# Generation Interconnection

# System Impact Study Report

# for

# Queue Project AF1-028

# ENDLESS CAVERNS 115 KV

# 200 MW Capacity / 200 MW Energy

Revision 1: November 2021

Revision 0: August 2020

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# 1 Introduction

This System Impact Study has been prepared in accordance with the PJM Open Access Transmission Tariff, 205, as well as the System Impact Study Agreement between the Interconnection Customer (IC), and PJM Interconnection, LLC (PJM), Transmission Provider (TP). The Interconnected Transmission Owner (ITO) is Dominion.

# 2 Preface

The intent of the System Impact Study is to determine a plan, with approximate cost and construction time estimates, to connect the subject generation interconnection project to the PJM network at a location specified by the Interconnection Customer. As a requirement for interconnection, the Interconnection Customer may be responsible for the cost of constructing: Network Upgrades, which are facility additions, or upgrades to existing facilities, that are needed to maintain the reliability of the PJM system. All facilities required for interconnection of a generation interconnection project must be designed to meet the technical specifications (on PJM web site) for the appropriate transmission owner.

In some instances an Interconnection Customer may not be responsible for 100% of the identified network upgrade cost because other transmission network uses, e.g. another generation interconnection or merchant transmission upgrade, may also contribute to the need for the same network reinforcement. The possibility of sharing the reinforcement costs with other projects may be identified in the Feasibility Study, but the actual allocation will be deferred until the System Impact Study is performed.

The System Impact Study estimates do not include the feasibility, cost, or time required to obtain property rights and permits for construction of the required facilities. The project developer is responsible for the right of way, real estate, and construction permit issues. For properties currently owned by Transmission Owners, the costs may be included in the study.

An Interconnection Customer with a proposed new Customer Facility that has a Maximum Facility Output equal to or greater than 100 MW shall install and maintain, at its expense, phasor measurement units (PMUs). See Section 8.5.3 of Appendix 2 to the Interconnection Service Agreement as well as section 4.3 of PJM Manual 14D for additional information.

# 3 Revision 1 Summary- November 2021

This revision is being issued to incorporate the results of a stability study which was recently performed.

## 4 General

The Interconnection Customer (IC), has proposed a Storage generating facility located in Rockingham County, Virginia. The installed facilities will have a total capability of 200 MW with 200 MW of this output being recognized by PJM as Capacity. The proposed in-service date for this project is October 31, 2023. This study does not imply a TO commitment to this in-service date.

| Queue Number | AF1-028 |
|---|---|
| Project Name | ENDLESS CAVERNS 115 KV |
| State | Virginia |
| County | Rockingham |
| Transmission Owner | Dominion |
| MFO | 200 |
| MWE | 200 |
| MWC | 200 |
| Fuel | Storage |
| Basecase Study Year | 2023 |

Any new service customers who can feasibly be commercially operable prior to June 1st of the basecase study year are required to request interim deliverability analysis.

## 5 Point of Interconnection

AF1-028 "Endless Caverns 115 kV" will interconnect with the Dominion's transmission system via an existing substation Endless Caverns 115 kV substation. This is the primary Point of Interconnection (POI) chosen by the IC within the ITO's transmission system. The IC is responsible for securing right-of-way, permits and constructing the proposed attachment line from the battery energy storage facility site to the existing switching station. Attachment 1 shows a one-line diagram of the proposed interconnection facilities. The IC may not install any facilities on Dominion's right-of-way without first obtaining the necessary approval from Dominion Energy.

## 6 Cost Summary

The AF1-028 project will be responsible for the following costs:

| Description | Total Cost |
|---|---|
| Total Physical Interconnection Costs | $ 3,700,000 |
| Allocation towards System Network Upgrade Costs* | $ 0 |
| **Total Costs** | **$ 3,700,000** |

*As your project progresses through the study process and other projects modify their request or withdraw, then your cost allocation could change.

