NEXTERA ENERGY RESOURCES, LLC
TRELINA SOLAR ENERGY CENTER, LLC

115– 34.5KV SUBSTATION
DESIGN CRITERIA

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55 East Monroe Street
Chicago, IL 60603-5780 USA
312-269-2000
www.sargentlundy.com

Sargent & Lundy

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Checked by: J. Bridgwood, N. Roth, J. Perry	Date		

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1.0 Scope

1.1 Introduction

This document describes the electrical and civil/structural design basis used for the design of the new 115/34.5 kV substation facilities for Trelina Solar Energy Center, LLC at Trelina Solar Substation. A 80 MW solar facility is connected to this substation. The 34.5 kV bus consists of one (1) 34.5 kV collection feeders. The 115 kV bus consists of a straight bus, 115 kV circuit breaker. The high side and low side are separated by a 115/34.5 kV, 89 MVA GSU Transformer. The substation will connect to a 115 kV transmission line interconnecting with a new New York State Electric & Gas (NYSEG) Substation.

2.0 Permitting

2.1 Introduction

As part of the approval process the conditions and constraints imposed by regulatory bodies that affect the design of the substations shall be processed and documented. This section lists the regulatory bodies (AHJ) which may have approval authority processes that will affect the design of the substation.

2.2 Federal

- Federal Energy Regulatory Commission (FERC)
- North American Electric Reliability Corporation (NERC)
- Northeast Power Coordinating Council
- U.S. Army Corps of Engineers
- Federal Bureau of Public Roads
- Federal Fish and Wildlife Service

2.3 State

- New York Independent System Operator (NYISO)
- New York State Department of Environmental Conservation (NYDEC)
- New York State Department of Public Service (NYDPS)
- New York Department of Transportation (NYDOT)
- New York State Building Code

2.4 County and Local

- County Highway Department
- County Zoning
- Conditional Use Permits
- Erosion Control/Storm Water Permits
- City, Village and Township Highway Permits
- Driveway Permits, Curb Cut or Pavement Requirements
- Fence Permit
- Sign Permit
- Building Permit
- ICC International Building Code (IBC)

2.5 Other

- Private Landowners
- Environmental Impact Statement

3.0 Electrical Design

3.1 Codes and Standards

The electrical designs of the substations shall be in accordance with applicable industry codes/standards, in effect as of the approval date of this design criteria. Applicable federal, state, and local codes and standards shall also be observed. A summary of the industry codes and standards to be used are as follows:

- International Building Code (IBC)
- New York State Building Code
- IEEE C27.13 – Standards for High Accuracy Instrument Transformers
- ANSI/IEEE 81 Part 1 – Guide for Measuring Earth Resistivity, Ground Impedance, and Earth Surface Potentials of a Ground System
- ANSI/IEEE 81 Part 2 – Guide for Measurement of Impedance and Safety Characteristics of Large, Extended or Interconnected Grounding Systems
- IEEE 80 – Guide for Safety in AC Substation Grounding
- IEEE 100 – The Authoritative Dictionary of IEEE Standards Terms
- IEEE 487 – Recommended Practice for the Protection of Wire-Line Communication Facilities Serving Electric Power Stations
- IEEE 519 – IEEE Recommended Practices and Requirements for Harmonic Control in Electrical Power Systems
- IEEE 605 – Guide for Bus Design in Air Insulated Substations
- IEEE 693 – Recommended Practice for Seismic Design at Substations
- IEEE 738 – Standard for Calculating the Current – Temperature Relationship of Bare Overhead Conductor
- IEEE 980 – IEEE Guide for Containment and Control of Oil Spills in Substations
- IEEE 998 – Guide for Direct Lighting Stroke Shielding of Substations
- IEEE 1427 - 2006, IEEE Guide for Recommended Electrical Clearances and Insulation Levels in Air-Insulated Electrical Power Substations
- NESC C2 - National Electrical Safety Code
- ANSI C29.9 – Wet-Process Porcelain Insulators – Apparatus, Post-Type
- ANSI 37.32 – High Voltage Switches, Bus Support and Accessories Schedule of Preferred Ratings, Construction Guidelines and Specifications.
- ANSI 57.12.10 – Requirements for Liquid Immersed Transformers
- ANSI C84.1 – Electric Power System and Equipment – Voltage Ratings (60 Hz)
- National Fire Protection Association (NFPA) 70 - National Electrical Code
- NERC Operating Standards
- NERC/ Planning Standards
- NERC/ Reliability Criteria including:
    - Reliability Criteria for System Design
    - Power Supply Design Criteria
- National Electric Manufacturers Association (NEMA)
- Electronics Institute of America (EIA) RS-232-D

