STAFF DR 1-16:

Refer to the Application, Effect on Kentucky Electricity Generation System at 15. Provide a copy of the most recent Tennessee Valley Authority (TVA) Feasibility Study Report and System Impact Study Report.

Response: TVA indicated they would provide redacted versions of the Feasibility Study and System Impact Study Reports. Dogwood Corners will submit these reports as soon as TVA provides them.

Supplemental Response (2/22/2024): Dogwood Corners is attaching the System Impact Study reports, which are being filed in conjunction with a Petition for Confidential Treatment.

Witness: Megan Stahl

,

Interconnection System Impact Study

Requester: [redacted]

#453 – Dogwood Solar

Study Performed By:

Interconnection Planning & Special Studies

FINAL – Rev 2

REDACTED

Revision 2 - June 23, 2022
Revision 1 - December 21, 2021
Original - March 12, 2021

CRITICAL ENERGY INFRASTRUCTURE INFORMATION (CEII)
CONFIDENTIAL
BUSINESS SENSITIVE

Executive Summary

The Tennessee Valley Authority (TVA) conducted an Interconnection System Impact Study (SIS) at the request of [redacted] to interconnect a solar Generating Facility with a maximum generating capability of 125 MW (net) to the TVA system in Christian County, KY (see Appendix B).

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. [redacted] was identified as Potentially Affected Systems as a result of the proposed interconnection.

The SIS was performed with and without prior requesters within the local study area. Prior requester queue numbers include: Q364, 388, 395, 401, 417, 426, 441, and 448.

Revision 1 is issued due to a change in TVA's inclusion of priors in the local area for thermal and stability analysis. The revised SIS was performed with consideration to scenarios with and without prior requesters within the local study area. No prior queued facility falls within the study area for steady-state or stability analysis. Priors listed above were included for the breaker duty analysis. Additionally, a correction was made to the reactive power analysis in Section 4.1.1.6.

Revision 2 is issued due to provide clarification and additional details to Section 4.1.1.4 Power Quality related to transformer energization and to harmonic distortion.

<u>With and Without Priors</u>

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 not cause thermal violations on the TVA transmission system.

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

- Transient stability analysis determined that the proposed interconnection will not cause any new transient stability issues on the TVA transmission system.

- The evaluation of the reactive capability requirement of a 95% power factor (injecting and absorbing) at the Point of Interconnection (POI) identified the need for additional reactive support. Details are in section 4.1.1.6, including the method of mitigation chosen by Oriden.

The study identified a need for the following system improvements:

Table ES-1: Direct Assignment Facilities & Required Network Upgrades

Direct Assignment Facilities	Cost Estimate ($k)
Provide new 161-kV three position ring bus station (Q453 POI) on the existing Hopkinsville – Lost City 161 kV line as shown in Appendix C. Provide generation meter, associated instrument transformers, PMU, and PQ relay. Includes needed system protection upgrades for required transfer trip and pilot protection.	[redacted]
Provide communications equipment for required transfer trip, AGC, and SCADA at new Generating Facility.	[redacted]
System protection and communications work at remote sites for pilot protection and communications path (Hopkinsville and Lost City)	[redacted]
Network Upgrades	
None.	[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 [redacted] 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.

Table of Contents

Executive Summary 2
1.0 Introduction 5
2.0 Model Development 5
3.0 Study Criteria and Methodology 6
4.0 Study Results 7
4.1 With and Without Prior Requesters 7
4.1.1 Direct Assignment Facilities 7
4.1.1.1 Interconnection 7
4.1.1.2 Fault Study 7
4.1.1.3 System Protection 7
4.1.1.4 Power Quality 8
4.1.1.5 Transient Stability 8
4.1.1.6 Reactive Power Capability and Voltage Control 8
4.1.2 Network Upgrades 9
4.3 Project Schedule 9
5.0 Conclusion 10
Appendix A: Notice Regarding Transmission Planning Study Information 12
Appendix B: Interconnection Map 13
Appendix C: Interconnection Arrangement 14
Appendix D: Definitions 15

List of Tables

Table ES-1: Direct Assignment Facilities & Required Network Upgrades 3
Table 1-1: Requester Oriden LLC 5
Table 4-1: Direct Assignment Facilities 7
Table 4-2: Reactive Power Evaluation 9
Table 5-1: Direct Assignment Facilities & Required Network Upgrades 10

1.0 Introduction

The purpose of this SIS is to determine all Adverse System Impacts on TVA's transmission system caused by the Dogwood Solar 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 Christian County, KY.

