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Witness:	Carlos Rodriguez
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MISSOURI PUBLIC SERVICE COMMISSION

FILE NO.

EA-2023-0017

DIRECT TESTIMONY

OF

CARLOS RODRIGUEZ

ON

BEHALF OF

GRAIN BELT EXPRESS LLC

August 24, 2022

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I. INTRODUCTION

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

A. My name is Carlos Rodriguez, I am Senior Vice President of Interconnections and Grid Analysis at Invenergy LLC ("Invenergy"). My business address is One South Wacker Drive Suite 1900, Chicago, IL, 60606.

Q. Q. What are your duties and responsibilities in your present position?

A. My main responsibilities are leading and coordinating the electrical interconnections for Invenergy at a global level, including projects in the United States, Canada, Latin America and other parts of the world. This includes performing electrical studies for site prospecting, submitting interconnection requests and associated technical data, reviewing power system studies performed by utilities, Regional Transmission Organizations and Independent System Operators and negotiating interconnection agreements.

Q. Please describe your education and professional background.

A. I have a Bachelor of Science degree in electrical engineering from Universidad Metropolitana in Caracas, Venezuela (1991) and also a graduate degree as Specialist in Electric Power Systems from Universidad Central de Venezuela in Caracas, Venezuela (1998). I was involved in generation and transmission planning in what used to be the largest private utility in Venezuela, Electricidad de Caracas. I worked in Electricidad de Caracas for 8 years (1991–2000) and when I left the company, I was the Manager of Generation and Transmission Planning, responsible for producing mid-term and long-term expansion plans for the company. In 2000 I immigrated to the United States and initially worked at a consulting company in Chicago called MWH from 2000 to 2004, doing power system analysis and interconnection studies. From 2004–2005, I worked at two different companies, Operations Technology, Inc. (a developer of a power system software called ETAP) and at Citadel Investment Group (a hedge fund located in Chicago).

In 2006 I started at Invenergy and I have held several positions, including Manager, Director, Vice President and now Senior Vice President. At Invenergy I have been involved in the interconnection of close to 30 GW of projects across a range of technologies (such as wind, solar, storage, thermal, offshore wind and HVDC).

My curriculum vitae is attached as Schedule CR-1.

Q. Have you previously provided testimony before the Missouri Public Service Commission or other state regulatory commissions?

A. Yes. I previously provided testimony to the Illinois Commerce Commission on behalf of Grain Belt Express LLC ("Grain Belt Express") in Case No. 22-0499 on similar topics as those discussed in this testimony.

Q. Q. What is the purpose of your direct testimony?

A. I am testifying on behalf of Grain Belt LLC ("Grain Belt Express"), which is requesting that the Missouri Public Service Commission ("Commission") amend its existing certificate of public convenience and necessity ("CCN") to construct, install, own, operate, maintain, and otherwise control and manage an approximately 800-mile, overhead, multi-terminal +/-600 kilovolt ("kV") high-voltage, direct current ("HVDC") transmission line and associated facilities including converter stations and alternating current ("AC") connector lines (the "Project").

My testimony will demonstrate that the Project will promote the public convenience and necessity by using modern transmission technology to transmit electricity from Kansas to the markets in Missouri and further east. My testimony will also demonstrate that points of interconnection ("POIs") at and near the McCredie Substation are in the public interest and superior to the previously proposed POI on the Maywood-Spencer Creek-Montgomery 345 kV

transmission line. I will also address misconceptions expressed by some in the public domain that the proposed amendments to the Project are related to a proposed solar facility in Callaway County. Finally, I will also describe the status of the interconnection process for the Project and describe Grain Belt Express's work with the PJM Interconnection, LLC ("PJM"), the Midcontinent Independent System Operator, Inc. ("MISO"), Associated Electric Cooperative Incorporated ("AECI") and Southwest Power Pool ("SPP") to process and obtain the interconnection studies and other approvals from these organizations necessary to proceed with the Project.

Q. Are you sponsoring any schedules or exhibits as part of your direct testimony?

A. Yes, I am sponsoring the following exhibits/schedules:

- Schedule CR-1 – Curriculum vitae
- Schedule CR-2 – Transmission Map of McCredie 345kV substation
- Schedule CR-3 – Transmission map showing POIs in Missouri

II. OVERVIEW OF PROJECT

Q. Please describe the Project and its planned interconnections to the grid.

A. The Project is a multi-terminal overhead HVDC transmission line capable of transmitting electricity at voltages of up to a nominal +\-600 kilovolts ("kV") but no less than 345 kV. The HVDC portion of the Project is approximately 800 miles long. The Project will also include AC transmission lines to interconnect with the AC grid. The Project (as amended) will deliver up to 5,000 megawatts ("MW") of electricity generated from renewable sources in western Kansas to customers in Missouri, Illinois, Indiana and states farther east. The western terminus of the Project will interconnect to the ITC Great Plains ("ITC") 345 kV system in SPP. Three delivery stations proposed for the Project (as amended) will be interconnected to, respectively, the Ameren Missouri ("Ameren") 345 kV system in MISO, the AECI 345 kV system in Missouri and the American Electric Power ("AEP") 345 kV system in PJM.