- Electronics Institute of America (EIA) RS-310-D
- Electronics Institute of America (EIA) RS-422-D
- Electronics Institute of America (EIA) RS-485
- Electronics Institute of America (EIA) 568
- Electronics Institute of America (EIA) 569
- International Electrotechnical Commission (IEC) 8802 or IEEE-802
- International Electrotechnical Commission (IEC) 1131

3.2 Emergency Ratings

The ratings of the required equipment are usually based upon normal loadings, load cycles, ambient service conditions and the life of the insulation. This information is based on ANSI/IEEE/NEMA Standards and Manufacturer's data. In general, equipment shall be sized for continuous operation at the maximum continuous value specified by the manufacturer.

3.2.1 Meteorological Conditions

Table - 1 Meteorological and Environmental Conditions	
Ambient Temperature Range	-40˚C to +40˚C
Average Ambient Temperature	60°F
Altitude	500 ft
Keraunic Level	3 to 6 flashes/sq mile/year
Maximum Relative Humidity	80
Minimum Relative Humidity	55
Maximum Wind Speed (ASCE 7-05)	90 mph
Location	42°53'42.92"N, 76°57'24.95"W

3.2.2 Voltage Rating

The substation and switchyard equipment and bus systems shall be designed for the voltage ratings in accordance with Table 2.

Table - 2 Equipment Voltage Ratings		
Nominal Operating Voltage (phase to phase) [kV]	115	34.5
Nominal Phase-to-Phase Voltage [kV]	115	34.5
Nominal Phase-to-Ground Voltage [kV]	66.4	19.9
Maximum Operating Voltage (phase to phase) [kV]	123	38
Maximum of the Nominal Phase-to-Phase Voltage [kV]	123	38
Maximum of the Nominal Phase-to-Ground Voltage [kV]	71	21.9
Basic Insulation Level (BIL) [kV]	550	200

3.2.3 Current Rating

The new substation bus shall be designed for the following minimum current ratings in accordance with Table 3. These values are based on the collection output of 120 MVA at 0.95 Power Factor. Equipment attached to buses but not a part of the bus system, such as surge arrester and CCVT jumpers, shall be designed to service the equipment maximum capabilities.

Table - 3 Equipment Current Ratings	
	Continuous Current (A)
115 kV High Side Equipment	423
115/34.5 kV Transformer & 34.5 kV Bus	1410
34.5 kV Feeders	1410

3.2.4 Clearances and Spacing

3.2.4.1 Yard Clearances

All substation and switchyard equipment shall be designed to maintain the yard clearances and spacing in Table 4.

Table - 4 Yard Minimum Clearances		
Nominal Operating Voltage (phase-to-phase) [kV]	115	34.5
Basic Impulse Level (BIL) [kV]	550	200
Phase-to-Phase, minimum centerline to centerline [1,5]	53 inches	18 inches
Phase-to-ground, minimum metal-to-metal [1,5]	41 inches	15 inches
Bottom of insulator or bushing porcelain to foundation top [2,3,5]	102 inches	102 inches
Vertical clearance of unguarded live parts to foundation top [2,3,5]	139 inches	114 inches
Vertical clearance of conductor over substation internal roadways [4]	20 feet	20 feet
Horizontal clearance of unguarded live parts [2]	73 inches	48 inches

[1] IEEE C37.30.1-2011
[2] IEEE 1427
[3] NESC, Part 1, Section 12
[4] The top of all foundations shall be approximately 6 inches above the substation finished grade.
[5] NESC, Part 2, Table 232-1
[6] Substation Best Practices

Table - 5 115 kV Takeoff Structure Details	
Incoming line phase spacing at dead-end structure	17 feet
Pull off angle at dead-end structure	± 15 degrees
Phase Conductor Attachment Height at "H" Frame (Dead-end Structure)	40 feet
Shield Wire Attachment Height at "H" Frame (Dead-end Structure)	55 feet
Maximum phase conductor tension at "H" frame[1]	2200 lbs
Maximum shield wire tension at "H" frame[1]	1100 lbs
[1] NESC Heavy	

3.2.4.2 Bus Spacing and Clearances

Substation bus spacing and clearances shall conform to the requirements of Table 6. The spacing between two adjacent buses on a ring bus or a breaker-and-a-half bus shall be a minimum of 30 feet on at least one side for maintenance purposes.

