



Interconnection Feasibility Study Report
Request # GI-2016-3
Final Report

600 MW Wind Generating Facility
Missile Site 345 kV Substation, Colorado

Public Service Company of Colorado
Transmission Planning
April 20, 2016

Executive Summary

Public Service Company of Colorado (PSCo) received an Interconnection Request (IR) on February 12, 2016 which was assigned GI-2016-3 queue position. GI-2016-3 is a wind generating facility rated at 600 MW gross electrical output that will be located in Elbert, Lincoln and Kit Carson Counties in Colorado. The point of interconnection (POI) requested for GI-2016-3 is the 345 kV bus within the PSCo Missile Site Substation.

The proposed 600 MW generating facility is expected to consist of approximately 300 wind turbine generators (WTG), where each WTG is rated ~2.0 MW and is equipped with a 0.69/34.5 kV step-up transformer. Preliminary information on the wind generating facility's layout suggests that the 300 WTG's will be grouped together into two or three 34.5 kV collector systems, and each 34.5 kV collector system will connect to a 34.5/345 kV main step-up transformer (MST). The two or three MST's will be connected to the POI using a customer-owned 85 miles, 345 kV radial transmission line.

The commercial operation date (COD) requested for the generating facility is December 31, 2018 and the requested back-feed date is August 1, 2018. The IR indicated that this Feasibility Study should include studies for both Network Resource Interconnection Service (NRIS) and Energy Resource Interconnection Service (ERIS).

The main purpose of this Feasibility Study is to determine the feasibility of interconnecting 600 MW of generation at the Missile Site 345 kV POI for delivery to PSCo network loads. Towards this purpose, the study also identifies the transmission improvements needed to enable delivery of the rated 600 MW output of GI-2016-3 to the PSCo network load for NRIS.

The Feasibility Study consisted of steady state (power flow) and short-circuit analyses. The power flow analyses were performed using a 2021 heavy summer (2021HS) base case. Three power flow models were created from the 2021HS case – a Benchmark Case which models the planned transmission system topology before the proposed GI-2016-3 interconnection (i.e. Before GI-2016-3 case), one Study Case that includes the 600 MW generation under study (i.e. After GI-2016-3 case), and another Study Case



that also includes the network upgrades identified to qualify GI-2016-3 as NRIS (i.e. After GI-2016-3 plus network upgrades case).

The power flow analysis results provided in Table A.1 identified the following thermal constraints for the additional 600 MW injection:

- (a) The 345/230 kV transformation capacity at Smoky Hill substation due to single contingency outage of any one of the two 345/230 kV auto-transformers;
- (b) The Missile Site – Daniels Park 230 kV line for the single contingency outage of Missile Site – Smoky Hill 345kV line; and
- (c) The Clark – Jordan 230 kV underground line for several single contingencies, with the worst overload resulting from the single contingency outage of the Smoky Hill – Tollgate – Leetsdale 230 kV line.

The Pawnee – Daniels Park 345 kV project¹ is a PSCo planned project for which the Colorado Public Utility Commission (CPUC) has approved a Certificate of Public Convenience and Necessity (CPCN) that includes an in-service date of May 2022. Therefore, this Feasibility Study evaluated the effectiveness of Pawnee – Daniels Park 345 kV (P-DP) project in mitigating the thermal overloads due to the proposed 600 MW interconnection. Mitigation of all three thermal overloads due to the aggregate impact of transmission improvements comprising the P–DP project is evident from the power flow analysis results provided in Table A.2.

The Pawnee – Daniels Park (P-DP) project alleviates the 345/230 kV transformation capacity constraint at Smoky Hill because it includes installing a 345/230 kV, 560 MVA auto-transformer at a new Harvest Mile substation, which is electrically the same as adding a third auto-transformer at Smoky Hill. Further, the Smoky Hill (Harvest Mile) – Daniels Park 345 kV line comprised in the P–DP project helps eliminate the thermal overload on the Clark – Jordan 230 kV line by redirecting a significant amount of power into Daniels Park from Smoky Hill. Also, the Missile Site – Daniels Park 345 kV line within the P–DP project provides a new parallel path from Missile Site to Daniels Park. Therefore, the P–DP project is effective in mitigating the thermal overloads attributed to GI-2016-3 and is recommended as the network upgrade(s) for delivery of 600 MW rated output.