Q. Will the Project be constructed in phases?

A. Yes, as described in further detail in Shashank Sane's Direct Testimony, Grain Belt Express is proposing to construct the Project in two phases (*i.e.* Phase I and Phase II).

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

A. Phase I of the Project will interconnect to ITC's Saddle 345 kV substation, which will break the 345 kV double circuit line between the Clark County substation and the Spearville/Ironwood substations in Ford County in southwestern Kansas, near Dodge City. From the converter station near Dodge City, Kansas, the HVDC transmission line will traverse approximately 370 miles to the Kansas-Missouri border. The HVDC transmission line will cross the Kansas River south of St. Joseph and enter Missouri. From there, the HVDC transmission line will traverse approximately 156 miles to a converter station in Monroe County, Missouri.

The converter station in Missouri is proposed to be interconnected with the MISO system along the Ameren 345 kV AC transmission line connecting the McCredie substation and the Montgomery substation, near the McCredie 345kV substation. The proposed connection will be made via a single 345 kV circuit from the converter station to a tap point along the Ameren 345 kV transmission line. The proposed converter station will also interconnect with the AECI system at the McCredie 345 kV substation. The proposed connections will be made via a single, approximately 40-mile 345 kV circuit from the converter station in Monroe County to the two POIs at and near AECI's McCredie 345 kV substation. This 345 kV AC transmission line is referred to as the "Tiger Connector."

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

A. Phase II of the Project will begin at the Monroe County converter station and then traverse an additional approximately 58 miles in Missouri to the Illinois border. The Project will then cross the Mississippi River and enter Illinois.

The Proposed Route in Illinois will continue approximately 207 miles through Illinois to the Indiana border. The 207-mile Proposed Route in Illinois consists primarily of an HVDC transmission line and includes approximately three to eight miles of an AC transmission line. The AC line will run from a converter station proposed in Clark County, Illinois—where current will be converted between DC and AC—to the Indiana border. The Project will then traverse approximately two miles in Indiana to terminate at AEP's Sullivan 345 kV substation in Southwestern Indiana. This final POI, which is approximately two miles into Indiana, will provide direct access to the 765 kV network in PJM via two 345/765 kV transformers in the AEP 765 kV Sullivan substation.

Q. What will be the delivery capability of the Project as amended?

A. As amended, the Project will be capable of delivering up to 1,500 MW of power to the MISO market in Missouri, 1,000 MW to AECI in Missouri, and up to 2,500 MW of power to the PJM market through the interconnections with the existing transmission grid in Missouri and Indiana, respectively.[1] The HVDC portion of the Project will consist of the HVDC line and three HVDC converter stations. Each converter station will be capable of converting DC into AC or vice versa.

[1] In early conceptual designs of the new configuration for the Project, the flow to the AECI POI was 1018 MW, so we requested an interconnection of this amount from AECI and have approximated it to 1000 MW ever since.

III. TECHNICAL SPECIFICATIONS OF THE CONVERTER STATION AND HVDC CONDUCTORS

Q. Please describe the converter technology that will be used for the Project.

A. The Project is utilizing voltage sourced converter ("VSC") technology, which is the same technology that enables connection to islanded off-shore wind. This technology is a significant upgrade from Line Commutated Converter ("LCC") HVDC technology, which was the technology proposed in the original CCN. Unlike the LCC HVDC technology, the amended Project utilizing the VSC HVDC technology will not require a connection to the existing grid in SPP but by connecting to the system, it will allow for a more robust operation and for the ability to provide emergency energy and ancillary services in the future, such as voltage control and black-start capabilities if required. Furthermore, the exchange to the network will be tightly controlled by the HVDC system to ensure minimal impact to the grid.

Q. Are there other advantages of VSC technology?

A. Another advantage of the modern VSC technology is that it does not require "commutation" to take place as the LCC technology did. The design of the converter allows for current flow in any direction by controlling the voltage of the converter. Using this technology, one can actually create a 60 Hz voltage to synchronize generation, as in the case of off-shore wind. As such, the proposed HVDC technology is able to operate in very weak and even islanded systems.

Q. Why has Grain Belt Express decided to use HVDC technology for the Project instead of high voltage AC technology?

A. In the Commission's 2019 Report and Order on Remand, the Commission found as follows with regard to HVDC technology:

> The HVDC technology of the Project is the most cost-effective and efficient way to move large amounts of electric power over long distances and can transfer significantly more

> power with lower line losses over longer distances than comparable AC lines. The HVDC design will provide a congestion-free delivery source of power, unlike using an interconnected AC system to move power.[2]

This finding remains accurate. It is a well-established fact that HVDC is a more efficient technology for the long-haul transmission of large amounts of electric power. Substantially more power can be transmitted with lower losses, narrower right-of-way, and fewer conductors than with an equivalent high voltage AC ("HVAC") system. 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. Additionally, 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 takes more lines (and thus more right-of-way) to move large amounts of power over a long distance with AC than it does with DC.