Table - 6 Minimum Bus Clearances		
Nominal Operating Voltage (phase-to-phase)	115kV	34.5kV
Phase-to-Phase Spacing, bus centerline[1]	84 inches (7'-0")	36 inches (3'-0")
High Bus Height, bus centerline above top of foundation[2]	240 inches (20'-0")	N/A
Low Bus Height, bus centerline above top of foundation[2]	156 inches (13'-0")	N/A
[1] IEEE C37.30.1-2011 [2] The top of foundations shall be approximately 6 inches above the substation finished grade.		

3.2.4.3 Drive Access and Road Design

The roadways shall be designed for the width and turning radius of the largest vehicle using roadway with required clearance to overhead power lines. Drive area clearances shall be a minimum of 20 feet or NESC, Section 124, "Guarding Live Parts" whichever is greater.

3.2.4.4 Phase Sequence

The phase sequence (i.e. phase rotation) at the Trelina Solar Substation shall be A-B-C (CCW).

3.2.4.5 Oil Filled Equipment Separation

Oil-filled equipment shall be separated from other equipment and buildings to prevent potential fire hazards that may impede restoring or maintaining electric service. The following minimum separations are required:

- A minimum distance of 50 feet shall exist between the edge of the transformer containment pit and the control building, per NFPA 70.

- A minimum distance of 8 feet shall exist between the transformer and any building or wall to ensure there is adequate space for normal operating and maintenance work. Cable trenches shall not be routed adjacent to oil immersed equipment.
- Barriers that are required due to inadequate separation to equipment or buildings shall be constructed of non-combustible, heat-resistant, fire-rated material. The barrier height shall extend a minimum of 1 foot above the top of any oil filled equipment and any of their components. Barriers shall also extend horizontally a minimum of 2 feet beyond the line of sight of the subject building or equipment.
- Small transformers less than 5 MVA containing less than 250 gallons of insulating oil shall be a minimum of 10 feet from buildings having a fire resistance of less than three hours. Small transformers less than 5 MVA containing more than 250 gallons of insulating oil shall be a minimum of 20 feet from such buildings. These clearances also apply to doorways, windows, ventilation ducts, fire escapes and other items constructed of materials with less than a three-hour fire rating.

3.3 Overhead Conductor System Design

The overhead conductor system consists of the rigid bus conductor, the supporting structures, bus insulators and jumper conductors to equipment and lines. The overhead conductor system shall be designed to meet the voltage and continuous current rating requirements, as well as the mechanical requirements for bus design.

3.3.1 Overhead Bus Configuration – Trelina Solar Substation

The overhead bus configuration at Trelina Solar Substation will consist of tube bus with flexible jumpers connecting to equipment.

3.3.2 Overhead Conductor Type and Size

Approved outdoor substation overhead tube systems are as follows:

- 115 kV – 3” Schedule 80 Aluminum 6063-T6
- 34.5 kV – 3” Schedule 80 Aluminum 6063-T6

Approved outdoor substation overhead cable systems are as follows:

- 795 KCMIL 26/7 ACSR
- 1272 KCMIL 61 AAC

Strain bus conductors shall not be supported by equipment bushings, terminators or arresters unless these are specifically designed for the application.

Jumpers shall be used to connect strain bus to equipment bushings, terminators or arresters. Direct connection of a strain bus to a disconnect switch will be evaluated as needed.

The approved type, size and rating of stranded aluminum conductor shall be as shown in Table 7. The current ratings are from the Aluminum Electrical Conductor Handbook, 1989, Reaffirmed 1998 published by the Aluminum Association.

