Interconnection System Impact Study

Requester: [redacted]

#517 – [redacted]

Study Performed By:

Interconnection Planning & Special Studies and
PowerGrid Engineering

FINAL

May 4, 2023

CRITICAL ENERGY INFRASTRUCTURE INFORMATION (CEII)
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Executive Summary

The Tennessee Valley Authority (TVA) conducted a System Impact Study (SIS) at the request of [redacted] to interconnect a Solar Generating + BESS Facility with a maximum generating capability of 120 MW (net) to the TVA system in Graves County, KY (see Appendix B). The BESS is grid-charge capable and was studied as both a generator (discharging) and as a load (charging).

The objective of the SIS 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 SIS 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 its Local Power Companies (LPCs) as well as neighboring transmission systems for impacts. Big Rivers Electric Cooperative (BREC) and the U.S. Army Corps of Engineers (USACE) were identified as Potentially Affected Systems as a result of the proposed interconnection. TVA will hold TVA Generation's Interconnection Right contingent upon the completion of an Affected System Impact Study by the identified Affected Systems and the mitigation of any impacts identified by the Affected System Impact Studies.

The SIS was performed with and without prior requesters within the local study area. Prior requester queue numbers include: Q292, Q299, Q337, Q342, Q401, Q426, Q430, Q453, Q469, Q473, Q476, Q483, Q488, Q500, Q503, Q510, Q511, AS053, AS056, and AS057.

This Study utilized a recent change in TVA's inclusion of priors in the local area for thermal and stability analysis. The SIS was performed with consideration to scenarios with and without prior requesters within the local study area. There were no prior queued facilities that fell within the study area for steady-state, reactive power, or stability analysis. Priors listed above were included for breaker duty analysis.

With & Without Priors

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

- Steady-state loadflow analysis determined that the proposed interconnection will cause thermal violations on the TVA transmission system. See Section 4.1.2.1 of this report for more details.
- Short circuit analysis determined that the proposed interconnection did not result in any breaker duty issues on the TVA transmission system.
- Transient stability analysis determined that the proposed interconnection did not cause any new transient stability issues on the TVA transmission system.
- Initial evaluation of the reactive capability requirement of a 95% power factor (injecting and absorbing) at the Point of Interconnection (POI) did not identify the need for additional reactive support.

The study identified a need for the following system improvements:

Table ES-1: Direct Assignment Facilities & Required Network Upgrades With & Without Priors

Direct Assignment Facilities	Cost Estimate ($k)
Provide new 161-kV three position ring bus station on the existing Paris-Mayfield 161-kV line. Provide generation meters, associated instrument transformers, and required communications path. Includes needed system protection upgrades for required transfer trip and pilot protection.	[redacted]
Provide communications equipment for required transfer trip and SCADA at new Generating Facility.	[redacted]
System protection and communications work at remote sites for pilot protection and communications path. (Paris & Mayfield).	[redacted]
Configuration and testing of communications interface with TVA SCADA system for remote control and/or curtailment of generator real power output.	[redacted]
Network Upgrades	
Various 161 kV system upgrades including jumpers, breakers and other station equipment.	[redacted]
Installation of fiber on the Paris-Mayfield 161 kV transmission line (31.7 miles) and fiber equipment for required system protection.	[redacted]
Total	[redacted]

Notes:

1. Costs provided for SIS are based on planning level estimates (±50%).
2. Typical project completion time for this scope of work is approximately 5 years after the completion of the Facilities Study and TVA receives authorization to begin work; however, a refined project schedule will be developed during the Facilities Study.
3. [redacted] is responsible for the construction and cost of the 161 kV TL and fiber path needed between the solar + storage facility and the TVA POI, built to TVA's specifications.

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1.0 Introduction

The purpose of this SIS is to determine all Adverse System Impacts on TVA's transmission system caused by the [redacted] 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 Graves County, KY.

Table 1-1: Requester [redacted]

Interconnection Location	Number of Units	Gross AC Max Capacity
Paris - Mayfield 161 kV Line (L5252)	155 PV inverters + 45 BESS inverters	167.9 MVA / 153.7 MW
POI Coordinates	**Requested ISD**	**Net AC Max Capacity**
36.637469, -88.541235	6/15/2026	120 MW

* Based on the estimated project completion timeline, it is unlikely that the Interconnection Customer's Requested ISD will be achievable. A more refined project schedule will be completed during the Facilities Study process, should the Interconnection Customer elect to proceed.