Q. Please provide the voltage rating (kV), operating voltage (kV) and normal peak operating current rating for the Project.

A. As was the case at the time of the 2016 CCN Application in Missouri, the Project will be rated up to a nominal ±600 kV. In a bipolar HVDC project, as proposed for the Project, the positive electrical pole ("pole") is at a potential of +600 kV relative to ground and the negative pole is at a potential of -600 kV relative to ground. Thus, the voltage of the project is stated as ±600 kV (plus-minus 600 kV). For Phase I of the amended Project, the system will be rated to deliver 2,500 MW and will have a peak operating current of approximately 2,100 amperes ("A"). For Phase II of the amended Project, an additional bipole will be added which will increase the

[2] Report and Order on Remand, p. 10 (internal citations omitted).

rating to 5,000 MW with another 2,500 MW bipole and a total DC line current of 4,200 A. Two bipoles were also planned under the pre-amendment design of the Project at 4,000 MW. Accordingly, the use of two bipoles is not a material change in the design and engineering of the Project.

Q. In HVDC projects, does one refer to a "pole" as opposed to a "phase"?

A. Yes. In EHV AC transmission, there are three phases, hence three-phase power. Each phase has a set of conductors associated with it. With HVDC, we talk about "poles." These poles are not to be confused with the structures that hold the wires. A bipolar HVDC project has two poles and each pole has a set of conductors associated with it. A very rough analogy would be the "poles" on your car battery where you have a positive pole and a negative pole.

Q. What are the various operating modes of an HVDC bipole?

A. An HVDC bipole project normally operates so that both poles are transmitting one-half of the power and the current is equal in the poles. However, certain circumstances, such as a contingency or maintenance condition, can occur, which result in only one pole being available for transmitting power. In this case, the project would be operating in what is known as monopolar mode. (Again, the term "monopole" in this context should not be confused with the structures used to support the conductors.) Monopolar operation may occur through an earth return path or a dedicated metallic return if the other pole conductor is not available to act as the return.

For example, if a maintenance outage is required to repair power electronic devices in the valve hall of one of the converter stations, then the monopolar operation would utilize both sets of pole conductors. However, if the pole outage were due to maintenance on one of the sets of pole conductors, then the monopolar operation will utilize a current return path via dedicated metallic return or earth return path.

Q. Please describe what is meant by a dedicated metallic return and an earth return and which one Grain Belt Express intends to utilize for the Project.

A. In HVDC configurations, a return path for current must always exist. During normal, bi-polar operation, the current flows through the positive pole and returns through the negative pole. If one of the poles were to be interrupted, the other pole could continue to operate as long as a closed path for the current existed. As indicated above, this is called "monopolar" operation. This path can either be through the earth (via a ground electrode), in what is described as "earth return," or through a separate set of conductors referred to as a dedicated metallic return. Grain Belt Express has opted to design the Project for use with a dedicated metallic return. This avoids interference issues with subsurface utilities during normal monopolar operations.

Q. What type of conductors will be utilized on this project?

A. The Project will utilize 2156 kilo-circular mil ("kcmil") ACSR ("Bluebird") in a triple bundle configuration for the pole conductors. For the dedicated metallic return ("DMR conductor"), we plan on using two, 2156 kcmil ACSR ("Bluebird") conductors. Final engineering is typically completed after a final route has been approved by regulatory authorities, so the design could change slightly at that time or based upon further optimization studies.

Q. Who will be addressing the design and engineering of the Tiger Connector?

A. The design and engineering of the Tiger Connector is addressed in the Direct Testimony of Aaron White filed simultaneously herewith.

IV. THE NEW PROPOSED POINTS OF INTERCONNECTION ARE IN THE PUBLIC INTEREST

A. Limitations of the Maywood-Spencer Creek-Montgomery Point of Interconnection

Q. Under the currently-certificated Project, are there any operational limitations related to the POI on the Maywood-Spencer Creek-Montgomery 345 kV line?

A. Yes. the Certificated Project's interconnection point in Ralls County is not sufficiently robust to handle the proposed increased injection of power from 500 MW to 2500 MW, as is explained below.

B. Benefits of the McCredie Points of Interconnection

Q. Where does Grain Belt Express propose to move the point of interconnection?

A. Grain Belt Express proposes two POIs in Callaway County, Missouri. One POI will be with AECI at the McCredie Substation. The other POI will be with Ameren, near the McCredie Substation, on the McCredie-Montgomery 345 kV line. To facilitate these POIs, Grain Belt Express proposes to move the location of the converter station from Ralls County to Monroe County, along the currently certificated HVDC route, for optimal location relative to the McCredie Substation. The modified location of the converter station and the Tiger Connector are necessary to deliver the power into the McCredie Substation.

