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MISSOURI PUBLIC SERVICE COMMISSION

CASE NO. EA-2016-0358

SURREBUTTAL TESTIMONY OF

DR. ANTHONY WAYNE GALLI, P.E.

ON BEHALF OF

GRAIN BELT EXPRESS CLEAN LINE LLC

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TABLE OF CONTENTS

I. INTRODUCTION AND QUALIFICATIONS 1

II. INTERCONNECTION STUDIES 2

a. General 2

b. Cost Impacts of Remaining Interconnection Studies 3

c. MISO 9
i. Study Updates and Developments 9
ii. Next Steps 11

d. PJM 22
i. Study Updates and Developments 22
ii. Next Steps 24

e. SPP 30
i. Study Updates and Developments 30
ii. Next Steps 30

III. ADDITIONAL INFORMATION AND CLARIFICATIONS PERTAINING TO OPERATIONS AND MARKET INTERACTIONS 32

IV. RESPONSE TO STAFF'S CONCERNS RELATED TO THE LEVEL OF ENGINEERING DESIGN 38

V. RESPONSE TO STAFF'S CONCERNS RELATED TO SAFETY AND COORDINATION WITH NEARBY UTILITIES 40

VI. RESPONSE TO STAFF'S RECOMMENDED CONDITIONS 41

I. INTRODUCTION AND QUALIFICATIONS

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

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

Q. Have you previously submitted prepared testimony in this proceeding?

A. Yes, I submitted direct testimony on August 29, 2016.

Q. What is the subject matter of this surrebuttal testimony?

A. I will address items raised by the Missouri Public Service Commission Staff ("Staff") in their Staff Rebuttal Report ("Staff Report") related to the Grain Belt Express Clean Line HVDC Project ("Grain Belt Express Project" or "Project") with respect to interconnection studies, design status, Project operational modes, and safety. I will also address various conditions that were recommended by Staff.

Q. Please summarize your testimony's organization.

A. First, in response to Staff's discussion of various technical studies in its Rebuttal Report, I will describe the difference between interconnection studies that deal with Bulk Electric System ("BES") impacts versus studies which are performed in the design of an HVDC transmission project. Second, I will provide updates, clarifications, and next steps related to the Project's Regional Transmission Organization ("RTO") interconnection studies, including why the scope and cost of network upgrades from these studies are not risks to the Project's economic feasibility. Third, I'll explain why the present level of design of the Grain Belt Express Project is completely appropriate at the current stage of its

development. Fourth, I'll explain why consideration of additional operating modes of the Project is reasonable because the RTOs can accommodate bi-directional power flow. Fifth, I will address Staff's testimony regarding the Project's crossings of existing underground utilities. Sixth, I'll address some of the conditions proposed by Staff.

II. INTERCONNECTION STUDIES

a. General

Q. Staff points to several ongoing and future interconnection studies for the Project beginning on page 22 of the Staff Report. Notwithstanding that some studies remain to be completed, will Grain Belt Express design, construct and operate the Grain Belt Express Project in a reliable manner?

A. Yes. Grain Belt Express will design, construct and operate the Project to be compliant with industry standards, codes, and best practices such as those of the Institute of Electrical and Electronics Engineers, National Fire Protection Association, International Electrotechnical Commission, and the International Council on Large Electric Systems, to name a few. Additionally, Grain Belt Express will be required to meet national, regional, and local reliability standards, including Good Utility Practice.[1]

Q. Will other regulatory bodies, procedures and laws ensure that the Grain Belt Express Project is designed and operated in a reliable manner?

A. Yes. As I described in my direct testimony, Grain Belt Express must design, construct and operate the Project in a manner that complies with the mandatory reliability standards of the North American Electric Reliability Corporation ("NERC")[2] and of the regional

[1] Direct Testimony of Dr. Anthony Wayne Galli, P.E, p. 15, line 1.

[2] Direct Testimony of Dr. Anthony Wayne Galli, P.E, pp. 15-16.

entity, ReliabilityFirst Corporation ("RFC"). Grain Belt Express must sign Interconnection Agreements with the Southwest Power Pool ("SPP"), the Midcontinent Independent System Operator ('MISO") and PJM Interconnection L.L.C. ("PJM"). These Interconnection Agreements will require Grain Belt Express to fund and complete any transmission upgrades required to ensure the reliability of the grid prior to energizing the Project. Further, these Interconnection Agreements will require that the Project also operate in a manner that complies with mandatory reliability standards of the other relevant regional entities, Southwest Power Pool Regional Entity and the Midwest Reliability Organization.

b. Cost Impacts of Remaining Interconnection Studies

Q. Does Grain Belt Express have a reasonable basis to estimate network upgrades for its SPP, MISO, and PJM interconnections?

A. Yes. SPP, MISO, and PJM have conducted technical studies in sufficient detail to support cost estimates with a reasonable level of certainty. In addition, Grain Belt Express has hired reputable technical consultants to conduct studies that confirm the expected level of network upgrades. In the remainder of this section of my surrebuttal, I explain why there is limited risk of additional costs for network upgrades within the SPP, MISO, and PJM transmission systems due to the knowledge gained from (1) the January and March, 2013 SPP Criterion 3.5 study work performed by Siemens PTI, (2) the September 2013 SPP Criterion 3.5 verification studies performed by SPP, (3) the March 2015 Facilities Study performed by ITC Great Plains, (4) the October 2012 Feasibility study performed by MISO, (5) the November 2014 SPA Study and January 2017 Optional Study performed by Ameren Missouri, (6) the Project HVDC model

development and stability testing performed by TransGrid Solutions, (7) the January 2013 Feasibility Study performed by PJM and AEP, and (8) the October 2014 System Impact Study (and ongoing re-tooled System Impact Study) performed by PJM and AEP.

Q. Please respond to Staff witness Sarah Kliethermes' concern at pages 30-31 that the costs of network upgrades identified by MISO in the interconnection studies for the Project could be partially recovered by Missouri ratepayers.

A. Grain Belt Express and its transmission customers bear the risk of costs associated with network upgrades. Ms. Kliethermes describes a process of partial cost allocation of network upgrades[3] which currently exists only for generator interconnection projects. This process, as Ms. Kliethermes correctly points out, acknowledges the value of network upgrades to both the generator interconnection, as well as to the BES at-large. There is currently no way for an HVDC project developer to seek any amount of cost allocation of network upgrades identified by MISO through interconnection studies. If a process was implemented to allow partial cost recovery of network upgrades identified as a result of an HVDC interconnection, there is no reason to believe that it would deviate from the process that exists for generators. The current approach that MISO applies for generator interconnections provides for 10% cost recovery of any network upgrades across all MISO load where individual load zones within MISO are allocated their load-ratio share of the 10%. In order to apply this approach to new HVDC interconnections, MISO and its stakeholders would need to develop the appropriate tariff language and receive FERC approval.

[3] Staff Rebuttal Report, p. 31.

Q. If MISO extends the cost allocation process from its generator interconnection procedures to apply to HVDC interconnections and specifically, for the Project, what would be the implications to Missouri load?

A. If MISO utilized the generator interconnection cost allocation process for the Grain Belt Express Project network upgrades identified by Ameren to date, $2.02 million would be cost allocated across all of MISO. Of this $2.02 million, in accordance with the load-ratio share of Missouri load to the rest of MISO, 6.2% of this $2.02 million, or approximately $125,200, would be allocated to Missouri customers. This is a very low cost to Missouri load for enhancements that will make the transmission system in Missouri more reliable and would be available to all users of that transmission system.

Q. In your professional opinion, does the possibility that network upgrades are higher than expected affect the economic feasibility of the Project?

A. No. In my roles at SPP and NextEra Energy, I oversaw and participated in many interconnection studies. Compared to other projects on which I have worked, Grain Belt Express, at this stage of the Project's development, has performed a larger number of studies and done more due diligence about the level of network upgrades potentially associated with the Project. The completed studies and due diligence provide a solid basis for Grain Belt Express' financial estimates and business plan. Mr. Berry's surrebuttal testimony more specifically addresses the manageable financial impact to the Project of potentially higher upgrades. **Schedule AWG-7** is a table that summarizes the studies that have been performed at each point-of-interconnection including its status and references to where each study is discussed in both of my direct and surrebuttal testimony.

Q. The Staff Report at pages 24-29 points to a number of ongoing and future technical studies related to the Project's interconnection. Please explain the distinction between studies that deal with a new project's impacts on the Bulk Electrical System ("BES") and studies that deal with a new project's performance in relation to the BES.

A. It is helpful to visualize a new project and consider the fence line which separates the equipment within the boundaries of that new project substation ("inside the fence") and the rest of the BES on the other side of the fence line ("outside the fence"). The project developer, in this case Grain Belt Express, is responsible for designing the "inside the fence" facilities, while the interconnecting utility is responsible for designing the "outside the fence" facilities.

When a new project desires to interconnect to the BES, the regional grid operator conducts, or engages a third-party to conduct, a study to identify impacts "outside the fence" to the BES. This study is typically referred to as an Impact Study. Impact Studies identify potential violations of reliability standards that could occur due to operation of the new project. The results of the Impact Study may recommend network upgrades to the BES (i.e., "outside the fence") that would mitigate the identified reliability standard violations or otherwise an affirmation that the new project can be reliably interconnected without network upgrades.

Grain Belt Express, together with the manufacturer of the HVDC equipment, will perform Design-Level Studies in the normal course of designing the converter stations. The Design-Level Studies ensure that operation of the Project will meet interconnection requirements consistent with the Impact Study results including the RTO's and the

interconnecting utilities' operating and planning criteria. The Design-Level Studies assure that the final HVDC converter station equipment located "inside the fence" allows for the seamless integration of the new project into the BES at the chosen points-of-interconnection and complies with all interconnection requirements.

Q. What is the purpose of differentiating between the Impact Studies or BES studies that are performed by the RTO, and the Design-Level Studies that are performed by Grain Belt Express and the equipment manufacturers?

A. In the Staff Report, Staff suggests that various ongoing or future technical studies could potentially increase costs to Grain Belt Express due to unidentified network upgrades.[4] The majority of the studies that Staff discusses, however, are Design-Level Studies which only impact equipment "inside the fence" of the Grain Belt Express Project. They do not affect the number and/or scope of network upgrades identified "outside the fence" by SPP, MISO, or PJM.

Q. What studies are required in order to properly <u>design</u> an HVDC project such as the Grain Belt Express Project?

A. **Schedule AWG-8** is a table that shows Impact Studies (green-shaded) which, as I previously described, deal with BES impacts "outside the fence," as well as Design-Level Studies (un-shaded) which deal with the equipment requirements "inside the fence." Mr. Stahlman and Mr. Lange express concern in Staff's testimony about items that are studied and addressed through Design-Level Studies including harmonic performance,[5]

[4] Staff Rebuttal Report, p. 22.

[5] Staff Rebuttal Report, pp. 26, 60-61.

studies on control interaction with other DC links,[6] subsynchronous torsional interaction studies[7], as well as dynamic performance studies.[8] These studies and the others identified in **Schedule AWG-8** will be performed during the design process of the Grain Belt Express Project and will be complete prior to the start of construction since the results of these studies are required for final design and manufacture of equipment. The Design-Level Studies will prescribe an HVDC design which meets all interconnection requirements and complies with the HVDC model used in the completed RTO interconnection studies. As I previously described, these Design-Level Studies only impact Project equipment "inside the fence." Therefore, Staff's concerns are unfounded as to whether the RTOs have sufficient information about future Design-Level Studies to finalize the Impact Studies and identify any needed transmission upgrades.

Q. Will SPP, MISO PJM and the interconnecting utilities coordinate and review the Design-Level Studies?

A. Yes. Each utility which the Project interconnects with will advise on and review the Design-Level Studies. The utilities will advise on the scope of the study, provide applicable standards and data inputs, verify system parameters and assumptions, and review and confirm results. MISO's Merchant HVDC Task Team ("MHTT") is

[6] Staff Rebuttal Report, pp. 59-60.

[7] Staff Rebuttal Report, pp. 59-60.

[8] Staff Rebuttal Report, p. 58. Mr. Lange discusses short-circuit ratio issues which directly deals with dynamic performance.

discussing and developing a coordination process for MISO and interconnecting utilities to participate in HVDC Design-Level Studies.[9]

c. MISO

i. Study Updates and Developments

Q. Were there any new MISO study results provided to Grain Belt Express since you filed your direct testimony?

A. Yes. On January 25, 2017 MISO issued its Optional Study Report which was prepared by Ameren Service Company ("Ameren") at MISO's direction and is attached as **Schedule AWG-9.** This is the same report that I referred to as a "more advanced study".[10] The name of the study was changed from a System Planning & Analysis or "SPA Study" to an "Optional Study" because of FERC's January 3, 2017 Order[11] accepting MISO's proposed revisions[12] to MISO's generator interconnection procedures which included, among other changes, elimination of the SPA study phase. However, the scope and purpose of the study have not changed.[13]

Q. How is the MISO Optional Study Report more advanced than the MISO SPA Study Report previously provided?

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[9] See p. 9-10 of the MHVDC Process Draft from the December 2016 MHTT meeting at: https://www.misoenergy.org/Library/Repository/Meeting%20Material/Stakeholder/MHTT/20161209/20161209%20MHTT%20Item%2004%20MHVDC%20Process%20Draft.pdf

[10] Direct Testimony of Dr. Anthony Wayne Galli, P.E, p. 12, lines 15-17.

[11] Midcontinent Indep. System Operator, Inc., Order Accepting Tariff Revisions Subject to Condition, No. ER17-156-000 (Jan. 3, 2017).

[12] Direct Testimony of Timothy Aliff, pp. 46-47, *available at*: https://www.misoenergy.org/Library/Repository/Tariff/FERC%20Filings/2016-10-21%20Docket%20No.%20ER17-156-000.pdf

[13] More information on Optional Studies is available on the MISO Generator Interconnection site available at: https://www.misoenergy.org/Planning/GeneratorInterconnection/Pages/ProceduresRequirements.aspx

A. Yes. This more advanced study addressed some concerns raised in Staff's Rebuttal Report. Compared to previous MISO studies, the Optional Study considered more contingency scenarios. In addition to NERC P0-P1 events (f/k/a category A and B events), the Optional Study also considered P2-P7 events (f/k/a category C1-C5 events) and other Ameren Local Planning Criteria.[14] Staff Witness Mr. Lange expressed concern that previous MISO studies did not include NERC category C events.[15] The Optional Study included these additional contingencies and provides more certainty regarding the impacts from interconnection of the Project's Missouri HVDC Converter Station.

Q. Did the Optional Study Report consider stability analyses?

A. No. Stability analyses are not typically performed until the Definitive Planning Phase ("DPP") of the MISO interconnection process since they involve even more detailed and expensive studies which require significant staffing resources from MISO and Ameren.

Q. Does Grain Belt Express have a reasonable basis to believe MISO's stability analysis will not result in a large amount of additional upgrades?

A. Yes. Outside of the MISO interconnection process, Grain Belt Express has commissioned technical studies that include stability analysis. In 2013, Siemens PTI performed a stability analysis for the SPP Criterion 3.5 Studies and did not identify any stability-related issues from interconnection of the Missouri HVDC Converter Station which would require new transmission upgrades. Siemens PTI is a highly reputable technical consultant, who is often hired by grid operators to perform stability analysis as part of interconnection studies.. SPP, through their consultant Excel Engineering, Inc.,

[14] See Optional Study Report at p.7, Schedule AWG-9

[15] Staff Rebuttal Report, pp.55, 60.

verified Siemens PTI's work and concluded in their report, which I have included as **Schedule AWG-10**, that "[n]o stability problems were found for faults near the AMMO [Ameren Missouri] Palmyra station. The AMMO system is able to handle the additional 500 MW injection without a problem."[16]

Finally, Grain Belt Express' HVDC technical consultant, TransGrid Solutions Inc. ("TGS")[17] developed an HVDC model of the Project which has been and will continue to be utilized in the MISO and PJM interconnection studies. TGS performed detailed model testing which found that the HVDC performed as expected under fault conditions. TGS' testing considered the most severe faults that could impact operation of the Project; these are the same faults that will be included in the stability study that will be performed by MISO in the DPP. TGS did not identify any issues at the MISO interconnection in the HVDC model development. Therefore Grain Belt Express is confident that no additional network upgrades will be identified by MISO for the Project due to stability issues.

ii. Next Steps

Q. The Staff Report at page 58 appears to suggest that transmission upgrades in MISO cannot be known until a short-circuit analysis is performed for the Project. Is this correct?

A. No. Short circuit studies determine if, with the addition of a new power injection, fault current levels can still be safely managed in accordance with ratings of existing substation equipment. The contribution to fault current levels from HVDC converters are insignificant compared to fault currents produced from synchronous generators. This is

[16] Schedule AWG-9, p.8.

[17] I described the credentials of both Siemens PTI and TGS in my direct testimony. Direct Testimony of Dr. Anthony Wayne Galli, P.E, p.36, lines 7-19.

highlighted in the "Short Circuit Analysis" section of the MISO SPA Study Report which states "[n]o short-circuit analysis should be required for this connection because the customer's HVDC line should not contribute current to an ac short circuit (except for its rated load current)." Staff also acknowledged this in response to a Grain Belt Express data request where Staff was asked about its understanding of the contribution to short circuit currents by HVDC converter stations. Staff witness Mr. Stahlman responded: "HVDC transmission does not contribute to the short circuit current of the interconnected AC system."[18]

Q. In response to Staff's concerns regarding MISO studies at pages 24-25, does the most recent Optional Study Report provide additional certainty regarding MISO interconnection studies?

A. Yes. In the Optional Study Report, Ameren lists the network upgrades and interconnection facilities that were identified as a result of the interconnection of the Project's Missouri HVDC Converter Station.[19] The Optional Study included the same set of contingency events that will be included in the MISO DPP Impact Study which is the final stage of MISO's interconnection process. Thus, the Optional Study Report is a realistic view of the impacts from the Project and provides specific recommendations on the location and cost estimates of the network upgrades in MISO.[20] Ameren estimates that the cost to interconnect the Grain Belt Express Project to the MISO network is $21 million. While this is an increase from the Company's previous estimate of $10

[18] Question #11, *Staff Responses to Grain Belt Express Clean Line LLC's First Set of Data Requests Directed to Staff Witness Stahlman*, p.5.

[19] Schedule AWG-9, p.14.

[20] Staff Rebuttal Report, pp.22, 24, 26, 31, 33.

million,[21] it is less than 0.5% of the overall Project cost. All of these costs will be paid for by Grain Belt Express. The Optional Study Report confirms that while refinements of the Project's interconnection studies may result in additional upgrades or changes to identified upgrades, they will not affect the underlying economic feasibility of the Project.

Q. How will the MISO interconnection process ultimately lead to the Project being interconnected to the Ameren transmission system?

A. The final phase of study with MISO will be conducted in a new HVDC-specific interconnection process that MISO plans to roll-out by June 2017. This new process will include an Impact Study with the same scope as the Optional Study, to include MISO's up-to-date transmission topology, load, and generation assumptions, and will also include the stability analysis previously discussed.

Although MISO is still developing a process to study new HVDC interconnections, it has significant operational experience with HVDC links operating within its footprint, along with two (soon to be three) other HVDC lines in Manitoba Hydro's transmission system that actively participate in MISO's markets. MISO and its stakeholders recognize the value and need for HVDC transmission, and are dedicated to implementing a process for study and administration of new HVDC interconnections.

In MISO's generation interconnection FERC filings in Docket No. ER-17-156-000, MISO's Director of Reliability Planning Timothy Aliff testified: "MISO is currently developing, through a MISO stakeholder Task Team, a separate merchant HVDC process for the existing HVDC requests currently in the SPA. These HVDC projects [which

[21] Direct Testimony of Dr. Anthony Wayne Galli, P.E, p. 30, lines 15-21.

include the Grain Belt Express Project will be moved to this new process upon its completion."[22] The stakeholder process that Mr. Aliff is referring to is the MISO Merchant HVDC Task Team or MHTT.

Q. Who participates in the MISO MHTT?

A. The MHTT is open to all MISO stakeholders but is primarily attended by several MISO Transmission Owners, including Ameren, and merchant transmission developers, including Grain Belt Express staff.

Q. What is the anticipated timeline for the MHTT to finalize development of merchant HVDC-specific interconnection procedures?

A. MISO has targeted a roll-out of an HVDC interconnection process for June 2017. At that time, MISO would have a process to begin final studies for HVDC projects that are ready to advance to an Interconnection Agreement. The DPP is the final stage of the MISO interconnection process, which involves detailed studies and additional costs.[23] Grain Belt Express already has developed an advanced model of the Project sufficient for performing these final DPP studies with MISO.

Q. Have other RTOs successfully implemented an interconnection process for HVDC lines?

A. Yes. There are several relevant precedents of successfully implemented approaches to interconnect new HVDC projects in the United States. As Staff is aware,[24] PJM has interconnection procedures specific to HVDC projects. The New York Independent

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[22] Direct Testimony of Timothy Aliff, p. 53, lines. 8-11 *available at: (see fn 12).*

[23] Direct Testimony of Dr. Anthony Wayne Galli, P.E, pp. 29-30.

[24] Staff Rebuttal Report, p.60.

System Operator, Inc ("NYISO"), utilizing their existing generation interconnection study processes, worked with the Consolidated Edison Company of New York, Inc. and Hudson Transmission Partners, LLC to revise the NYISO Large Generator Interconnection Agreement to accommodate the HVDC Hudson Transmission Project.

Q. Is it possible to interconnect and operate the Project without the approval of the relevant RTOs that are charged with ensuring the reliability of the transmission system in Missouri?

A. No. Staff witness Mr. Beck seems to suggest that the Company's CCN Application has placed the Commission in a position to determine whether Ameren and other Missouri utilities will be able to meet NERC reliability standards and Local Transmission Owner Planning Criteria. This concern is misplaced. The Project cannot interconnect with Ameren and the MISO-controlled transmission system without an executed Interconnection Agreement ("IA"). The execution of an IA cannot be achieved until all reliability studies – which "provide insight into the effect on reliability that a 500 MW interconnection on the Maywood-Montgomery 345kV Transmission Line would have" [25] – are completed. Furthermore, Grain Belt Express has agreed to a condition to receiving a CCN that all interconnections studies be completed and interconnection agreements be executed before energizing the Project.

Q. Given Staff's comments at pages 56-58 the Staff Report, is it reasonable for MISO to continue to assume that the Mark Twain Transmission Project will be in-service prior to commercial operation of the Grain Belt Express Project?

[25] Staff Rebuttal Report, p. 15.

A. Yes. Staff witness Mr. Lange points out on page 57 of the Staff Report that the Mark Twain Transmission Project ("Mark Twain") is part of the MISO Multi-Value Project ("MVP") portfolio. The MVP portfolio, among other benefits, allows MISO to "[m]aintain system reliability by resolving reliability violations on approximately 650 elements for more than 6,700 system conditions and mitigating 31 system instability conditions" [26] Nevertheless, Mr. Lange seems to suggest that even with the Commission's approval of this important transmission line, it may not get built.[27] Mark Twain has been modeled in every single transmission expansion plan and generation interconnection study performed by MISO, Associated Electric, SPP, and Southwestern Power Administration since Mark Twain was approved by the MISO Board of Directors in 2012. This is the case because approval by the MISO BOD eventually results in implementation of these approved facilities into the NERC Multi-Regional Modeling Working Group loadflow and stability cases which are used for reliability and expansion planning throughout the entire Eastern Interconnection. MISO justified the need for Mark Twain in 2012 as follows[28]:

...the new lines provide reliability benefits by mitigating a number of contingent outage events during peak and shoulder periods, where the wind generation component is much higher. The addition of the 345 kV lines and step down transformer at West Adair is especially effective in resolving 161 kV line overloads on the lines out of West Adair and preventing the loss of the generation at West Adair during certain NERC Category C events. This project will mitigate two bulk electric system (BES) NERC Category B thermal constraints and five NERC Category C constraints. It will also relieve three non-BES NERC Category B and two NERC Category C constraints.

[26] Staff Rebuttal Report, p. 57.

[27] Staff Rebuttal Report, pp. 57-58.

[28] *Multi Value Project Portfolio, Results and Analysis, MISO, January 10, 2012, p.31, available at: https://www.misoenergy.org/Library/Repository/Study/Candidate%20MVP%20Analysis/MVP%20Portfolio%20Analysis%20Full%20Report.pdf*

This highlights that MISO, should Mark Twain not proceed, must identify an alternative project(s) to Mark Twain with very similar characteristics in order to address these future reliability issues.

Q. If the Mark Twain Project is not completed, what will MISO do?

A. MISO will have to identify alternative solutions that provide the same or similar benefits offered by Mark Twain. In no way will MISO operate in a manner that jeopardizes reliability. The result of a delay in implementing Mark Twain (or an equivalent project) would likely involve redispatch of the MISO market generation fleet around any constraints that would have otherwise been addressed by Mark Twain.

Q. Is potential congestion an indication of a risk to the reliable operation of the transmission system?

A. No. Staff witness Mr. Lange uses the word "congestion" in a manner that seems to suggest that congestion is an indication that reliability criteria have been violated. Congestion – a condition that arises on the transmission system when one or more restrictions prevents the most economic dispatch of electric energy from serving load – results in electric prices that represent the inability to use the least expensive generation to meet the electricity demand due to transmission limitations. In other words, congestion is a market inefficiency. This is important because Staff witness Ms. Dietrich states that one of the reasons why a determination cannot be made at this time whether the Grain Belt Express Project is in the public interest is due to her perceived uncertainty surrounding Mark Twain and "its effects on the Missouri converter station and corresponding congestion"[29] Further, Ms. Dietrich suggests a condition where Grain Belt

[29] Staff Rebuttal Report, p.7.

Express would be required to submit "a modified plan to address congestion should [Mark Twain] not proceed...." [30] Requiring a new transmission or generation interconnection project to address market inefficiencies has never been a requirement in any interconnection processes that I am aware of and such a condition here inappropriately requests that Grain Belt Express become the sponsor of new, unknown market efficiency transmission projects. If the Mark Twain line does not proceed, as I have discussed previously, the requirement to identify an alternative transmission solution properly belongs to the transmission planners at MISO, not to Grain Belt Express.

Q. Based on the meaning of "congestion" as you describe above, is identification of transmission system congestion within an interconnection process, such as that identified in the PJM System Impact Study, a reliable source to predict expected congestion due to operation of the Grain Belt Express Project once the Project enters commercial operation?

A. No. The interconnection planning studies performed to analyze the impacts of a new interconnection project utilize "snap shots" in time to identify conditions that would stress the transmission grid in order to identify network upgrades that need to be constructed to reliably integrate the new project. These interconnection processes do not rely on a market based security constrained economic dispatch of the generation fleet in determining which resources will be dispatched and at what levels in order to determine potential reliability violations. This is why the results of congestion-based studies, such

[30] Staff Rebuttal Report, p.7.

as that portion of the PJM System Impact Study ("SIS") dealing with energy deliveries[31], do not require mitigation. Interconnection Impact Studies point out where reliability violations may occur in various scenarios and the appropriate mitigations so that a project can operate reliably under a reasonable set of stressed scenarios. A production simulation tool would be a better approach to estimating congestion in a power system such as those studies performed by Grain Belt Express witness Mr. Copeland.

Q. Regarding Staff's discussion of power factor criteria on page 25 of the Staff Report, what is power factor?

A. Power factor is most simply defined as the ratio of real power to apparent power; where real power is the power transferred to do work and apparent power is simply the product of the root-mean-square values of voltage and current. Power factor is a dimensionless quantity that ranges from 0 to 1 and is indicative of how reactive a circuit is (i.e., how much reactive power it may draw). A low power factor means that a high reactive current is being drawn and thus more current is drawn to produce the same amount of work than an equivalent load with a high power factor (which means a low amount of reactive current is being drawn). At the transmission level, power factors are typically near unity depending on the loading of the transmission line, but can vary. There are typically no standards for power factor on a transmission line interconnection, as the concept is most often applied to loads and generators to ensure that they are unduly burdensome to the system from a reactive power perspective.

[31] *PJM Impact Study Report For PJM Merchant Transmission Request Queue Position X3-028 Breed 345 kV, October 2014,* p.12 (*Delivery of Energy Portion of Interconnection Request*), available at: http://www.grainbeltexpresscleanline.com/sites/grain_belt/media/x3028_imp.pdf

Q. Are issues of power factor relevant to an HVDC project like the Grain Belt Express Project?

A. No. HVDC projects are not designed to meet a specific power factor. Rather they are designed to ensure compliance with applicable reliability criteria including voltage criteria. An HVDC link that uses line commutated converter ("LCC") technology does not have the ability to control reactive power except by switching of reactive power devices, changing of transformer taps, or making slight changes to the control of the converter station. A generator, on the other hand, can independently and dynamically control reactive power output in a very straightforward manner.

In Staff's rebuttal testimony, Mr. Stahlman states that "if the Grain Belt converter station in Missouri is providing power to an AC transmission grid, it is effectively acting as a generator that would need to meet generation interconnection requirements."[32] Mr. Stahlman suggests that the Project would be, or should be, required to meet the generator-specific power factor requirements of the FERC pro-forma generation interconnection procedures. However, the Grain Belt Express Project is not a generator and, more importantly, adding additional equipment "inside the fence" of the Project's Missouri HVDC Converter Station is unnecessary for the Project to meet MISO's and Ameren's voltage criteria. In fact, in the Optional Study Report Ameren presents a more appropriate approach whereby appropriate equipment is installed in order to maintain system voltage and meet applicable criteria at the time the Project enters the DPP of the MISO interconnection process.[33]

[32] Staff Rebuttal Report, p. 25.

[33] Schedule AWG-9, p.5

The reactive power control design of an HVDC project like the Grain Belt Express Project ensures compliance with power quality standards (which is affected by both reactive power device switching and transformer tap changes); meets system voltage schedules "outside the fence" at each point-of-interconnection; maintains reactive power exchange within a pre-determined range; and otherwise operates in a reliable manner during system contingencies.

For any new transmission line interconnecting between transmission systems, if the AC system voltages at the points-of-interconnection can be shown to meet each utilities' existing voltage criteria in steady state and dynamic studies after the new transmission line is integrated into the studies, no additional equipment should be introduced into the network. The Grain Belt Express Project's reactive power control will be designed and operate to ensure compliance with MISO and Ameren's voltage criteria.

Q. Regarding Staff's discussion on short circuit ratio on page 58 of the Staff Report, is the short circuit ratio between the Missouri HVDC Converter Station and the AC grid at the point-of-interconnection in Ameren Missouri a concern?

A. Not at all. As Staff points out on page 58 of the Staff Report, the short circuit ratio ("SCR") is the ratio of the system short circuit level Mega Volt-Amperes ("MVA") to the DC power MW. Further, the denominator in the SCR is the DC power MW for the converter station interconnecting at that location; for the Missouri HVDC Converter Station this is 500 MW.[34] With a 345 kV system to interconnect to, the 500 MW interconnection of the Missouri HVDC Converter Station will have a relatively high

[34] In response to a data request from Grain Belt Express, Mr. Lange acknowledged this fact. Schedule AWG-11, Question 11c), p.5.

SCR. Using an SPP winter peak powerflow model, which had the nearby Audrain peaking power plant offline[35], the calculated short circuit power was 7.28 Giga Volt-Amperes ("GVA") which results in an SCR of 14.6 (or approximately seven times (7x) the SCR of 2.0). Removing the 345 kV transmission line between the Missouri HVDC Converter Station and the Maywood substation (and N-1 condition[36]) results in a short circuit power of 3.38 GVA which results in an SCR of 6.76 (or approximately three times (3x) the SCR of 2.0). Removing yet another line from service between Labadie and Montgomery (an N-2 condition), the calculated short circuit power dropped to 3.23 GVA which results in an SCR of 6.45. Therefore, as Mr. Lange concedes,[37] there are no concerns regarding whether the point-of-interconnection of the Missouri HVDC Converter Station would be too "weak".

d. PJM

i. Study Updates and Developments

Q. The October 2014 PJM System Impact Study ("SIS") report states that a new model of the Project is required in order to address issues that were identified in the analysis. Is that model still necessary to resolve issues raised in the SIS?

A. No. Grain Belt Express and its HVDC consultant TransGrid Solutions Inc. (TGS) analyzed the issues that were identified in the PJM SIS report and the need to ensure that

[35] When calculating the SCR during HVDC design studies, the HVDC manufacturer will perform calculations under multiple contingency conditions to identify the lowest short circuit ratio that would need to be accommodated to allow the Project's converters to maintain reliable operation at that specific point-of-interconnection.

[36] Note that this contingency also effectively eliminates any expected SCR benefit provided by the Mark Twain Transmission Project and therefore even without Mark Twain the grid in Missouri is considered strong from the perspective of a 500 MW HVDC converter.

[37] **Schedule AWG-11**, Question 10, pp. 4-5.

the HVDC model of the Project provided to PJM was properly tuned. TGS discovered that some of the issues identified by PJM resulted from numerical instabilities (software limitations) in other (that is, non-Grain Belt Express) generator models within the simulation cases that PJM was using. This can occur for various reasons when using the simulation software tool. When these numerical instabilities were addressed, PJM agreed that the model previously provided by Grain Belt Express was sufficient and that the Company was not required to provide a new model. Grain Belt Express did provide TGS's supporting technical notes to assist PJM in working with the existing model. These notes are provided in Highly Confidential **Schedule AWG-12.HC** and are considered Critical Energy Infrastructure Information ("CEII") under FERC rules.

.Q. What issues did Staff identify in the PJM SIS?

A. Staff witness Mr. Lange expressed concern over the PJM SIS, referencing language[38] from the SIS report which stated:

- The Grain Belt Project circuits disconnect from the system for several contingencies.
- The Grain Belt Project addition causes two wind farms to trip for several contingencies.

> "As X3-028 [the Grain Belt Express Project's PJM queue position nomenclature] is required to stay connected to the system for all faults, an updated model that exhibits this behavior is needed. The results suggest that further transmission reinforcement may also be required; the extent of this reinforcement cannot be confirmed prior to an updated X3-028 dynamic model being available."

Q: Did the work of TGS resolve these issues?

A; Yes. As a result of the TGS analysis, including the technical notes of Highly Confidential **Schedule AWG-12.HC**, all modeling issues have been resolved with PJM, which should also address Mr. Lange's concern.

[38] Staff Rebuttal Report, p.54.

Q. What is the status of the PJM re-tooled SIS?

A. PJM has indicated that the re-tooled SIS should be completed by the end of March 2017.

ii. Next Steps

Q. Are there additional interconnection studies that are required before executing an Interconnection Agreement[39] with PJM and AEP?

A. Yes. The final stage of study in the PJM process is the Facilities Study phase for which Grain Belt Express executed a study agreement in October 2014.[40] Additionally, as Staff is aware,[41] there are additional "detailed studies" that are required to be performed at some point before commercial operation of the Project. These will be performed before or after an Interconnection Agreement is executed and include some of the studies shown in **Schedule AWG-8** which are required as a matter of the Project design as well. To be clear, all of the studies that are included in **Schedule AWG-8** will be completed before construction of the Grain Belt Express Project since they are predecessors to the manufacturing of the Project's converter station equipment. All of the additional "detailed studies" which PJM requires to be completed before commercial operation are included in the list of studies in **Schedule AWG-8**.

