Generator Interconnection – Affected System Impact Study

Plains & Eastern Clean Line
Final Report

May 19, 2015

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TABLE OF CONTENTS

LIST OF TABLES & FIGURES

Disclaimer

The accuracy of the conclusion contained in this study is sensitive to the assumptions made with respect to the generation addition (size, location, modeling data), prior queued generation projects, and other network changes being contemplated outside this study. Any change in these assumptions will affect this study's conclusion.

1 Executive Summary

This report documents the affected system impact due to the interconnection of the Plains & Eastern HVDC project on the MISO Transmission system. Clean Line Energy Partners LLC is currently developing the Plains & Eastern Clean Line Project (P&E Project) which will use HVDC technology to deliver wind and solar generated electricity from southwestern Kansas, the Texas Panhandle and northwestern Oklahoma to serve load centers in the Tennessee Valley Authority (TVA) and other areas of the southeastern United States. It includes an approximately 700 mile +/- 600kV HVDC transmission link, capable of delivering 3500 MW to the inverter in the TVA system.

Please note that this report only documents the system impacts on the MISO system from an Affected System perspective, it does not grant any interconnection or transmission rights on the MISO system.

Two power flow scenarios were studied - Near term (2017) and Out-Year (2024). Steady State AC analysis was performed to identify any reliability criteria violations caused by the interconnection of the study project. The analysis did not identify any constraints in both the near term (2017) and the out year (2024) scenarios.

Based on steady state results and consensus from the Ad-hoc group, no transient analyses were performed as part of this Affected System Study (AFS).

Table 1.1. – Study Project Overview

Project Type	Control Area	County	Point of Interconnection (POI)	Summer Injection(MW)
HVDC Injection	TVA	Shelby	Shelby 500kV	3500

1.1 Transmission Upgrade Cost and Allocation

The cost allocation of Network Upgrades for the study project reflects responsibilities for mitigating system impacts affected by the study project.

The steady state thermal and voltage analyses have not identified any injection constraints. No network upgrades are being proposed at this point as outlined in Table 1.2

Table 1.2. – Total Estimated Network Upgrade Cost

ERIS Network Upgrades ($)			NRIS Network Upgrades ($)	Interconnection Facilities ($)	Shared Network Upgrade	Total Cost ($)
Steady-State & Voltage Stability	Transient Stability	Short-circuit	Deliverability			
$0	N/A	Future	N/A	N/A – Non MISO POI	N/A	$0

1.2 Study Overview

The study was performed by MISO. An ad hoc group was formed to participate in the study. The ad hoc group reviewed the study models and provided feedback on issues including but not limited to the equipment rating verification, suggestions for Network Upgrades, physical limitations at the existing substations, etc. The following companies were invited to participate in the study:
AMRN, EES, EMI, LAGN, SMEPA, CLECO, LAFA, AECI & TVA

The Affected system study included the following evaluations:

- A steady state thermal and voltage analysis to identify the limiting conditions at increasing levels of generation for NERC category A, B, and selected C events.
- An Effective Short Circuit Ratio(SCR) Calculation

1.2.1 Steady State Analyses

The steady state thermal and voltage analyses have not identified any injection constraints. No network upgrades are being proposed at this point.

1.2.2 Stability Analysis

This has been redacted from the scope of this study.

1.2.3 Effective Short Circuit Ratio

The effective short circuit capabilities were found to be acceptable to accommodate the injection from the HVDC facility. No additional transient voltage control devices are currently being recommended.

2 Introduction

The proposed project is a 700 mile +/- 600kV Line Commutated HVDC transmission link, capable of delivering 3500 MW to the inverter in the TVA system. This report presents the results of an Affected System Study (AFS) performed to evaluate the impact of interconnection on the Midcontinent ISO(MISO) facilities.