Table 1-1: Requester Oriden LLC

Interconnection Location	Requested ISD	Number of Units	Gross AC Max Capacity	Net AC Max Capacity
Hopkinsville – Lost City 161 kV TL	10/01/2023	36 inverters	151.2 MVA / 143.6 MW	125.0 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) 2020 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) 2020 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 with an updated TVA system model. Studies were performed using a 2030 Summer Peak base case and a 2021 Light Load base case. Since induction load models were used in the stability study, any FIDVR issues caused by the proposed generation were also studied.

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 Appendices C & D 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, and stability studies.

4.1 With and 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

Direct Assignment Facilities	Cost Estimate ($k)
Provide new 161-kV three position ring bus station (Q453 POI) on the existing Hopkinsville – Lost City 161 kV line as shown in Appendix C. Provide generation meter, associated instrument transformers, PMU, and PQ relay. Includes needed system protection upgrades for required transfer trip and pilot protection.	[redacted]
Provide communications equipment for required transfer trip, AGC, and SCADA at new Generating Facility.	[redacted]
System protection and communications work at remote sites for pilot protection and communications path (Hopkinsville and Lost City)	[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 [redacted] 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.

4.1.1.2 Fault Study

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

4.1.1.3 System Protection

Dual Pilot protection will be required on the Hopkinsville – Lost City 161 kV TL. Transfer trip protection will be required from Hopkinsville and Lost City to the Generating Facility. TVA reserves the right to disconnect the Generating Facility for loss of communications between Hopkinsville, Lost City, and the Generating Facility.

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.

TVA calculated the Short Circuit Ratio (SCR) to be 5.46 at the POI with the strong source (Hopkinsville) out, using the traditional calculation method.

Due to the combination of system strength and the transformer size proposed for this interconnection, TVA analysis shows voltage dips of approximately 6% during transformer energization with strong source out (Hopkinsville). TVA will not allow voltage dips over 5% of nominal voltage (161kV) during transformer energization. TVA will require the IC to mitigate this issue. In addition, a control scheme will be configured to not allow any 34kV feeder to be connected when the main GSU is energized. The control scheme shall allow no more than one 34kV feeder to be energized at a time after the main GSU is on-line.

In strong source out conditions, evaluation of harmonic performance of Dogwood Solar indicates potential harmonics distortion beyond IEEE 519's allowable limit. Installing a 27 MVAR filter on the 34kV at the Q453 Dogwood Solar substation will solve this issue such that the total harmonic distortion remains under the 2.5% IEEE 519 limit.

Following construction of the interconnecting facilities, TVA will require Oriden LLC 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

At Generator				At POI			Additional Reactive Power Needed
MW	MVA	Operating PF	MVAR (injecting & absorbing)	MW (injecting)	MVAR (injecting)	MVAR Needed	MVAR
143.6	151.2	0.95	47.2	142.1	21.9	41.1	20

The evaluation of the reactive capability requirement of a 95% power factor (leading and lagging) at the POI identified the need for additional reactive support. Oriden elected to install a 20 MVAR capacitor bank on the 34kV bus to resolve the deficiency.

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 Oriden LLC designs the inverter controls such that momentary cessation of current injection is avoided.

4.1.2 Network Upgrades

4.1.2.1 Loadflow

Steady-state loadflow analysis determined that the proposed interconnection will not cause thermal violations on the TVA transmission system.

4.3 Project Schedule

The interconnection of this [redacted] Dogwood Solar 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] Dogwood Solar 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] to interconnect the Dogwood Solar 125 MW (net) solar generating facility to the TVA transmission system.

Table 5-1: Direct Assignment Facilities & Required Network Upgrades

Direct Assignment Facilities	Cost Estimate ($k)
Provide new 161-kV three position ring bus station (Q453 POI) on the existing Hopkinsville – Lost City 161 kV line as shown in Appendix C. Provide generation meter, associated instrument transformers, PMU, and PQ relay. Includes needed system protection upgrades for required transfer trip and pilot protection.	[redacted]
Provide communications equipment for required transfer trip, AGC, and SCADA at new Generating Facility.	[redacted]
System protection and communications work at remote sites for pilot protection and communications path (Hopkinsville and Lost City)	[redacted]
Network Upgrades	
None.	[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 [redacted] 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.

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. [redacted] was identified as Potentially Affected Systems as a result of the proposed interconnection.

If [redacted] decides to pursue a Facilities Study for Dogwood Solar, 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.

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.