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), and the SERC Long Term Working Group (LTWG) 2022 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) 2021 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 used in this study was based on the most recent SERC dynamically reduced base cases which were created in 2021. 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. In addition to summer peak loads, other demand levels were considered such as shoulder peak and light load. However, impacts due to FIDVR are most significant under summer peak conditions.

A notice concerning assumptions made in the model development process is contained in Appendix A.

3.0 Study Criteria and Methodology

This study was conducted consistent with TVA SIS processes and practices. All studies performed in the SIS 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, PowerWorld Simulator, and PowerGEM TARA.

[redacted] provided modeling details regarding the proposed interconnection to Transmission Planning.

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

The following sections summarize the facilities required for the interconnection based on the results of steady state, short circuit, stability, power quality, and reactive power studies.

4.1 With & Without Prior Requesters

4.1.1 Direct Assignment Facilities

4.1.1.1 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.

Table 4-1: Direct Assignment Facilities With & Without Priors

Direct Assignment Facilities	Cost Estimate ($k)
Provide new 161-kV three position ring bus station on the existing Paris-Mayfield 161-kV line. Provide generation meters, associated instrument transformers, and required communications path. Includes needed system protection upgrades for required transfer trip and pilot protection.	[redacted]
Provide communications equipment for required transfer trip and SCADA at new Generating Facility.	[redacted]
System protection and communications work at remote sites for pilot protection and communications path. (Paris & Mayfield).	[redacted]
Configuration and testing of communications interface with TVA SCADA system for remote control and/or curtailment of generator real power output.	[redacted]
[redacted]	[redacted]

Notes:

1. Costs provided for SIS are based on planning level estimates (±50%).
2. Typical project completion time for this scope of work is approximately 5 years after the completion of the Facilities Study and TVA receives authorization to begin work; however, a refined project schedule will be developed during the Facilities Study.
3. [redacted] s responsible for the construction and cost of the 161 kV TL and fiber path needed between the solar + storage facility and the TVA POI, built to TVA's specifications.

4.1.1.2 Fault Study

The short circuit analysis determined that the proposed interconnection will not cause any breaker duty issues on the TVA transmission system.

4.1.1.3 System Protection

Dual digital pilot protection on the Paris-Q517 POI 161-kV TL and on the Q517 POI-Mayfield 161-kV TLs will be required for interconnection. Transfer trip protection will be required from the Q517 POI station to the Generating Facility. TVA reserves the right to

disconnect the Generating Facility for loss of communications between the Q517 POI station and the Generating Facility. Additionally, transfer trip will be sent from the Q517 POI station to Paris and Mayfield for breaker failure scenarios.

The planning level assumption is that a single fiber path is adequate for pilot protection. During the Facilities Study, a full pilot study will be performed and the need for redundant fiber paths may be identified.

4.1.1.4 Power Quality

TVA will require the Generating Facility to meet harmonic limits of IEEE 519, flicker limits of IEEE 1453, and unbalance limits of IEC 61000-3-13 at the metering point. The power quality of the Generating Facility will be monitored by the meter installed under the Direct Assignment Facilities of this Interconnection. If the power quality does not meet IEEE 519, IEEE 1453, or IEC 61000-3-13 then TVA reserves the right to disconnect the Generating Facility. A TVA-owned PQ relay may be required to trip for harmonic voltage distortion and/or excessive harmonic currents. Specific details including time delay settings will be outlined in the interconnection agreement.

Preliminary harmonic studies revealed that the Q517 project does have the potential to cause significant harmonic voltage distortion at the Paris substation or the Mayfield substation. Prior to signature of an Interconnection Agreement, TVA will evaluate the need to require harmonic injection limits that are more stringent than IEEE 519.

TVA calculated the Short Circuit Ratio (SCR) to be 5.94 at the POI with the strong source out using the traditional calculation method. TVA requires mitigation in the form of a new transmission line if the SCR at the POI is below 3.0. No mitigation is needed at this SCR.

TVA analysis shows voltage dips of approximately 6.2% that occur during transformer energization. TVA will not allow voltage dips over 5% of the nominal voltage (161 kV) during transformer energization. Special mitigation (i.e. enhanced high-side breaker) will be required to limit the energization voltage sag below 5%. Additionally, a control scheme must be implemented and configured to not allow any 34.5 kV feeder to be connected when its transformer is energized. This control scheme will allow no more than one 34.5 kV feeder at a time to be energized at a given time after the main GSU is energized.