The short circuit analysis results based on the 2017-18 transmission topology did not identify the need for any network upgrades for the proposed GI-2016-3 interconnection.

Consequently this Feasibility Study concludes that the GI-2016-3 interconnection would not achieve 600 MW NRIS[^] until the Pawnee – Daniels Park 345 kV project is placed in

¹ More information at: <http://www.transmission.xcelenergy.com/Projects/Colorado>

[^] Network Resource Interconnection Service allows Interconnection Customer's Large Generating Facility 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 Transmission Provider's Transmission System, and to be studied as a Network Resource on the assumption that such a designation will occur. (*section 3.2.2 of Attachment N in Xcel Energy OATT*)



service. As noted in the 2016 project update², advancing the in-service date to October 2019 for Smoky Hills – Daniels Park portion of the project is intended by petitioning the CPUC to modify their previous decision.

Prior to the Pawnee – Daniels Park 345 kV project being in-service, GI-2016-3 may be interconnected as ERIS* to deliver its output using the existing firm or non-firm transmission capacity on an “as available” basis.

Therefore, for GI-2016-3 interconnection:

NRIS (before network upgrades) = 0 MW

NRIS (after network upgrades) = 600 MW

ERIS (before network upgrades) = 0 to 600 MW on “as-available” basis

Cost estimates for the Transmission Provider Interconnection Facilities are provided in Tables 1 and 2, and the cost estimates for the Pawnee – Daniels Park 345 kV project are provided in Table 3 – Network Upgrades for Delivery. The estimated total cost for the required Interconnection Facilities is **\$6.579M** (of which \$3.552M Interconnection is Customer Funded and \$3.027M PSCo is Transmission Provider Funded) and the estimated total cost for the Network Upgrades is **\$178.3M**.

Total Estimated Cost for Interconnecting GI-2016-3 as NRIS = ~\$184.9M

Total Estimated Cost for Interconnecting GI-2016-3 as ERIS = ~\$6.6M

² More information at:

<http://www.transmission.xcelenergy.com/staticfiles/microsites/Transmission/Files/PDF/Projects/CO/Pawnee-Daniels/CO-Transmission-Pawnee-Daniels-March-2016-Project-Update.pdf>

* Energy Resource Interconnection Service allows Interconnection Customer to connect the Large Generating Facility to the Transmission System and be eligible to deliver the Large Generating Facility's output using the existing firm or non-firm capacity of the Transmission System on an "as available" basis. Energy Resource Interconnection Service does not in and of itself convey any right to deliver electricity to any specific customer or Point of Delivery. (*section 3.2.1 of Attachment N in Xcel Energy OATT*)

Power Flow N-1 Contingency Analysis

The 2021HS base case was updated to dispatch the existing and planned generation within the Pawnee and Missile Site “generation pockets” (i.e. aggregate of generation in the local area) at their respective highest coincident output deemed appropriate for the planning of adequate transmission capacity. This was done in accordance with the generation dispatch assumptions practiced by PSCo Transmission Planning function to study the feasibility and system impact of generator interconnection requests as a Transmission Provider. Accordingly, the existing, planned and proposed generating plants at Pawnee and Missile Site stations were dispatched as noted below.

Pawnee local “generation pocket”

- ✓ Pawnee Fossil Fuel generation = 100% of rated capacity = 536 MW
- ✓ Manchief Gas generation = 90% of rated capacity = 252 MW
- ✓ Peetz Logan Wind generation = 40% of rated capacity = 230 MW

Aggregate Generation Dispatched at Pawnee in all Cases = 1018 MW

Missile Site local “generation pocket”

- ✓ Cedar Point (Missile Site 230kV) = 80% of rated capacity = 200 MW
- ✓ Limon I, II, III (Missile Site 345kV) = 80% of rated capacity = 480 MW
- ✓ GI-2016-3 (Missile Site 345kV) = 100% of rated capacity = 600 MW

Aggregate Generation Dispatched at Missile Site in Benchmark Case = 680 MW

Aggregate Generation Dispatched at Missile Site in Study Case(s) = 1280 MW

The GI-2016-3 *Benchmark Case* was derived from the 2021HS base case by changing the generation dispatch at Pawnee and Missile Site as noted above. Also, transmission facilities comprising the Pawnee –Daniels Park project modeled in the 2021HS case were removed in the Benchmark Case.