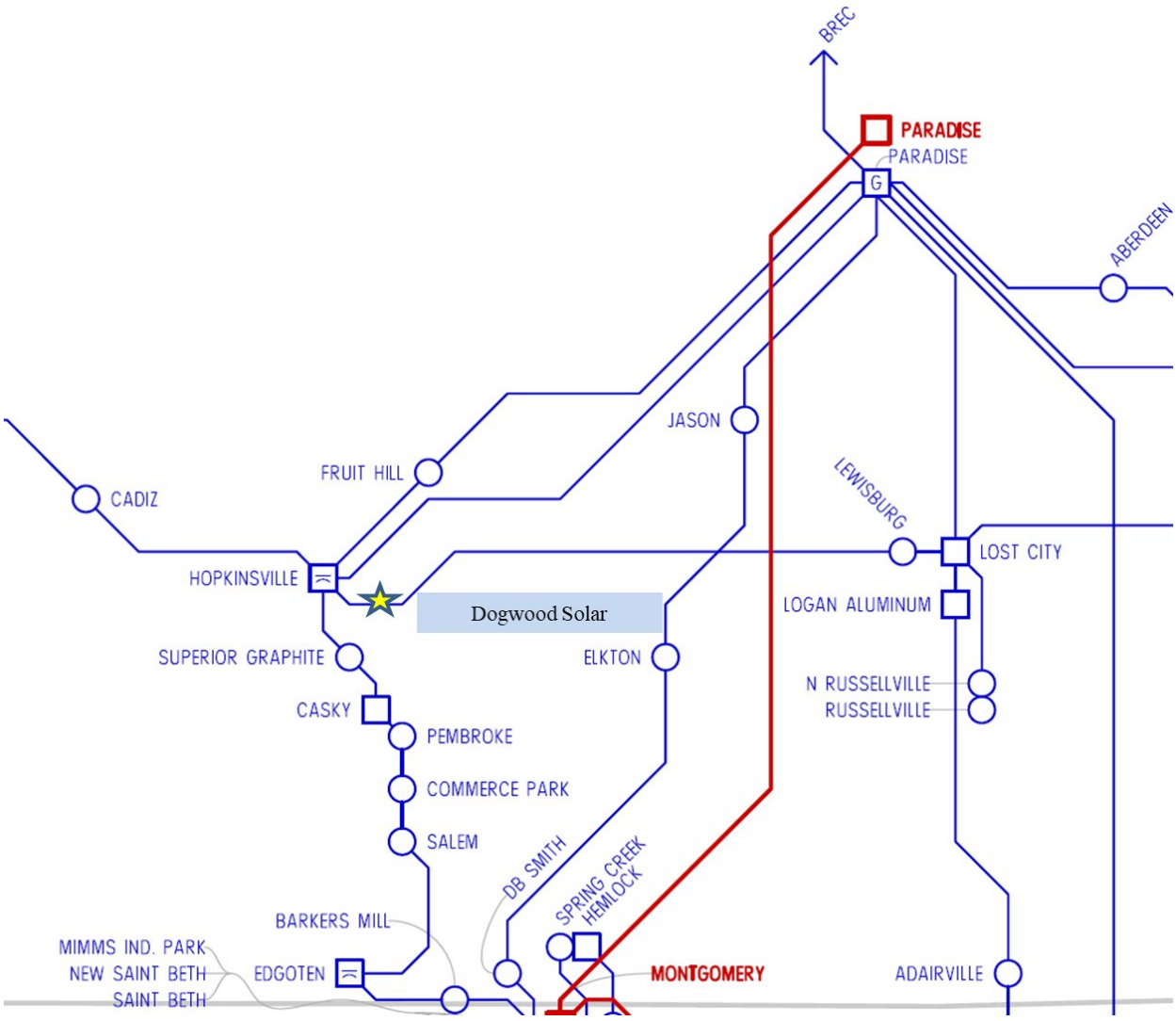
This SIS only evaluates the impacts of interconnecting Dogwood Solar Generating Facility to the TVA transmission system. Transmission service may be requested from TVA in accordance with TVA's Transmission Service Guidelines to transfer power from the solar PV project. However, if transmission service 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 Dogwood Solar facilities (including the direct assignment facilities identified in this study) required for a safe and reliable interconnection being completed.