Following construction of the interconnecting facilities, TVA will require [redacted] to set their inverters such that they remain connected during defined frequency and voltage excursions. Exact settings will be documented in the interconnection agreement.

4.1.1.5 Transient Stability

Transient stability analysis determined that the proposed interconnection has no detrimental impact on the stability of the TVA transmission system.

4.1.1.6 Reactive Power Capability and Voltage Control

In compliance with FERC Order No. 827, nonsynchronous generators are required to provide dynamic reactive power to ensure 95% power factor (injecting and absorbing) at the generator bus. TVA enforces FERC Order No. 827 and requires 95% power factor (injecting and absorbing) operation at the POI. Static capacitors may be used only to compensate for system losses between the generator bus and the POI. Therefore, TVA will evaluate the dynamic power capability at the generator bus and also confirm that the 95% power factor (injecting and absorbing) is able to be met at the POI.

Please see the following table for utilized model parameters based on the Interconnection Request.

Table 4-2: Reactive Power Evaluation With & Without Priors (PV Only)

At Generator				At POI			Additional Reactive Power Needed
MW	MVA	Operating PF	MVAR	MW (injecting)	MVAR (injecting)	MVAR Needed	MVAR
121.4	129.6	0.95	45.3	120.0	65.0	40.0	0

Table 4-3: Reactive Power Evaluation With & Without Priors (BESS Only)

At Generator				At POI			Additional Reactive Power Needed
MW	MVA	Operating PF	MVAR	MW (injecting)	MVAR (injecting)	MVAR Needed	MVAR
30.3	36.45	0.95	20.25	30.0	53.5	10.0	0

The reactive power requirement was met under injecting and absorbing conditions provided that the customer-specified 30 MVAR capacitor bank is installed as planned.

The installed inverters must be capable of controlling voltage. Voltage control capability may not be enabled, but is required for interconnection.

In accordance with NERC guidance, TVA asks that [redacted] designs the inverter controls such that momentary cessation of current injection is avoided.

4.1.2 Network Upgrades

Table 4-4: Network Upgrades With & Without Priors

Network Upgrades	
Various 161 kV system upgrades including jumpers, breakers and other station equipment.	[redacted]
Installation of fiber on the Paris-Mayfield 161 kV transmission line (31.7 miles) and fiber equipment for required system protection.	[redacted]
Total	[redacted]

Notes:

1. Costs provided for the System Impact Study are based on planning level estimates (±50%).
2. Typical project completion time for this scope of work is approximately 5 years after the completion of the Facilities Study and TVA receives authorization to begin work; however, a refined project schedule will be developed during the Facilities Study.
3. [redacted] is responsible for the construction and cost of the 161 kV TL and fiber path needed between the solar + storage facility and the TVA POI, built to TVA's specifications.

4.1.2.1 Loadflow

Steady-state loadflow analysis determined that the proposed interconnection will cause thermal violations on the TVA transmission system.

Table 4-5: Thermal Overload Violations With & Without Priors

Season	Contingency	Overload	Rating (MVA)	Loading % Before	Loading % After	Fix	Cost Estimate ($k)
Spring	Marshall #2 – N. Star Tap 161 kV + Marshall #1 – Calvert 161 kV	Livingston – Barkley HP 161 kV (BREC tie line)	319.0	100.0%(1)	103.8%(1)	Preliminary USACE scope: Replace breaker, switch, trap, CT, and secondary devices at Barkley HP to 2700A minimum. TVA scope – implement relay settings and update drawings.	[redacted]
Spring	Marshall #2 – N. Star Tap 161 kV + Marshall #1 – Calvert 161 kV	Livingston – Marshall #1 161 kV (BREC tie line)	319.0	100.0%(1)	104.5%(1)	TVA scope: Replace jumper at Marshall to 1800A minimum.	[redacted]

1. Barkley terminal is owned by the US Army Corps of Engineers (USACE). Scope of work listed is based on the best available information to which TVA has access. Coordination with the USACE will be necessary to fully define the scope.
2. Livingston terminal is owned by BREC. Coordination with BREC will be necessary to identify any limiting elements that BREC must upgrade for the overload.

4.2 Project Schedule

Typical project completion time for this scope of work is approximately 5 years after the completion of the Facilities Study and TVA receiving authorization to begin work. Based on this estimated timeline, it is unlikely that Interconnection Customer's Requested In-Service Date is achievable; however, a refined project schedule will be developed during the Facilities Study, should the Interconnection Customer elect to proceed.

