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Witness: Anthony Wayne Galli
Type: Direct Testimony
Sponsoring Party: Grain Belt Express
Clean Line LLC
Case No.: EA-2014-0207
Date: March 26, 2014

MISSOURI PUBLIC SERVICE COMMISSION

CASE NO. EA-2014-0207

DIRECT TESTIMONY OF

DR. ANTHONY WAYNE GALLI, P.E.

ON BEHALF OF

GRAIN BELT EXPRESS CLEAN LINE LLC

March 26, 2014

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I. 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 (i) provide an overview of the physical and operating characteristics of the Grain Belt Express Clean Line transmission project ("Grain Belt Express Project" or "Project"), (ii) describe interactions with regional transmission organizations ("RTOs") Southwest Power Pool, Inc. ("SPP"), Midcontinent Independent System Operator, Inc. ("MISO"), and PJM Interconnection, LLC ("PJM"), (iii) discuss details relating to construction activities, including the anticipated construction schedule and potential vendor contracts, and (iv) address the issue of electric and magnetic fields ("EMF") associated with the Project.

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 ("IEEE"), a member of the International Council on Large Electric Systems ("CIGRE"), and a registered Professional Engineer in the Commonwealth of Virginia.

I have over 15 years of experience in the electric transmission industry, in both technical and managerial roles, ranging from power system planning and operations to regulatory matters and project development. Just prior to my current position, I served as Director of Transmission Development for NextEra Energy Resources ("NextEra"), 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 high voltage direct current ("HVDC") transmission solutions in the CREZ, and I led all efforts in routing, siting, and engineering transmission lines in the CREZ projects, which were awarded to Lonestar Transmission (NextEra's newly formed utility in the state of Texas). Prior to my time at NextEra, 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 moved toward 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 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 helped design shipboard power systems for the U.S. Department of Defense.

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 ("KCC"), the Oklahoma Corporation Commission, the Illinois Commerce Commission, the Indiana Utility Regulatory Commission ("IURC"), and the Arkansas 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 750-mile, overhead, $\pm$600 kV, multi-terminal HVDC transmission line ("HVDC Line") and associated facilities that will deliver wind-generated energy from western Kansas to utilities and customers in Missouri, Illinois, Indiana, and states farther east. The wind energy will be independently developed within the geographic footprint of SPP and will be delivered to the geographic footprint of MISO and PJM via the Grain Belt Express Project. As such, the Project will be electrically interconnected to the SPP, MISO, and PJM systems. While the Project's electrical interconnections with both MISO and PJM will be designed to accommodate all or part of the wind energy being delivered by the Project, the electrical interconnection with SPP is primarily required to facilitate the alternating current ("AC") to direct current ("DC") conversion process and therefore will be designed to have a minimal power exchange with the SPP system during normal operations.

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

A. The Grain Belt Express Project will run from a tap of the new Spearville to Clark County 345 kV line in southwestern Kansas near Dodge City to an interconnection location in northeastern Missouri along Ameren Missouri's Maywood to Montgomery 345 kV transmission line and then on to American Electric Power's ("AEP") Sullivan 345 kV substation in Southwestern Indiana. This final point of interconnection provides direct access to the 765 kV network in PJM via two 345/765 kV transformers in AEP's Sullivan 765 kV substation. The Project will be capable of delivering up to 3,500 megawatts ("MW") of power to the PJM market and up to 500 MW of power to the MISO market through interconnections with the existing transmission grid in Indiana and Missouri, respectively.[1]

[1] The power will be transmitted approximately 550 miles to near the Maywood 345 kV substation and then another approximately 200 miles east to the Sullivan substation. The Maywood converter station is expected to deliver up to 500 MW, pursuant to MISO interconnection studies, and will be rated at 1,000 MW in the event market demand later necessitates it. Grain Belt Express is currently studying the interconnection and delivery capability of 500 MW with MISO.

The HVDC portion of the Project will consist of the HVDC Line and three HVDC converter stations located near the substations described above. Each converter station will be capable of converting DC into AC or vice versa. The converter in Ralls County, Missouri will interconnect with the MISO system along a 345 kV AC transmission line connecting the Maywood substation and the Montgomery substation. The connection will be made via a single 345 kV circuit from the converter station to a nearby tap point along the transmission line connecting Maywood to the Montgomery 345 kV substation.