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

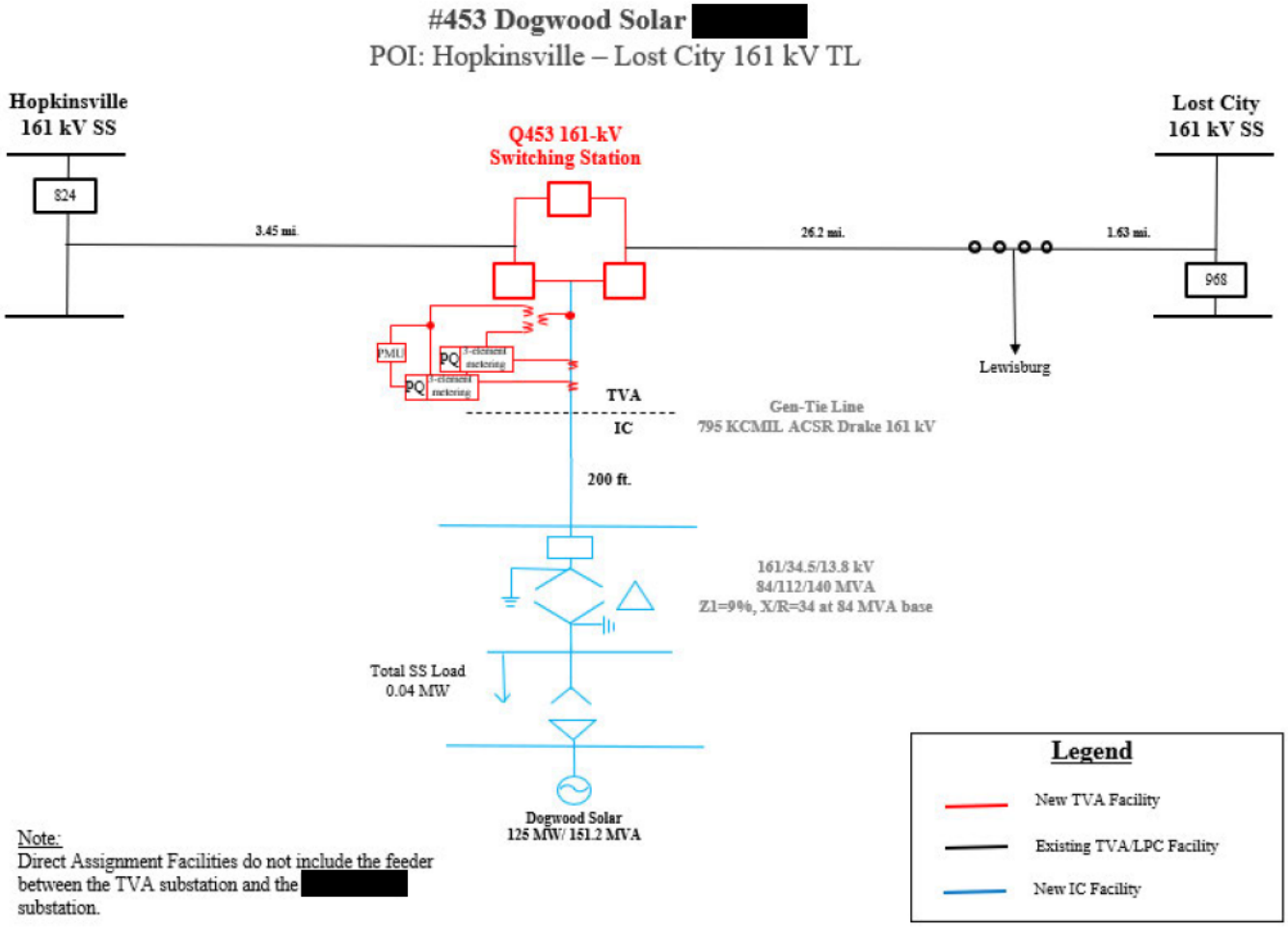


Legend

161 kV

500 k

Appendix C: Interconnection Arrangement



Note:
Direct Assignment Facilities do not include the feeder between the TVA substation and the [redacted] substation.

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 – Interconnection System Impact Study

Interconnection System Impact Study

[redacted] Dogwood Storage
#Q488

Study Performed By:

Interconnection Planning & Special Studies

FINAL – R3

REDACTED

October 24, 2023

CRITICAL ENERGY INFRASTRUCTURE INFORMATION (CEII)
CONFIDENTIAL
BUSINESS SENSITIVE

Revision	Date	Affected Page Numbers	Description of Revision
0	06/08/2022	All	Original (50 MW battery)
1	10/27/2022	All	Size Reduction (25 MW battery)
2	09/06/2023	10	Reactive power evaluation update
3	10/24/2023	5 & 18	Updated to reflect change in POI coordinates as requested by the IC.

Executive Summary

The Tennessee Valley Authority (TVA) conducted a SIS at the request of [redacted] Dogwood Storage to interconnect a Generating Facility with a maximum generating capability of 25 MW (net) to the TVA system in Christian County, KY (Appendix B). This will be an increase to Q453 Dogwood Solar for a total of 150 MW (net) and was studied as an increase.

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. [redacted] were identified as affected systems.

