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MISSOURI PUBLIC SERVICE COMMISSION

CASE NO. EA-2016-0358

DIRECT TESTIMONY OF

DR. ANTHONY WAYNE GALLI, P.E.

ON BEHALF OF

GRAIN BELT EXPRESS CLEAN LINE LLC

August 30, 2016

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I. INTRODUCTION AND QUALIFICATIONS

Q. Please state your name, present position, and business address.

A. My name is Anthony Wayne Galli. I am Executive Vice President – Transmission and Technical Services of Clean Line Energy Partners LLC ("Clean Line"). Clean Line is the ultimate parent company of Grain Belt Express Clean Line LLC ("Grain Belt Express" or "Company"), the Applicant in this proceeding. My business address is 1001 McKinney Street, Suite 700, Houston, Texas 77002.

Q. What are your duties and responsibilities as Executive Vice President – Transmission and Technical Services of Clean Line?

A. I oversee and am responsible for the planning, engineering, design, construction, and other technical activities of Clean Line and its subsidiaries with respect to their transmission projects. I am also involved in developing strategy for Clean Line.

Q. What is the purpose of your testimony in this docket?

A. The purpose of my testimony is to 1) provide an overview of the Grain Belt Express Clean Line transmission project ("Grain Belt Express Project" or "Project") and the Project's three points of interconnection with the existing alternating current ("AC") grid; 2) explain why Grain Belt Express has decided to utilize high-voltage direct current ("HVDC") technology for the Project; 3) describe the types of transmission structures that are suitable for use on the Project; 4) describe the processes and statuses of interconnecting each terminal of the Project with the relevant regional planning authorities of Southwest Power Pool, Inc. ("SPP"), the Midcontinent Independent System Operator, Inc. ("MISO") and PJM Interconnection, LLC ("PJM"), as well as how the Project will ensure compliance with the North American Electric Reliability Corporation ("NERC") and other reliability standards; 5) provide an overview of how the Project will operate its interconnections with each of SPP, MISO, and PJM; and 6) explain how Grain Belt Express, through the experience of its staff and the many highly qualified vendors that are engaged in the Project, will design and construct the Project ensuring safety and reliability; and 7) discuss the very unlikely possibility of interference to GPS systems that are typical for use in agriculture.

Q. Please describe your education and professional background.

A. I received Bachelor of Science and Master of Science degrees from Louisiana Tech University and a Doctor of Philosophy degree from Purdue University, all in electrical engineering. I am a Senior Member of the Institute of Electrical and Electronics Engineers, a member of the International Council on Large Electric Systems, and a registered Professional Engineer in the Commonwealth of Virginia.

I have over 18 years of experience in the electric transmission industry, in both technical and managerial roles, ranging from power system planning, engineering, market implementation and operations to regulatory matters and project development. Prior to joining Clean Line, I served as Director of Transmission Development for NextEra Energy Resources, a subsidiary of NextEra Energy, Inc. (formerly FPL Group, Inc.), where I developed transmission projects under the Competitive Renewable Energy Zones ("CREZ") initiative in Texas. In this position, I focused on, among other issues, the development of HVDC transmission solutions in the CREZ, and I led my company's efforts in routing, siting and engineering transmission lines in the CREZ. Previously, I spent six years at SPP, where I led the implementation of several components of the SPP market and grew the SPP Operations Engineering Group over fourfold to help ensure reliable operations of the SPP grid as it transitioned to a market paradigm. As the Supervisor of Operations Engineering at SPP, my group was responsible for the real-time and short-term engineering support of SPP's Regional Transmission Organization ("RTO") functions. These duties included activities primarily directed toward maintaining real-time system reliability through engineering support for the SPP Reliability Coordinator and Market Operations, performing short-term tariff studies, operational planning activities (e.g., processing outage requests), and engineering analysis support of the SPP Energy Imbalance Services Market. Additionally, my group led the implementation of several facets of the SPP market system and performed acceptance testing of various software systems.

My background also includes system planning experience with Southern Company Services, a subsidiary of Southern Company, where I analyzed expansion plans for 500 kilovolt ("kV") transmission facilities, and commercial power systems experience with Siemens Westinghouse Technical Services. Additionally, I have held academic positions at the university level and have designed new and innovative shipboard power and propulsion systems for the U.S. Navy.

Q. Have you testified previously before any regulatory commissions?

A. Yes, I have provided testimony in proceedings before the Federal Energy Regulatory Commission ("FERC"), the Public Utility Commission of Texas, the Kansas Corporation Commission, the Oklahoma Corporation Commission, the Illinois Commerce Commission, the Indiana Utility Regulatory Commission, the Tennessee Regulatory Authority, the Arkansas Public Service Commission, and the Missouri Public Service Commission.

II. OVERVIEW OF PROJECT

Q. Please provide a general description of the proposed Grain Belt Express Project and explain the RTOs to which it will interconnect.

A. The Grain Belt Express Project is an approximately 780-mile, ±600 kV, multi-terminal overhead HVDC transmission line (the last approximately 5.2 miles of the transmission line will be AC facilities). The Project will deliver 500 megawatts ("MW") of wind generated electricity from western Kansas to customers in Missouri, and another 3,500 MW to states farther east. The western terminus of the Project will interconnect to the ITC Great Plains ("ITC") 345 kV, AC system in SPP. The two other stations of the Project will be interconnected to, respectively, the Ameren Missouri ("Ameren") 345 kV system in MISO and the American Electric Power ("AEP") 765 kV system in PJM.

Q. Please describe the transmission facilities that Grain Belt Express proposes to build.

A. I have provided a general diagram of the facilities as **Schedule AWG-1.**

Starting from the western end of the Project to the eastern end of the Project, the facilities may be described as follow:

- New wind plant facilities will be constructed by generation owners in and around southwestern Kansas where one of the absolute best wind resources exists. These new wind plant facilities will have their own, dedicated underground collector lines to collect the power from each string of wind turbine-generators that are part of any given wind plant. Each wind plant will also have its own, dedicated substation to transform the wind-generated electricity from 34.5kV to 345kV. These facilities associated with the generation utilizing the Project are not owned or operated by the Grain Belt Express Project, but are rather facilities that will be owned and operated by the generation customers of Grain Belt Express.

- Each wind plant facility will connect to the Grain Belt Express Project through 345kV collector transmission lines that will be built by Grain Belt Express or by the generation customer and will connect to the AC yard of the Kansas HVDC Converter Station.
- In Ford County, Kansas, the Grain Belt Express Project will include an HVDC converter station ("the Kansas HVDC Converter Station"). The Kansas HVDC Converter Station will be rated at approximately 4,390 MW in order to accommodate 500 MW of delivery to the MISO market in Missouri, 3,500 MW of delivery to the PJM market in Indiana, and the electrical losses in the HVDC converter station equipment and the DC transmission lines that are part of the Project as further described. The Kansas HVDC Converter Station, like all HVDC converter stations, will include an AC yard and a DC yard along with other associated equipment (e.g., cooling systems, valve halls, control buildings, and filter banks).
- The Grain Belt Express Project will interconnect to a new substation in Ford County, Kansas (near Dodge City) that will be built by ITC in order to interconnect the Project to SPP. ITC will loop-in its existing Spearville - Clark County and Ironwood - Clark County 345kV transmission lines to better interconnect this new ITC substation to the existing ITC grid in SPP.
- A double-circuit 345kV transmission line will be constructed by Grain Belt Express to connect the AC yard of the Kansas HVDC Converter Station to the new ITC substation.

- A bi-pole (two circuits) HVDC transmission line will traverse from the DC yard of the Kansas HVDC Converter Station to the location of the Missouri HVDC Converter Station in northeastern Missouri.
- An HVDC converter station will be located in Ralls County, Missouri (the "Missouri HVDC Converter Station"), which will have an AC yard and a DC yard. One or both of the HVDC poles (i.e. circuits) will connect to the DC yard of the Missouri HVDC Converter Station and will enable delivery of 500 MW to the MISO market.
- A 345kV transmission line will be constructed by Grain Belt Express to connect the AC yard of the Missouri HVDC Converter Station to a new 345kV substation which will be built as an interconnection facility for the Project pursuant to the MISO interconnection process. This new interconnection substation will loop-in the existing Maywood[1] - Montgomery 345kV transmission line.
- Both poles (i.e. circuits) of the HVDC line will then cross the Mississippi River and enter Illinois where they will continue to the location of the final HVDC converter station., This converter station will be located in Clark County, Illinois (the "Illinois HVDC Converter Station").
- The Illinois HVDC Converter Station will include an AC yard and a DC yard. Two 345kV AC lines will connect the AC yard of the Illinois HVDC Converter Station to AEP's Sullivan 345 kV substation in southwestern Indiana approximately 5.2 miles to the east.

[1] Ameren's Maywood 345 kV substation is a MISO Multi-Value Project that will be in-service in advance of the interconnection of the Grain Belt Express Project.

- The Sullivan substation in Indiana will provide direct access to the 765 kV network in PJM via three 345/765 kV transformers.

The Grain Belt Express Project will be capable of delivering 500 MW of power to the MISO market and 3,500 MW of power to the PJM market through the interconnections with the existing transmission grid in Missouri and Indiana, respectively. The HVDC portion of the Project will consist of the HVDC line and three HVDC converter stations.

Q. What do converter stations do and how do they operate?

A. Each converter station will be capable of converting AC power into DC power or vice versa (that is the converters are bi-directional in nature). When operating, HVDC converter stations can operate in one of two modes: rectifier mode (converting AC power to DC power) and inverter mode (converting DC power back to AC power). The normal mode of operation for the Kansas HVDC Converter Station will be a rectifier mode, i.e., converting AC power from the interconnected wind plants to DC power for transmission to MISO and PJM. The normal mode of operation for the Missouri HVDC Converter Station will be an inverter mode, i.e., converting the HVDC-transmitted wind power back into AC for use by load customers in Missouri and the rest of MISO. The normal mode of operation for the Illinois HVDC Converter Station will also be an inverter mode. All of the HVDC converter stations will also be capable of operating in the alternate mode to accommodate customer needs.

Q. Why has Clean Line decided to use HVDC technology for the Grain Belt Express Project?

A. HVDC is a more efficient technology than AC for the long-haul transmission of large amounts of electric power. In general, over long distances, extra-high voltage ("EHV")

AC transmission lines require intermediate switching or substations approximately every 200 miles in order to segment the line to handle issues attendant with voltage support, transient over-voltages, and transient recovery voltages. HVDC lines do not require intermediate switching or substations, reducing cost and complexity. Additionally, compared to HVDC lines, EHV AC lines used for long-haul applications exhibit angular and voltage stability limitations, have a higher requirement of reactive power dependent upon loading, and have higher charging currents at light load. It is typically found that at distances beyond about 300 miles, HVDC is the most efficient means to move power via overhead lines.

In light of the purpose of the Grain Belt Express Project – to move a large amount of wind-generated electricity over a long distance – HVDC technology is a particularly appropriate solution. In this application, DC lines result in a lower cost of transmission than AC lines. The use of HVDC technology has a number of additional benefits, including the following:

(1) HVDC lines can transfer significantly more power with lower line losses over longer distances than comparable AC lines;

(2) HVDC lines complement AC networks without exacerbating short circuit fault currents that would, in the case of an AC line, require higher-rated circuit breakers at nearby substations;

(3) HVDC lines do not create a need for additional reactive power requirements on the system since their design ensures reactive power neutrality;

(4) HVDC lines can dampen power oscillations in an AC grid through fast modulation of the AC-to-DC converter stations and thus improve system stability;

(5) HVDC technology can be automatically coordinated with the aggregated power output of the wind generators giving operations direct control of energy flows, which makes HVDC particularly well-suited to managing the injection of variable wind generation;

(6) HVDC lines, unlike AC lines, will not become overloaded by parallel outages, because the amount of power delivered is strictly limited by the DC converters at each end of the HVDC line, thereby reducing the likelihood that outages will propagate from one region to another;

(7) HVDC lines provide a new injection of power distant from the location of the generators that are the source of that power in locations that might otherwise be inappropriate or difficult to build new generation sources. This provides for congestion-free delivery from these remote locations, resulting in a more reliable source of power than the alternative of using the interconnected AC system to move power across multiple regions; and

(8) HVDC lines utilize narrower rights-of-way and fewer conductors than comparable AC lines, thereby making more efficient use of transmission corridors and minimizing visual and land use impacts.

Q. Please describe how the power from the wind farms is "collected" and transferred the HVDC line.

A. Just as is the case with all wind farms currently operating in Kansas, each string of wind turbines will have its own dedicated, typically underground, sub-transmission collector system, usually at a voltage of 34.5kV, which provides for the power output of multiple individual wind turbine-generators to be aggregated to a single collection substation ("Wind Farm Substation") which transforms voltage from 34.5kV to 345kV.

Wind generators most likely will connect directly to the AC yard of the Kansas Converter Station via a 345kV, overhead AC transmission collector system (the "EHV Collector System"), which will connect each Wind Farm Substation to the Project's converter station in Kansas. Wind generators may build this EHV Collector System themselves. Alternatively, the Kansas Corporation Commission ("KCC") authorized Grain Belt Express to build the EHV Collector System from the Kansas HVDC Converter Station in Grain Belt Express' certification proceeding in Docket No. 11-GBEE-624-CIC, wherein the KCC granted to Grain Belt Express a Transmission Only Certificate to operate as a public utility in Kansas.[2] The EHV Collector System will be designed and constructed to accommodate the specific wind farm locations and capacities.

Since the EHV Collector System is effectively a set of dedicated lead lines from the Wind Farm Substations to the AC yard of the Kansas HVDC Converter Station, there will not be congestion as power makes its way from the wind farms via the EHV Collector System to the Kansas HVDC Converter Station.

Q. How is an HVDC converter station different than a typical AC substation?

A. In general, electric substations function as junctures, where transmission or distribution lines meet and form a network. Within a typical AC substation, circuit breakers, switches, transformers (for changing voltage levels), protection and control equipment, capacitors, and perhaps line or shunt reactors can be found. Similar equipment is also found in an

[2] *In the Matter of the Application of Grain Belt Express Clean Line LLC for a Limited Certificate of Public Convenience to Transact the Business of a Public Utility in the State of Kansas.*

HVDC converter station. The primary difference is that an HVDC converter station contains two, side-by-side buildings called valve halls and an adjoining control building. The valve halls contain the power electronics that perform the conversion from AC to DC or from DC to AC. The HVDC converter station also includes a DC switchyard and many AC filter banks (capacitors and reactors, designed and connected to remove harmonics from the conversion process as well as provide reactive power for the HVDC system). A typical HVDC converter station layout is provided in my **Schedule AWG-2**

Q. What type of transmission structures will be utilized by the Project and how many?

A. Clean Line has engaged POWER Engineers, Inc. ("POWER") to design structures for the Project. Three primary structure types have been identified: traditional self-supporting lattice structures, tubular steel "monopole" structures, and self-supporting lattice mast structures. The lattice mast structures have similar footprint dimensions as the tubular steel "monopole" structures. Other lattice structure types, such as guyed "vee" and guyed lattice mast structures, have also been identified in the preliminary engineering performed by POWER as being suitable structures. Grain Belt Express considers land compatibility, project costs, environmental impacts, local terrain, and other relevant factors when making determinations as to the predominant structure type in a given region or segment of the line. It is likely that a mix of structures will be utilized to design the most efficacious solution.

Our typical designs for lattice towers and tubular steel monopoles allow for up to 1,500-foot spans for lattice towers and up to 1,200-foot spans for tubular steel monopoles or self-supporting lattice mast structures. Given conditions that allow for such spans, there would typically be four lattice structures per mile or five tubular steel monopoles or self-supporting lattice masts per mile. However, the number of structures per mile may be higher in certain areas where shorter spans are necessary based on terrain and engineering constraints. On occasion, longer spans may be required. These longer spans typically are used for conditions such as river crossings and situations where sensitive areas such as wetlands must be avoided or where topography allows for them. Longer spans typically require taller and more robust structures than are needed for the aforementioned 1,200-foot or 1,500-foot spans.

Q. Have you provided diagrams showing structure types for the Project?

A. Yes, they are attached to my testimony as **Schedule AWG-3.**

III. NEW DEVELOPMENTS

Q. Are there any new developments in the engineering, design, construction, and other technical activities with respect to the Grain Belt Express Project since the first application that Clean Line filed with the Missouri Public Service Commission?

A. Yes. Firstly, there have been some developments with regards to the Project's interconnection studies with MISO. As discussed later in my testimony, in April 2016, the Project's J-255 queue position in MISO's generation interconnection queue initiated a second, more advanced System Planning & Analysis ("SPA") study.

Additionally, Grain Belt Express has completed the studies required (i.e., Facilities Study) to execute, and is negotiating an Interconnection Agreement with ITC, and SPP. This Interconnection Agreement will memorialize SPP's approval of the Grain Belt Express technical studies, set forth the cost and timeline of the required upgrades, and set forth the legal terms and conditions of Grain Belt Express' interconnection with SPP.

Also, Grain Belt Express has entered into an HVDC Transmission Line Development Agreement with Quanta Services, Inc. ("Quanta"), under which Quanta is providing development support and constructability review through its affiliate PAR Electrical Contractors Inc. ("PAR Electric")[3] and other Quanta subsidiaries for the Grain Belt Express Project during the remainder of the development phase. This HVDC Transmission Line Development Agreement contemplates that Quanta will enter into a contract to serve as the engineering, procurement and construction contractor for the Project. PAR Electric is one of the largest outside electrical contractors in North America, and Quanta is a Fortune 400, global provider of engineering, procurement, and construction services for the electric power, oil, and natural gas industries.[4] Company witness Thomas Shiflett provides information on Quanta's capabilities and experience.

Finally, one of Clean Line's other HVDC transmission project developments, the Plains & Eastern Clean Line ("Plains & Eastern Project), has developed and issued a Performance Specification which dictates how that Project must perform in order to meet the operational and reliability requirements established by NERC, the RTOs, and interconnected utilities. The Plains & Eastern Project is nearly identical in nature to the Grain Belt Express Project from a technical design perspective. Detailed studies have begun for the Plains & Eastern Project to define the equipment specifications and ratings to align with the Project description and the applicable performance requirements. This is important to the Grain Belt Express Project because it and the Plains & Eastern Project are materially similar. The similarities between the Grain Belt Express Project and the Plains

[3] Additional information about PAR Electric can be found at http://www.parelectric.com

[4] Additional information about Quanta Services can be found at: http://www.quantaservices.com/.

& Eastern Project will benefit the Grain Belt Express Project since much of the work that is being done for one project will be applicable to the other.

IV. RELIABLE INTERCONNECTION AND OPERATION OF THE GRAIN BELT EXPRESS PROJECT

a. Reliability Benefit to Missouri

Q. Will the Project provide a reliability benefit to the electric system in Missouri?

A. Yes. Construction of the Grain Belt Express Project will provide new transmission paths between Kansas and Missouri and between Indiana and Missouri. These transmission paths will provide for additional energy and capacity resources to reliably serve customer demand (load); increase transfer capability into Missouri from distant power sources that are not impacted by the same weather patterns, interconnected system congestion, and constraints; and increase the reserve margin in the State of Missouri. Grain Belt Express witness Edward Pfeiffer of Quanta Technology, LLC explains in his testimony one of the measured reliability benefits in the form of a reduction to Missouri's loss of load expectation.

b. Compliance with Reliability Standards and Safety Standards

Q. Will the Project be studied and designed to operate in accordance with NERC criteria, Good Utility Practice, and applicable laws?

A. Yes. NERC reliability standards became mandatory and enforceable (through the imposition of monetary penalties) in June 2007, pursuant to Section 215 of the Energy Policy Act of 2005 and subsequent regulations and orders of the FERC. Compliance with these standards ensures the reliability of the bulk power system. These reliability standards apply to Grain Belt Express' operations and maintenance practices and its interconnection studies and agreements. In addition, as a FERC-regulated transmission utility, Grain Belt

Express will be required to comply with Good Utility Practice[5] and all other applicable laws and regulations related to electric reliability.

Q. How will Grain Belt Express be operated and maintained in compliance with NERC standards?

A. In terms of operations and maintenance, Grain Belt Express will subject to the compliance requirements of the NERC Mandatory Standards which, as mentioned above, are enforceable by FERC through the assessment of monetary penalties. The specific standards to which the Project must abide in terms of operation and maintenance include the following: Resource and Demand Balancing (BAL); Critical infrastructure Protection (CIP); Communications (COM); Emergency Preparedness and Operations (EOP); Facilities Design, Connections, and Maintenance (FAC); Interchange Scheduling and Coordination (INT); Interconnection Reliability Operations and Coordination (IRO); Personnel Performance, Training, and Qualifications (PER); Protection and Control (PRC); Transmission Operations (TOP); Voltage and Reactive (VAR). Prior to operation, the Project will have to undergo a readiness audit by the appropriate Regional Entities (described in more detail below) to ensure that the operations and maintenance of the Project are in compliance with the aforementioned standards. Additionally, the readiness audit will assess non-operational standards associated with the Project, namely: Transmission Planning (TPL) and Modeling, Data, and Analysis (MOD).

5 FERC Order No. 888 defines "Good Utility Practice" as follows: "Any of the practices, methods and acts engaged in or approved by a significant portion of the electric utility industry during the relevant time period, or any of the practices, methods and acts which, in the exercise of reasonable judgment in light of the facts known at the time the decision was made, could have been expected to accomplish the desired result at a reasonable cost consistent with good business practices, reliability, safety and expedition. Good Utility Practice is not intended to be limited to the optimum practice, method, or act to the exclusion of all others, but rather to be acceptable practices, methods, or acts generally accepted in the region."

Grain Belt Express will be prepared to comply with the requirements of the aforementioned reliability standards and this will be affirmed through the readiness audits. Furthermore, an Internal Reliability Compliance Program ("ICP") has been developed for the Project to ensure it will meet full compliance with all applicable reliability standards adopted by NERC. This is a "live" document that will be updated as the Project moves towards completion and operational status and as the applicable NERC reliability standards are updated. A copy of the current version of the ICP is attached as **Schedule AWG-4**.