Table 2.1– Project Overview

Project Type	Control Area	County	Point of Interconnection (POI)	Study Sink	Summer Injection(MW)
HVDC Injection	TVA	Shelby	Shelby 500kV	TVA	3500

As shown in Figure 2-1, the study project is located in Shelby County in Tennessee.

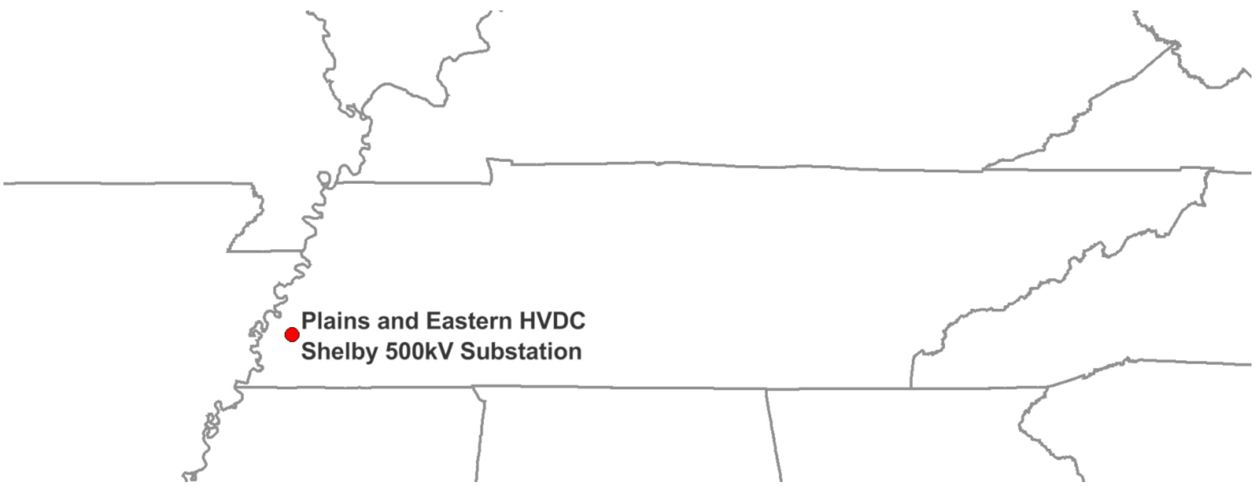

Figure 2-1 – Approximate Geographic Location

3 Steady State Analysis

3.1 Criteria Methodology and Assumptions

The objective of this AFS is to identify all adverse system impacts on the MISO transmission system as a result of the Plains & Eastern HVDC injection in TVA.

3.2 Computer Programs

Steady-state analyses were performed using PSS®E version 32.2.1 and PSS®MUST version 11.0.1.

3.3 Model Development

The starting models used for the thermal analysis were developed from the MTEP14 models with additional modification for access planning studies and used for the DPP-2014-August study. Models were created using the Model on Demand (MOD) base cases, then load and generation changes were made to represent a summer peak scenario. All approved MTEP A projects submitted to MOD with effective dates through June 1, 2017 for the near term and June1, 2024 for the Out year scenarios were applied to the models.

The injection into TVA was modeled as a generating facility at unity power factor and dispatched to the entire TVA footprint

The power flow cases were solved with transformer tap adjustment enabled, area interchange disabled, phase shifter adjustment enabled and switched shunt adjustment enabled.

3.4 Monitored Elements

The study area is defined in Table 3.1. Facilities in the study area were monitored for system intact and contingency conditions. Under NERC category A conditions (system intact) branches were monitored for loading above the normal (PSS®E rate A) rating. Under NERC category B and C conditions, branches were monitored for loading as shown in the column labeled "Post-Disturbance Thermal Limits". In addition to the criteria below, all buses with defined voltage criteria have been monitored as per their planning voltage schedules.