The SIS was performed without and with prior requesters within the local study area. Prior requester queue numbers include: Q364, Q388, Q395, Q401, Q417, Q426, Q441, Q448, Q476, AS053, AS057, Q483, and Q486.

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. No prior queued facility falls within the study area for steady-state, reactive power, or stability analysis. Priors listed above were included for breaker duty analysis.

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

- Steady-state loadflow analysis determined that the proposed interconnection will cause thermal violations on the TVA transmission system. Details regarding these violations are shown in Table 4-4.
- Short circuit analysis determined that the proposed interconnection will not cause any breaker duty issues on the TVA transmission system.
- Stability analysis determined that the proposed interconnection will not cause any new stability issues on the TVA transmission system.
- The evaluation of the reactive capability requirement of a 95% power factor (injecting and absorbing) at the 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

Direct Assignment Facilities	Cost Estimate ($k)	Contingent Cost ($k)
Provide new 161-kV three position ring bus station (Q453 POI) on the existing Hopkinsville – Lost City 161 kV line as shown in Appendix C. Provide generation meter, associated instrument transformers, PMU, and PQ relay. Includes needed system protection upgrades for required transfer trip and pilot protection.	[redacted]	[redacted]
Provide communications equipment for required transfer trip, AGC, and SCADA at new Generating Facility.	[redacted]	[redacted]
System protection and communications work at remote sites for pilot protection and communications path (Hopkinsville and Lost City)	[redacted]	[redacted]
Network Upgrades	**Cost Estimate ($k)**	**Contingent Cost ($k)**
Various 161-kV Upgrades	[redacted]	[redacted]
Total	[redacted]	[redacted]

Notes:
1. Costs provided for SIS are based on planning level estimates (±50%).
2. [redacted] is responsible for the construction and cost of the 161 kV TL and fiber communication path needed between the Generating Facility and the TVA switching station, built to TVA's specifications.
3. Low-side metering for the battery's main GSU is required, as shown in Appendix C.
4. Typical project completion time for this scope of work is approximately [redacted] 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.

Table of Contents

Executive Summary 2
1.0 Introduction 5
2.0 Development 6
3.0 Study Criteria and Methodology 7
4.0 Study Results 8
4.1.1 Direct Assignment Facilities 8
4.1.1.1 Interconnection 8
4.1.1.2 Fault Study 9
4.1.1.3 System Protection 9
4.1.1.4 Power Quality 9
4.1.1.5 Transient Stability 10
4.1.1.6 Reactive Power Capability and Voltage Control 10
4.1.2 Network Upgrades 11
4.1.2.1. Loadflow 11
4.3 Project Schedule 13
5.0 Conclusion 14
Appendix A: Notice Regarding Transmission Planning Study Information 16
Appendix B: Interconnection Map 17
Appendix C: Interconnection Arrangement 18
Appendix D: Definitions 19

List of Tables

Table ES-1: Direct Assignment Facilities & Required Network Upgrades 3
Table 1-1: Requester - Oriden LLC Dogwood Storage 5
Table 4-1: Direct Assignment Facilities 8
Table 4-2: Reactive Power Evaluation 10
Table 4-3: Network Upgrade Summary 11
Table 4-4: Thermal Overload Violations 12
Table 5-1: Direct Assignment Facilities & Required Network Upgrades 14

1.0 Introduction

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

Table 1-1: Oriden LLC Dogwood Storage

Queue Position	Interconnection Location	Requested ISD	Number of Units	Gross AC Max Capacity (at terminals)	Net AC Max Capacity (at POI)	Max Charging
Q453	Hopkinsville – Lost City 161 kV TL	10/01/2025	17	151.2 MVA / 143.6 MW	125 MW	N/A
Q488	36.945659, -87.428103		8	27.6 MVA / 23.7 MW	25 MW	25 MW / 100 MWh

Notes:

1. 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 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) 2020 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) 2022 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 with an updated TVA system model. Studies were performed using a 2031 Summer Peak base case and a 2022 Light Load base case. 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, and reactive capability studies.

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 5-1: Direct Assignment Facilities

Direct Assignment Facilities	Cost Estimate ($k)	Contingent Cost ($k)
Provide new 161-kV three position ring bus station (Q453 POI) on the existing Hopkinsville – Lost City 161 kV line as shown in Appendix C. Provide generation meter, associated instrument transformers, PMU, and PQ relay. Includes needed system protection upgrades for required transfer trip and pilot protection.	[redacted]	[redacted]
Provide communications equipment for required transfer trip, AGC, and SCADA at new Generating Facility.	[redacted]	[redacted]
System protection and communications work at remote sites for pilot protection and communications path (Hopkinsville and Lost City)	[redacted]	[redacted]
Total	[redacted]	[redacted]

Notes:

1. Costs provided for SIS are based on planning level estimates (±50%).
2. [redacted] is responsible for the construction and cost of the 161 kV TL and fiber communication path needed between the Generating Facility and the TVA switching station, built to TVA's specifications.
3. Low-side metering for the battery's main GSU is required, as shown in Appendix C.