The ICP sets forth Clean Line's and Grain Belt Express's policies and procedures for reliability standards compliance and identifies roles and responsibilities of positions in the compliance organization, as well as a number of administrative requirements such as training and periodic program audits and reviews. A key portion of the ICP will be the development of individual reliability compliance procedures for each NERC reliability standard to which the Project is subject, and the assignment of specific roles and responsibilities for implementation of the requirements of each reliability compliance procedure. Attachment 2 to the ICP will also be a "live" document that will list each requirement of a reliability standard that is applicable to Grain Belt Express, which registered entity reliability function each requirement applies to, the text of each requirement, the person(s) within Clean Line or Grain Belt Express responsible for ensuring compliance with each requirement, and the Grain Belt Express reliability compliance procedure that sets forth the activities to be performed in order to comply with the requirement. As the Project progresses towards completion and operational status, the operating organization is established, and the reliability functions and reliability standards for which Grain Belt Express is responsible are finalized, Grain Belt Express will develop the reliability compliance procedures based on the then-current versions of the applicable reliability standards, and will complete the ICP document, including Attachments 1 and 2 of that document.

Q. How is Grain Belt Express ensuring that the engineering and design of the Project will allow the Project to meet the applicable reliability and safety standards?

A. As detailed above, the Project is subject to all mandatory NERC Standards. Engineering and design of the project will incorporate requirements of these and the regional standards via a Performance Specification document as previously described. These standards are enforced by Regional Entities ("REs") in which the Project will be interconnected. In the case of the Grain Belt Express Project, the Project will be subject to the jurisdiction of the SPP RE, SERC Reliability Corporation, and Reliability First Corporation. Since the Project interconnects with each of these jurisdictions, the Project must become a member of all three and subject itself to the REs respective audit processes. First and foremost of these audits is the readiness audit that must be passed before the RTOs will allow the Project to operate. The readiness audit will occur approximately six months prior to system operations.

All engineering and design activities of the Project will meet applicable safety standards as set forth by the National Electrical Safety Code ("NESC"), any applicable local or regional code requirements and the tenets of Good Utility Practice. Preliminary design criteria, which demonstrate the application of the aforementioned principles, for the Grain Belt Express Project have been developed and are attached as **Schedule AWG-5**. Final engineering drawings will be sealed by a Professional Engineer with current registration in the appropriate discipline and jurisdictions (i.e., Kansas, Missouri, Illinois, and Indiana) to ensure compliance with all safety codes.

Q. How do the Project's interconnection processes and agreements ensure that the Grain Belt Express Project will be operated in accordance with applicable reliability standards?

A. The RTOs with which the Project interconnects have studied and are studying the potential impacts of the Project during various system conditions and under various contingency scenarios in order to ensure that the reliability of the bulk electric system will remain secure and that the Project is compliant with NERC standards (specifically TPL and FAC), regional standards (SPP, SERC, and RFC), and local reliability/design standards (ITC, Ameren, and AEP). **Schedule AWG-6** is a letter from Mr. Tim Aliff who serves as Director of Reliability Planning at MISO. This letter was sent to Mr. Deral Danis (who is under my direct supervision) in response to a very similar question, and indicates MISO will ensure that the interconnection processes provide for a reliable interconnection.

Q. Will Grain Belt Express comply with all relevant aspects of Missouri-specific requirements for Electric Utilities, namely, 4 CSR 240-23.010 (Electric Utility Reliability Monitoring and Reporting Submission Requirements), 4 CSR 240-23.020 (Electric Corporation Infrastructure Standards) and 4 CSR 240-23.030 (Electrical Corporation Vegetation Management Standards and Reporting Requirements)?

A. Yes. Grain Belt Express will comply with all relevant aspects of 4 CSR 240-23.010 (Electric Utility Reliability Monitoring and Reporting Submission Requirements), 4 CSR 240-23.020 (Electric Corporation Infrastructure Standards) and 4 CSR 240-23.030 (Electrical Corporation Vegetation Management Standards and Reporting Requirements).

c. SPP Interconnection Process and Status

Q. Please describe the nature of the Project's interconnection with SPP.

A. As described above, the Kansas HVDC Converter Station will interconnect to a new ITC substation that is networked via the looping-in of ITC's Spearville-Clark County and Ironwood-Clark County 345kV transmission lines. The Grain Belt Express Project is being designed so that during normal operating conditions, there is no need for real power exchange between SPP and Grain Belt Express facilities. This is because the power that is transmitted by the Grain Belt Express Project is anticipated to come from new, direct-connected wind generation facilities via the EHV Collector System previously described.

Q. What is the purpose of the interconnection studies related to the Project's interconnection with SPP?

A. Studies of the Project's interconnection with SPP have focused on contingency scenarios where, as a result of the loss of one or both of the Project's HVDC poles (i.e. circuits), there is a temporary injection of power from the Project into SPP. The purpose of the SPP interconnection studies is to assure that there are no reliability issues with such a temporary injection during system intact conditions in SPP, as well as when there are concurrent AC transmission facility outages in the nearby SPP network.

Q. Did Grain Belt Express work with SPP and affected Transmission Owners to develop the scope of and to conduct the SPP interconnection studies?

A. Yes. The studies for Grain Belt Express' interconnection with SPP were conducted pursuant to SPP's Criterion 3.5 which applies to transmission-to-transmission agreements. Grain Belt Express initially met with SPP and affected parties, including SPP Transmission

Owners and neighboring systems, on June 9, 2011 to develop the scope of the steady state and dynamic stability studies required under SPP Criterion 3.5.

Q. What was the process for performing the Criterion 3.5 interconnection studies?

A. In collaboration with Siemens Power Technologies International ("Siemens PTI"), Grain Belt Express has submitted various technical studies to SPP.[6] Siemens PTI conducted both steady state and dynamic and voltage stability studies, in accordance with SPP Criterion 3.5,[7] simulating the effect of the Project on SPP's and other affected parties' electric systems. Based on the agreed-upon scope, the initial steady state results were shared with SPP and the affected parties on November 1, 2011 to gather their input and to incorporate any needed study scope modifications. Additional analyses were conducted based on feedback and the final steady state results were reviewed and vetted with SPP and affected parties during two webinars on February 1, 2013 and February 7, 2013. The final transient and dynamic stability study results have been completed and were also reviewed and vetted with SPP and the affected parties on February 13, 2013. The models used in these studies along with the study reports were made available to SPP and the affected utilities when the study results were shared with them.

Q. What were the results of the SPP Criterion 3.5 studies?

A. The results of the SPP Criterion 3.5 studies indicate that in all but one scenario (out of nine total power flow cases), there are no overloads or abnormal system voltages during a contingency of the loss of a single DC pole. In one scenario case, a single transmission

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[6] Meeting minutes and the submitted study reports can be viewed at: http://www.grainbeltexpresscleanline.com/site/page/interconnection-studies

[7] Southwest Power Pool, *Southwest Power Pool Criteria; (available at):* https://www.oasis.oati.com/SWPP/SWPPdocs/SPP_Criteria_&_Appendices_July_29,_2014.pdf.

line in the SPP grid would be loaded above its applicable thermal rating due to this inadvertent interchange, however, this overload can be mitigated in a way that system reliability is maintained. Specifically, mitigation of this overload can occur through orderly redispatch of the wind. For all other scenarios included in the studies, the loss of a single DC pole did not cause any adverse impacts.[8]

The loss of both DC poles resulted in the thermal overloads of a single 138 kV line (Harper-Milan Tap-Clearwater 138 kV line) and a single transformer (Spearville 345/230 kV transformer). No system stability issues were observed on the SPP end from the loss of both DC poles. Note that the loss of both DC poles is a rare event that NERC categorizes as a "P7 – Multiple Contingency" event, thus curtailing the Project's wind generation, post-contingency, is an acceptable mitigation response.

Q. Did SPP perform an independent review of the Criterion 3.5 studies?

A. Yes. As part of Grain Belt Express' agreement with SPP, in the summer of 2013, SPP performed an independent review[9] of the studies which confirm the results of the Grain Belt Express interconnection studies.

Q. Has SPP approved the required interconnection studies under Criterion 3.5?

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[8] The intent of the Criterion 3.5 study was to identify potential impacts of the Project to the SPP transmission system. Additional study work will be conducted in cooperation with SPP and the SPP Transmission Working Group based on the specific wind generation locations and characteristics. Appropriate mitigation measures will be developed by and between Grain Belt Express, ITC, SPP, and any other affected party in order to ensure grid reliability is maintained during normal and contingency conditions.

[9] Excel Engineering, Inc., *Grain Belt Express HVDC System Impact Study Final Report for Southwest Power Pool; (available at):* http://www.grainbeltexpresscleanline.com/sites/grain_belt/media/docs/SPP_GBX_HVDC_Study_Final_Report_09-06-2013.pdf.

A. Yes. In September 2013, the SPP Transmission Working Group approved Clean Line's studies as meeting SPP's coordinated planning requirements, which include all applicable NERC, SPP and local utility reliability standards.[10]

Q. What further steps have been and need to be taken with SPP?

A. Having obtained the Criterion 3.5 approval, Grain Belt Express began working with ITC on an interconnection agreement. In September 2014, Grain Belt Express executed a Facilities Study Agreement with ITC, which began the process for ITC to determine the specific equipment needed in order to interconnect the Grain Belt Express Project to the ITC system.[11] This Facilities Study was completed in March 2015, and Grain Belt Express, ITC, and SPP are negotiating an interconnection agreement. Additionally, Grain Belt Express is continuing discussions with SPP staff regarding the need for appropriate operating agreements and seams agreements.

Finally, the SPP Criterion 3.5 studies approved to date for the Project were based on the Project delivering a total of 3500 MW (500 MW in MISO and 3000 MW in PJM). To deliver this 3500 MW, the new Project wind generation included in the study to account for losses was approximately 3760 MW. SPP's approval of these studies included the condition to refresh these studies once the project specific, proprietary HVDC models are finalized by the selected HVDC technology vendor. During this refresh study, the Project wind generation will be increased accordingly to deliver 4000 MW (500 MW in MISO and 3500 MW in PJM). Given that the that the initial studies took an extremely conservative

[10]The motion can be found at: http://www.spp.org/documents/20543/twg%208.14-15.13%20minutes%20&%20attachments.pdf

[11] The scope of the Facilities Study includes identification of equipment such as switchgear, buswork, and metering that will be required in order to physically interconnect the Project to the ITC transmission system.

approach and indicated no major issues on the SPP end with approximately 3760 MW of new Project wind generation, increasing this figure by approximately 525 MW (to account for losses to deliver 500 MW), is likely not to raise any new major issues given. In addition, since the initial Criterion 3.5 studies were conducted, new transmission projects have been approved for construction which will further strengthen the SPP system and make it unlikely that the 525 MW increase will be more problematic.

Q. Does Grain Belt Express have a cost estimate from SPP and ITC for how much it will cost to interconnect the Grain Belt Express Project to the SPP transmission system?

A. Yes. Per the Facilities Study that was completed by ITC in March, 2015, the estimated cost for the interconnection facilities with ITC is $21,448,762.

d. PJM Interconnection Process and Status

Q. Please describe the nature of the Project's interconnection with PJM.

A. The Project's Illinois HVDC Converter Station will interconnect to AEP's Sullivan Substation in Indiana via a double circuit 345kV transmission line. The Sullivan Substation includes equipment and buswork at both 345kV and 765kV with three 345/765 kV transformers interconnecting the 345kV and 765kV networks. The Project will be capable of delivering 3,500 MW of power to the PJM market through its interconnection at the Sullivan substation.

Q. Through what process is PJM studying the Project's interconnection?

A. PJM's Open Access Transmission Tariff and Business Practice Manuals define a process for the technical studies for the interconnection of merchant (i.e., participant-funded) transmission lines like the Grain Belt Express Project. Under this process, Grain Belt Express has filed an interconnection request to deliver 3,500 MW of power at the Sullivan

Substation. The merchant transmission interconnection process is similar to PJM's large generator interconnection process. The two processes are performed together and by queue priority on a "first-in, first-out" basis. Requests that are accepted into the interconnection process are studied in groups that are identified with a letter (e.g., "X" which would come after "W") or a letter and a number (e.g., "X3" which would come after "X2"). Any queue position with an "X3" designation would be part of the "X3 queue." Once an interconnection customer submits a request to interconnect its project, that project receives a queue position number, for example X3-028 (in the case of the Grain Belt Express Project), corresponding to the queue letter and the position among the rest of the queue positions in the "X3" queue. PJM's interconnection study process, which is outlined in PJM's Manual 14 series, involves a three-phase study approach: first, the Feasibility Study; second, the System Impact Study; and third, the Facility Study.[12] As in the case of SPP, PJM incorporates all applicable NERC, regional and local utility standards into its interconnection studies. At the conclusion of these three studies, the applicant (in this case Grain Belt Express) signs an interconnection service agreement with PJM.

Q. At which stage of the interconnection process is Grain Belt Express?

A. Grain Belt Express is currently in the System Impact Study stage. The System Impact Study involves a robust analysis of the thermal, voltage, and stability impacts that the Project could have on the PJM system. The System Impact Study involves steady-state and stability analyses under both peak and light load conditions. The study also provides a cost estimate of any required reinforcements that might be needed to enable the interconnection of the new project and delivery of the project's energy and capacity.

[12] PJM's Manuals are located on the PJM website at: http://www.pjm.com/documents/manuals.aspx.

During the System Impact Study phase, PJM identifies impacts to the reliability of the system and then works with the affected transmission owners to develop mitigations of those impacts which assure a reliable interconnection. PJM can perform additional "re-tools" of the System Impact Study if certain events, defined within the PJM Tariff, trigger such a re-tool.

Q. Where does PJM stand in completing the system impact study for the Grain Belt Express Project?

A. PJM released a System Impact Study report in October 2014.[13] The results of the System Impact Study outlined the scope and cost estimate for the interconnection facilities to interconnect the Project to the Sullivan 345kV/765 kV substation (the "Attachment Facilities") and also outlined the need to mitigate several impacts with network upgrades (the "Network Upgrades"). The Attachment Facilities include three, 345kV circuit breakers and revenue metering at an estimated cost of $3.45 million. The Network Upgrades include:

- A new AEP 765kV transmission line from the Sullivan Substation to Northern Indiana Public Service Company's new Reynolds substation ("Sullivan to Reynolds") at an estimated cost of $500 million.
- A wavetrap at AEP's Dumont 765kV substation at an estimated cost of $1 million.
- The possibility of work associated with re-arranging breakers at the Reynolds 345kV substation; this upgrade does not currently have a cost estimate as it does not involve new equipment.

[13] PJM, *Merchant Transmission Interconnection PJM Impact Study Report For PJM Merchant Transmission Request Queue Position X3-028 Breed 345 kV; (available at):* http://www.pjm.com/pub/planning/project-queues/merch-impact-studies/x3028_imp.pdf.

Q. How does this level of upgrades affect the economic feasibility of the Project?

A. The Attachment Facilities and Network Upgrades identified by PJM (and for which PJM has provided a cost estimate) are included in Grain Belt Express' financial model and are incorporated into its transmission service charge to customers. As discussed in the testimony of Grain Belt Express witness David Berry, the cost of the Project (including required upgrades) and the interconnected wind generation is still lower than other alternatives and provides an inexpensive source of power to utilities and other buyers of electricity.

Q. What is the next level of analyses that PJM will perform as part of its interconnection process?

A. In October 2014, Grain Belt Express executed a Facilities Study Agreement with PJM, which launched the final phase of the PJM interconnection process. However, some changes in the PJM interconnection queue are causing PJM to re-perform certain aspects of the PJM System Impact Study. Specifically, a number of generation interconnection projects, which had entered PJM's interconnection queue before Grain Belt Express, have since withdrawn from the PJM interconnection queue. Therefore, PJM is "re-tooling" the Grain Belt Express System Impact Study to incorporate these changes. PJM will then release a new report of the System Impact Study results before work on the Facilities Study commences. Such a "re-tooling" is a standard procedure in PJM and commonly occurs during the interconnection process.

It is anticipated that PJM will conclude the re-tool System Impact Study and release a new report in late 2016 and begin the Facilities Study shortly thereafter. The Facilities

Study may take up to twelve months to complete. After the Facilities Study, PJM will issue an Interconnection Service Agreement to Grain Belt Express.

e. MISO Interconnection Process and Status

Q. Please describe the nature of the Project's interconnection with MISO.

A. The Missouri HVDC Converter Station will be located in Ralls County, Missouri and will be capable of delivering 500 MW of power at its point-of-interconnection along Ameren's Maywood—Montgomery 345kV transmission line.

Q. Please describe MISO's interconnection process with respect to the Project.

A. Grain Belt Express is participating in the MISO large generation interconnection process, which MISO agreed was the appropriate means to study the Project. MISO operates its queue of requests on a "first-ready, first-served" basis (as opposed to PJM's "first in, first out" approach). That is, the timing of interconnection studies is based primarily on when a project is ready to sign an interconnection agreement, not when the project filed its queue request.

Q. What studies has MISO already completed with respect to the Grain Belt Express Project?

A. Pursuant to an interconnection request filed by Grain Belt Express in September 2012, assigned queue position J-255, MISO has conducted a Feasibility Study of the impacts of the Project delivering 500 MW of power into the 345kV system in northeastern Missouri.[14]

[14] The MISO interconnection process allows for an interconnection customer to choose two points of injection to study. In the Feasibility Study, MISO studied both (1) Grain Belt Express' planned interconnection along the 345 kV line between Maywood and Montgomery and (2) a second point of injection at the Palmyra Tap substation (now known as Maywood). Grain Belt Express plans to use the first point of interconnection.

The Feasibility Study, completed in October 2012, did not identify any constraints associated with the 500 MW injection into MISO.[15]

In May 2014, a SPA study was initiated for the Project to address Grain Belt Express' request that a refresh of the Feasibility Study be conducted in order to determine if the similar impacts to the October 2012 Feasibility Study would result. In November 2014, MISO released the SPA study report, which indicated that there were still no constraints on the MISO transmission system due to the interconnection and injection of 500 MW at the chosen point-of-interconnection.[16] Together, the completed Feasibility Study and SPA study show that, based on the studies completed to date, no network upgrades are needed to accommodate the Project's injection of 500 MW of power to Missouri.

Q. What is the final level of analyses that MISO will perform as part of its interconnection process?

A. The final study stage within MISO's interconnection process is the Definitive Planning Phase ("DPP"). The scope for the DPP involves MISO performing a System Impact Study and Facilities Studies to determine the facilities necessary to interconnect the new project, and allow for delivery of the project's energy and capacity. The MISO DPP is estimated to take up to 180 days to complete. As discussed previously in my testimony, Grain Belt Express is also undergoing interconnection studies with PJM/AEP. Grain Belt Express plans to enter the MISO DPP when 1) the PJM interconnection studies have progressed

[15] MISO, *Queue Position J255 Feasibility study report; (available at):* https://www.misoenergy.org/_layouts/MISO/ECM/Redirect.aspx?ID=139420

[16] MISO, *SPA-2014-May-Missouri System Impact Study Final Report; (available at):* https://www.misoenergy.org/_layouts/MISO/ECM/Redirect.aspx?ID=187297.

beyond the retool studies currently underway, and 2) Grain Belt Express is able to meet the readiness milestones, as described below, for the MISO interconnection process. Coordination of the MISO study progress with that of PJM will allow for the results of the PJM studies to be incorporated into the scope of the MISO DPP studies which is prudent given the large, 3,500 MW injection of power into PJM near the Ameren Illinois seam with AEP.

Q. What are the readiness milestones that Grain Belt Express must meet in order to enter the DPP?

A. MISO's DPP process is designed to deter customers from advancing into the DPP until they are able to make large financial commitments and to execute Interconnection Agreements (see **Schedule AWG-6**, answer three). To do this, MISO has established an extraordinary, at-risk deposit payment (referred to as the "M2" milestone payment) that is required 30 days prior to entering a DPP study cycle. For Grain Belt Express, this M2 deposit payment is reflected in the Feasibility Study results for J-255 as $1,603,848. Additionally, within 30 days of the conclusion of the DPP and execution of an Interconnection Agreement, 10% of the cost of any identified Network Upgrades and Interconnection Facilities would also be due; for Grain Belt Express it is estimated that this payment would be approximately $1 million, depending on the results of the Facilities Studies. Grain Belt Express would also be required to fund the DPP study deposit (known as the "D3" deposit) which is estimated to be $360,000. In effect, Grain Belt Express would need to fund almost $2 million before entering the DPP process and fund another $1 million or more within 200 days of entering the DPP.

MISO has designed the DPP process to prevent interconnection customers from entering the DPP and signing interconnection agreements until it is certain the customer's project will be built. Withdrawal of projects that enter the DPP process creates significant problems for MISO because future interconnection projects are modeled assuming projects in the DPP are built. Changing the assumptions causes study delays, additional study costs, and general uncertainty. Considering all of this, including the need to coordinate with PJM study results, the financial cost of entering the DPP process and MISO's goals in administering the DPP process, Grain Belt Express does not believe it would be prudent to enter the DPP process until it receives an approval from the Missouri Public Service Commission. Grain Belt Express expects that it would enter the DPP process promptly upon receiving such an approval.

Q. What does Grain Belt Express expect the cost to be from MISO and Ameren in order to interconnect and deliver 500 MW to MISO from the Grain Belt Express Project?

A. The Feasibility Study and the SPA Study have not identified any injection constraints for the full 500 MW of interconnection from the Grain Belt Express Project that would require mitigation in the form of network upgrades. We know, however, that tapping a 345kV transmission line will require a new switching station at the location of the tap. Previous System Impact Study reports[17] from Ameren's Illinois utility indicate that the cost of a 345kV breaker-and-a-half station is less than $10 million. Grain Belt Express does not expect any network upgrades (aside from the interconnection facilities just described) in order to obtain delivery service of the 500 MW from the Missouri HVDC Converter Station.