The interconnection of this [redacted] project to the TVA system shall at all times be in accordance with the terms and conditions of the interconnection agreement. Subject to (a) the completion of all required studies, (b) execution of an appropriate interconnection agreement, and (c) the completion of all TVA and [redacted] facilities (including the direct assignment facilities identified in this study) required for a safe and reliable interconnection, no such interconnection shall occur without the prior approval of TVA.

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 [redacted] LLC. to interconnect the [redacted] 120 MW (net) generating facility to the TVA transmission system.

With & Without Priors

Table 5-2: Direct Assignment Facilities & Required Network Upgrades With & Without Priors

Direct Assignment Facilities	Cost Estimate ($k)
Provide new 161-kV three position ring bus station on the existing Paris-Mayfield 161-kV line. Provide generation meters, associated instrument transformers, and required communications path. Includes needed system protection upgrades for required transfer trip and pilot protection.	[redacted]
Provide communications equipment for required transfer trip and SCADA at new Generating Facility.	[redacted]
System protection and communications work at remote sites for pilot protection and communications path. (Paris & Mayfield).	[redacted]
Configuration and testing of communications interface with TVA SCADA system for remote control and/or curtailment of generator real power output.	[redacted]
Network Upgrades	
Various 161 kV system upgrades including jumpers, breakers and other station equipment.	[redacted]
Installation of fiber on the Paris-Mayfield 161 kV transmission line (31.7 miles) and fiber equipment for required system protection.	[redacted]
[redacted]	[redacted]

Notes:

1. Costs provided for SIS are based on planning level estimates (±50%).
2. Typical project completion time for this scope of work is approximately 5 years after the completion of the Facilities Study and TVA receives authorization to begin work; however, a refined project schedule will be developed during the Facilities Study.
3. [redacted] responsible for the construction and cost of the 161 kV TL and fiber path needed between the solar + storage facility and the TVA POI, built to TVA's specifications.

In addition to identifying all Adverse System Impacts on the TVA transmission system, TVA monitors its Local Power Companies (LPCs) as well as neighboring transmission systems for impacts. BREC and USACE were identified as Potentially Affected Systems as a result of the proposed interconnection. TVA will hold TVA Generation's Interconnection Right contingent upon the completion of an Affected System Impact Study by the identified Affected Systems and the mitigation of any impacts identified by the Affected System Impact Studies.

TVA will require the Generating Facility to meet harmonic limits of IEEE 519, flicker limits of IEEE 1453, and unbalance limits of IEC 61000-3-13 at the metering point. The power quality of the Generating Facility will be monitored by the meter installed under the Direct Assignment Facilities of this Interconnection. If the power quality does not meet

IEEE 519, IEEE 1453, or IEC 61000-3-13 then TVA reserves the right to disconnect the Generating Facility. A TVA-owned PQ relay may be required to trip for harmonic voltage distortion and/or excessive harmonic currents. Specific details including time delay settings will be outlined in the interconnection agreement.

Preliminary harmonic studies revealed that the Q517 project does have the potential to cause significant harmonic voltage distortion at the Paris substation or the Mayfield substation. Prior to signature of an Interconnection Agreement, TVA will evaluate the need to require harmonic injection limits that are more stringent than IEEE 519.

TVA calculated the Short Circuit Ratio (SCR) to be 5.94 at the POI with the strong source out using the traditional calculation method.

TVA analysis shows voltage dips of approximately 6.2% that occur during transformer energization. TVA will not allow voltage dips over 5% of the nominal voltage (161 kV) during transformer energization. Special mitigation (i.e. pre-insertion resistance) will be required to limit the energization voltage sag below 5%. A control scheme will be required to be implemented and configured to not allow any 34.5 kV feeder to be connected when its transformer is energized. This control scheme will allow no more than one 34.5 kV feeder at a time to be energized at a given time after its GSU is energized.

Following construction of the interconnecting facilities, TVA will require [redacted] to set their inverters such that they remain connected during defined frequency and voltage excursions. Exact settings will be documented in the interconnection agreement.

Transient stability analysis determined that the proposed interconnection has no detrimental impact on the stability of the TVA transmission system.

This SIS only evaluates the impacts of interconnecting [redacted] to the TVA transmission system. Transmission service may be requested from TVA in accordance with TVA's Transmission Service Guidelines to transfer power from the solar project. However, if transmission service is available, service will be contingent on an Interconnection Agreement (which will provide only for the interconnection of the project 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 project) being executed and all TVA and [redacted] (including the direct assignment facilities identified in this study) required for a safe and reliable interconnection being completed.