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

A. HVDC is a more efficient technology for long haul transmission of large amounts of electric power because substantially more power can be transmitted with lower losses, narrower rights-of-way, shorter transmission towers and fewer conductors than with an equivalent high voltage AC ("HVAC") system. In general, when considering distance effects, long haul HVAC transmission lines require intermediate switching or substations approximately every 200 miles in order to segment the line to handle issues relating to voltage support, transient over-voltages, and transient recovery voltages. Additionally, HVAC 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.

In essence, it takes more lines (and thus more right-of-way) to move large amounts of power long distances with AC than it does with DC. The current school of thought is that at distances beyond approximately 300 miles, HVDC is the most efficient means to move more power. Yet HVDC and HVAC facilities can be quite complementary when considering the integration of large amounts of renewable power into the electric transmission grid.

The use of HVDC technology is the appropriate technology solution for the Grain Belt Express Project to move large amounts of power from variable generation sources (such as wind farms) over long distances, primarily or exclusively in one direction. In this context, DC lines result in a lower cost of transmission than AC lines. The use of HVDC technology has a number of distinct benefits, including the following:

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

(2) HVDC lines complement AC networks without contribution to short circuit current power or additional reactive power requirements.

(3) 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.

(4) HVDC technology gives the operators complete control of energy flows, which makes HVDC particularly well-suited to managing the injection of variable wind generation.

(5) HVDC lines, unlike AC lines, will not become overloaded by unrelated outages, since 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.

(6) HVDC lines utilize narrower rights-of-way, shorter towers and fewer conductors than comparable AC lines, thereby making more efficient use of

transmission corridors, minimizing visual and land use impacts, and offering a transmission solution with a lower capital cost per mile.

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

A. In general, when referring to the transmission grid, substations function as junctures, where transmission and 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. When looking at an HVDC converter station, all of the aforementioned equipment would be easily recognized, as well. The primary difference is that an HVDC converter station contains two, side-by-side buildings called valve halls. 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 system). A typical HVDC converter station layout is provided in my **Schedule AWG-1**.

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

A. In the design work that has been performed by POWER Engineers, Inc. ("POWER"), three primary structure types have been identified: traditional self-supporting lattice structures, tubular steel "monopole" structures, and self-supporting lattice mast structures, which 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 has not made a final determination as to the predominant structure type so that landowner preferences, project costs, local terrain, land use, and other relevant factors can be considered when making a final selection. It is likely that a mix of structures will be utilized to help maximize flexibility and minimize costs and impacts with respect to varying terrains and land uses.

The current 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 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. Longer spans require larger structures than are needed for the typical 1,200-foot or 1,500-foot spans.

Q. Have you provided diagrams showing converter station configurations and structure types for the Project?

A. Yes, they are attached to my testimony as **Schedule AWG-2.**

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

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

A. Yes. While the Grain Belt Express Project is not intended to prevent the bulk power system from falling below some predetermined, minimum level of reliability, the addition of a new transmission path that did not previously exist for additional energy resources to access consumer demand (load) will increase the transfer capability into the area and result in an increase in the reserve margin of the area where that demand is located. This will help further ensure that load within the area can be adequately served. Grain Belt Express witness Robert M. Zavadil of EnerNex, LLC explains in his testimony the measured reliability benefits in the form of a reduction to Missouri's loss of load expectation.

A. NERC

Q. Will the Project be designed in accordance with Good Utility Practice, applicable laws, and North American Electric Reliability Corporation ("NERC") criteria?

A. Yes. Grain Belt Express, along with its consultants, is actively engaged in various aspects of the Project design process. This includes studying the potential impacts of the Project during various system conditions and under various contingency scenarios in order to ensure that the systems to which the Project will interconnect will remain secure and compliant with NERC reliability standards. This is being accomplished through open stakeholder processes involving various RTOs and identified parties, potentially affected by the operation of the Project, via a series of system studies that I will describe in detail later in this testimony. NERC reliability standards became mandatory and enforceable (through the imposition of monetary penalties or other sanctions) 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 is important to ensure the reliability of the bulk power system.