Table - 7 Aluminum Conductor Size and Rating

Conductor Size	Type	Normal Ampacity Rating (Amps)
1 - 1272 KCMIL 61 "Narcissus"	AAC	1149.4
2 - 1272 KCMIL 61 "Narcissus"	AAC	2298.8
3" Schedule 80	6063-T6	2647

Notes:
1 – Current ratings are based on 90˚C substation conductor temperature, 100˚C transmission conductor temperature, 40˚C ambient, 2 ft/1s wind, 93 watts/sq. foot sun, 1293 ft elevation, 0.7 coefficient of emissivity (0.5 rigid) and 0.8 coefficient of absorptivity (0.5 rigid).
2 – IEEE Std 738-2006 Steady-State Thermal Rating Report
3 – IEEE Std 605-2008 IEEE Bus Design Guide

3.3.3 Bus Insulator Selection

All insulators for the bus system and disconnect switches shall be porcelain station post type and shall be ANSI 70 gray in color. The voltage rating of all insulators shall be per Table 2. High strength or extra-high strength insulators may be required. Polymer or porcelain station post insulators may be used for jumper standoff support.

The required strength of the insulators shall be determined in accordance with IEEE Standard 605-1998, the Guide for Design of Substation Rigid-Bus Structures, and shall not exceed the manufacturer's published mechanical strength ratings.

3.3.4 Bus Fitting Selection

Fittings for tubular aluminum conductor shall be of the weldment type. A-Frame fittings shall be bolted to reduce filed welding time. Fittings for stranded conductor shall be of the bolted or compression type. Bolted and Compression tee and dead-end fittings shall have NEMA 4-hole terminal pads for connection of conductor jumpers. Fittings for conductor jumpers shall be of the bolted or compression type to a bolted pad. Jumpers shall be designed so that they can be unbolted and removed from equipment for maintenance, repair, or replacement.

3.4 Substation Equipment

This section summarizes the major equipment to be installed in the substation.

3.4.1 Circuit Breakers

Trelina Solar Substation will have two different types of circuit breakers in use. The HV circuit breakers shall be SF6 gas insulated, dead-tank, "puffer" type design with a spring-spring type operating mechanism and utilize polymer bushings. The MV circuit breakers will utilize a vacuum interrupter and porcelain bushings. Auxiliary contacts for breaker internal control functions shall be provided plus additional form "a" and form "b" field convertible contacts. Circuit breaker shall conform to Purchaser's standards and ratings in Appendices A1 and A2.

3.4.1.1 Current Transformers:

Current transformers shall follow Purchaser's circuit breaker material specification and use ratings detailed in Appendices A1 and A2.

3.4.2 Disconnect Switches

The disconnect switches shall be three-pole, group operated, single-throw complete with station post insulators, switch blades, contacts, operating mechanisms and include all necessary hardware for the assembly and mounting to steel structures. All disconnect switches shall conform to Purchaser's material specification. Ratings for disconnect switches shall be as shown in Appendices A3 and A4. Standard practice is to orient the vertical and side break switches so that the blade shall be dead when the switch is in the open position. All disconnect switches shall be provided with arcing horns which will interrupt charging or magnetizing currents to prevent any arcing at the main switch contacts. Grounding switches are not required.

3.4.3 Transformers

Power transformers shall be designed and built in accordance with IEEE C57.12.00

3.4.3.1 Typical Ratings

See Appendix A8 for Supplied Transformer Rating Nameplates.

3.4.3.2 Transformer Sound

IEEE Standard 1127 will be applied if there is any local sensitivity to noise. At this time no sensitivity or special requirements have been identified.

3.4.3.3 Oil Containment

The Transformer spill containment volume design utilizes 100% of the transformer oil volume plus a freeboard for rain water in a 25-year 24-hour event. The oil containment system shall be a below-grade membrane type designed in accordance with IEEE 980, Guide for Containment.

3.4.4 Surge Arresters

The surge arresters shall be station class, metal-oxide (MOV) type. Arresters shall not be used as strain bus supports. Arresters shall be installed at transformer terminals. Arresters shall be installed as close as possible to the equipment being protected. Surge arresters shall be in accordance with ANSI-C62.11. Ratings for surge arresters shall be as shown in Table 8.

