PJM Generator Interconnection Request Queue AB1-055 Balls Gap 34.5 kV Feasibility/Impact Study Report

February 2016

Preface

The intent of the Feasibility/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 Feasibility/System Impact Study is performed.

The Feasibility/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.

This report is divided into two sections:

Part I – AEP Distribution Planning Analysis and Results
Part II – Transmission Planning Analysis and Results

Part I - AEP Distribution Planning Analysis and Results

Request

Appalachian Power Company has requested an impact study for a 2MW NAS Battery with a maximum output of 2.0 MW. This installation will be referred to as a distributed generation (DG) facility in the remainder of this study. The DG facility is presently in service at Appalachian Power's Balls Gap Station in Milton, WV. It was placed in service in January 2009 and has been utilized for peak shaving and islanding capability. It is the customer's intention to place this battery in the PJM market for frequency regulation.

Assuming ample charge, the battery is available 24 hours per day, seven days per week, except for routine maintenance.

The DG facility is connected to the Milton/Balls Gap Feeder. The Point of Common Coupling (PCC) is AEP pole 38820153D30115.

Disclaimer

The results of this impact study apply only to the system described in the attached Distributed Generation Interconnection Request. All modeling is based on a DG location at Balls Gap Station.

This review is limited to equipment affecting the AEP system operations. The customer has taken all necessary steps to assure compliance with all laws, ordinances, building codes and other applicable regulations. AEP granting approval of the requested connection is not an endorsement of a particular design nor does it assure fitness of the DG to accomplish an intended function.

The customer understands and is in compliance with IEEE 1547 concerning the DG installation and its requirements for interconnection with the utility grid. The DG was tested in accordance with IEEE 1547-1.

Modeling and Assumptions

Balls Gap Station is served from the 69-34.5 KV, Milton Station via the Balls Gap Feeder. The Balls Gap Feeder is a radial configuration, three-phase multi-grounded four-wire, wye system. The primary voltage is 34.5 kV line-to-line and 19.9 kV line-to-ground.

The DG system consists of two 1 MW NAS batteries. The DG contributes up to a maximum of 2.4 MVA when operating. The DG output voltage is 480 volts. The voltage is stepped up to 34.5 KV through two 1,500 kVA, .48/34.5 KV step-up transformers.

The customer owned 1,500 kVA, 34.5/.48 KV transformers are configured Wye-Delta and have an impedance of Z=5.75%. Each transformer is connected to the Milton/Balls Gap Feeder via 120' of 35 kV, 1/0 AL underground cable. Each underground riser is protected with a 19.9 kV, 40T line fuse. The transformers connect to the batteries via 3 single-phase, 35 kV, 500 MCM Copper cables.

Each battery is connected to the main 480 volt bus via a 1600 Amp breaker.

The DG system will be operated in parallel with the AEP System and the customer intends to export power to the utility grid.

Analysis

The system conditions of concern are:

1. Battery location.
2. Battery fault contribution.
3. Battery effect on system steady state voltage at peak load.
4. Battery effect on system steady state voltage at light load.
5. Battery effect on power flow at the Milton Station transformer.
6. Battery effect on voltage flicker

DG Location

The DG system's modeled location is at AEP distribution pole #38820153D30115.

Fault Contribution

Maximum available fault at PCC

The total maximum available three-phase bolted fault (LLL) at the customer PCC is 1,988 amps symmetrical when the DG system is connected. The maximum available AEP contribution to a three-phase bolted fault (LLL) at the customer PCC is 1,849 amps symmetrical.

The total maximum available single-phase fault (LG) at the customer PCC is 1,570 amps when the DG is connected. The maximum available AEP contribution to a single-phase fault (LG) at the customer PCC is 1,490 amps symmetrical.

The DG system results in a 7.5% raise in available three-phase bolted fault (LLL) and a 5.4% raise in available L-G fault when connected. The rise in fault current is not expected to significantly impact the operation of the AEP protection system at Milton Station. It is important to note that these values are subject to change if AEP distribution system enhancements and/or substation enhancements are made in the future. These values are also subject to change if the customer changes their equipment.

System Protection

The customer responsibilities include providing adequate protection to AEP facilities due to events arising from the operation of the DG under all AEP distribution system operating conditions. The customer is responsible for protecting their own facility under all AEP distribution system operating conditions whether the DG is connected to AEP facilities or not, including but not limited to:

1. Abnormal voltage or frequency
2. Loss of a single phase of supply
3. Equipment failure
4. Distribution system faults
5. Lightning
6. Excessive harmonic voltages
7. Excessive negative sequence voltages
8. Separation from supply
9. Loss of synchronization

Ground Current Sources – Protective relays must be utilized to detect line-to-ground faults. Appalachian Power Company has installed adequate protection to comply with IEEE 1547 to clear generation source for all types of faults on the AEP system including any breaker failure events. Adequate protection requires that all fault types are cleared before equipment damage occurs to AEP facilities.

When the AEP source breakers trip and isolate the Balls Gap NAS Battery, Appalachian Power shall ensure that their generation equipment is disconnected from AEP facilities in accordance with requirements established in IEEE 1547 prior to automatic reclosure by AEP. Automatic reclosing out-of-phase with Appalachian Power's generation equipment may cause damage to Appalachian Power's equipment. Appalachian Power is solely responsible for the protection of their equipment from automatic reclosing by AEP.