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[17] *MISO SPA Illinois 2010 System Impact Study Report, Ameren Services Transmission Planning, February 2012, (available at):* *https://www.misoenergy.org/_layouts/MISO/ECM/Redirect.aspx?ID=125497*

V. <u>COORDINATION, DISPATCH, AND OPERATION OF THE PROJECT</u>

Q. What is the typical operational scenario for the Grain Belt Express Project?

A. It is anticipated that the Project will normally operate as a direct link for wind from western SPP to be delivered to MISO and PJM. As previously described, the Project would typically be dispatched so that the Kansas Converter Station is operating as a rectifier (drawing power from SPP) and the Missouri and Illinois converter stations are operating as inverters (delivering power to MISO and PJM, respectively)

Q. Is it possible for other dispatches or interchanges to occur?

A. Yes.

Q. Can customers of the Project schedule power <u>from SPP</u> to the Grain Belt Express Project facilities for transmission <u>to MISO and/or PJM</u>?

A. Yes. First, it is important to remember that the Grain Belt Express Project will be an open access, interstate transmission line. This designation obligates Grain Belt Express to offer transmission service to any qualified entity that requests such service. From a technical perspective, the 345 kV AC transmission tie-lines between SPP and the Grain Belt Express Project will be able to transmit scheduled power just like any other interchange transaction between two Balancing Authorities.

Q. Can customers of the Project schedule power <u>from the Grain Belt Express Project</u> facilities for transmission <u>to SPP</u>?

A. Yes. The customer would have to acquire transmission service from PJM (as the TSP for the Grain Belt Express Project) that would source from either MISO or PJM and sink into SPP. The SPP Integrated Market has a product referred to as Market Import Service ("MIS") which is available for transactions sinking power into SPP from outside SPP. This product is described in Section 4.2.2.7 of the Market Protocols for the SPP Integrated Marketplace.[18]

Q. Can a customer <u>within MISO</u> obtain access to the Grain Belt Express Project Facilities to deliver power <u>to SPP or PJM</u>?

A. Yes. Although the current MISO interconnection process is not designed to study energy withdrawals from the MISO market, anyone can request, and have studied, transmission service across the MISO system in order to access the Grain Belt Express Project facilities.

Q. How will generator customers of the Grain Belt Express Project offer into the MISO market and how will MISO's economic dispatch consider those offers?

A. There are two methods for the generator customers of the Grain Belt Express Project to interact with the MISO day-ahead and real-time markets.

1. Some generators will choose to become MISO Market Participants ("MPs") and register as Dispatchable Intermittent Resources ("DIR"). This allows MISO to dispatch these wind plants just as MISO has the ability to do with any wind plants within the traditional territory of the MISO market footprint. MISO would send dispatch signals to these MPs and the MPs would be required to respond according to the active rules applicable to DIRs. MISO would settle the energy transactions through the existing processes using the day-ahead and real-time market locational marginal prices ("LMPs"). Congestion within the MISO market would be handled via the existing MISO security constrained economic dispatch ("SCED") congestion management processes and these DIRs will be responsive to MISO's dispatch signals as a result of that process.

[18] https://www.spp.org/documents/39052/integrated%20marketplace%20protocols%2038.pdf

2. The second way the generator customers of the Grain Belt Express Project will interact with the MISO markets is through interchange transaction schedules. If any given customer desires the flexibility to offer into multiple markets or to buy energy from the SPP market to sell to the MISO market, that customer would be required to utilize the existing electronic tagging rules of the North American Energy Standards Board. MISO would incorporate these interchange transaction schedules into their day-ahead and real-time markets like any other interchange transaction from their existing seam neighbors. These transactions would be either price-takers in the market or would be bi-lateral transactions in the market subject to only congestion and loss costs. MISO would manage congestion that is contributed by these interchange transactions through the existing Interchange Distribution Calculator tool which allows MISO to seek and obtain curtailment relief due to transactions that are contributing to congestion.

The Grain Belt Express HVDC facilities are completely controllable and can accommodate both of the arrangements described above. Dispatch signals that are sent from MISO to the DIR customers will be mirrored to the HVDC controls to ensure that the HVDC power order set-point is matched-up with the aggregate output of these wind plant facilities. Schedules that are electronically tagged to sink into MISO (or PJM) can be incorporated into the HVDC controls as well to either a) match-up with the output of the energy source behind the tag (in the case of dynamic schedules) or b) as a variable set-point to align with submitted schedules.

Q. How will generator customers of the Grain Belt Express Project offer into the PJM market and how will PJM's economic dispatch consider those offers?

A. Just as in the case of the MISO market, customers of the Grain Belt Express Project will become Market Participants of the PJM markets and submit energy and capacity offers into PJM's day-ahead, real-time, and capacity markets. Those customers that prefer to not register with PJM but still desire to sell energy into PJM utilizing the Grain Belt Express Project facilities would need to do so through PJM's SPOT-IN energy transactions, which can be submitted as non-dispatchable, price-taker schedules or as schedules that are dispatchable upon meeting a pre-established congestion charge threshold referred to as "willing to pay congestion" or WPC transactions. As previously described for the MISO market interaction options, the HVDC power set-point is matched up with the aggregate output of the PJM-committed wind plant facilities and associated energy transactions.

Q. How is the power from customers of the Grain Belt Express Project that is intended for delivery to MISO or PJM properly accounted for along the Grain Belt Express Project facilities?

A. Each wind park facility's generator step-up transformer substation will have revenue quality meters to measure voltage and current, and to determine the number of MWh produced. Thus, we can track the contribution from each wind park and any transactions from SPP that enter the HVDC facilities (which will also have electric metering) and leave the HVDC facilities at the MISO point-of-interconnection or the PJM point-of-interconnection (both of which will also have electric metering). Each contribution to flow on the EHV Collector system and through the HVDC facilities will be used to allocate electrical losses and be the basis for inadvertent interchange accounting to ensure that customers that do not have rights to utilize any given portion of the Grain Belt Express Project facilities are easily identified. This concept also describes how energy imbalance is properly accounted for should any given customer of the Grain Belt Express Project become unable to properly follow dispatch instructions from MISO or PJM.

Q. How is the power from customers of the Grain Belt Express Project that is intended for delivery to MISO or PJM disallowed from inadvertently being injected into the SPP transmission system?

A. A power flow controller is integrated into the Project design concept to ensure that only energy transactions that are scheduled between SPP and the Grain Belt Express Project are allowed to flow. Otherwise the power flow controller will provide a feedback signal to the HVDC power order set-point to ensure that interchange between the Grain Belt Express Project and SPP is nominally zero MW.

VI. <u>CONSTRUCTION ACTIVITIES</u>

Q. What is the expected construction timeline of the Grain Belt Express Project?

A. Construction activities can begin as early as 2018 and will take around three years to complete. At the present time, lead times for delivery of HVDC converter stations are on the order of 36 months. The transmission line construction would need to be completed approximately four months prior to operation so that the converter stations can be fully tested. Construction would begin in several different areas of the Project simultaneously. The Project is expected to achieve commercial operation as early as 2021.

Q. Has Grain Belt Express secured the services of a third party firm to assist with the design and construction of the Project?

A. Yes. POWER is providing transmission line engineering support for the Grain Belt Express Project. POWER provides engineering/design, construction, asset management, and other services to the power generation and power delivery industries and other industries.[19] POWER has performed the necessary engineering to specify preliminary design criteria and structure design requirements for the Project, as previously described and as shown in **Schedule AWG-5.** POWER has also provided engineering support in the route development process. Further, POWER will serve as the Owner's Engineer ("OE") for the Project.

Grain Belt Express is also working with TransGrid Solutions Inc. ("TGS") as an OE for the HVDC converter stations. TGS has developed HVDC models of the Project that are actively being used in the MISO and PJM interconnection study processes. It is also providing additional expertise based on its global experience in commissioning HVDC projects.[20] TGS has provided consulting services for Clean Line's Plains & Eastern project, including model development, HVDC engineering support, and the development of the previously described Performance Specification. Given the fact that the Grain Belt Express and Plains & Eastern Projects are materially similar, this work will be leveraged to assist in design work (modified for the specific system to which the Grain Belt Express Project will connect) and HVDC manufacturer decisions.

Grain Belt Express has also engaged Siemens PTI to conduct the SPP Criterion 3.5 studies that I previously described. Siemens PTI consults for the global electric power industry on system impact studies, renewables integration, power quality studies, and grid

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[19] Additional information about POWER Engineers, Inc.'s qualifications, capabilities and scope of services is available at: http://powereng.com.

[20] Additional information about TGS can be found at: http://www.transgridsolutions.com/default.htm.

code compliance.[21] Siemens PTI has conducted similar studies for the Plains & Eastern project.

Additionally, as mentioned earlier in my testimony, Grain Belt Express has entered into an HVDC Transmission Line Development Agreement with Quanta Services, under which they are providing development support, constructability review, and engineering services for the Grain Belt Express Project during the remainder of the development phase of the Project. The HVDC Transmission Line Development Agreement contemplates that Quanta Services, with PAR Electric as the leading contractor, will enter into a contract to serve as the engineering, procurement and construction contractor for the Project.

Q. Does the Company have agreements with any Missouri suppliers?

A. Yes. Grain Belt Express has designated Hubbell Power Systems ("Hubbell") as the preferred supplier of conductor hardware and insulators for the Project. Hubbell is a global manufacturer of a wide variety of transmission, distribution, substation, and telecommunications products that are well known and trusted throughout the industry and are used by many of the largest utilities in the U.S. Hubbell will also make its engineering resources available to aid in the design of conductor hardware and insulator assemblies and will work to establish a supplier base within the Project area states, including Missouri, Kansas, Illinois and Indiana, to source raw material from businesses in states that host the Project. Hubbell was chosen as the supplier for insulation hardware for the Plains & Eastern project and much of this hardware is produced in Hubbell's Centralia, Missouri facility as well as other domestic and international facilities. Hubbell is currently

[21] Additional information about Siemens PTI can be found at: http://w3.usa.siemens.com/smartgrid/us/en/transmission-grid/consulting-and-design/Pages/consulting-and-design.aspx.

performing tests with other of Plains & Eastern's suppliers to ensure that the design of the insulation hardware will meet the required strength requirements to accommodate that Project's design. Because the Plains & Eastern Project and the Grain Belt Express Project are materially similar, the testing and design work that is taking place for the Plains & Eastern Project will be useful for the Grain Belt Express Project as well and puts Hubbell in a good position to provide this equipment for the Grain Belt Express Project.

Grain Belt Express has designated General Cable Industries, Inc. ("General Cable") as a preferred supplier of conductor for the Project. General Cable is a $6.4 billion, Fortune 500 company and is the third largest wire and cable manufacturer in the world. General Cable will manufacture and manage inventory and logistics for roughly 23 million feet of steel core for the transmission line conductor. General Cable planned to source all of the aluminum rod used in the conductor it provides for the Project from the Noranda Aluminum smelter near New Madrid, Missouri. Unfortunately, Noranda has announced its intent to shutter this facility and therefore General Cable will be seeking alternative supply options for the aluminum in the Project footprint.

Finally, Grain Belt Express has designated ABB, Inc ("ABB") as the preferred supplier of AC power transformers associated with the Project's EHV Collector System. ABB is a global leader in the design and manufacture of high voltage transformers with over 14,500 transformer units delivered globally with a capacity of over 17 million mega volt-amperes. ABB will also make its engineering resources available to aid in the design of the transformers, which will be manufactured at ABB's St. Louis, Missouri manufacturing facility.

Q. What is the estimated cost to construct the Project and the Missouri portion, specifically?

A. The total cost to construct the Project is expected to be approximately $2.35 billion, which includes the cost for the HVDC Line and the three converter stations. From this $2.35 billion, approximately $525 million is expected to be specifically associated with the Missouri portion of the Project, where roughly $425 million will be for the transmission line and $100 million will be for the converter station in Missouri.

VII. IMPACTS TO GPS

Q. What is a Global Positioning System?

A. A Global Positioning System ("GPS"), is a space-based navigation system that depends on a series of geosynchronous satellites to provide time and location signals to receivers on earth. Modern farming equipment relies increasingly on GPS in order to efficiently manage many aspects of crop planting and harvesting.

Q. Is it possible that a transmission line, such as the Grain Belt Express Project, would impact GPS systems, such as those used by farming equipment?

A. It is very unlikely. The Grain Belt Express Project should not create any disturbances to radio frequencies that affect GPS operations. Nor should the physical presence of a transmission line create any physical obstruction that interferes with GPS.

Q. What is corona and how does it affect radio frequencies?

A. In the context of transmission lines, corona refers to a partial discharge of energy that ionizes air molecules resulting mostly in heat, as well as audible and electromagnetic noise. Corona occurs along the surface of conductors on high-voltage transmission lines where irregularities (e.g., nicks on the conductor or debris such as dead mosquitoes) occur. If the electric field becomes sufficiently concentrated at these irregularities, the insulating properties of air break down, producing corona.

Q. Does corona create radio noise?

A. Yes, but only within a limited band of frequencies in the electromagnetic spectrum. The radio frequency portion of electromagnetic spectrum is typically defined from 3 kilohertz ("kHz") to 300 gigahertz ("GHz"). Corona primarily produces radio noise in the range of 0.1 megahertz ("MHz") to 10 MHz, with the power of radio noise decreasing rapidly with frequency; that is, the radiated power at 10 MHz is significantly lower than at 0.1 MHz. The highest levels of radio noise are measured underneath the transmission line and diminish with distance away from the conductors.

Q. How does the frequency of corona radio noise compare to the frequency used by GPS devices?

A. Real Time Kinematic ("RTK") systems, which are ground-based controls used to make differential calculations and improve positional accuracy of GPS, receive GPS satellite signals at 1227.60 MHz and 1575.42 MHz frequencies. RTK systems transmit and receive terrestrial signals typically at Ultra High Frequencies ("UHF") which are greater than 300 MHz. Since both GPS and terrestrial signals on which RTK systems rely are at far higher frequency than the upper range of frequencies of significant corona noise, the terrestrial and the satellite signals are very unlikely to be affected by the corona noise.

Q. Will the Grain Belt Express Project interfere with GPS signals?

A. It is extremely unlikely. As I have pointed out, frequencies that are used to communicate between orbiting satellites and GPS units, including those associated with farm equipment, are much higher than the frequencies of radio noise from transmission lines. Therefore, GPS units will operate with their traditional degree of accuracy near and under high voltage transmission lines. A report published by consultants to Manitoba Hydro (the provincial agency that operates two large HVDC projects similar to the Grain Belt Express Project) concluded:

> The differences between the ground truth positions established using conventional survey and the GPS observations indicate that transmission lines that supply Direct Current have no appreciable effect on either GPS measurements or ultra-high frequency radios/cell phones that supply GPS correction messages. The results obtained were well within the manufacturer's quoted equipment accuracies (i.e., centimeter level).[22]

A similar conclusion regarding these DC transmission lines was reached by engineers in the Position, Location and Navigation Group at the University of Calgary:

> GNSS [Global Navigation Satellite Systems] data collected under two 500 kV HVDC bipole lines were analyzed .... No transmission line effect on GNSS measurements was found to affect the quality of the navigation solutions. In addition, the test results showed normal operation of a commercially available survey grade RTK system and its radio link (450 MHz) for static and perpendicular test segments perpendicular to the transmission lines.[23]

Q. What about physical interference of GPS signals?

A. GPS signals can be physically blocked by objects such as dense forest canopy or they can be degraded by reflections off large solid objects like commercial building or agricultural structures like barns or silos. It is theoretically possible that the signal from a *single* GPS satellite could be blocked or degraded by a transmission structure.

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[22] Pollock & Wright, "Effects of Transmission Lines on Global Positioning Systems" (2011) at p. 10. See PLAN Group, "Manitoba Hydro DC-Line GNSS Survey Report" (Nov. 2011); http://www.hydro.mb.ca/projects/bipoleIII/eis/BPIII_GPS_Reports_November%202011.pdf

[23] J.B. Bancroft, A. Morrison, G. Lachapelle, "Validation of GNSS under 500,000 V Direct Current (DC) Transmission Lines," Computers and Electronics in Agriculture, 83:58, 66 (2012).

Q. Could this result in a loss of functionality for a GPS system operating near a transmission line?

A. It is extremely unlikely that this could result in a loss of functionality for a GPS receiver in an agriculture setting. The United States Government ensures that at any given time there are at least 24 functioning GPS satellites in geosynchronous orbit in all parts of the sky and many GPS receivers today make use of other sources of satellite signals as well. A GPS receiver requires signal from only three satellites to calculate the horizontal position on earth. All GPS receivers regularly add and drop satellites, and receive signal from 12 or more satellites simultaneously. While a transmission structure might theoretically block the signal from a single satellite, because the structure stands in a single location, it cannot simultaneously block signals from multiple satellites in different locations in the sky. Hence, it is very unlikely that a brief or even prolonged blockage of a single satellite would adversely affect GPS operation.

Q. Does this conclude your testimony?

A. Yes, it does.

BEFORE THE PUBLIC SERVICE COMMISSION
OF THE STATE OF MISSOURI

In the Matter of the Application of Grain Belt Express Clean Line LLC for a Certificate of Convenience and Necessity Authorizing it to Construct, Own, Control, Manage, Operate and Maintain a High Voltage, Direct Current Transmission Line and an Associated Converter Station Providing an Interconnection on the Maywood-Montgomery 345 kV Transmission Line	)))))))	Case No. EA-2016-0358

AFFIDAVIT OF ANTHONY WAYNE GALLI

STATE OF Texas)
) ss
COUNTY OF Harris)

Anthony Wayne Galli, being first duly sworn on his oath, states:

1. My name is Anthony Wayne Galli. I am Executive Vice President – Transmission and Technical Services for Clean Line Energy Partners LLC.

2. Attached hereto and made a part hereof for all purposes is my Direct Testimony on behalf of Grain Belt Express Clean Line LLC consisting of 44 pages, having been prepared in written form for introduction into evidence in the above-captioned docket.

3. I have knowledge of the matters set forth therein. I hereby swear and affirm that my answers contained in the attached testimony to the questions therein propounded, including any attachments thereto, are true and accurate to the best of my knowledge, information and belief.

Anthony Wayne Galli

Subscribed and sworn before me this 29th day of August, 2016.

NANCY BEMIS
Notary Public, State of Texas
Comm. Expires 02-05-2019
Notary ID 11483156