Q. What is the anticipated timeline for conclusion of the PJM interconnection process?

A. A Facilities Study could take 12-18 months to perform. Thereafter, PJM, AEP, and Grain Belt Express will negotiate, execute, and file an IA with FERC.

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[39] MISO and SPP use the terms "Interconnection Agreement" while PJM uses the term "Interconnection Service Agreement." Since this refers to the same type of agreement, I use Interconnection Agreement in discussing PJM.

[40] Direct Testimony of Dr. Anthony Wayne Galli, P.E, pp. 26-27.

[41] Staff Rebuttal Report, p. 28.

Q. Will the Grain Belt Express detailed design studies that are expected to be coordinated and reviewed by PJM and AEP create conditions that must be met under the Interconnection Agreement ("IA") between Grain Belt Express and PJM/AEP?

A. Yes. Any of the "detailed studies" that are not performed and reviewed prior to execution of an IA will be listed within the IA as milestones that must be completed before commercial operation.

Q. Is it possible that additional transmission upgrades will be identified as a result of the "re-tooled" System Impact Study ("SIS")?

A. Yes, however, there have been positive developments for the Grain Belt Express Project since the first SIS was completed. Changes have occurred within the transmission system models that are being used to analyze the interconnection of the Project to the PJM system. This includes generator projects that have withdrawn from the PJM queue, as well as transmission topology changes that should help strengthen the grid near the interconnection of the Project's Illinois HVDC Converter Station. Two topology changes, in particular, will directly benefit this region of the PJM system: (1) approval by MISO and PJM of the interregional Rockport-Duff-Coleman 345 kV transmission line,[42] which will eliminate all of the stability limitations at AEP's Rockport Coal Plant, and (2) re-configuration of the Sullivan/Breed substation including the addition of a third

[42] *Selection Report, Duff-Coleman EHV 345 kV Competitive Transmission Project, MISO, December 20, 2016, available at: https://www.misoenergy.org/Library/Repository/Study/Transmission%20Developer/20161220_FINAL_Selection%20Report_SRPT_v1.pdf*

765/345 kV autotransformer.[43] Notably, this is the station to which the Project interconnects with PJM.

Staff witness Mr. Lange expressed concern surrounding "issues under certain conditions"[44] in this region, especially when the Rockport-Jefferson 765 kV line is out-of-service. However, beyond the inherent flexibility of HVDC transmission projects, the upgrades represented by the Rockport-Duff-Coleman 345 kV transmission line, and the re-configuration and addition of a third autotransformer at Sullivan/Breed will support overall grid stability in this region.

Q. Will a "major transmission upgrade" be necessary within PJM to interconnect the Illinois HVDC Converter Station?

A. Staff witness Mr. Lange references SPP's confirmation of the SPP Criterion 3.5 study work (**Schedule AWG-10**) where SPP's consultant Excel Engineering, Inc., stated that if a special protection system is not an acceptable solution to the stability issues near the point-of-interconnection of the Illinois HVDC Converter Station, "then a major transmission upgrade or reduction in the size of the [Grain Belt Express Project] will have to be considered."[45] As I discussed in my direct testimony, this fact has already been accounted for in the business plans of Grain Belt Express where I described the required network upgrades in PJM including "[a] new AEP 765kV transmission line from

[43] See PJM Baseline upgrade B1465.1 and Supplemental project S0764 which have projected in-service dates of June 2017, *PJM RTEP upgrades status website, available at: http://pjm.com/planning/rtep-upgrades-status/construct-status.aspx*

[44] Staff Rebuttal Report, pp.55-56.

[45] Staff Rebuttal Report, p.56

the Sullivan Substation to Northern Indiana Public Service Company's new Reynolds substation ("Sullivan to Reynolds") at an estimated cost of $500 million."[46]

Since the focus of the SPP Criterion 3.5 studies is the SPP system and not PJM, and the PJM SIS report was not available at the time of the SPP study, the system topology within the PJM system was not properly represented within the SPP Criterion 3.5 studies.[47] While this did not affect analysis of impacts on the SPP system, no conclusions can be drawn from that SPP report about the impacts of the Project on the PJM system. The SPP Criterion 3.5 studies did not include the Sullivan-Reynolds network upgrade within their models, nor did those models include the third autotransformer discussed above and in my direct testimony.[48] As such, "major transmission upgrades" will exist to address the issues raised by Mr. Lange.

Q. Even though Grain Belt Express is going through PJM's interconnection process, will the generators that interconnect to the Kansas HVDC Converter Station have to go through the PJM interconnection process as well?

A. No. As I discussed in my direct testimony, at pages 23-27, Grain Belt Express will enter into an Interconnection Agreement with PJM regarding the Project's PJM delivery point at the Sullivan/Breed Substation in Indiana[49]. Grain Belt Express' customers will avail themselves of the rights conveyed in Grain Belt Express' Interconnection Agreement

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[46] Direct Testimony of Dr. Anthony Wayne Galli, P.E, p. 26-27

[47] Schedule AWG-10, Figure 3-1, p. 10.

[48] Direct Testimony of Dr. Anthony Wayne Galli, P.E, p. 23, ll.12-18.

[49] AEP has a Sullivan 765kV substation and a Breed 345kV substation next to one another. It is understood that these are effectively the same substation and therefore I refer to the stations interchangeably or simply as "Sullivan/Breed."

with PJM.

Q. Staff witness Mr. Stahlman asserted in the Staff Report on page 35 that because transmission customers that utilize the Grain Belt Express Project are not themselves going through a PJM interconnection process, they would be subject to PJM Tariff schedules. Is this correct?

A. No. Mr. Stahlman cites Grain Belt Express' response to Staff Data Request 0035 which requires clarification. Mr. Stahlman asked: "Will the wind farms that connect directly to Grain Belt's converter station in Kansas be required to perform a generator interconnection study with a RTO? If so, which RTO? If not, why not?"

Grain Belt Express responded: "The wind generators that interconnect directly to the converter station in Kansas will be required to undergo an interconnection study process to ensure compliance with the Grain Belt Express Open Access Transmission Tariff and applicable NERC and regional reliability requirements. Pursuant to Grain Belt's FERC negotiated rate authority, Grain Belt Express will turn over administration of the Grain Belt Express project facilities to an RTO or RTO-like entity prior to commercial operation (in the case of Grain Belt that will be PJM). PJM, in their role as Transmission Provider on behalf of their Transmission Owner members, administer the generator interconnection procedures in accordance with the open access requirements of FERC."

The interconnection process described in the above response occurs in western Kansas near the Project's Kansas HVDC Converter Station. It does not occur at the Project's Illinois HVDC Converter Station or at the Sullivan/Breed substation at the Project's point of interconnection with PJM. Moreover, prior to PJM assuming

functional control of the Project, Grain Belt Express -- not PJM -- will perform any necessary studies. The Company, not PJM, will enter into interconnection agreements with generators. PJM will administer any new generator interconnection requests that are proposed for interconnection to the Kansas HVDC Converter Station after PJM assumes functional control of the Project. These new interconnection studies and agreements will convey rights to interconnect with the Project in Kansas. Generators will still be able to use the rights that the Grain Belt Express Project will receive through PJM's transmission interconnection procedures at the Project's point-of-interconnection with PJM.

Q. Will transmission customers using service on the Grain Belt Express Project from Kansas (SPP) to Missouri (MISO) have to pay PJM rate schedules 1 and/or 1A, as the Staff Report suggests at page 35?

A. No. Schedule 1 and 1A to the PJM Tariff are the traditional "Scheduling, System Control, and Dispatch Service" fees which are billed to transmission system users in PJM. They do not apply to MISO customers.

Q. Is it possible to interconnect and operate the Project without the approval of the authorities charged with ensuring reliability of the transmission system in Illinois and Indiana?

A. No. The Grain Belt Express Project cannot interconnect to the PJM-controlled transmission system without an executed Interconnection Agreement ("IA") and execution of an IA cannot be achieved until all Impact Studies have been completed. The responsibility to ensure a reliable interconnection to the AEP system belongs to Grain Belt Express as the future Transmission Owner and Transmission Operator of the Project, as well as to PJM and ReliabilityFirst Corporation.

e. SPP

i. Study Updates and Developments

Q. Have there been any updates with SPP and ITC Great Plains since your direct testimony?

A. Yes. On October 17, 2016, Grain Belt Express, SPP, and ITC Great Plains ("ITC") executed an IA[50] to interconnect the Project's Kansas HVDC Converter Station to the ITC system.

ii. Next Steps

Q. Are there any additional studies outlined in the IA with SPP/ITC?

A. Yes. As Staff witness Mr. Stahlman points out, a few studies remain to be completed before the Project can enter commercial operation. These studies will be completed as part of the HVDC design process.

Q. Is it possible that additional transmission upgrades will be identified as a result of the updated Criterion 3.5 studies?

A. Based on the results of the existing Criterion 3.5 study work, it is unlikely that any additional transmission upgrades would be required in order to accommodate the interconnection of the Kansas HVDC Converter Station. Instead, one or more Remedial Action Schemes (a/k/a Special Protection Systems) will be developed to ensure grid reliability when fault conditions on the Project or near the AC terminals of the Project cause a temporary injection of power into SPP at the Kansas HVDC Converter Station. These Remedial Action Schemes are required because the AC system in SPP was not

[50] *Interconnection Agreement Between Grain Belt Express Clean Line LLC and ITC Great Plains, LLC and Southwest Power Pool, Inc,* available at: http://etariff.ferc.gov/TariffSectionDetails.aspx?tid=1225&sid=208517

constructed to accommodate the full amount of power that will be produced by the generator facilities expected to interconnect to the Kansas HVDC Converter Station. Therefore any faults that result in a temporary halt of power flow on one or both poles (i.e. circuits) of the HVDC link may require immediate cross-tripping of some amount of interconnected generators to maintain stability of the BES in SPP. The SPP Criterion 3.5 studies and SPP's confirmation of these studies did successfully simulate any necessary Remedial Action Schemes designed to maintain stability of the Grain Belt Express Project generation during multiple-contingency events within SPP while maintaining operation of the Grain Belt Express Project facilities.[51]

Q. Does the IA between Grain Belt Express and SPP/ITC limit the amount of generators that can interconnect to the Kansas HVDC Converter Station?

A. No. Staff witness Mr. Stahlman asserts that the additional studies discussed above are identified in the IA because the initial SPP studies were performed under an assumption that there would be 3,500 MW of simultaneous delivery between the MISO and PJM converter stations.[52] On the contrary, the IA with SPP/ITC specifically acknowledges the Grain Belt Express Project as a "high voltage direct current electric transmission system and associated facilities with the capacity to deliver approximately 4,000 MW...."[53] SPP and ITC included the additional studies in the IA in order to update their models to reflect near-final HVDC assumptions, and to ensure another opportunity to review before more advanced Design-Level Studies proceed.

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[51] Schedule AWG-10, pp.7-8

[52] Staff Rebuttal Report, p. 26.

[53] *Interconnection Agreement Between Grain Belt Express Clean Line LLC and ITC Great Plains, LLC and Southwest Power Pool, Inc,* p.1, available at: http://etariff.ferc.gov/TariffSectionDetails.aspx?tid=1225&sid=208517

Q. Is it possible to interconnect and operate the Project without the approval of the authorities charged with ensuring the reliability of the transmission system in Kansas?

A. No. The Grain Belt Express Project cannot interconnect to the SPP-controlled transmission system without meeting all of the obligations within the IA. The responsibility to ensure a reliable interconnection to the ITC system belongs to Grain Belt Express, as well as to SPP and the SPP Regional Entity.

III. ADDITIONAL INFORMATION AND CLARIFICATIONS PERTAINING TO OPERATIONS AND MARKET INTERACTIONS

Q. The Staff Report at pages 34-36 raises issues about the bi-directional capability of the Project. Is the Grain Belt Express Project being designed to allow for bi-directional operation of the converter stations?

A. Yes. HVDC converter stations are inherently capable of bi-directional functionality. The Grain Belt Express Project is being designed as a bi-directional, interregional transmission asset.

Q. Is the Grain Belt Express Project being studied within the interconnection processes of SPP, MISO, and PJM to operate in modes other than the baseline modes represented in testimony?

A. No. Grain Belt Express has not requested specific approval to withdraw power from the SPP, MISO, or PJM markets, nor has Grain Belt Express specifically requested approval to inject power into the SPP market. However, this does not preclude Grain Belt Express transmission customers from making such requests in the future including in day-to-day operation of the Project without long-term access rights.

Q. Do any of SPP, MISO and PJM have existing processes that could be used to withdraw power from those markets for transmission exports by the Project?

A. Yes. PJM already has a process to request withdrawal of energy through their interconnection process and a means to administer requests of transmission service to export from the PJM market. SPP also has existing procedures to export from and sell into their market. Generators that are directly connected to the Kansas HVDC Converter Station but wish to inject power into the SPP market (due to short-term maintenance outages, for example) would be able to do so by pre-arranging interchange reservations using SPP's Market Import Service, which would not incur a transmission service fee from SPP. Options exist to withdraw energy from the SPP market as well through, for example, procurement of point-to-point transmission service to export power from SPP to adjacent transmission systems (which could include the Grain Belt Express Project). SPP and PJM's existing processes to move power to MISO support Grain Belt Express witness Mr. Pfeiffer's assumption that the Missouri HVDC Converter Station is able to deliver 500 MW from SPP and PJM in his Loss of Load Expectation ("LOLE") study.

Finally, while MISO does not have an existing interconnection process to accommodate energy withdrawal from their market, MISO does have existing processes for MISO Market Participants to procure point-to-point transmission service to export power from MISO to adjacent transmission systems (which could include the Grain Belt Express Project). Additionally, the MHTT, which I discussed previously, is developing a process for requesting, studying, and assigning energy withdrawal rights for HVDC interconnections.

Q. To the extent that RTO processes for exports and bi-directionality have not been fully developed, is there any reason to expect that the processes will not be developed in the future?

A. No. Based on my experience at SPP and other organizations, RTOs regularly develop new processes to manage their interactions with adjacent transmission systems. A transmission flow into or from the Project is not impossible just because a new RTO process may be needed. The benefits of operating the Project in other modes of operation should not be ignored.

Q. In light of comments in the Staff Report on page 35, how will ancillary services within the AC collector system be handled?

A. Staff witness Mr. Stahlman indicated that when he filed his testimony the response from Grain Belt Express to Staff Data Request No. 0046 regarding ancillary services on the Kansas AC collector system was still pending. The response is offered here in order to address Mr. Stahlman's inquiry.

Question: How does GBE expect ancillary services, such as voltage and frequency regulation, to be maintained on its AC collector system?

Response: Grain Belt Express is being designed to consider the needs of the AC collection system in order to ensure power delivery from the interconnected generator facilities to the Kansas [HVDC] Converter Station and beyond. This includes the reactive power requirements along these collector lines to ensure proper voltages for effective power delivery. In effect, the interconnected generator facilities, tie-lines to SPP, HVDC facilities, and tie-lines to MISO and PJM are to be looked at as a single, dispatchable aggregate whereby ancillary services, losses, and transmission service are all provided as a result of the design of the aggregate facilities.

As an example, frequency regulation is accommodated through the design of the controls between the HVDC facilities, SPP tie-line facilities, and the generator facilities. As generator outputs change, the measured electrical current outputs are communicated to the HVDC facility controls resulting in proper setting of the power order set-point of the HVDC facilities. This arrangement also accommodates scheduling or limiting exchange

with the SPP system with an integrated power flow controller for those SPP tie-line facilities.

Q. Has SPP, the Staff of the Kansas Corporation Commission or ITC Great Plains (the transmission owner with which the Project will interconnect) raised any concerns regarding the maintenance of ancillary services at the Project's AC collector system?

A. No, they have not.

Q. Please address Staff witness Sarah Kliethermes' claim that the Project will cause reserve requirements to increase in MISO.

A. Ms. Ms. Kliethermes stated in the Staff Report:[54]

> "In fact, Staff is not aware of any reason that the converter station would not cause the need for contingency planning of a sudden failure of a 500MW generator in Northeast Missouri. To the extent that contingency planning for the region would need to account for the sudden failure of a 500MW generator, **this would increase reserve margin requirements to preserve existing reliability**."

In response to data requests from Grain Belt Express seeking clarity on Staff's concerns surrounding reserve margin requirements, Ms. Kliethermes seems to backtrack on her statement in the Staff Report. In response to the Company's data requests, she stated that her use of the terms "the region," "contingency planning," and "reserve margin requirements" was "intentionally vague" because Ms. Kliethermes was "uncertain" what Grain Belt Express witness and former FERC Commissioner Suedeen Kelly meant when she used these terms in her direct testimony. See **Schedule AWG-13**, Staff Response to Data Request 9(a)-(c) at pp. 8-9. Subsequently, Ms. Kliethermes conceded that:

[54] Staff Rebuttal Report, p.40.

"Staff has not stated or alleged that the 500MW injection from the Missouri converter station has any impact to **increase** or decrease the **reserve margin requirements** for "the region" as described by Ms. Kelly."

Id., Data Response 9(e) at p. 9 (emphasis added).

Q. What is your response to Ms. Kliethermes' statement at page 40 of the Staff Report that the Project could increase "reserve margin requirements to preserve existing reliability?"

A. In using the term "reserve margin requirements," it is unclear whether Ms. Kliethermes refers to "reserve margins" or "contingency reserves." In an attempt to seek clarity on Ms. Kliethermes' concern Grain Belt Express submitted data requests asking for Staff's understanding of how reserve margins are established in the region. Ms. Kliethermes responded with links to a NERC document and website for "reserve margins".[55] This suggests that Ms. Kliethermes is talking about "reserve margins" (otherwise referred to as "resource adequacy") on page 40 of the Staff Report. On the other hand, Grain Belt Express also asked for "relevant citations or documentations which support Staff's belief [of] the potential for additional reserve margins to be added because of the interconnection in Missouri." Ms. Kliethermes responded that "Staff does not agree that this question accurately states Staff's belief. Staff understands that every interconnection is studied in an N-1-1 contingency state."[56] This suggests that Ms. Klietheremes was talking about "contingency reserves" on page 40 of the Staff Report.

Either way, her claim is incorrect. "Reserve margin" refers to capacity reserves to ensure enough generation is available to meet load at all times—a requirement often

[55] Schedule AWG-13, Question #8(a), p.7.

[56] Schedule AWG-13, Question #8(d), pp.7-8.

termed "resource adequacy." Using this translation of the words "reserve margin requirement," Ms. Kliethermes' assertion implies that Grain Belt Express' injection causes the need for more generation to meet peak load. This cannot be right. A power injection into Missouri does not create the need for more generation to be available in case power from that power injection is no longer available. That assertion would imply that for every power plant that is built, one must build an additional backup plant; this is not the case.

Alternatively, Ms. Kliethermes may be referring to contingency reserves. Contingency reserves ensure the reliability of the electric grid if there is a sudden outage. However, the amount of contingency reserves required is typically determined by the size of the largest single generator in the region of interest. The portion of Missouri within MISO's purview (Columbia Water and Light and Ameren Missouri) is Load Resource Zone #5 (LRZ-5). Grain Belt Express' 500 MW power injection would not increase the contingency reserve margin requirements in LRZ-5 because it is not the largest injection in the region. A 500 MW injection is smaller in size by Ameren Missouri's units like the Labadie coal units (612 MW each) and Rush Island coal units (613 MW each), and Associated Electric Cooperative's Thomas Hill unit #3 (665 MW) and New Madrid units (575 MW each). It is dwarfed in size by Ameren Missouri's Callaway Nuclear Plant (1,224 MW). Thus, in no way does a 500 MW contingency from the loss of the Project's Missouri HVDC Converter Station create an increase to the contingency reserve requirements or the resource adequacy requirements to the State of Missouri.

IV. RESPONSE TO STAFF'S CONCERNS RELATED TO THE LEVEL OF ENGINEERING DESIGN

Q. Is it reasonable that specific transmission structure designs for the Grain Belt Express Project are not available since the siting process has not been completed and certain regulatory approvals still need to be issued?

A. Yes. Staff witness Mr. Stahlman states that he is unclear why the Project design has not been further developed.[57] He refers to the Company's response to an intervenor's data request seeking structure height information regarding the Missouri and Mississippi River crossings. Grain Belt Express advised that this information will not be known until a final route is established, siting is complete, and a specific location is confirmed. The design of such structures is not only impacted by those location decisions, but also by the location of adjacent structures. Moreover, the cost to design large and robust river-crossing structures is significant. It would be imprudent to do so without accurate site and geotechnical information to determine the relevant soil conditions.

Q. Please address Staff witness Stahlman's claim on page 22 of the Staff Report that there is insufficient information to conclude that the Project is economically feasible because the RTOs have insufficient information on the design of the Project to perform final and conclusive studies.

A. As discussed above in Section II, the only studies that affect the need for network upgrades (and, therefore, the economics of the Grain Belt Express Project) are the Impact Studies which have been performed in one form or another and only require refreshing prior to construction. Design-Level Studies will need to be performed at each point-of-

[57] Staff Rebuttal Report, p.33-34.

interconnection, but these studies will not change the scope or number of network upgrades. Staff acknowledges this fact when, in response to data requests from Grain Belt Express requesting Staff's understanding of the mitigation measures for control interactions (with other HVDC facilities) [58] sub-synchronous torsional interactions ("SSTI" a/k/a sub-synchronous resonance studies), [59] and harmonic performance compliance,[60] Mr. Lange responded with lists of mitigation measures and what appear to be textbook excerpts, none of which include a single reference to network upgrades. See **Schedule AWG-11** Staff Response to Data Requests 12, 13, and 14 at pp. 6-13.

The combination of (1) the January and March, 2013 SPP Criterion 3.5 study work performed by Siemens PTI, (2) the September 2013 SPP Criterion 3.5 verification studies performed by SPP, (3) the March 2015 Facilities Study performed by ITC Great Plains, (4) the October 2012 Feasibility study performed by MISO, (5) the November 2014 SPA Study and January 2017 Optional Study performed by Ameren Missouri, (6) the Project HVDC model development and stability testing performed by TransGrid Solutions, (7) the January 2013 Feasibility Study performed by PJM and AEP, and (8) the October 2014 System Impact Study (and ongoing re-tooled System Impact Study) performed by PJM and AEP, clearly show that the network upgrades will not significantly change from what has been identified to date.

[58] Schedule AWG-11, Question 12, pp.6-7. Requested in reference to Staff Rebuttal Report, pp. 59-60.

[59] Schedule AWG-11, Question 13, pp.7-8. Requested in reference to Staff Rebuttal Report, pp. 26, 59.

[60] Schedule AWG-11, Question 14, pp.8-13. Requested in reference to Staff Rebuttal Report, pp. 60-61.

V. RESPONSE TO STAFF'S CONCERNS RELATED TO SAFETY AND COORDINATION WITH NEARBY UTILITIES

Q. Regarding the Staff's discussion in Section IV(b) at pages 47-51 of the Staff Report, is it safe to operate an HVDC transmission line that crosses a natural gas pipeline?

A. Yes. To my knowledge, there is not a single overhead HVDC transmission line in the United States that does not cross or parallel one or more natural gas pipelines. This fact is presented in **Schedules AWG-14, AWG-15, and AWG-16** which are maps showing the HVDC transmission lines located in western North America, central North America, and eastern North America, respectively, along with all instances where those facilities cross major natural gas pipelines.

Q. Has any Company witness identified measures that Grain Belt Express will implement to protect utilities with underground utility infrastructure?

A. Yes. As Staff witness Ms. McNelis noted on page 48 of the Staff Report, I provided Schedule AWG-5 with my direct testimony which is the design criteria of the HVDC transmission line. These criteria include the design characteristics[61] of the Dedicated Metallic Return Conductors ("MRC") which is also referred to as a Dedicated Metallic Return ("DMR"). Ms. McNelis correctly acknowledges on page 48 of the Staff Report that use of a DMR prevents "stray current flow through the ground under normal conditions." In fact, use of a DMR prevents current from flowing into the ground in all defined operating modes.

Q. What occurs when lightning strikes the line or a structure on the line that is paralleling or crossing a pipeline and a faulted condition occurs?

[61] Schedule AWG-5, pp. 20, 22, and 29.

A. Fault currents that enter the ground as a result of a lightning strike are similar whether the transmission line is AC or DC. Although the waveforms of the transient currents in faulted conditions of AC and DC projects have similarities, DC projects limit the fault current to approximately two times (no more than three times) the full load current since the fault is only fed from the converter. AC faults, on the other hand, are fed from both ends the AC line resulting in a fault magnitude that will be larger in size and duration than a fault fed from a DC project of a similar voltage level.

Due to the similarity of the faulted waveforms, mitigation techniques that are used for an HVAC line can be applied to HVDC lines. The Canadian Association of Petroleum Producers developed guidelines on impact mitigation for HVDC line impacts on pipelines,[62] which the Grain Belt Express Project will follow to the extent applicable. To my knowledge, these guidelines are the only published recommendations in the energy industry outside of various academic and trade publications.

VI. RESPONSE TO STAFF'S RECOMMENDED CONDITIONS

Q. Which of the conditions proposed in the Staff Report do you accept?

A. A list of conditions recommended by Staff is included in Schedule DAB-9, attached to the surrebuttal testimony of Grain Belt Express witness David Berry. On behalf of Grain Belt Express, I accept, without modification, the following conditions:

- All conditions in Section II, Interconnection Studies
- All conditions in Section III, Nearby Utility Facilities, with one minor addition to each Condition 1 and Condition 4.
- All conditions in Section IV, Emergency Restoration Plans

[62] Staff Rebuttal Report, p.48 (see fn 72).

- Conditions 12, 13, and 14 within Section V, Construction and Clearing

Q. Which of the conditions proposed in the Staff Report do you not accept?

A. Grain Belt Express does not accept Staff's recommendation on page 7 of the Staff Report that it submit "a modified plan to address congestion should the ATXI Mark Twain project not proceed as planned …"[63] Any plan to address congestion or other related issues is the responsibility of the relevant RTO, not the entity that proposes to build a project.

Q. Is there a quick summary of the issues from the Staff Report that you address in this surrebuttal testimony?

A. Yes. **Schedule AWG-17** includes both, a listing of the issues with references to where each is discussed in the Staff Report, as well as responses to each issue with references to where those responses can be found in my testimony.

Q. Does this conclude your surrebuttal testimony?

A. Yes.

[63] Staff Rebuttal Report, p. 7.

BEFORE THE PUBLIC SERVICE COMMISSION
OF THE STATE OF MISSOURI

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

AFFIDAVIT OF ANTHONY WAYNE GALLI

STATE OF Texas)
) **ss**
COUNTY OF Harris)

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

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

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

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

Anthony Wayne Galli

Subscribed and sworn before me this 21st day of February, 2017.

Notary Public

My commission expires: 1/6/2018

DORCAS RUTH O'QUINN
Notary Public, State of Texas
Comm. Expires 01-06-2018
Notary ID 12966547-8

	A	B	C	D	E	F	G	H
	RTO	Requirement	Study or Task	Study Performer	Results	Status	Cost Impact	Reference
1	SPP	SPP Planning Criteria Criterion 3.5 "Interconnection Review Process" https://www.oasis.oati.com/SWPP/SWPPdocs/SPP_Criteria_&_Appendices_July_29,_2014.pdf	*Steady State Assessment of the Grain Belt Express Clean Line HVDC Project* **(2013)** *Dynamic Stability Assessment of Grain Belt Express Clean Line HVDC Project* **(2013)** Combined, these studies are referred to as the: **"SPP Criterion 3.5 Studies"**	Grain Belt Express, via their consultant **Siemens PTI**	The report identifies potential impacts to the SPP electric system that could occur during abnormal system events that affect operation of the Project Remedial Action Schemes and/or Operating Guides are identified that can be implemented to ensure stability in the SPP region during abnormal system events.	Complete	None. The cost to implement one or more RAS and/or Operating Guides is inherent in the cost of the Project facilities. This has been the experience on other Clean Line projects as well	Galli Direct pp. 19-23, 36. Galli Surrebuttal pp. 3, 10, 25-26, 31-32, 38.
2	SPP	See B2; SPP confirmation of the results of task C1.	*Grain Belt Express HVDC System Impact Study, Final Report for Southwest Power Pool* **(September 2013)**	SPP, via their consultant **Excel Engineering, Inc.**	The report identifies Remedial Action Schemes or Operating Guides that ensure stability in the SPP region as a result of contingency events on or nearby the Project facilities	Complete	See G1.	Schedule AWG-9 Galli Direct pp. 21-22 Galli Surrebuttal pp. 3, 10-11, 25-26, 29-30, 38.
3	SPP	See B1.	*Generation Interconnection Facilities Study Report For GBX Clean Line High Voltage Direct Current Facility In Ford County, Kansas.* **March 19, 2015**	ITC Great Plains	The report provides a cost estimate for the interconnection facilities to accomodate the Project's interconnection with SPP.	Complete; Interconnection Agreement executed and filed at FERC.	The report estimates costs to interconnect the Project at $21,448,762	Galli Direct pp. 5, 12, 19, 23. Galli Surrebuttal pp. 3.
4	SPP	See B1.	SPP Criterion 3.5 Refresh Studies	HVDC Manufacturer for the Project.	Not yet started	To begin in 2018 when detailed HVDC design is underway.	See G1.	Schedule AWG-9 Galli Direct pp. 21-22 Galli Surrebuttal pp. 3, 10-11, 25-26, 29-30, 38.
5	MISO	MISO FERC Electric Tariff, Attachment X "Generator Interconnection Procedures (GIP)" https://www.misoenergy.org/Library/Repository/Tariff%20Documents/Attachment%20X.pdf	*MISO Interconnection Feasibility Study for Queue Position J255*, **October 2012**	MISO	The Feasibility Study, completed in October 2012, did not identify any constraints associated with the 500 MW injection into MISO.	Complete	Superceded by Optional Study. See G7.	Galli Direct pp.27-28. Galli Surrebuttal pp. 3, 38.
6	MISO	See B5.	*Midwest ISO SPA-2014-May-Missouri System Impact Study Final Report* **(November 2014)**	Ameren Services Company - Transmission Planning	The analysis uncovered no injection-related constraints for the 500 MW Maywood interconnection	Complete	Grain Belt Express estimated network upgrade costs after receipt of the SPA Study report at "less than $10 million." Superceded by Optional Study. See G7.	Galli Direct pp. 6, 28, 30. Galli Surrebuttal pp. 3, 9-10, 12-13, 38.
7	MISO	See B5.	*MISO Project J255 Clean Line Energy Grain Belt Express, 500 MW in Ralls County, MO Optional Study Report,* **(January 2017)**	Ameren Services Company - Transmission Planning	The study showed that the Project will cause a constraint on two transmission elements that will require Network Upgrades to accommodate the Project.	Complete	The report estimates costs to interconnect the Project will be $9.5 million (in line with Grain Belt Express estimates). The report also estimates costs to mitigate constraints identified as a result of local planning criteria will be $11.5 million The total estimated cost of network upgrades in MISO is estimated to be the summation of these: $21 million	Schedule AWG-8 Galli Direct pp. 6, 12, 30. Galli Surrebuttal pp. 3, 9-10, 12-14, 20, 38.

	A	B	C	D	E	F	G	H
	RTO	Requirement	Study or Task	Study Performer	Results	Status	Cost Impact	Reference
8	MISO	Expected modifications to MISO FERC Electric Tariff, Attachment X	MISO Definitive Planning Phase (DPP)	Ameren Services Company - Transmission Planning and MISO	Not yet started	Grain Belt Express plans entry into the MISO DPP upon conclusion of the Missouri regulatory approval process After the DPP, Grain Belt Express, MISO, and Ameren Missouri will negotiate, execute, and file with FERC, an Interconnection Agreement	See G7. Estimate to be refreshed in the DPP.	Galli Direct pp. 28-30 Galli Surrebuttal pp. 10-12, 14, 20.
9	PJM	PJM Open Access Transmission Tariff: http://pjm.com/media/documents/merged-tariffs/oatt.pdf PJM Manuals 14A, 14B and 14E: http://pjm.com/library/manuals.aspx	*PJM Interconnection Feasibility Study report* **(2013)**	PJM and American Electric Power	Thermal overloads were identified requiring mitigation for further review in the System Impact Study	Complete	Superceded by System Impact Study. See G11.	Galli Direct p. 24. Galli Surrebuttal pp. 4, 38.
10	PJM	See B9.	Grain Belt Express Project HVDC Model Development and Testing Required in order for PJM to be able to perform Impact Study **(October 2013, March 2015, August 2015)**	Grain Belt Express consultant TransGrid Solutions, Inc	A steady state and dynamic model was developed, tested, and delivered to Grain Belt Express for use in RTO interconnection studies	Complete	Not applicable	Galli Direct p. 36. Galli Surrebuttal pp. 3-4, 11, 21-22, 38.
11	PJM	See B9.	*Merchant Transmission Interconnection PJM Impact Study Report For PJM Merchant Transmission Request Queue Position X3-028 Breed 345 kV* **(October 2014)**	PJM and American Electric Power	Thermal overloads and stability constraints were identified along with mitigation in the form of network upgrades. Additional issues were identified as requiring further review during an in-progress re-tool study.	PJM is actively re-tooling this study with an anticipated result in March 2017.	The report estimates costs to interconnect the Project will be $3,447,100. The report also estimates costs to mitigate constraints identified as a result of planning criteria will be $501 million The total estimated cost of network upgrades in PJM is estimated to be the summation of these: ~$505 million	Galli Direct pp. 24-27. Galli Surrebuttal pp. 4, 18-19, 21-22, 24-26, 38.
12	PJM	See B9.	PJM Facilities Study	American Electric Power	Study Underway	After the Facilities Study is complete, Grain Belt Express, PJM, and AEP will negotiate, execute, and file with FERC, an Interconnection Service Agreement	See G11. The Facilities Study is a fine-tuning of the cost estimates from the System Impact Study.	Galli Direct pp. 26-27. Galli Surrebuttal p. 23.