This cost excludes a Federal Income Tax Gross Up charges. This tax may or may not be charged based on whether this project meets the eligibility requirements of IRS Notice 88-129. If at a future date it is determined that the Federal Income Tax Gross charge is required, the Transmission Owner shall be reimbursed by the Interconnection Customer for such taxes.

Note 1: PJM Open Access Transmission Tariff (OATT) section 217.3A outline cost allocation rules. The rules are further clarified in PJM Manual 14A Attachment B. The allocation of costs for a network upgrade will start with the first Queue project to cause the need for the upgrade. Later queue projects will receive cost allocation contingent on their contribution to the violation and are allocated to the queues that have not closed less than 5 years following the execution of the first Interconnection Service Agreement which identifies the need for this upgrade.

Note 2: For customers with System Reinforcements listed: If your present cost allocation to a System Reinforcement indicates $0, then please be aware that as changes to the interconnection process occur, such as prior queued projects withdrawing from the queue, reducing in size, etc, the cost responsibilities can change and a cost allocation may be assigned to your project. In addition, although your present cost allocation to a System Reinforcement is presently $0, your project may need this system reinforcement completed to be deliverable to the PJM system. If your project comes into service prior to completion of the system reinforcement, an interim deliverability study for your project will be required.

## 7 Transmission Owner Scope of Work

To accommodate the proposed AF1-028 Project, Dominion Energy will install one span of overhead 115 kV line to the point of interconnection ("POI") including 115 kV interconnection metering and will add two new 115 kV breakers to the existing Endless Caverns substation to allow for the proposed interconnection.

The total physical interconnection costs is given in the table below:

| Description | Total Cost |
|---|---|
| **Install metering and associated protection equipment** | $ 500,000 |
| **Install one span of overhead 115 kV Transmission to POI** | $ 1,200,000 |
| **Additional Substation Breakers (2) and Associated Equipment** | $ 2,000,000 |
| **Total Physical Interconnection Costs** | **$ 3,700,000** |

It is estimated to take 18-24 months to complete this work upon execution of an Interconnection Construction Service Agreement (ICSA). These preliminary cost estimates are based on typical engineering costs. A more detailed engineering cost estimates are normally done when the IC provides an exact site plan location for the generation substation during the Facility Study phase. See Attachment 1.

# 8 Schedule

The schedule for the required Network Impact Reinforcements will be more clearly identified in future study phases. The estimate elapsed time to complete each of the required reinforcements is identified in the "System Reinforcements" section of the report.

# 9 Transmission Owner Analysis

## 9.1 Power Flow Analysis

PJM performed a power flow analysis of the transmission system using a 2023 summer peak load flow model and the results were verified by Dominion. Additionally, Dominion performed an analysis of its transmission system and no further deficiencies were identified.

## 9.2 Short Circuit Analysis

PJM performed a short circuit analysis and the results were verified by Dominion. The connection of AF1-028 project to the system does not result in any newly overdutied circuit breakers on the Dominion transmission system and does not have a significant fault current contribution to existing overdutied circuit breakers

## 9.3 Stability Analysis

PJM has completed a dynamic stability analysis and the results of this analysis has been reviewed by Dominion. Based on the Impact Study data provided, the AF1-028 queue project meets the 0.95 lagging and 0.95 leading reactive power factor requirement. See the result summary in **Section 15 Stability and Reactive Power**.

# 10 Interconnection Customer Requirements

## 10.1 System Protection

The IC must design its Customer Facilities in accordance with all applicable standards, including the standards in Dominion's "Dominion Energy Electric Transmission Generator Interconnection Requirements" documented in Dominion's Facility Interconnection Requirements "Exhibit C" located at: https://www.dominionenergy.com/company/moving-energy/electric-transmission-access. Preliminary Protection requirements will be provided as part of the Facilities Study. Detailed Protection Requirements will be provided once the project enters the construction phase.

## 10.2 Compliance Issues and Interconnection Customer Requirements

The proposed Customer Facilities must be designed in accordance with Dominion's "Dominion's Facility Interconnection Requirements" document located at: https://www.dominionenergy.com/company/moving-energy/electric-transmission-access. In particular, the IC is responsible for the following:

1. The purchase and installation of a fully rated protection device (circuit breaker, circuit switcher, fuse) to protect the IC's GSU transformer(s).