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 Pilot protection will be required on the Hopkinsville – Lost City 161 kV TL. Transfer trip protection will be required from Hopkinsville and Lost City to the Generating Facility. TVA reserves the right to disconnect the Generating Facility for loss of communications between Hopkinsville, Lost City, and the Generating Facility.

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.

TVA calculated the Short Circuit Ratio (SCR) to be 5.79 at the POI with the strong source (Hopkinsville) out, using the traditional calculation method and the combined generation amount of Dogwood Storage and Dogwood Solar (178.8 MVA). TVA calculated the Short Circuit Ratio (SCR) to be 37.36 at the POI with the strong source (Hopkinsville) out, using the traditional calculation method and the generation amount of Dogwood Storage (27.6 MVA).

Please note that the Power Quality evaluation of Dogwood Storage was completed under the assumption that the harmonic issues identified for Dogwood Solar had been appropriately addressed via a 27 MVAR filter located at the 34.5-kV bus.

Following construction of the interconnecting facilities, TVA will require Oriden LLC to set their inverters such that they remain connected during defined frequency and voltage excursions. Exact settings will be documented in the interconnection agreement. Please also note that the control scheme shall allow no more than one 34.5-kV feeder to be energized at a given time after the GSU is on-line.

4.1.1.5 Transient Stability

Transient stability analysis identified no stability issues due to the Dogwood Storage proposed project.

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.

Table 5-2: Reactive Power Evaluation

At Generator				At POI			Additional Reactive Power Needed
MW	MVA	Operating PF (Leading & Lagging)	MVAR (injecting & absorbing)	MW (injecting)	MVAR (injecting)	MVAR Needed	MVAR
26.7	31.05	0.861	15.79	25	10.8	8.22	0

The evaluation of the reactive capability requirement of a 95% power factor (leading and lagging) at the POI did not identify the need for additional reactive support.

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 the requester designs the inverter controls such that momentary cessation of current injection is avoided.

4.1.2 Network Upgrades

Table 5-3: Network Upgrades

Network Upgrades	Cost Estimate ($k)	Contingent Cost ($k)
Various 161-kV Upgrades	[redacted]	[redacted]
Total	[redacted]	[redacted]

Notes:
1. Costs provided for SIS are based on planning level estimates (±50%).

4.1.2.1. Loadflow

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

Table 5-4: Thermal Overload Violations

Season	Contingency	Overload	Rating (MVA)	Loading % Before	Loading % After	Fix	Cost Estimate ($k)	Contingent Cost Estimate ($k)
Summer (Injecting)	Lost City – Paradise 161 kV +Gen at Russellville	Hopkinsville – Q453_POI	167.3	86.7%	106%	Uprate Hopkinsville to Lewisburg line from 80 deg C to 100 deg C (Approx 3.5 mi)	[redacted]	[redacted]
Spring (Injecting)	Paradise – Aberdeen 161 kV + Bowling Green – Paradise 161 kV	Bowling Green – Lost City 161 kV	237.3	110.3%	119.1%	Reconductor approx. 26.71 mi from ACSR to ACSS 636.0 26/7 and set sag temperature to 150 deg C	[redacted]	[redacted]

Notes:

1. A TVA project is planned to increase the thermal rating of this TL. The expected ISD is [redacted]. Should the project become delayed or canceled, the IC may become responsible for the cost of the upgrade.

4.3 Project Schedule

Typical project completion time for this scope of work is approximately four years after completion of the Facilities Study and TVA receives authorization to begin work. 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.

The interconnection of this [redacted] Dogwood Storage 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] Dogwood Storage 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] to interconnect the Dogwood Storage 25 MW (net) Generating Facility to the TVA transmission system. This project was studied as an increase to Q453 Dogwood Solar for a total generation amount of 150 MW net to the POI.