Q. How will Grain Belt Express comply with NERC's standards and protocols?

A. Grain Belt Express expects to be registered on the NERC Compliance Registry for the reliability functions of a "Transmission Owner," a "Transmission Operator," and a "Transmission Service Provider" (depending on the nature of its arrangements with a third party or parties to operate the Project, which could result in some or all of the Transmission Operator or Transmission Service Provider functions being assigned to the third party). Therefore, Grain Belt Express will be subject to applicable requirements of one or more NERC reliability standards in some or all of the following categories: Resource and Demand Balancing; Communications; Critical Infrastructure Protection; Emergency Preparedness and Operations Procedures; Facilities Design, Connections and Maintenance; Interchange Scheduling and Coordination; Interconnection Reliability Operations and Coordination; Modeling, Data, and Analysis; Personnel Performance, Training, and Qualifications; Protection and Control; Transmission Operations; Transmission Planning; and Voltage and Reactive.

Grain Belt Express will be prepared to comply with the requirements of the reliability standards that are applicable to its activities. Additionally, the Company is applying the results of studies that were conducted for the design of Clean Line's other projects to ensure that the Project will meet the National Electrical Safety Code (NESC) requirements and the tenets of Good Utility Practice.[2] Preliminary design criteria have been developed in order to guide this process, and are attached as Schedule **AWG-3**.

Q. Will Grain Belt Express 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-

[2] 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."

23.030 (Electrical Corporation Vegetation Management Standards and Reporting Requirements)?

A. Yes. Grain Belt Express is aware of the Commission's electric service reliability rules and 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).

B. <u>SPP</u>

Q. What interaction has Grain Belt Express had with SPP, and what studies have been conducted as a result?

A. Grain Belt Express has worked with SPP to conduct bulk electric grid reliability studies with affected Transmission Owners and it will continue to do so. In collaboration with Siemens Power Technologies International ("Siemens PTI"), Grain Belt Express has met with affected Transmission Owners and has submitted various technical studies to SPP.[3] Siemens PTI conducted both steady state and dynamic stability studies, in accordance with SPP Criterion 3.5, simulating the effect of the Project to SPP's and other affected parties' electric systems. Criterion 3.5 requires entities requesting transmission interconnections to work with SPP and affected parties to ensure grid reliability. Parties were presented with the study models and reports in early 2013 and were given the opportunity to ask questions about the results and to request additional analyses.[4]

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[3] Meeting minutes and copies of the submitted studies can be viewed at http://www.grainbeltexpresscleanline.com/site/page/technical_studies. The Stability and Steady State Study Reports can be viewed at http://www.grainbeltexpresscleanline.com/site/page/technical_studies.

[4] The models used in SPP studies and the one-line diagram, attached as **Schedule AWG-5,** show the Project interconnecting directly to the Clark County substation. This is simply a modeling convenience

Furthermore, as part of Grain Belt Express' agreement with SPP, in the summer of 2013, SPP performed an independent review of the studies and provided their opinion prior to SPP Transmission Working Group approval. The final report from SPP's independent review is attached as Schedule **AWG-4**.

Q. Did Grain Belt Express work with SPP and affected parties to develop the scope of and to conduct studies under SPP Criterion 3.5?

A. Yes. Grain Belt Express initially met with SPP and affected parties on June 9, 2011 to develop the scope of the steady state and dynamic stability studies required under SPP Criterion 3.5. 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 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. As mentioned previously, the models used in these studies along with the study reports were made available to SPP and the affected parties when the study results were shared with them. In September 2013, the SPP Transmission Working Group passed a motion to "approve

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and, from a results perspective, is virtually identical to studying a tap of the Clark County – Spearville 345 kV line. The final report from SPP's independent review, attached as Schedule AWG-4, confirms that the results from the Project interconnecting directly to the Clark County substation or via a tap of the Clark County – Spearville 345 kV line is virtually identical.

the GBX [Grain Belt Express] studies completed to date as meeting their coordinated planning requirements under SPP Criteria ....”[5]

Q. What are the operational realities that will exist between Grain Belt Express and SPP with regard to the Project?

A. The Project is being designed so that during normal operating conditions, there is nominally zero active power exchange and very little, if any, reactive power exchange between the Grain Belt Express AC bus and the SPP grid. However, following the loss of a single-pole, some of the power transmitted by the Project will temporarily flow into the SPP grid. The results of the SPP Criterion 3.5 studies indicate that during this occurrence, using one of the future scenario cases, only one circuit in the SPP grid would be loaded above its applicable rating. For all other future scenarios included in the studies, the loss of a single pole does not cause any adverse impacts.

