Interconnection System Impact Study

Requester: Clean Line

Shelby Option

Study Performed By:

Transmission Interconnection Engineering

March 19, 2014

[redacted]

EXECUTIVE SUMMARY

The Tennessee Valley Authority (TVA) conducted an Interconnection System Impact Study (ISIS) at the request of Clean Line to interconnect a High Voltage Direct Current (HVDC) transmission line with the maximum capability of delivering 3500 MW to the TVA system in Shelby County, Tennessee (see Appendix B).

Clean Line's interconnection request is for the unidirectional delivery of up to 3,500 MW of power into the TVA system. It has been accepted under TVA's Large Generator Interconnection Procedures (LGIP) based on the stated purpose of the interconnection request to deliver power from generating facilities connected to the Clean Line Project into the TVA system. If Clean Line expands the project to provide for bi-directional flows of power though the Clean Line Project, then (1) additional studies by TVA will be required and (2) the LGIP will no longer be the appropriate process for the interconnection of the Clean Line Project to the TVA system.

The objective of the ISIS is to identify all Adverse System Impacts on TVA's transmission system in order to maintain system reliability as a result of the Interconnection Request. The ISIS will also determine the facility additions, modifications, and upgrades that are needed to maintain a reliable interconnection.

In addition to identifying all Adverse System Impacts on the TVA transmission system, TVA monitors TVA customers and neighboring transmission systems for impacts. Entergy and MLGW have been identified as Affected Systems that are impacted as a result of the Clean Line HVDC interconnection. TVA will hold Clean Line's Interconnection Right contingent upon the completion of an Affected System Impact Study by all identified Affected Systems and the mitigation of any impacts identified by those Affected System Impact Studies.

The study included steady-state (thermal & voltage) analysis, short circuit analysis, and transient stability analysis.

- Steady-state loadflow analysis determined the need for the construction of one [redacted] transmission line, the upgrade of three [redacted] transmission lines, and the upgrade of twenty-seven [redacted] transmission lines.

- Short circuit analysis determined that the proposed interconnection did not cause any breaker duty issues on the TVA transmission system.

- Transient stability will be studied further when more detailed HVDC models are provided in the Facilities Study. No transient stability issues were noted using the generic HVDC model provided.

The study identified a need for the following system improvements:

Direct Assignment Facilities	Cost Estimate ($k)
Interconnect the HVDC lines and create a double-breaker arrangement by adding 3 bays[4], 10 breakers, 16 switches, line relays, and interchange metering at the [redacted] substation	[redacted]
Network Upgrades	
Construct [redacted] transmission line (37 miles)	[redacted]
Convert [redacted] switchyard to a double breaker arrangement (required for switchyard expansion) and construct a double breaker bay at [redacted]	[redacted]
Upgrade three [redacted] transmission lines	[redacted]
Upgrade twenty-seven [redacted] transmission lines (354.2 miles)	[redacted]
Total	[redacted]

Notes:

1. Costs based on planning level estimates (± 50%).
2. Estimated project completion time is 8 years after TVA receives authorization to begin work and the completion of the Facilities Study.
3. Clean Line will be responsible for any generation re-dispatch cost incurred by TVA as a result of the construction of any of the facilities associated with this Clean Line interconnection project. Estimated re-dispatch cost will be determined during the Facilities Study when more detailed outage schedules are developed.
4. TVA is still investigating the possibility of utilizing substation equipment which will allow the HVDC lines to be interconnected by adding 2 bays instead of 3 bays. The final interconnection arrangement will be determined during the Facilities Study.

TVA's interconnection policies require generators that interconnect to the TVA transmission system to be capable of operating at a power factor range from 0.95 leading to 0.95 lagging. The amount of dynamic MVAR injection required will be determined during the Facilities Study.

Table of Contents

Section	Description	Page
	Executive Summary	2
1.0	Introduction	5
2.0	Model Development	5
3.0	Study Criteria and Methodology	6
4.0	Study Results	7
5.0	Conclusion	12
Appendix A	Notice Regarding Transmission Planning Study Information	14
Appendix B	Interconnection Map	15
Appendix C	Interconnection Arrangement	16
Appendix D	Glossary of Terms	17

1.0 Introduction

The purpose of this ISIS is to determine all Adverse System Impacts on TVA's transmission system caused by Clean Line's Interconnection Request. This report identifies the required Network Upgrades and Direct Assignment Facilities in order to maintain the reliability of the TVA system as a result of a new interconnection in Shelby County, TN. The HVDC transmission line was only evaluated for injecting power into the TVA transmission system. Additional studies will be required to allow power to flow in the opposite direction on the HVDC transmission line.