Table 3.1 - Monitored Elements

Owner / Area	Monitored Facilities	Thermal Limits		Voltage Limits	
		Pre-Disturbance	Post-Disturbance	Pre-Disturbance	Post-Disturbance
327 / EES & EES-EAI	69 kV and above	100% of Rate A	100% of Rate B	1.05/0.95	1.05/0.92
351 / EES & EES-EMI	69 kV and above	100% of Rate A	100% of Rate B	1.05/0.95	1.05/0.92
332 /LAGN	69 kV and above	100% of Rate A	100% of Rate B	1.05/0.95	1.05/0.92
349 /SMEPA	69 kV and above	100% of Rate A	100% of Rate B	1.05/0.95	1.05/0.92
502 /CLECO	69 kV and above	100% of Rate A	100% of Rate B	1.05/0.95	1.05/0.92
356 /AMMO	100 kV and above	100% of Rate A	100% of Rate B	1.05/0.95	1.05/0.90
357 /AMIL	100 kV and above	100% of Rate A	100% of Rate B	1.05/0.95	1.05/0.90
503 /LAFA	69 kV and above	100% of Rate A	100% of Rate B	1.05/0.95	1.05/0.92
330 /AECI	69 kV and above	100% of Rate A	100% of Rate B	1.05/0.95	1.05/0.92

3.5 Contingency Criteria

Contingency information as supplied by member of the Ad Hoc Study Group and included the following contingency files:
A variety of contingencies were considered for steady-state analysis:

- NERC Category A with system intact (no contingencies)
- NERC Category B contingencies
    - Single element outages, at buses with a nominal voltage of 69 kV and above, in areas: EES, EMI, LAGN, SMEPA, CLECO, LAFA, AECI & TVA
    - Multiple-element outages initiated by a fault with normal clearing such as multi-terminal lines.
- NERC Category C
    - Selected NERC Category C events in the study region

In addition to theabove, blanket statements were included for all single contingencies 60 kV and above for areas shown in Table 3.1.

For all contingency analyses, cases were solved with transformer tap adjustment enabled, area interchange adjustment disabled, phase shifter adjustment disabled (fixed) and switched shunt adjustment enabled

3.6 Performance Criteria

A branch is considered a thermal injection constraint if both of the following conditions are met:

1) The branch is loaded above its applicable normal or emergency rating for the post-change case, and
2) the generator has a larger than 20% DF on the overloaded facility under post contingent condition or 5% DF under system intact condition, or
3) the megawatt impact due to the generator is greater than or equal to 20% of the applicable rating (normal or emergency) of the overloaded facility, or
4) the overloaded facility or the overload-causing contingency is at generator's outlet.

A bus is considered a voltage constraint if both of the following conditions are met. All voltage constraints must be resolved before a project can receive interconnection service.

1) the bus voltage is outside of applicable normal or emergency limits for the post-change case,
   and
2) the change in bus voltage is greater than 0.01 per unit.

3.7 Thermal Analysis

The analysis did not identify any thermal injection constraints both in the near term (2017) and out year (2024) scenarios as per the above planning criteria.

3.8 Voltage Analysis

The analysis did not identify any steady state voltage constraints both in the near term (2017) and out year (2024) scenarios as per the above planning criteria.

4 Stability Analysis

Based on the steady state results and ad-hoc group agreement this set of analysis has been redacted from the study. Should the interconnection choose to submit a firm transmission service request with MISO, a stability study may need to be performed.

5 Effective Short Circuit Ratio

5.1 Introduction

The strength of the A.C. network at the bus of the HVDC substation can be expressed by the short circuit ratio (SCR), defined as the relation between the short circuit level in MVA at the HVDC substation bus at 1.0 per-unit A.C. voltage and the D.C. power in MW.

$$Short\ Circuit\ Ratio(SCR) = \frac{Short\ Circuit\ Capacity}{DC\ Power(Pdc)}$$

The capacitors and A.C. filters connected to the A.C. bus reduce the short circuit level. The expression effective short circuit ratio (ESCR) is used for the ratio between the short circuit level reduced by the reactive power of the shunt capacitor banks and A.C. filters connected to the A.C. bus at 1.0 per-unit voltage and the rated D.C. power.

