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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. <u>NEW DEVELOPMENTS</u>

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. <u>RELIABLE INTERCONNECTION AND OPERATION OF THE GRAIN BELT EXPRESS PROJECT</u>

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.

[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 within MISO obtain access to the Grain Belt Express Project Facilities to deliver power to SPP or PJM?

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. CONSTRUCTION ACTIVITIES

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. <u>IMPACTS TO GPS</u>

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.

[22] Pollock & Wright, "Effects of Transmission Lines on Global Positioning Systems" (2011) at p. 10. <u>See</u> 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.

[signature]
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

[signature]
Notary Public

My commission expires: ______

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