Interconnection including any modifications, additions or upgrades to such facilities and equipment. Transmission Provider's Interconnection Facilities are sole use facilities and shall not include Distribution Upgrades, Stand Alone Network Upgrades or Network Upgrades.