Q. How does this benefit the overall Project?

A. The proposed modifications will allow Grain Belt Express to increase the amount of power the Project can inject, therefore increasing the overall effectiveness of the Project to transport power across the region.

Grain Belt Express has submitted interconnection requests to MISO to establish HVDC transmission connection and injection rights on Ameren's McCredie-Montgomery 345 kV line, near AECI's McCredie Substation. Combined, the interconnection requests at MISO will enable

the interconnection of 1,500 MW with injection rights to the MISO system. Additionally, Grain Belt Express has signed an interconnection agreement with AECI for a point of interconnection at the McCredie Substation and injection rights of approximately 1,000 MW to the AECI system.

Q. How did Grain Belt Express select the POIs at and near the McCredie Substation?

A. The original POI to the Maywood-Spencer Creek-Montgomery 345kV line consisted of looping in and out the existing single circuit 345kV line, which has a rating of 1072 MVA normal and 1272 MVA emergency. Based on the existing rating, the line is capable of accepting an injection of 500 MW, which is below its rating. However, the existing line cannot handle an injection of 2500 MW. Looping in and out the existing line provides only two outlets for the power, one from the POI to the Maywood 345kV substation and another one from the POI to the Spencer Creek 345kV substation. Under the unexpected loss of one of the outlets (N-1 condition), this would limit the injection to 1272 MVA, per NERC planning standards. Given the size of the new injection at 2500 MW, a stronger connection is needed with more outlets and more injection capacity. POIs at and near the McCredie substation offer a good option for the injection of 2500 MW, given the number of outlets and the capacity of the existing lines.

Q. Why are the POIs at and near the McCredie Substation superior to the Maywood-Montgomery POI?

A. As seen in Schedule CR-2, the existing McCredie 345kV substation has four outlets for power being injected to it, as follows: McCredie – Thomas Hill 345kV line, McCredie Montgomery 345kV line, McCredie – Overton 345kV line, and McCredie – Kingdom City 345kV line. The total capacity of these four 345kV outlet lines is 3878 MVA under normal operating conditions (N-0, all lines in service). Under the loss of the highest rated outlet (N-1 condition), the

McCredie total capacity is 3026 MVA. Therefore, POIs at and near the McCredie substation have significantly more capacity (3026 MVA vs 1272 MVA under N-1 conditions) and more outlets (4 outlets vs 2 outlets) than the original POI to the Maywood-Spencer Creek-Montgomery 345kV line. See Schedule CR-3, showing existing transmission facilities in Missouri. In addition, the Maywood – Spencer Creek – Montgomery 345kV line experiences a heavy North to South flow, due in part from wind generation coming from Iowa. Moreover, there is an existing power plant, the Audrain Generating Station (gas fired, 814 MW), which connects to the same Maywood – Spencer Creek – Montgomery 345kV line, aggravating even more the North to South congestion on this line. For the above technical reasons, POIs at and near the McCredie substation are superior, stronger, more reliable, and therefore preferred for a 2500 MW injection. Moreover, although Grain Belt Express considered other potential POIs in addition to McCredie (the Maywood 345kV substation, the Thomas Hill 345 kV substation, and the Montgomery 345 kV substation), which, from a purely electrical perspective are similar, the geographic location and associated real estate options at and near McCredie make it the preferred POI to the others. One additional advantage is that McCredie is at the seam between MISO and AECI, so it offers the possibility of serving both MISO and AECI systems, therefore providing more opportunities to serve customers in Missouri.

C. The Proposed POIs Are Not Related to Nearby Solar Development

Q. Did Grain Belt Express select the POIs at and near the McCredie Substation for the purpose of carrying power from a solar development in Callaway County?

A. No. I am aware that there have been rumors or misconceptions expressed by some individuals regarding the proposed POIs and their relationship to nearby solar development. I can confirm that Grain Belt Express did not select the proposed POIs for the purpose of carrying power from the solar development in Callaway County. As discussed elsewhere, the primary purpose of the Grain Belt Project is to deliver power generated in western Kansas to Missouri and points

further east. While power generated in Missouri could flow on the Grain Belt Project in an emergency, that is not the purpose for which the Project is being built.