Requester: Clean Line

Interconnection Bus	Requested In-Service Date	Interconnection Type	HVDC Capacity
[redacted]	06/01/2018	HVDC Transmission	3500 MW

2.0 Model Development

The power flow models utilized in this study originated from the Eastern Interconnection Reliability Assessment Group (ERAG) Multi-Regional Modeling Working Group (MMWG) 2010 summer series of power flow base cases. These models are created as part of the ERAG and SERC regional modeling process. The most up-to-date TVA load forecast and generation plans available at the time of case creation were used in the cases, including any projected transmission upgrades. Deviations from the normal generation dispatch may be made, if the request is found to be sensitive to local generation. All confirmed prior Interconnection Requests have priority over TVA's available transmission capacity. Offline generators that have existing Interconnection Rights on the TVA system may be dispatched at the output that was studied through the interconnection process in order to necessarily reflect those rights.

The short circuit models utilized in this study originated from the SERC Short Circuit Database Working Group (SCDWG) 2011 series of short circuit models. The most up-to-date transmission and generation plans, including prior Interconnection Requests were considered during the process of case creation.

The transient stability model utilized in this study originated from the ERAG MMWG 2009 series of dynamic base cases. The most up-to-date load forecast, transmission, and generation plans available at the time of case creation were considered in the cases, including prior Interconnection Requests.

3.0 Study Criteria and Methodology

This study was conducted consistent with TVA ISIS processes and practices. All studies performed in the ISIS are designed to meet applicable reliability standards and TVA's planning practices and procedures. Information regarding contingencies, monitored elements, generation dispatch, and load profiles evaluated in this study are provided upon request.

The analysis of the Interconnection Request was conducted using a combination of software including PTI PSS/E and PowerWorld Simulator.

Clean Line provided modeling details regarding the proposed interconnection to TVA including reactive compensation to meet TVA's 95% power factor requirement at the point of interconnection.

The interconnection arrangement used for this study can be seen in the interconnection diagram included in Appendix C of this report. Any changes to the proposed interconnection arrangement could result in the need for a new study and/or a change in the estimated costs.

4.0 Study Results

4.1 Direct Assignment Facilities

- *Interconnection*

The table below describes the necessary Direct Assignment Facilities on the TVA system in order to support the interconnection arrangement shown in Appendix C and includes cost estimates.

Direct Assignment Facilities	Cost Estimate ($k)
Interconnect the HVDC lines and create a double-breaker arrangement by adding 3 bays[1], 10 breakers, 16 switches, line relays, and interchange metering at the [redacted] substation	[redacted]
Total	[redacted]

Notes:

1. TVA is still investigating the possibility of utilizing substation equipment which will allow the HVDC lines to be interconnected by adding 2 bays instead of 3 bays. The final interconnection arrangement will be determined during the Facilities Study.

- *Fault Study*

No breaker duty issues were found on the TVA system as a result of the Interconnection Request.

4.2 Network Upgrades

- *Loadflow*

TVA has identified thermal overload violations as a result of the Clean Line HVDC transmission line interconnection. The tables below describe the violations and provide the estimated cost for necessary upgrades.

Table 1 identifies the scenarios that require the construction of the new [redacted] transmission line. The study results listed in each subsequent table following Table 1 include the construction of the [redacted] transmission line in the study cases.

Table 1: Thermal Overload Violations (Summer N-2)

Season	Contingency	Overload	Rating (MVA)	Loading % Before	Loading % After	Fix	Cost Estimate ($k)
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]		
						[redacted]	[redacted]

Notes:

1. The scenario shown is a summer N-2 case. This overload also appears in a winter N-2 and a spring N-1-1 scenario.
2. If the [redacted] transmission line is uprated to [redacted] the transmission line loading will be 105.5%.