Study	What is the study's intent?	What is the output from this study?	When does this study get conducted?	Who conducts this study?
Steady State Impact Study (Load Flow)	Identify new thermal overloads and voltage violations with respect to local, regional, and NERC standards.	Transmission network upgrades to mitigate identified violations	Interconnection studies performed by or in coordination with the interconnecting Transmission Provider / Owner.	Separately: 1) Interconnecting utilities and 2) HVDC Equipment Manufacturer. The HVDC Equipment Manufacturer conducts these studies to ensure that the HVDC solution can meet specific performance requirements while the utilities perform this analysis to ensure secure and reliable operation of their transmission system with the inclusion of the interconnection project.
Short Circuit Impact Study	Identify the minimum and maximum short circuit levels at the points of interconnection. Ensure existing breakers are still within their current breaking capability at increased short circuit levels due to new transmission lines, and additional equipment (e.g. synchronous condensers).	Replacement of substation equipment due to higher short circuit levels.	Interconnection studies performed by or in coordination with the interconnecting utilities.	Separately: 1) Interconnecting utilities and 2) HVDC Equipment Manufacturer. The HVDC Equipment Manufacturer conducts these studies to ensure that the HVDC solution can meet specific performance requirements while the utilities perform this analysis to ensure secure and reliable operation of their transmission system with the inclusion of the interconnection project.
Transient Stability Study (Dynamic Performance)	Identify possible local or widespread instabilities that require mitigation to accommodate the new project. In addition to instabilities, also identifies violations of local, regional and NERC performance standards with respect to things such as under- and over-voltage, transient voltage recovery, frequency, damping of oscillations, etc.	Transmission network upgrades or HVDC control requirements to mitigate identified violations. May also define the need for an overload criteria of the HVDC system or a special protection system	Interconnection studies performed by or in coordination with the interconnecting Transmission Provider / Owner.	Separately: 1) Interconnecting utilities and 2) HVDC Equipment Manufacturer. The HVDC Equipment Manufacturer conducts these studies to ensure that the HVDC solution can meet specific performance requirements while the utilities perform this analysis to ensure secure and reliable operation of their transmission system with the inclusion of the interconnection project.
Reactive Power Scheme Design	Determine reactive power requirements to meet HVDC converter reactive power needs as well as voltage performance criteria and reactive power exchange limits at each point-of-interconnection.	Reactive Power Scheme that meets voltage performance and reactive power exchange requirements.	Detailed HVDC design	HVDC Equipment Manufacturer, potential review by interconnecting utilities to ensure voltage performance and reactive power exchange criteria are met.
Unit Interaction Factor (UIF) – SSR Screening	Identify the potential risk of SSR due to the introduction of the HVDC project.	A list of units/plants that require more detailed analysis of SSR risks.	Interconnection studies performed to develop the control performance requirements in the IA	HVDC Equipment Manufacturer with review by interconnecting utilities.
Fundamental Frequency Overvoltage Study	Ensure utilities' TOV curve requirement is met based on the operation of the HVDC system + filters based on the specific system conditions at each point-of-interconnection.	Identification of size and type of proper dynamic reactive power equipment, if required, to meet voltage performance criteria. This also feeds into the sizing of the surge arrestors in the AC yard of the converter station at each converter station.	Detailed HVDC design	HVDC Equipment Manufacturer with review by interconnecting utilities.

Study	What is the study's intent?	What is the output from this study?	When does this study get conducted?	Who conducts this study?
Filter/PLC Design	Determine background harmonics in existing AC systems and harmonic output from the DC converters.	Filter design that meets performance criteria for system-normal as well as selected outages of nearby transmission facilities, and selected dispatch scenarios of nearby reactive compensation.	Detailed HVDC design	HVDC Equipment Manufacturer with review by interconnecting utilities through a harmonic performance analysis.
DC Filter and Smoothing Reactor	Identify induced harmonic noise and ripple currents from the proposed HVDC project.	Design parameters for the DC Filter/smoothing reactor to limit harmonic noise and reduce DC ripple currents.	Detailed HVDC design	HVDC Equipment Manufacturer
Circuit breakers, DC Switches	Identify expected current breaking requirements.	Determine proper circuit breaker sizes and types.	Detailed HVDC design	HVDC Equipment Manufacturer
Insulation Coordination	Study of the potential over-voltages that can be expected on the electrical equipment at the converter stations based on the specific atmospheric and electrical conditions anticipated.	Identification of placement, size, and type of proper insulation equipment and arresters to meet performance criteria. This study also drives the HVDC converter valve design.	Detailed HVDC design	HVDC Equipment Manufacturer, potential review by interconnecting utilities.
Single Line Diagram, Layout & Seismic Design	Identify and gather environmental constraints, physical space constraints, seismic design requirements, and other site-related data.	Develop a single-line-diagram based on the final equipment set/design. Develop a site layout that conforms to the environmental constraints, electrical design (insulation requirements, etc), and seismic requirements and otherwise meets the requirements of the performance specification.	Detailed HVDC design	HVDC Equipment Manufacturer
Losses Analysis	Identify the actual expected losses based on the final equipment specifications and project design.	Guaranteed loss estimates from the HVDC equipment vendor.	Detailed HVDC design	HVDC Equipment Manufacturer
Audible noise	Identify the audible noise constraints and determine the expected audible noise from the HVDC converter equipment per the final, as-designed equipment.	Audible noise mitigation plan including site layout modification and/or things like noise barriers.	Detailed HVDC design	HVDC Equipment Manufacturer
Radio / TV Interference	Identify the potential for radio and TV interference based on the as-design electromagnetic properties of the equipment set.	Mitigate interference through filtering, layout, barriers, or other mitigation techniques, if necessary.	Detailed HVDC design	HVDC Equipment Manufacturer
Pole overload optimization	Identify the amount of inherent overload capability in each pole of the HVDC project to allow for operation above 50% of project capability during monopolar outages.	A short-term and continuous monopolar rating per-pole.	Detailed HVDC design	HVDC Equipment Manufacturer

Study	What is the study's intent?	What is the output from this study?	When does this study get conducted?	Who conducts this study?
Reliability and Availability	Identify the required reliability and availability requirements as discussed in the performance specification and a means to meet those requirements through equipment sizing and optimization.	Guaranteed Reliability and Availability performance from the HVDC equipment vendors and re-optimization of equipment set to accommodate guarantee.	Detailed HVDC design	HVDC Equipment Manufacturer
Commissioning Plan	Identify the scope of the commissioning study to include a timeline, personnel needs, the types of studies that will be conducted, and the approval process to complete commissioning.	A commissioning plan including the types of tests, outage requirements, timing requirements, test power requirements, identification of required personnel, etc.	Detailed HVDC design	HVDC Equipment Manufacturer, review by interconnecting utilities
Sub-Synchronous Torsional Interaction	Study the final, as-designed HVDC system to determine whether any risks of resonance with nearby generators is present study can be done in two stages, a screening followed by a detailed study if required	Adjustment of control algorithm to prevent operation near resonant points where torsional interactions have the potential to occur.	Detailed HVDC design	HVDC Equipment Manufacturer, review by interconnecting utilities
Stability, Modulation & Frequency Control Interaction with SVC's, STATCOM's and other nearby HVDC systems.	Identify potential power electronic-based equipment near the HVDC Project and identify potential interference/coordination requirements.	Adjustment of control algorithm to accommodate interference from nearby power electronic equipment.	Detailed HVDC design	HVDC Equipment Manufacturer, review by interconnecting utilities

FINAL

MISO Project J255
Clean Line Energy Grain Belt Express

500 MW in Ralls County, MO

Optional Study Report

Prepared for the
Midcontinent Independent System Operator

by

Ameren Services Company
Transmission Planning

January 2017

DISCLAIMER

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The Federal Energy Regulatory Commission ("FERC") has defined CEII as "specific engineering, vulnerability, or detailed design information about proposed or existing critical infrastructure that: (1) relates details about the production, generation, transportation, transmission, or distribution of energy; (2) could be useful to a person in planning an attack on critical infrastructure; (3) is exempt from mandatory disclosure under the Freedom of Information Act, 5 U.S.C. 552 (2000); and (4) does not simply give the general location of the critical infrastructure."

This report, which has been prepared for the Midcontinent Independent System Operator ("MISO") by Ameren Services Company ("Ameren"), contains information that has been identified by Ameren as CEII. The report should not be shared with persons or entities that have not entered into the appropriate non-disclosure agreement with the MISO. The CEII identified herein is to be redacted prior to posting this report on a public web site.

Table of Contents

I. Executive Summary 1
A. Thermal Analysis 1
B. Reactive Power at Point of Interconnection 1
C. Ameren Local Planning Criteria Analysis 2
D. NIPSCO Local Planning Criteria Analysis 2
E. Cost Estimate of Interconnection Facilities and Network Upgrades at the POI 2
II. Introduction 3
III. Generation Interconnection Details 4
IV. Power Flow Analysis 5
A. Introduction 5
B. Ad-hoc Study Group Participation 6
C. Monitored Areas and Elements 7
D. Contingencies 7
E. Power Flow Models 8
F. Power Flow Base Case Impacts (N-0) 9
G. Power Flow Single Contingency (P1) Impacts (N-1) 9
H. Power Flow Contingency Impacts (P2-P7) 9
I. Local Planning Criteria (Line + Generator Analysis) 10
J. Local Planning Criteria (Transfer Capability Analysis) 11
K. Local Planning Criteria (345 kV Line + Line Analysis) 12
L. NIPSCO Local Planning Criteria 13
M. Voltage Analysis and Reactive Power Requirements 13
N. Mitigation of Constraints 13
O. Summary of Cost Estimates 14
V. Conclusion 14

I. Executive Summary

This report presents the results of the optional System Impact Study for generation interconnection project J255. The project involves connecting an HVDC line originating in western Kansas to the MISO and PJM service territories. The interconnection customer's rectifier station (345 kV AC to 600 kV DC) will be located in Spearville, Kansas, with their 345 kV AC bus connected to wind farm feeds and also to ITC's 345 kV Clark Substation. A 600 kV DC line will be built from Spearville to a 500 MW inverter station (600 kV DC to 345 kV AC) in Ralls County, Missouri. The Ralls County inverter station will interconnect to a new Ameren 345 kV switching station to be built on Ameren's Maywood-Spencer Creek 345 kV transmission line approximately 24 miles south of Maywood. The 600 kV DC line will continue from the Ralls County inverter station to a 3500 MW inverter station (600 kV DC to 345 kV AC) in eastern Indiana that will interconnect to the 345kV bus at AEP's Breed Substation.

This study looked only at the 500 MW injection onto Ameren's Maywood-Spencer Creek 345 kV transmission line. PJM will study the 3500 MW injection at Breed.

The analyses were performed for two load levels, summer peak load and shoulder peak load, for the year 2021. The study models included MTEP Appendix A transmission projects that are scheduled to be in service by the summer of 2021. Generation dispatch in the study models was based on expected generator availability and seasonal dispatch patterns.

The study showed that J255 will cause a constraint on two transmission elements that will require Network Upgrades to accommodate the project.

A. Thermal Analysis

Thermal analysis was performed to determine if any transmission elements will be constrained by the addition of J255. No thermal constraints were identified.

B. Reactive Power at Point of Interconnection

J255 will be required to provide reactive support at the AC terminal of the inverter station to assist in controlling system voltage per applicable FERC/MISO/Local Planning Criteria requirements in place during the DPP study period.

C. Ameren Local Planning Criteria Analysis

Transfer Capability analysis was performed to determine whether J255 would reduce Ameren import capability. No constraints were identified due to Transfer Capability.

Line + Generator contingency analysis was performed for fifty-two (52) unique generation outage scenarios in both the summer peak and shoulder peak models. Two thermal constraints were identified based on this portion of the Local Planning Criteria. They are presented in the table below.

Line + Line contingency analysis was performed for all 345 kV lines on the Ameren system. No thermal constraints were identified based on this portion of the local Planning Criteria.

Table I.C.1 – Estimated Cost of Constraint Mitigation

Facility Owner	Local Planning Criterion	Constraint	Mitigation Suggested	Planning Level Cost Estimate
Ameren	Line + Generator	Rush Island Bus Tie 1-2	Upgrade bus with materials capable of > 3000 Amps continuous capability	$ 1,500,000
Ameren	Line + Generator	Fargo 345/138 kV Transformer	Add a second 560 MVA transformer at Fargo substation	$10,000,000
			Total Estimated Cost	**$11,500,000**

D. NIPSCO Local Planning Criteria Analysis

NIPSCO Local Planning Criteria requires that mitigation be performed for all constraints identified under system intact and N-1 contingency conditions where the study generation has a 3% distribution factor and a 3% MW impact of the facility rating is indicated on the constrained facility. No thermal constraints were identified based on the NIPSCO Local Planning Criteria.

E. Cost Estimate of Interconnection Facilities and Network Upgrades at the POI

The planning-level cost estimate for the Transmission Owner Interconnection Facilities and Network Upgrades at the Point of Interconnection is approximately $9,500,000 based on a recent MISO Interconnection Facilities Study for similar interconnection. This is in addition to the $11,500,000 planning-level cost estimate for Network Upgrades to mitigate constraints caused by the study project. The total planning-level estimated cost for Transmission Owner Interconnection Facilities and Network Upgrades is **$21,000,000**.

II. Introduction

MISO project J255 involves connecting an HVDC line originating in western Kansas to the MISO and PJM service territories. The interconnection customer's rectifier station (345 kV AC to 600 kV DC) will be located in Spearville, Kansas, with their 345 kV AC bus connected to wind farm feeds and also to ITC's 345 kV Clark Substation. A 600 kV DC line will be built from Spearville to a 500 MW inverter station (600 kV DC to 345 kV AC) in Ralls County, Missouri. The Ralls County inverter station will interconnect to a new Ameren 345 kV switching station to be built on Ameren's Maywood-Spencer Creek 345 kV transmission line approximately 24 miles south of Maywood. The 600 kV DC line will continue from the Ralls County inverter station to a 3500 MW inverter station (600 kV DC to 345 kV AC) in eastern Indiana that will interconnect to the 345kV bus at AEP's Breed Substation.

This study looked only at the 500 MW injection onto Ameren's Maywood-Spencer Creek 345 kV transmission line. PJM will study the 3500 MW injection at Breed.

The study considered two load levels, summer peak and shoulder peak for the 2021 planning year. In the summer peak case J255 was dispatched at 100% of maximum output, 500 MW, and all wind generation in the study region was dispatched at 20% of its maximum output. In the shoulder peak case J255 and all wind generation in the study region was dispatched at 100% of maximum output.

The planning-level cost estimate for the Transmission Owner Interconnection Facilities and Network Upgrades at the POI, shown in Table III following, is approximately $9,500,000 based on a recent MISO Interconnection Facilities Study for a similar interconnection.

Table III – Planning Level Cost Estimate for Interconnection Facilities and Network Upgrades to Interconnect J255

Facility Type	Facilities to be Constructed by the Transmission Owner	Planning-Level Cost Estimate
Interconnection Facilities	Construct Transmission Owner Interconnection Facilities at the J255 Interconnection Switching Station	$ 800,000
Stand-Alone Network Upgrade	Construct the J255 Interconnection Switching Station	$ 8,150,000
Network Upgrade	Tap the Maywood-Spencer Creek 345 kV transmission line to connect the J255 Interconnection Switching Station	$ 550,000
TOTAL PLANNING-LEVEL ESTIMATED COST		**$ 9,500,000**

IV. Power Flow Analysis

A. Introduction

The steady-state power-flow analysis was performed using MISO Generator Interconnection Criteria and Ameren Transmission Planning Criteria. The study interconnection was dispatched at maximum output, and all wind generation in the area of study was dispatched at 20% of maximum output during summer peak conditions, and at 100% of maximum output during shoulder peak conditions. The analysis considered all Explicit P1 contingencies in the following control areas: AMMO, AMIL, AECI, CWLD, CLWP, ITC, and MEC. Numerous Explicit P2, P3, P4, P5, P6, and P7 contingencies were also simulated in these areas as provided by MISO.

The power flow analysis considered both MISO criteria and Ameren Transfer Capability (i.e., Import) criteria. MISO constraints are classified as either injection related or non-injection related.

For N-0 conditions, a constraint is identified as an injection related constraint if one or more of the following apply:

- The interconnection has a larger than 5% Distribution Factor on the overloaded facility.
- The overloaded facility is at the study interconnection's outlet.
- The megawatt impact due to the study interconnection is greater than or equal to 20% of the applicable (Normal) rating of the overloaded facility.

For N-1 and certain N-2 conditions, a constraint is identified as an injection related constraint if one or more of the following apply:

- The interconnection has a larger than 20% Distribution Factor on the overloaded facility under post contingency conditions.
- The overloaded facility or the overload-causing contingency is at the study interconnection's outlet.
- The megawatt impact due to the study interconnection is greater than or equal to 20% of the applicable (Emergency) rating of the overloaded facility.

The power flow analysis included the evaluation of all single contingencies in the study area.

Ameren's Local Planning Criteria considers the outage of a single generator combined with the loss of a single transmission element to be treated as single contingency (N-1 condition). Constraints were identified if the study interconnection had a distribution factor of 3% or higher on the overloaded facility or the addition of the interconnection increased the overload by 5% of the facility rating and the constraint did not previously appear as overloaded in the N-1 analysis.

The analysis also considered Ameren's import requirements for summer peak conditions. The import analysis tests the system for 2000 MW of simultaneous import capability. Any reduction in the First Contingency Incremental Transformer Capability (FCITC) of more than 200 MW and a distribution factor of 3% or higher from the study interconnection on a transmission facility will cause that facility to be considered an affected facility and will require mitigation.

Additionally, Ameren's Local Planning criterial considers the loss of any 345 kV line combined with the loss of a second 345 kV line to be treated as a violation if the study interconnection had a distribution factor of 3% or higher on any overloaded facility.

B. Ad-hoc Study Group Participation

MISO system impact studies are facilitated using ad-hoc study groups made up of affected transmission owners and regional transmission organizations. The participants in the ad-hoc study group formed for this study include representatives from Ameren; American Electric Power; Associated

Electric Cooperative Inc.; City Water, Light, and Power (Springfield, IL); Columbia Water and Light Department; International Transmission Company, and MidAmerican Energy Company. These companies participated in the study process, reviewed models and study results, and provided information related to their systems.

C. Monitored Areas and Elements

The study area included the following Balancing Areas in Illinois, Missouri, and Indiana: AMMO, AMIL, EEI, AEP, OVEC, HE, DEI, SIGE, DEO&K, IPL, NIPS, BREC, CWLD, CWLP, SIPC, and LGEE. Monitored facilities included all branches and tie lines 100 kV and above in AMMO and AMIL, and all branches and tie lines 69 kV and above in all other Balancing Areas.

D. Contingencies

The study considered the following system conditions for evaluation of the transmission system:

- System performance under normal conditions (N-0)
- System performance under single contingency (N-1) conditions (P1), including the loss of a single section of a multi-terminal line (P2-1)
- System performance under bus fault (P2-2) and breaker failure (P2-3, P2-4) scenarios
- System performance under loss of line contingency conditions along with a loss of a nearby generator (Line + Generator) (P3-2)
- System performance under loss of Double Circuit Tower (P7)
- System performance with various Line + Line outage scenarios including all Ameren 345 kV pairs (P6)
- System performance with various Line + Transmission Facility outage scenarios including local transformers and shunts (P6)
- Ameren simultaneous and non–simultaneous import capability

The outage of generators, lines, and transformers were simulated explicitly as defined in the contingency files for AMMO, AMIL, AECI, CWLD, CLWP, ITCM, and MEC. MISO provided the contingency files for the non-Ameren portion of the study area. Typically these contingencies represent all elements removed from service during a fault condition with normal relay operation.

For Line + Generator analysis, all generating facilities within Ameren were chosen. For all contingencies that involve the loss of a generator, power was made up from MISO generators excluding Ameren.

F. Power Flow Base Case Impacts (N-0)

Transmission elements that were loaded above their summer normal ratings with J255 in service were flagged if J255 had at least a 5% distribution factor on that element. To qualify as an injection constraint, a flagged element must be at the study project's outlet or the study project must have a minimum of a 5% distribution factor on the flagged element. No transmission elements were identified as constraints under these criteria.

G. Power Flow Single Contingency (P1) Impacts (N-1)

Transmission elements that were over 100% of their summer emergency ratings under single contingency and have a distribution factor of 3% or higher from the study interconnection were flagged for review. For N-1 conditions, a constraint is identified as an injection-related constraint if one or more of the following apply:

- The interconnection has a larger than 20% Distribution Factor on the overloaded facilities under post contingent conditions
- The overloaded facility or the overload causing contingency is at the study interconnection's outlet
- The megawatt impact due to the study interconnection is greater than or equal to 20% of the applicable rating (normal or emergency) of the overloaded facility

No transmission elements were identified as constraints under these criteria.

H. Power Flow Contingency Impacts (P2-P7)

Transmission elements that were over 100% of their summer emergency ratings under P2-P7 contingency conditions and have a distribution factor of 3% or higher from the study interconnection were flagged for review. The same methodology was used to determine whether a constraint would be considered injection related as was used in the P1 analysis.

There were no P2-P7 injection-related constraint identified during shoulder peak or summer peak conditions. Table IV.H.1 details the non-injection related constraints identified during P2 - P7 contingency analysis.

Table IV.H.1 –P2-P7 Non-Injection Related Constraints

Transmission Owner	Overloaded Facility	Contingency	Model	Emerg. Rating (MVA)	POST Project Loading (MVA)	PRE Project Loading (MVA)	DF*
AECI	300103 5NEWMAD 345 - 300046 7NEWMAD 161: 2	P6: New Madrid – Dell 500 & New Madrid 345 / 161 # 1	2021 Shoulder	424	676.5	661.1	3.08%
AECI	345436 7PALMYRA 345 - 345437 5PALMYRA 161: 1	P6: Herleman – Maywood 345 & Zachary 345 / 161	2021 Shoulder	336	371.6	304.7	13.4%
AECI	345436 7PALMYRA 345 - 345437 5PALMYRA 161: 1	P6: Herleman – Maywood 345 & Clean Line – Spencer Ck. 345	2021 Shoulder	336	533.7	387.1	29.3%
AECI	345436 7PALMYRA 345 - 345437 5PALMYRA 161: 1	P6: Herleman – Maywood 345 & Montgomery – Spencer Ck. 345	2021 Shoulder	336	533.6	388.2	29.1%
AECI	345436 7PALMYRA 345 - 345437 5PALMYRA 161: 1	P6: Herleman – Maywood 345 & Audrain SPS 345	2021 Shoulder	336	533.6	388.2	29.1%
AECI	345436 7PALMYRA 345 - 345437 5PALMYRA 161: 1	P6: Montgomery– Spencer Cr. 345 & Herleman 345 / 161	2021 Peak	336	382.4	304.9	15.5%
AECI	345436 7PALMYRA 345 - 345437 5PALMYRA 161: 1	P6: Herleman 345 / 161 & Meredosia 345 / 138	2021 Peak	336	306.5	339.5	6.6%

*DF = Distribution Factor

(Note): These constraints would not be considered injection related and would not require mitigation by the customer. They have been included in the table for informational purposes to indicate possible areas of congestion once the study interconnection has been placed in service.

I. Local Planning Criteria (Line + Generator Analysis)

Ameren's Local Planning Criteria considers the outage of a transmission element with the simultaneous outage of a large generator, peaking plant, or wind farm as a single contingency event. The analysis considered all Ameren generation. Single contingency analysis was performed on the powerflow cases with the generation switched offline in N-1-1 contingency analysis and dispatched to MISO areas

excluding Ameren. Ameren facilities were monitored for thermal overloads during this analysis. There were two constraints identified under shoulder peak conditions. These constraints are listed below.

Table IV.I.1 – Injection Related Constraints for Line + Generator Analysis

Transmission Owner	Overloaded Facility	Contingency	Model	Emerg. Rating (MVA)	POST Project Loading (MVA)	PRE Project Loading (MVA)	DF*
Ameren	345667 7RUSH 1 345 - 345668 7RUSH 2 345 BUS TIE	P3: RUSH UNIT 2 & PRARIE STATE – MT. VERNON 4541 345 kV	2021 Shoulder	1494	1508.4	1484.5	4.78%
Ameren	349730 7FARGO 345 - 349650 4FARGO 138 1 XFMR	P3: EDWARDS U 3 & TAZEWELL – MAPLERIDGE 345 kV	2021 Shoulder	560	563.2	544.4	3.76%

J. Local Planning Criteria (Transfer Capability Analysis)

All study projects are required to meet Ameren's local planning criteria for import capability. This criteria states that a minimum simultaneous import capability of 2,000 MW, which is measured by the first contingency incremental transfer capability (FCITC) as limited by an Ameren transmission facility, should be used as a proxy to maintain transmission capability related to generation reserves in the Ameren Missouri (AMMO) or Ameren Illinois (AMIL) footprint. Table IV.J.1 summarizes the simulations of simultaneous imports to various subsystems in the AMMO and AMIL areas from non-Ameren areas inside and outside the MISO footprint using the 2021 Summer Peak case. Various combinations of generators located in the Ameren control areas and dispatched in the power flow case, excluding study generation, served as sinks for these imports. The analysis included simulations with and without the study generators dispatched. A distribution factor of 3% or greater and a decrease of 200 MW of first contingency incremental transfer capability (FCITC) for the simulated import served as the basis for determining if an Ameren facility was limiting.

Importing scenarios simulated in this study are shown in Table IV.J.1 below:

Table IV.J.1 – Summary of Import Simulations

Source	Sink	Comments
WORLD_NOAMRN_E	AMIL_IMA	Imports to all on-line AMIL generators
WORLD_NOAMRN_E	AMMO_IMA	Imports to all on-line AMMO generators
WORLD_NOAMRN_E	IL_138	Imports to on-line generators in Illinois connected to 138 kV
WORLD_NOAMRN_E	IL_345	Imports to on-line generators in Illinois connected to 345 kV
WORLD_NOAMRN_E	IL_COAL	Imports to on-line coal plants in Illinois
WORLD_NOAMRN_E	MO_138	Imports to on-line generators in Missouri connected to 138 kV
WORLD_NOAMRN_E	MO_345	Imports to on-line generators in Missouri connected to 345 kV
WORLD_NOAMRN_E	MO_COAL	Imports to on-line coal plants in Missouri
WORLD_NOAMRN_E	AMIL_BASE	Imports to on-line AMIL base-load generators
WORLD_NOAMRN_E	AMMO_BASE	Imports to on-line AMMO base-load generators

There were no constraints related to transfer capability identified due to the addition of J255 in this portion of the local planning criteria analysis.

K. Local Planning Criteria (345 kV Line + Line Analysis)

A line + line outage analysis was performed for all Ameren 345 kV lines to determine whether the addition of the J255 generation would cause additional constraints with the combination of two 345 kV lines out of service. There were no additional constraints identified under shoulder peak or summer peak conditions beyond those injection-related constraints previously described in Sections IV.I.

L. NIPSCO Local Planning Criteria

NIPSCO Local Planning Criteria requires that mitigation be performed for all constraints identified under system intact and N-1 contingency conditions where the study interconnection has a 3% distribution factor and a 3% MW impact of the facility rating is indicated on the constrained facility. There were no constraints that met these criteria for this study.

M. Voltage Analysis and Reactive Power Requirements

The analysis evaluated the impact of the addition of J255 on voltages under single contingency conditions. To be identified as a voltage constraint, the voltage at the transmission bus should degrade by 1% with the addition of the study interconnection. The study did not identify any voltage degradation during single contingencies with the addition of study interconnection.

Non-synchronous generators (like wind farms) are required to operate across the power factor range of 0.95 lagging to 0.95 leading at the Point of Interconnection (POI).

N. Mitigation of Constraints

The mitigation of thermal constraints was provided by the Transmission Owners of each constraint. Table IV.N.1 below provides additional details and a planning-level cost estimate for the mitigation of each injection-related constraint.

Table IV.N.1 Mitigation of Injection-Related Constraints

Facility Owner	Local Criteria	Constraint	Mitigation Suggested	Planning-Level Cost Estimate
Ameren	Line + Generator	Rush Island Bus Tie 1- 2	Upgrade bus with materials capable of > 3000 Amps continuous capability	$ 1,500,000
Ameren	Line + Generator	Fargo 345 / 138 kV Transformer	Add second 560 MVA transformer at Fargo substation	$10,000,000
			Total Planning Level Estimated Cost	**$11,500,000**

O. Summary of Cost Estimates

The planning-level cost estimates to mitigate injection-related constraints and to construct the Transmission Owner Interconnection Facilities and Network Upgrades at the POI are shown below in Table IV.N.1.

Table IV.O.1 Summary of Cost Estimates

Facility Type	Facilities to be Constructed by the Transmission Owner	Planning-Level Cost Estimate
Interconnection Facilities	Construct Transmission Owner Interconnection Facilities at the J255 Interconnection Switching Station	$ 800,000
Stand-Alone Network Upgrade	Construct the J255 Interconnection Switching Station	$ 8,150,000
Network Upgrade	Tap the Maywood-Spencer Creek 345 kV transmission line to connect the J255 Interconnection Switching Station	$ 550,000
Network Upgrade	Upgrade the Rush Island bus tie with materials capable of > 3000 Amps continuous capability	$ 1,500,000
Network Upgrade	Add a second 560 MVA transformer at Fargo substation	$ 10,000,000
TOTAL PLANNING-LEVEL ESTIMATED COST		**$ 21,000,000**

V. Conclusion

The results of the optional System Impact study indicate that the addition of J255 will cause constraints on the transmission system that will require mitigation. Ameren has provided mitigation for these constraints. The mitigation was generally the re-building of existing facilities.

Grain Belt Express HVDC

System Impact Study

Final Report for

Southwest Power Pool

Prepared by:
Excel Engineering, Inc.

September 6, 2013

Principal Contributor:

William Quaintance, P.E.

TABLE OF CONTENTS

LIST OF FIGURES 4

LIST OF TABLES 4

0. CERTIFICATION 5

1. BACKGROUND AND SCOPE 6

2. EXECUTIVE SUMMARY 7

3. STUDY DEVELOPMENT AND ASSUMPTIONS 9

3.1 Simulation Tools 9

3.2 Models Used 9

3.3 Monitored Facilities 12

3.4 Performance Evaluation Methods 14

4. RESULTS AND OBSERVATIONS 18

4.1 Stability Analysis Results 18

4.2 Discussion of Notable Results 22

4.2.1 Faults near SPP Clark County 345 kV Station 22

4.2.2 Faults near SPP Clark County 345 kV Station – New POI 26

4.2.3 Faults near AEP Sullivan 765/345 kV Station 29

4.2.4 Faults near AMMO Palmyra Tap 345 kV Station 29

4.2.5 Both HVDC Poles Blocked 33

4.2.6 Transient Voltage Review 33

4.3 General Review of the Previous Report 37

5. CONCLUSIONS 39

Appendix A – 2017 Light Load Plots

Appendix B – 2017 Summer Peak Plots

Appendix C – 2022 Summer Peak Plots

Appendix D – Transient Voltage Results

Appendix E – SPP Transmission One-line Diagrams

List of Figures

Figure 3-1. Power Flow One-line of GBX HVDC with 345 kV Option at Sullivan – 2017 Summer Peak 10
Figure 3-2. Power Flow One-line of GBX Wind Generation – 2017 Summer Peak 11
Figure 4-1. Wind and HVDC Powers for FLT11A, 3ph fault on Clark Co – Thistle 345 #1 with prior outage of #2 23
Figure 4-2. Wind and HVDC Powers for FLT11A_voltcont, 3ph fault on Clark Co – Thistle 345 #1 with prior outage of #2, trip some wind generation post-fault 24
Figure 4-3. Wind and HVDC Powers for FLT11C, 3ph fault on Clark Co – Thistle 345 #1 with prior outage of #2, trip some wind generation PRE-fault 25
Figure 4-4. Transmission Voltages for FLT11D, 3ph fault on GBX POI – Clark Co 345 #1 and #2 double circuit 28
Figure 4-5. Transmission Voltages for FLT11D, 3ph fault on GBX POI – Clark Co 345 #1 and #2 double circuit, trip some wind generation post-fault 28
Figure 4-6. Rockport Speeds and HVDC Powers for FLT34, 3ph fault on Rockport – Jefferson 765 30
Figure 4-7. Rockport Speeds and HVDC Powers for FLT34, 3ph fault on Rockport – Jefferson 765, tripping one GBX HVDC pole post-fault 31
Figure 4-8. Bus Voltages and HVDC Powers for FLT36, 3ph fault on Palmyra Tap – Sub T 345 32
Figure 4-9. GBX Wind Power and Bus Voltages for FLT01, 3ph fault at GBX SPP converter AC bus, tripping both GBX HVDC poles 34
Figure 4-10. GBX Wind Power and Bus Voltages for FLT04, 3ph fault at GBX AEP converter AC bus, tripping both GBX HVDC poles 35
Figure 4-11. GBX Wind Power and Bus Voltages for FLT07, 3ph fault at GBX Palmyra converter AC bus, tripping both GBX HVDC poles 36

List of Tables

Table 3-1. Areas Monitored 12
Table 3-2. Additional Generators Monitored Near Sullivan 12
Table 3-3. Additional Generators Monitored Near Palmyra 13
Table 3-4. Fault Definitions 14
Table 4-1. Summary of Stability Results 18
Table 4-2. Summary of Stability Results for new POI 27

0. Certification

I hereby certify that this plan, specification, or report was prepared by me or under my direct supervision and that I am a duly Licensed Professional Engineer under the Laws of the State of **Kansas**.

William Quaintance
Kansas License Number 20756

Excel Engineering, Inc.
Kansas Firm License Number 1611

1. Background and Scope

The ±600 kV Grain Belt Express (GBX) HVDC line is being developed by Clean Line Energy Partners LLC to transport renewable energy from SPP (near Clark County Substation, Kansas) to AMMO (Palmyra Tap Substation, Missouri) and AEP (Sullivan Substation, Indiana). Clean Line hired Siemens PTI to perform power flow and stability studies of the project's impact on the electric system. SPP hired Excel Engineering to review and repeat the results of the PTI stability study.

Excel analyzed system stability characteristics in the SPP footprint with the GBX HVDC line and renewable generation modeled in the system. The study was performed for select three phase and single line to ground faults at and near the converter stations in three seasonal cases: 2017 light load, 2017 summer peak, and 2022 summer peak. The three seasonal cases were provided by SPP with the HVDC line and wind generation already incorporated into the cases.

This study by Excel Engineering, Inc. consisted of analyzing system stability following faults in the area of the proposed HVDC project as well as providing comments on the project developer's report.

In August 2013, PTI provided new results based on a change in the Point of Interconnection. The new POI is 14 miles closer to Spearville than the previous POI at Clark Co. The new PTI stability results showed the same performance as the original POI. Analysis of the stability of the new POI is included in Section 4.2.2 of this report.

Study assumptions in general have been based on Excel's knowledge of the electric power system and on the specific information and data provided by SPP. The accuracy of the conclusions contained within this study is sensitive to the assumptions made with respect to generation additions and transmission improvements being contemplated. Changes in the assumptions of the timing of other generation additions or transmission improvements will affect this study's conclusions.

2. Executive Summary

The analysis performed by Excel Engineering confirms the results of the PTI stability report. The main conclusions of the report were as follows:

- The worst faults in SPP were N-1-1 and N-2 faults on the parallel 345 kV lines connected to Clark County substation. If one Clark Co – Thistle 345 kV line is out of service and there is a three-phase fault on the parallel line, the GBX wind generators may go unstable and trip off-line by over-frequency protection. The same behavior was seen if one Clark Co – Spearville 345 kV line is out of service and a three-phase fault occurs on the second line.