V. STATUS OF INTERCONNECTION PROCESS AND OTHER INTERACTIONS WITH RTOS

A. SPP

Q. What studies have been conducted for the interconnection of the Project to SPP in Kansas?

A. When the HVDC technology under consideration was the LCC technology, Grain Belt Express (at the time, Grain Belt Express Clean Line LLC, under the then-current ownership of Clean Line Energy Partners LLC) conducted bulk electric grid reliability studies with affected Transmission Owners, in collaboration with Siemens Power Technologies International, in accordance with SPP Criterion 3.5. These studies assumed a transmission line capacity of 4,000 MW. Grain Belt Express submitted various technical studies to SPP, including steady state, dynamic and voltage stability studies simulating the effect of the Project on SPP's and other affected parties' electric systems. Criterion 3.5 required entities requesting transmission interconnections to work with SPP and affected parties to ensure grid reliability. Potentially affected 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. Furthermore, as part of Grain Belt Express's agreement with SPP, in the summer of 2013, SPP performed an independent review[3] of the studies and provided its opinion prior to seeking SPP Transmission Working Group approval. In September 2014, Grain Belt Express executed a Facilities Study

[3] Excel Engineering, Inc., *Grain Belt 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.

Agreement with ITC, which began the process for ITC to determine the specific equipment needed in order to interconnect the Project to the ITC system.[4] This Facilities Study was completed in March 2015. After the completion of the Facilities Study, Grain Belt Express and ITC worked on the Interconnection Agreement, which was executed on October 17, 2016, with an expected commercial operation date of October 1, 2020 and an estimated cost of $23,489,044, which included a new 345 kV 9-breaker switching station.

While these studies assumed the use of older LCC HVDC technology, they are still a good reference and demonstrate that the Project will work well with the SPP system without jeopardizing stability or reliability. The Project now anticipates using even better VSC HVDC technology.

Q. What were the objectives of the steady state studies and stability studies conducted in this context?

A. Steady state and stability studies identify the impact that a new project (transmission, generation or other equipment) might have on the electric grid to which that equipment is being interconnected. The objective of the studies that were performed to meet SPP's Criterion 3.5 was to identify the impact that the Project would have on the SPP electric grid during abnormal conditions. Such conditions include when one or more transmission circuits within the SPP grid are out-of-service and, concurrently, the Project experiences a pole or bipole outage where the wind energy that was being delivered by the HVDC line is now temporarily injected into the SPP grid.

[4] 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.

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 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 in February 2013. The final dynamic and voltage stability study results were 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 parties when the study results were shared with them. In September 2013, the SPP Transmission Working Group passed a motion to "approve the GBX [Grain Belt Express] studies completed to date as meeting their coordinated planning requirements under SPP Criteria . . . ."[5]

Q. What power transfers are anticipated between the Project and SPP during operation of the Project?

A. When the LCC technology was being considered, the Project was being designed so that during normal operating conditions, there was nominally zero active power exchange and very little, if any, reactive power exchange between the Project AC bus and the SPP grid. However, following the loss of a single pole of the HVDC transmission line, some of the power transmitted by the Project would temporarily flow into the SPP grid. The results of the SPP

[5] SPP Transmission Working Group, *Minutes of the TWG Meeting, August 14-15 2013*; *(available at):* http://www.spp.org/publications/TWG%208.14-15.13%20Minutes%20&%20Attachments.pdf.

Criterion 3.5 studies indicated that during such an occurrence, using one of the scenario cases, only one circuit in the SPP grid would be loaded above its applicable rating; this overload could be mitigated by curtailing some amount of wind generation to bring the flow of this facility below its thermal limit. For all other scenarios included in the studies, the loss of a single DC pole does not cause any adverse impacts.

Q. Please explain your reference to "loss of a single DC pole."

A. As discussed previously in this testimony, an AC transmission line has three (3) phase conductors for every AC circuit. A DC transmission line, in contrast, has one pole conductor for each circuit. A DC bipole (as in the case of the Project) is really two DC circuits. An outage of one of these circuits is referred to as a "pole outage" while an outage of both circuits is considered a "bipole outage." The "loss of a single DC pole" is another way to say a DC pole outage occurs.

Q. What further steps does Grain Belt Express need to take with SPP to complete the interconnection study process and obtain approval to interconnect to the SPP grid?

A. Because Grain Belt Express expects to use upgraded VSC HVDC technology, it contacted SPP to identify next steps for the evaluation of the new technology. SPP indicated that Criterion 3.5 had been replaced with SPP's Planning Criteria Section 5.5 and Section 14. Grain Belt Express retained Hatch Associates Consulting Inc. to conduct the system studies related to SPP's Planning Criteria Section 5.5 and Section 14. In accordance with SPP's Planning Criteria Section 5.5 and 14, a presentation was made to the SPP Transmission Working Group ("TWG") in November 2020 to discuss the Project and also the preparation of a revised scope of work for the evaluation of the new VSC technology (with the previously assumed capacity of 4,000 MW). This revised scope of work was discussed with SPP's affected transmission owners for several months and their input and comments included in the scope of work. The scope of work was