2. The purchase and installation of the minimum required Dominion generation interconnection relaying and control facilities as described in the System Protection noted above. This includes over/under voltage protection, over/under frequency protection, and zero sequence voltage protection relays.

3. The purchase and installation of supervisory control and data acquisition ("SCADA") equipment to provide information in a compatible format to the Dominion Transmission System Control Center.

4. Compliance with the Dominion and PJM generator power factor and voltage control requirements.

   The GSU(s) associated with the IC queue request shall meet the grounding requirements as noted in Dominion's "Dominion's Facility Interconnection Requirements" document located at: https://www.dominionenergy.com/company/moving-energy/electric-transmission-access.

The IC will also be required to meet all PJM, SERC, and NERC reliability criteria and operating procedures for standards compliance. For example, the IC will need to properly locate and report the over and under voltage and over and under frequency system protection elements for its units as well as the submission of the generator model and protection data required to satisfy the PJM and SERC audits. Failure to comply with these requirements may result in a disconnection of service if the violation is found to compromise the reliability of the Dominion system.

# 11 Power Factor Requirements

The IC shall design its non-synchronous Customer Facility with the ability to maintain a power factor of at least 0.95 leading (absorbing VARs) to 0.95 lagging (supplying VARs) measured at the high-side of the facility substation transformer(s) connected to the Dominion transmission system.

# 12 Revenue Metering and SCADA Requirements

## 12.1 PJM Requirements

The Interconnection Customer will be required to install equipment necessary to provide Revenue Metering (KWH, KVARH) and real time data (KW, KVAR) for IC's generating Resource. See PJM Manuals M-01 and M-14D, and PJM Tariff Section 8 of Attachment O.

## 12.2 Interconnected Transmission Owner Requirements

See Section 3.4.6 “Metering and telecommunications” of Dominion’s “Dominion’s Facility Interconnection Requirements” document located at: https://www.dominionenergy.com/company/moving-energy/electric-transmission-access.

## 13 Summer Peak Analysis

The Queue Project AF1-028 was evaluated as a 200.1 MW (Capacity 200.0 MW) injection at the Endless Caverns 115 kV substation in the Dominion area. Project AF1-028 was evaluated for compliance with applicable reliability planning criteria (PJM, NERC, NERC Regional Reliability Councils, and Transmission Owners). Project AF1-028 was studied with a commercial probability of 100.0 %. Potential network impacts were as follows:

### 13.1 Generation Deliverability

(Single or N-1 contingencies for the Capacity portion only of the interconnection)

None

### 13.2 Multiple Facility Contingency

(Double Circuit Tower Line, Fault with a Stuck Breaker, and Bus Fault contingencies for the full energy output)

None

### 13.3 Contribution to Previously Identified Overloads

(This project contributes to the following contingency overloads, i.e. "Network Impacts", identified for earlier generation or transmission interconnection projects in the PJM Queue)

None

### 13.4 Steady-State Voltage Requirements

None

### 13.5 Potential Congestion due to Local Energy Deliverability

PJM also studied the delivery of the energy portion of this interconnection request. Any problems identified below are likely to result in operational restrictions to the project under study. The developer can proceed with network upgrades to eliminate the operational restriction at their discretion by submitting a Merchant Transmission Interconnection request.

Note: Only the most severely overloaded conditions are listed below. There is no guarantee of full delivery of energy for this project by fixing only the conditions listed in this section. With a Transmission Interconnection Request, a subsequent analysis will be performed which shall study all overload conditions associated with the overloaded element(s) identified.

None

## 13.6 System Reinforcements

None

## 13.7 Queue Dependencies

The Queue Projects below are listed in one or more indices for the overloads identified in your report. These projects contribute to the loading of the overloaded facilities identified in your report. The percent overload of a facility and cost allocation you may have towards a particular reinforcement could vary depending on the action of these earlier projects. The status of each project at the time of the analysis is presented in the table. This list may change as earlier projects withdraw or modify their requests.