  The recommendation in the PTI study is to trip up to 877 MW of GBX wind generation after the fault occurs. This solution was confirmed for the original fault list. With an additional N-1-1 fault studied at the Thistle end, up to 1637 MW of wind generation will need to be tripped. However, SPP and the transmission owner will have to decide if a Special Protection System (SPS) such as this would be acceptable.

  An alternative is to reduce the GBX wind generation in a controlled fashion after the first outage occurs, to be prepared in case a fault occurs on the second circuit. Successful performance of this option was also confirmed. However, this option is not available if these double-circuit transmission lines share transmission towers for a significant distance and NERC Category C5 is considered.

  Similar results were found when the SPP POI was changed to a location 14 miles from Clark Co on the Clark Co-Spearville 345 kV lines.

  If neither the post-fault wind tripping SPS nor the pre-fault wind reduction is an acceptable solution, then a major transmission upgrade or reduction in the size of the GBX project will have to be considered.

- The worst faults in AEP were on the Rockport – Jefferson 765 kV line. Outage of this line leaves the 2600 MW Rockport plant feeding radially to Sullivan, the same place where the GBX HVDC converters are injecting 3000 MW. Following this fault, the Rockport generators go unstable and trip. In power flow, the solution diverges for this contingency.

  The recommendation in the PTI study is to trip one of the HVDC poles (1500 MW) after the fault occurs. This solution was confirmed. However, AEP and the transmission owner will have to decide if an SPS such as this would be acceptable.

  If the post-fault HVDC reduction SPS is not an acceptable solution, then a major transmission upgrade or reduction in the size of the GBX project will have to be considered.

- No stability problems were found for faults near the AMMO Palmyra station. The AMMO system is able to handle the additional 500 MW injection without a problem.

Outages of a single pole or both poles of the HVDC line were of particular interest for this study. The analysis confirms stable system response for the faults with loss of one or both poles. It should be noted that only a small portion of generation in the SPP Generator Interconnection Queue in the Spearville, Clark County, and Thistle areas were included in the analysis based on the information provided during the MDWG model development process.

In summary, the following mitigation options were confirmed to eliminate the unstable responses:

- A 900 Mvar Synchronous Condenser was assumed in all cases
- An SPS to reduce GBX wind generation following parallel circuit outages at Clark Co. Up to 1650 MW of wind generation tripping may be needed for certain double line outages.
- An SPS to reduce HVDC power by up to 1500 MW following outage of the Rockport-Jefferson 765 kV line.

It will be critical for the GBX project to maintain a balance in both its MW flow and its Mvar flow. The project is designed to have a normal power exchange with SPP of 0 MW and 0 Mvar. This target needs to be maintained during dynamic conditions as best as possible. Large imbalances can cause voltage violations and generator instability.

Additional considerations for futures studies of the GBX project include:

- Consideration of more breaker failure faults.
- Inclusion of other planned wind generation in the SPP footprint.
- Modeling the maximum 3500 MW HVDC injection at the AEP Sullivan end.
- If the SPS solutions are not acceptable, other solutions such as new transmission lines or reduced GBX project size will have to be found.

The results of this study depend on the assumed models for the HVDC equipment, wind generators, wind collector system, and the power systems in the area of the project. Some of these assumptions will surely change or come into better focus as the project moves forward. The stability analysis will need to be repeated when the assumptions are better defined.

3. Study Development and Assumptions

3.1 Simulation Tools

The Siemens PTI PSS/E power system simulation program Version 30.3.3 was used in this study. The time step used in all simulations was a quarter of a 60 Hz cycle (0.004167s). Simulation duration was as indicated in the fault definition table.

3.2 Models Used

SPP provided the power flow and dynamics models from PTI for 2017 Light Load, 2017 Summer Peak and 2022 Summer Peak conditions. There were also two connection options considered initially at Sullivan, 765 kV and 345 kV, giving a total of six (6) base cases. All other files used to run the original study, such as fault scripts, were also provided by PTI. They were reviewed for accuracy before use in the study.

Figure 3-1 and Figure 3-2 show power flow one-lines for the 2017 Summer Peak case with the 345 kV option at Sullivan and the GBX wind generation model, respectively. One-line diagrams of GBX and the full SPP 345 kV system for all three seasons are provided in Appendix E.

As in the PTI study, all faults in SPP, AMMO, and AEP were run on the cases with the 765 kV connection option at Sullivan. Only faults in AEP were tested with the 345 kV option at Sullivan. It is assumed that the faults in SPP and AMMO would not vary significantly between the two different connection options at AEP's Sullivan station.

Near the end of the study, Clean Line informed SPP that the 765 kV connection option at Sullivan should be dropped from consideration, and only the 345 kV option should be considered. However, most of the simulation work had already been completed. The results of the fault simulations in SPP and AMMO with the 765 kV option in AEP are still considered valid. For faults in AEP, results with the 765 kV option were set aside and only results with the 345 kV option are discussed in this report.

No changes were made to the provided models.

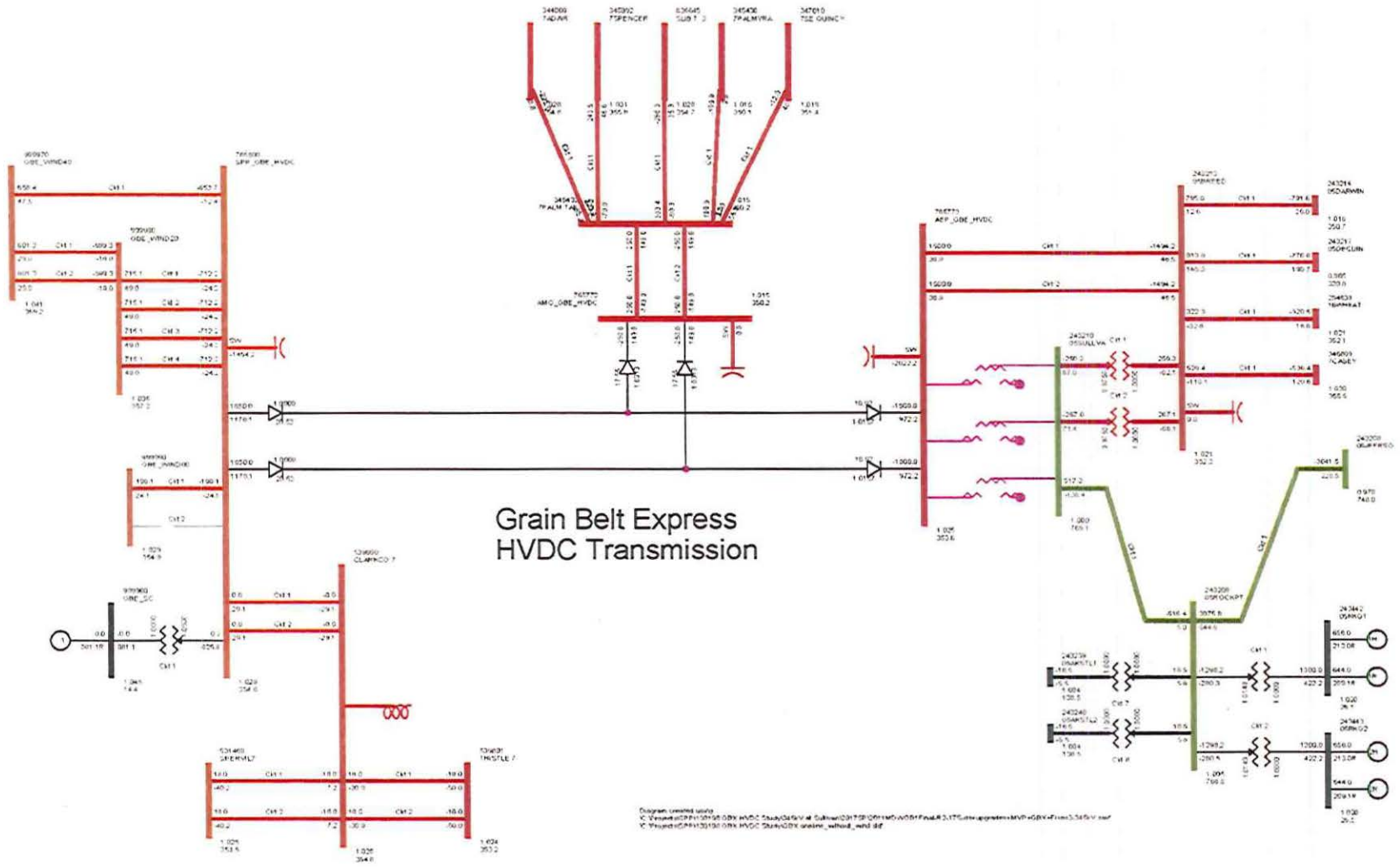


Figure 3-1. Power Flow One-line of GBX HVDC with 345 kV Option at Sullivan – 2017 Summer Peak

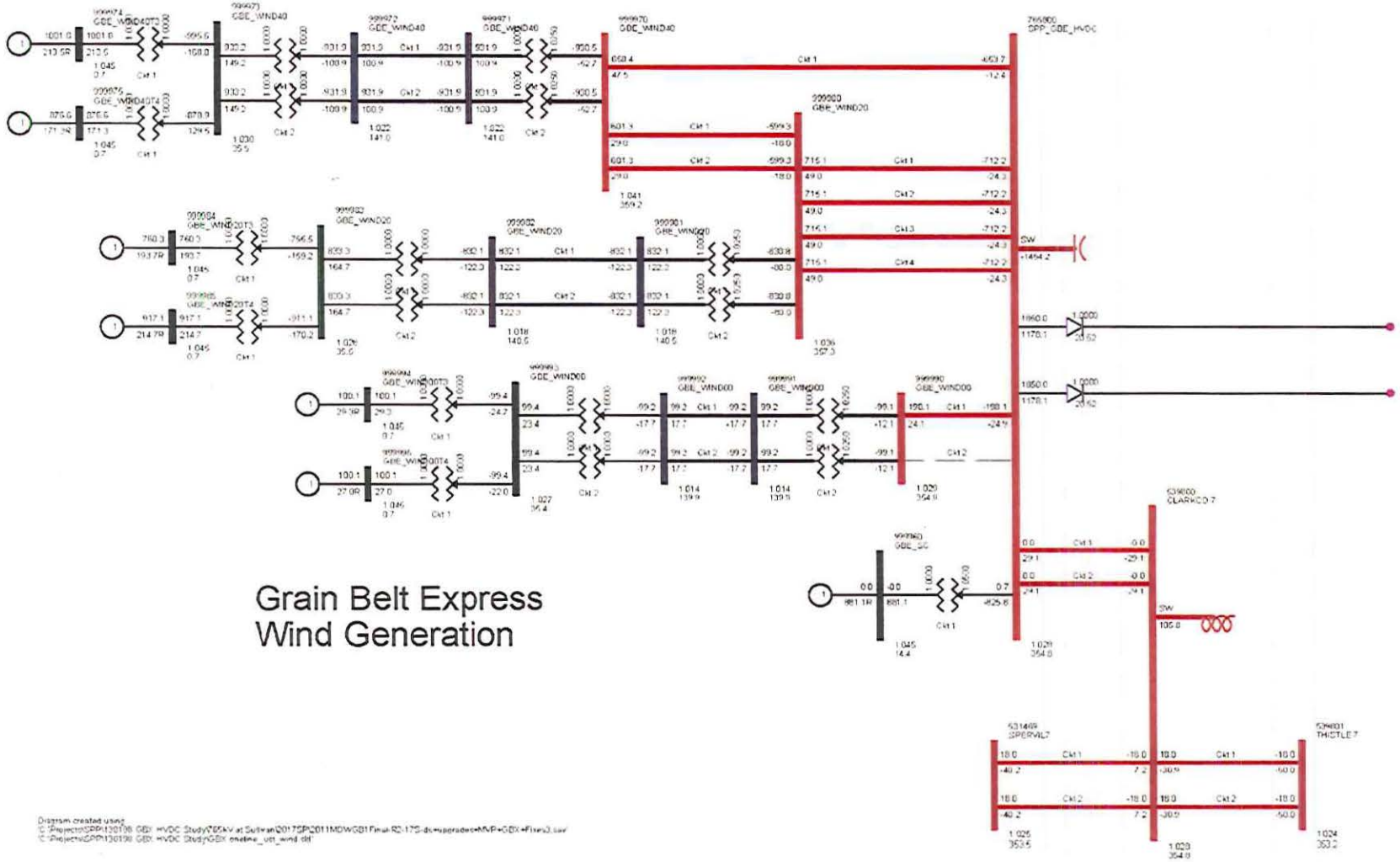


Figure 3-2. Power Flow One-line of GBX Wind Generation – 2017 Summer Peak

3.3 Monitored Facilities

Generators and transmission voltages were monitored in the following areas:

Table 3-1. Areas Monitored

AREA	NAME	AREA	NAME
523	GRDA	540	GMO
524	OKGE	541	KCPL
526	SPS	542	KACY
531	MIDW	640	NPPD
534	SUNC	330	AECI
536	WERE	351	EES

Additional generators were monitored near the AEP Sullivan and AMMO Palmyra rectifier stations, as listed in Table 3-2 and Table 3-3, respectively.

A selection of plots of voltage, frequency, rotor angle and speed from the HVDC project generation and across the SPP footprint were selected as the default plots provided in the appendices.

Table 3-2. Additional Generators Monitored Near Sullivan

Station	Buses	Area
Rockport	243442 - 243443	205 AEP
Petersburg	254811-254814	216 IPL
Gibson	251861-251865	208 DEM
Wheatland	251897-251900	208 DEM
Merom	248773	207 HE
Clifty Ck	248000	206 OVEC
Trimble Co	324034 - 324041	363 LGEE
Cayuga	251849 - 251850	208 DEM
Amos	242891 - 242893	205 AEP
Mountaineer	242894	205 AEP
Mitchel	243188 - 243189	205 AEP
Muskingum	242940	205 AEP
Lawrenceburg	243226	205 AEP
Tanner	243233	205 AEP
Cook	243440 - 243441	205 AEP
Conesville	243622	205 AEP
Big Sandy	243763 - 243764	205 AEP
Killen	253038	209 DAY
Stuart	253077	209 DAY

Table 3-3. Additional Generators Monitored Near Palmyra

Station	Buses	Area
Audrain	344061 - 344063	356 AMMO
Callaway	344225	356 AMMO
Kinmundy	344876	356 AMMO
Labody	344894 - 344895	356 AMMO
Meramad	345132 - 345156	356 AMMO
Osage	345400	356 AMMO
Peno Creek	345441	356 AMMO
Rush Island	345670	356 AMMO
Sioux	345756 - 345765	356 AMMO
Venice	345882	356 AMMO
Raccoon Ck	345994	356 AMMO
Goose Creek	345998	356 AMMO
Keokuk	344863	356 AMMO
Alsey	346516	357 AMIL
Avena	346573	357 AMIL
Coffeen	346897	357 AMIL
Gibson City	347112	357 AMIL
Grand Tower	347170	357 AMIL
Holland Energy	347231	357 AMIL
Hutsonville	347271	357 AMIL
RELU	347819	357 AMIL
Newton	347832	357 AMIL
Clinton	349101	357 AMIL
Vermilion	349109	357 AMIL
Wood River	349115	357 AMIL
Havana	349121	357 AMIL
Tilton	349122	357 AMIL
Baldwin	349126	357 AMIL
Prairie State	349129	357 AMIL
Edwards	349632	357 AMIL
Duck Ck	349633	357 AMIL
Railsplitter	349724	357 AMIL

3.4 Performance Evaluation Methods

The faults shown in Table 3-4 were simulated in this study. This list includes all faults from the PTI report plus some faults at 230 kV and lower voltage levels added at the request of transmission owner Sunflower Electric Power Corporation (SEPC).

Some N-1-1 and N-2 faults were also added to the list. Since both ends of the Clark Co – Spearville 345 kV lines were tested in the original study (FLT12A, FLT12B), a new FLT11B was added to the existing FLT11A so that the Clark Co – Thistle 345 kV lines received the same treatment. The solutions to these faults were tested as pre-fault wind reductions (FLT11C, FLT12C). N-2 faults (aka NERC Category C5) were added for these lines as well (FLT11D, FLT11E, FLT12D).

Simulation channels of voltages, frequencies, rotor angles, and speed deviation from areas covering the entire SPP footprint were selected as the default plot for each disturbance simulation.

All generators were reviewed for stability and tripping. Transmission bus voltages checked against the SPP requirement of 70% to 120% after fault clearing.

Table 3-4. Fault Definitions

No	Description	kV
	3-phase faults with normal clearing	
1	At Clark Co 765800, both poles are blocked	345
2	At Clark Co 765800, one pole is recovered	345
3	At Clark Co 765800, both poles are recovered	345
4	At Sullivan 765773, both poles are blocked	345
5	At Sullivan 765773, one pole is recovered	345
6	At Sullivan 765773, both poles are recovered	345
7	At Palmyra 765772, both poles are blocked	345
8	At Palmyra 765772, one pole is recovered	345
9	At Palmyra 765772, both poles are recovered	345
10	the Palmyra inverter of the recovered pole is still	345
11	Clark Co 539800 - Thistle 539801	345
12	Clark Co 539800 - Spearville 531469	345
13	Thistle 539801 - Wichita 532796	345
14	Thistle 539801 - Woodward 515375	345
15	Woodward 515375 - Tatonga 515407	345
16	Spearville 531469 - Holcomb 531449	345
17	Spearville 531469 - Post Rock 530583	345
18	Spearville 345/230 kV TF (531469 - 539695)	345/230

No	Description	kV
19	Spearville 539695 - Mullergren 539679	230
20	Post Rock 530583 - Axtell 640065	345
21	Holcomb 531449 - Finney 523853	345
22	Holcomb 531449 - Setab 531465	345
23	Finney 523853 - Hitchland 523080	345
24	Finney 523853 - Lamar 599950	345
25	Setab 531465 - Mingo 531451	345
26	Mingo 531451 - Red Willow 640325	345
27	Sullivan 3wnd TF (243210-765773-999920)	765/345
28	Sullivan 765/345 kV TF (243210 - 243213)	765/345
29	Sullivan 243210 - Rockport 243209	765
30	Breed 243213 - Casey 346809	345
31	Breed 243213 - Darwin 243216	345
32	Breed 243213 - Dequine 243217	345
33	Breed 243213 - Wheat 254539	345
34	Rockport 243209 - Jefferson 243208	765
35	Palmyra 765772 - Palmyra tap 345435	345
36	Palmyra Tap 345435 - Sub T 636645	345
37	Palmyra Tap 345435 - Palmyra 345436	345
38	Palmyra Tap 345435 - Adair 344000	345
39	Palmyra Tap 345435 - Spencer 345992	345
40	Palmyra Tap 345435 - Se Quincy 347010	345
	SLG faults with protection failure	
41	Clark Co 539800 - Thistle 539801	345
42	Clark Co 539800 - Spearville 531469	345
43	Thistle 539801 - Wichita 532796	345
44	Thistle 539801 - Woodward 515375	345
45	Woodward 515375 - Tatonga 515407	345
46	Spearville 531469 - Holcomb 531449	345
47	Spearville 531469 - Post Rock 530583	345
48	Spearville 345/230 kV TF (531469 - 539695)	345/230
49	Spearville 539695 - Mullergren 539679	230
50	Post Rock 530583 - Axtell 640065	345
51	Holcomb 531449 - Finney 523853	345
52	Holcomb 531449 - Setab 531465	345
53	Finney 523853 - Hitchland 523080	345
54	Finney 523853 - Lamar 599950	345
55	Setab 531465 - Mingo 531451	345

No	Description	kV
56	Mingo 531451 - Red Willow 640325	345
57	Sullivan 3wnd TF (243210-765773-999920)	765/345
58	Sullivan 765/345 kV TF (243210 - 243213)	765/345
59	Sullivan 243210 - Rockport 243209	765
60	Breed 243213 - Casey 346809	345
61	Breed 243213 - Darwin 243216	345
62	Breed 243213 - Dequine 243217	345
63	Breed 243213 - Wheat 254539	345
64	Rockport 243209 - Jefferson 243208	765
65	Palmyra 765772 - Palmyra tap 345435	345
66	Palmyra Tap 345435 - Sub T 636645	345
67	Palmyra Tap 345435 - Palmyra 345436	345
68	Palmyra Tap 345435 - Adair 344000	345
69	Palmyra Tap 345435 - Spencer 345992	345
70	Palmyra Tap 345435 - Se Quincy 347010	345
	SLG faults with stuck breaker	
71	Fault at Rectifier, block the pole and trip line to collector system	345
72	Fault at Sullivan, trip 3wnd and 2wnd transformers	765/345
73	Fault at Palmyra Tap, trip lines to inverter station and to Palmyra	345
	Faults Added by Sunflower	
74	Mullergren 539679 - Circle 532871, 3-phase	230
75	Mullergren 539679 - Circle 532871, 1-phase delayed	230
76	Pile 531432 - Dobson 531419, 3-phase	115
77	Pile 531432 - Dobson 531419, 1-phase delayed	115
78	Holcomb transformer 531449-531448, 3-phase	345/115
79	Holcomb transformer 531449-531448, 1- phase delayed	345/115
80	Harper 539668 - Milan Tap 539675 - Clearwater 533036, 3-phase	138
81	Harper 539668 - Milan Tap 539675 - Clearwater 533036, 1- phase delayed	138
	N-1-1 and N-2, 3 phase fault with normal clearing	
11A	Prior outage of Clark Co - Thistle #1, fault on #2	345
11B	Prior outage of Thistle - Clark Co #1, fault on #2	345
11C	Prior outage of some GBX wind generation and Clark Co - Thistle #1, fault on #2	345
11D	Clark Co 539800 - Thistle 539801 double circuit	345
11E	Thistle 539801 - Clark Co 539800 double circuit	345
12A	Prior outage of Spearville - Clark Co #1, fault on #2	345

No	Description	kV
12B	Prior outage of Clark Co - Spearville #1, fault on #2	345
12C	Prior outage of some GBX wind generation and Clark Co - Spearville #1, fault on #2	345
12D	Clark Co 539800 - Spearville 531469 double circuit	345
17A	Prior outage of Spearville - Holcomb, fault on Spearville - Post Rock	345

4. Results and Observations

4.1 Stability Analysis Results

Table 4-1 summarizes the results of the initial simulations. Discussion of specific results follows the table.

Table 4-1. Summary of Stability Results

No	Description	2017 LL	2017 SP	2022 SP
	3-phase faults with normal clearing			
1	At Clark Co 765800, both poles are blocked	ok	ok	ok
2	At Clark Co 765800, one pole is recovered	ok	ok	ok
3	At Clark Co 765800, both poles are recovered	ok	ok	ok
4	At Sullivan 765773, both poles are blocked	ok	ok	ok
5	At Sullivan 765773, one pole is recovered	ok	ok	ok
6	At Sullivan 765773, both poles are recovered	ok	ok	ok
7	At Palmyra 765772, both poles are blocked	ok	ok	ok
8	At Palmyra 765772, one pole is recovered	ok	ok	ok
9	At Palmyra 765772, both poles are recovered	ok	ok	ok
10	the Palmyra inverter of the recovered pole is still	ok	ok	ok
11	Clark Co 539800 - Thistle 539801	ok	ok	ok
12	Clark Co 539800 - Spearville 531469	ok	ok	ok
13	Thistle 539801 - Wichita 532796	ok	ok	ok
14	Thistle 539801 - Woodward 515375	ok	ok	ok
15	Woodward 515375 - Tatonga 515407	ok	ok	ok
16	Spearville 531469 - Holcomb 531449	ok	ok	ok
17	Spearville 531469 - Post Rock 530583	ok	ok	ok
18	Spearville 345/230 kV TF (531469 - 539695)	ok	ok	ok
19	Spearville 539695 - Mullergren 539679	ok	ok	ok
20	Post Rock 530583 - Axtell 640065	ok	ok	ok
21	Holcomb 531449 - Finney 523853	ok	ok	ok
22	Holcomb 531449 - Setab 531465	ok	ok	ok
23	Finney 523853 - Hitchland 523080	ok	ok	ok
24	Finney 523853 - Lamar 599950	ok	ok	ok
25	Setab 531465 - Mingo 531451	ok	ok	ok
26	Mingo 531451 - Red Willow 640325	ok	ok	ok
27	Sullivan 3wnd TF (243210-765773-999920)	ok	ok	ok
28	Sullivan 765/345 kV TF (243210 - 243213)	ok	ok	ok

No	Description	2017 LL	2017 SP	2022 SP
29	Sullivan 243210 - Rockport 243209	ok	ok	ok
30	Breed 243213 - Casey 346809	ok	ok	ok
31	Breed 243213 - Darwin 243216	ok	ok	ok
32	Breed 243213 - Dequine 243217	ok	ok	ok
33	Breed 243213 - Wheat 254539	ok	ok	ok
34	Rockport 243209 - Jefferson 243208	ok	ok	ok
35	Palmyra 765772 - Palmyra tap 345435	ok	ok	ok
36	Palmyra Tap 345435 - Sub T 636645	ok	ok	ok
37	Palmyra Tap 345435 - Palmyra 345436	ok	ok	ok
38	Palmyra Tap 345435 - Adair 344000	ok	ok	ok
39	Palmyra Tap 345435 - Spencer 345992	ok	ok	ok
40	Palmyra Tap 345435 - Se Quincy 347010	ok	ok	ok
	SLG faults with protection failure			
41	Clark Co 539800 - Thistle 539801	ok	ok	ok
42	Clark Co 539800 - Spearville 531469	ok	ok	ok
43	Thistle 539801 - Wichita 532796	ok	ok	ok
44	Thistle 539801 - Woodward 515375	ok	ok	ok
45	Woodward 515375 - Tatonga 515407	ok	ok	ok
46	Spearville 531469 - Holcomb 531449	ok	ok	ok
47	Spearville 531469 - Post Rock 530583	ok	ok	ok
48	Spearville 345/230 kV TF (531469 - 539695)	ok	ok	ok
49	Spearville 539695 - Mullergren 539679	ok	ok	ok
50	Post Rock 530583 - Axtell 640065	ok	ok	ok
51	Holcomb 531449 - Finney 523853	ok	ok	ok
52	Holcomb 531449 - Setab 531465	ok	ok	ok
53	Finney 523853 - Hitchland 523080	ok	ok	ok
54	Finney 523853 - Lamar 599950	ok	ok	ok
55	Setab 531465 - Mingo 531451	ok	ok	ok
56	Mingo 531451 - Red Willow 640325	ok	ok	ok
57	Sullivan 3wnd TF (243210-765773-999920)	ok	ok	ok
58	Sullivan 765/345 kV TF (243210 - 243213)	ok	ok	ok
59	Sullivan 243210 - Rockport 243209	ok	ok	ok
60	Breed 243213 - Casey 346809	ok	ok	ok
61	Breed 243213 - Darwin 243216	ok	ok	ok
62	Breed 243213 - Dequine 243217	ok	ok	ok
63	Breed 243213 - Wheat 254539	ok	ok	ok
64	Rockport 243209 - Jefferson 243208	ok	ok	ok

No	Description	2017 LL	2017 SP	2022 SP
65	Palmyra 765772 - Palmyra tap 345435	ok	ok	ok
66	Palmyra Tap 345435 - Sub T 636645	ok	ok	ok
67	Palmyra Tap 345435 - Palmyra 345436	ok	ok	ok
68	Palmyra Tap 345435 - Adair 344000	ok	ok	ok
69	Palmyra Tap 345435 - Spencer 345992	ok	ok	ok
70	Palmyra Tap 345435 - Se Quincy 347010	ok	ok	ok
	SLG faults with stuck breaker			
71	Fault at Rectifier, block the pole and trip line to collector system	ok	ok	ok
72	Fault at Sullivan, trip 3wnd and 2wnd transformers	ok	ok	ok
73	Fault at Palmyra Tap, trip lines to inverter station and to Palmyra	ok	ok	ok
	Faults Added by Sunflower			
74	Mullergren - Circle, 3-phase	ok	ok	ok
75	Mullergren - Circle, 1-phase delayed	ok	ok	ok
76	Pile - Dobson, 3-phase	ok	ok	ok
77	Pile - Dobson, 1-phase delayed	ok	ok	ok
78	Holcomb transformer, 3-phase	ok	ok	ok
79	Holcomb transformer, 1- phase delayed	ok	ok	ok
80	Harper - Milan Tap - Clearwater, 3-phase	ok	ok	ok
81	Harper - Milan Tap - Clearwater, 1- phase delayed	ok	ok	ok
	N-1-1 and N-2, 3 phase fault with normal clearing			
11A	Prior outage of Clark Co - Thistle #1, fault on #2	unstable	unstable	unstable
11A _voltcont	Prior outage of Clark Co - Thistle #1, fault on #2 Trip some wind generation	Ok if trip 877 MW	Ok if trip 760 MW	Ok if trip 760 MW
11B	Prior outage of Thistle - Clark Co #1, fault on #2	unstable	unstable	unstable
11B _voltcont	Prior outage of Thistle - Clark Co #1, fault on #2 Trip some wind generation	Ok if trip 1637 MW	Ok if trip 1637 MW	Ok if trip 1637 MW
11C	Prior outage of some GBX wind generation and Clark Co - Thistle #1, fault on #2	Ok if trip 877 MW	Ok if trip 877 MW	Ok if trip 877 MW
11D	Clark Co - Thistle double circuit	unstable	unstable	unstable
11D _voltcont	Clark Co - Thistle double circuit Trip some wind generation	Ok if trip 877 MW	Ok if trip 877 MW	Ok if trip 877 MW
11E	Thistle - Clark Co double circuit	unstable	unstable	unstable
11E _voltcont	Thistle - Clark Co double circuit Trip some wind generation	Ok if trip 1637 MW	Ok if trip 1637 MW	Ok if trip 1637 MW
12A	Prior outage of Spearville - Clark Co #1, fault on #2	ok	ok	ok

No	Description	2017 LL	2017 SP	2022 SP
12B	Prior outage of Clark Co - Spearville #1, fault on #2	unstable	unstable	unstable
12B _voltcont	Prior outage of Clark Co - Spearville #1, fault on #2 Trip some wind generation	Ok if trip 877 MW	Ok if trip 877 MW	Ok if trip 877 MW
12C	Prior outage of some GBX wind generation and Clark Co - Spearville #1, fault on #2	Ok if trip 877 MW	Ok if trip 877 MW	Ok if trip 877 MW
12D	Clark Co - Spearville double circuit	unstable	unstable	unstable
12D _voltcont	Clark Co - Spearville double circuit Trip some wind generation	Ok if trip 877 MW	Ok if trip 877 MW	Ok if trip 877 MW
17A	Prior outage of Spearville - Holcomb, fault on Spearville - Post Rock	ok	ok	ok

4.2 Discussion of Notable Results

4.2.1 Faults near SPP Clark County 345 kV Station

All of the NERC Category B faults in SPP were stable. Some of the NERC Category C faults were unstable, including the N-1-1 (aka NERC Category C3) faults on the Clark Co. – Spearville 345 kV lines (FLT12A, FLT12B) and the Clark Co. – Thistle 345 kV lines (FLT11A, FLT11B). If one of the lines is out of service and the parallel line has a fault, the GBX wind generators trip on over-frequency (see plot of FLT11A in Figure 4-1). To fix this problem, the PTI report proposes tripping some of the wind generation (760-877 MW) at the same time as the faulted line. This solution is confirmed to work and allows the remaining GBX wind generation to stay on-line and stable (Figure 4-2). However, generation tripping will require a Special Protection System (SPS) that may not be acceptable to SPP or the transmission owner.

Another option is to reduce wind generation after the first contingency occurs but before the second contingency. This option was tested in PSS/E as FLT11C and FLT12C, and the results were stable but without the need for an SPS (Figure 4-3).

If the parallel Clark Co. – Spearville 345 kV lines share towers, or if the parallel Clark Co. – Thistle 345 kV lines share towers, then NERC Category C5 will have to be considered as well. In this case, there is no option to reduce wind generation and HVDC schedule between the two line trips. Consideration of Category C5 would bring back the need for post-fault generation tripping. Simulations were run (FLT11D, FLT11E, and FLT12D) that demonstrated the generation tripping solution works for the N-2 contingencies just as well as for the N-1-1 contingencies. However, if an SPS is not acceptable to SPP, then a new transmission line or other major upgrade may be needed.

The original study did not simulate the fault at Thistle for the N-1-1 outage of the Clark Co. – Thistle 345 kV lines. When that fault was tested in this study (FLT11B), more generation tripping was required than for the other faults – 1637 MW. Since a fault can occur anywhere along a line, the largest amount of tripping found while testing faults at both ends will need to be used.

In the original simulations, the HVDC power schedule did not always follow the over-frequency tripping of GBX wind generation. In the actual equipment, HVDC power will need to follow the wind power, at least in the steady state, if not faster. One possibility is for the HVDC control system to continually adjust its power schedule to maintain zero flow on the lines connecting to SPP. This could include active power flow, reactive power flow, or both. The speed of this control will have to be agreed to by Clean Line, SPP, and the local transmission utility. A faster control will reduce inadvertent flows and impacts on the SPP system.