approved by TWG in May 2021 and it includes a rerun of the steady state, short circuit and stability analysis that were previously done with the LCC technology. The steady state analysis was completed and Grain Belt Express presented the results to TWG on June 7, 2022 for their review. Based on the study results, there were no facilities in the SPP area requiring upgrades due to the Project. Temporary violations were observed due to the loss of a single pole (N-1), bipole (N-2) as well as the loss of a single pole coupled with a single contingency (N-1-1) in the network. These overloads could be mitigated by curtailing some amount of wind generation to bring the flow of the facilities below its thermal limits. Now that the steady state results have been presented to TWG, next steps per TWG's guidance are to work on the stability and short circuit studies. At the present time, Grain Belt Express is working with TWG and the affected parties to discuss the different assumptions and models that will be used for the stability and short circuit studies. The expectation is to have the studies completed and approved for 4,000 MW capacity by the end of 2022 or early 2023. Grain Belt Express's next step is to initiate review with the TWG in accordance with SPP's Planning Criteria Section 5.5 and 14 for an additional 1,000 MW capacity (bringing the total capacity for Project up to 5,000 MW), which Grain Belt Express anticipates completing mid to late 2023.

Q. What power transfers are anticipated between the Project and SPP during operation of the Project with the new VSC technology?

A. With the VSC technology, the Project is still 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 Project AC bus and the SPP grid. However, just as with the previously evaluated LCC technology, following the loss of a single pole of the HVDC transmission line, some of the power transmitted by the Project would temporarily flow into the

SPP grid. The results of the SPP's Planning Criteria Section 5.5 and 14 studies indicate that there were no facilities in the SPP area requiring upgrades due to the Project. Temporary violations were observed due to the loss of a single pole (N-1), bipole (N-2) as well as the loss of a single pole coupled with a single contingency (N-1-1) in the network. These overloads could be mitigated by curtailing some amount of wind generation to bring the flow of the facilities below its thermal limits. Now that the steady state results have been presented to TWG, next steps per TWG's guidance are to work on the stability and short circuit studies. At the present time, Grain Belt Express is working with TWG and the affected parties to discuss the different assumptions and models that will be used for the stability and short circuit studies. The expectation is to have the studies completed and approved by the end of 2022 or early 2023. Once all the studies are approved, the existing interconnection agreement with ITC will be amended to reflect any changes arising from the studies, as well as to update interconnection costs and schedule.

B. MISO

Q. Has an interconnection request for the Project been submitted to MISO?

A. Yes. Four interconnection requests were submitted to MISO in April 2019. The point of interconnection for all four interconnection requests is breaking Ameren's McCredie – Montgomery 345 kV line, near AECI's McCredie 345 kV substation. Two of the interconnection requests (total 1,500 MW) are being processed per MISO's Merchant HVDC Transmission Connection Procedures ("MHCP," Attachment GGG) and the two remaining are being processed per MISO's Generator Interconnection Procedures ("GIP," Attachment X). The queue numbers for the MHCP requests are H104 (1,000 MW) and H105 (500 MW). The queue numbers for the GIP requests are J1490 (1,000 MW) and J1488 (500 MW). The reason to have four interconnection requests is that per the MISO process, the MHCP requests provide physical interconnection and

the GIP requests provide injection rights. So even though there are 3,000 MW in the MISO queue, the four queue positions will enable the interconnection of 1,500 MW with injection rights.

Q. Was any additional analysis conducted by MISO for the interconnection of the Project?

A. For the MHCP requests, steady state, stability, Sub-Synchronous Torsional Interaction and delta-P studies have been completed and the expectation is for MISO to start the facilities study soon. The expectation is to sign a Transmission Connection Agreement ("TCA") in early 2023. The results from the MHCP studies have identified a total of $110,750,000 in network upgrades, which include two new 345 kV lines from the point of interconnection to the Montgomery 345 kV substation, as well as other smaller network upgrades. The GIP requests are in the Decision Planning Phase 3 of the MISO process and the decision point 3 is expected in October 2022. The MISO process has three phases of studies—DPP1, DPP2 and DPP3—and then the tendering of an interconnection agreement. Grain Belt Express expects MISO to tender a TCA for the GIP positions in early 2023. The injection rights studied in the GIP request will be set forth in Appendix F to the TCA, per Attachment GGG of the MISO Tariff. The results from the DPP2 studies indicate a total cost of $177,656,953 including interconnection facilities, network upgrades and affected system upgrades in the AECI system. These include several upgrades at the 161 kV, 138kV, and 69 kV voltage levels. As part of DPP2, MISO also asked PJM, SPP and TVA to evaluate any impact on their system as Affected System but none of these identified any Network Upgrades for J1488 and J1490. The final costs will be known after the DPP3 process is completed.

Q. What further steps need to be taken with MISO to complete the interconnection study process and obtain approval for the proposed interconnection?

A. For the GIP positions, the Project is currently in DPP3. which includes a facilities study. After the facilities study is completed (expected in October 2022) MISO will tender a TCA, which is expected to be executed in early 2023. The injection rights studied in the GIP request will be set forth in Appendix F to the TCA, per Attachment GGG of the MISO Tariff. As for the MHCP requests, those will also be part of the TCA.