Table 2: Thermal Overload Violations (Summer and Winter N-1)
The summer and winter N-1 study analysis included the upgrade from Table 1

Season	Contingency	Overload	Rating (MVA)	Loading % Before	Loading % After	Fix	Cost Estimate ($k)
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
						[redacted]	[redacted]

Table 3: Thermal Overload Violations (Summer and Winter N-2)
The summer and winter N-2 study analysis included upgrades from Tables 1 and 2

Season	Contingency	Overload	Rating (MVA)	Loading % Before	Loading % After	Fix	Cost Estimate (Sk)
[redacted]							

Table 4: Maintenance Thermal Overload Violations (Spring N-1-1)
The spring N-1-1 study analysis included upgrades from Tables 1, 2 and 3

Scenario	Contingency	Overload	Rating (MVA)	Loading % Before	Loading % After	Fix	Cost Estimate (Sk)
[redacted]							

Scenario	Contingency	Overload	Rating (MVA)	Loading % Before	Loading % After	Fix	Cost Estimate ($k)
[redacted]							

[redacted]

4.3 Transient Stability

TVA did not find transient stability issues using the generic HVDC model provided. However, it was found that transient stability can be sensitive to certain HVDC parameters. Voltage oscillations can be initiated for certain faults on TVA's system when a parameter is adjusted slightly.

As a result, TVA is delaying the transient stability portion of the ISIS and will perform the analysis during the Facilities Study. Clean Line will be required to provide more detailed HVDC models at that time in order for TVA to complete the transient stability analysis. Any Network Upgrades identified as a result of the transient stability analysis will be provided to Clean Line in the course of the Facilities Study.

4.4 Project Schedule

The estimated completion time for all projects identified by this ISIS is 8 years after TVA receives authorization to begin work and the completion of the Facilities Study. The completion date will be determined by the construction of the [redacted] transmission line project.

Subject to (a) the completion of all required studies, (b) execution of an appropriate interconnection agreement, and (c) the completion of all TVA and Clean Line facilities (including the direct assignment facilities identified in this study) required for a safe and reliable interconnection, the Clean Line Project may be able to interconnect to the TVA system prior to the completion of all the Network Upgrades identified by this study; provided, however, that no such interconnection shall occur without the prior approval of TVA. The interconnection of the Clean Line Project to the TVA system shall at all times be in accordance with the terms and conditions of the interconnection agreement.

5.0 Conclusion

In conclusion, the identified Direct Assignment Facilities and Network Upgrades on the TVA transmission system (as shown below) are required in order for Clean Line to permanently interconnect the HVDC transmission line capable of delivering 3500 MW to the TVA transmission system.

Direct Assignment Facilities	Cost Estimate ($k)
Interconnect the HVDC lines and create a double-breaker arrangement by adding 3 bays[4], 10 breakers, 16 switches, line relays, and interchange metering at the [redacted] substation	[redacted]
Network Upgrades	
Construct [redacted] transmission line (37 miles)	[redacted]
Convert [redacted] switchyard to a double breaker arrangement (required for switchyard expansion) and construct a double breaker bay at [redacted]	[redacted]
Upgrade three [redacted] transmission lines	[redacted]
Upgrade twenty-seven [redacted] transmission lines (354.2 miles)	[redacted]
Total	[redacted]

Notes:

1. Costs based on planning level estimates (± 50%).
2. Estimated project completion time is 8 years after TVA receives authorization to begin work and the completion of the Facilities Study.
3. Clean Line will be responsible for any generation re-dispatch cost incurred by TVA as a result of the construction of any of the facilities associated with this Clean Line interconnection project. Estimated re-dispatch cost will be determined during the Facilities Study when more detailed outage schedules are developed.
4. TVA is still investigating the possibility of utilizing substation equipment which will allow the HVDC lines to be interconnected by adding 2 bays instead of 3 bays. The final interconnection arrangement will be determined during the Facilities Study.

In addition to identifying all Adverse System Impacts on the TVA transmission system, TVA monitors TVA customers and neighboring transmission systems for impacts. Entergy and MLGW have been identified as Affected Systems that are impacted as a result of the Clean Line HVDC interconnection. TVA will hold Clean Line's Interconnection Right contingent upon the completion of an Affected System Impact Study by all identified Affected Systems and the mitigation of any impacts identified by those Affected System Impact Studies.