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

A. Following the Criterion 3.5 approval, Grain Belt Express is working with ITC Great Plains and Sunflower Electric Power Corporation on an interconnection service agreement which will include a requirement to conduct additional, detailed studies including a Facilities Study for the facilities needed to interconnect the Project to the SPP grid. Additionally, Grain Belt Express is continuing discussions with SPP staff regarding the need for appropriate operating agreements, seams agreements, and possible administrative requirements (e.g. tariff administration).

[5] The motion can be found at: http://www.spp.org/publications/TWG%208.14-15.13%20Minutes%20&%20Attachments.pdf.

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C. MISO

Q. What interaction has Clean Line had with MISO regarding the Grain Belt Express Project?

A. Initially, Grain Belt Express anticipated injecting 3,500 MW of power to the MISO market at the St. Francois 345 kV substation in eastern Missouri. However, after working with MISO, the interconnection studies showed that significant upgrades at and around the 345 kV St. Francois substation would be necessary for a 3,500 MW interconnection. The magnitude of the upgrades required, including several new transmission lines, made this initial proposal uneconomical. As a result, the Company examined alternatives that led to the current plan of injecting a smaller portion of the power into MISO in northeastern Missouri and transmitting the bulk of the power to PJM. MISO is currently studying the impacts of the Project delivering up to 500 MW of power into the existing 345 kV system in northeastern Missouri both at and near the Ameren Maywood 345 kV substation, pursuant to an interconnection request filed in September 2012 and subsequently assigned queue position J-255.

MISO completed a Feasibility Study for J-255 in October 2012, and the study is attached as **Schedule AWG-6**. The Feasibility Study did not identify any constraints associated with the 500 MW injection into MISO at the requested locations. Additionally, Grain Belt Express is working with PJM to complete the necessary studies for interconnection at the Sullivan 345 kV substation in Indiana. Currently, the J-255 queue position is in MISO's "parked" status in order to ensure that any applicable results from the PJM System Impact Study (which is expected to be completed during the second quarter of 2014) can be incorporated in the scope of the next level of analyses in MISO's interconnection process.

Q. What is the next level of analyses that MISO will perform as part of its interconnection process after completion of the Feasibility Study?

A. Following the conclusion of the Feasibility Study, MISO's interconnection process includes two additional levels of analysis: (i) System Planning and Analysis ("SPA") and (ii) Definitive Planning Phase ("DPP"). The SPA is an optional analysis that the interconnection customer may choose to bypass and proceed directly to the DPP. The scope for the SPA may include the following:

- Power flow
- Short circuit
- Steady state voltage
- Transient and voltage stability
- System protection
- Loss analysis
- Mitigation of constraints

The scope for the DPP involves MISO performing a System Impact Study and an Interconnection Facilities Study, which then is followed by a Network Upgrade Facility Study.

D. PJM

Q. What interaction has Clean Line had with PJM regarding the Grain Belt Express Project?

A. In August 2011, Grain Belt Express submitted an interconnection request in PJM's merchant transmission queue and subsequently was assigned queue position X3-028. In January 2013, PJM completed a Feasibility Study[6] and subsequently initiated a System Impact Study in February 2013.

IV. FUNCTIONAL CONTROL

Q. What does a transfer of Functional Control entail?

A. The requirement to transfer Functional Control is to ensure that a transmission asset owner, Grain Belt Express in this case, cannot exercise undue discrimination in fulfilling its FERC Open Access Transmission Tariff commitments. FERC also ensures that undue discrimination cannot occur during the open season by requiring Grain Belt Express to file open season reports with FERC, which provide the terms of the open season; notice of open season; bid evaluation methodology; identity of parties purchasing capacity; and the amount, term, and price of the capacity.