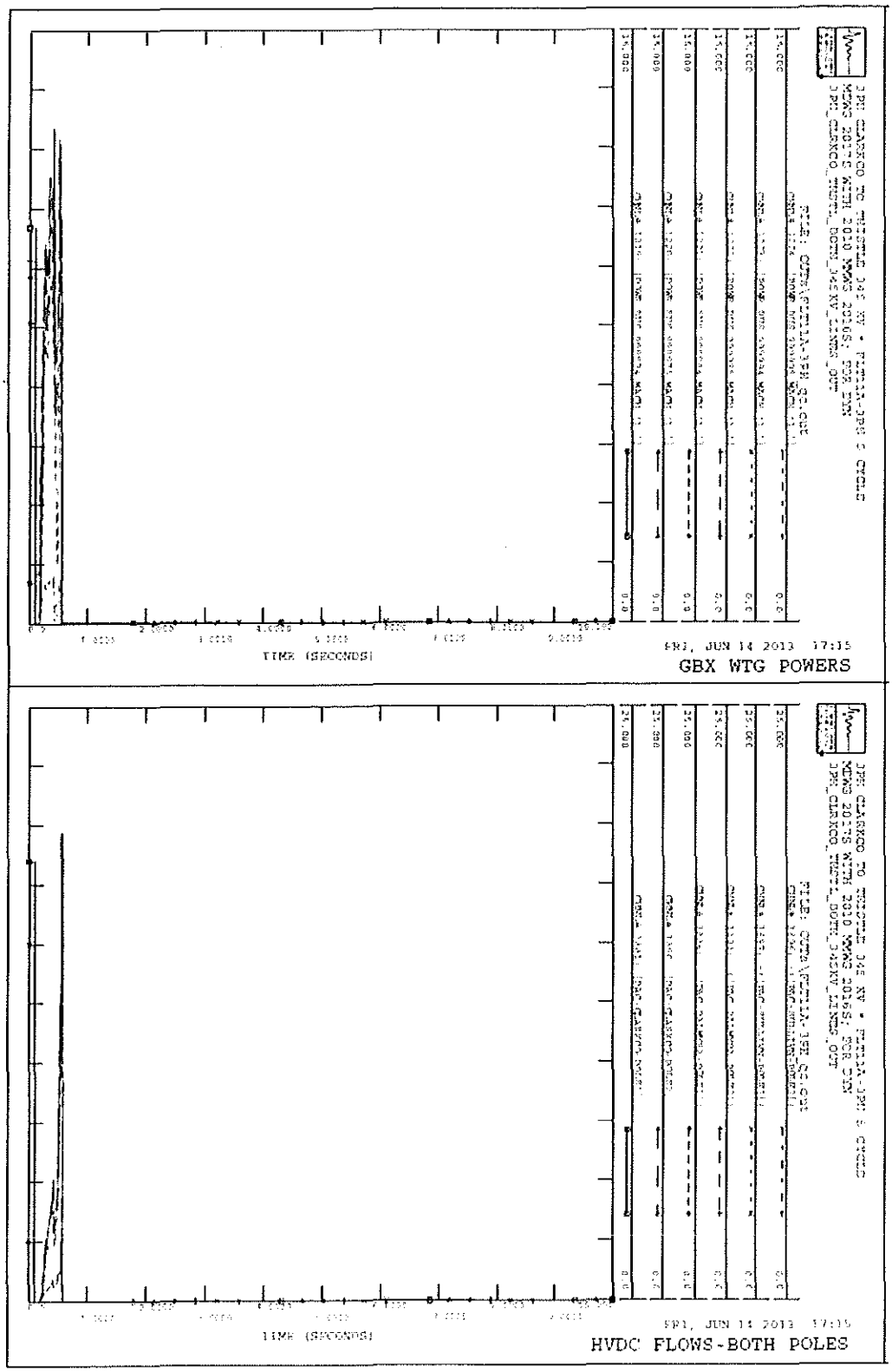


Figure 4-1. Wind and HVDC Powers for FLT11A, 3ph fault on Clark Co – Thistle 345 #1 with prior outage of #2

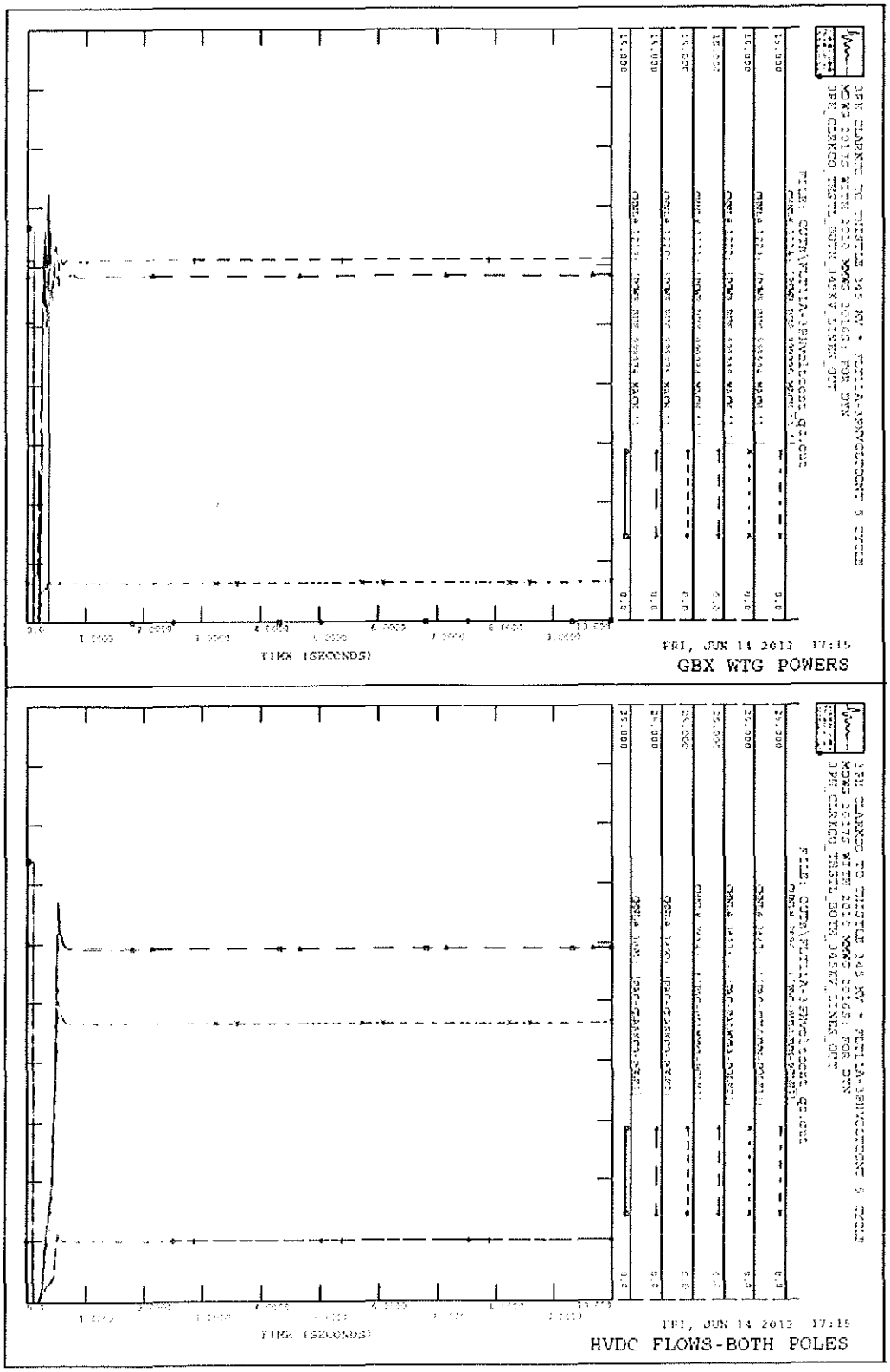


Figure 4-2. Wind and HVDC Powers for FLT11A_voltcont, 3ph fault on Clark Co – Thistle 345 #1 with prior outage of #2, trip some wind generation post-fault

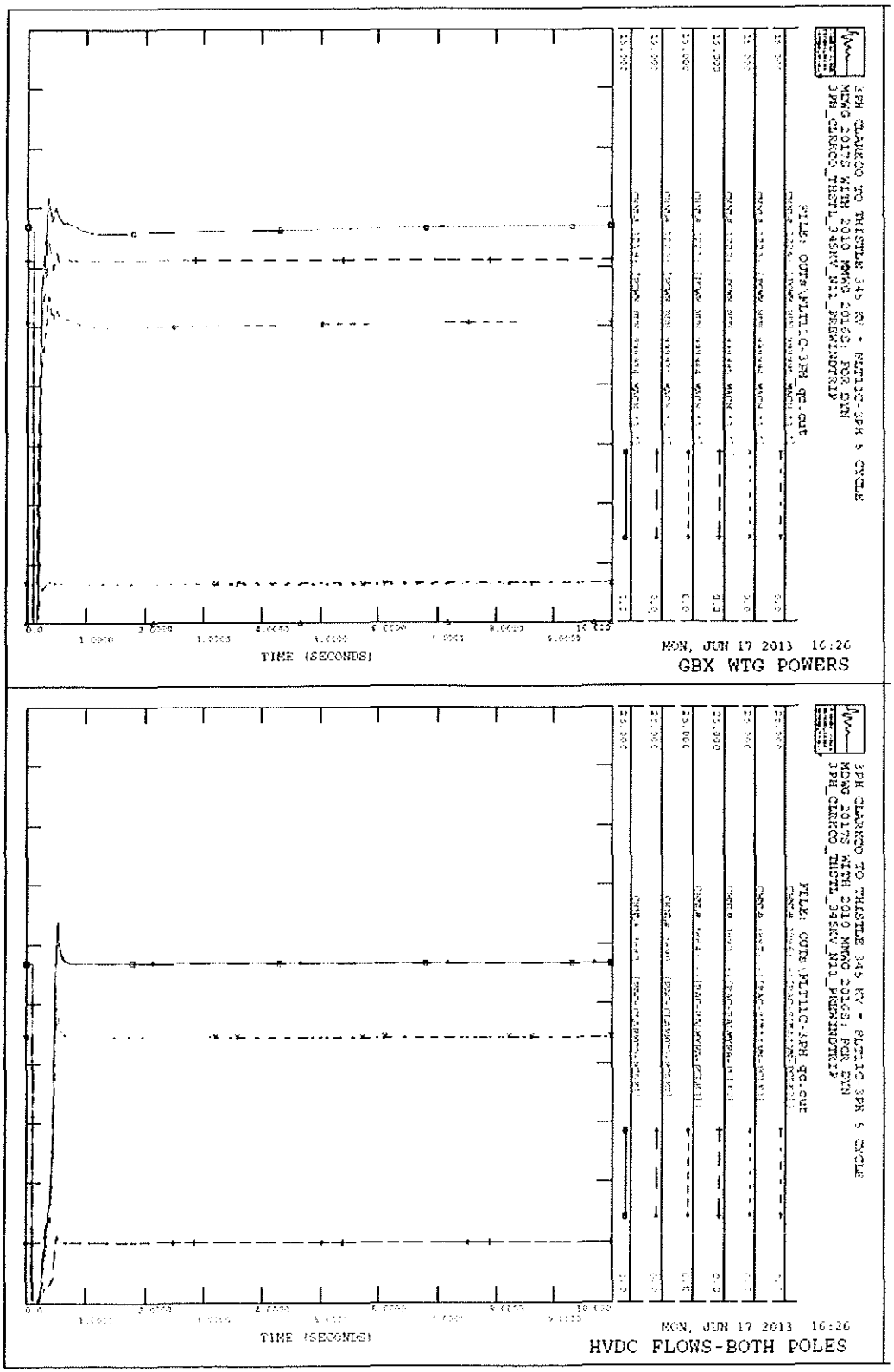


Figure 4-3. Wind and HVDC Powers for FLT11C, 3ph fault on Clark Co – Thistle 345 #1 with prior outage of #2, trip some wind generation PRE-fault

4.2.2 Faults near SPP Clark County 345 kV Station – New POI

The GBX project developer notified SPP of a desire to change the POI to a point 14 miles from Clark Co on the 345 kV lines to Spearville. Section 4.2.1 showed that the critical faults in SPP are the N-1-1 and N-2 faults around the POI. The critical faults were updated and repeated for the new POI location. Faults that were previously simulated at Clark Co, which was the POI for the initial analysis, were moved to the new GBX POI. Faults at Spearville and Thistle were left at those buses. Results are summarized in Table 4-2.

Most of the results are the same as with the previous POI. The most notable difference is that faults 11A and 11D are stable **in the 2017SP case** with the new POI (but still unstable in the 2017LL and 2022SP cases). Losing the lines toward Thistle may not be quite as severe now that the POI is closer to Spearville. However, while the fault 11A and 11D results are officially stable in the 2017SP case, they are not acceptable. After fault clearing, transmission voltage dips as low as 45% at the Post Rock 345 kV bus (Figure 4-4). The solution to trip up to 877 MW of wind generation following faults 11A and 11D continues to work for the new POI, providing both stability and keeping post-fault voltages above 70% (Figure 4-5).

These results match the results shown in PTI's August 13-14 power point slides, for the same faults. As with the original POI, PTI's slides do not discuss faults at the Thistle end of the Clark Co – Thistle 345 kV lines. In this study, these Thistle faults are shown to require the largest amounts of GBX wind tripping.

Table 4-2. Summary of Stability Results for new POI

No	Description	2017 LL	2017 SP	2022 SP
	N-1-1 and N-2, 3 phase fault with normal clearing			
11A	Prior outage of GBX POI - Clark Co #1, fault on #2	unstable	severe voltage dip	unstable
11A _voltcont	Prior outage of GBX POI - Clark Co #1, fault on #2 Trip some wind generation	Ok if trip 877 MW	Ok if trip 760 MW	Ok if trip 760 MW
11B	Prior outage of Thistle - Clark Co #1, fault on #2	unstable	unstable	unstable
11B _voltcont	Prior outage of Thistle - Clark Co #1, fault on #2 Trip some wind generation	Ok if trip 1637 MW	Ok if trip 1637 MW	Ok if trip 1637 MW
11C	Prior outage of some GBX wind generation and GBX POI - Clark Co #1, fault on #2	Ok if trip 877 MW	Ok if trip 877 MW	Ok if trip 877 MW
11D	GBX POI - Clark Co double circuit	unstable	severe voltage dip	unstable
11D _voltcont	GBX POI - Clark Co double circuit Trip some wind generation	Ok if trip 877 MW	Ok if trip 877 MW	Ok if trip 877 MW
11E	Thistle - Clark Co double circuit	unstable	unstable	unstable
11E _voltcont	Thistle - Clark Co double circuit Trip some wind generation	Ok if trip 1637 MW	Ok if trip 1637 MW	Ok if trip 1637 MW
12A	Prior outage of Spearville - GBX POI #1, fault on #2	ok	ok	ok
12B	Prior outage of GBX POI - Spearville #1, fault on #2	unstable	unstable	unstable
12B _voltcont	Prior outage of GBX POI - Spearville #1, fault on #2 Trip some wind generation	Ok if trip 877 MW	Ok if trip 877 MW	Ok if trip 877 MW
12C	Prior outage of some GBX wind generation and GBX POI - Spearville #1, fault on #2	Ok if trip 877 MW	Ok if trip 877 MW	Ok if trip 877 MW
12D	GBX POI - Spearville double circuit	unstable	unstable	unstable
12D _voltcont	GBX POI - Spearville double circuit Trip some wind generation	Ok if trip 877 MW	Ok if trip 877 MW	Ok if trip 877 MW
17A	Prior outage of Spearville - Holcomb, fault on Spearville - Post Rock	ok	ok	ok

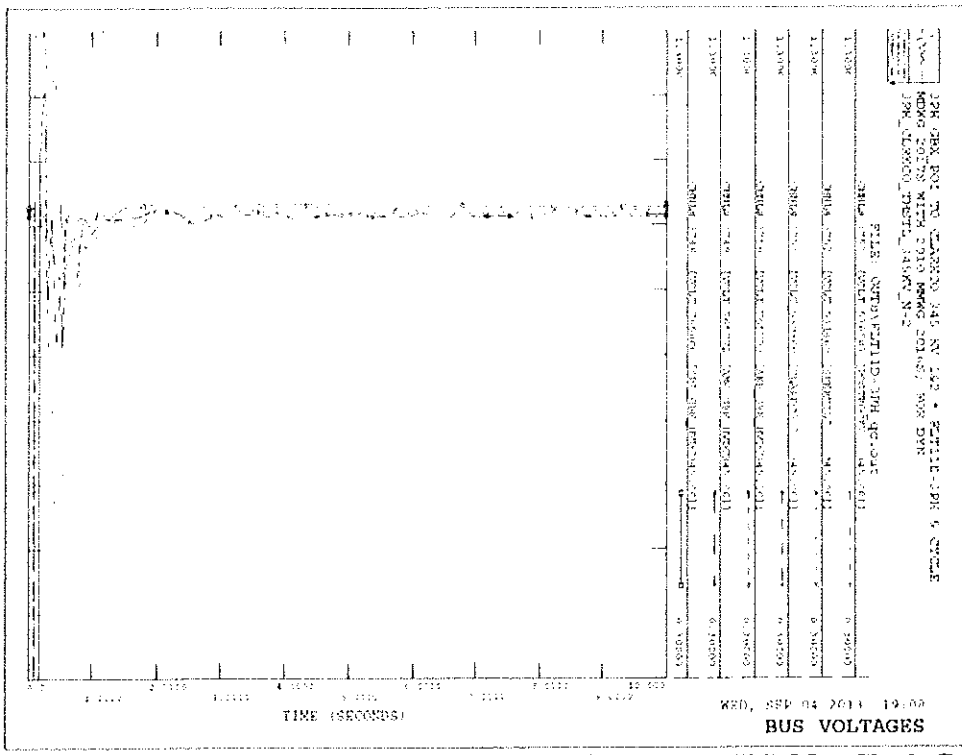


Figure 4-4. Transmission Voltages for FLT11D, 3ph fault on GBX POI – Clark Co 345 #1 and #2 double circuit

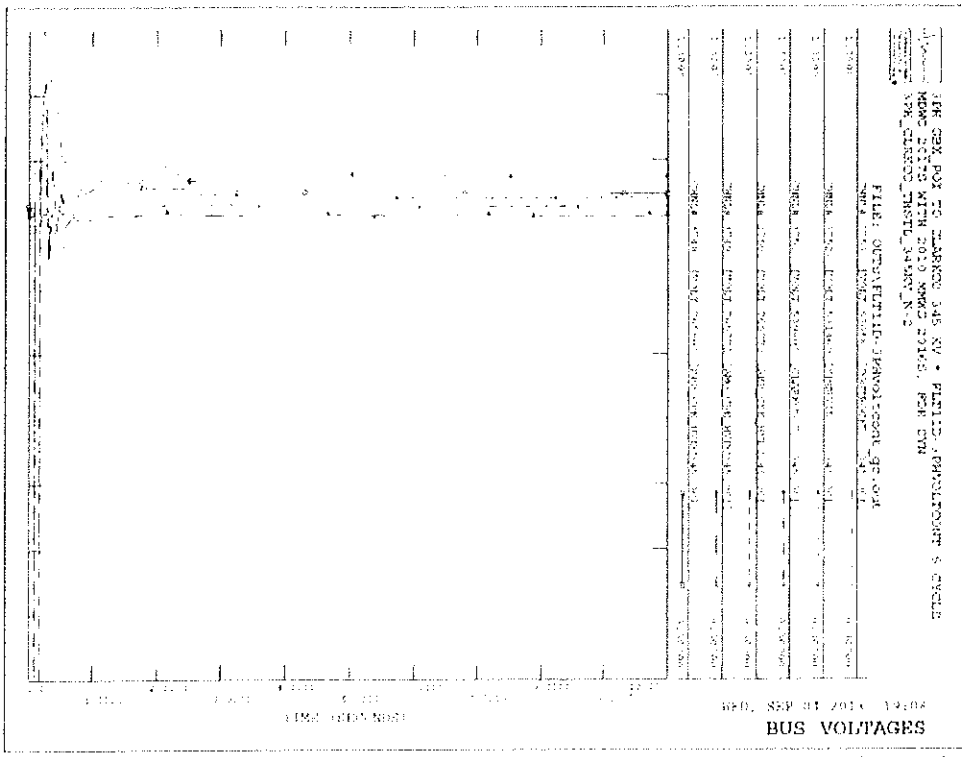


Figure 4-5. Transmission Voltages for FLT11D, 3ph fault on GBX POI – Clark Co 345 #1 and #2 double circuit, trip some wind generation post-fault

4.2.3 Faults near AEP Sullivan 765/345 kV Station

After most of this study work was complete, Clean Line notified SPP that the 765 kV connection option at the AEP Sullivan station should no longer be considered. The 345 kV connection at Sullivan is now the only option considered at the AEP end of the HVDC line. The following discussion applies to the Sullivan 345 kV connection.

The most severe fault near Sullivan was on the Rockport – Jefferson 765 kV line. Loss of this line results in all 2600 MW from the Rockport plant feeding into Sullivan 765 and Breed 345 stations, the same place where 3000 MW is injected from the GBX project. The Rockport generators go unstable and trip off-line in the 2017SP (Figure 4-6) and 2022SP cases. This problem did not show up in the 2017LL case because Rockport was dispatched at a lower level of 1760 MW.

When this contingency was tested in AC power flow on the 2017SP and 2022SP cases, the Newton solution algorithm diverged. Looking at the pre-contingency 2017SP base case with the GBX project, the Rockport – Jefferson 765 kV line is loaded to 3076 MW, beyond its surge impedance loading of 2270 MW. The line is consuming a total of 773 Mvar of reactive power (including 300 Mvar of line shunt reactors) and the Rockport generators are running at a high reactive power output.

The PTI report showed that reducing HVDC power injection at Sullivan to 1500 MW by tripping one pole following the Rockport – Jefferson 765 kV fault allowed the Rockport units to remain stable. This solution was confirmed in dynamics (Figure 4-7) and was also stable in power flow. However, this solution would require an SPS that may not be allowed by AEP. If an SPS is not acceptable, then a major transmission upgrade, such as a new line, may be needed near Sullivan or Rockport, or the project size may need to be reduced.

The 3500 MW injection option at Sullivan was not studied. This scenario will need to be addressed if the project moves forward with its current design.

4.2.4 Faults near AMMO Palmyra Tap 345 kV Station

All faults near the AMMO Palmyra Tap station were stable. The GBX HVDC project only injects 500 MW at this 345 kV station that includes five (5) 345 kV transmission lines. Figure 4-8 shows example plots for a three-phase fault on the Palmyra Tap – Sub T 345 kV transmission line. Voltages are stable and the HVDC recovers to pre-contingency power flows.

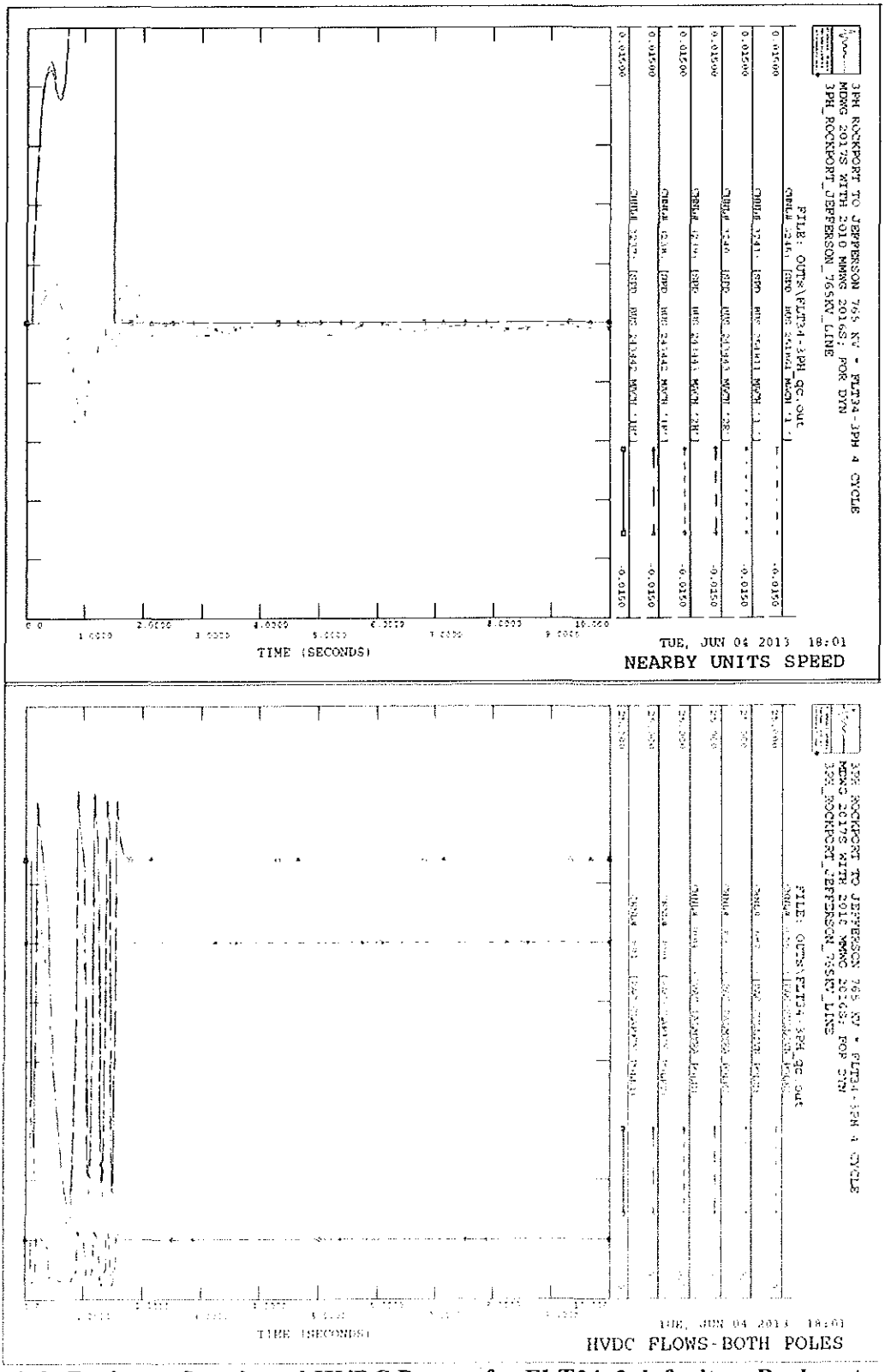


Figure 4-6. Rockport Speeds and HVDC Powers for FLT34, 3ph fault on Rockport – Jefferson 765

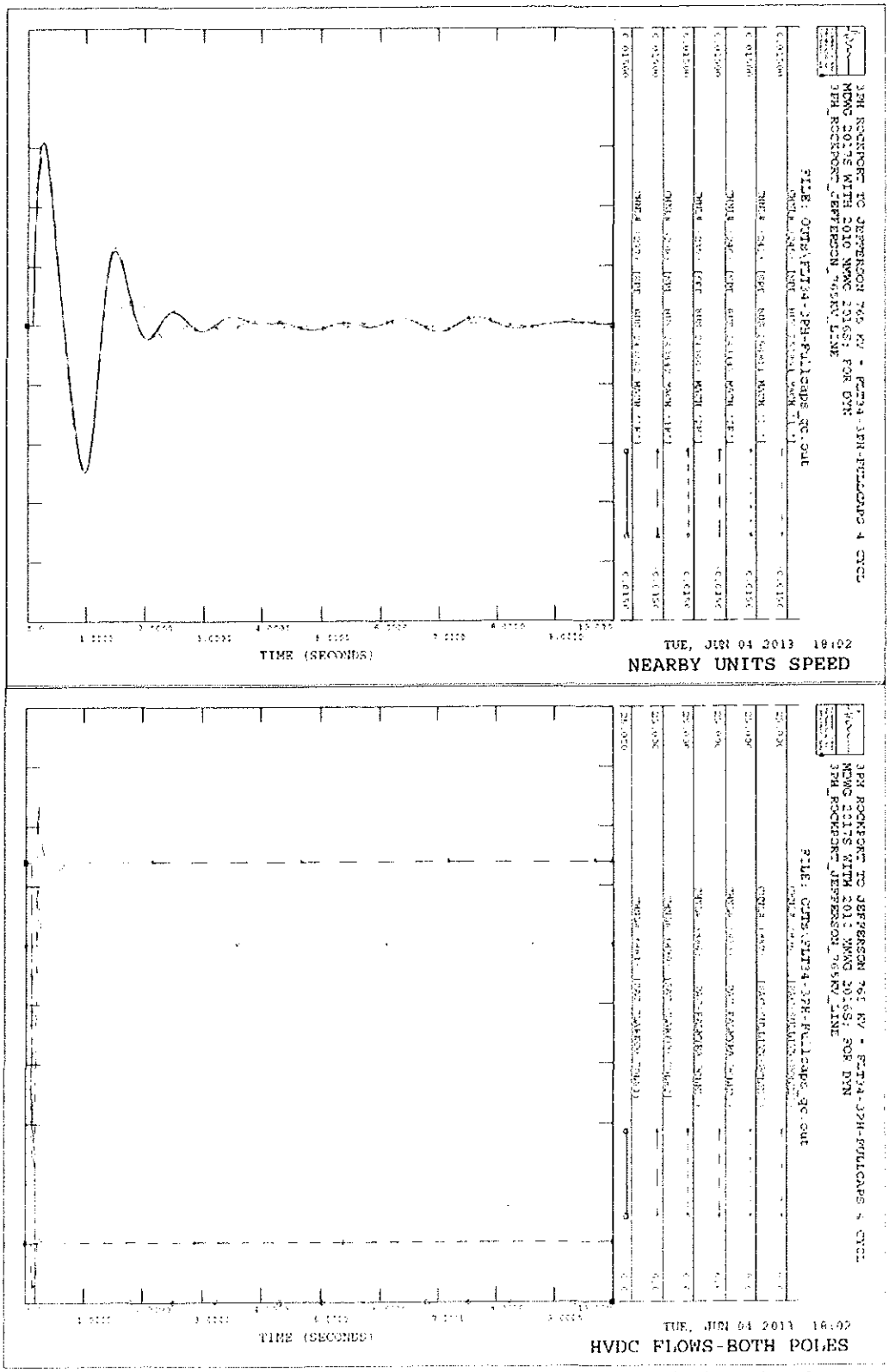


Figure 4-7. Rockport Speeds and HVDC Powers for FLT34, 3ph fault on Rockport – Jefferson 765, tripping one GBX HVDC pole post-fault

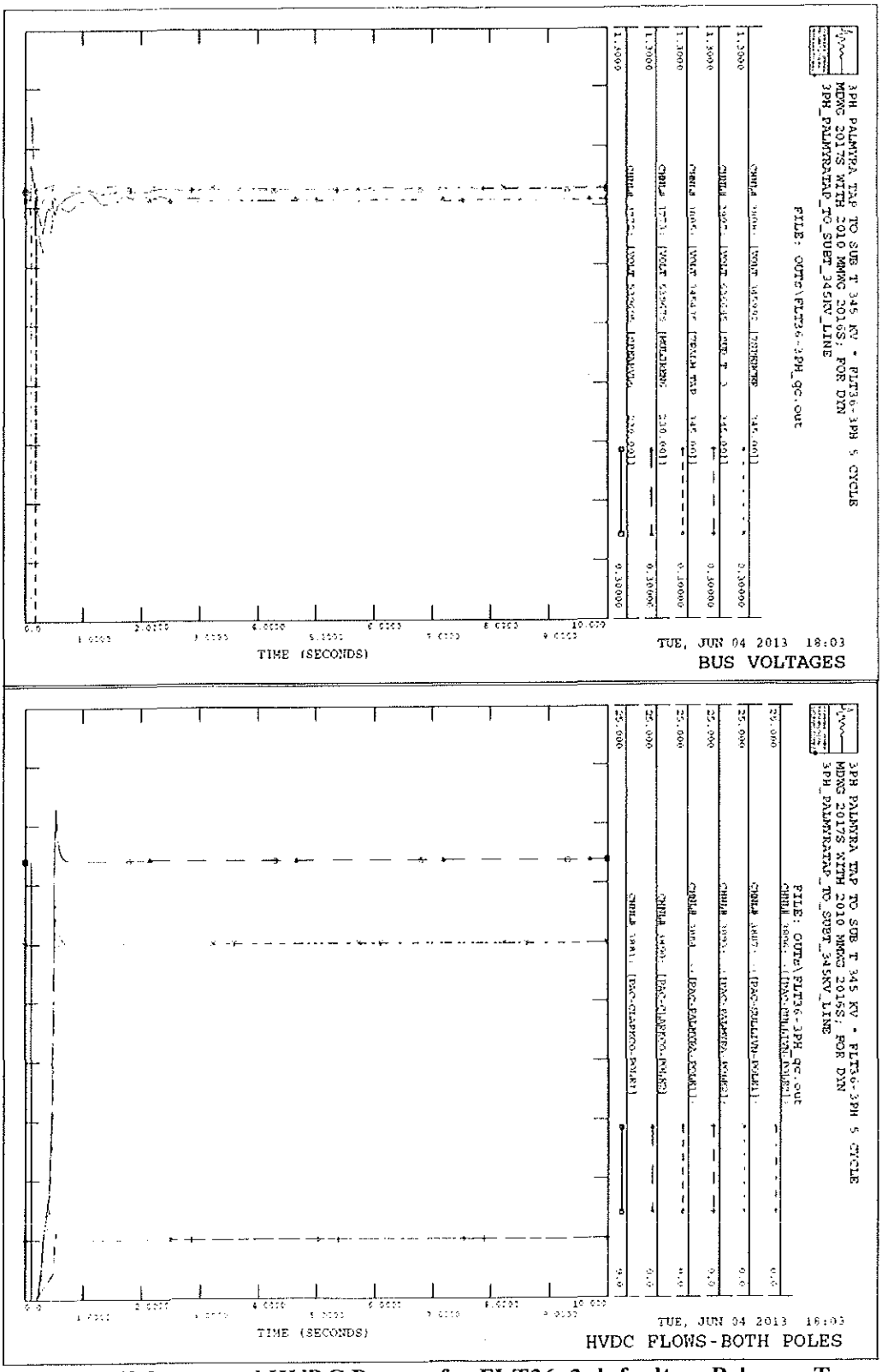


Figure 4-8. Bus Voltages and HVDC Powers for FLT36, 3ph fault on Palmyra Tap – Sub T 345

4.2.5 Both HVDC Poles Blocked

Of particular interest to the existing AC transmission owners and operators is what happens when both HVDC poles are lost. On the SPP side, this results in all GBX wind generation flowing into the SPP AC grid rather than the HVDC lines. The power then flows over the rest of the Eastern Interconnection AC grid to the MISO and PJM loads. The simulations show stable operation following loss of both HVDC poles (Figure 4-9). There is certainly significant power flow onto the SPP transmission network, but the AC grid is able to handle the flow in the short term. The GBX project will still need a control scheme that matches GBX wind generation and HVDC flow as quickly as feasible after an imbalance occurs.

Note however that most wind generation from the SPP interconnection queue is NOT present in the study cases. The current SPP queue contains hundreds of MW of wind plants that plan to connect at or near Clark Co, Spearville, and Thistle 345 kV stations. Stability results could change for the worse if SPP queue generation were included in the analysis.

For faults at the AEP Sullivan and AMMO Palmyra converters resulting in loss of both HVDC poles, simulation results were also stable (Figure 4-10, Figure 4-11).

4.2.6 Transient Voltage Review

After fault clearing, transmission voltages were checked to determine if they fell outside the SPP criteria of 70% to 120%. The previously-discussed unstable faults had many transient voltage violations and are not discussed further in this section.

For stable faults, there were frequent excursions above 120% in the time from fault clearing until the HVDC poles were ramped back up to full power. During this time, the HVDC capacitors were on line but the converters were consuming little to no reactive power. Among the initial fault runs, the highest voltage found was 134.5% at the AEP HVDC converter bus following a fault on the Sullivan-Rockport 765 kV line. The highest voltage seen at an existing bus was 128.7% at Breed 345 for the same fault. During the generation-tripping solutions for some of the N-1-1 faults, up to 136% voltage was seen near the AEP HVDC converter and up to 125.5% near the SPP converter bus.

The GBX project will need to control its reactive power sources and sinks to ensure acceptable voltages. For example, the capacitors can be taken off-line during severe faults that shut down the HVDC converters, and the capacitors can be brought back on in steps as HVDC power is ramped back up.