My commission expires: ____________

Notary Public

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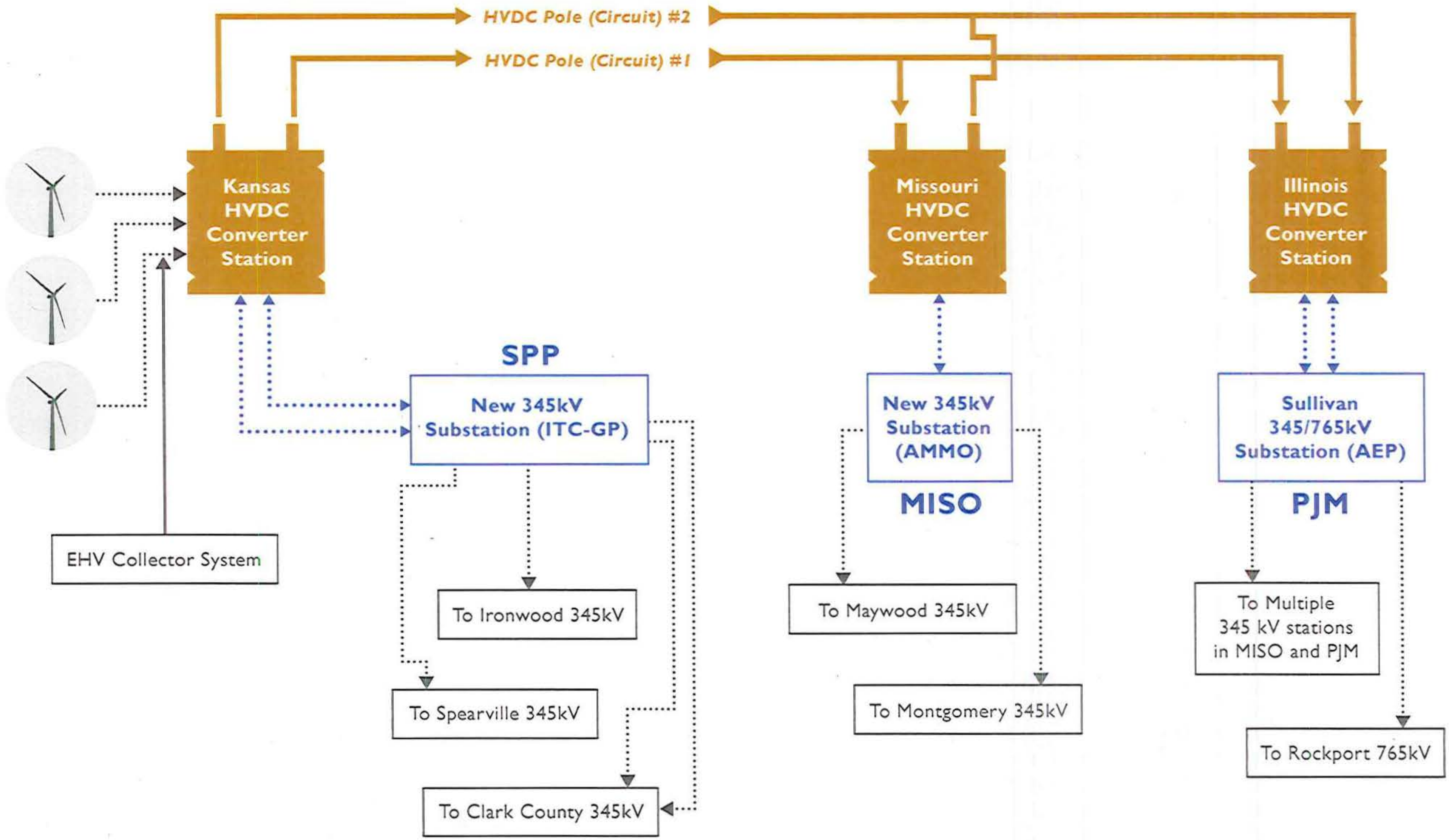
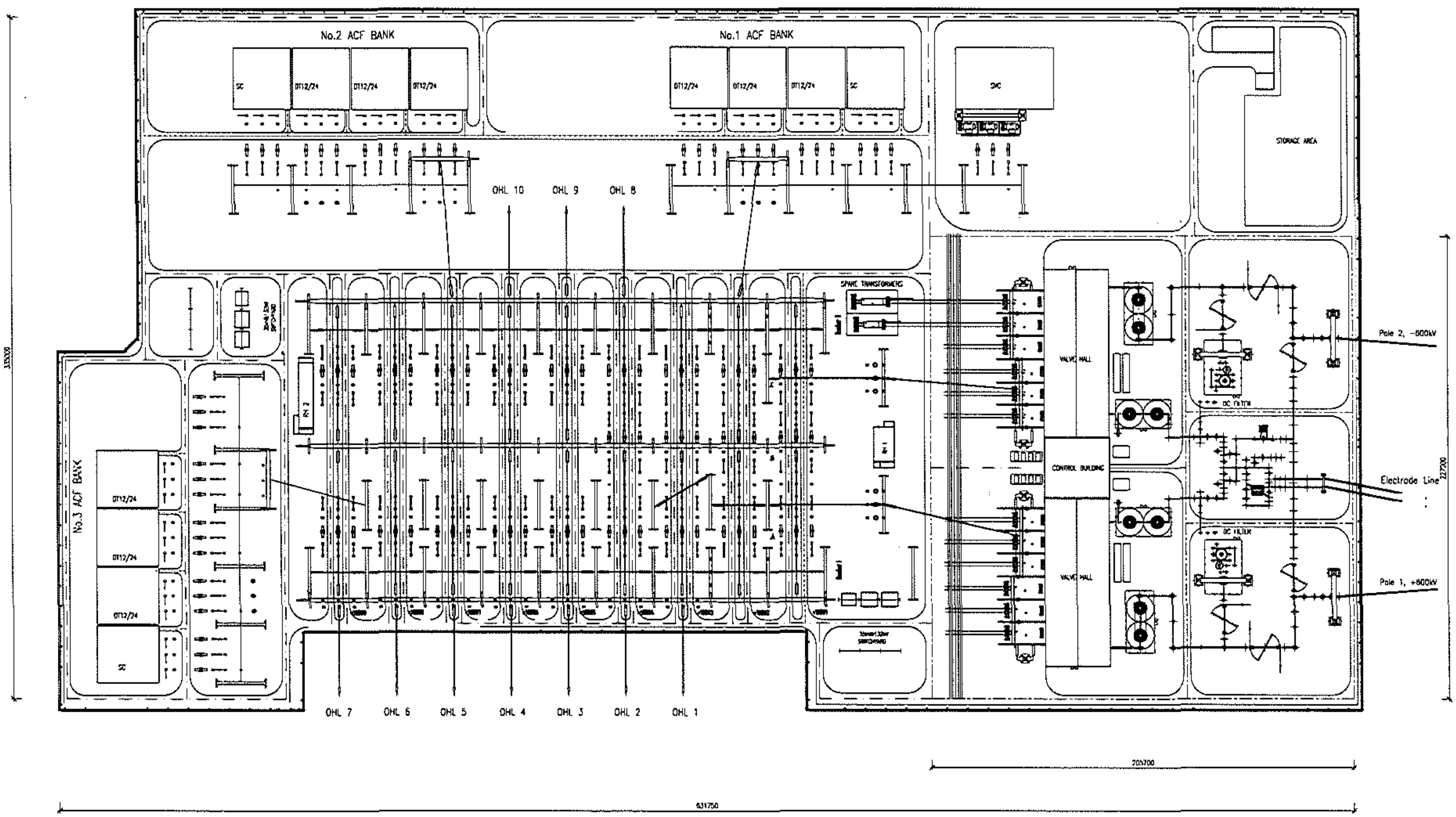

HVDC Pole (Circuit) #2
HVDC Pole (Circuit) #1
Kansas HVDC Converter Station
Missouri HVDC Converter Station
Illinois HVDC Converter Station
SPP
New 345kV Substation (ITC-GP)
New 345kV Substation (AMMO)
MISO
Sullivan 345/765kV Substation (AEP)
PJM
EHV Collector System
To Ironwood 345kV
To Spearville 345kV
To Clark County 345kV
To Maywood 345kV
To Montgomery 345kV
To Multiple 345 kV stations in MISO and PJM
To Rockport 765kV



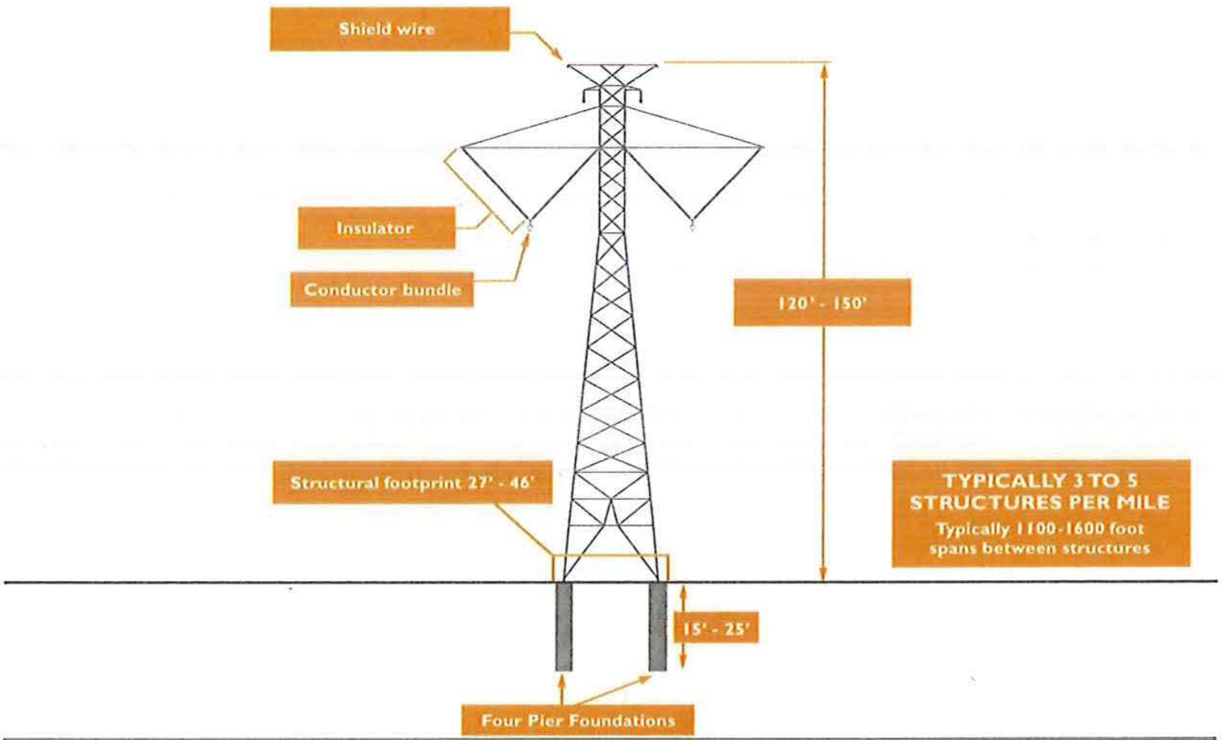
Schedule AWG-2 - Page 1 of 1

CLEAN LINE HVDC CONVERTERS

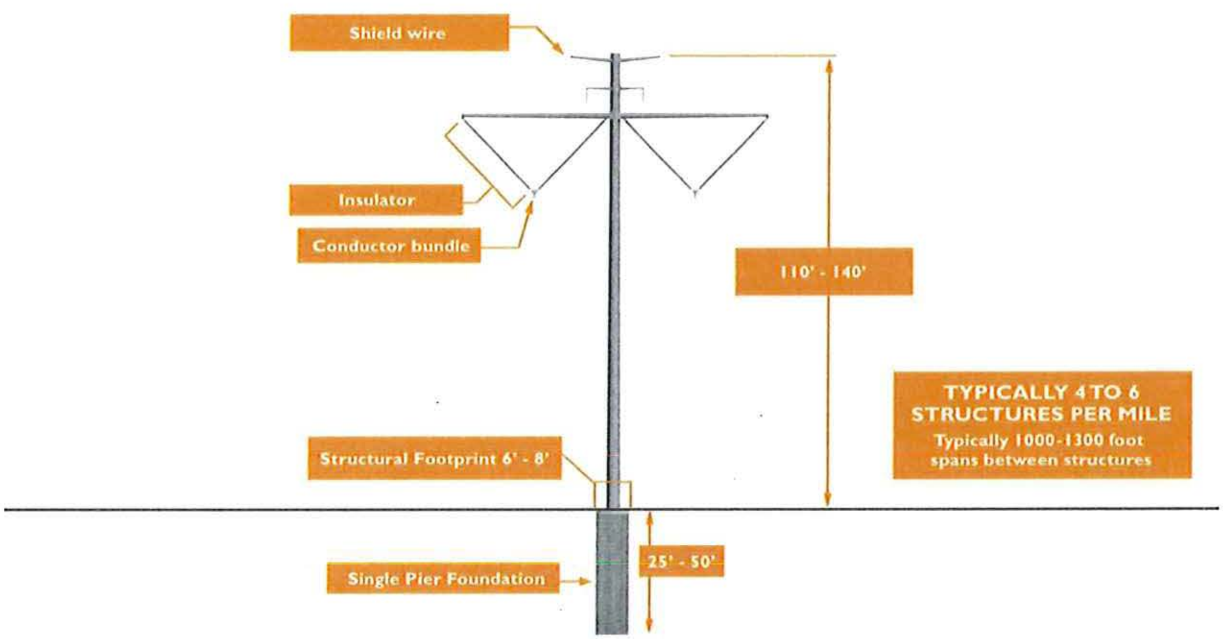
KANSAS CONVERTER STATION
GENRAL LAYOUT
ARRANGEMENT DRAWING

Siemens AG (1) E50105 - R2851 - V025 - 0

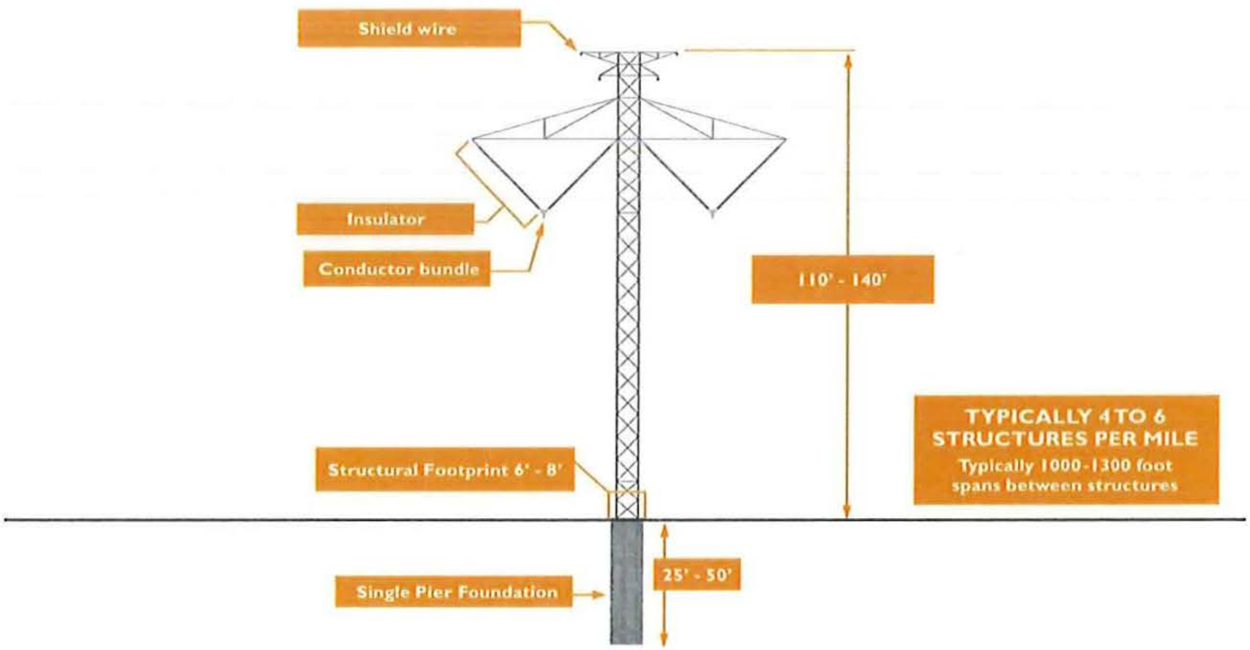
TYPICAL LATTICE STRUCTURE: 120 - 150 FEET



TYPICAL MONOPOLE STRUCTURE: 110 - 140 FEET



TYPICAL LATTICE MAST STRUCTURE: 110 - 140 FEET



Draft 5-18-2016

GRAIN BELT EXPRESS CLEAN LINE LLC.

INTERNAL RELIABILITY COMPLIANCE PROGRAM

FOR COMPLIANCE WITH

NORTH AMERICAN ELECTRIC RELIABILITY CORPORATION

RELIABILITY STANDARDS

AND REGIONAL ENTITY RELIABILITY STANDARDS

REVISION 0

EFFECTIVE [DATE]

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1.0 Scope of Internal Reliability Compliance Program

This document is the Internal Reliability Compliance Program (ICP) of Grain Belt Express Clean Line LLC (GBE) for compliance with Reliability Standards adopted by the North American Electric Reliability Corporation (NERC) and Regional Reliability Standards adopted by the Southwest Power Pool Regional Entity (SPP RE), SERC Reliability Corporation (SERC), Midwest Reliability Organization (MRO), and Reliability First Corporation (RFC) (collectively, "Regional Entities"), in each case as approved by the Federal Energy Regulatory Commission (FERC) pursuant to the Federal Power Act, that are applicable to GBE in its ownership and operation of its electric transmission line and related Bulk Electric System (BES) facilities. The FERC-approved NERC Reliability Standards and Regional Reliability Standards that are applicable to GBE are referred to collectively in this ICP as the "Reliability Standards."

GBE is registered with NERC as a registered entity for the reliability functions of some or all of the following functions: Balancing Authority (BA), Planning Coordinator (PC), Transmission Owner (TO), Transmission Operator (TOP), Transmission Planner (TP) and Transmission Service Provider (TSP), and is subject to the requirements of Reliability Standards that are applicable to BAs, PCs, TOs, TOPs, TPs and TSPs. Additionally, GBE will contract services with an existing NERC Reliability Coordinator (RC), likely to be PJM.

This GBE ICP: (i) states the overall Compliance Policy and Principles of GBE and its parent organizations concerning compliance with the Reliability Standards; (ii) describes the organizational structure of the GBE ICP and the responsibilities of individuals within GBE and its parent organizations with respect to the GBE ICP; and (iii) sets forth the specific program elements and procedures of the GBE ICP. The GBE ICP also identifies the detailed operating procedures, protocols and other rules (Reliability Compliance Procedures) by which GBE achieves, documents and demonstrates compliance with the Reliability Standards. Those Reliability Compliance Procedures are located within the GBE Reliability Compliance Manual, which consists of the procedures, protocols and other rules by which GBE achieves, documents and demonstrates compliance with the individual Reliability Standards applicable to GBE in its registered functions as a BA, PC, RC, TO, TOP, TP and TSP.

This GBE ICP does not address GBE's compliance with other laws, regulations, codes and standards applicable to GBE, such as FERC Standards of Conduct and environmental laws and regulations and occupational health and safety laws and regulations of the federal government and the states in which GBE's operations and facilities are located.

The implementation of the GBE ICP is subject at all times to the provisions of the Code of Business Conduct and Ethics of Clean Line Energy Partners LLC (Clean Line). Clean Line and GBE intend for there to be no conflicts or inconsistencies between the GBE ICP and the Clean Line Code of Business Conduct and Ethics.

2.0 Authority for Approval and for Revisions

The GBE ICP is approved, under authority of the Clean Line Board of Directors, by the Clean Line President and CEO and the Corporate Compliance Program Officer (CCPO). All revisions to this GBE ICP shall be approved, by signature, by both the Clean Line President and CEO and the CCPO. Approval of revisions shall be recorded, with approval and (if different) effective dates, in the Approval and Revision History in Section 13.0.

3.0 Reliability Compliance Policy and Principles

It is the policy of GBE and its parent organizations: (i) to proactively achieve and maintain compliance with all Reliability Standards applicable to GBE; (ii) to proactively achieve and maintain an overall culture of compliance at GBE; and (iii) that GBE, its parent organizations and their employees shall conduct their operations and activities to achieve these objectives. This policy is supported by the following ten Reliability Compliance Principles:

1. Compliance with applicable Reliability Standards is the responsibility of the management and all employees of GBE, of the management and all employees of GBE's parent organizations who are assigned responsibilities in this ICP, and, with appropriate notice, of third-party contractors and other providers of services and products to GBE at the GBE site.

2. Senior management of GBE and its parent organizations will be actively involved in achieving, monitoring and maintaining compliance with applicable Reliability Standards.

3. Under no circumstances will GBE knowingly not comply with an applicable Reliability Standard for economic reasons. That is, GBE will not violate an applicable Reliability Standard as a matter of economic choice because it is less costly or more remunerative to GBE to not comply with the Reliability Standard than it is to comply.

4. GBE will be provided with sufficient resources, including management and employee time, to carry out compliance activities, including training, internal self-auditing, and compliance program reviews. The need for, and allocation of, sufficient resources for compliance activities will be expressly recognized in the business planning and budgeting processes of GBE and its parent organizations.

5. GBE shall maintain appropriate data, documentation and other records to demonstrate compliance with applicable Reliability Standards in accordance with the requirements and measures of the applicable Reliability Standards and the provisions of the NERC and the Regional Entities' Compliance Monitoring and Enforcement Programs.

6. Employees of GBE and of its parent organizations are encouraged to promptly detect and report possible noncompliances with applicable Reliability Standards and with GBE Reliability Compliance Procedures, and to participate in corrective actions and remediation to prevent recurrence.

7. Employees of GBE and its parent organizations will act in a professional manner and with respect at all times in their interactions with representatives of NERC and the Regional Entities. The responses of GBE

and its parent organizations to requests for data and information from NERC and the Regional Entities in the performance of their compliance monitoring and enforcement responsibilities will be complete and truthful.

8. An employee's performance in achieving and maintaining compliance with applicable Reliability Standards will be a factor taken into account by management in employment status, advancement and compensation determinations, along with, and on a comparable basis as, other elements of performance evaluation such as achievement of economic and operational performance objectives and health and safety objectives.

9. Similarly, employee actions or inactions that result in noncompliance with an applicable Reliability Standard, or with a GBE Reliability Compliance Procedure, shall be subject to disciplinary actions in the same manner as is noncompliance with other laws and regulations applicable to GBE's operations and noncompliance with other GBE policies, procedures, protocols and rules, up to, and including in appropriate circumstances, termination of employment.

10. GBE shall establish and maintain channels by which employees may in good faith raise and express complaints, questions, issues and concerns with respect to compliance with applicable Reliability Standards and with GBE Reliability Compliance Procedures. All employees shall have access to the Corporate Compliance Program Officer and the Clean Line President and CEO to raise compliance-related complaints, questions, issues and concerns, without fear of retaliation or adverse consequences in employment status or compensation, except in regards to the employee's personal involvement in any noncompliance, or actions or inactions resulting in noncompliance, with an applicable Reliability Standard or with a GBE Reliability Compliance Procedure. All such complaints, questions, issues and concerns raised by an employee will be subject to the strict non-retaliation policy set forth in the Clean Line Code of Business Conduct and Ethics.

4.0 GBE and its Parent Organizations

GBE is a limited liability company that owns and operates a high voltage direct current electric transmission line and related facilities, including three converter stations, that originates in Ford County, Kansas, crosses the states of Kansas, Missouri, and Illinois, and terminates at an interconnection point with the transmission grid of the PJM Interconnection LLC in Sullivan County, Kansas. The ultimate parent company of GBE is Clean Line. For purposes of this ICP, Clean Line is a "parent organization" of GBE.

5.0 Positions in the GBE ICP

While compliance with applicable Reliability Standards is the responsibility of all employees of GBE, the positions described below have been created to perform, or assigned, specific responsibilities in the GBE ICP. **Attachment 1** to this ICP is the organization chart for the GBE ICP.

5.1 Clean Line Board of Directors

The Clean Line Board of Directors (Board) is comprised of representatives of the owners of Clean Line. The Board manages the affairs of Clean Line and its subsidiary companies, including GBE, similar to the manner in which a board of directors governs a corporation. As such, the Board has ultimate oversight responsibility with respect to the matters described in the GBE ICP

5.2 Clean Line President and CEO

The Clean Line President and CEO is the senior executive responsible for the operations and performance of Clean Line and its subsidiary companies, including GBE. As such, the Clean Line President and CEO is the senior executive with responsibilities for the overall compliance by GBE with applicable Reliability Standards and for implementation of the GBE ICP. The Clean Line President and CEO reports directly to the Clean Line Board, and is responsible for reporting to the Clean Line Board, on both a regular, periodic basis and as specific developments and occurrences warrant, on GBE's performance with respect to compliance with applicable Reliability Standards and implementation of the GBE ICP. The Clean Line President and CEO and/or the Corporate Compliance Program Officer will provide a report on reliability compliance matters to the Clean Line Board in connection with each regular meeting of the Clean Line Board.

The GBE Corporate Compliance Program Officer is the [position] of [company] and reports directly to the Clean Line President and CEO. The GBE Reliability Compliance Manager is the [position] of GBE and also reports directly to the Clean Line President and CEO, including with respect to reliability compliance matters.