Q. Will Grain Belt Express turn over Functional Control of the Project to a RTO or RTO-like entity?

A. Yes. Grain Belt Express could turn over Functional Control of the Grain Belt Express Project to SPP, MISO, or PJM.

[6] The PJM feasibility study can be viewed at the following location: http://www.grainbeltexpresscleanline.com/site/page/technical_studies.

Q. Has the Grain Belt Express determined which specific RTO or RTO-like entity will have functional control of the Project?

A. Yes. Grain Belt Express has made a decision to hand functional control of the Project to PJM. While all three of the RTOs that this Project will be interconnecting to are fully capable of taking over functional control of the Project, for operational and practical purposes, it was determined that PJM would be best positioned to have functional control since the majority of the energy transferred on the Project will be delivered to the PJM market. However, significant coordination will occur between Grain Belt Express, PJM, MISO, and SPP.

V. <u>CONSTRUCTION ACTIVITIES</u>

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

A. I expect that construction could begin as early as 2016 and could take two to three years to complete. Lead times for delivery of HVDC converter stations are typically on the order of 36 months at the present time. The transmission line construction would need to be completed approximately six months prior to operation so that the converter stations can be fully tested. Construction could begin in several different areas of the Project simultaneously depending on labor availability and environmental conditions. The Project is expected to achieve commercial operation as early as 2018.

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. Grain Belt Express has secured the services of POWER Engineers, Inc. ("POWER") to serve the role of consulting engineer. POWER is an experienced engineering consulting firm founded in 1976 that has been providing advice and assistance in both the design and constructability analysis of the Project. Focusing primarily on the electric power industry, the firm has performed work in all parts of the country including Kansas, Missouri, and Illinois. The individuals we work with at POWER have significant experience in engineering and construction of transmission facilities. POWER has also performed preliminary engineering to specify design criteria and develop preliminary structure types and requirements for the Project, as described in **Schedule AWG-3**.

Q. Does the Company have agreements with any suppliers?

A. Yes. The Company has supplier agreements with ABB Inc. ("ABB"), Hubbell Power Systems, Inc. ("Hubbell"), and General Cable Industries, Inc. ("General Cable") that will support manufacturing jobs in factories in St. Louis, Centralia, and Sedalia. The Memorandum of Understanding ("MOU") with ABB designates it as the "Preferred Supplier" of AC transformers associated with the Project's AC collector system, which will connect new wind farms in Kansas with the HVDC Line. 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 manufacturing facility, supporting roughly 20 jobs.

The MOU with Hubbell designates it as the Preferred Supplier of conductor hardware and polymer insulators for the Project. Hubbell will manufacture the insulator cores and conductor hardware at its Centralia, Missouri facility, creating an estimated 52 jobs in Centralia over two to three years. Hubbell will also make its engineering resources available to aid in the design of conductor hardware assemblies and polymer insulators and work to establish a supplier base within the Project area states, including Illinois and Indiana to source raw material from businesses in states that host the Project.

The Grain Belt Express MOU with General Cable designates it as a Preferred Supplier of conductor for the Project. General Cable will manufacture roughly 23 million feet of steel core for the transmission line conductor and manage inventory and logistics in Sedalia, where it employs roughly 185 people, supporting roughly 10 Missouri jobs. General Cable has also committed to sourcing all of the aluminum rod used in the conductor they provide for the Project from the Noranda Aluminum smelter near New Madrid. These partnerships demonstrate Grain Belt Express' commitment to working with qualified, local businesses to maximize the economic benefits of the Project to Missouri.

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 $2.2 billion, which includes the cost for the HVDC Line and the three converter stations. From this $2.2 billion, approximately $500 million is expected to be specifically associated with the Missouri portion of the Project, where roughly $400 will be for the transmission line and $100 million will be for the converter station in Missouri.

VI. ELECTRIC AND MAGNETIC FIELDS

Q. What are electric and magnetic fields?

A. In the context of the Project, electric and magnetic fields ("EMF") collectively refer to the static electric and magnetic fields produced by the HVDC transmission line. These fields are of a different nature (i.e., they are static) than the EMF produced by typical AC transmission lines, which are time-varying in nature.