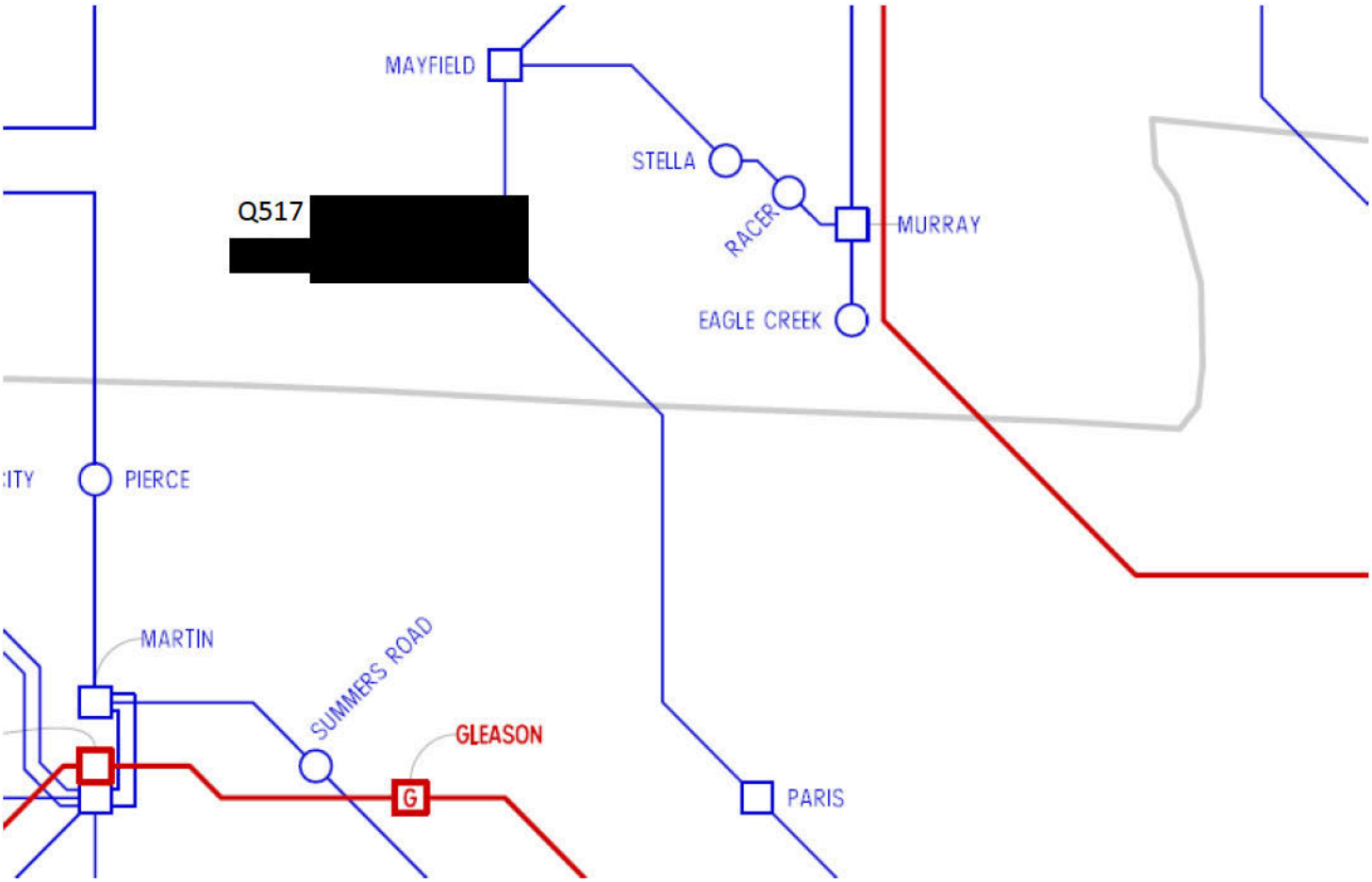
If [redacted] decides to pursue a Facilities Study for [redacted] TVA will conduct the Facilities Study consistent with TVA's LGIP and at the requester's expense. All costs in this report are planning estimates; however, the requester is responsible for actual installed costs of the required system upgrades.