5.3 Corporate Compliance Program Officer

The [position] of [company] is the Corporate Compliance Program Officer in the GBE ICP. The CCPO has oversight of the GBE ICP. The CCPO reports directly to the Clean Line President and CEO. The GBE Reliability Compliance Manager is the [position] of GBE and reports directly to the CCPO with respect to reliability compliance matters, and to the Clean Line President and CEO with respect to reliability compliance and other matters. The CCPO also is responsible for reporting to the Clean Line Board, on both a regular, periodic basis and as specific developments and occurrences warrant, on GBE's performance with respect to compliance with applicable Reliability Standards and implementation of the GBE ICP. The responsibilities of the CCPO include:

(i) Implementation of the GBE ICP at the parent organization level.

(ii) Direct supervision and oversight of implementation of the GBE ICP from the parent organization level.

(iii) Approval of changes to the GBE ICP, subject to review and approval by the Clean Line President and CEO and review and consent by the Clean Line Board.

(iv) Oversight and approval, after consultation with the Clean Line President and CEO, of semi-annual reviews of the GBE ICP, including any proposed revisions or corrective actions resulting from a semi-annual review.

(v) Approval, after consultation with the Clean Line President and CEO, of the results of semi-annual internal self-audits of GBE's compliance with applicable Reliability Standards, including any proposed corrective actions resulting from an internal self-audit.

(vi) Supervision of the preparation and approval, after consultation with the Clean Line President and CEO, of GBE's response to any Notices of Possible Violation, Alleged Violation, Confirmed Violation, Penalty or Sanction, or Remedial Action Directive, and approval of the submission of any Mitigation Plan or other plan for mitigating activities, to a Regional Entity or to NERC.

(vii) Investigation and resolution of any complaints, questions, issues or concerns raised or submitted by GBE employees (or any other individual or entity) with respect to the implementation of the GBE ICP or to any other matters relating to compliance with applicable Reliability Standards.

(viii) Presentation of regular reports on reliability compliance matters to the Clean Line President and CEO at least once per calendar quarter, as well as other reports to the Clean Line President and CEO on reliability compliance matters as warranted by events and circumstances.

5.4 Reliability Compliance Manager (RCM)

The Reliability Compliance Manager (RCM) is the [position] of GBE. [Note: If possible, the RCM is supposed to be someone not involved in "production" operations that must comply with the Reliability Standards.] The RCM reports directly to the CCPO and also reports directly to the Clean Line President and CEO, including with respect to reliability compliance matters. The RCM also has direct access to the Clean Line Board to report and discuss reliability compliance matters as needed.

The RCM is responsible for compliance with applicable Reliability Standards in the operations of GBE on an ongoing, day-to-day basis; and for implementation of this ICP on an ongoing, day-to-day basis. These responsibilities include:

(i) Initiation and performance of semi-annual internal self-audits of GBE's compliance with applicable Reliability Standards, including identification and initial development of any proposed corrective actions resulting from an internal self-audit.

(ii) With oversight by the CCPO, performance of semi-annual reviews of the GBE ICP, including identification of the need for, and initial development of, any proposed modifications or corrective actions resulting from a semi-annual review.

(iii) Development of training materials and other information, and execution of regular training of, and other dissemination of information to, GBE employees concerning the ICP, and reliability compliance matters generally.

(iv) Dissemination of information, including training if applicable, concerning the ICP and reliability compliance matters generally, to third-party contractors and other providers of services and products to GBE or for GBE facilities.

(v) Preparation of GBE's responses to any compliance monitoring and enforcement processes initiated by a Regional Entity or by NERC, such as spot checks, self-certification requests and compliance audits.

(vi) Initial development of GBE's response to any Notices of Possible Violation, Alleged Violation, Confirmed Violation, Penalty or Sanction, or to any Remedial Action Directive, and of any Mitigation Plan, mitigating activities, or other actions undertaken as part of the NERC Find, Fix and Track or Compliance Exceptions programs.

(vii) Implementation and performance of GBE's self-reporting and self-logging programs.

(viii) Initial preparation and submission of budget and off-budget-cycle requests for resources needed for implementation of the ICP.

(ix) Review and approval of all GBE Reliability Compliance Procedures, including revisions to such Reliability Compliance Procedures.

(x) Ensuring that staff members at the GBE site have sufficient time and resources to complete their assigned responsibilities with respect to reliability compliance matters.

(xi) Performing, pursuant to delegation by the Clean Line President and CEO, the function and responsibilities of "Senior Manager" for purposes of GBE's compliance with applicable requirements of NERC Critical Infrastructure Protection Reliability Standards, pursuant to Requirement R.2 of Reliability Standard CIP-003.

(xii) Approval of responses to NERC Alerts prepared by the Maintenance Supervisor and/or Operations Supervisor. The RCM shares responsibility for acknowledgment of NERC Alerts and preparation and submittals of responsibilities to NERC Alerts, with the Operations Supervisor and Maintenance Supervisor.

Because the RCM is also, in his/her capacity as [position], responsible for other physical operations and for economic performance of GBE, the Clean Line Board and the Clean Line President and CEO expressly recognize that the responsibilities of the RCM are separate responsibilities from the responsibilities of the [position], and that the responsibilities of the [position] shall not conflict with nor take precedence over the responsibilities of the RCM. [This paragraph not needed if the RCM does not also have "production" responsibilities.]

5.5 Maintenance Supervisor

In addition to the responsibilities for compliance with applicable Reliability Standards expected of all employees at GBE, the GBE Maintenance Supervisor has the following duties relative to GBE's compliance with Reliability Standards.

(i) Preparation of and periodic review of (including identification of the need for revisions to), GBE Reliability Compliance Procedures, including preparation of any revisions to Reliability Compliance Procedures.

(ii) Preparation and submittal of monthly Misoperations and Compliance Enforcement Program reports as required by a Regional Entity.

(iii) Preparation of responses for all Self-Certifications requested by a Regional Entity or by NERC.

(iv) Acknowledgement and preparation of responses to NERC Alerts. This responsibility is shared and coordinated with the RCM and the Operations Supervisor.

(v) Approval of acknowledgements and responses to NERC Alerts in the absence of the RCM.

5.6 Operations Supervisor

In addition to the responsibilities for compliance with applicable Reliability Standards expected of all employees at GBE, the GBE Operations Supervisor has the following duties relative to GBE's compliance with Reliability Standards:

(i) Preparation of and periodic review of (including identification of the need for revisions to), GBE Reliability Compliance Procedures, including preparation of any revisions to Reliability Compliance Procedures.

(ii) Review of all proposed responses to Self-Certifications required by a Regional Entity or by NERC, prior to submission. Preparation of all proposed responses to Self-Certifications in the absence of the Maintenance Supervisor.

(v) Acknowledgement and preparation of responses to all NERC Alerts. This responsibility is shared and coordinated with the RCM and the Maintenance Supervisor.

(vi) Periodic review and implementation of the Facility Ratings Methodology for GBE pursuant to Reliability Standard FAC-008 or any similar Reliability Standards or procedure which becomes mandatory; and submittal of the results of implementation of the methodology to the RCM for approval on at least an annual basis.

(vii) Performing, or causing to be performed, consistent with Section 6.0 of this ICP, annual training for all GBE operational employees, including those employees who might be reasonably expected to fill in for an operations employee. If another GBE employee, or a vendor, provides this training, it will be done with the review and concurrence of the RCM.

5.7 Environmental & Safety Manager

In addition to the responsibilities of for compliance with Reliability Standards expected of all employees at GBE, the GBE Environmental & Safety Manager (E&S Mgr) has the following duties relative to GBE's compliance with Reliability Standards:

As assigned by the RCM, the E&S Mgr has the responsibility to participate in: (i) the periodic reviews of the GBE ICP; and (ii) the periodic internal self-audits of GBE's compliance with Reliability Standards. Because the E&S Mgr does not have direct responsibility for maintenance and testing or production at GBE, he/she is in a unique position to review GBE's reliability compliance activities in an independent and unbiased manner. Specifically, the responsibilities of the E&S Mgr include:

(i) Participates in periodic reviews and internal self-audits conducted in accordance with the GBE ICP.

(ii) Periodically checks the "suggestion box" located [some where]. Any suggestions, complaints, questions, issues or concerns regarding reliability compliance matters left in the "suggestion box" will be reviewed and forwarded by the E&S Mgr to the RCM and the CCPO for further action in accordance with Section 7.5 of the ICP.

5.8 Program Administrator

In addition to the responsibilities for compliance with Reliability Standards expected of all employees at GBE, the GBE Program Administrator has the following duties relative to GBE's compliance with Reliability Standards:

(i) Ensures that all documentation of compliance-related activities is forwarded to the online Fileroom.

(ii) Control of all Controlled Procedure Manuals, in particular, and relevant to the GBE ICP, the Reliability Compliance Manual. In order to verify compliance for an entire compliance audit period, the RCM's copy of the Reliability Compliance Manual will contain all versions of the Reliability Compliance Procedures that were in effect during that period. If necessary, a secondary book will be added to accommodate previous versions. All versions must be maintained consistent with the GBE File Retention Policy. Absent such a policy, copies of all versions must be maintained.

(iii) Tracking all required training and reading activities (i) required for compliance with Reliability Standards, (ii) required by this ICP, or (iii) assigned by the RCM each January, in each case to completion, and filing the records of completion in Compliance Suite or an equivalent software system.

(iv) Maintaining **Attachment 2** to the ICP on a current basis.

6.0 Dissemination of the GBE ICP to GBE Employees; Employee Training on the Reliability Compliance Program

6.1 The GBE ICP shall be provided to: (i) each employee of GBE promptly following the initial effective date of the program; and (ii) to all new employees of GBE promptly following commencement of their employment. The program may be provided to employees either in paper copy or in electronic format readily accessible to the employee. Each employee shall be required to sign a statement that he/she has received, read, and had the opportunity to ask questions about the program. The signed statement shall be provided either in paper form or through an on-line system that allows the employee to make the required statements electronically.

6.2 GBE employees shall be timely notified of any revisions to the GBE ICP. The notification shall include a brief summary of the nature and purpose of the revision and shall inform employees as to how or where they can obtain or review the revised program document, either in paper copy or electronically. Each employee shall be required to sign a statement that he/she has received, read, and had the opportunity to ask questions about, the notice of revision. The signed statement shall be provided either in paper form or through an on-line system that allows the employee to make the required statements electronically.

6.3 Copies of this GBE ICP shall be readily accessible to GBE employees at each GBE employee location, in either or both paper copy or electronic format.

6.4 A minimum of four (4) hours of training shall be provided to each GBE employee annually on the GBE ICP and other reliability compliance matters. The coverage of the training sessions, and the specific training materials, for each quarter shall be developed by the RCM and approved by the CCPO. Training may be provided in group sessions, through on-line programs which the employee can use on an individual basis, or using these two delivery methods in combination. Paper or electronic records shall be maintained to show that each employee has completed the required hours of training annually; such records shall be signed by the employee and by the RCM or his/her designee. The records of training completion shall be maintained in compliance with any applicable NERC requirements.

6.5 The training required by Section 6.4 shall be in addition to training provided to employees (i) in compliance with requirements of applicable Reliability Standards, or (ii) on specific GBE Reliability Compliance Procedures.

7.0 Employees May Raise Any Complaints, Questions, Issues or Concerns Regarding Reliability Compliance Matters with Compliance Program Officials

7.1 All employees of GBE are entitled, and encouraged, to raise, in good faith, any complaints, questions, issues or concerns regarding the GBE ICP, compliance or non-compliance with applicable Reliability Standards at GBE, or any other matters relating to Reliability Standards compliance at GBE, to Compliance Program officials or other members of management. Employees may raise any complaints, questions, issues or concerns without fear of retaliation or adverse employment consequences concerning the employee's job status or position, advancement, or compensation. However, the protection against adverse employment consequences does not apply to prohibit disciplinary actions or other employment-related actions concerning an employee who is personally involved in an action or inaction that results in a noncompliance with an applicable Reliability Standard or a failure to comply with a GBE Reliability Compliance Procedure.

7.2 Employees may submit complaints, questions, issues or concerns on an anonymous basis at the employee's option, recognizing that if a complaint, question, issue or concern is submitted anonymously, it may not be possible to submit a response directly to the employee.

7.3 Employees are encouraged to raise complaints, questions, issues or concerns, including those which may indicate a possible violation of or noncompliance with an applicable Reliability Standard or with a GBE Reliability Compliance Procedure, when they are first identified, rather than waiting or delaying, as the matter may grow in scope or severity if not reported promptly.

7.4 Employees may raise complaints, questions, issues or concerns by any of the following means:

(i) Leaving a written message in the "suggestion box" located [some place].

(ii) Sending an e-mail to the following e-mail address which has been established to receive complaints, questions, issues and concerns regarding reliability compliance matters: XXXXX.com. This e-mail address will be monitored by the CCPO.

(iii) By speaking directly with the RCM.

(iv) By speaking directly with the employee's immediate supervisor.

(v) By calling the CCPO at [phone number] or the Clean Line President and CEO at [phone number].

(vi) By contacting the Clean Line [Human Resources Officer] at [phone number], or any other officer of Clean Line or GBE.

7.5 All employee complaints, questions, issues and concerns submitted through any of the means listed in Section 7.4 shall be brought to the attention of the RCM and the CCPO. The CCPO shall have principal responsibility for preparation and delivery of a response to the complaint, question, issue or concern, but may assign to the RCM responsibility to (i) investigate the basis for the complaint, question, issue or concern, (ii) prepare a proposed response to the complaint, question, issue or concern, and/or (iii) develop any proposed actions that may be necessary to address the complaint, question, issue or concern.

7.6 The CCPO and the RCM shall promptly bring to the attention of the Clean Line President and CEO, all complaints, questions, issues and concerns of higher significance or urgency as they are received.

8.0 Impact of Reliability Compliance Performance on Employment Status and Compensation and Disciplinary Actions

8.1 A GBE employee's performance in complying with the ICP, and in achieving and maintaining compliance with applicable Reliability Standards and with GBE Reliability Compliance Procedures, will be a factor taken into account by management in performance evaluations, including in determinations as to the employee's employment status, compensation, and advancement to or eligibility for other positions. Such evaluations and determinations shall be made, along with and on a comparable basis as other elements of performance evaluation such as achievement of economic and operational performance objectives and health and safety objectives, and shall be included in the employee's performance reviews.

8.2 Actions or inactions of GBE employees that result in noncompliance with an applicable Reliability Standard, or in noncompliance with a GBE Reliability Compliance Procedure, shall be subject to disciplinary actions in the same manner as is noncompliance with other laws and regulations applicable to GBE's operations and noncompliance with other GBE policies, procedures, protocols and rules, up to, and including in appropriate circumstances, termination of employment.

9.0 Review of and Response to Noncompliances with Reliability Standards and with the Internal Reliability Compliance Programs

9.1 The RCM shall be responsible for initial investigation and development of a response to any of the following occurrences at the GBE site: (1) a potential or actual noncompliance with an applicable Reliability Standard, (2) a noncompliance with a GBE Reliability Compliance Procedure, and (3) a noncompliance with the GBE ICP. The investigation and response, including any mitigation plan and/or other corrective action, shall address the following issues:

(i) the cause of the noncompliance,

(ii) the actions required to correct the noncompliance,

(iii) the actions to be taken to correct the cause of the noncompliance,

(iv) the actions to be taken to prevent recurrence of the noncompliance, and

(v) the schedule or timetable for any actions under (ii), (iii) and (iv).

9.2 If the potential or actual noncompliance being investigated is of an applicable Reliability Standard, as soon as the investigation has concluded that a Reliability Standard has been violated, a self-report shall be filed with the applicable Regional Entity. If a mitigation plan or other plan for mitigating activities cannot be developed in time to submit with the self-report, the mitigation plan or other plan for mitigating activities will be developed promptly thereafter and be submitted to the applicable Regional Entity as soon as is reasonably possible under the circumstances of the noncompliance.

9.3 The CCPO shall review and, based on consultation with the Clean Line President and CEO, approve, the results of the investigation conducted and response developed pursuant to section 9.1.

9.4 The RCM shall be responsible for managing and monitoring, as appropriate, the timely completion of the actions identified in the investigation of and response to a noncompliance. The RCM shall report to the CCPO when the actions identified in the investigation of and response to the noncompliance are completed as well as at any milestone dates as required by the mitigation plan, mitigating activities, and/or other corrective action.

10.0 Semi-Annual Internal Self-Audits of Compliance with Applicable Reliability Standards

10.1 Two times per year, the RCM shall cause an internal self-audit to be performed of GBE's compliance with all Reliability Standards applicable to GBE. Each semi-annual internal self-audit shall be performed no less than 5 months, and no more than 7 months, after the previous internal self-audit.

10.2 The performance of a review for purposes of a Self-Certification required by a Regional Entity or by NERC with respect to one or more applicable Reliability Standards satisfies the requirement for an internal self-audit for compliance with the Reliability Standards covered by the Self-Certification, if the review for the Self-Certification occurs within the time period specified in Section 10.1.

10.3 Prior to initiating an internal self-audit, the RCM shall consult with the CCPO and, if appropriate, the Clean Line President and CEO, to determine if external consultants, or employees from other Clean Line portfolio companies, should be used as part of the internal self-audit team. Use of consultants or of personnel from other Clean Line companies shall be approved by the CCPO.

10.4 In order that GBE plant personnel may devote sufficient attention to the internal self-audit, the internal self-audit will be scheduled so as not to conflict with scheduled major activities such as maintenance outages. Should it appear that operational activities may interfere with the ability to conduct a thorough internal self-audit, outside personnel, such as consultants or employees from a GBE parent organization or another Clean Line company, may be used in lieu of or in addition to GBE employees to perform the internal self-audit. If personnel from a GBE parent organization or another Clean Line company are used in performance of the internal self-audit, at least one of those persons will be from a facility having responsible for compliance with NERC Reliability Standards.

10.5 The results of each internal self-audit shall be documented in a report which shall be provided to, and approved by, the CCPO. The approved report shall be provided to the Clean Line President and CEO and to the Clean Line Board.

10.6 Any noncompliances with applicable Reliability Standard discovered in the internal self-audit, and corrective actions, shall be addressed in accordance with Section 9.0 as well as reported to the applicable Regional Entity or NERC as required.

11.0 Semi-Annual Reviews of the ICP

11.1 Two times per year, approximately 6 months apart, the CCPO shall cause to occur, and shall participate in, a review of the GBE ICP.

11.2 The CCPO shall be responsible for the performance of the semi-annual reviews of the ICP. Prior to initiating a semi-annual review, the CCPO shall consider, and shall consult with the RCM and with the Clean Line President and CEO as appropriate, whether external consultants, or employees from other Clean Line portfolio companies, should participate as part of the review team.

11.3 The semi-annual reviews of the ICP shall address both (i) whether the existing program has been complied with since the previous review, and (ii) whether any revisions should be made prospectively to the program.

11.4 A semi-annual review of the ICP shall result in a report which shall (i) describe the manner in which the review was conducted, (ii) identify any noncompliances with the program and actions taken to address the noncompliance(s), (iii) state a conclusion or conclusion(s) as to whether the program is continuing to function effectively overall and whether any changes to the program should be made, and (iv) describe any changes that are recommended to be made and a timeline(s) for making the change(s).

11.5 Each report of a semi-annual review of the ICP shall be approved by the CCPO and copies provided to the Clean Line President and CEO and to the Clean Line Board. The CCPO and the Clean Line President and CEO shall make a presentation to the Clean Line Board at its next regular meeting following completion of the semi-annual review and report.

11.6 Any findings in a semi-annual review of the ICP that the program has not been complied with, and the corrective actions, shall be addressed in accordance with Section 9.0

12.0 Mapping of Applicable Reliability Standards to Reliability Compliance Procedures

Attachment 2 to this ICP lists (1) each Reliability Standard and, where applicable, the individual Requirements of each Reliability Standard, that is applicable to GBE in its registered functions as a GO and a GOP; (2) for each Reliability Standard and individual Requirement, the GBE Reliability Compliance Procedure by which GBE achieves, documents and demonstrates compliance with the Reliability Standard or Requirement; and (3) the GBE employee position or positions assigned responsibility for GBE's operations pursuant to each Reliability Compliance Procedure listed.

The Reliability Compliance Procedures are contained in the Reliability Compliance Manual, copies of which are available at the GBE plant site.

Attachment 2 shall be promptly revised to reflect the addition or removal of Reliability Standards and Requirements that are applicable to GBE; the addition or removal of GBE Reliability Compliance Procedures; adoption of revisions to or new versions of Reliability Compliance Procedures; and changes in GBE employee position responsibility for GBE's operations pursuant to a Reliability Compliance Procedure. The Program Administrator shall be responsible for maintaining **Attachment 2** on a current basis.

13.0 Approval and Revision History

Revision	Description	Date Approved	Date Effective
Rev. 0	Original program		

Executive Approvals

Revision 0

By:______________________________ ____________________________

Clean Line President and CEO Date:

By:______________________________ ____________________________

Corporate Compliance Program Officer Date:

Attachment 1 – Internal Compliance Program Organization Chart

Attachment 2 – Reliability Standards Compliance Matrix

Reliability Standard	BA	PC	RC	TO	TOP	TP	TSP	Requirement Number	Requirement Text	Responsible Party	GBE Reliability Compliance Procedure

[This table lists: (1) each applicable Reliability Standard, (2) each applicable Requirement of the Standard and the text of the Requirement based on the most up to date applicable standards published by NERC (http://www.nerc.com/pa/Stand/Pages/AllReliabilityStandards.aspx?jurisdiction=United%20States); the reliability function (BA, PC, RC, TO, TOP, TP and/or TSP) that the Requirement applies to; (3) the position ("Responsible Party") in the GBE organization that has responsibility for compliance; and (4) the GBE Reliability Compliance Procedure that details the tasks and procedures that will be followed to maintain compliance with the requirements.]