If Clean Line decides to pursue a Facilities Study consistent with TVA's LGIP, TVA will conduct the Facilities Study at the requester's expense. All costs in this report are planning estimates; however, the requester is responsible for actual installed costs of the required system upgrades.

This study only evaluates the impacts of interconnecting Clean Line's HVDC Line to the TVA transmission system. Transmission service may be requested from TVA in accordance with TVA's Transmission Service Guidelines to transfer power from Clean Line's HVDC Line. However, no service will be granted until an Interconnection Agreement (which will provide only for the interconnection of Clean Line's HVDC Line

to the TVA transmission system and will not in any way guarantee the ability of the transmission system to deliver, transmit, or otherwise transfer power from the HVDC Line) has been executed and all TVA and Clean Line facilities (including the direct assignment facilities identified in this study) required for a safe and reliable interconnection have been completed. Further, until such time that the Network Upgrades identified by this study have been completed, TVA may limit the availability of such transmission service.

Additional studies specific to HVDC transmission will be performed during the Facilities Study. These studies include, but are not limited to, subsynchronous torsional analysis, AC system harmonic analysis, and detailed power quality studies.

TVA's interconnection policies require generators that interconnect to the TVA transmission system to be capable of operating at a power factor range from 0.95 leading to 0.95 lagging. The amount of dynamic MVAR injection required will be determined during the Facilities Study.

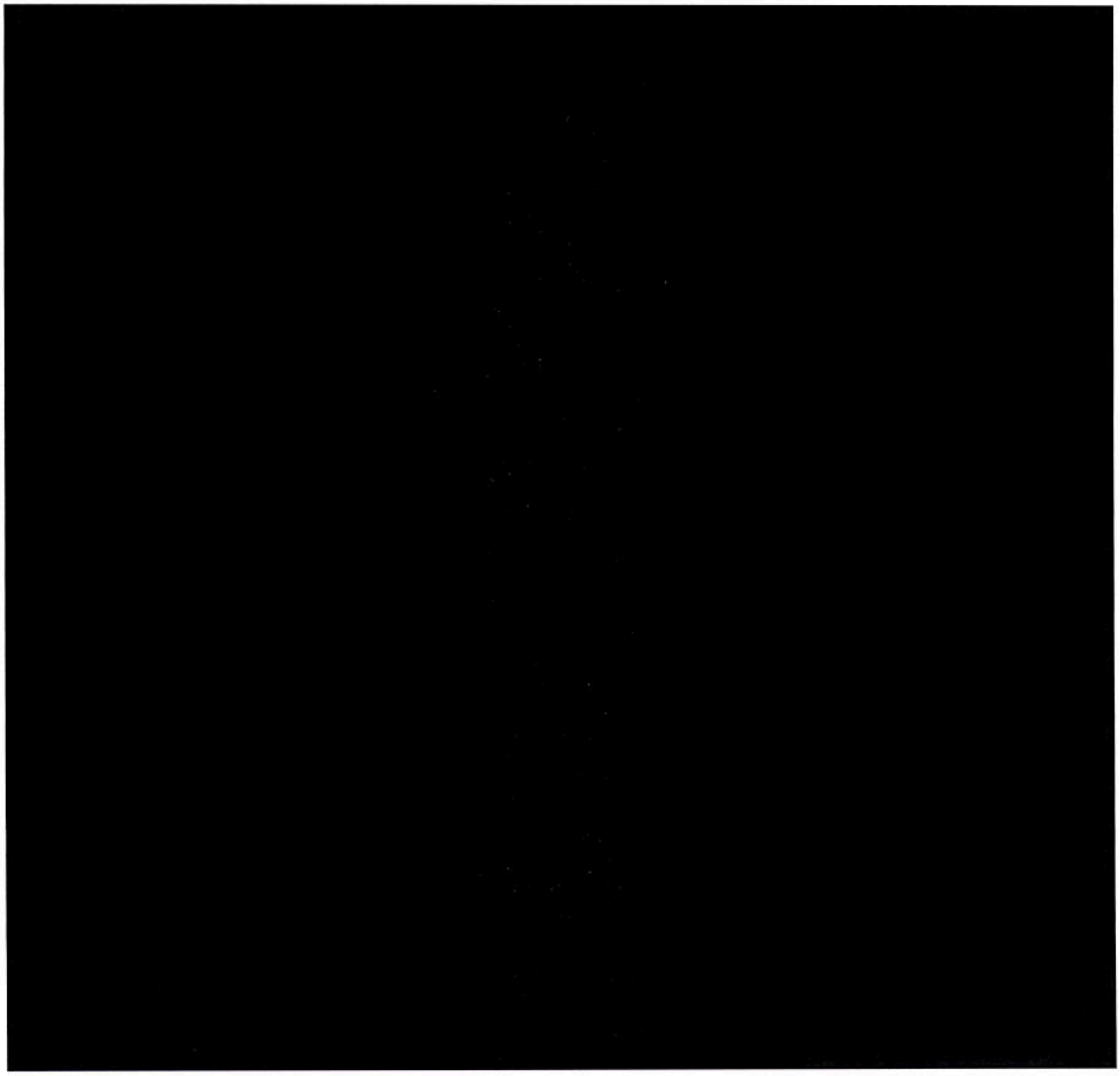
Appendix A: Notice Regarding Transmission Planning Study Information