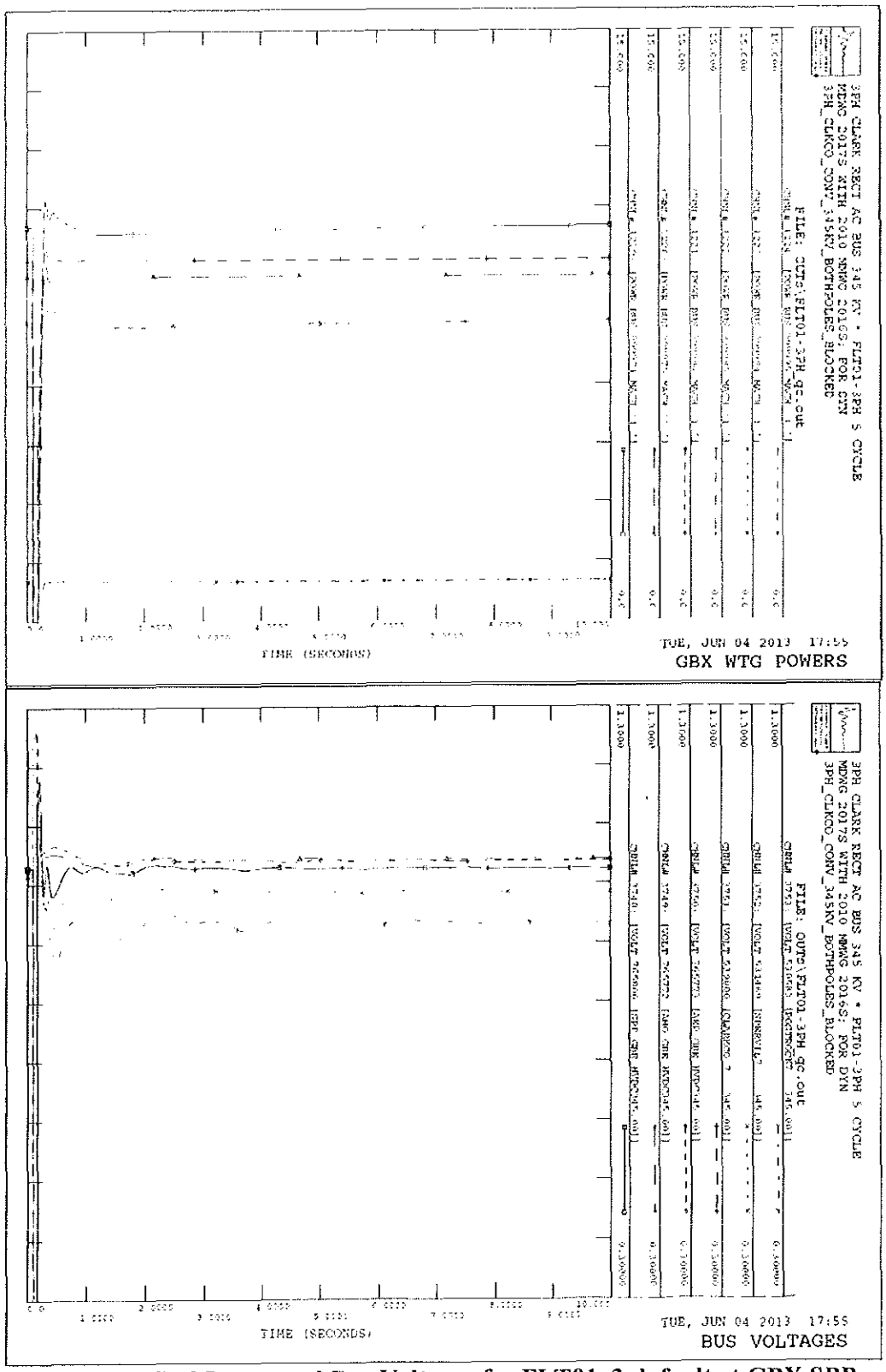


Figure 4-9. GBX Wind Power and Bus Voltages for FLT01, 3ph fault at GBX SPP converter AC bus, tripping both GBX HVDC poles

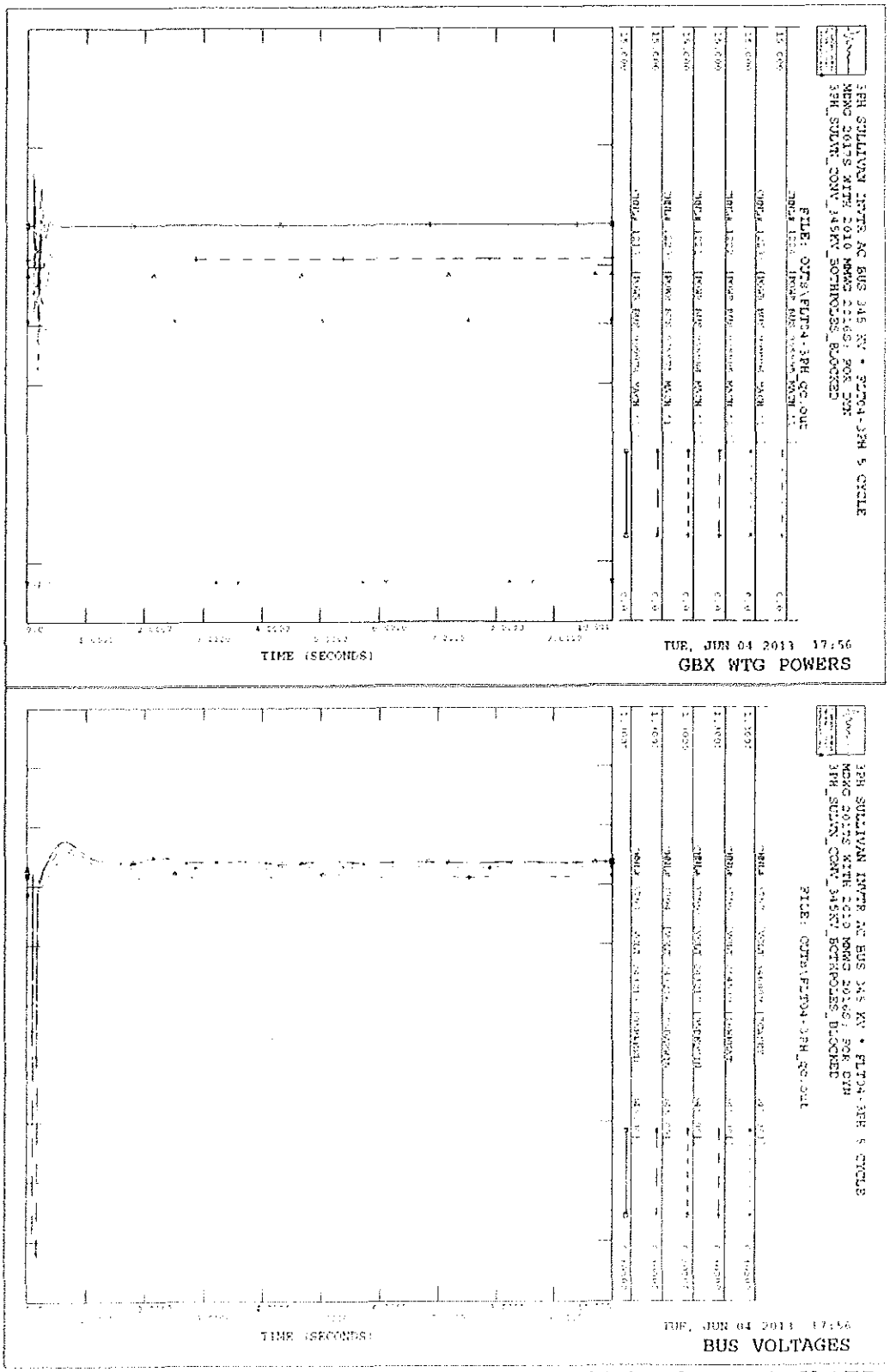


Figure 4-10. GBX Wind Power and Bus Voltages for FLT04, 3ph fault at GBX AEP converter AC bus, tripping both GBX HVDC poles

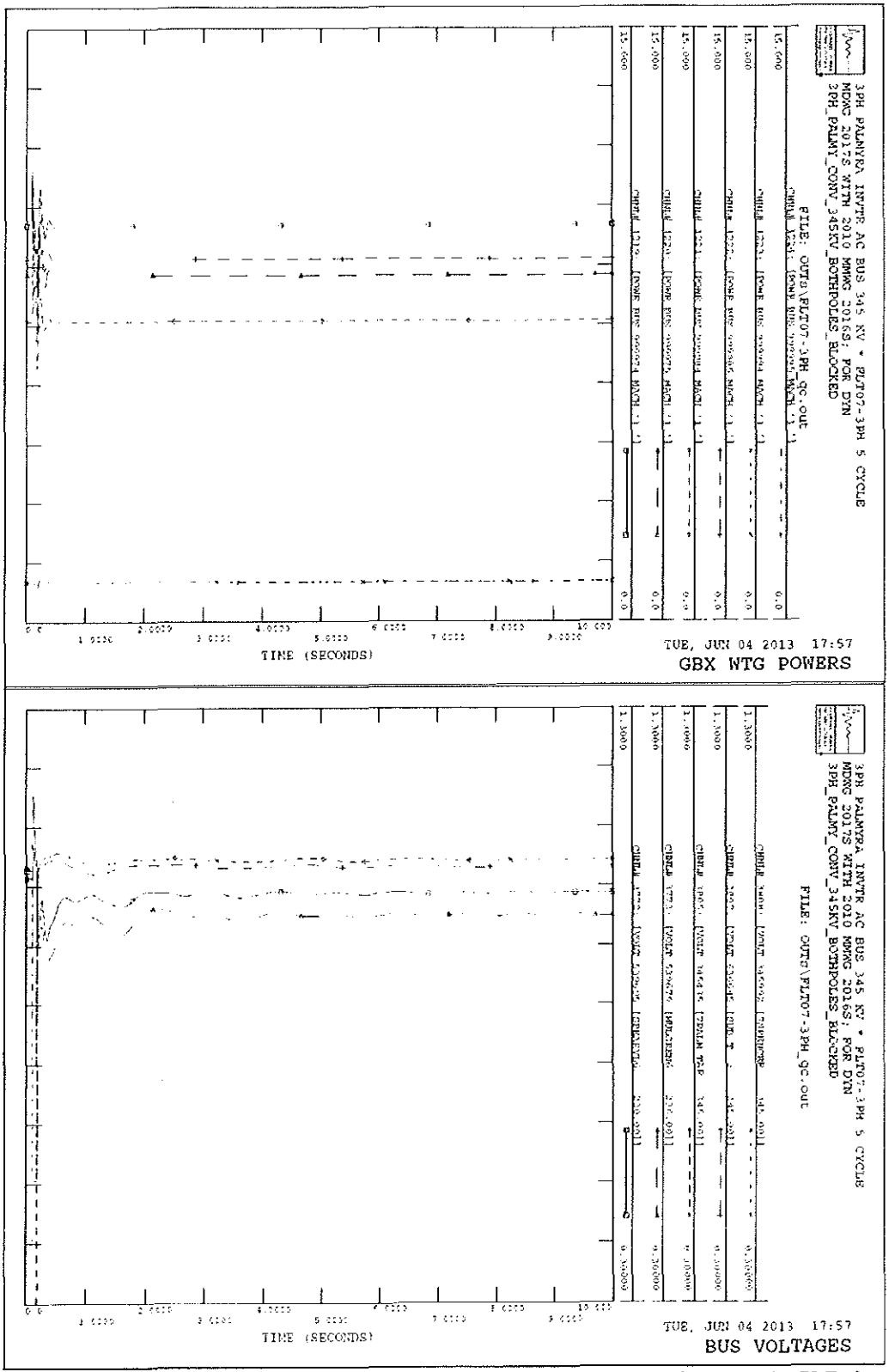


Figure 4-11. GBX Wind Power and Bus Voltages for FLT07, 3ph fault at GBX Palmyra converter AC bus, tripping both GBX HVDC poles

4.3 General Review of the Previous Report

Part of the scope of this project was to review the report created by the developer's consultant. The March 2013 report from Siemens PTI is well-written and describes the problems found and proposed solutions to fix those problems. A few comments on that report and study are as follows:

Conditions Analyzed

The analysis included three-phase faults with normal clearing and single-line-to-ground faults with delayed clearing. Most of the delayed clearing faults assumed protection system failure, so the fault took longer to clear but no additional branches were tripped. Only a few faults were analyzed with delayed clearing due to breaker failure. Future studies should examine more single-line-to-ground faults with breaker failure. Clark Co 345 would be especially interesting. Breaker configurations will need to be known or assumed.

The interconnection request states that 3500 MW may be injected at the AEP Sullivan converter, with the AMMO Palmyra Tap converter running at 0 MW. This operating state will need to be examined in a future study. It will certainly add further stress to the AEP transmission system near Sullivan.

Solutions Proposed

For the stability problems seen at the SPP and AEP ends of the project, the primary solutions involved tripping parts of the GBX project – wind generation and/or HVDC flow – following certain faults. These types of solutions are generally considered Special Protection Systems (SPS) and are not favored by some utilities. SPS's add more complexity and modes of failure to an already complex electric grid. Passive solutions such as new transmission lines or reduced project size may also need to be considered. The PTI report included a sensitivity test of reducing the project size by half. This option showed stable results without an SPS.

Wind Farm Design

The PTI report shows that tripping some of the wind generation can eliminate instability following some NERC Category C faults. While this amount was shown to work for the studied base cases, the project should be designed to be able to adjust this tripping amount easily as system conditions change. An alternative may be to state the maximum MW that can remain on-line following specific contingencies. Because wind generation is variable, this method may be easier to implement and could result in less tripping of wind generation.

Such a large amount wind generation (3700 MW) added to the power system needs to support grid frequency the same as any other large plant such as nuclear or coal-fired. Two important controls that are now available for wind turbines allow both inertia- and governor-like response from wind turbines. For the inertia response, the wind turbine controls take energy out of the spinning blades, slowing their speed, and inject that energy into the electric grid. This is similar

to the inertia response from synchronous generators, except that the wind turbine response is actively implemented by controls, as opposed to the natural response of synchronous generators.

For a governor-like control, the wind farm may not be able to ramp up power in response to low frequency (except for the short-term inertia response just discussed) because a wind farm typically runs at its maximum available output all the time. However, with the right controls, wind turbines can respond to high frequency by reducing power output. For a wind farm development as large as this project, it is especially important that the latest advanced controls be included to help support the electric power grid.

5. Conclusions

The results of the PTI report on the Grain Belt Express project have been confirmed by this study. The following mitigation options were confirmed to eliminate the unstable responses:

- A 900 Mvar Synchronous Condenser was assumed in all cases
- An SPS to reduce GBX wind generation following parallel circuit outages at Clark Co. Up to 1650 MW of wind generation tripping may be needed for certain double line outages.
- An SPS to reduce HVDC power following outage of the Rockport-Jefferson 765 kV line.

It will be critical for the GBX project to maintain a balance in both its MW flow and its Mvar flow. The project is designed to have a normal power exchange with SPP of 0 MW and 0 Mvar. This target also needs to be maintained during dynamic conditions as best as possible.

Additional considerations for futures studies of the GBX project include:

- Consideration of more breaker failure faults.
- Inclusion of other planned wind generation in the SPP footprint.
- Modeling the maximum 3500 MW HVDC injection at the AEP Sullivan end.
- If the SPS solutions are not acceptable, other solutions such as new transmission lines or reduced GBX project size will have to be found.

The results of this study depend on the assumed models for the HVDC equipment, wind generators, wind collector system, and the power systems in the area of the project. Some of these assumptions will surely change or come into better focus as the project moves forward. The stability analysis will need to be repeated when the assumptions are better defined.

STAFF RESPONSES TO
GRAIN BELT EXPRESS CLEAN LINE LLC'S FIRST SET OF
DATA REQUESTS DIRECTED TO STAFF WITNESS LANGE

For its First Set of Data Requests Directed to Staff of the Missouri Public Service Commission ("Staff"), Grain Belt Express Clean Line LLC ("Grain Belt Express" or "Company") states the following:

Definitions

1. The term "documents" includes all of the items listed in Missouri Rule of Civil Procedure 58.01(a)(1).

2. The term "Grain Belt Express Project" or "Project" means the transmission line and associated facilities described in Paragraph 14 of the Application in this proceeding.

Data Requests

1) Mr. Lange discusses conclusions within the PJM SIS report with reference to footnotes 83 and 84 on page 54 of Staff's testimony. On page 15 of this study report there is a one-line diagram. How many autotransformers are identified in the one-line diagram between the 765kV Sullivan and 345kV Breed buses?

STAFF RESPONSE: There are two transformers in the one-line diagram on page 15 of the PJM SIS report.

Provided by Staff Witness Shawn Lange

2) Please explain Mr. Lange's understanding of the withdrawal process and rules of interconnection in PJM.

a. What are the implication of withdrawal of a queue position in the PJM interconnection queue on queue positions that are behind the withdrawing interconnection queue position?

STAFF RESPONSE: The impact of a withdrawal of a queue position on a project whose queue position is lower is that the analysis of the later queue position projects may include impacts of the withdrawal project.

Provided by Staff Witness Shawn Lange

3) Is Mr. Lange aware of any queue positions identified in the PJM SIS report which are no longer in an active status within the PJM interconnection queue?

STAFF RESPONSE: No, but the only "queue position" identified in the PJM SIS report is for the GrainBelt X3-028 project.

Provided by Staff Witness Shawn Lange

4) Is Mr. Lange aware of the Coleman-Duff-Rockport 345 kV transmission line project?

STAFF RESPONSE: Yes.

Provided by Staff Witness Shawn Lange

5) Based on Staff's review of Dr. Galli's direct testimony, what is Mr. Lange's understanding with respect to the number of autotransformers that will exist between the 345 kV and 765 kV systems at the Breed/Sullivan substation in Indiana?

STAFF RESPONSE: It is unclear in Dr. Galli's direct testimony how many transformers are autotransformers.

"The Sullivan substation includes equipment and buswork at both 345kV and 765kV with three 345/765kV transformers interconnecting the 345kV and 765kV networks." Galli Direct Pg. 23 lines 14-16

"The Sullivan substation in Indiana will provide direct access to the 765kV network in PJM via three 345/765 kV transformers" Galli Direct Pg. 7 lines 1-2

Provided by Staff Witness Shawn Lange

6) Mr. Lange discusses conclusions within the SPP SIS report with reference to footnote 87 on page 56 of Staff's testimony. On page 10 of this study report there is a one-line diagram:

a. How many autotransformers are identified in the one-line diagram between the 765kV Sullivan and 345kV Breed buses?

STAFF RESPONSE: Two.

Provided by Staff Witness Shawn Lange

b. Is there a transmission line depicted between the 765kV Sullivan bus and the Reynolds 765kV bus?

STAFF RESPONSE: No.

Provided by Staff Witness Shawn Lange

c. Would Mr. Lange consider a ~100 mile, 765kV transmission line to be "a major transmission upgrade"?

STAFF RESPONSE: It depends on the network prior to and after the existence or the plan to be in existence of a "~100 mile, 765kV transmission line." A "~100 mile, 765kV transmission line" does not specify whether it is a general or a specific "~100 mile, 765kV transmission line" or give details of transmission network prior to and after the "~100 mile, 765kV transmission line" existed or planned to be in existence.

Provided by Staff Witness Shawn Lange

7) Please explain Mr. Lange's understanding of what a transmission system congestion issue represents. Specifically, when there's congestion in a transmission network:

a. What is the cause of that congestion?

STAFF RESPONSE: In general transmission system congestion is caused by transmission limitations imposed on the system, and/or changes in the load or generation at one or more points in the system. These limitations may include, but not limited to, lack of transmission capacity or transmission rating limitations in certain areas due to possible overloading of certain transmission equipment (transformers, substations, etc.).

Provided by Staff Witness Shawn Lange

b. How is it fixed?

STAFF RESPONSE: In general, transmission congestion is resolved by improving the transmission system. This may include, but not limited to, upgrading a transformer, substation, reconductoring a transmission line or possibly adding new transmission capacity in a region or area or a change in load in a region or area.

Provided by Staff Witness Shawn Lange

c. Why would someone want to fix it?

STAFF RESPONSE: In general resolving congestion improves the efficiency of the system overall and may now resolve issues including, but not limited to, dispatching units out of economic order.

Provided by Staff Witness Shawn Lange

8) Is the Audrain SPS, as discussed by Mr. Lange on page 56 of Staff's testimony, still active? If so, when will it no longer be active?

STAFF RESPONSE: It is Staff's understanding that the Multi-Value projects included in MISO's MTEP 11 would resolve the Audrain SPS if and/or when those projects are operational.

Provided by Staff Witness Shawn Lange

9) Is the Audrain SPS currently being modeled/studied in interconnection and other MTEP planning studies by the planning authorities in Missouri? If not, why not? If so, please provide evidence supporting this claim.

STAFF RESPONSE: It is Staff's understanding that the Audrain SPS is not being currently modeled/studied in other MTEP studies. However, the Palmyra substation issue does show up in LOLE modeling done by MISO.

It is Staff's understanding that all prior MTEP approved projects would be included in any studies, performed by MISO or on behalf of MISO, performed after that approved MTEP.

Provided by Staff Witness Shawn Lange

10) If Staff was to discover that for the 500 MW Missouri HVDC Converter Station of the Grain Belt Project, the short circuit ratio at the chosen point-of-interconnection is much higher than 2.0 (which Mr. Lange identified as being an indication of a "weak interconnection point"), would Staff's concerns on this topic be alleviated? If not, why not?

STAFF RESPONSE: Staff's concerns on the short circuit ratio topic would be alleviated if sufficient analysis was provided showing the short circuit ratio for the 500 MW Missouri HVDC converter station at the chosen point of interconnection was 2.0 or higher.

Provided by Staff Witness Shawn Lange

11) Regarding short circuit currents:

a. What is Mr. Lange's understanding of the contributors to short circuit currents in an AC power system?

STAFF RESPONSE: Generally speaking, short circuit currents arise out of the establishment of a low resistance or impedance connection between two points that bypass at least part of a circuit. Since current flows in the direction of least resistance, current will flow between the two points created. The capacity of the system and the duration of the short circuit will determine the consequences of the short circuit will have on the system. Adequate sizing and sequencing of protection devices such as circuit breakers and feeder protection relays, helps to limit damages to the AC system by detecting and removing them from the system as quickly as possible.

Provided by Staff Witness Shawn Lange

b. Does Mr. Lange agree that the short circuit ratio, as discussed on page 58 of Staff's testimony, is calculated as the ratio of the [AC] system short circuit level at the point-of-interconnection to the DC power of the converter station interconnected to that AC system? If not, why not?

STAFF RESPONSE: Yes

Provided by Staff Witness Shawn Lange

c. Does Mr. Lange agree that the denominator of the short circuit ratio for the Missouri Converter Station is the nameplate DC power level of 500 MW? If not, why not?

STAFF RESPONSE: Based on Staff's current understanding of the proposed project, yes.

Provided by Staff Witness Shawn Lange

d. Does the answer to a) suggest that a well-networked transmission system, such as the that near the point-of-interconnection of the Missouri HVDC Converter Station of the Project, would have a higher short circuit ratio, withrespect to the DC power level of the Missouri Converter Station, than a less networked transmission system's (such as southwestern Kansas) short circuit ratio with respect to the DC power level of the Kansas Converter Station? If not, why not?

STAFF RESPONSE: The answer to a) says nothing about the transmission system near the point-of-interconnection of the Missouri HVDC converter Station nor the level of network in southwestern Kansas. In general a well-networked transmission system would suggest a higher short circuit ratio than a less networked transmission system.

Provided by Staff Witness Shawn Lange

12) Regarding the topic of control interactions (CI) as it relates to HVDC converter stations impacts on other HVDC facilities, what is Mr. Lange's understanding of the mitigation measures that could be implemented in order to address such identified CI risks?

STAFF RESPONSE: "Commutation failure may occur both at the initiation of the fault and during recovery from fault. A commutation failure may also occur in one converter as a consequence of commutation failure at the other inverter station electrically close connected. Hence, the HVDC system might become more vulnerable to an ac disturbance when the inverters of several dc links are located in the same ac system with close proximity."

https://library.e.abb.com/public/b3b16a30843135a0c1256fda004aeaee/Aspects_Multiple_Infeed_HVDC_1.pdf

Mitigation techniques for dealing with commutation failures are:

"Temporary increase of inverter extinction angle by 10-12° before AC switching operations or immediately after fault inception.

Temporary increase of rectifier firing angle during disturbances on the rectifier network.

Voltage dependent current order limiter which reduces the DC current order, and hence the reactive power consumption upon reduction of the AC system voltage.

The use of fast acting reactive controllers such as synchronous condensers and static VAR compensators (SVCs) to help alleviate the risk of commutation failure."

Bayliss, Colin and Hardy, Brian (2012). Transmission and Distribution Electrical Engineering pg. 1049

13) Regarding the topic of control interactions (SSTI) as it relates to HVDC converter stations impacts on electrically nearby generator facilities, what is Mr. Lange's understanding of the mitigation measures that could be implemented in order to address such identified SSTI risks?

STAFF RESPONSE:

System Conditions where SSTI Occurs (As per Detailed Studies)	Mitigation/Protection Options
N-0	• Mitigation o Re-tune SSDC in HVDC control system o Install filters o Consideration of turbine-generation parameters during the design/procurement stage o Dynamic stabilizer control o Machine excitation system damping • Protection o Generator protection (TSRs), as an optional backup. This protection must be coordinated with the TFO protection scheme to avoid nuisance tripping and adverse system impacts.
N-1, N-2	• Mitigation o Remedial action scheme o Install filters o Re-tune SSDC in HVDC control system o Consideration of turbine-generation parameters during the design/procurement stage o Dynamic stabilizer control o Machine excitation system damping • Protection o Generator protection (TSRs), as optional for consideration. This protection must be coordinated with the TFO protection scheme to avoid nuisance tripping and adverse system impacts.
N-1-1, N-1-2, N-2-1, N-2-2 Above N-4	• Mitigation o Operational measures/awareness o Remedial action scheme o Install filters o Re-tune SSDC in HVDC control system o Consideration of turbine-generation parameters during design/procurement

	stage o Dynamic stabilizer control o Machine excitation system damping • Protection o Generator protection (TSRs), as optional for consideration. This protection must be coordinated with the TFO protection scheme to avoid nuisance tripping and adverse system impacts.

https://www.google.com/url?sa=t&rct=j&q=&esrc=s&source=web&cd=6&cad=rja&uact=8&ved=0ahUKEwj947eq1fvRAhVnxFQKHXjiBboQFggrMAU&url=https%3A%2F%2Fwww.aeso.ca%2Fassets%2FUploads%2Fprocess-for-SSTI-studies-and-mitigation-protection.docx&usg=AFQjCNET5kRjSzzjhXnbENSbOALEOTZCTQ&bvm=bv.146094739,d.amc

Provided by Staff Witness Shawn Lange

14) Regarding the topic of harmonic currents that are produced by HVDC converter stations, what is Mr. Lange's understanding of the mitigation measures that could be implemented in order to ensure compliance with harmonic performance requirements?

(SEE NEXT PAGE FOR STAFF RESPONSE)

STAFF RESPONSE:

5.3. Methods for Harmonic Mitigation

Majority of large power (typically three-phase) electrical nonlinear equipments often requires mitigation equipment in order to attenuate the harmonic currents and associated voltage distortion to within necessary limits. Depending on the type of solution desired, the mitigation may be supplied as an integral part of nonlinear equipment (e.g., an AC line reactor or a line harmonic filter for AC PWM drive) or as a discrete item of mitigation equipment (e.g., an active or passive filter connected to a switchboard). There are many ways to reduce harmonics, ranging from variable frequency drive designs to the addition of auxiliary equipment. Few of the most prevailing methods used today to reduce harmonics are explained below.

a) *Delta-Delta and Delta-Wye Transformers*

This configuration uses two separate utility feed transformers with equal non-linear loads. This shifts the phase relationship to various six-pulse converters through cancellation techniques. Similar technique is also used in 12-pulse front end of the drive, which is explained in the subsequent section of this document

b) *Isolation Transformers*

An isolation transformer provides a good solution in many cases to mitigate harmonics generated by nonlinear loads. The advantage is the potential to "voltage match" by stepping up or stepping down the system voltage, and by providing a neutral ground reference for nuisance ground faults. This is the best solution when utilizing AC or DC drives that use SCRs as bridge rectifiers.

c) *Use of Reactors*

Use of reactor is a simple and cost effective method to reduce the harmonics produced by nonlinear loads and is a better solution for harmonic reduction than an isolation transformer. Reactors or inductors are usually applied to individual loads such as variable speed drives and available in a standard impedance ranges such as 2%, 3%, 5% and 7.5%.

When the current through a reactor changes, a voltage is induced across its terminals in the opposite direction of the applied voltage which consequently opposes the rate of change of current. This induced voltage across the reactor terminals is represented by equation below.

(5.1) $$e = L\frac{di}{dt}$$

where:

e = Induced voltage across the reactor terminals

L = Inductance of the reactor, in Henrys

di/dt = Rate of change of current through reactor in Ampere/Second

This characteristic of a reactor is useful in limiting the harmonic currents produced by electrical variable speed drives and other nonlinear loads. In addition, the AC line reactor reduces the total harmonic voltage distortion (THD_v) on its line side as compared to that at the terminals of the drive or other nonlinear load.

In electrical variable speed drives, the reactors are frequently used in addition to the other harmonic mitigation methods. On AC drives, reactor can be used either on the AC line side (called AC line reactors) or in the DC link circuit (called DC link or DC bus reactor) or both, depending on the type of the drive design and/or necessary performance of the supply.

AC line reactor is used more commonly in the drive than the DC bus reactor, and in addition to reducing harmonic currents, it also provides surge suppression for the drive input rectifier. The disadvantage of use of reactor is a voltage drop at the terminals of the drive, approximately in proportion to the percentage reactance at the terminals of the drive.

In large drives, both AC line and DC bus reactors may be used especially when the short circuit capacity of a dedicated supply is relatively low compared to the drive kVA or if the supply susceptible to disturbances. Typical values of individual frequency and total harmonic distortion of the current waveform of a 6-pulse front end without & with integral line reactor are given in Table 5.1.

d) *Passive Harmonic Filters (or Line Harmonic Filters)*

Passive or Line harmonic filters (LHF) are also known as harmonic trap filters and are used to eliminate or control more dominant lower order harmonics specifically 5th, 7th, 11th and 13th. It can be either used as a standalone part integral to a large nonlinear load (such as a 6-pulse drive) or can be used for a multiple small single-phase nonlinear loads by connecting it to a switch board. LHF is comprised of a passive L-C circuit (and also frequently resistor R for damping) which is tuned to a specific harmonic frequency which needs to be mitigated (for example, 5th, 7th, 11th, 13th etc). Their operation relies on the "resonance phenomenon" which occurs due to variations in frequency in inductors and capacitors.

The resonant frequency for a series resonant circuit, and (in theory) for a parallel resonant circuit, can be given as:

$$f_r = \frac{1}{2\pi\sqrt{LC}} \qquad (5.3)$$

where:

f_r = Resonant frequency, Hz

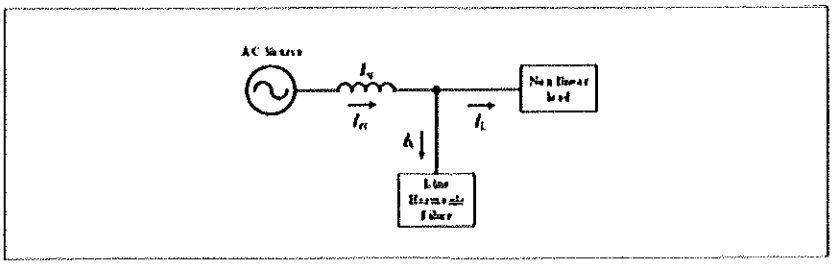
L = Filter inductance, Henrys,

C = Filter capacitance, Farads

The passive filters are usually connected in parallel with nonlinear load(s) as shown in Figure 5.1, and are "tuned" to offer very low impedance to the harmonic frequency to be mitigated. In practical application, above the 13th harmonic, their performance is poor, and therefore, they are rarely applied on higher-order harmonics.

Passive filters are susceptible to changes in source and load impedances. They attract harmonics from other sources (i.e. from downstream of the PCC), and therefore, this must be taken into account in their design. Harmonic and power system studies are usually undertaken to calculate their effectiveness and to explore possibility of resonance in a power system due to their proposed use. Typical values of individual frequency and total harmonic distortion of the current waveform of a 6-pulse front end with integral LHF are given in Table 5.1.

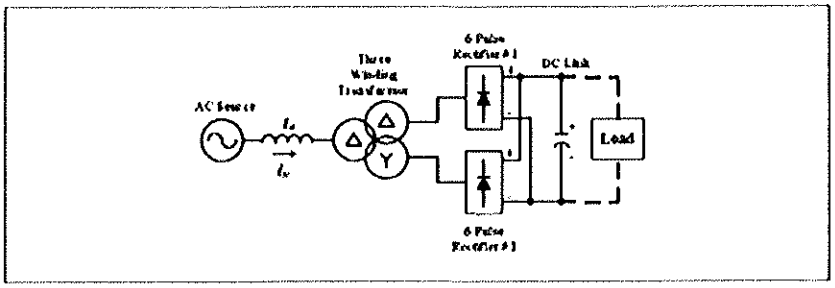
Figure 5.1
Typical connection of a passive harmonic filter



e) *12-pulse converter front end*

In this configuration, the front end of the bridge rectifier circuit uses twelve diodes instead of six. The advantages are the reduction of the 5th and 7th harmonics to a higher order where the 11th and 13th become the predominant harmonics. This will minimize the magnitude of these harmonics, but will not eliminate them.

Figure 5.2
Typical 12 pulse converter front end



The disadvantages are higher cost and special construction, as it requires either a Delta-Delta and Delta-Wye transformer, "Zig-Zag" transformer or an autotransformer to accomplish the 30° phase shifting necessary for the proper operation of 12-pulse configuration. This configuration also affects the overall drive system efficiency rating because of the voltage drop associated with the transformer/s. Figure 5.2 illustrates the typical elementary diagram for a 12-pulse converter front end. The DC sides of both 6-pulse bridge rectifiers are connected in parallel for higher current (Figure 5.2) and connected in series for higher voltage. Typical values of harmonic distortion of the current drawn by 12-pulse converter are given in Table 5.1.

f) *18-pulse converter front end*

An 18-pulse converter front end topology is comprised of either a three phase to nine phase isolation transformer or a lower cost patented design of three phase to nine phase autotransformer, to create a phase shift of ±20° necessary for the 18-pulse operation, and a nine phase diode rectifier containing 18 diodes (two per leg) to convert nine phase AC to DC. Figure 5.3 shows the block diagram of 18-pulse system. Similar to 12-pulse configuration, 18-pulse also has a disadvantages of higher cost & special construction.