$$Effective\ Short\ Circuit\ Ratio(ESCR) = \frac{Short\ Circuit\ Capacity - Capacitive\ MVAR(Qc)}{DC\ Power(Pdc)}$$

Lower ESCR or SCR means more pronounced interaction between the HVDC substation and the A.C. network. A.C. networks can be classified in the following categories according to strength

Strong systems with high ESCR: ESCR > 3.0

Systems with low ESCR: 3.0 > ESCR > 2.0

Weak systems with very low ESCR: ESCR < 2.0

In the case of high ESCR systems, changes in the active/reactive power from the HVDC substation lead to small or moderate A.C. voltage changes. Therefore the additional transient voltage control at the inverter bus is not normally required. The reactive power balance between the A.C. network and the HVDC substation can be achieved by switched reactive power elements.

In the case of low and very low ESCR systems, the changes in the A.C. network or in the HVDC transmission power could lead to voltage oscillations and a need for special control strategies. Dynamic reactive power control at the A.C. bus at or near the HVDC substation by some form of power electronic reactive power controller such as a Static Var Compensator (SVC) or Static Synchronous Compensator (STATCOM) may be necessary.

5.2 Methodology

TVA provided the sequence data for the study. The short circuit fault MVA was calculated using the Automatic Sequencing Fault Calculation (ASCC) activity in PSS/E. The following Flat conditions were used

- BUS VOLTAGES SET TO 1 PU AT 0 PHASE ANGLE
- GENERATOR P=0, Q=0
- TRANSFOMRER TAP RATIOS=1.0 PU and PHASE ANGLES=0.0
- LINE CHARGING=0.0 IN +/-/0 SEQUENCE
- LOAD=0.0 IN +/- SEQUENCE, CONSIDERED IN ZERO SEQUENCE
- LINE/FIXED/SWITCHED SHUNTS=0.0
- DC LINES AND FACTS DEVICES BLOCKED
- TRANSFORMER ZERO SEQUENCE IMPEDANCE CORRECTIONS IGNORED

As per the Interconnection Customer, the reactive compensation at the inverter station will be provided by 4 x 252 MVAR AC filters, this amount of compensation will be reduced from the short circuit levels to yield effective short circuit numbers.

5.3 Results

A 3 phase fault was applied at the Shelby 500kV bus in TVA to determine existing short circuit capacity. An additional sensitivity was performed by taking the strongest short circuit source out of service to account for prior outage conditions. The Shelby – Sans Souci 500kV line was found to be the strongest short circuit source and was taken out of service to simulate a prior outage condition. The table below summarizes the findings

Table 2.1 Short Circuit Ratios

System Condition	Prior Outage	Short Circuit Capacity (MVA)	Short Circuit Ratio	Effective Short Circuit Ratio	System Strength
N-0	None	25190	7.2	6.91	Strong system with high ESCR
N-1	Shelby – Sans Souci 500kV line	18758	5.36	5.07	Strong system with high ESCR

The effective short circuit capabilities under system intact and N-1 conditions were found to be acceptable to accommodate the injection from the HVDC facility. No additional transient voltage control devices are currently being recommended.

6 Conclusion

This report documents the affected system impact due to the interconnection of the Plains & Eastern HVDC project on the MISO Transmission system. Steady State AC analysis was performed to identify any reliability criteria violations caused by the interconnection of the study project. The analysis did not identify any constraints in both the near term (2017) and the out year (2024) scenarios.

An effective short circuit ratio calculation was performed to identify the need for transient reactive support devices and mitigate any risk of commutation failure. The effective short circuit capabilities were found to be acceptable to accommodate the injection from the HVDC facility.

No network upgrades are currently being proposed for this interconnection from an affected system perspective.