Two GI-2016-3 *Study Cases* were created -- without and with the network upgrades. The GI-2016-3 *Study Case without network upgrades* was created by adding the GI-2016-3 generating plant at Missile Site 345kV bus into the Benchmark Case and dispatching it at 600 MW rated output. The GI-2016-3 *Study Case with network upgrades* was created by adding the Pawnee –Daniels Park Project’s transmission facilities to the previous case.

PSCo adheres to all applicable NERC Standards & WECC Criteria for Bulk Electric System (BES) acceptable performance, as well as its internal transmission planning criteria for all studies. During system intact (N-0) conditions, PSCo’s steady-state performance criteria require the transmission bus voltages remain within 0.95 – 1.05 per unit of nominal and the power flows stay below the applicable normal ratings of the transmission facilities. Following a single contingency, the steady state bus voltages must remain within 0.90 – 1.05 per unit of nominal, and the power flows must continue



to stay below the applicable normal facility ratings. For N-1 post-contingency system conditions, the applicable normal rating is the seasonal continuous rating of the transmission facility – but PSCo allows use of eight-hour facility rating for transformers for which it is available. Further, PSCo does not rely on 30-minute emergency ratings of transmission facilities for meeting N-1 system performance in planning studies.

Based on the results of the steady-state power flow analyses on the Benchmark and Study Cases provided in Table A.1 in the Appendix, it is evident that injecting 600 MW at Missile Site 345 kV bus results in heavy N-1 thermal overloads on the Smoky Hill 345/230 kV auto-transformers, the Missile Site – Daniels Park 230 kV line, and the Clark – Jordan 230 kV underground line. Without any transmission improvements (i.e. network upgrades) to mitigate these three thermal constraints – that is, by only utilizing the existing capability of PSCo’s transmission system – the GI-2016-3 interconnection qualifies for NRIS at 0 MW and for ERIS within the 0–600 MW output range by using the “as available” firm or non-firm capacity of the existing transmission system. The power flow results provided in Table A.2 in the Appendix demonstrate that the GI-2016-3 interconnection will achieve NRIS for its rated 600 MW output after the network upgrades are constructed (i.e. Pawnee – Daniels Park 345kV Project is in service).

Therefore, for GI-2016-3 interconnection:

NRIS (before network upgrades) = 0 MW

NRIS (after network upgrades) = 600 MW

ERIS (before network upgrades) = 0 to 600 MW on “as-available” basis

Voltage Regulation and Reactive Power Capability

Interconnection Customers are required to interconnect its Large Generating Facility with Public Service of Colorado’s (PSCo) Transmission System in accordance with the *Xcel Energy Interconnection Guidelines for Transmission Interconnected Producer-Owned Generation Greater Than 20 MW* (available at: <http://www.transmission.xcelenergy.com/staticfiles/microsites/Transmission/Files/PDF/Interconnection/Interconnections-POL-TransmissionInterconnectionGuidelineGreat20MW.pdf>).

In addition, wind generating plant interconnections must also fulfill the performance requirements specified in FERC Order 661-A. Accordingly, the following voltage regulation and reactive power capability requirements at the POI are applicable to this interconnection request:

- To ensure reliable operation, all Generating Facilities interconnected to the PSCo transmission system are expected to adhere to the *Rocky Mountain Area Voltage Coordination Guidelines (RMAVCG)*. Accordingly, since the POI for this interconnection request is located within Northeast Colorado - Region 7 defined in the *RMAVCG*; the applicable ideal transmission system voltage profile range is 1.02 – 1.03 per unit at regulated buses and 1.0 – 1.03 per unit at non-regulated buses.