This information has been derived utilizing power flow models of projected future system conditions. These planning models incorporate many assumptions concerning loads, transmission system configuration, generation dispatch, firm transactions, and other information pertinent to building power flow models. TVA uses available information about transmission and generation additions and upgrades that may subsequently change. The system models external to TVA were either obtained from the applicable control area, or from the most recent SERC base cases. TVA is not responsible for the information provided by others in the development of these models. The cases represent TVA's best effort in developing power flow models for use within TVA as a starting point for interconnection studies, at the point in time when the analysis is done. TVA retains the right to update the models as additional information becomes available or as additional possible scenarios are needed. The decision to use the study or underlying assumptions for any particular purpose other than to obtain the requested Interconnection Rights is the sole responsibility of the user.

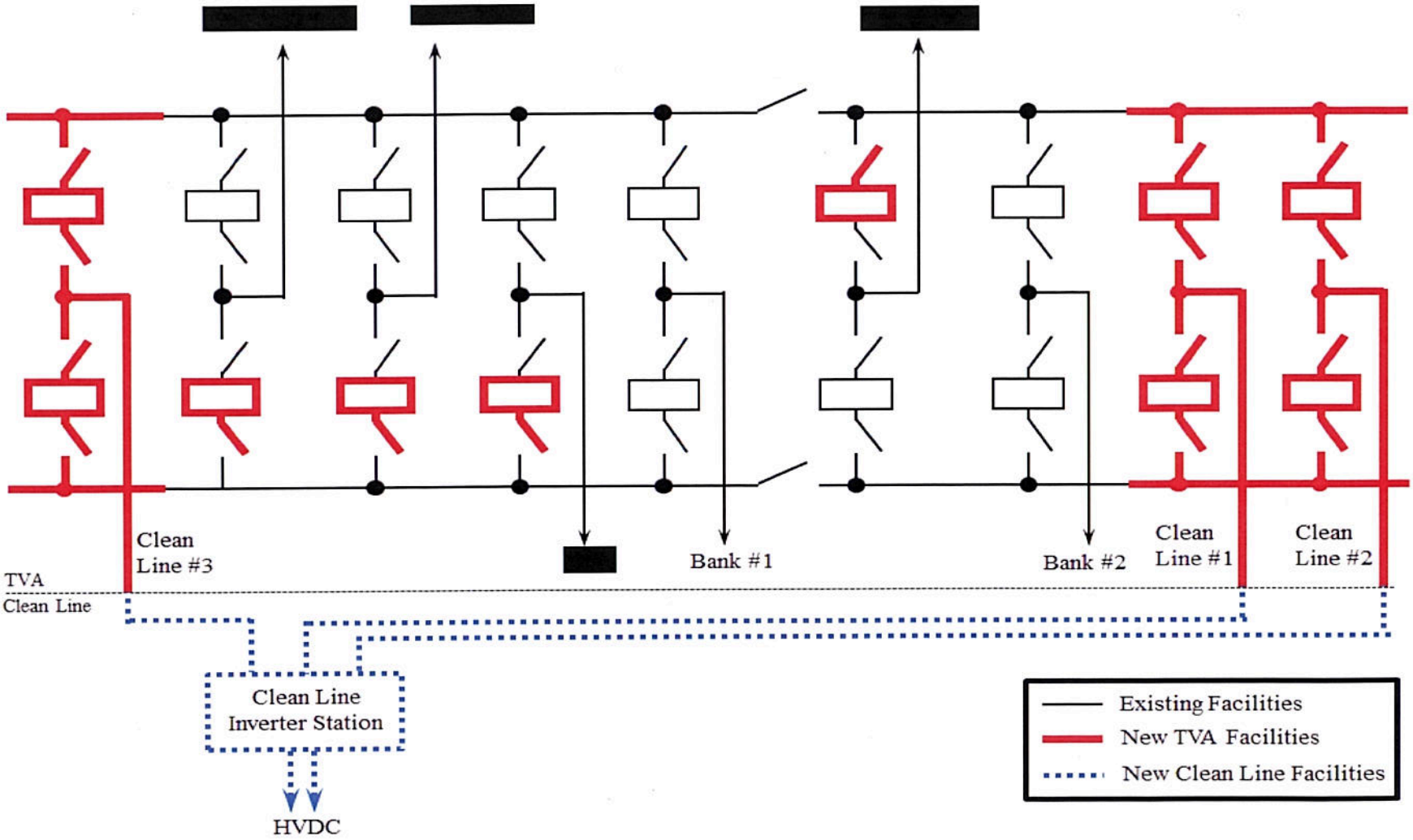
Scheduling and cost estimates provided in this report do not include time or money to resolve unforeseen issues such as those that may be identified during TVA's review of environmental impacts as required by the National Environmental Policy Act (NEPA).[i]