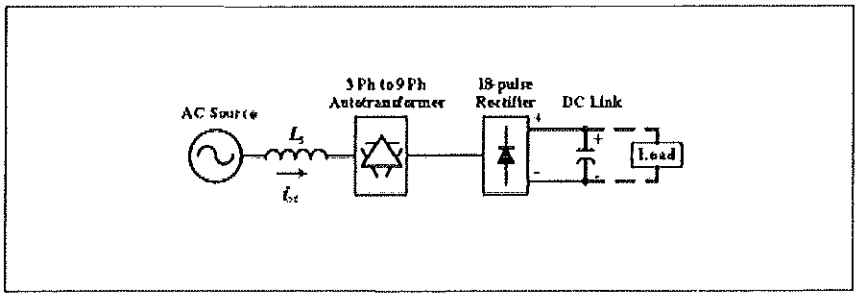


Figure 5.3
18 pulse converter front end

Nine-phase, 18-pulse converters not only have low harmonic distortion in the ac input current, but they also provide a smoother, higher average value of dc output. In addition, since the characteristic harmonics for 18-pulse configuration are $18n \pm 1$ (where n is an integer 1, 2, 3,...), it virtually eliminates the lower order non-characteristic harmonics (5th, 7th, 11th and 13th). A typical harmonic performance of 18-pulse configuration is shown in Table 5.1.

g) *Active filters*

Active filters are now relatively common in industrial applications for both harmonic mitigation and reactive power compensation (i.e., electronic power factor correction). Unlike passive L-C filters, active filters do not present potential resonance to the network and are unaffected to changes in source impedance. Shunt-connected active filters (i.e. parallel with the nonlinear load) as shown in Figure 5.4 below are the common configuration of the active filter. The active filter is comprised of the IGBT bridge and DC bus architecture similar to that seen in AC PWM drives. The DC bus is used as an energy storage unit.

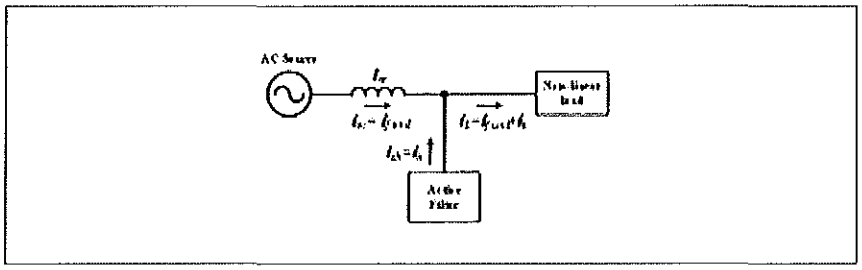


Figure 5.4
Typical connection of active filter

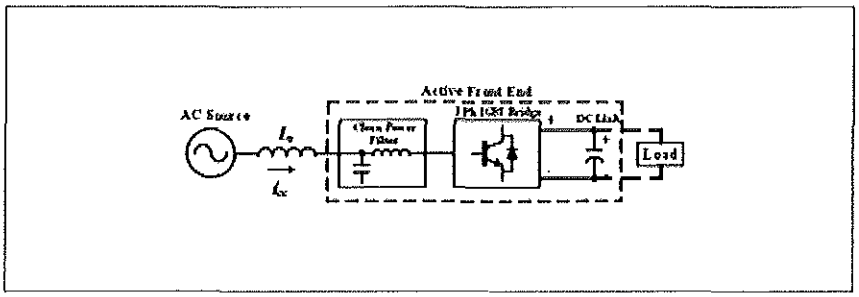
The active filter measures the "distortion current" wave shape by filtering out the fundamental current from the nonlinear load current waveform, which then fed to the controller to generate the corresponding IGBT firing patterns to replicate and amplify the "distortion current" and generate the "compensation current", which is injected into the load in anti-phase (i.e. 180° displayed) to compensate for the harmonic current. When rated correctly in terms of "harmonic compensation current", the active filter provides the nonlinear load with the harmonic current it needs to function while the source provides only the fundamental current.

Active filters are complex and expensive products. Also, careful commissioning of active filter is very important to obtain optimum performance, although "self tuning" models are now available. However, active filters do offer good performance in the reduction of harmonics and the control of power factor. Their use should be examined on a project-by-project basis, depending on the application criteria.

h) *Active front end*

"Active front ends" (AFE), also known as "sinusoidal input rectifiers", are offered by a number of AC drive and UPS system companies in order to offer a low input harmonic footprint. A typical configuration of the AC PWM drive with active front end is shown below in Figure 5.5.

Figure 5.5
Active Front End



As can be seen below, a normal 6-pulse diode front end is replaced by a fully controlled IGBT bridge, an identical configuration to the output inverter bridge. The DC bus and the IGBT output bridge architecture are similar to that in standard 6-pulse AC PWM drives with diode input bridges.

The operation of the input IGBT input bridge rectifier significantly reduces lower order harmonics compared to conventional AC PWM drives with 6-pulse diode bridges (<50th harmonic). However, as an inherent nature it introduces significant higher order harmonics, above the 50th. In addition, the action of IGBT switching introduces a pronounced "ripple" at carrier frequencies (~2-3 kHz) into the voltage waveform which must be attenuated by a combination of AC line reactors (which also serve as an energy store that allows the input IGBT rectifier to act as a boost regulator for the DC bus) and capacitors to form a passive (also known as clean power) filter. As compared to conventional 6-pulse AC PWM drives of same rating, AFE drives have significantly higher conducted and radiated EMI emissions, and therefore, special precautions and installation techniques may be necessary when applying them. AFE drives are inherently "four quadrant" (i.e. they can drive and brake in both directions of rotation with any excess kinetic energy during braking regenerated to the supply), offer high dynamic response and are relatively immune to voltage dips. The true power factor of AFE drive is high (approximately 0.98-1.0). The reactive current is usually controllable via the drive interface keypad.

i) *Power System Design*

Harmonics can be reduced by limiting the non-linear load to 30% of the maximum transformer's capacity. However, with power factor correction capacitors installed, resonating conditions can occur that could potentially limit the percentage of non-linear loads to 15% of the transformer's capacity. Use the following equation to determine if a resonant condition on the distribution could occur:

(5.1) $$h_r = \sqrt{\frac{kVA_{sc}}{kVAR_c}}$$

https://www.industry.usa.siemens.com/drives/us/en/electric-drives/ac-drives/Documents/DRV-WP-drive_harmonics_in_power_systems.pdf

Provided by Staff Witness Shawn Lange

15) Is Mr. Lange aware of any electric generating or transmission facilities which are owned and/or operated by entities regulated by the Electric Reliability Organization (ERO) Enterprise (i.e. NERC and the Regional Entities) which were not designed in accordance with IEEE, NESC, and/or IEC standards? If so, please explain.

STAFF RESPONSE: Staff witness Shawn Lange is not aware "of any electric generating or transmission facilities which are owned and/or operated by entities regulated by the Electric Reliability Organization (ERO) Enterprise (i.e. NERC and the Regional Entities) which were not designed in accordance with IEEE, NESC, and/or IEC standards".

Provided by Staff Witness Shawn Lange

16) Grain Belt Express intends to register with NERC in its various functions within the NERC Reliability Functional Model as outlined on page three (3) of Schedule AWG-4. Please provide an explanation as to why Mr. Lange believes that a NERC Reliability Functional Model entity would design equipment that is considered part of the Bulk Electric System without consideration of IEEE, NERC, and IEC standards.

STAFF RESPONSE: Staff witness Shawn Lange is not alleging that any or all "NERC Reliability Functional Model entity[sic] would design equipment that is considered part of the Bulk Electric System without consideration of IEEE, FERC, and IEC standards." Neither is Staff witness Shawn Lange alleging Grain Belt Express has not followed or taken into consideration IEEE, NERC, and IEC standards with the information that has been provided.

Staff witness Shawn Lange cannot predict all future business considerations that may be taken into account to cause a "NERC Reliability Functional Model entity would[sic] design equipment that is considered part of the Bulk Electric System without consideration of IEEE, FERC, and IEC standards."

Nor can Staff witness Shawn Lange predict all future business considerations that may cause an entity to change its intentions.

Provided by Staff Witness Shawn Lange

/s/ Karl Zobrist

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CERTIFICATE OF SERVICE

I certify that a copy of the foregoing Data Request was served upon the party to which it was directed by email or U.S. Mail, postage prepaid, this ___3rd__ day of February, 2017.

/s/ Karl Zobrist

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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, Operate, Control, Manage and Maintain a High Voltage, Direct Current Transmission Line and an Associated Converter Station Providing an Interconnection on the Maywood-Montgomery 345kV transmission line.	)	Case No. EA-2016-0358

STAFF RESPONSES TO
GRAIN BELT EXPRESS CLEAN LINE LLC'S
FIRST SET OF DATA REQUESTS DIRECTED TO
STAFF WITNESS KLIETHERMES

For its First Set of Data Requests Directed to Staff of the Missouri Public Service Commission ("Staff"), Grain Belt Express Clean Line LLC ("Grain Belt Express" or "Company") states the following:

Definitions

1. The term "documents" includes all of the items listed in Missouri Rule of Civil Procedure 58.01(a)(1).

2. The term "Grain Belt Express Project" or "Project" means the transmission line and associated facilities described in Paragraph 14 of the Application in this proceeding.

Data Requests

1) In reference to page 39 of Staff's testimony where Ms. Kliethermes writes "...each converter station is in effect a new seam, not a resolution of an existing seam." Please provide any references to testimony or data request responses from any Grain Belt witness, including Ms. Kelly, asserting that the Grain Belt Project is resolving an existing seam.

STAFF RESPONSE: The "Application of Grain Belt Express Clean Line LLC for A Certificate of Convenience and Necessity", verified by the affidavit of Michael P. Skelly, at page 22, states that "Suedeen Kelly: Ms. Kelly is a former Chair of the New Mexico Public Service Commission and a former FERC Commissioner. She explains why a participant-funded business model, like the Project, is a market-driven solution to transmission expansion. She reviews the facts demonstrating that there is a need for the Project, why it is economically feasible and in the public interest, and discusses why the Project fulfills the goals of FERC Order 1000 that encourages interregional transmission projects and the resolution of inter-RTO seams issues."

Staff does not allege that Ms. Kelly asserts that the Grain Belt Project is resolving an existing seam. Staff indicates that Ms. Kelly's testimony is unproductively confusing on introducing the concepts of (1) "a limited number of transmission connections across a seam boundary" and (2) Missouri's investigation *In the Matter of an Investigation Into the Possible Methods Mitigating Identified Harmful Effects of Entergy Joining MISO on non-MISO Missouri Utilities and Their Ratepayers and Maximizing the Benefits For Missouri Utilities and Ratepayers Along RTO and Cooperative Seams*, File No. EW-2014-0156, as apparently intended as factual support for her conclusions at page 32 that "The Project's participant-funded business model protects Missouri's captive electric customers from the costs and risks inherent in traditional, rate-based transmission;" and "The Project meets the clear need for interregional transmission—and provides the multiple benefits of interregional transmission--while avoiding the contentious and problematic cost allocation processes across multiple RTOs;" See testimony at Page 15 – 16, Ms. Kelly stating:

14 Q. What happens at the boundaries between regions?
15 A. When the boundary of one regional transmission system abuts the boundary of another
16 regional transmission system, this is called a "seam." Because there are usually a limited
17 number of transmission connections across a seam boundary, regional seams can create
18 congestion, limit the efficient use of electric infrastructure near the seam boundary, and cut
19 off LSEs from cost-effective generation resources, even those located geographically
20 nearby, but on the other side of the seam. Additionally, transmitting energy across seams
21 usually results in additive transmission costs, i.e. rate pancaking, where the transmission
1 customer pays the postage stamp rate for both regions. As the Commission is aware, the
2 presence of multiple transmission seams within Missouri has resulted in increased costs to
3 consumers.[32]

[32] See e.g., In the Matter of an Investigation Into the Possible Methods Mitigating Identified Harmful Effects of Entergy Joining MISO on non-MISO Missouri Utilities and Their Ratepayers and Maximizing the Benefits For Missouri Utilities and Ratepayers Along RTO and Cooperative Seams, File No. EW-2014-0156, Order Opening a Case to Investigate Methods of Eliminating or Mitigating the Negative Effects of the MISO/SPP Seam (Mo. P.S.C. Nov. 26, 2013).

Response provided by Staff Witness Sarah Lliethermes.

2) In reference to page 39 of Staff's testimony where Ms. Kliethermes writes "…each converter station is a discrete source or sink, and it is Staff's understanding that Grain Belt will restrict the free flow of energy through each converter station."

a. Please provide as many references to testimony or data request responses from any Grain Belt witness, including Ms. Kelly, describing the converter stations as discrete sources or sinks.

STAFF RESPONSE: This question is not grammatically sound and is confusing. Staff does not allege that Ms. Kelly generally acknowledges the converter stations as discreet sources or sinks. However, at one location, at pages 18 – 19, Ms. Kelly does acknowledge that "Direct current lines are particularly valuable during transmission outages, as converters control the flow of power over the line."

Response Provided By Staff Witness Sarah Kliethermes.

b. ~~Does Staff's statement that each converter station is a "discrete source or sink" align with the discussion found Section V of the direct testimony of Grain Belt Express witness Dr. Galli, Coordination, Dispatch, and Operation of the Project, related to scheduling power: from SPP to MISO and/or PJM (page 31), from the MISO or PJM to SPP (page 31-32), and from MISO to SPP and/or PJM (page 32)?~~

b. Staff makes a statement that each converter station is a "discrete source or sink". However, as discussed in Section V of the direct testimony of Grain Belt Express witness Dr. Galli, Coordination, Dispatch, and Operation of the Project, power can be scheduled from SPP to MISO and/or PJM (page 31), from the MISO or PJM to SPP (page 31-32), and from MISO to SPP and/or PJM (page 32) utilizing existing processes for request and procurement of transmission services for these interchange transactions. What does Staff mean by stating that each of the Project's converter stations is a "discrete source or sink"?

STAFF RESPONSE: Staff is referencing the fact that a given converter station cannot physically operate to both uptake and inject energy from an AC power system at the same time or switch between uptake and injection without some form of operator input. Staff is not speaking as to whether a given converter station can be switched to perform either function.

Response Provided By Staff Witness Sarah Kliethermes.

c. Does Staff believe that loop flows, which are a result of "the free flow of energy" are desirable? If not, why not? If so, why?

STAFF RESPONSE: Staff does not believe that loop flows are "desirable" as a goal of system design. Staff does believe that loop flows are preferable to system failure due to thermal overload of the segment bypassed by the loop flow.

Response Provided By Staff Witness Sarah Kliethermes

d. Is it Staff's understanding that the Grain Belt Project, which is utilizing HVDC technology – a completely controllable transmission solution – is capable of being operated in a manner that allows the "free flow of energy"? If so,

STAFF RESPONSE: No.

Response provided by Staff Witness Sarah Kliethermes.

i. How would operation of the Project to allow the "free flow of energy" be accomplished?

ii. Would the Project be able to remain a merchant project? If so, how would the Project determine who the shippers are that are utilizing the Project?

e. Does Staff believe that a transmission solution that allows the "free flow of energy" provides greater reliability benefits than one that can control exactly how much power is transmitted?

STAFF RESPONSE: Neither provides greater reliability benefits in the abstract. Staff's use of this term was not with reference to reliability, but rather with reference to Mr. Skelly's verified statement that Ms. Kelly's testimony would discuss the Project's fulfillment of "the resolution of inter-RTO seams issues" as stated in the Application he verified.

Response provided by Staff Witness Sarah Kliethermes.

3) With regard to page 39 of Staff's testimony, please identify the specific reference in Ms. Kelly's or any other Grain Belt witness's testimony and/or data request responses which states that the Grain Belt Project will "address the Missouri-specific seams issues concerning potentially uncompensated flows…".

STAFF RESPONSE: Staff indicates that Ms. Kelly's testimony (at page 15 line 14 through page 16 line 3, including footnote 32) is unproductively confusing on introducing the concept of Missouri's investigation *In the Matter of an Investigation Into the Possible Methods Mitigating Identified Harmful Effects of Entergy Joining MISO on non-MISO Missouri Utilities and Their Ratepayers and Maximizing the Benefits For Missouri Utilities and Ratepayers Along RTO and Cooperative Seams*, File No. EW-2014-0156, as apparently intended as factual support for her conclusions at page 32 that "The Project's participant-funded business model protects Missouri's captive electric customers from the costs and risks inherent in traditional, rate-based transmission;" and "The Project meets the clear need for interregional transmission—and provides the multiple benefits of interregional transmission--while avoiding the contentious and problematic cost allocation processes across multiple RTOs;"

The "Application of Grain Belt Express Clean Line LLC for A Certificate of Convenience and Necessity", verified by the affidavit of Michael P. Skelly, at page 22, states that "Suedeen Kelly: Ms. Kelly is a former Chair of the New Mexico Public Service Commission and a former FERC Commissioner. She explains why a participant-funded business model, like the Project, is a market-driven solution to transmission expansion. She reviews the facts demonstrating that there is a need for the Project, why it is economically feasible and in the public interest, and discusses why the Project fulfills the goals of FERC Order 1000 that encourages interregional transmission projects and the resolution of inter-RTO seams issues."

See testimony at Page 15 – 16, Ms. Kelly stating:

14 Q. What happens at the boundaries between regions?
15 A. When the boundary of one regional transmission system abuts the boundary of another
16 regional transmission system, this is called a "seam." Because there are usually a limited
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1 customer pays the postage stamp rate for both regions. As the Commission is aware, the
2 presence of multiple transmission seams within Missouri has resulted in increased costs to
3 consumers.[32]

[32] See e.g., In the Matter of an Investigation Into the Possible Methods Mitigating Identified Harmful Effects of Entergy Joining MISO on non-MISO Missouri Utilities and Their Ratepayers and Maximizing the Benefits For Missouri Utilities and Ratepayers Along RTO and Cooperative Seams, File No. EW-2014-0156, Order Opening a Case to Investigate Methods of Eliminating or

Mitigating the Negative Effects of the MISO/SPP Seam (Mo. P.S.C. Nov. 26, 2013).

Response provided by Staff Witness Sarah Kliethermes.

4) Please provide Staff's understanding of the in-service date of the most recent Extra High Voltage (i.e. voltage of 345 kV or higher) transmission line projects built from, into, or across Missouri between the following Transmission Providers:

a. SPP and AECI

b. SPP and MISO

c. MISO and AECI

d. SPP and SWPA

e. MISO and SWPA

f. SWPA and AECI

STAFF RESPONSE: This is not information that is readily available to Staff.

Response provided by Staff Witness Sarah Kliethermes.

5) Does Staff believe that there's a need for construction of new transmission interconnections/facilities between Transmission Providers that operate in Missouri? If not, why not? If so, why?

STAFF RESPONSE: Staff does not have an opinion.

Response provided by Staff Witness Sarah Kliethermes.

6) Does Staff believe that construction of new transmission interconnections/facilities between Transmission Providers that operate in Missouri involves a straightforward, defined process and is work ing to the benefit of Missouri customers? Why or why not?

STAFF RESPONSE: Staff does not have an opinion.

Response provided by Staff Witness Sarah Kliethermes.

7) On page 40 of Staff's testimony, Ms. Kliethermes states "These additional seams and the discrete interconnection of the Project exacerbates the issues…". What is meant by "the issues"? Specifically what issues are being referenced here?

STAFF RESPONSE: As stated at page 40, "the issues" refers to "the issues that Ms. Kelly appears to imply the Project would help to resolve at page 18 of her direct testimony, where she states; 'The ability of interregional transmission to import power from outside of a region also provides reliability benefits. In times of generation scarcity within a region, excess resources from another region can be imported using the interregional line. The availability of resources from outside a given region can also reduce the reserve margin necessary to ensure reliability for the region. Lowered reserve margins decrease consumer costs in the region, as ratepayers no longer have to support extra resources within the region.'"

Response provided by Staff Witness Sarah Kliethermes.

8) On page 40 of Staff's testimony there is an excerpt from Ms. Kelly's testimony. Please identify where within this excerpt, or otherwise within Ms. Kelly's testimony, Ms. Kelly implies resolution of something that she also identifies as needing to be resolved.

STAFF RESPONSE: The "Application of Grain Belt Express Clean Line LLC for A Certificate of Convenience and Necessity", verified by the affidavit of Michael P. Skelly, at page 22, states that "Suedeen Kelly: Ms. Kelly is a former Chair of the New Mexico Public Service Commission and a former FERC Commissioner. She explains why a participant-funded business model, like the Project, is a market-driven solution to transmission expansion. She reviews the facts demonstrating that there is a need for the Project, why it is economically feasible and in the public interest, and discusses why the Project fulfills the goals of FERC Order 1000 that encourages interregional transmission projects and **the resolution of inter-RTO seams issues.**" **[emphasis added]**

Response provided by Staff Witness Sarah Kliethermes.

9) In reference to page 40 of Staff's testimony where Ms. Kliethermes states that "To the extent that contingency planning for the region would need to account for the sudden failure of a 500MW generator, this would increase reserve margin requirements to preserve existing reliability."

a. Please identify "the region" as it is referred to in this statement. Is "the region" a local resource zone within MISO?

STAFF RESPONSE: Staff's use of "the region" is intentionally vague as Staff is uncertain what "the region" is intended to mean in the language quoted from Ms. Kelly, which is referenced.

Response provided by Staff Witness Sarah Kliethermes.

b. Please identify what is meant by "contingency planning" as it is referred to in this statement.

STAFF RESPONSE: Staff's use of "contingency planning" is intentionally vague as Staff is uncertain what exact scenario or set of scenarios is intended to be described in the language quoted from Ms. Kelly, which is referenced.

Response provided by Staff Witness Sarah Kliethermes.

c. Please identify what is meant by "reserve margin requirements" as it is referred to in this statement.

STAFF RESPONSE: Staff's use of "reserve margin requirement" is intentionally vague as Staff is uncertain what "lowered reserve margins" are intended to be described in the language quoted from Ms. Kelly, which is referenced

Response provided by Staff Witness Sarah Kliethermes.

d. Please identify the specific reliability planning criteria, processes, and procedures that are applicable to "the region" which Staff relief upon for their assertion that an increase to "reserve margin requirements" would occur if contingency planning was required to consider the injection from the Missouri converter station.

STAFF RESPONSE: See responses to parts a, b, c, above

Staff Response Provided by Staff Witness Sarah Kliethermes.

e. Please provide the study results performed for or by Staff where the 500MW injection from the Missouri converter station has been considered and resulted in an increase in the reserve margin requirements for "the region".

STAFF RESPONSE: Staff has not stated or alleged that the 500MW injection from the Missouri converter station has any impact to increase or

decrease the reserve margin requirements for "the region" as described by Ms. Kelly.

Response Provided by Staff Witness Sarah Kliethermes.

f. Please provide the calculations relied upon for the assertion that considering the 500MW injection from the Missouri converter station will result in an increase in the reserve margin requirements for "the region".

STAFF RESPONSE: Staff has not stated or alleged that the 500MW injection from the Missouri converter station has any impact to increase or decrease the reserve margin requirements for "the region" as described by Ms. Kelly.

ResponsePrrovided by Staff Witness Sarah Kliethermes.

g. Is Staff aware of any Missouri-located generating units that are exempt from being considered in transmission planning analyses performed by any of the Transmission Providers in the State of Missouri? If so, please list those units.

STAFF RESPONSE: Staff does not have an opinion.

Response Provided by Staff Witness Sarah Kliethermes.

h. Please provide Staff's opinion or knowledge, in general (e.g. as a percentage of nameplate), on the amount of capacity (as opposed to energy) that is attributable to wind plants located within the State of Missouri which contribute to meeting reserve margin requirements for "the region".

STAFF RESPONSE: See response to parts a, above.

Response Provided by Staff Witness Sarah Kliethermes.

i. How would a planning authority consider the outage of a Missouri-located wind plant within "contingency planning" in the determination of impacts to "reserve margin requirements"?

STAFF RESPONSE: See responses to parts b and c, above.

Response Provided by Staff Witness Sarah Kliethermes.

j. How would a planning authority consider the outage of a fossil-fueled generator within "contingency planning" in the determination of impacts to "reserve margin requirements"?

STAFF RESPONSE: See responses to parts b and c, above.

Response Provided by Staff Witness Sarah Kliethermes.

k. What is the largest generating unit within "the region" as it is defined in response to part a)?

STAFF RESPONSE: See response to parts a, above.

Response Provided by Staff Witness Sarah Kliethermes.

l. Would introduction of a generating unit of a smaller nameplate capacity than that which was identified in response to part k increase the reserve margin requirements as defined in part c?

STAFF RESPONSE: See response to parts a, above.

Response provided by Staff Witness Sarah Kliethermes.

10) Please provide the reference(s) within Ms. Kelly's testimony that indicates that the Grain Belt Project is being studied by the relevant RTOs as a generator.

STAFF RESPONSE: As stated at page 40 of the Staff Report "...Ms. Kelly does not indicate that MISO is studying the Project as a generator...." Specifically, at pages 28-29, Ms. Kelly testifies, "The Project will go through the relevant interconnection study processes to determine whether it can be reliably interconnected to the transmission grid." Staff suggests that this is needlessly confusing and would benefit from inclusion of the word "generator" between the words "relevant" and "interconnection".

Response provided by Staff Witness Sarah Kliethermes.

11) Please provide the reference(s) within Ms. Kelly's testimony that indicates that the Grain

Belt Project is being studied by the relevant RTOs as a transmission line.

STAFF RESPONSE: As stated at page 40 of the Staff Report "However, Ms. Kelly does not indicate that MISO is studying the Project as a generator, as opposed to studying it as a 'transmission line.'" Specifically, at pages 28-29, Ms. Kelly testifies, "The Project will go through the relevant interconnection study processes to determine whether it can be reliably interconnected to the transmission grid." Staff suggests that this is needlessly confusing and would benefit from inclusion of the word "generator" between the words "relevant" and "interconnection". Absent reference to the word "generator" as constructed, this statement appears to imply that the interconnection study process is a study of transmission interconnection.

Response provided by Staff Witness Sarah Kliethermes.

12) In reference to page 40 of Staff's testimony,

a. Please explain what is confusing about the "interconnection status of the Missouri converter station".

STAFF RESPONSE: Staff is not stating that the interconnection status of the Missouri converter station is confusing. Staff is stating that Grain Belt's testimony concerning the interconnection status is confusing, in that sections of Grain Belt's testimony imply that the interconnection study process will study Grain Belt as a transmission line as opposed to as a generation interconnection.

Response provided by Staff Witness Sarah Kliethermes.

b. Please clarify if the status of the interconnection requests is confusing. If so, what additional information will help address Staff's confusion?

STAFF RESPONSE: The status of the interconnection requests is confusing only in the context of Grain Belt's testimony.

Response provided by Staff Witness Sarah Kliethermes.

c. Please clarify whether Staff is confused about the process of studying transactions to support energy transfers from MISO to PJM utilizing the Project in the manner described by Dr. Galli in the exchange excerpted on page 40-41 of Staff's testimony.

STAFF RESPONSE: Staff is confused by Dr. Galli's testimony to the extent that "any one can request" to initiate a process that has not yet been established. Staff is further confused by the interaction of Dr. Galli's testimony quoted at page 40 of the Staff Report with Mr. Lawlor's testimony quoted at page 40 of the Staff Report, as stated on page 40 of the Staff Report. Staff is further confused by the interaction of these quoted statements with the statement at page 7 of the Application verified by Mr. Skelly that "In addition, the Missouri converter station will have bi-directional functionality, allowing Missouri utilities the opportunity to sell up to 500 MW of excess power into the energy markets operated by PJM. The additional revenue from these off-system sales can be used to reduce the cost of electricity for the end-use customers of these Missouri utilities."

Response Provided by Staff Witness Sarah Kliethermes.

13) Is Staff aware of a process for requesting transmission service from MISO for export of energy to Transmission Providers adjacent to MISO?

STAFF RESPONSE: Staff does not have an opinion as this question is presented in the abstract.

Transmission service is typically procured by other market participants, rather than a transmission provider, for the purpose of transmitting energy from a specified source to a specified load. For sources located outside a market participant's RTO, the market participant can use point-to-point service, establish a contract path, or establish a pseudo-tie to move the energy from the source RTO to a border location at the participant's RTO. From there, the market participant can use network integrated transmission service to transmit the energy to their load node.

Response Provided by Staff Witness Michael Stahlman

14) In the discussion with Staff in November 2016 referenced on page 41 of Staff's testimony, Grain Belt highlighted the development of the HVDC interconnection process currently taking place among MISO stakeholders within the MISO Merchant HVDC Task Team ("MHTT").

a. Have any members of Staff been engaged in the MHTT? If not, why not?

STAFF RESPONSE: No. Staff does not have an opinion.

Response provided by Staff Witness Sarah Kliethermes.

b. In reference to Staff's testimony at page 41 where Ms. Kliethermes states that "the process to establish a process has not yet been established", is this statement regarding a process to study energy withdrawals from the MISO system via a HVDC project?

STAFF RESPONSE: No

Response Provided by Staff Witness Sarah Kliethermes.

c. If the answer to part b is "no", please clarify what the "process" is for which Ms. Kliethermes asserts that a process has yet to be developed to establish.

STAFF RESPONSE: The process that does not which have a process developed to be established is the process of applying to MISO for study to convert AC MISO energy to DC energy for export from the MISO system.

Response Provided by Staff Witness Sarah Kliethermes.

d. If the answer to part b is "yes", does Staff believe that the discussions and process materials that are part of the MHTT meetings do not constitute "a process to establish a process"? If not, please explain why Staff believes that a MISO stakeholder-driven task force with regular meetings to discuss the implementation of an interconnection process for a HVDC project, including provisions related to injection and withdrawal of energy, does not meet Staff's expectations.

15) In reference to Staff testimony on page 41, what is meant by the statement "uploading Missouri energy"?

STAFF RESPONSE: Taking MISO AC energy into a DC converter station for conversion to DC and export out of MISO.

Response provided by Staff Witness Sarah Kliethermes.

16) A new transmission line has been constructed and placed in-service which interconnects Ameren Missouri to Associated Electric. The line was identified as needed in order to support power transfers primarily in the direction from Associated Electric to

Ameren Missouri.

a. If a MISO market participant desires to transmit energy from Ameren Missouri to Associated Electric, what study process, if any, would that market participant be required to utilize in order to obtain the right to effectuate transmission of energy as described?

STAFF RESPONSE: Staff does not have an opinion as this question is presented in the abstract

Response Provided by Staff Witness Sarah Kliethermes.

b. Please provide an explanation supporting the need to undergo study of the transfer described in a), if any.

c. Please describe why your response to a) could not apply to transfers from Ameren Missouri to PJM and provide any evidence that supports your position.

17) Is there a process available for transmission customers within MISO to procure transmission service to sink energy into PJM?

STAFF RESPONSE: This question is vague to the extent that it is unclear whether "procure transmission service" refers to a contractual or tariff-governed transaction or to the literal flow of energy. Staff takes no position on whether or not paying a through and out rate is a "process" within the meaning of this question, but Staff states that MISO does allow market participants to schedule both physical and financial export transactions.

Staff Response Provided by Staff Witness Sarah Kliethermes.

a. If not, does this mean that energy transfers from MISO to PJM cannot exist?

b. If so, what process would a MISO transmission customer go through?

STAFF RESPONSE: Staff takes no position on whether or not paying a through and out rate is a "process" within the meaning of this question, but Staff states that MISO does allow market participants to schedule both physical and financial export transactions.

Staff Response Provided by Staff Witness Sarah Kliethermes.

18) Considering the existing transmission topology of MISO and PJM (that is, without consideration of the Grain Belt Project), if a MISO transmission customer was able to procure transmission service from [source = Ameren Missouri] to [sink = PJM]…

a. Would that power get transmitted directly between Ameren Missouri and PJM or would that power need to be transmitted across intermediate and/or adjacent Transmission Owner transmission systems? Why?

STAFF RESPONSE: MISO does allow market participants to schedule both physical and financial export transactions. Staff cannot speculate on the specifics of any given transaction, including whether any energy actually left a given RTO.

Staff Response provided by Staff Witness Sarah Kliethermes.

c. In Staff's opinion, could there be loop flows (aka "uncompensated flows") that would occur as a result of this energy transfer?

STAFF RESPONSE: MISO does allow market participants to schedule both physical and financial export transactions. Staff cannot speculate on the specifics of any given transaction, including whether any energy actually left a given RTO.

Staff Response provided by Staff Witness Sarah Kliethermes.

19) Please clarify the final statement by Ms. Kliethermes on page 41 of Staff's testimony.

a. Specifically, please outline the "assertions" that are being referenced.

STAFF RESPONSE: See Staff Report from page 39 – 41, which specifies what assertions are referred to as "these assertion" and includes citations. See also Staff responses to questions 1, 2-2e, 3 , 7, 8, 9-9l, 10, 11, 12-12c, and 15, provided above.

Staff Response provided by Staff Witness Sarah Kliethermes.

b. What are the assertions "internal" to?

STAFF RESPONSE: Grain Belt's direct testimony and Application.

Staff Response provided by Staff Witness Sarah Kliethermes.

c. What and with whom are the assertions conflicting against?

STAFF RESPONSE: See Staff Report from page 39 – 41, which specifies what assertions are referred to as "these assertion" and includes citations. See also Staff responses to questions 1, 2-2e, 3, 7, 8, 9-9l, 10, 11, 12-12c, and 15, provided above.

Response provided by Staff Witness Sarah Kliethermes.

/s/ Karl Zobrist

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CERTIFICATE OF SERVICE

I certify that a copy of the foregoing Data Request was served upon the party to which it was directed by email or U.S. Mail, postage prepaid, this ___3rd__ day of February, 2017.