Table 6-1: Direct Assignment Facilities & Required Network Upgrades

Direct Assignment Facilities	Cost Estimate ($k)	Contingent Cost ($k)
Provide new 161-kV three position ring bus station (Q453 POI) on the existing Hopkinsville – Lost City 161 kV line as shown in Appendix C. Provide generation meter, associated instrument transformers, PMU, and PQ relay. Includes needed system protection upgrades for required transfer trip and pilot protection.	[redacted]	[redacted]
Provide communications equipment for required transfer trip, AGC, and SCADA at new Generating Facility.	[redacted]	[redacted]
System protection and communications work at remote sites for pilot protection and communications path (Hopkinsville and Lost City)	[redacted]	[redacted]
Network Upgrades	**Cost Estimate ($k)**	**Contingent Cost ($k)**
Various 161-kV Upgrades	[redacted]	[redacted]
Total	[redacted]	[redacted]

Notes:

1. Costs provided for SIS are based on planning level estimates (±50%).
2. [redacted] is responsible for the construction and cost of the 161 kV TL and fiber communication path needed between the Generating Facility and the switching station, built to TVA's specifications.
3. Low-side metering for the battery's main GSU is required, as shown in Appendix C.
4. Typical project completion time for this scope of work is approximately [redacted] 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

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. [redacted] were identified as affected systems.

If [redacted] decides to pursue a Facilities Study for Dogwood Storage, 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.

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.

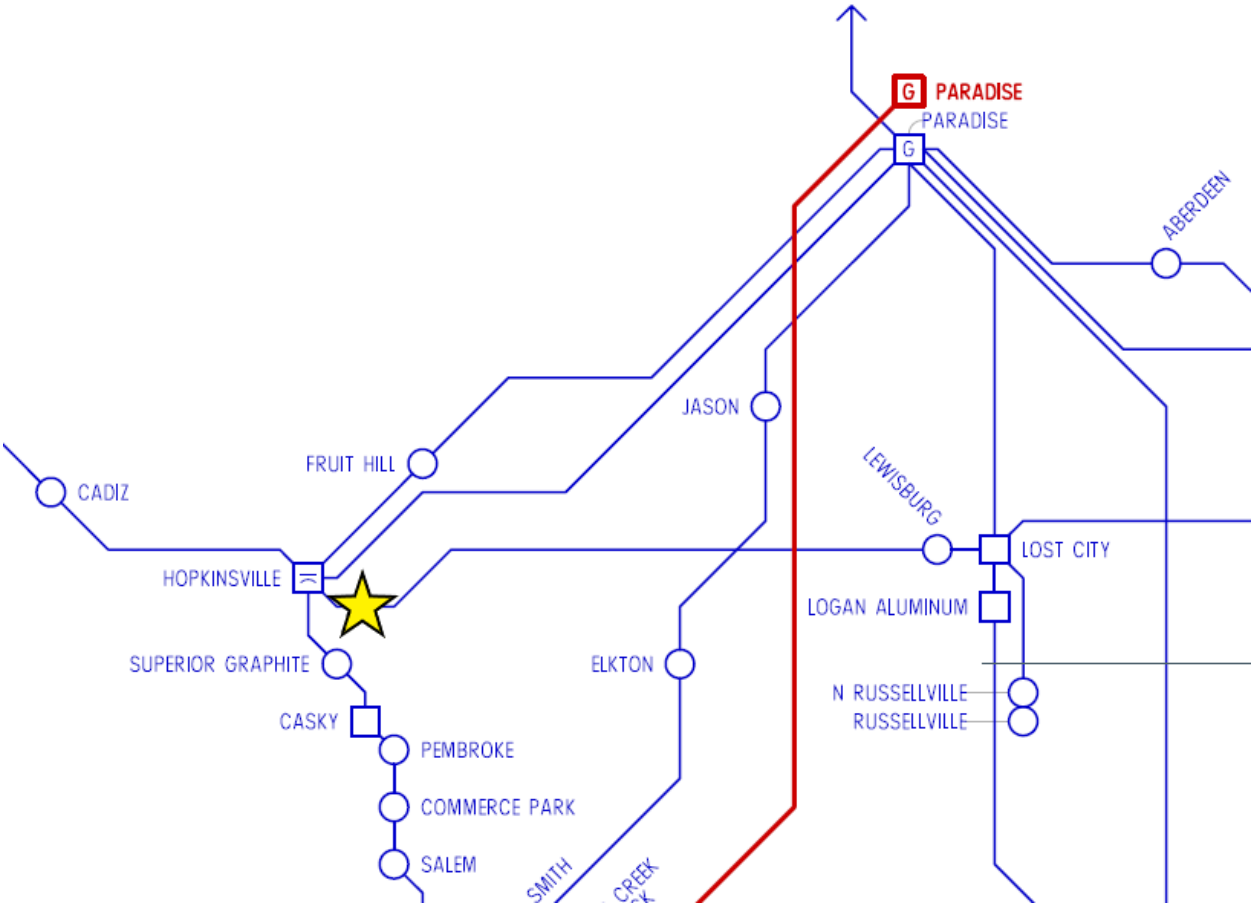
This SIS only evaluates the impacts of interconnecting [redacted] Dogwood Storage to the TVA transmission system. Transmission service may be requested from TVA in accordance with TVA's Transmission Service Guidelines to transfer power from the project. However, if transmission service is available,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