C. AECI

Q. Has an interconnection request for the Project been submitted to AECI?

A. Yes. One 1018 MW interconnection request (queue number GI-083) was submitted to AECI in June 2019, with a point of interconnection to the McCredie 345 kV substation.

Q. Was any additional analysis conducted by AECI for the interconnection of the Project?

A. All the studies have been completed (system impact study and facilities study) and an Interconnection Agreement was executed in December 2021. The total costs are $98,618,000, including interconnection facilities, network upgrades and affected systems upgrades in the MISO system. These include rebuilding the McCredie – Montgomery 345 kV line and several upgrades in the MISO and AECI systems at the 69 kV, 138 kV, 161 kV voltage levels. The commercial operation date in the Interconnection Agreement is currently December 2025, but will be amended to December 2026.

Q. Did Grain Belt Express provide a copy of the AECI Interconnection Agreement to Commission Staff?

A. Yes. The 2019 Report and Order on Remand directed Grain Belt Express to comply with certain conditions agreed upon between Staff and Grain Belt Express, as reflected in Attachment 1 thereto. Section II.1 of Attachment 1 to the Report and Order on Remand states that "Grain Belt will provide Staff with completed RTO Interconnection Agreements and any associated studies. Should the studies raise new issues, Grain Belt will provide its plan to address those issues." Although the Interconnection Agreement is with AECI, and not an RTO as referenced in the above condition, Grain Belt Express provided Commission Staff with a copy of the AECI Interconnection Agreement and associated studies shortly after the Interconnection Agreement was executed in December 2021. The studies did not raise any new issues that would necessitate Grain Belt Express providing a plan to address those issues.

D. PJM

Q. Has an interconnection request for the Project been submitted to PJM?

A. Yes. Four merchant transmission interconnection requests have been submitted to PJM with a point of interconnection to the Sullivan 345 kV substation. The requests are AF1-088 (1,000 MW Energy/1,000 MW capacity, injection/withdrawal) submitted in August 2019, AF2-008 (1,000 MW Energy/500 MW capacity, injection) submitted in October 2019, AH1-084 (500 MW Energy/500 MW capacity, injection) submitted in July 2021 and AH1-085 (500 MW Energy/500 MW capacity, withdrawal) submitted in July 2021.

Q. Please describe the PJM Merchant Transmission Interconnection process.

A. The PJM merchant transmission interconnection process is initiated by a developer submitting to PJM an executed Transmission Interconnection Feasibility Study Agreement per

Attachment S to the PJM OATT. PJM's interconnection study process, which is outlined in PJM's Manual 14 series, involves a three-phase study approach.[6] Phase I is the Feasibility Study, which assesses the practicality and cost of accommodating the interconnection of a project with the PJM transmission system. This study focuses solely on the peak load flow analysis of probable contingencies and provides high-level, preliminary estimates of the type, scope, cost and lead-time for construction of facilities required to interconnect a project.

Phase II is the Impact Study, the intent of which is to determine a plan, with cost and construction time estimates, to connect the project to the PJM network at a location specified by the interconnection customer. This study involves an expanded focus of not only load flow, but also voltage and angular stability and short circuit impacts of the proposed interconnection on the PJM network.

The final phase is the Facilities Study. The purpose of the Facilities Study is to provide engineering and, as appropriate, detailed design, including cost estimates and project schedules, to implement the conclusions of the Impact Study regarding new installations or modifications to existing facilities required to facilitate the requested interconnection to the PJM network.

The three phases of studies described above are all performed by PJM, the interconnected transmission owner (here, AEP) or by consultants retained by these entities, but they are paid for by the entity requesting interconnection.

Q. What is the status of the interconnection requests that Grain Belt Express has submitted to PJM?

A. The status of the four requests are as follows:

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

AF1-088 (1,000 MW Energy/1,000 MW capacity, injection/withdrawal): PJM completed the feasibility study in January 2020 and the system impact study was completed in February 2022. The system impact study identified a total of $200,029,000 in interconnection costs, including $3,517,000 in total physical interconnection costs and $196,512,000 in allocation towards system network upgrades. The physical interconnection costs consist of one new 345 kV breaker and associated equipment at the Sullivan 345 kV substation. The majority of the costs of the network upgrades include two new 345 kV lines: build a second parallel Breed – Casey 345 kV line and rebuild the Sullivan – Darwin – Eugene 345 kV line.

It is important to point out that PJM staff and stakeholders are nearing consensus on a new interconnection process framework and transition mechanism for projects currently in the queue. The proposed new framework will move from a serial process to a cluster-based study process. The new process will also have stricter land control requirements and require more collateral at risk to remain in the queue. PJM filed its proposal at FERC on June 14, 2022 and asked FERC to approve it by October 3, 2022. PJM asked for a January 3, 2023 effective date. If FERC rejects PJM's proposal, the effective date could move later into Q1 2023 and delay the implementation of the new process. PJM will grandfather projects into the existing rules that receive an Interconnection Service Agreement for execution before the effective date. PJM expects to complete all projects in queue windows AD2 and prior before the effective date, which will grandfather those projects into the existing rules. PJM also proposes to grandfather projects into the existing process in queue windows AE1-AG1 that contribute to Network Upgrades of less than or equal to $5 million.