- Xcel Energy’s OATT requires all Interconnection Customers to have the reactive capability to achieve +/- 0.95 power factor at the POI, with the maximum reactive capability (corresponding to rated output) available at all output levels. Furthermore, Xcel Energy requires all Generating Facilities to have dynamic voltage control capability and maintain the POI voltage specified by the Transmission Operator as long as the generating plant is on-line, producing power and it is not called upon to operate outside its 0.95 lag – 0.95 lead power factor range capability at the POI.
- It is the responsibility of the Interconnection Customer to determine the type (switched shunt capacitors and/or switched shunt reactors, etc.), the size (MVAR), and the locations (34.5 kV or 345 kV bus) of any additional static reactive power compensation needed within the generating plant in order to have adequate reactive capability to meet the +/- 0.95 power factor and the 1.02 – 1.03 per unit voltage range standards at the POI. Further, for wind generating plants to meet the LVRT (Low Voltage Ride Through) performance requirements specified in FERC Order 661-A, an appropriately sized and located dynamic reactive power device (DVAR, SVC, etc.) may also need to be installed within the generating plant.
- The Interconnection Customer is required to demonstrate to the satisfaction of PSCo Transmission Operations prior to the commercial in-service date of the generating plant that it can safely and reliably operate within the required power factor and voltage ranges (noted above).

Short Circuit Analysis

The short circuit study results show that no circuit breakers in the Missile Site station (or any adjoining station) will be over-dutied by interconnecting the proposed GI-2016-3 wind generation facility.

GI-2016-3 Impact on Short Circuit Levels and Breaker Duty Margins at Missile Site 345 kV POI

System Condition	Three-Phase (3-Ph) Fault Level (Amps)	Single-Line-to-Ground (SLG) Fault Level (Amps)	Breaker Duty Margin for 3-Ph Fault	Breaker Duty Margin for SLG Fault
Before GI-2016-3 Y2017-18	10,910	10,151	82.7 %	83.9 %
After GI-2016-3 Y2017-18	11,967	11,208	81.0 %	82.2 %



Costs Estimates and Assumptions

Scoping level cost estimates (+/- 30% accuracy) for the Transmission Provider Interconnection Facilities and Network Upgrades for Delivery were developed by PSCo Engineering.

Tables 1–3 below list the transmission improvements needed to accommodate the interconnection and delivery of GI-2016-3 generation output as NRIS. The estimated total cost for the Interconnection Facilities is **\$6.579M** (of which \$3.552M Interconnection is Customer Funded and \$3.027M PSCo is Transmission Provider Funded) and for the Network Upgrades for Delivery is **\$178.3M**. The transmission improvements are subject to change upon a more detailed and refined design.

Figure 1 below represents a conceptual one-line diagram of the proposed interconnection at Missile Site Station 345 kV bus.