Table - 8 Station Class Surge Arrester Ratings		
Nominal Operating Voltage (phase-to-phase) [kV]	115	34.5
Maximum Voltage (phase-to-phase) [kV]	123	38
Maximum Continuous Operating Voltage (MCOV) [kV]	70	29
Duty Cycle Voltage Rating [kV]	90	30
Construction Material	Polymer	Polymer

3.4.5 Wire-Wound Voltage Transformers (VTs)

Wire-Wound Voltage Transformers (VTs) shall be used for protective relaying and metering applications on the low voltage side of the transformers. The VTs shall be in accordance with Purchaser's material specification. The VTs shall use the ratings shown in Appendix A6.

3.4.6 Capacitor Voltage Transformers (CVTs)

Capacitor Voltage Transformers (CVTs) shall be used for protective relaying and metering applications on the high voltage side of the transformer. The CVTs shall be in accordance with Purchaser's material specification. The CVTs shall use ratings shown in Appendix A6.

3.4.7 Metering

The CVT and 52U1 CT shall be used for kWH revenue metering on the high side of the transformer.

3.5 Auxiliary Station Service

3.5.1 AC Station Service

AC station service shall be 120/240 volts, single phase, 3-wire. Two sources (i.e. normal source and an emergency source) of AC station service shall be provided for the site. The normal source will be fed from a transformer connected to the 34.5 kV bus. The emergency source will be fed from a transformer connected to an offsite distribution feeder. An emergency diesel generator is not required at the substation site.

The station auxiliary transformer along with its associated protection and disconnect equipment shall be designed to carry all the critical loads and located to allow safe and easy access and operation. Preliminary calculations indicate a 50 kVA AC station service transformer will be needed, but this will be confirmed during detailed design. The AC service equipment will be designed for the full 50 kVA (200A) rating.

An automatic transfer switch is required to select between the two sources (Normal and Emergency) of AC auxiliary power. The automatic transfer switch shall have a delayed transition between the two sources since they are not synchronized. Both normal and emergency source availability will be monitored through RTU inputs. Automatic transfer switch position will be monitored through an RTU input.

The AC station service shall be provided with two fused service disconnect switches installed on the source sides of the auto-transfer switch. Main breaker load panels, as required, shall be installed on the load side of the auto transfer switch.

3.5.2 DC Station Service

The DC station service shall consist of one 125 volt DC distribution panel supplied from one 125 volt DC battery and charger system. Design of the DC system will be in accordance with IEEE 484, 485, & 946. The station battery shall have sufficient capacity to permit operation of the station for an 8-hour period of time in the event of a loss of its battery charger or the AC supply source. The station battery and its associated charger should have sufficient capacity to supply the total DC load of the station. The battery chargers and all

DC circuits shall be protected against short circuits. All protective devices shall be coordinated to minimize the number of DC circuits interrupted. The regulation of the DC voltage should be such that, under all possible charging and loading conditions, voltage within acceptable limits will be supplied to all devices.

DC systems shall be monitored to detect abnormal voltage levels (both high and low), DC grounds, and loss of AC to the battery chargers. The protection systems shall be designed to detect an abnormal or loss of power supply. DC systems shall be designed to minimize AC ripple and voltage transients.

3.6 Protective Relaying & Control System

The design of the protective relaying and control systems shall be in accordance with industry standards (IEEE, ANSI standards).

Schweitzer and GE relays will be used to provide primary and secondary protection schemes on the lines, buses and transformers.

3.6.1 Boundary Inter-tie Metering

Revenue metering shall be at the high side of the transformer and shall include the following:

- Instrument Transformers: CVT and CT. Refer to Section 3.4.7 for specific equipment information.

3.6.2 Voltage Input to Protective Systems

The primary and secondary protection elements shall be supplied from separate voltage sources, which may include utilizing separate windings on one transformer, provided the following requirements are met:

- Complete loss of voltage does not prevent all tripping of the protected element.
- Each secondary winding has sufficient capacity to permit fuse protection of the circuit.
- Each secondary winding circuit is adequately fuse protected. Special attention should be given to the physical properties of the fuses used in protection voltage circuits.

3.6.3 Transmission Lines

The line protection systems must be coordinated with the transmission line owner and the remote end sites to secure the system from false operations. The primary and secondary relay systems on any line relay scheme will use separate CTs. In addition, separate windings of the CCVTs will be used. The primary and secondary relay system will trip both line breaker trip coils.