/s/ Karl Zobrist

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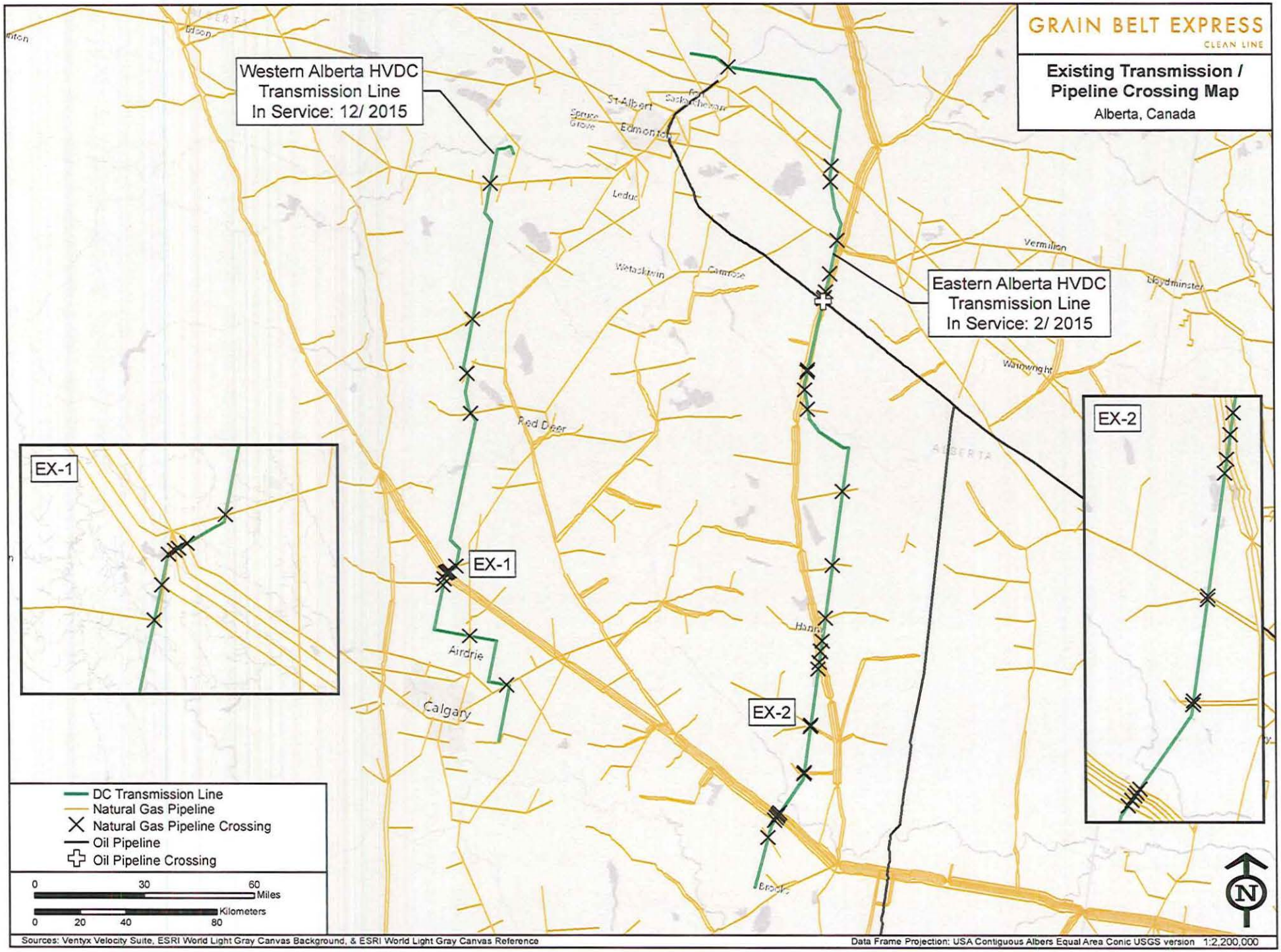
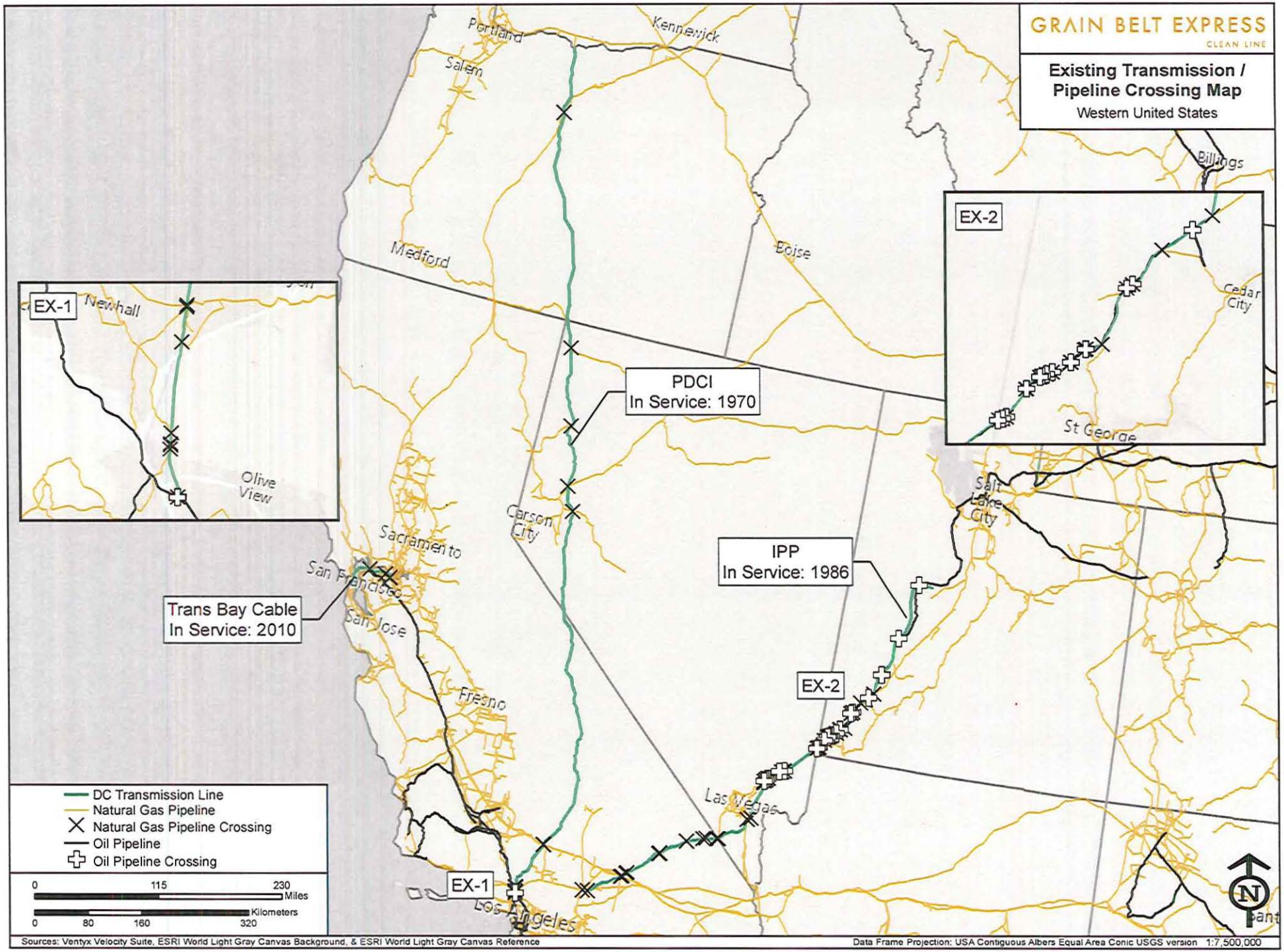


Schedule AWG-14



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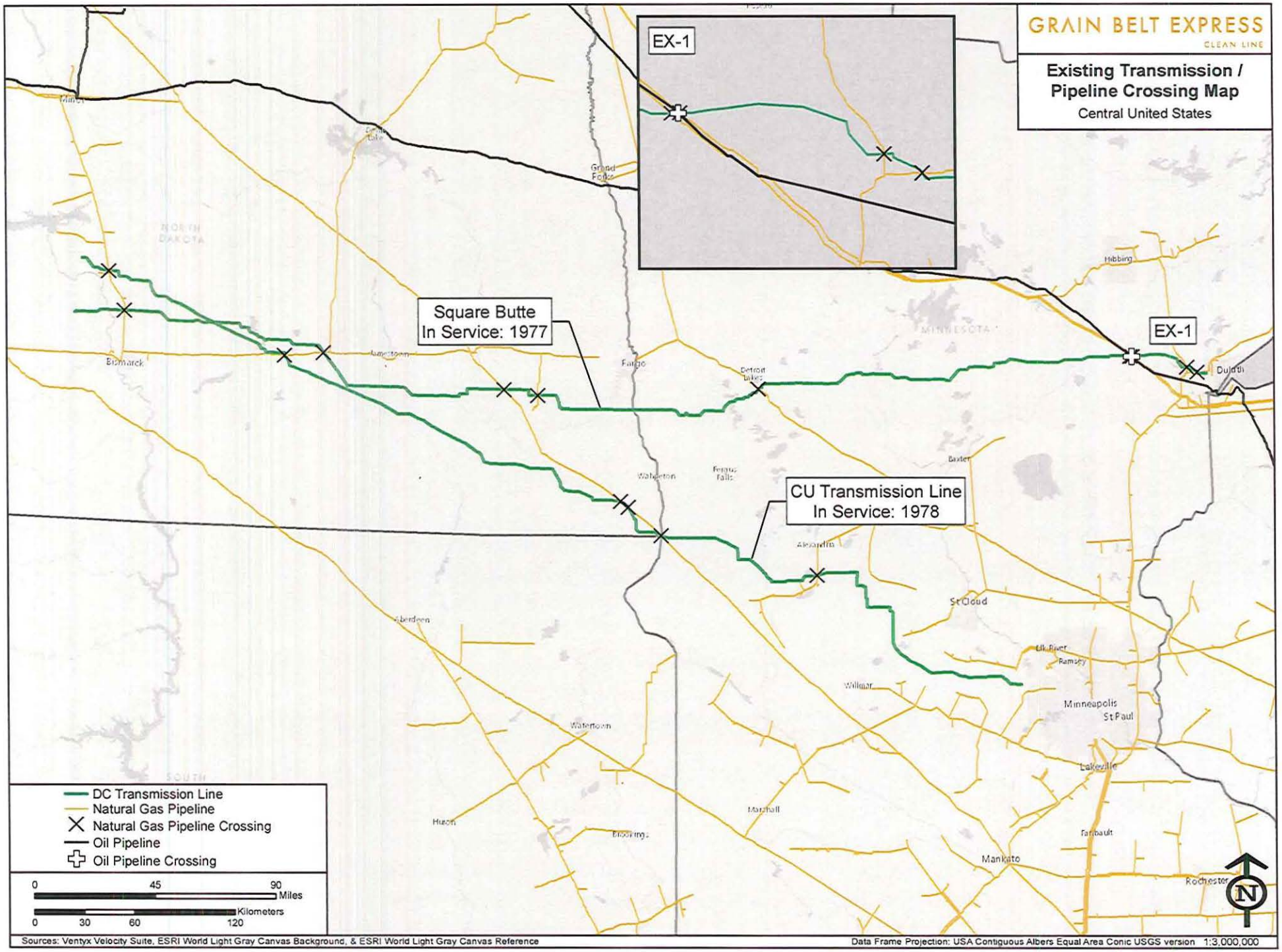

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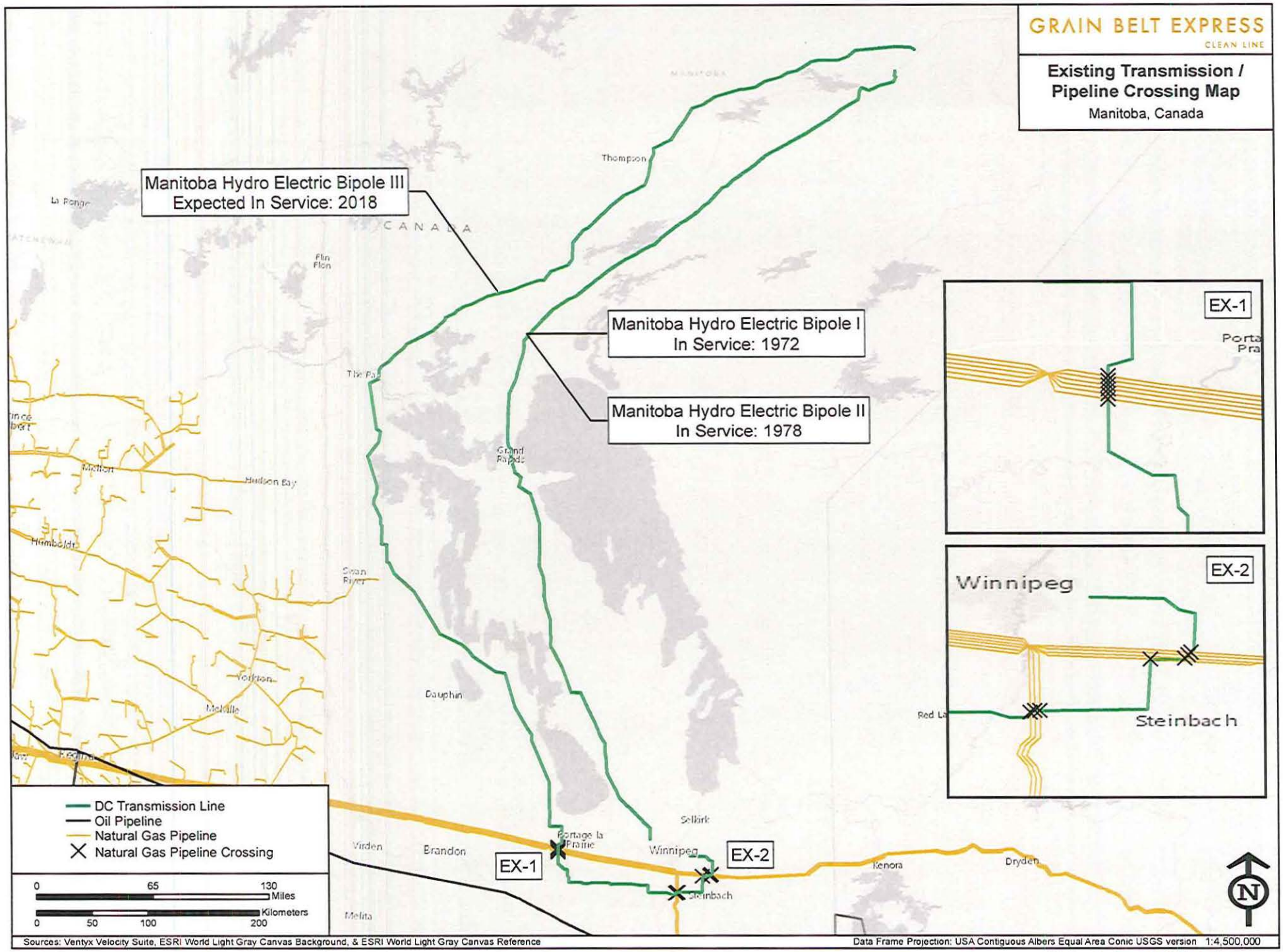
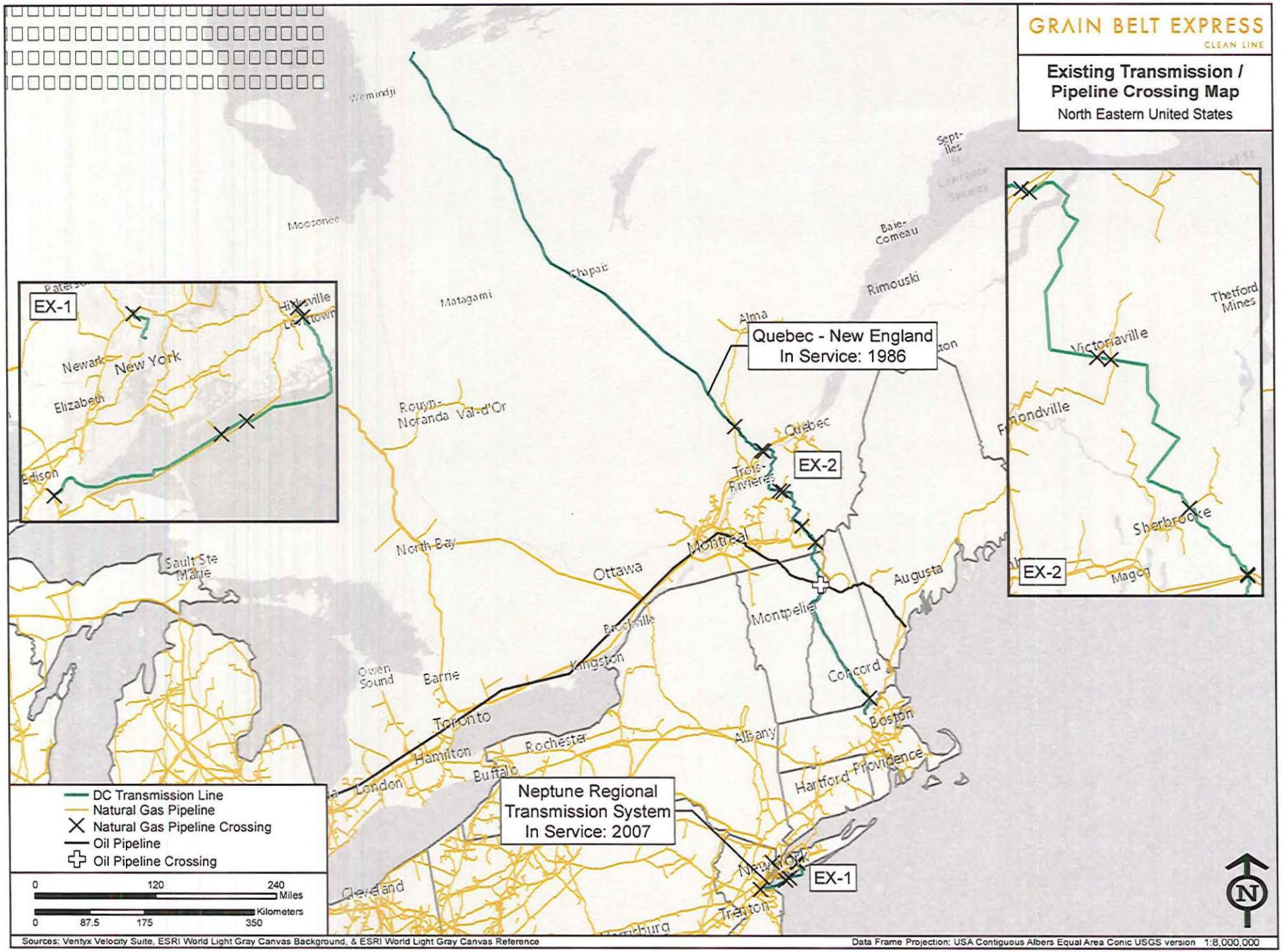


Schedule AWG-15



Schedule AWG-16

Staff Issue Description	Staff Report Reference	Grain Belt Express Response	Galli Surrebuttal Testimony References
Heading: "Whether the proposal is economically feasible"			
RTO Interconnection Studies: MISO Network Upgrades cannot be known at this time.	pp. 22-26	Grain Belt has sufficient certainty that MISO network upgrade costs will not vary significantly from the current estimate [$21 million].	pp. 10-12
RTO Interconnection Studies: SPP Network Upgrades cannot be known at this time.	pp. 26-27	It is unlikely that network upgrade costs in SPP will change from their current estimate [$21.5 million].	pp. 30-31
RTO Interconnection Studies: PJM Network Upgrades cannot be known at this time.	pp. 27-29	PJM network upgrade costs could vary. However system enhancements have occurred to the PJM system which are expected to alleviate any potential need for additional upgrades to the PJM system beyond the current estimate [~$505 million].	pp. 25-27
The level of cost to be incurred from non-subscribing Missourians: MISO network upgrades that are required for the Project could be cost-allocated to Missouri customers.	p. 31	There is no method in MISO to cost-allocate network upgrades for HVDC interconnections. Even if/when MISO develops such a method - which would align with their existing method for generators - the costs to Missouri would be insignificant.	pp. 4-5
Design: The Project's design is not further developed.	pp. 33-34	The Project is at an appropriate level of design based on its remaining required regulatory approval and prudent project management.	pp. 38-39

Staff Issue Description	Staff Report Reference	Grain Belt Express Response	Galli Surrebuttal Testimony References
Operation: No power transfer will occur from the Project to SPP.	pp. 34, 40-41	Power transfers can occur from the Project to SPP. When customers desire this service they will undergo the appropriate study process to acquire the rights to do so.	pp. 32-34
Operation: MISO customers using the Project will have to pay PJM Tariff rate schedules.	p. 35	MISO customers using the Project will not have to pay PJM rate schedules other than those that are specific for service on the Project within the PJM Tariff; this includes Schedules 1 and 1A.	p. 29
Operation: It is unclear how ancillary services will be handled for the Project's AC collector system in Kansas.	p. 35	Ancillary Services on Project facilities, including the AC collector lines in Kansas, are considered within design work and are not separately charged or administered.	pp. 34-35
Operation: Service on the Project from MISO to PJM cannot be studied because there's no process for such a study.	pp. 36, 41	Power can be transferred from MISO to PJM using the Project. One process to accomodate this is the Point-to-Point transmission service process which already exists for service from MISO to PJM and could be applied for the Project. Additionally, the MISO Merchant HVDC Task Team is developing a process that will include rights to withdraw energy from the MISO market.	pp. 13-15
Heading: "Public Interest"			
Impact on reliability and regional planning: The Project would increase reserve margin requirements to preserve existing reliability.	p. 40	The Project will not cause an increase on Missouri's reserve margin requirements.	pp. 35-36

Staff Issue Description	Staff Report Reference	Grain Belt Express Response	Galli Surrebuttal Testimony References
Heading: "Safety"			
Potential effects on nearby utility facilities: Submissions from Grain Belt Express do not clearly address possible harmful effects on existing utilities.	pp. 47-48	The Project has always been described as utilizing DMR conductors. Utilizing a DMR is, and will remain, within the Project design.	p. 40
Potential effects on nearby utility facilities: DMR conductors help address ground current concerns. The CCN should be conditioned on ensuring the Project will have DMR conductors.	pp. 48-49	Grain Belt Express has committed to the condition related to installing a DMR.	p. 41
Potential effects on nearby utility facilities: Lightning or a natural disaster could cause ground currents. The CCN should be conditioned on ensuring the Project has control and protection measures to de-energize the Project within 150 milliseconds.	pp. 49-50	Grain Belt Express has committed to the condition related to de-energizing the Project within 150 milliseconds during faults.	p. 41
Potential effects on nearby utility facilities: The Project should be required to perform studies to identify potential impacts to nearby utilities and determine proper mitigation. The CCN should be conditioned to require that Grain Belt Express perform studies to determine if the Project facilities in Missouri will have adverse impacts on nearby utilities and coordinate with Staff regarding studies and monitoring and mitigation measures.	pp. 50-51	Grain Belt Express has committed to the condition related to study, coordination, and reporting with respect to the Project's potential impacts to nearby underground utilities.	p. 41
Interconnection Studies: Impacts were identified in the PJM System Impact Study. Due to these impacts, it is unclear whether transmission upgrades, a special protection scheme, or a reduction to the Project's capacity in Illinois would be required.	pp. 54-55	Transmission upgrades are already required for the Project's interconnection with PJM. Studies that were performed for the SPP point-of-interconnection did not consider any PJM upgrades.	pp. 26-27

Staff Issue Description	Staff Report Reference	Grain Belt Express Response	Galli Surrebuttal Testimony References
Interconnection Studies: NERC Category C events were not included in the MISO SPA Study.	p. 55	Category C events were modeled in the MISO/Ameren Optional Study and resulted in additional network upgrades.	p. 10
Interconnection Studies: The SPP studies show that the Project causes issues in AEP under certain contingencies. Due to these issues, it is unclear whether a major transmission upgrade, a special protection scheme, or a reduction to the Project's capacity in Illinois would be required.	pp. 55-56	Transmission upgrades, including a "major transmission upgrade" are already required for the Project's interconnection with PJM. Studies that were performed for the SPP point-of-interconnection did not consider any PJM upgrades.	pp. 26-27
Heading: "Additional Concerns"			
Mark Twain: Without Mark Twain or something comparable, the Project will induce thermal overloads in the MISO system.	pp. 56-58	MISO is obligated to identify an alternative to Mark Twain should it not get constructed. In the interim, the MISO market will, as it currently does, properly ensure security of the system.	pp. 15-17
Short Circuit Ratio: A short circuit ratio of 2.0 or less is considered a "weak system" and it is unclear what the short circuit ratio will be at the interconnection of the Missouri HVDC Converter Station.	p. 58	The short circuit ratio for the Project's interconnection in Missouri is multiples of the "rule of thumb" for "weak" grids (2.0). Therefore the grid in Missouri is considered "strong" for the Missouri HVDC Converter Station.	pp. 21-22
Grain Belt and ITC Great Plains, LLC interconnection agreement: Studies have not been performed to determine Control Interaction risks of the Project on other HVDC lines and DC ties in the MISO region.	p. 59	These studies are performed during Design-Level Studies and only impact the equipment characteristics of the Project and would not impact network upgrade cost or scope.	pp. 6-8, 38-39

Staff Issue Description	Staff Report Reference	Grain Belt Express Response	Galli Surrebuttal Testimony References
Grain Belt and ITC Great Plains, LLC interconnection agreement: Screening or actual studies have not been performed to determine whether there will be SSTI risks to generators in Missouri near the Project's interconnection.	pp. 59-60	These studies are performed during Design-Level Studies and only impact the equipment characteristics of the Project and would not impact network upgrade cost or scope.	pp. 6-8, 38-39
Grain Belt and ITC Great Plains, LLC interconnection agreement: A harmonic performance study has not been completed to determine impacts from the Project on the MISO system.	pp. 60-61	These studies are performed during Design-Level Studies and only impact the equipment characteristics of the Project and would not impact network upgrade cost or scope.	pp. 6-8, 38-39

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, Operate, Control, Manage and Maintain a High Voltage, Direct Current Transmission Line and an Associated Converter Station Providing an Interconnection on the Maywood-Montgomery 345kV transmission line.	)	Case No. EA-2016-0358

STAFF RESPONSES TO
GRAIN BELT EXPRESS CLEAN LINE LLC'S
FIRST SET OF DATA REQUESTS DIRECTED TO
STAFF OF THE MISSOURI PUBLIC SERVICE COMMISSION

For its First Set of Data Requests Directed to Staff of the Missouri Public Service Commission ("Staff"), Grain Belt Express Clean Line LLC ("Grain Belt Express" or "Company") states the following:

Definitions

1. The term "documents" includes all of the items listed in Missouri Rule of Civil Procedure 58.01(a)(1).

2. The term "Grain Belt Express Project" or "Project" means the transmission line and associated facilities described in Paragraph 14 of the Application in this proceeding.

Data Requests

1. On p. 18 of its Rebuttal Report, Staff writes "It is possible that KCP&L might be willing to sell some of the RECS from these two wind farms..."?

a. Please provide all relevant information and documentation which support this "possibility."

Staff Response: Staff's statement based on the fact that KCPL and GMO were expected to have excess Renewable Energy Credits ("RECs"), RECs that will not be needed to comply with Missouri's Renewable Energy Standard ("RES"), when Staff filed testimony on September 15, 2014 in Case No. EA-2014-0207. Since that time, KCP&L announced the purchase from the two wind farms referenced above. Since Staff continues to believe that KCP&L can meet the RES requirements without these two wind farms, the addition of these two wind farms should result even more excess RECs and therefore there is an opportunity for KCP&L to sell excess RECs. If an electric utility has excess RECs, it would be prudent to sell those RECs at a fair market value as has been the practice in Missouri.

Provided by Staff Witness Daniel I. Beck, PE

b. Does Staff know if KCP&L will be purchasing the RECs "bundled" with the power from these wind generators or will KCP&L be purchasing the power exclusively from the wind generators?

Staff Response: All current contracts for wind that are in place for the 4 Missouri investor-owned electric utilities are for "bundled" resources. It is Staff's understanding that is also true of the two wind farm contracts discussed above.

Provided by Staff Witness Daniel I. Beck, PE

c. Has Staff analyzed the effect of the differing wind speeds on cost of wind energy between these two wind generators versus the wind speeds found in western Kansas.

Staff Response: Staff has not performed any analysis that compares the Osborn Wind Farm or the Rock Creek Wind Farm to any wind farms that might be located in western Kansas.

Provided by Staff Witness Daniel I. Beck, PE

2. Other than Staff's legal position regarding the obtainment of necessary county assents, does Staff have any basis to believe that Ameren Transmission Company's Mark Twain project will not be in service by the end of 2021? If so, please explain and provide all relevant information and documentation.

Staff Response: The Missouri Public Service Commission ordered in the EA-2015-0146 Report and Order Pg. 40 Item 2:

"The certificate is contingent upon ATXI providing certified copies of county assents for the Mark Twain Project from Marion, Shelby, Knox, Adair, and Schyler Counties, Missouri"

As Staff indicated in its report, Staff is aware that cases are pending regarding the Mark Twain Project which may have an impact on the timing of the Mark Twain Project in-service date:

ATXI V SHELBY COUNTY COMMISSION	16SB-CC00009
ATXI V SHELBY COUNTY COMMISSION	16SY-CV00145
ATXI V ADAIR COUNTY COMMISSION	16AR-CV00790
ATXI V KNOX COUNTY COMMISSION	16KN-CC00051
ATXI V MARION COUNTY COMMISSION	16MM-CV00182

In addition, Staff is aware of a pending case that involves legal issues beyond just the obtainment of necessary county assents. The following case involves multiple legal issues and may have an impact on the timing of the Mark Twain Project in-service date:

AMEREN TRANSMISSION, RES NEIGHBORS UNITED, APEL	WD79883

It should be noted that Staff has not stated an in-service date for the Mark Twain project in the current case proceeding.

Provided by Staff Witness Shawn Lange

3. On p. 30 of its Rebuttal Report, Staff writes "The MJMEUC contracts accounts for up to 5.71% of the SPP-MISO capacity, and up to .63% of the MISO-PJM capacity." Please provide Staff's calculation and basis for this statement.

Staff Response: This was provided as Sarah Kliethermes' workpaper.

Provided by Staff Witness Sarah Kliethermes

4. On p. 31 of its Rebuttal Report, Staff writes "Another concern with the assertion that costs will not be recovered from Missouri ratepayers is that if upgrades are necessary to the MISO grid associated with the Missouri converter station, and those upgrades are determined by MISO to address a local reliability concern, the pro rata of those costs is recoverable through MISO from those entities deemed to be beneficiaries of the improvement, and ultimately incurred by Missouri ratepayers." Please provide the basis, including relevant documentations or citations, for Staff's assertion.

Staff Response: See MISO OATT, and MISO OATT, Attachment X, Appendix 6 to GIP, 9.9.2: Other Users. If required by Applicable Laws and Regulations or if the Parties mutually agree, such agreement not to be unreasonably withheld or delayed, to allow one or more Parties to use the Transmission Owner's Interconnection Facilities, or any part thereof, Interconnection Customer will be entitled to compensation for the capital expenses it incurred in connection with the Interconnection Facilities based upon the pro rata use of the Interconnection Facilities by Transmission Owner, all non-Party users, and Interconnection Customer, in accordance with Applicable Laws and Regulations or upon some other mutually-agreed upon methodology. In addition, cost responsibility for ongoing costs, including operation and maintenance costs associated with the Interconnection Facilities, will be allocated between Interconnection Customer and any non-Party users based upon the pro rata use of the Interconnection Facilities by Transmission Owner, all non-Party users, and Interconnection

Customer, in accordance with Applicable Laws and Regulations or upon some other mutually agreed upon methodology. If the issue of such compensation or allocation cannot be resolved through such negotiations, it shall be submitted to Dispute Resolution pursuant to Section 12 of the Tariff."

Provided by Staff Witness Sarah Kliethermes

5. On p. 37 of its Rebuttal Report, Staff cites "Statistic Brain (2016)" regarding "failure rate" of an industry category entitled "Transportation, Communications and Utilities":

a. Please provide documentation of which companies are included in the Transportation, Communication and Utilities category in the cited survey.

Staff Response: Please refer to the citation, 'Statistic Brain (2016). "Startup Business Failure Rate By Industry" http://www.statisticbrain.com/startup-failureby-

industry. (1/13/2017). Staff did not seek further documentation of which companies were included in the Transportation, Communication and Utilities category.

Provided by Staff Witness Michael Stahlman

b. Are any companies owning transmission lines included in the survey?

Staff Response: Staff does not know.

Response provided by Staff Witness Michael Stahlman

c. Has Staff ever used "Statistic Brain" in another proceeding before the Missouri Public Service Commission?

Staff Response: Staff is unaware of any other citation of the Statistic Brain Research Institute's information before the Commission.

Response provided by Staff Witness Michael Stahlman

6. On p. 37 of its Rebuttal Report, Staff writes "While the category is broad, Grain Belt's business model is atypical of the utilities that are generally granted regulatory protections by this Commission."

a. What "protections" will Grain Belt be provided if the Missouri Commission approves its CCN application? Please explain what the word "protections" means?

Staff Response: In the context of quotation above, "protections" was used as describing the granting of a certificated service territory. If approved, Grain Belt will be authorized it to construct, own, operate, control, manage, and maintain electric transmission facilities within Buchanan, Clinton, Caldwell, Carroll, Chariton, Randolph, Monroe and Ralls Counties, Missouri, as well as an associated *converter station in Ralls County.*

Response provided by Staff Witness Michael Stahlman

b. How many receiverships has the Commission sought for utilities with what the Staff would consider typical business models, including small water and sewer in the last 10 years?

Staff Response: 8.

Response provided by Staff Witness Michael Stahlman

c. Does Staff consider a PPA between a wind generator and load-serving entity to be a typical business model?

Staff Response: Yes.

Response provided by Staff Witness Michael Stahlman

7. Does Staff agree that changes in off-system sales are included in Mr. Copeland's Adjusted Production Cost analysis presented in his direct testimony?

Staff Response: Staff doesn't know. Staff agrees that at page 16 Mr. Copeland testifies: "Adjusted Production Cost ($) – The total variable cost of generation plus the cost of energy purchases minus revenue from off-system sales (exports). This metric captures the ability for Missouri to recognize revenue from outside sales, as well as the costs associated with market purchases. It is a proxy for the cost to serve wholesale load within the State of Missouri."

Response provided by Staff Witness Sarah Kliethermes

8.

8. On page 40 of Staff's Rebuttal Report, Staff writes, "To the extent that contingency planning for the regional would need to account for the sudden failure of a 500 MW generator, this would increase reserve margin requirements to preserve existing reliability."

a. Please provide Staff's understanding of how reserve margins are established in the region.

Staff Response:
See:http://www.nerc.com/pa/RAPA/ri/Pages/PlanningReserveMargin.aspx; http://www.nerc.com/comm/PC/Performance%20Analysis%20Subcommittee%20PAS%202013/1-3%20July%209.pdf

Response provided by Staff Witness Sarah Kliethermes

b. Provide all relevant citations or documentation which support Staff's understanding of how reserve margins are set in the region.

Staff Response: Staff does not know what "the region" is as referenced by Ms. Kelly in the statement Staff discusses in the quoted text. Citations to general documents informing Staff's understanding of reserve margins are provided in response to 8.a.

Response provided by Staff Witness Sarah Kliethermes

c. Please provide any examples of additional capacity being added in Missouri which has required the reserve margin for Missouri to increase?

Staff Response: Staff is not aware that there is a reserve margin "for Missouri" specified.

Response provided by Staff Witness Sarah Kliethermes

d. Please provide all relevant citations or documentations which support Staff's belief the potential for additional reserve margins to be added because of the interconnection in Missouri.

Staff Response: Staff does not agree that this question accurately states Staff's belief. Staff understands that every interconnection is studied in an N-1-1

8.

contingency state. *Response provided by Staff Witness Sarah Kliethermes*

8(9) Is Staff aware of any transmission line which have been decommissioned in the first twenty years of their operation? If so, please provide relevant documentation.

Staff Response: No.
Response provided by Staff Witness Daniel I. Beck, PE