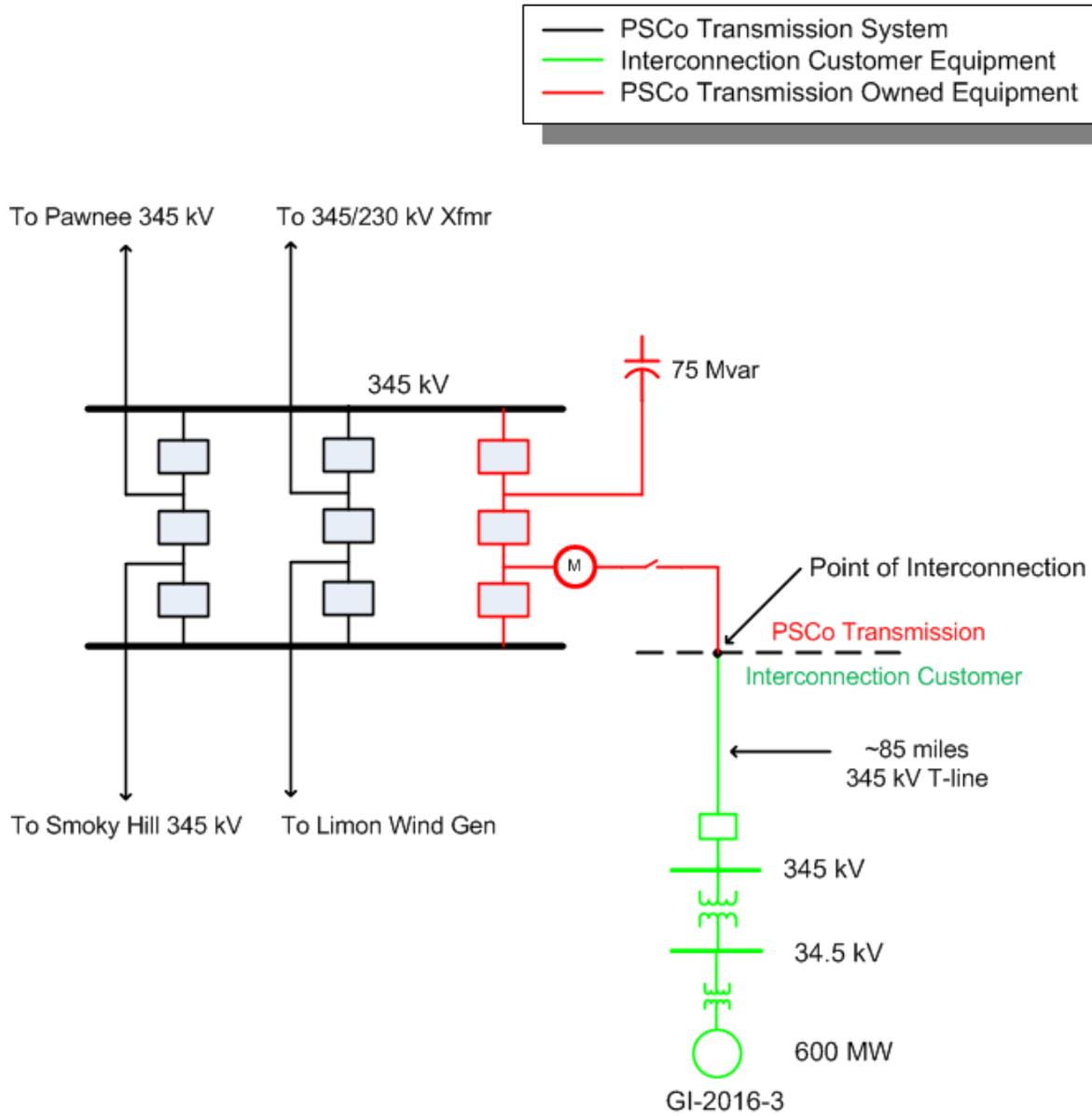


Figure 1 GI-2016-3 Interconnection to 345kV Bus in Missile Site Substation

Table 1: PSCo Owned; Interconnection Customer Funded Interconnection Facilities

Element	Description	Cost Est. (Millions)
PSCo's Missile Site 345 kV Transmission Substation	Interconnect Customer to the 345kV bus at the Missile Site Substation. The new equipment includes: <ul style="list-style-type: none"> • One 345kV, 3000 amp IPO circuit breaker • One 345kV, 75MVAR shunt capacitor bank • Two 345kV, 3000 amp gang switches • Three 345kV CT metering units • Three 345kV PT metering units • Six 345kV lightning arresters • Primary metering for Load Frequency/Automated Generation Control • Power Quality Metering • Associated electrical equipment, bus, wiring and grounding • Associated foundations and structures • Associated transmission line communications, fiber, relaying and testing 	\$3.357
	Transmission line tap from Customer's last line structure outside of PSCo's yard into new bay position (assumed 300' span, conductor, hardware and labor).	\$0.075
Customer's 345 kV Substation	Load Frequency/Automated Generation Control (LF/AGC) RTU and associated equipment.	\$0.120
	Total Cost Estimate for PSCo-Owned, Customer-Funded Interconnection Facilities	\$3.552
Time Frame	Site, design, procure and construct	24 Months

Table 2: PSCo Owned; PSCo Transmission Provider Funded Interconnection Facilities

Element	Description	Cost Estimate (Millions)
PSCo's Missile Site 345 kV Transmission Substation	Interconnect Customer to the bus at the Missile Site Substation. The new equipment includes: <ul style="list-style-type: none"> • Three 345kV, 3000 amp circuit breakers • Six 345kV, 3000 amp gang switches • Associated station controls, communications, supervisory and SCADA equipment • Associated electrical equipment, bus, wiring and grounding • Associated foundations and structures • Associated equipment and system testing 	\$3.027
	Total Cost Estimate for PSCo-Owned, PSCo-Funded Interconnection Facilities	\$3.027
Time Frame	Site, design, procure and construct	24 months