GRAIN BELT EXPRESS
CLEAN LINE

May 26, 2016

CLEAN LINE ENERGY

GRIAN BELT EXPRESS HVDC LINE

DESIGN CRITERIA
Revision A

PROJECT NUMBER:
133798

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REVISION HISTORY		
DATE	REVISED BY	REVISION
A	CIM	Preliminary Design Draft for Review

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ABBREVIATIONS

ACSR:	Aluminum Conductor, Steel Reinforced
ACSS:	Aluminum Conductor, Steel Supported
ACCR:	Aluminum Conductor Composite Reinforced
AGS:	Armor Grip Support
ASCE:	American Society of Civil Engineers
CTZFS:	Cable Tension For Zero Fiber Strain
CSZFS:	Cable Strain For Zero Fiber Strain
FC:	Sag Tension Limit, Final After Creep Condition
FL:	Sag Tension Limit, Final After Load Condition
Hz:	Hertz
I:	Sag Tension Limit, Initial Condition
kcmil:	1000 Circular Mills
kips:	1000 pounds
kV:	kilovolts
Manual No. 74	ASCE Manual and Report on Engineering Practice No. 74 "Guidelines for Electrical Transmission Line Structural Loading
N/A	Not Applicable
NESC:	National Electrical Safety Code, 2007
OHSW:	Overhead Shield Wire
OPGW:	Fiber Optic Ground Wire
ROW:	Right-of-Way
RUS:	Rural Utilities Service
TBD:	To Be Determined
TW:	Trapezoidal Shaped Conductor
MRC:	Metallic Return Conductor
PC:	Pole Conductor
MAD:	Minimum Approach Distance
WS:	Working Space

GENERAL

Project Information

Owner's Name:	Clean Line Energy Partners ("Clean Line")
Project Name:	Grain Belt Express HVDC Transmission Line
Length:	Approximately 725 miles
Voltage:	+/- 600 kV DC (Bi-Pole)
Planned Energization Date:	2022

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Project Description

This project includes developing Preliminary Design Criteria and other supporting information for the purpose of supporting regulatory, permitting, estimating, and other preliminary design activities by Clean Line Energy Partner's ("Clean Line") and its project partners for the proposed Grain Belt Express HVDC transmission line. The project is currently in a regulatory phase in Missouri having received approvals in Kansas and Illinois, and is moving from the conceptual and preliminary design and estimating stage to the final design criteria definition to be used in final detailed design after the all regulatory approvals are received. The purpose of this design update is to advance the project definition from the prior conceptual and preliminary design level to a design level which will serve as the basis for detailed pre-construction design of the transmission line. This design and associated specifications will be used by Clean Line and the Grain Belt Express project partners to complete the next level design and contracting requirements for the project execution.

The design reflected in this Design Criteria document generally reflects updates to the conceptual and preliminary designs performed by POWER for several potential Clean Line HVDC projects. As such, the revisions and updates to this Design Criteria document reflect a combination of revised or updated studies reflecting the information known at this stage of the project. The format and approach taken by POWER is to update the conceptual design information, revising where appropriate. In some cases, primarily in appendices, prior content has not been updated since the conclusions are known to be unchanged. In such cases, a clarifying note has been added to the appendix.

The design parameters for this initial publication of a Grain Belt Express Design Criteria reflect current design criteria for Plains & Eastern Clean Line from March 2016, revised to reflect known changes due to project location, primarily NESC loading district requirements. Other changes will be incorporated as further project definition is known.

HVDC SYSTEM DESIGN PARAMETERS

Based on information available after selection of an HVDC vendor and establishment of performance specifications for the converter stations, the following overall inputs are applicable for line design purposes:

Nominal operating voltage for the project is +/- 600 kV.

The convertor overrating factor (used for prior line emergency condition design) is now 1.0, so there are no longer normal and emergency design regimes commonly referred to in prior publications of the design documents associated with Grain Belt Express.

Windward HVDC Station (Kansas):

- Maximum Power at Rectifier: P rect= 4356 MW
- Maximum Power per Pole: P pole=P rect /2= 2178 MW
- Maximum Current per Pole: I pole= (P pole /V) *1000=(2178 MW / 600 kV) *1000=3630 Amps
- Maximum Current per Conductor: I cond= I pole/3=1210 Amps (3 conductors/pole)
- Maximum Current per Metal Return Conductor (MRC): I mrc= I pole/2=1815 Amps
  (Operating condition when one pole is lost and all current from that pole must be split between the 2 MRC)

Missouri HVDC Station:

- 500 MW maximum delivery to a HVDC converter in Ralls County Missouri.

Illinois HVDC Station:

- 3500 MW delivery to a HVDC converter in Clark county, Illinois.

CODE(S) AND LOADING CONDITIONS

Controlling Code(s)

NESC:	NESC Rule 250 B Heavy District NESC Rule 250C Extreme Wind, adjusted for 50-year return period NESC Rule 250D Extreme Ice with Concurrent Wind, adjusted for 50-year return period
Location or State Specific:	Kansas, Missouri, Illinois
Client Specific:	Clean Line Energy

Loading Conditions For Non-Deadend Structures

Case	Description	Weather Case	Ref	Cable Condition	Vert. Load Factor	Wind Load Factor	Tension Load Factor	Strength Reduction Factor
1	NESC HEAVY ALL WIRES INTACT (STEEL & CONCRETE)	0°F, 0.5" ICE, 4 PSF	NESC 250B, 253-1 / 261-1A	Initial	1.5	2.5	1.65	1
2	EXTREME WIND ALL WIRES INTACT (STEEL & CONCRETE)	60°F 90 MPH (50 YR RP) ASSUMED 230' MAX STR HEIGHT, WITH 820' SPAN; Kz,c=1.57, Kz,s=1.35; Gf,c=0.66; Gf, s=0.80 Results: 20.74 PSF ON WIRE 23.00 PSF ON STR	NESC 250C, 253-1 / 261-1A Table 250-2 Table 250-3	Initial	1.0	1.0	1.0	1
3	NESC EXTREME ICE WITH CONCURRENT WIND ALL WIRES INTACT (STEEL & CONCRETE)	15°F 1.00" ICE (50 YR RP) 4.1 PSF WIND	NESC 250D, 253-1 / 261-1A	Initial	1.0	1.0	1.0	1
4	F2 TORNADIC WIND <u>ON STRUCTURE WITH NO WIRES</u>	60°F, 157 MPH (63.1 PSF)	ASCE #74 2.7.1	Not Applicable	1.0	1.0	1.0	1
5	EVERYDAY LOADS	60°F		Initial	1.0	1.0	1.0	1
6	CONSTRUCTION, SNUB-OFF, 3:1	0°F	IEEE524 Annex D	Initial	1.5	1.5	1.5	1
7	STRINGING/BROKEN SHIELD WIRE LOAD	0°F, 4 PSF	ASCE #74 3.3.2 Failure Containment	Initial	1.5	1.5	1.5	1
8	STRINGING/BROKEN METAL RETURN CONDUCTOR LOAD	0°F, 4 PSF	ASCE #74 3.3.2 Failure Containment	Initial	1.5	1.5	1.5	1
9	STRINGING/BROKEN POLE CONDUCTOR LOAD	0°F, 4 PSF	ASCE #74 3.3.2 Failure Containment	Initial	1.5	1.5	1.5	1

Notes:

1. Load cases 1 through 5 shall be analyzed assuming a foundation rotation of 1.72° (3%) when used with pole structures.

2. Load case 3 is a maximum deflection case when used with pole structures. Deflection at the pole tip shall be limited to 9% of the above ground structure height under this load condition. The total of 9% includes 1.72° (3%) due to foundation rotation.

3. Load case 6 is for deflection control of pole structures under every day conditions. The maximum deflection for tangent structures is one pole tip diameter. The maximum deflection for angle structures at the pole tip is 1 ½ % of the above ground height. Angle structures not meeting this requirement shall be cambered.

4. For structure load calculations (ruling spans, wind spans, weight spans, etc. for each type of structure), see attached Appendix AA-Design Assumptions.

5. Load Case 3 shall be analyzed with the wind in a transverse direction, at a 45° yawed angle, and in a longitudinal direction.

6. Load Case 7, snub-off, is applied with wires snubbed off at three horizontal to one vertical. All wires (shieldwires, MRCs, pole conductors) should be assumed that will snub-off simultaneously (worst case). See attached Appendix AB, for Snub-Off Case Loadings example of calculations (based on IEEE 524, Annex D).

7. Load Case 8, stringing/broken shield wire, accounts for a stringing block getting hung up at one of the shieldwires or for breaking one of the shieldwires. The longitudinal load applied to the structure at that broken shield wire position: back span: 0% of tension, 100% of weight span, ahead span: 100% of tension, 100% of weight span (assumed the shield wire breaks in the middle of back span, which is the worst case, that means its vertical load remains intact, assumed leveled spans). All other wire loads should be assumed intact. See ASCE Manual 74-2010, Section 3.3.2. Longitudinal Loads and Failure Containment for detailed calculations and attached Appendix AE-Stringing /Broken Case Example of Calculation.

8. Load Case 9, stringing/broken MRC (metal return conductor), accounts for a stringing block getting hung up at one of the MRCs or for breaking one of the MRCs. The longitudinal load applied to the structure at that broken MRC position: back span: 0% of tension, 100% of weight span; ahead span: 70% of tension (the broken MRC insulator string is assumed to swing longitudinally at a 45 deg angle towards ahead span), 100% of weight span (assumed the MRC breaks in the middle of back span, that means its vertical load remains intact, which is the worst case, assumed levels spans). All other wire loads should be assumed intact. See ASCE Manual 74-2010, Section 3.3.2. Longitudinal Loads and Failure Containment for detailed calculations and attached Appendix AE-Stringing /Broken Case Example of Calculation.

9. Load Case 9, stringing/broken pole conductor, accounts for a stringing block getting hung up at one sub-conductor out of three in the bundle, of only one pole (positive or negative) or for breaking of one sub-conductor out of three in the bundle, of only one pole (positive or negative). The longitudinal load applied to the structure at that broken sub-conductor: back span: 0% of tension, 100% of weight span; ahead span: 70% of tension (the broken pole conductor insulator string is assumed to swing longitudinally at a 45 deg angle towards the ahead span), 100% of weight span (assumed that sub-conductor breaks in the middle of back span, which is the worst case, that means its vertical load remains intact, assumed levels spans). The other two sub-conductors, from the pole where we broke one sub-conductor, and all the other pole three sub-conductors, both shield wires, and both MRCs locations should be assumed intact. See ASCE Manual 74-2010, Section 3.3.2. Longitudinal Loads and Failure Containment for detailed calculations and attached Appendix AE-Stringing /Broken Case Example of Calculation.

10. The structure should be designed for an additional load case, for loads anticipated due to rigging for wire clip in during construction. Loads shall be applied as follows: at one pole conductor location, apply load: W_{CL} directly above the work point (WP). Each location should be analyzed separately. The values should be:
    - Tangent Suspension 0-2 deg:
        - Basic: W_{CL}=26,650 lbs; Medium: W_{CL}=31750 lbs; Heavy: W_{CL}=43600 lbs.
    - Small Angle Suspension 2-10 deg:
        - W_{CL}=31750 lbs
    - Medium Angle Suspension 10-30 deg:
        - W_{CL}=31750 lbs

    Apply load case 6 to all other attachment points.

11. All load cases shall include the weight of the clamp and hardware (shieldwires) and the weight of insulators and hardware (for MRC and pole conductors) provided in attached Appendix AC-Clamps and Insulator Parameters and attached Appendix AD1 & AD2- Insulator Assembly Types ("Medium" & "Light" Pollution). The wind load on clamps (shieldwire) and insulators (MRC, pole conductor) will use the Area Exposed to Wind [ft^2] provided in attached Appendix AC-Clamps and Insulator Parameters.

12. Load case 6 will also include 800 lb. additional vertical load at the tip of each arm to account for <u>two</u> maintenance men and equipment.

13. Load Case 5 shall be for wind on <u>structure only</u> with no wires attached. Structure shall be analyzed with the wind in a transverse direction, at a 45° yawed angle, and with a longitudinal wind.

14. Insulators will be designed for the following overload factors and strength reduction factors (reference RUS Bulletin 1724E-200 Paragraph 8.9.1)
    a. Case 1: Overload Factor = 1.0, Strength Reduction Factor = 0.4
    b. All the other cases: Overload Factor = 1.0, Strength Reduction Factor = 0.5 for non-ceramic, 0.65 for ceramic and glass.

15. All lattice structural members shall be able to hold a 350 lb load, applied vertically at their midpoint, conventionally combined with the stresses derived from Load Case 6.

Loading Conditions For Deadend Structures

Case	Description	Weather Case	Ref	Cable Condition	Vert. Load Factor	Wind Load Factor	Tension Load Factor	Strength Reduction Factor
1	NESC HEAVY ALL WIRES INTACT (STEEL & CONCRETE)	0°F, 0.5" ICE, 4 PSF	NESC 250 B, 253-1 / 261-1A	Initial	1.5	2.5	1.65	1
2	EXTREME WIND ALL WIRES INTACT (STEEL & CONCRETE)	60°F 90 MPH (50 YR RP) ASSUMED 230' MAX STR HEIGHT, WITH 820' SPAN; Kz,c=1.57, Kz,s=1.35; Gf,c=0.66; Gf, s=0.80 Results: 20.74 PSF ON WIRE 23.00 PSF ON STR	NESC 250C, 253-1 / 261-1A Table 250-2 Table 250-3	Initial	1.0	1.0	1.0	1
3	NESC EXTREME ICE WITH CONCURRENT WIND ALL WIRES INTACT (STEEL & CONCRETE)	15°F 1.00" ICE (50 YR RP) 4.1 PSF WIND	NESC 250D, 253-1 / 261-1A	Initial	1.0	1.0	1.0	1
4	F2 TORNADIC WIND ON STRUCTURE WITH NO WIRES	60°F, 157 MPH (63.1 PSF)	ASCE #74 2.7.1	Not Applicable	1.0	1.0	1.0	1
5	EVERYDAY LOADS	60°F		Initial	1.0	1.0	1.0	1
6	NESC HEAVY DEADEND ALL WIRES REMOVED FROM ONE SPAN (STEEL & CONCRETE)	0°F, 0.5" ICE, 4 PSF	NESC 250B, 253-1 / 261-1A	Initial	1.5	2.5	1.65	1
7	EXTREME WIND DEADEND ALL WIRES REMOVED FROM ONE SPAN (STEEL & CONCRETE)	60°F 90 MPH (50 YR RP) ASSUMED 230' MAX STR HEIGHT, WITH 820' SPAN; Kz,c=1.57, Kz,s=1.35; Gf,c=0.66; Gf, s=0.80 Results: 20.74 PSF ON WIRE 23.00 PSF ON STR	NESC 250C, 253-1 / 261-1A	Initial	1.0	1.0	1.0	1
8	NESC EXTREME ICE WITH CONCURRENT WIND; DEADEND; ALL WIRES REMOVED FROM ONE SPAN	15°F 1.0" ICE (50 YR) 4.1 PSF WIND	NESC 250D, 253-1 / 261-1A	Initial	1.0	1.0	1.0	1

Notes:

1. Load cases 1 through 4 shall be analyzed assuming a foundation rotation of 1.72° (3%) when used with pole structures.

2. Load case 2 is a maximum deflection case when used with pole structures. Deflection at the pole tip shall be limited to 9% of the above ground structure height under this load condition. The total of 9% includes 1.72° (3%) due to foundation rotation.

3. Load case 5 is for deflection control of pole structures under every day conditions. The maximum deflection for tangent structures is one pole tip diameter. The maximum deflection for angle

structures at the pole tip is 1 ½ % of the above ground height. Angle structures not meeting this requirement shall be cambered.

4. For structure load calculations (ruling spans, wind spans, weight spans, etc. for each type of structure), see attached Appendix AA-Design Assumptions.

5. Load Cases 6, 7, and 8, shall be used to verify all deadend structures are designed to carry all wires deadended on one side of the structure.

6. Load Case 2 shall be analyzed with the wind in a transverse direction, at a 45° yawed angle, and with a longitudinal wind.

7. All load cases shall include the weight of the clamp and hardware (shieldwires) and the weight of insulators and hardware (for MRC and pole conductors) provided in attached Appendix AC-Clamps and Insulator Parameters and attached Appendix AD & AD2- Insulator Assembly Types ("Medium" & "Light" Pollution). The wind load on clamps (shieldwire) and insulators (MRC, pole conductor) will use the Area Exposed to Wind [ft^2] provided in attached Appendix AC-Clamps and Insulator Parameters.

8. Load case 5 will also include 800 lb. additional vertical load at the tip of each arm to account for two maintenance men and equipment.

9. Load Case 4 shall be for wind on structure only with no wires attached. Load Case 4 shall be analyzed with the wind in a transverse direction, at a 45° yawed angle, and with a longitudinal wind.

10. Insulators will be designed for the following overload factors and strength reduction factors (reference RUS Bulletin 1724E-200 Paragraph 8.9.1):
    a. Case 1 and 6: Overload Factor = 1.0, Strength Reduction Factor = 0.4
    b. All the other cases: Overload Factor = 1.0, Strength Reduction Factor = 0.5 for non-ceramic, 0.65 for ceramic and glass.

11. All lattice structural members shall be able to hold a 350 lb load, applied vertically at their midpoint, conventionally combined with the stresses derived from Load Case 5.

WIRES FOR THE MAIN LINE

Transmission Conductor

Size (kcmil/AWG):	2156 kcmil
Composition (ACSR, AAC, etc.):	ACSR
Code Word:	Bluebird
Diameter:	1.762 inches
Weight:	2.511 lbs/ft
Rated Breaking Strength:	60,300 lbs
Design Voltage:	600 kV HVDC
Typical Operating Voltage:	600 kV HVDC
Maximum Operating Voltage:	632 KV HVDC
Maximum Conductor Temperature (Temperatures calculated using IEEE 738 methodology for predicted line loadings under normal and emergency conditions):	I_{PC}=I pole/3=3630/3=1210 A: 72 Deg C (162 Deg F)

Appendix J provides comparison between the possible conductors which could be selected for this contract and ends with a recommendation of the selection. Sag and Tension calculations for the Pole Conductor (PC): ACSR Bluebird, Metal Return Conductor (MRC): ACSR Chukar, and OPGW are shown in Appendices E & E1, while Appendices F & F1 reports Ampacity calculation.

OPGW

There will be two shield wires, one to protect each pole conductor:

- Shield Wire Alternative 1: Two OPGW (Limited Use)
- Shield Wire Alternative 2: One OPGW and One ACSR Leghorn (Primary Design)

It is anticipated that Alternative 1 with two OPGW will only be used in isolated situations, such as river crossings or other areas that may warrant redundancy in OPGW for ease of communication service restoration in case of an OPGW failure.

Detailed Specification for the OPGW is presented in Appendix B. POWER requested quotations from several vendors and all of them came back with a "stranding stainless steel tube" type of OPGW design, trying to match the Power's specification. POWER chose the vendor with the design providing the highest CTZFS (Cable Tension for Zero Fiber Strain), and highest CSFZFS (Cable Strain for Zero Fiber Strain), also called "Strain Margin", and which had also the lowest cost for OPGW and its hardware. Details of the chosen OPGW are listed below.

Size (kcmil/AWG):	49AY85ACS-2C
Composition (EHS, AW, etc.):	12 Aluminum Clad Steel Wires ACS20.3% IACS 2 Aluminum Alloy Wires AY6201-T81 2 Stainless Steel Tubes 304 containing 6-24 fibers each and gel
Diameter:	0.591 inches
Weight:	0.473 lbs/ft
Rated Breaking Strength:	25,369 lbs
Number of Fibers:	12-48, depending on final project requirements

Appendix C lists the Lightning Algorithm used to check the OPGW while Appendix D shows the outer layer's wire required diameter calculation based on expected lighting charge at line location.

OPGW Selection based on fault current rating is presented in 2 appendices:
*Appendix AJ-1: OPGW Selection based on Fault Current-Variant 1: Two OPGW.
*Appendix AJ-2: OPGW Selection based on Fault Current-Variant 2: One OPGW and One ACSR Leghorn.
*Appendix AJ-3: OPGW Specification-Clean Line Projects.

OPGW will be paired with ACSR Leghorn, which has a similar DC Resistance at 40 C: **0.6833 [Ohm/mile]** as the OPGW: **0.8517 {Ohm/mile]** (where 40 C is the initial temperature in fault current calculations). Therefore, the maximum fault current expected at the Converter Stations, (1LG): 62.7 kA) will be split nearly in half between the 2 shieldwires: 45% in the OPGW and 55% in the ACSR Leghorn. The similar DC resistance makes the ACSR Leghorn a better shield wire to pair with the OPGW than a smaller shield wire, such as 7#8 Alumoweld, which would have a higher DC resistance, and would therefore take only 25-30% of the fault current, leaving 70-75% of the fault current to go to the OPGW. This would result in the fault current exceeding the capacity of the OPGW.[1] Pairing the Brugg 49AY85ACS-2C OPGW with ACSR Leghorn, the OPGW will take 45% and the ACSR Leghorn 55% of the maximum fault current.[2]

Appendices AJ-1 & AJ-2 contain all the Electrical Calculations, in all scenarios:

- Fault current At AC/DC Converter Substation and within 1 mile from AC/C Converter Station: worst case: 1LG: I=62.6 kA; t=0.1 sec

- Over 1 mile away from AC/D Converter Substation: 1LG:
  - I=20.8 kA; t=0.25 sec (best scenario)
  - I=20.8 kA; t=0.75 sec (worst scenario: maximum duration: 0.75 sec, coming from: 0.1 sec (primary)+0.25 sec (back-up)+4x0.1 sec (4 reclosures at 0.1 sec primary each)).

Appendix AJ-3 is the OPGW Specification for procurement of OPGW.

[1] 70% of the fault current would be: 62.6 kA*0.7=43.8 KA, which would mean (assuming the fault current at substation will be cut in t=0.1 sec) a fault current rating of: $I^2*t=43.8^2*0.1$ sec=192 kA^2*sec, which exceed the maximum allowed for the OPGW: 100 kA^2*sec.
[2] 62.6 kA*0.45=28.17 kA, thus the fault current rating will be: $I^2*t=28.17^2*0.1$=80 kA^2*sec, under the maximum allowed for the OPGW design: 98 kA^2*sec.