None

## 14 Light Load Analysis

The Queue Project AF1-028 was evaluated as a 200.1 MW injection at the Endless Caverns 115 kV substation in the Dominion area. Project AF1-028 was evaluated for compliance with applicable reliability planning criteria (PJM, NERC, NERC Regional Reliability Councils, and Transmission Owners). Project AF1-028 was studied with a commercial probability of 100.0 %. Potential network impacts were as follows:

### 14.1 Generation Deliverability

(Single or N-1 contingencies)

None

### 14.2 Multiple Facility Contingency

(Double Circuit Tower Line, Fault with a Stuck Breaker, and Bus Fault contingencies)

None

### 14.3 Contribution to Previously Identified Overloads

(This project contributes to the following contingency overloads, i.e. "Network Impacts", identified for earlier generation or transmission interconnection projects in the PJM Queue)

None

### 14.4 Steady-State Voltage Requirements

None

### 14.5 Potential Congestion due to Local Energy Deliverability

PJM also studied the delivery of the energy portion of this interconnection request. Any problems identified below are likely to result in operational restrictions to the project under study. The developer can proceed with network upgrades to eliminate the operational restriction at their discretion by submitting a Merchant Transmission Interconnection request.

Note: Only the most severely overloaded conditions are listed below. There is no guarantee of full delivery of energy for this project by fixing only the conditions listed in this section. With a Transmission Interconnection Request, a subsequent analysis will be performed which shall study all overload conditions associated with the overloaded element(s) identified.

None

### 14.6 System Reinforcements

None

## 15 Short Circuit Analysis

The following Breakers are overdutied:

None

### 15.1 System Reinforcements - Short Circuit

None

## 16 Stability and Reactive Power

Generator Interconnection Request AF1-028 is for a 200 MW battery storage generation plant consisting of 102 x 1.978 MW SC2200-US inverters. AF1-028 has a Point of Interconnection (POI) connecting to the Endless Caverns 115 kV substation in Rockingham, Virginia, in the Dominion Virginia Power (DVP) transmission system.

The power flow scenario for the analysis was based on the RTEP 2023 summer peak case, modified to include applicable queue projects. AF1-028 dispatched online at maximum facility output, with approximately unity power factor at the high side of the station transformer.

AF1-028 was tested for compliance with NERC, PJM, Transmission Owner and other applicable criteria. For this study, 83 contingencies were simulated, each with a 20 second simulation time period. Studied faults included:

- Steady-state operation (20 second simulation)
- Three-phase faults with normal clearing time
- Single-phase faults with a stuck breaker
- Single-phase faults placed at 80% of the line with delayed (Zone 2) clearing at remote line end because of primary communications/relaying failure

Note no P7 faults were not included since they were none identified within 2 substations of the POI.

The 83 fault contingencies tested on the 2023 summer peak case met the recovery criteria:

- The AF1-028 generator was able to ride through the faults except for faults where protective actions trip one or more generator(s).
- All generators maintained synchronism and any post-contingency oscillations are positively damped with a damping margin of at least 3%.
- All bus voltages recover to 0.7 p.u. within 2.5 seconds and the final voltages are within the steady-state voltage ranges below per DVP's transmission planning criteria.
    - P1 Category Contingencies:
        - 0.93 to 1.05 p.u. for 230, 138, 115, 69 kV facilities
        - 1.01 to 1.08 p.u. for 500 kV facilities
    - P2, P4, P5, and P7 Category Contingencies:
        - 0.90 to 1.05 p.u. for 230, 138, 115, 69 kV facilities
        - 1.00 to 1.08 p.u. for 500 kV facilities
- No transmission element trips, other than those either directly connected or designated to trip as a consequence of the fault.

Based on the Impact Study data provided, the AF1-028 queue project meets the 0.95 lagging and 0.95 leading reactive power factor requirement.

## 17 Affected Systems

None

## 18 Attachment 1: One Line Diagram