3.6.4 Substation Buses

All bus sections will be covered by one (1) local relay system except those bus sections directly connected to a line. The relay system will trip a primary lockout relay, which trips all bus breaker’s TC1, and the relay system will trip a secondary lockout relay, which trips all bus breaker’s TC2. Bus sections connected directly to a line are covered under the line protection.

3.6.5 Substation Transformers

All power transformers will be covered by at least two (2) local relay systems. One relay will directly trip the breakers while the second relay trips a lockout.

3.6.6 Breaker Failure

All circuit breakers will have a breaker failure scheme.

3.7 Substation Communications and Teleprotection

Communication facilities required for teleprotection shall have a level of performance consistent with that required of the protective system, such as:

- Where each of the two protection groups protecting the same bulk power system element requires a communication channel, the equipment and channel for each group shall be separated physically and designed to minimize the risk of both protection groups being disabled simultaneously by a single event or condition.
- Teleprotection equipment shall be monitored in order to assess equipment and channel readiness.
- Teleprotection systems should be designed to assure adequate signal transmission during bulk power system disturbances, and shall be provided with means to verify proper signal performance.
- Teleprotection systems shall be designed to prevent unwanted operations such as those caused by equipment or personnel.
- Teleprotection equipment shall be powered by the substation batteries or other sources independent from the power system.

Purchaser will arrange for any telephone lines that will be required.

3.8 SCADA

Remote Terminal Unit(s) (RTUs) are required at the substations and will provide remote operation and SCADA data for the relevant Control Center.
The data that shall be provided includes:

- Breaker Status
- MW, MVAR, and Power Factor
- Switchyard availability status
- Battery system alarms
- DC voltage high/low alarms
- Relay protection alarms
- Transformer alarms
- Breaker alarms

A SCADA system shall be installed to allow full monitoring of equipment status and alarms that shall be transmitted to the Operations Center. Additional control points shall be provided to fully control all functions of the control system. Control would be provided for breakers. Specific functionality will be determined during the detail design stage of the project.

Standardized functional communication protocols for use in the SCADA network for data gathering and transfers are DNP3.0.

3.9 Substation Grounding System

3.9.1 Description of Grounding System

The grounding system shall be modeled using the SES CDEGS grounding analysis software package. The grid will be designed to meet the requirements of ANSI/IEEE Standard 80. Soil resistivity measurements are required and shall be obtained during detailed design. The grounding grid will be optimized for the minimum amount of material required to satisfy all step and touch potential concerns.

3.9.2 Grounding System Components

3.9.2.1 Soil Structure

The SES CDEGS program will determine the number of soil layers present based on field test results input via the RESAP module. The soil model results are considered usable if the resultant soil model accurately reflects the measured data. The original RESAP soil model can be adjusted to minimize the RMS error. The field data cannot be modified.

3.9.2.2 Ground Grid

The ground grid conductor shall be 4/0 copper clad steel in accordance with Purchaser's standards. The standard ground grid burial depth is a minimum of 18 inches below the final grade.

3.9.2.3 Grounding Electrodes

The standard ground electrode shall be 10 feet long and made of 5/8 inch diameter copper-clad steel rod. Longer lengths can be made by joining multiple rods together. Ground rods shall be installed near major equipment and at applicable ground grid locations. Applicable locations include substation perimeter, dead-end structures, lightning masts, etc.

3.9.2.4 Connections

All below grade grid conductors and ground rod connections shall be exothermic connections. All above grade connections shall be made with compression or bolted connectors.

3.9.2.5 Above Grade Structures

Equipment and structure grounds, or "stingers," consisting of bare conductors shall connect each piece of the substation equipment and steel structure to the ground grid. There will be two (2) ground connections to each two legged structure like disconnect switch structure and dead end structures and single (1) ground connections to each single legged bus supporting structure. All piece of equipment will be grounded per manufacturer's standards. Disconnect switch structures shall have grounding mats provided in locations where an operator would be standing. These grounding mats shall be adequately grounded.

3.9.2.6 Crushed Rock

Crushed rock shall have an assumed resistivity of 3000 ohm-meters (NYSDOT #1 and #2 rock) when wet. The type of rock to be used shall be tested and verified since local available materials may have different resistivity measurements. The site will be covered with a 4-inch layer of crushed rock that provides adequate resistive value. Compacted layers of rock will be used in the drive areas. The crushed rock shall be installed throughout the entire substation area and extend a minimum of three (3) feet beyond the fence and swing radius of the gates.