Shieldwire

In Shield Wire Alternative 2, OPGW will be paired with ACSR Leghorn, the specifications of which are shown below:

Size (kcmil/AWG):	134.6 kCMIL 12/7 Strands
Composition (AW, ACSR etc.):	ACSR
Code Word:	Leghorn
Diameter:	0.530 inches
Weight:	0.304 lbs/ft
Rated Breaking Strength:	13,000 lbs
Cross-Sectional Area:	0.1674 sq. inch

Optical Amplifier Repeaters for OPGW

Optical Amplifier Repeaters are used to extend the reach of optical communications links by overcoming loss due to the attenuation of the optical fiber (signal degradation in dB/km with distance) and distortion of the optical signal.

The maximum allowed distance between Optical Amplifier Repeater depends on many factors, not just the type of fiber used. These factors are discussed in detail in Appendix AL.

In general, optical repeaters (fiber optic regeneration sites) are required every 50 to 63 miles.

Because the OPGW for this project will **use G.655** type of single mode fiber instead of **G.652D** type of single mode fiber, with its advantages presented in detail in Appendix AL, we anticipate repeaters to be necessary every 63 miles. For 700 miles, this will result in at least 11 repeaters (regeneration sites).

A typical fiber regeneration site will be approximately 100'x100', with a fenced area of approximately 75'x75'. Regeneration sites are typically adjacent to the ROW, and may or not may abut the ROW. Regeneration Equipment will be enclosed within a small control building made of either metal or concrete, approximately 12x32' x 9' tall. Access road and power supply to the site will be required, which will be typically be provided from an existing electric distribution line near the fiber optic regeneration site. The voltage of the power supply is typically 34.5 kV or lower.

The location of the regeneration sites and obtaining power for the new sites will be addressed during the detailed design process.

An emergency generator with fuel storage is typically installed at the site, inside the fenced area.
Two cables routes (aerial and/or buried) between the transmission ROW and the equipment shelter will be required. A permanent access road to each fiber regeneration site will be required. These access roads will also be used for permanent access to the transmission lines and should be included in the access road numbers for the HVDC and HVAC transmission lines.

Metal Return Conductor (MRC)

Size (kcmil/AWG):	1780 kcmil
Composition (ACSR, AAC, etc.):	ACSR
Code Word:	Chukar
Diameter:	1.602 inches
Weight:	2.075 lbs/ft
Rated Breaking Strength:	51,000 lbs
Design Voltage:	104 kV HVDC
Typical Operating Voltage:	104 kV HVDC
Maximum Operating Voltage:	109 KV HVDC
Maximum Conductor Temperature (Temperatures calculated using IEEE 738 methodology for predicted line loadings under normal and emergency conditions):	$I_{MRC} = I$ pole/2=3630/2=1815 A: 117 Deg C (242 Deg F)

Appendix P lists the required Metal Return Conductor clearances while appendix Q presents the Metal Return Conductor selection analysis.

WIRES FOR MISSISSIPPI RIVER CROSSING SPANS

Transmission Conductor- FOR MISSISSIPPI RIVER CROSSING SPANS

Size (kcmil/AWG):	1622 kcmil
Composition (ACSR, AAC, etc.):	ACCR-TW_1622-T13
Code Word:	Pecos (this trap wire is diameter equivalent to round wire Martin)
Diameter:	1.417 inches
Weight:	1.774 lbs/ft
Rated Breaking Strength:	55500 lbs
Design Voltage:	600 kV HVDC
Typical Operating Voltage:	600 kV HVDC
Maximum Operating Voltage:	632 KV HVDC
Maximum Conductor Temperature (Temperatures calculated using IEEE 738 methodology for predicted line loadings under normal and emergency conditions):	Normal Regime: Emergency Regime: I_{PC} =I pole/3=3630/3=1210 A: 82 Deg C (180 Deg F)

The ampacity calculations and corresponding MOTs are presented in attached Appendices F& F1 - Ampacity calculations 2014; Appendix F2- Ampacity Calculations 2015-for River Crossing.
The comparison leading to the selection of the ACCR/TW Pecos wire is shown in Appendix G, titled Mississippi River Crossing-Conductor Comparison and Selection.

OPGW - FOR MISSISSIPPI RIVER CROSSING SPANS

Like the main line, there will be two OPGW, one to protect each pole. But the OPGE design for the Mississippi River Crossing, is different than the OPGW for the rest of the line, due to the fact the OPGW for the river crossing has to go over a very long span, so a special OPGW design is required, with high CTZFS (over 80%) and CSFZFS (over 0.55%), even for a span of 4000' or more.

Size (kcmil/AWG):	161 ACS-2C
Composition (EHS, AW, etc.):	17 Aluminum Clad Steel Wires ACS20.3% IACS 2 Stainless Steel Tubes 304 containing 6-24 fibers each and gel
Diameter:	0.646 inches
Weight:	0.678 lbs/ft
Rated Breaking Strength:	38,079 lbs
Number of Fibers:	12-48, depending on final project requirements

Metal Return Conductor (MRC) - FOR MISSISSIPPI RIVER CROSSING SPANS

Size (kcmil/AWG):	1622 kcmil
Composition (ACSR, AAC, etc.):	ACCR/TW_1622-T13
Code Word:	Pecos
Diameter:	1.417 inches
Weight:	1.774 lbs/ft
Rated Breaking Strength:	55,500 lbs
Design Voltage:	114 kV HVDC
Typical Operating Voltage:	114 kV HVDC
Maximum Operating Voltage:	120 KV HVDC
Maximum Conductor Temperature (Temperatures calculated using IEEE 738 methodology for predicted line loadings under normal and emergency conditions):	I_{MRC} =I pole/2=3630 A/2=1815 A: 128 Deg C (262 Deg F)

Information pertaining to the type of MRC selected for Mississippi river crossing is in appendix G1-Mississippi river crossing-metal return conductor comparison and selection and appendix P1-Mississippi river crossing-metal return conductor clearances tables.

Notes:

1) The ACCR/TW Pecos conductor has a different maximum conductor temperature when it is used as pole conductor vs. when it is used as metal return conductor, due to the different ampacity for each case.

- Pole Conductor:
  - I conductor=I pole/3=3630/3=1210 A, with MOT=82 C (180 F)
- Metal Return Conductor:
  - I conductor=I pole/2=3630/2=1815 A, with MOT=128 C (262 F)

2) The Metal Return Conductor ACSR Chukar used on the entire line (except Mississippi River Crossing) will be energized at +/- 104 KV, and its required clearances are provided in Appendix P, while the Metal Return Conductor ACCR/TW Pecos used on the Mississippi River Crossing will be energized at +/-114 kV, and its required clearances are provided in Appendix P1.

CONDUCTOR RATING CRITERIA

The following table summarizes conductor ampacity calculated using IEEE 738 methodology under the maximum loading conditions, using the following assumptions:

Ambient air temperature = 40 deg C (104 deg F), Wind Speed=2 ft/s, Emissivity factor = 0.5; and Solar absorptivity factor = 0.5 (expect for conductors "with special coating", for which Emissivity factor = 0.9; and Solar absorptivity factor = 0.2).

See Appendix F (Ampacity Calculations 2014), F1 (Ampacity Calculations 2015) & F2 (River Crossing Ampacity Calculations 2015), for other parameters used in these calculations, and the resulting maximum operating temperatures for the conductors analyzed.

Please note that an analysis was included to compare any potential to alter the project design by using an optional coating system available from General Cable. While the data required for that analysis is included in some of the appendices, the alternative was not deemed cost effective due to the relatively cool operating temperatures on the line.

Circuit	Conductor	Voltage (kV)	Maximum Line Ratings			
			Winter		Summer	
			MW	Amps	MW	Amps
Plains & Eastern	ACSR Bluebird 3 sub-conductors per pole	Nominal: 600 Maximum: 632	4356 At rectifier	3630 Per pole 1210 Per sub-conductor	4356 At rectifier	3630 Per pole 1210 Per sub-conductor
Plains & Eastern Mississippi River Crossing Span	ACCR-TW Pecos 3 sub-conductors per pole	Nominal: 600 Maximum: 632	4356 At rectifier	3630 Per pole 1210 Per sub-conductor	4356 At rectifier	3630 Per pole 1210 Per sub-conductor

WIRE SAG/TENSION LIMITS

Conductor and Metalic Return Conductor Sag-Tension Limits for main line.
The following table summarizes all sag-tension limits considered. The most stringent limit will be utilized to control the sag-tension in each span, or an agreed upon control tension will be used that will also meet the requirements below. See Appendices E & E1-Sag & Tension Files.

Weather Case				Sag or Tension Limit		
Wind (psf)	Ice (inches)	Temp (°F)	Cond.	NESC Limit	South wire Sag10 Program Limit	Project Specific Limit
4	0.5	0	I	60% RBS	50% RBS	50% RBS
4	0.25	15	I	60% RBS	50% RBS	50% RBS
20.74	0	60	I	--	--	75% RBS
4.1	1	15	I			75% RBS
0	0	60	I	35% RBS	--	--
0	0	60	F	25% RBS	--	-
0	0	0	I	--	33.3% RBS	33.3% RBS
0	0	0	F	--	25% RBS	25% RBS
0	0	-20	I	--	--	Uplift Condition
4	0.5	0	I	--	--	Slack Tension Into Substation D.E. Frame. 5000 lbs maximum per sub-conductor. Max per HVDC pole = 5000 lbs x no. of sub-conductors.
4	0.25	15	I	--	---	
20.74	0	60	I	--	--	
4.1	1	15	I	--	--	

Conductor and Metallic Return Conductor Sag-Tension Limits - for river crossing spans.
The following table summarizes all sag-tension limits considered. The Mississippi River Crossing Span is about 5000 ft. The most stringent limit will be utilized to control the sag-tension in each span, or an agreed upon control tension that will also meet the requirements below. See Appendices E & E2-Sag & Tension Files.

Weather Case				Sag or Tension Limit		
Wind (psf)	Ice (inches)	Temp (°F)	Cond.	NESC Limit	Southwire Sag10 Program Limit	Project Specific Limit
4	0.5	0	I	60% RBS	50% RBS	50% RBS
4	0.25	15	I	60% RBS	50% RBS	50% RBS
20.74	0	60	I	--	--	75% RBS
4.1	1	15	I			75% RBS
0	0	60	I	35% RBS	--	--
0	0	60	F	25% RBS	--	-
0	0	0	I	--	33.3% RBS	33.3% RBS
0	0	0	F	--	25% RBS	25% RBS
0	0	-20	I	--	--	Uplift Condition

OPGW Sag-Tension Limits

The following table summarizes all sag-tension limits considered. The most stringent limit will be utilized to control the sag-tension in each span, or an agreed upon control tension will be used that will also meet the requirements below. See Appendices E, E1,-Sag & Tension Files.

Weather Case				Sag or Tension Limit		
Wind (psf)	**Ice (inches)**	**Temp (°F)**	**Cond.**	**NESC Limit**	**South wire Sag10 Program Limit**	**Project Specific Limit**
4	0.5	0	I	60% RBS	50% RBS	50% RBS
4	0.25	15	I	60% RBS	50% RBS	50% RBS
20.74	0	60	I	--	--	60% RBS
4.1	1	15	I			60% RBS
0	0	60	I	35% RBS	--	--
0	0	60	F	25% RBS	--	<= 85% of the Conductor Sag at the Same Loading Condition
0	0	0	I	--	33.3% RBS	33.3% RBS
0	0	0	F	--	25% RBS	25% RBS
0	0	-20	I	--	--	Uplift Condition
4	0.5	0	I	--	--	Slack Tension Into Substation D.E. Frame. 3000 lbs maximum per OPGW
4	0.25	15	I			
20.74	0	60	I	--	--	
4.1	1	15	I	--	--	

<u>OPGW to Conductor Sag Ratios Requirements </u>(to ensure shielding angles are maintained):

OPGW Sag @ 60 F, No Wind, No Ice, Final <= 85% Conductor Sag @ 60 F, No Wind, No Ice, Final

OPGW Sag @ 32 F, No Wind, **0.5" Ice**, Final <= **95%** Conductor Sag @ 32 F, No Wind, **No Ice**, Final

The second ratio at 32 F with Ice vs. 32 F without ice (95%) controls the sag and tension of OPGW. See Appendices E, E1 -Sag and Tension Files.

OPGW Sag-Tension Limits – FOR RIVER CROSSING SPANS

The following table summarizes all sag-tension limits considered. The Mississippi River Crossing Span is about 5000 ft. The most stringent limit will be utilized to control the sag-tension in each span, or an agreed upon control tension that will also meet the requirements below. See Appendices E, E2-Sag & Tension Files.

Weather Case				Sag or Tension Limit		
Wind (psf)	**Ice (inches)**	**Temp (°F)**	**Cond.**	**NESC Limit**	**Alcoa Sag10 Program Limit**	**Project Specific Limit**
4	0.5	0	I	60% RBS	50% RBS	50% RBS
4	0.25	15	I	60% RBS	50% RBS	50% RBS
20.74	0	60	I	--	--	75% RBS
4.1	1	15	I			75% RBS
0	0	60	I	35% RBS	--	--
0	0	60	F	25% RBS	--	<= 85% of the Conductor Sag at the Same Loading Condition
0	0	0	I	--	33.3% RBS	33.3% RBS
0	0	0	F	--	25% RBS	25% RBS
0	0	-20	I	--	--	Uplift Condition

OPGW to Conductor Sag Ratios Requirements (to ensure shielding angles are maintained):

OPGW Sag @ 60 F, No Wind, No Ice, Final <= 85% Conductor Sag @ 60 F, No Wind, No Ice, Final

OPGW Sag @ 32 F, No Wind, **0.5" Ice**, Final <= 95% Conductor Sag @ 32 F, No Wind, **No Ice**, Final

The second ratio at 32 F with ice vs 32 F without ice (95%) controls the sag and tension of OPGW. See Appendices E, E2, E3-Sag and Tension Files.

Creep-Stretch Criteria

Condition for Final Sag after Load (Common Point):	NESC Heavy Rule 250 B: 0 Deg F, 4 PSF Wind, 0.5" Ice; k=0.3 (for Oklahoma State only)
	NESC Medium Rule 250 B: 15 Deg F, 4 PSF Wind, 0.25" Ice; k=0.2 (for Arkansas and Tennessee States only)
Condition for Final Sag after Creep:	60 Deg F, No Wind, No ice

Galloping

Double-loop galloping will be assumed for spans greater than 600 feet. Single-loop galloping will be assumed for spans less than 600 feet. Galloping ellipses will be allowed to overlap up to 10% of the elliptical major axis.

The weather case used to calculate swing angle used during galloping analyses will be 2 psf wind, 1/2" ice, 32°F final. The weather case used to calculate the ellipse size will be 0 psf wind, 1/2" ice, 32°F final.

Aluminum in Compression

It will be assumed that outer aluminum strands can go into compression under high temperature.

For ACSR and ACCR conductors, that is over 100 C (212 F).

The ACSR Bluebird (used as a pole conductor, for entire line, except for Mississippi River Crossing), does not follow "aluminum can go into compression" model, because its MOT (Maximum Operating Temperature), under both normal and emergency regime, does not go over 100 C (212 F).

The ACSR Chukar (used as metal return conductor for entire line, except Mississippi River Crossings), does follow "aluminum can go into compression" model, because its MOT (Maximum Operating Temperature), under both normal and emergency regime, does go over 100 C (212 F).

Note: The MRC will reach such high temperatures, over 100 C (212 F), only if one entire pole (positive or negative) is lost, in normal regime or emergency regime, with all its 3 sub-conductors, in which case, the current that was supposed to go through the 3 sub-conductors of that pole, will be split between the 2 MRCs. The probability of this to happen is very low, and even if it will ever happen, it will be just for a short period of time, up until the lost pole (positive or negative) will be repaired.

Under Emergency Case, the MRC ACSR Chukar MOT=242 F > 212 F, therefore the conductor model must be: " Aluminum can go into compression" (does not bird-cage).
Plus, being an ACSR conductor with % steel area: (At- Ao)/A t= (1.5126-1.3986)/1.5126*100=7.5%, and MOT over 212 F, it will have also "High Temperature Creep".

No issues there, for both "aluminum can go into compression" and "high temperature creep", several major US Utilities allow ACSR Conductors, during Emergency Regime, to reach maximum MOT=284 F (140 C), higher than it will be in this DC line application: 242 F (117 C). Of course, taking into consideration the model with "aluminum can go into compression" and "high temperature creep", the sag will be larger at MOT=242 F.

The ACCR/TW Pecos, when used as pole conductor in Mississippi River Crossing Spans, does not follow "aluminum can go into compression" model, under emergency regime: I cond=I pole/3=3630 A/3=1210 A because its MOT (Maximum Operating Temperature)=82 C (180 F), does not go over 100 C (212 C),

The ACCR/TW Pecos, when used as metal return conductor in Mississippi River Crossing Spans, does follow "aluminum can go into compression" model, under emergency regime: I mrc =I pole/2= 3630 A/2= =1815 A because its MOT (Maximum Operating Temperature)=128 C (262F), does go over 100 C (212 C),

The ACCR/TW Pecos when used as both pole conductor and metal return conductor in Mississippi River Crossing Spans, does not follow aluminum can go into compression" model under the normal regime, because in normal regime it does not go over 100 C (212 C).

Note: The ACCCR/TW Pecos, will still have its MOT, under both normal and emergency regime, under its limits imposed by the manufacturer (3 M) : 210 C (410 F), under normal regime, and 240 C (464 F), under emergency regime.

The maximum virtual compressive stress for ACSR Chukar, to be used in aluminum can go into compression" model is: 1.5 kpsi*($A_{AL\ outer}$/ A_{total})=1.5*1.3986/1.5126=1.387 kpsi

The maximum virtual compressive stress for ACSSR/TW Pecos, to be used in aluminum can go into compression" model is:

- Theoretical: 1.5 kpsi*($A_{AL\ outer}$/ A_{total})=1.5*1.274/1.437=1.329 kpsi

- Practical: based on manufacturer (3M) extensive testing of high temperature sag, the value that 3M found that it will give temperature sag results that are consistent with these extensive tests, is:
    - EF o actual=1.45 ksi
    - EF virtual=(ARo/AT)*EF o actual
    - EF virtual=0.862*1.45=1.25 ksi

Therefore, in PLS-CAD wire file model for ACCR/TW Pecos, when used as MRC, in emergency regime, the virtual stress value used is: 1.25 ksi.

STRUCTURES

Circuits

No. Circuits (Single or Double):	2-Pole Horizontal HVDC with 2 Dedicated Metallic Return Conductors (MRC)
Bundled:	3 conductors per bundle (positive pole and negative pole)
Guyed or Self-Supporting:	Potential both guyed and self-supporting structures

Material

Wood (DF, WRC, preservative):	Do not consider wood
Steel (self-weathering, painted, galv.):	Potential weathering steel and galvanized steel
Concrete:	Potential concrete
Other:	

Configuration

Single Pole:	Potential single pole structure types: • Self-supporting Steel Tubular • Self-supporting Concrete
H-Frame	No
3-Pole:	No
Lattice:	Consider the following lattice tower types • Self-supporting Steel Lattice, • Guyed Single Mast or Vee
Other:	Consider the following additional structure types: • Cross Rope Suspension, Guyed Steel Lattice (with two foundations) • Cross Rope Suspension, Guyed Steel Lattice (Vee Configuration with a single foundation) • Guyed Single Mast or Vee Tubular Steel

Are Transposition Structures Required: YES ☐ NO ☑

Foundations

Type:	Drilled Pier
Geotechnical Data Available:	YES ☐ NO ☑
Geotechnical Study Required:	YES ☑ NO ☐ Desktop geotechnical study was performed during the conceptual design phase to determine soil types that may be encountered along the line and to classify them into several primary groups with typical soil design parameters to allow for estimated designs for budgetary purposes. A secondary data mining effort may be used to further refine the geotechnical assumptions used for estimating foundation designs during the preliminary design phase.
Design Criteria for Foundations subject to Lateral Loads	Drilled piers and direct embed poles subject to lateral loads will be designed per POWER standard as shown in Appendix K.
Design Criteria for Foundations subject to Uplift/Compression	Drilled piers and direct embed poles subject to uplift/compression loads will be designed per POWER standard as shown in Appendix K.

Loads ______________________________

Calculated Lightning Outages

Calculated outages from lightning will not exceed 1 outage per 100 miles per year per HVDC pole.

Appendix C lists the Lightning Algorithm used to check the OPGW while Appendix D shows the outer layer's wire required diameter calculation based on expected lighting charge at line location.

Distance between Deadends

A deadend structure will be placed approximately every 10 miles.

But a dead end structure will be used anyway for any line angle over 30 degrees.

The suspension structures will be used only for line angles under or equal with 30 degrees.