Appendix A: Notice Regarding Transmission Planning Study Information

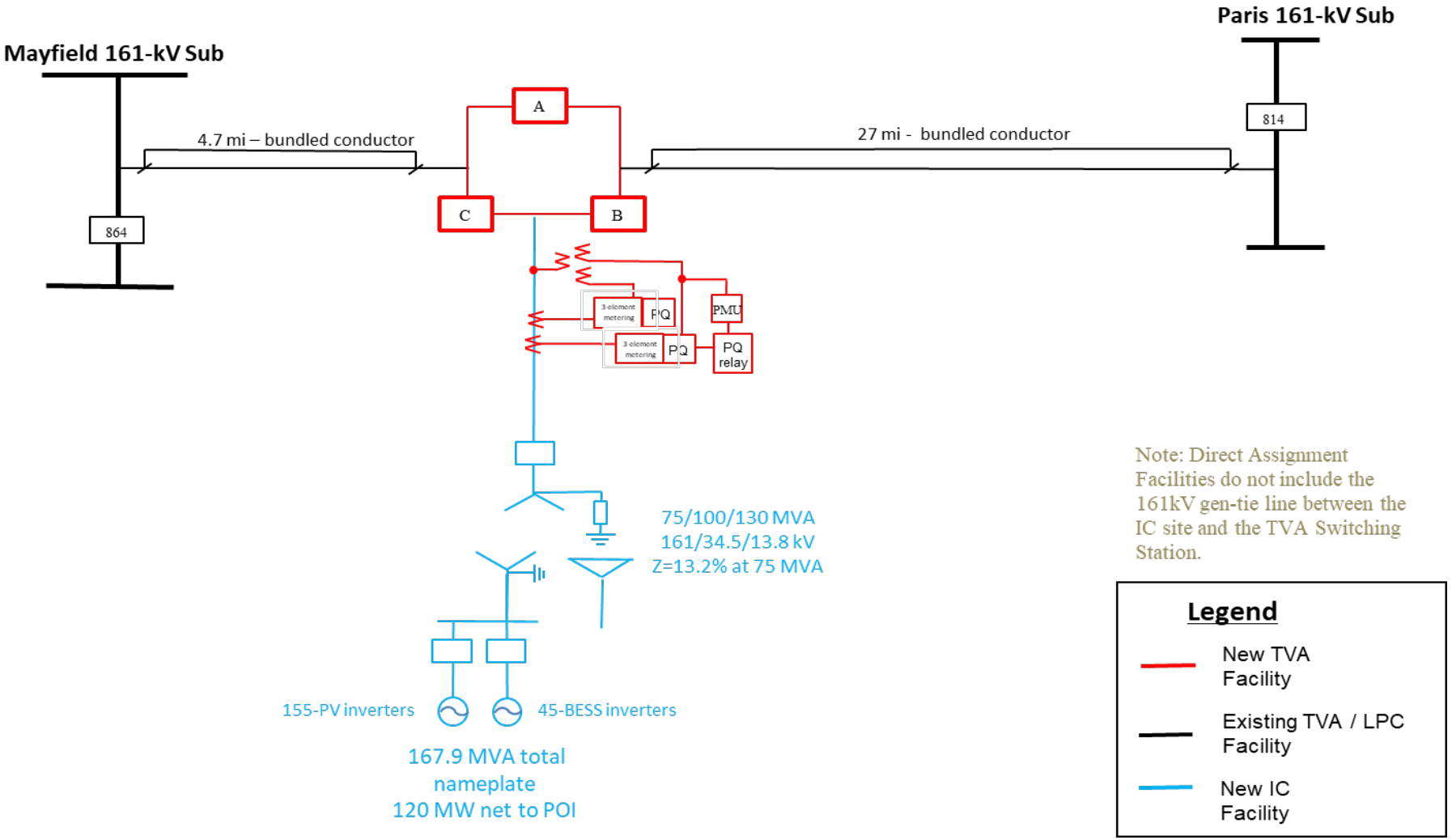
This information has been derived utilizing power flow models of projected future system conditions. These planning models incorporate many assumptions concerning loads, transmission system configuration, generation dispatch, firm transactions, and other information pertinent to building power flow models. 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).

Appendix B: Interconnection Map



Appendix C: Interconnection Arrangement With & Without Priors



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.

Direct Transfer Trip (DTT) – Used by TVA to provide remote primary protection for power equipment or remote backup protection for a failed breaker.

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.

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.

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.

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.

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.

SIS – System Impact Study