Q. How is EMF measured?

A. Electric fields are measured in units of kilovolts per meter ("kV/m"). The International System of Units ("SI") measures magnetic fields with the SI-derived unit of Tesla ("T"), which is widely applied in Europe; however, in North America magnetic fields are most commonly reported in units of gauss ("G"). As an example, a typical refrigerator magnet produces a magnetic field around 0.005 T (5 millitesla ["mT"]) which translates to 50 G (50,000 milligauss ["mG"]).

Q. Is EMF something people encounter every day?

A. Yes. Electric charges and the fields associated with them are found everywhere. We routinely encounter static electricity from rubbing our feet across the carpet on a dry winter day, from brushing our hair when the humidity is low, or from weather conditions, such as storms, snow, and blowing dust. The friction from walking across the carpet can create a static electric field at the surface of the body as high as 500 kV/m. This static charge is easily dissipated by touching another surface (such as a doorknob) and transferring the charge. Electric fields are easily blocked by most objects such as walls, trees, and fences. Few man-made devices produce static electric fields as frequently as does nature, but standing near a DC electrified railway, or sitting in front of a computer screen or television with a cathode ray tube ("CRT") are examples. In the case of sitting in front of a CRT television or computer screen, one may be exposed to a static electric field of about 10 – 20 kV/m at a distance of approximately one foot.

Likewise, magnetic fields are very commonplace. The primary natural source of static magnetic fields is the earth itself; its geomagnetic field covers the entire earth. Man-made sources include permanent magnets (e.g., the magnets contained in a set of headphones), battery-powered appliances, magnetic resonance imaging ("MRI") scanners, and, as stated above regarding static electric fields, DC electric railways. The earth's magnetic field ranges from 300 mG at the equator to 700 mG at the magnetic north and south poles. An MRI machine produces magnetic fields between 15,000,000 - 40,000,000 mG. Battery powered appliances may produce magnetic fields between 3,000 – 10,000 mG.

Q. What are the expected electric field levels associated with the Project's operation?

A. Based on applicable EMF calculations from similarly rated HVDC lines, the highest electric field level calculated on the right-of-way is expected to be approximately 40 kV/m. This includes the contribution of both the nominal field (i.e., the field that is derived from the voltage on the conductor) as well as the charges on air molecules ("air ions"). The contribution of air ions to the electric field is affected by weather conditions and the number presented above is expected to be a worst case condition with the likelihood that lower values would be typical.

Q. How does the Project's EMF compare to typical EMF exposure in day-to-day life?

A. As noted above, for electric fields, one can easily experience exposure up to 500 kV/m just by walking across a carpeted floor on a dry winter day, which is more than ten times the highest value expected from the Project's operation. As also noted previously, the magnetic field exposure experienced on a daily basis or in the course of one's life can range from strengths that are similar to what would be experienced within the right-of-way of the Grain Belt Express Project to levels that are orders of magnitude higher.

Q. Are you aware of any recommended limits of exposure or other documented scientific literature regarding DC EMF?

A. Yes. While questions have been raised about the possibility that static fields affect health, these questions have focused on sources of extremely strong magnetic fields. Since the weak magnetic fields produced by DC transmission lines are similar to naturally occurring magnetic fields, those sources have not prompted similar questions. The following organizations have reviewed and summarized the research on exposure to static or slowly varying fields:

- International Agency for Research on Cancer ("IARC") in 2002.[7]
- Nation Radiological Protection Board of Great Britain in 2004.[8]
- World Health Organization ("WHO") in 2006.[9]
- International Committee on Electromagnetic Safety ("ICES") in 2002 and 2007.[10]
- The Advisory Group on Non-ionising Radiation for the Health Protection Agency of Great Britain (2008).[11]
- International Commission on Non-ionizing Radiation Protection ("ICNIRP") in 2009.[12]

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[7] International Agency for Research on Cancer, IARC Monographs on the Evaluation of Carcinogenic Risks to Humans, Vol. 80: Static and Extremely Low-Frequency (ELF) Electric and Magnetic Fields (Lyon, France, IARC Press, 2002).