Other

Shield Angle (If Required): Inside: Maximum 15 degrees Outside: Maximum 15 degrees

Raptor Protection: YES ☐ NO ☐ Distance: APLIC (51" ht x 71" span)

Maximum or Minimum Pole Height Limitations (specify): TBD

Anodes Required: YES ☐ NO ☐ TBD

GUYS AND ANCHORS

Guys

Guy Strand (size, material):	TBD
Guy to Pole Attachment:	
Pole Eye Plate:	TBD
Pole Band:	TBD
Guy Hook:	TBD
Other:	
Guy Connection	
Pole Attachment:	
Preformed:	TBD
3-Bolt:	TBD
Automatic:	TBD
Other:	
@ Anchor:	
Preformed:	TBD
3-Bolt:	TBD
Automatic:	TBD
Other:	

Guy Strain Insulators

Type: TBD

Guy Guards
Locations Required: TBD
Plastic: TBD Metal: TBD
Color: TBD Cattle Stub: TBD
Other (describe):

Anchors
Type:

Plate: N/A Size: N/A
Screw: TBD Size: TBD
Log: N/A Size: N/A
Concrete (describe): TBD
Other (describe): TBD
Rod: Length: TBD Diameter: TBD
Anodes Required: YES ☐ NO ☐ TBD

HARDWARE

Deadend Attachment

Description	Bolted	Compression	Other (describe)
Transmission Conductor [1]		X	
Shield Wire		X	
OPGW	X		Preformed

[1]Corona free hardware required: YES ☑ NO ☐

Suspension Attachment

Description	Formed Tie	Trunion Clamp	Suspension Clamp	Armor Rod	Line Guard	AGS	Other (Describe
Transmission Conductor [1]	N/A	N/A	TBD	TBD	N/A	TBD	
Shield Wire	N/A	N/A	TBD	TBD	N/A	TBD	N/A
OPGW	N/A	N/A	TBD	TBD	N/A	TBD	

[1]Corona free hardware required: YES ☑ NO ☐

Bracing

Transmission:

Wood: N/A Steel: TBD

Other (describe): ______

Vibration Analysis

For preliminary cost estimating, vibration analysis will be performed using Vibrec software (AFL), Vortex software (PLP), or Select 4R-Fargo software (Hubbell). For final design, vibration analysis would be performed by the damper supplier.

- At 89 mm=3.5 in from end of suspension clamp, the Maximum Allowed Endurance Limits, per EPRI Orange Book, are:
  - Maximum Allowed Bending Strain=125 microns/m (0-to-Peak) (ACSR conductors)
  - Maximum Allowed Bending Amplitude=240 microns=10 mills (Peak-to-Peak)
  - Maximum Allowed Bending Stress: Sigma a =22 MPa=3190 psi
- Endurance Limit: f*Y max=118 mm/sec=4.65 in/sec (per EPRI Orange Book, for all ACSR Conductors, except 7/1 strands)
- Per EPRI Orange Book "Transmission Line-Wind Induced Conductor Motion", For ACSR Bluebird (Entire Line) Maximum Allowed Bending Amplitudes are:
  - At 15%RBS: Y_B=0.28 mm=11 mills
  - At 25%RBS: Y_B=0.24 mm=10 mills
  - At 35%RBS: Y_B=0.22 mm= 9 mills

Note: the same maximum allowed amplitudes will be applicable also for the ACCR/TW Pecos (used for Mississippi River Crossing).

Spacer Requirements

Spacer dampers will be utilized on conductors and will be installed such that:

- The spacer dampers will be spaced symmetrically in each span with a maximum spacing of 200 ft, or, preferably, asymmetrically, with 10-15% detuning, with maximum sub-span of 200 ft, minimum sub-span 100 ft, ratio of adjacent sub-spans=0.8 to 0.9, first and last sub-spans=0.5*(maximum sub-span), per CIGRE rules.
- Number of spacer dampers that will be installed in jumper strings: three (if 2 jumper strings are used-rectangle cross arm) or two (if 1 jumper string is used-triangle cross arm); two spacer dampers will be used in the jumper loop. The spacer dampers will be equally spaced between the deadends.

INSULATION

Type-Transmission	
I-String:	Considered, but Not Chosen.
V-String:	Considered; Currently Preferred Configuration.
Horizontal Post:	N/A
Horizontal Vee:	N/A
Horizontal Jumper Post:	N/A
Vertical Jumper Post:	N/A

Material Transmission	
Porcelain:	Considered, but Not Chosen
Glass:	Considered; Currently Preferred Material
Polymer:	Considered, but Not Chosen.
Other (fog, etc.):	To Be Considered
Corona Rings:	To Be Considered
End Fittings:	To Be Considered

Insulation Ratings-Transmission

M&E Strength (lbs)	Electrical Characteristics *			
	DC Withstand Voltage*		Dry Lightning Impulse Withstand Voltage (kV)	DC SF6 Puncture Withstand Voltage (kV)
	Dry one minute (kV)	Wet one minute (kV)		
25K	125	60	140	225
40K	150	65	140	225
50K	140	60	135	225
66K	140	60	135	225
90K	160	70	140	225
120K	160	70	140	255

Data based on the following toughened glass, ball & socket coupling, Sediver's DC fog type bells, all used, in different assemblies and configurations, in the different structure types (towers and poles) of this +/- 600 kV DC Transmission Line:

- 25 kips (N120PR/C 146 DR)
- 40 kips (N180P/C 160 DR)
- 50 kips (N220PJ/C 180 DR)
- 66 kips (F300PJ/C 195 DR)
- 90 kips (F400PQ/C 205 DR)
- 120 kips (F550/C 240 DR)

*Electrical characteristics in accordance with IEC 61325.

Bells Type Testing and Insulator Assemblies (Bells + Hardware) Type Testing will be performed per "PECL DC Insulator Assembly Testing Specification-Rev. G":

- Bells Type Testing: ,per IEC 61325 and ANSI C29.1
- Hardware Type Testing: per IEC 61284
- Insulator Assembly (Bells + Hardware):
    - Corona test and RIV (Radio Interference Voltage) Test: per IEC 60437
    - Pollution Test (DC Fog Withstand Test): per IEC 61245 (separate "Medium" & "Light" Pollution)
    - Rain (Wet) Withstand Voltage Test: per IEC 60060-1 & IEEE-4
    - Dry Lightning Impulse Voltage Test: per IEC 61325 & IEC 60060-1
    - Wet Switching Impulse Voltage Test: per IEC 60060-1

Additional required parameters regarding the insulators are presented in attached Appendices:
Appendix AA- Design Assumptions, Appendix AC-Clamp and Insulator Parameters
Appendix AD1and AD2- Insulator Assembly Types ("Medium" and "Light" Pollution)
Appendix AF-Tower and Pole Insulator Loading Check
Appendix AG-Required Clearances and Corresponding Insulator Swing Angles
Appendix AO1- Insulator, Jumper String, Jumper Loop Swing Angle Calculations-Towers
Appendix AO2- Insulator, Jumper String, Jumper Loop Swing Angle Calculations-Poles
Appendix P2- MRC Voltage Drop Calculation
Appendix P3-MRC Voltage Drop Calculation-River Crossing
Appendix P4-MRC Required Number of Bells Calculation
Appendix P5-MRC Required Number of Bells Calculation-River Crossing

RIGHT-OF-WAY

Description

Location of Line in ROW:	Assumed center
ROW Width:	Assumed 175' based on 1500' typical spans.

Right-of-Way Width Calculations for Blowout

Load Case 1:	0 PSF, No Ice, All Temperatures, Final (NESC 234 A.1)
Load Case 2:	6 PSF, No Ice, 60°F, Final (NESC 234 A.2)
Load Case 3:	Extreme Wind 20.74 psf, No Ice, 60°F, Final

Minimum clearances to be maintained from the blown out conductor to the edge of right-of way shall be as follows. Load Cases 1 and 2 are based on maintaining NESC clearance to buildings. See NESC 234 B. Clearances for Load Case 3 are not governed by NESC. This case is a criteria designed to keep the conductors on the right-of-way under an extreme wind. These clearances include a 3' buffer to accommodate survey and construction tolerances.

For required clearances to the ROW, see also Appendix A- Clearances Calculation Tables.

	Clearance for ±600 kV nominal & ±632 kV maximum
Load Case 1	25 ft*
Load Case 2	22 ft*
Load Case 3	0 ft – May vary by location

*See Appendix A- Clearances Calculation Tables.

The maximum structure deflection, including foundation rotation, for single shaft steel structures will be assumed at 9% of structure above ground height for Load Case 3 and 5% for Load Case 2. For lattice towers the maximum structure deflection will be assumed at 1% of the structure above ground height.

Electric Field Affects

Electric field calculations will be prepared using the Corona and Field Affects Program (CAFEP) developed by the Bonneville Power Administration. The calculations will be based on a maximum line to line voltage of the nominal 600 kV plus 5% (or 632 kV) at the sending end. Typical approximate structure configurations will be used along with a sample of the possible conductor bundling scenarios. Calculated values will be compared to the limits listed below as a reference. Note that Kansas, Missouri, and Illinois do not have any published limits.

IEEE Standard C95.6-2002 Limits

- Maximum E-field at edge of right-of-way: 5 kV/m
- Maximum E-field on the right-of-way: 20 kV/m

Corona

POWER will prepare corona effects calculations using the CAFEP software and the same scenarios as the electric field calculations. Clean Line Energy will provide the audible noise (AN) and AM radio interference voltage (RIV) limits to be maintained at the edge of right-of-way. If no values are provided, the typical industry guidance of 40 dB (100 μV) will be used for RIV and the EPA recommendation of no greater than 55 dBA (563 μV) will be used for AN. All values are calculated at the edge of the right-of-way.

In addition, the corona losses along the line will be calculated manually for the same scenarios as above. The calculations will assume a line length of 700 miles as the specific line length is yet to be determined.

CLEARANCES

All clearances, for Pole Conductor (PC), will be determined using 600 kV DC, nominal, pole-to-ground, and 632 kV DC, maximum, pole-to-ground.

For Pole Conductor (PC), for comparison purposes, clearances were calculated using an "AC equivalent" voltage of 735 KV, resulted from:

600 kV DC, peak, nominal, pole-to-ground is equivalent to:

600*sqrt(3)/sqrt(2)= 735 kV AC, rms, nominal, phase-to-phase.

All clearances, for Metal Return Conductor (MRC), will be determined using 104 kV DC, nominal, pole-to-ground, and 109 kV DC, maximum, pole-to-ground.

For Metal Return Conductor (MRC), for comparison purposes, clearances were calculated using an "AC equivalent" voltage of 127 KV, resulted from:

104 kV DC, peak, nominal, pole-to-ground is equivalent to:

104*sqrt(3)/sqrt(2)= 127 kV AC, rms, nominal, phase-to-phase.

All clearances, for Metal Return Conductor (MRC), ACCR/TW Pecos, used in Mississippi River Crossing Spans, it will be determined using 114 kV DC, nominal, pole-to-ground, and 120 kV DC, maximum, pole-to-ground.

For Metal Return Conductor (MRC), for comparison purposes, clearances were calculated using an "AC equivalent" voltage of 140 KV, resulted from:

114 kV DC, peak, nominal, pole-to-ground is equivalent to:

114*sqrt(3)/sqrt(2)= 140 kV AC, rms, nominal, phase-to-phase

See Appendix A-Pole Conductor Clearances Calculation Table and Appendix P-Metal Return Conductor Clearances Calculation Table (ACSR Chukar –Voltage=104 KV) and Appendix P1- Metal Return Conductor Clearances Calculations Table (ACCR/TW Pecos-Voltage=114 kV).

Voltage System

All systems are considered effectively grounded or systems where ground faults are cleared by promptly de-energizing the faulted section, both initially and following subsequent breaker operations. The maximum operating voltage is the normal voltage plus 5%.

Clearance to Structure/Insulator Swing

The maximum and minimum insulator swings will be limited by minimum clearances required to the structure. This clearance will be to the arm, tower body, or to the pole. The load cases considered for insulator swing as it relates to clearance to structure will be as follows:

Load Case 1:	0 PSF Wind, No Ice, All Temperatures, Final
Load Case 2:	6 PSF, No Ice, 60°F, Final (NESC 235 E.2)
Load Case 3:	Extreme Wind, No Ice, 60°F, Final

Minimum clearances to be maintained from the closest line conductor or other hot element to the face of the metal structures shall be as follows:

	Clearance for Pole Conductor (PC) ±600 kV nominal & ±632 kV maximum to Own Structure	Clearance for Metal Return Conductor (MRC) ± 104 kV nominal & ±109 kV maximum to Own Structure
Load Case 1	13.5 ft	2 ft
Load Case 2	13.5 ft	2 ft
Load Case 3	5 ft	0.90 ft

Load Case 1, Load Case 2, Load Case 3 required clearance is based on necessary air gap equivalent (dry arc distance) under to following combination of mechanical and electrical parameters:

- Case 1: best mechanical: no wind, with worst electrical: lighting impulse withstand voltage.
- Case 2: medium mechanical: medium wind, with medium electrical: switching impulse withstand voltage.
- Case 3: worst mechanical: extreme wind, with best electrical: steady state, normal regime.

Load Case 1 and Load Case 2 clearance based on NESC Rule 235 E.

Important Note:

Load Case 1 and 2 minimum clearances were NOT increased to 17.33' to meet IEEE 516-2009 MAD (Minimum Approach Distance) for tools (12.33') and the Working Space (4.5').

Live Line Maintenance was considered at the conceptual design stage, and the clearance requirements are noted in this document. However, Live Line Maintenance clearance requirements are no longer included in the structure geometry and design calculations. If maintenance work is necessary on a pole, that pole must be de-energized.

The line will still function in mono-pole regime (the other pole will still be energized).

Load Case 3 based on EPRI T/L Reference Book +/ -600 KV HVDC Lines where the mechanical case Extreme Wind corresponds to the electrical case Steady State , normal regime, Figure 10-3 page 145 and Fig.10-4, Page 146: 4.1', to which it was added a buffer of 0.9'.

See also for detailed clearance calculations attached Appendix A-Clearances Calculation Tables.

Ground Clearance

NESC: 34' (w/3' buffer) (See Appendix A-Clearances Calculation Tables).
REA: N/A
Other: N/A

Water Clearance for River Crossing Spans

NESC: 55' (w/3' buffer) (See Appendix A- Water Clearances Calculation Tables).
REA: N/A
Other: N/A

The water clearance was determined based on NESC Rule 232D, Table 232-3, f (DC Calculation) and NESC Rule 232, Table 232-1, 7 (AC Equivalent Calculation). It might change, based future requirements from the Corps of Engineers, or other regulators.

5 miliAmp Rule

This rule, NESC Rule 232.C.1.c, does not apply to HVDC lines because a DC line will not create a steady-state current as occurs with AC lines.

Clearance Between Wires on Different Supporting Structures

NESC:	Horizontal: 35 ft (w/3 ft buffer); Vertical: 28 ft(w/ 3 ft buffer) (Reference NESC Rule 233)
REA:	N/A
Other:	N/A

Clearance to Structures of Another Line

NESC:	Horizontal: 21.2 ft (at rest): 21.7' (displaced under 6 psf wind) (w/3 ft buffer) Vertical: 21,7 ft (w/3 ft buffer) (Reference NESC Rule 234B, 24C, 234D, 234E, 234G1)
REA:	N/A
Other:	N/A

Horizontal Clearance Between Line Conductors at Fixed Supports

CASE 1: The Horizontal clearance at the structure, of the same or different circuits, shall be per NESC 235B.3.a Alternate Clearance: Pole-to-Pole (horizontal configuration): 34.8' (w/3' buffer).

CASE 2: The Horizontal clearance at the supports, of the same or different circuits, shall also meet requirements according to sags per NESC 235B.1.b(2) :Pole-to-Pole (horizontal configuration): 27' (w/3' buffer).

CASE 3: Galloping

Refer to section titled "Galloping".

Vertical Clearance Between Line Conductors

Note: the poles (conductors) of the DC lines will be located horizontally, so these vertical clearances are just theoretical. Only the distance Pole Conductor to OPGW and Pole Conductor to MRC, will be a vertical clearance.

CASE 1: Pole-to-Pole (if they are located in vertical configuration): 30 ft (w/3' buffer).
Pole-to-OPGW: 19 ft (w/3' buffer).The Vertical clearance at the structure shall be per NESC 235C. Reference NESC Table 235-5.

CASE 2: Pole-to-Pole (if they are located in vertical configuration): 30 ft (w/3' buffer).

Pole Conductor-to-OPGW:	19 ft (w/ 3' buffer) (at support); 18.5 ft (w/ 3' buffer) (in span);
Pole Conductor-to-MRC:	21.5 ft (w/3' buffer) (at support); 21.0 ft (w/ 3' buffer) (in span)
MRC-to-OPGW:	5 ft (w/ 1' buffer) (at support); 4.0 ft (w/ 1' buffer) (in span)

Vertical clearances at the structure shall be adjusted to provide sag-related clearances at any point in the span per NESC 235C.2.b. The sag-related clearances in the span are considered as diagonal clearances.

CASE 3: Galloping

Refer to section titled "Galloping".

Radial Clearance from Line Conductors to Supports, and to Vertical or Lateral Conductors, Span or Guy Wires Attached to the Same Support

NESC: To supports: 13.5' per NESC Rule 235 E, under both no wind and 6 psf wind (see for details Appendix A-Clearances Calculation Tables)

The "Live Line Maintenance values are no longer a design requirement, but are provided below for reference:
17.33' (MAD for Tools"12.33 per IEEE 516-2009+Working Space: 4.5' per NESC Rule 236&237)

To anchor guys: 16.9' per NESC235E, 4 b., where 600 kV, dc equivalent to 735 kV ac.

REA:	N/A
Other:	N/A

Clearances of the Metal Return Conductors

For Clearances of the Metal Return Conductor , see Appendix P (for entire line, except Mississippi River Crossings; used ACSR Chukar energized at +/- 104 kV) and Appendix P1 (for Mississippi River Crossings; used ACCR/TW Pecos energized at +/-114 kV).

MISCELLANEOUS

Grounding Requirements (type and frequency of grounding required)

Ground Type:

Butt Plate:	N/A
Butt Wrap:	N/A
Ground Rod:	To be used.
Other:	

Frequency of Grounding:

All Structures:	Yes
No. Per Mile:	TBD
Maximum Resistance per Structure (ohms):	10
Other:	

Special Equipment

Describe any special equipment requirements (switches, fiber optic materials, distribution underbuild, reclosers, etc.):

Splice boxes for the OPGW fibers will be used at the splice structures where an OPGW reel will finish, and at certain dead-end structures. Underground loose tube (LT) type fiber optic cable will be used from the last structure to the substation. The fibers from this underground fiber optic cable will be spliced to the fibers from the OPGW inside the splice box located on the last structure before the substation.

Material

Describe Owner supplied material (attach additional sheets if necessary):

Does the utility have a standard material list it uses: YES ☐ NO ☐

Describe Contractor supplied material (attach additional sheets if necessary) :

Environmental Protection

State any measures required or agencies to be contacted for wildlife protection requirements:

Describe any known industrial, salt-water contamination or other environment that may impact or has been known to impact electrical insulation:

____

State any measures required for airborne contamination protection (dust control):

____
____
____

Describe any known caustic or corrosive soil conditions:

____
____
____

DRAWINGS AND MAPS

Maps

Existing facility maps, P&P's available: YES ☐ NO ☐

List foreign utilities to be considered for project, if maps are available:

Power:	____________	Gas:	____________
Phone:	____________	TV:	____________
Sewer:	____________	Water:	____________
Highways:	____________	Railroad:	____________
Other:	____________		

Separate access road maps required: YES ☐ NO ☐

Describe ROW/Environmental or Easement Maps required, if any:

____
____
____

Drawing Requirements

Map and Plan and Profile Scales:

Key Map Scale: ____________ **horiz.**

Plan Scale: ____________ horiz.

Profile Scale: ____________ vert. Size: ____________ horiz.

Plan Type:

Planimetric: ____________

Topographic: ____________

Other: ____________

Title Block:

POWER Standard: ____________

Other: ____________

Drawing Numbers:

POWER Generated: ____________

Owner Generated (describe): ____________

Final Drawings: ______________________

Describe structure numbering sequence:

Describe any controlling mapping specifications:
All coordinates will be based on various State Plane systems, as required. Vertical datum is based on NAVD 88.

SUBSTATION/SWITCHYARD INTERFACE

Terminate at existing substation entry structure: YES ☐ NO
Comments: ______________________

Maximum allowable tensions for substation deadend:

Conductor:	5000 lbs (assumed, no station data available)
OPGW/OHGW:	3000 lbs (assumed, no station data available)

Attachment height above ground substation deadend:

Conductor:	TBD (no station data available)
OPGW/OHGW:	TBD (no station data available)

Are substation drawings available? YES ☐ NO ☐, (if so, include)

OTHER

Describe any other items the engineer/designer may need to know to complete this project (attach additional sheets if necessary):

VIA ELECTRONIC MAIL

June 17, 2016

Mr. Deral Danis
Director, Engineering & Transmission
Clean Line Energy Partners, LLC
1001 McKinney Street, Suite 700
Houston, TX 77002

Dear Mr. Danis,

Thank you for your questions on the MISO interconnection process sent on June 6, 2016. Below are MISO's responses for your consideration. If there are further questions, please let me know.

1) Q: Does MISO's interconnection process ensure compliance with NERC, regional, and local planning/reliability standards?

MISO's interconnection process ensures compliance with all applicable standards. MISO studies interconnection requests under the NERC Standard FAC-002 which requires new interconnection requests to be studied under applicable NERC reliability standards. Those standards include TPL-001 standard which defines the time horizon, load conditions, contingency events, and other aspects of the Reliability Assessment in general. MISO also considers the Local Planning Criteria of the affected Transmission Owners in ensuring interconnections are made in a reliable manner.

2) Q: Is it anticipated that MISO's HVDC interconnection process, currently under development, would also ensure compliance with NERC, regional, and local planning/reliability standards?

Yes

3) Q: What is the intent of the readiness milestones in the interconnection process such as the M2 deposit?

Readiness milestone payments, specifically the M2, are meant to gauge the readiness of any project entering the MISO queue. The M2 milestone, as implemented today, was instituted in the 2012 queue reform because projects were languishing in the queue with uncertain intention of whether or not they would progress further. The current M2 milestone payment is based on MISO's Point to Point Transmission service rate and the Planning level estimate of Network Upgrades needed.

4) In line with the fourth paragraph of the Moeller Letter (Attached), Q: Are merchant transmission projects, like the Grain Belt Express Project, able to recover their costs through MISO's MTEP cost allocation processes?

No. As stated in Attachment FF of the MISO Tariff "A proposed merchant transmission developer assumes all financial risk and funding requirements for developing its transmission project(s) and constructing the proposed transmission facility(ies)." Projects that are defined as merchant transmission projects are not eligible for cost allocation through the MTEP process as they do not meet the criteria for cost allocation.

Respectfully,

Tim Aliff
Director, Reliability Planning