Appendix A: Notice Regarding Transmission Planning Study Information

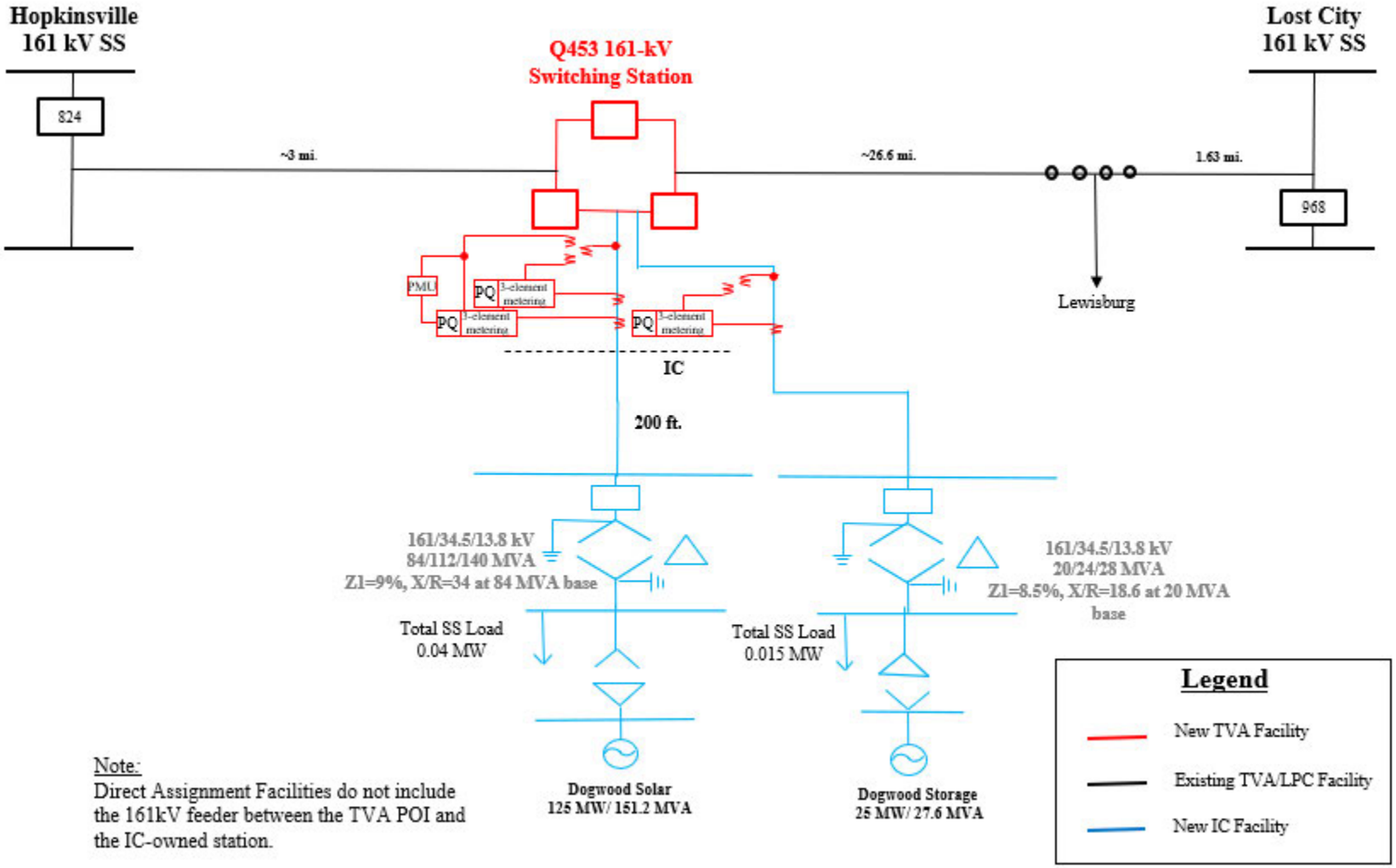
This information has been derived utilizing power flow models of projected future system conditions. These planning models incorporate many assumptions concerning loads, transmission system configuration, generation dispatch, firm transactions, and other information pertinent to building power flow models.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



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.

IFS – Interconnection Feasibility Study

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 – Interconnection System Impact Study