[i] TVA is a cooperating agency in the Environmental Impact Statement being prepared by the Department of Energy. It anticipates tiering from this EIS when it is completed to other environmental reviews that TVA would undertake to support projects on its system.

Appendix B: Interconnection Map



Appendix C: Interconnection Arrangement ([redacted] Switchyard)



Appendix D: Definitions

Glossary of Terms

Adverse System Impact - The negative effects due to technical or operational limits on conductors or equipment being exceeded that may compromise the safety and reliability of the electric system.

Affected System - An electric system other than TVA's transmission system that may be affected by the proposed interconnection.

Direct Assignment Facility - Any additions, modifications, or upgrades that are necessary to physically and electrically interconnect the specified Generating Facility, and are solely for the benefit of the specified Generating Facility.

ERAG – Eastern Interconnection Reliability Assessment Group

Facilities Study - Process in which TVA (with input from requester) further refines project scope, schedule and cost estimates (± 20%).

Generating Facility - Interconnection Customer's device for the production of electricity identified in the Interconnection Request, but not including the Interconnection Customer's Interconnection Facilities.

HVDC - High Voltage Direct Current

Interconnection Customer - Any entity, including TVA, that proposes to interconnect its Generating Facility with TVA's transmission system.

Interconnection Facilities - All facilities and equipment between the Generating Facility and the Point of Interconnection, as well as any other modifications, additions or upgrades that are necessary to physically and electrically interconnect the Generating Facility to TVA's Transmission System. Interconnection Facilities are sole use facilities and shall not include Network Upgrades.

In-Service Date - The date upon which the Interconnection Customer reasonably expects it will be ready to begin use of TVA's Interconnection Facilities to obtain back feed power.

Interconnection Request - An Interconnection Customer's request, to interconnect a new Generating Facility, or to increase the capacity of, or make a material modification to the operating characteristics of, an existing Generating Facility that is interconnected with TVA's transmission system.

Interconnection Right - A right to interconnect a specified Generating Facility into TVA's transmission system, contingent upon completion of all required system additions, modifications, and upgrades to accommodate the maximum capacity of the specified Generating Facility.

ISIS – Interconnection System Impact Study

MMWG – Multi-Regional Modeling Working Group

NERC - North American Electric Reliability Corporation or its successor organization.

Network Upgrades - Any additions, modifications, and upgrades that are required to accommodate the specified Generating Facility, and to enhance either the capacity or the reliability of TVA's transmission system.

SCDWG – Short Circuit Database Working Group

SERC – SERC Reliability Corporation - a regional entity with delegated authority from NERC for the purpose of proposing and enforcing reliability standards.