[8] National Radiological Protection Board (NRPB), Advice on Limiting Exposure to Electromagnetic Fields (0-300 GHz), Vol. 15, No. 2 (Didcot, UK, 2004).

[9] World Health Organization, Environmental Health Criteria Monograph No. 232. Static Fields (Geneva, Switzerland, World Health Organization, 2006).

[10] International Committee on Electromagnetic Safety, IEEE Standard for Safety Levels with Respect to Human Exposure to Electromagnetic Fields 0 to 3 kHz C95.6-2002 (Piscataway, NJ, IEEE, 2002) (Reaffirmed 2007).

[11] Advisory Group on Non-ionising Radiation, Static Magnetic Fields, RCE-6, Documents of the Health Protection Agency (Chilton, UK, 2008).

[12] International Commission on Non-ionizing Radiation Protection, Guidelines on Limits of Exposure to Static Magnetic Fields, Health Physics, 96:504-514 (2009).

None of these panels found that the body of research indicates that strong static magnetic fields cause long-term health effects. The ICNIRP and the ICES have developed exposure limits both for the general public and for occupational workers to protect against known, acute effects that occur only at levels above those found in certain specialized medical, research, and industrial environments. The ICNIRP has established these limits at 4,000,000 mG and 20,000,000 mG for the general public and occupational workers, respectively. The ICES has established limits of 1,180,000 mG and 3,530,000 mG for the general public and for occupational workers, respectively for frequencies up to 0.153 Hz.

Q. How does the Project's magnetic field compare to the limits of exposure described above?

A. The maximum expected magnetic field of the Grain Belt Express Project would be similar to that of the earth (~500 mG) and more than a thousand times lower than the aforementioned exposure limits (~4,000,000 mG).

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.

Q. What is corona?

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. The radio noise produced by corona, if strong enough, can create interference with signal reception in a certain 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. Some devices that operate in the lower frequency ranges of the corona discharge are potentially susceptible to interference. Such devices as amplitude-modulated ("AM") radio station receivers operating in the 0.52 – 1.72 MHz range could be noticeably affected when close to a transmission line, e.g., the static you hear on your AM radio when you drive under the conductors of a high-voltage transmission line.

Frequency-modulated ("FM") radio stations operate in the range between 88 – 108 MHz and are not typically affected by radio noise from transmission lines. 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. Reports published by consultants to Manitoba Hydro (the provincial agency that operates two large HVDC projects similar to the Grain Belt 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 manufacturers quoted equipment accuracies (i.e., centimeter level).[13]

A similar conclusion regarding these DC transmission lines was reached by engineers in the Position, Location and Navigation Group at the University of Calgary: [14]

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[13] 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

[14] 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).

> 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.

Q. What kinds of structures could disrupt 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 buildings 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.

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 a signal from only three satellites to calculate the horizontal position on earth. All GPS receivers regularly add and drop satellites, and receive a signal from 12 or more satellites simultaneously. Hence, it is unlikely that a brief or even prolonged blockage of a single satellite would adversely affect GPS operation.

Q. When major transmission projects are undertaken, concerns regarding EMFs are sometimes raised. Does Grain Belt Express believe EMFs present a health threat to people, plants, or animals?

A. No. There is no conclusive evidence to support the contention that EMFs from transmission lines are linked to health related risks to humans, plants or animals. This conclusion is based primarily on the 2006 report produced by the Oak Ridge National Laboratory attached as **Schedule AWG-7**. Furthermore, the IARC, the WHO, the ICES and the ICNIRP (cited above) have all concluded that the current body of research does not indicate that strong static electric or magnetic fields cause long-term health effects. Clean Line has also retained Exponent, an expert consultant in the area of EMF health risks, to prepare a brochure for use in our public outreach and communication efforts. The brochure explains the nature of EMFs created by DC transmission lines, summarizes the scientific study of their effects, and provides references to documents produced by the scientific community. A copy of the brochure is attached as **Schedule AWG-8**.

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 345 kV Transmission Line	)	Case No. EA-2014-0207

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 of 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 27 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 25 day of March, 2014.

[signature]
Notary Public

My commission expires: 7-22-2015

JUDY BLANKENSHIP
Notary Public, State of Texas
My Commission Expires
July 22, 2015

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