Table 3: PSCo Network Upgrades for Delivery

Element	Sub Cost (Millions)	Cost Est. (Millions)
Siting and Land Rights Permitting / Acquisition		\$ 7.0
Substation Costs		\$ 52.8
Pawnee Substaton	\$ 5.8	
Smoky Hill Substation	\$ 5.4	
Daniels Park Substation	\$ 6.9	
Harvest Mile Substation	\$27.7	
Missile Site Substaton	\$ 7.0	
Transmission Line Costs		\$118.5
Pawnee – Daniels Park		
Time Frame to site, design, procure and construct		54 months
Total Cost Estimate for PSCo Network Upgrades for Delivery		\$178.3

Cost Estimate Assumptions

- Scoping level project cost estimates for Interconnection Facilities and Network Upgrades for Delivery (+/- 30% accuracy) were developed by PSCo Engineering.
- Estimates are based on 2016 dollars (appropriate contingency and escalation included).
- Labor is estimated for straight time only – no overtime included.
- AFUDC has been excluded.
- Lead times for materials were considered for the schedule.
- The estimated time to site, design, procure and construct the Interconnection Facilities is approximately 24 months after authorization to proceed has been obtained.
- A CPCN will not be required and no new substation land will need to be acquired for the construction of Interconnection Facilities.
- The estimated time to site, design, procure and construct the Network Upgrades for Delivery is approximately 54 months after authorization to proceed has been obtained.

Appendix – Power Flow N-1 Contingency Analysis Results

High Coincidence Generation Dispatch at Pawnee & Missile Site:

Pawnee 230kV (100% Coal + 90% Gas + 40% Wind) = 1018 MW;

Missile Site 345kV Wind = 480 MW (80%); Missile Site 230kV Wind = 200 MW (80%)

600 MW output from GI-2016-3 is dispatched to sink at Spindle (268 MW), Ft St Vrain (264 MW) & Ft Lupton (50 MW)

Table A.1 – Differential Impact³ of GI-2016-3 on Facility Loadings Without Network Upgrades

				Branch N-1 Loading Before 600 MW GI		Branch N-1 Loading After 600 MW GI			
Monitored Facility (Line or Transformer)	Type	Owner	Summer Normal (Continuous / 8-hour) Facility Rating in MVA	Flow in MVA	Flow in % of Summer Normal Rating	Flow in MVA	Flow in % of Summer Normal Rating	Differential Impact of GI-2016-3	N-1 Contingency Outage
Smoky Hill 230/345 kV # T4/T5	Xfmr	PSCo	644	637.5	99.0%	897.0	139.3%	+40.3%	Smoky Hill 230/345 kV # T5/T4
Missile Site – Daniels Park 230kV	Line	PSCo	741	598.0	80.5%	789.6	109.5%	+29.0%	Missile Site – Smoky Hill 345 kV
Clark – Jordan 230 kV	Line	PSCo	331	310.5	94.1%	364.2	111.2%	+17.1%	Smoky Hill -- Leetsdale 230 kV

Table A.2 – After GI-2016-3 With Network Upgrades (i.e. Pawnee – Daniels Park 345kV Project)

				Branch N-1 Loading After 600 MW GI			
Monitored Facility (Line or Transformer)	Type	Owner	Summer Normal (Continuous / 8-hour) Facility Rating in MVA	Flow in MVA	Flow in % of Summer Normal Rating	% Flow Reduction	N-1 Contingency Outage
Smoky Hill 230/345 kV # T4/T5	Xfmr	PSCo	644	392.9	61.0%	-78.3%	Smoky Hill 230/345 kV # T5/T4
Missile Site – Daniels Park 230kV	Line	PSCo	741	480.0	64.7%	-44.8%	Missile Site – Smoky Hill 345 kV
Clark – Jordan 230 kV	Line	PSCo	331	269.0	81.4%	-29.8%	Smoky Hill -- Leetsdale 230 kV

³ Due to proposed 600 MW generation increase at Missile Site 345 kV Station