PJM will study the remaining AE1-AG1 projects in a transitional cluster under the new rules to be completed in 2025. PJM will then study projects in AG2-AH1 in a second transitional cluster under the new rules to be completed in 2026. All projects in AH2 and beyond will be subject to the new rules.

PJM will start accepting applications for the first new cycle in 2023 and plans to complete the first new cycle by 2027. Based on the proposed PJM interconnection process framework (likely to be approved by FERC) it is expected that Grain Belt Express queue position AF1-088 will enter a transitional cluster for restudy, which is expected to be completed in 2025. The interconnection costs and network upgrades identified in this future transitional cluster will likely be different than what has been identified by PJM for AF1-088.

AF2-008 (1,000 MW Energy/500 MW capacity, injection): PJM completed the feasibility study in July 2020 and the system impact study was completed in April 2022. The system impact study identified a total of $164,875,800 in interconnection costs, including $45,000 in total physical interconnection and $164,830,800 in allocation towards system network upgrades. The physical interconnection costs consist of the review of protection and control settings at the Sullivan 345 kV substation. The majority of the costs of the network upgrades include two new 345 kV lines: build a second parallel Breed – Casey 345 kV line and rebuild the Sullivan – Darwin – Eugene 345 kV line. Based on the proposed PJM interconnection process framework (likely to be approved by FERC) it is expected that Grain Belt Express queue position AF2-008 will enter a transitional cluster for restudy, which is expected to be completed in 2025. The interconnection costs and

network upgrades identified in this future transitional cluster will likely be different than what has been identified by PJM for AF2-008.

AH1-084 (500 MW Energy/500 MW capacity, injection): PJM has not started the studies for this queue position. Based on the proposed PJM interconnection process framework (likely to be approved by FERC) it is expected that Grain Belt Express queue position AH1-084 will enter a transitional cluster for restudy, which is expected to be completed in 2026. The interconnection costs and network upgrades identified in this future transitional cluster will likely be different than what has been identified by PJM for the other Grain Belt Express queue positions.

AH1-085 (500 MW Energy/500 MW capacity, withdrawal): PJM has not started the studies for this queue position. Based on the proposed PJM interconnection process framework (likely to be approved by FERC) it is expected that Grain Belt Express queue position AH1-085 will enter a transitional cluster for restudy, which is expected to be completed in 2026. The interconnection costs and network upgrades identified in this future transitional cluster will likely be different than what has been identified by PJM for the other Grain Belt Express queue positions.

Q. Will the chosen points of interconnection, as well as the electric grids of which these substations are a part, be able to accommodate the interconnection of the Project and the introduction of up to 5,000 MW of new generation capacity into the system?

A. Yes, this is what the interconnection study processes are intended to determine—either that the existing system can accommodate the proposed interconnection or, if not, what specific system upgrades, reinforcements or operating protocols are needed in order to accommodate the proposed interconnections.

Q. Has Grain Belt Express had discussions with the utilities to which the Project will interconnect regarding the proposed interconnections?

A. Yes. Grain Belt Express has had numerous discussions with ITC, Ameren, AECI and AEP. Additionally, through the interconnection processes of SPP, MISO and PJM, these utilities' planning personnel are directly involved in the analyses and/or scoping of the study work that resulted in the interconnection study results previously described.

Q. Will Grain Belt Express continue to comply with the reporting requirements of Section II.1 of Attachment 1 to the 2019 Report and Order on Remand?

A. Yes. Grain Belt Express will continue to comply with the requirement to provide Staff with completed RTO Interconnection Agreements and any associated studies. Should the studies raise new issues, Grain Belt Express will provide its plan to address those issues.

VI. CONCLUSION

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 LLC for an Amendment to its Certificate of Convenience and Necessity Authorizing it to Construct, Own, Operate, Control, Manage, and Maintain a High Voltage, Direct Current Transmission Line and Associated Converter Station	)))))))	File No. EA-2023-0017

AFFIDAVIT OF CARLOS RODRIGUEZ

1. My name is Carlos Rodriguez, I am Senior Vice President of Interconnections and Grid Analysis at Invenergy LLC ("Invenergy"). My business address is One South Wacker Drive Suite 1900, Chicago, IL, 60606.

2. I have read the above and foregoing Direct Testimony and the statements contained therein are true and correct to the best of my information, knowledge, and belief.

3. Under penalty of perjury, I declare that the foregoing is true and correct to the best of my knowledge and belief.

DocuSigned by:
Carlos Rodriguez
836916F891174BA...

Carlos Rodriguez
Senior Vice President of Interconnections and Grid Analysis
Invenergy LLC
Date: 8/24/2022