3.10 Lightning Shielding Design

The substation direct (lightning) stroke shielding design shall be performed in accordance with IEEE Standard 998-1996 "IEEE Guide for Direct Lightning Stroke Shielding of Substations" using the "electro-geometrical model" or the "rolling sphere technique." The fixed angle method is also acceptable for determining proper shielding protection.

After the substation layout is completed, the direct stroke shielding shall be analyzed to verify that the equipment within the substation fence is adequately protected. The substation location in New York is considered to have lighting activity with approximately three to six flashes / sq mile / year.

The shielding design shall utilize a combination of shielding masts and wires. Wires shall not cross multiple bus sections per Purchaser's requirements.

3.11 Substation Yard Raceway

Conduits shall be provided between the yard mounted equipment and the control house.
All below-grade and above-grade exposed conduit and fittings shall be schedule 40 PVC, rigid galvanized steel or flexible high density polyethylene. Galvanized steel conduits shall not be used in below-grade applications. These requirements also apply to any above-grade flexible conduits used to connect to yard equipment. Conduit fill restrictions do not apply to this project.

All below-grade conduits shall be buried to a minimum depth of twenty-four (24) inches below the finished grade.

3.12 Substation Cabling

The following is a partial list of the requirements for station power, instrumentation and control cabling within the substation. These requirements shall be in accordance with the relevant Purchaser's standards.

- The voltage drop for all control cables shall be verified not to exceed 10%.
- All power cables shall be sized based on the anticipated maximum continuous load currents and maximum short circuit current. Factors that shall be considered to determine the adequate cable size are conductor material, ambient conditions, cable insulation, cable stranding, proximity of parallel current carrying cables and whether the cables are in buried conduit, conduit in air, or in a cable tray.
- All low voltage power, instrumentation and control cables within the substation shall be insulated for a 600 volt rating.
- Coaxial and instrumentation cable shall be fully shielded both inside and outside the control house.
- All control cables outside the control house shall have a longitudinally corrugated copper tape shield.
- Returns for power, currents, potentials, controls, analogs and others shall be within the same cable.
- Cable shields and unused conductors are not required to be terminated or grounded inside the control house. Outside the control house cable shields and unused conductors are terminated and grounded.
- Separate cable systems shall be used to supply redundant communications and control systems in order to prevent a single event from interrupting the flow of critical substation information and operations.

- AC and DC circuits shall not be in the same cable.

3.13 Substation Yard Lighting

The substation outdoor lighting system will be designed to provide adequate illumination for security, emergency egress within the substation, and an indication of the position of disconnect switch blades. The illumination levels shall meet levels identified in the National Electric Safety Code (NESC) and shall be in accordance with the relevant Purchaser's standards.

3.14 Substation Security System

The substation is not currently categorized as part of the Bulk Energy System (BES). There are no security requirements that have been identified.

4.0 Civil/Structural Design

4.1 Codes and Standards

The civil/structural design of the substation shall be in accordance with applicable industry codes, standards, and design guides unless stated otherwise. Applicable federal, state and local codes and standards shall also be observed.

4.2 Civil Design Criteria

4.2.1 Conditions

A subsurface soil investigation shall be required for substation civil/structural design.

4.2.2 Site Grading and Drainage

The substation site grading and drainage will be designed based on geotechnical report.

4.2.3 Site Surfacing

Site surfacing shall be in accordance with the relevant Purchaser's standards and geotechnical report.

4.2.4 Fencing

Fencing shall be 8 feet tall, consisting of a 7-foot chain link design with a 1-foot barbed wire V-extension in accordance with Purchaser's standard.

4.3 Substation Structure Design Criteria

4.3.1 Material

All substation structures (including dead-ends and shield poles) shall be designed and constructed using either standard steel shapes or tapered tubular polygonal shapes. All structures shall be hot-dip galvanized for corrosion protection.

4.3.2 Design

Steel structures shall be designed in accordance with the ASCE Manual of Practice (MOP) 113 "Substation Structure Design Guide", including the specified LRFD or ASD load combinations. Analysis and design shall account for secondary moments from non-linear effects (i.e., P-delta).

4.3.3 Structure Design Loads

The following loading conditions shall be used to analyze and design the structure. Dead load is defined as the weight of the structure, conductors and equipment. Short circuit loading shall be applied in conjunction with each load condition for structures supporting rigid bus.

4.3.3.1 NESC Heavy

A wind pressure of 4-psf (with appropriate shape factors) shall be applied to structures, conductors, and equipment in combination with 0.5” of radial ice. The ambient air temperature shall be taken as 0°F. Note that the load factors specified in NESC shall be applied only to the wire loads.

4.3.3.2 Concurrent Ice and Wind

A wind pressure due to a 50-mph wind velocity (with appropriate shape factors) shall be applied to structures, conductors, and equipment in combination with 3/4” of radial ice. The wind pressure shall be calculated in accordance with ASCE MOP 113. The ambient air temperature shall be taken as 15°F.

4.3.3.3 Extreme Wind

A wind pressure due to a 90-mph wind velocity (with appropriate shape factors) shall be applied to the structures, conductors, and equipment. The wind pressure shall be calculated in accordance with ASCE MOP 113. The ambient air temperature shall be taken as 60°F.

4.3.3.4 Seismic

Due to the low spectral response accelerations for the State of NY, seismic loading will not be a governing design condition. Therefore, it is permissible to neglect seismic loading on substation structures and equipment.

4.3.4 Structure Deflections

Structure deflections shall be checked for the specified loading conditions with all load factors equal to 1.0 (see exception below), except that short circuit loading shall not be included. The calculated deflections shall not exceed:

Line Support Structures and Shield Poles:

- Horizontal deflection of vertical members: 1/100 of height
- Horizontal deflection of horizontal members: 1/200 of span
- Vertical deflection of horizontal members: 1/200 of span

All Other Structures:

- Horizontal deflection of vertical members: 1/200 of height
- Horizontal deflection of horizontal members: 1/300 of span
- Vertical deflection of horizontal members: 1/300 of span

Exception: It is permitted to apply a factor of 0.45 to extreme wind loads for deflection cases only (equivalent to 10yr MRI per ASCE 7).

4.4 Foundation Design

Foundation design shall conform to ACI standards, County and State Codes, and be in accordance with the general minimum criteria in Table 9.

Table - 9 Foundation Design		
Concrete Strength	fc = 4,500 psi at 28 days	
Reinforcing Steel (ASTM A615 Gr 60)	fy = 60,000 psi	
Foundation Loads		
Structures	From structure design calculations	
Equipment	From equipment manufacturer shop drawings or product literature	
Safety Factors (using service loads)		
Shallow Foundations – Bearing Capacity (see note)		3.0
Shallow Foundations – Stability (Overturning, Sliding and Uplift)		1.5
Drilled Piers		2.0

Note: A safety factor of 3.0 shall be used if only ultimate bearing capacity is provided. Lower safety factors may be used if recommended within the geotechnical report.

4.4.1 Drilled Pier Deflection Criteria

Deflection and rotation of drilled pier foundations shall be limited to 0.5 inch deflection and 0.5 degrees of rotation due to unfactored (service) loads for equipment-supporting structures. The deflection and rotation of drilled pier foundations for other structures (deadends and shield poles) shall be limited to 1.0 inch deflection and 1.0 degrees of rotation.

4.4.2 Equipment and Structure Foundations

Ground supported pieces of equipment, such as the gas circuit breakers and transformers, shall be supported by cast-in-place reinforced concrete slabs unless otherwise indicated by the geotechnical report. Foundations for the equipment support structures (bus supports, switches, etc.) and transmission line dead end structures shall be cast-in-place reinforced concrete drilled piers or spread footings, whichever is appropriate based on the subsurface soil information, unless otherwise indicated by the geotechnical report. Anchor bolts for all structures shall be of sufficient length to allow for the use of leveling nuts. The use of grout between the structure base plate and the top of the structure foundation is not required.

4.4.3 Foundation Depth

In general, foundations shall extend below the final grade as required by local or state code and the recommendations in the geotechnical report (i.e. frost depth or other soil factors).

APPENDIX A Switching Diagram
APPENDIX B General Arrangement