Voltage Regulation

Battery effect on system steady state voltage at peak load

The battery output has negligible effect on utility voltage at peak demand load.

Battery effect on system steady state voltage at light load

Light load conditions are assumed to be ½ peak demand. The battery output has negligible effect on utility voltage at light demand load.

Battery effect on power flow for the Milton Transformer during light load

Loading on the Balls Gap Feeder is greater than the maximum output of the battery in light load conditions. There is no concern for a backflow of power through the station transformer and on to the Milton-Winfield 69 KV line.

Battery effect on voltage flicker

A thorough flicker analysis was performed based on a 2-second signal from PJM. It was determined that the worst case flicker occurs when the battery goes from a full 2MVA discharge to charge. This operation results in a flicker of .8% and is within the acceptable range for 30 fluctuations per minute based on Appalachian Power flicker guidelines.

This analysis is based on the completion of an on-going project to reconductor 5.5 miles of 34.5 kV, #4 AC primary along Balls Gap Road with 556 AL primary and 4/0 AA neutral. This work is expected to be complete by June 1, 2016.

Summary

Facilities

The proposed interconnection will require the following improvements:

- Installation of a new RTU
- Telecommunications Upgrades
- Installation of a Greensmith Energy Management System
- Completion of Balls Gap Reconductoring Project (On going but separate project)

The estimated costs and a construction schedule will be detailed in a two party Interconnection Agreement (IA) between Appalachian Power Company (APCo) and the Interconnection Customer (IC).

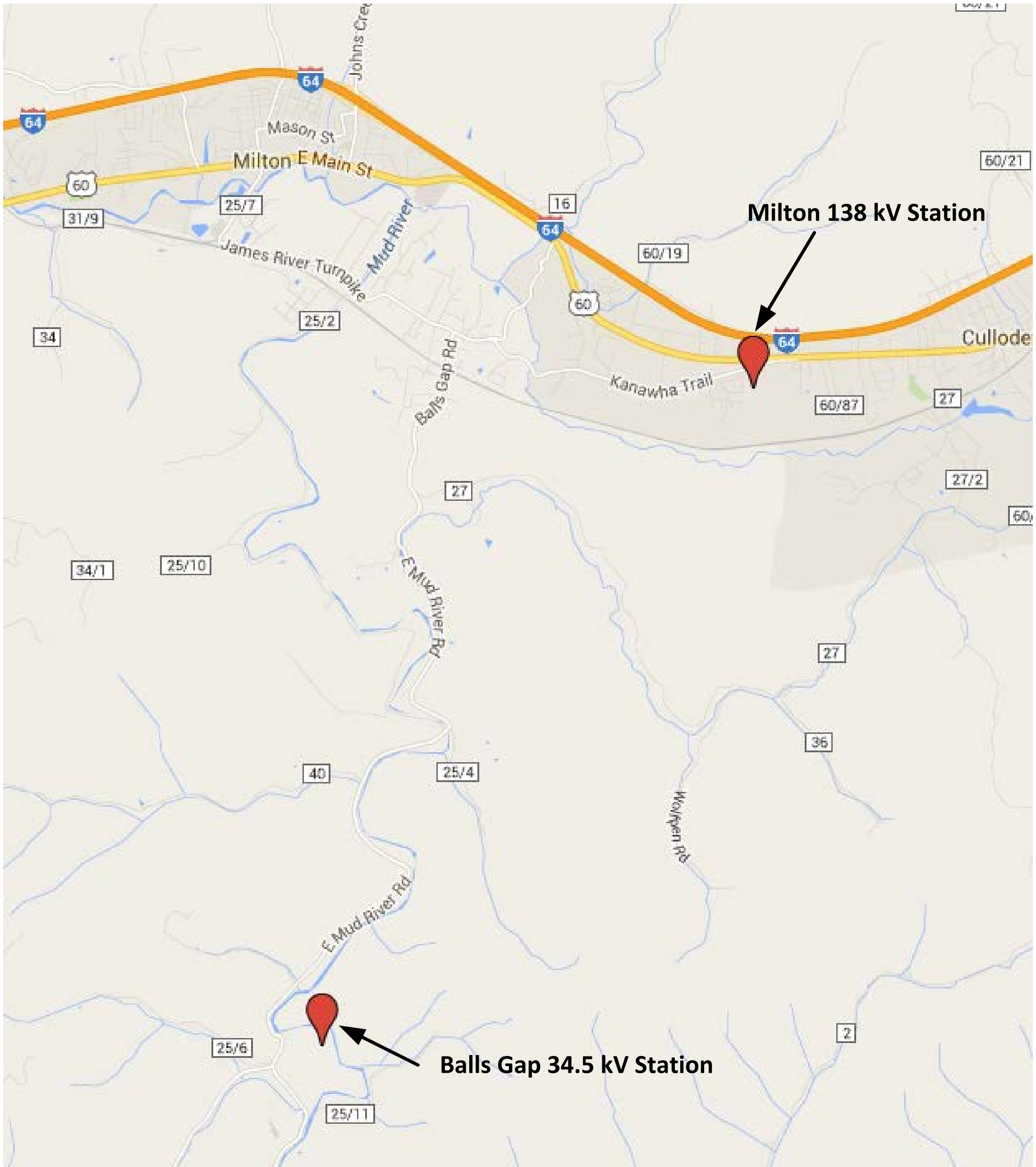

Figure 1 – Site Location

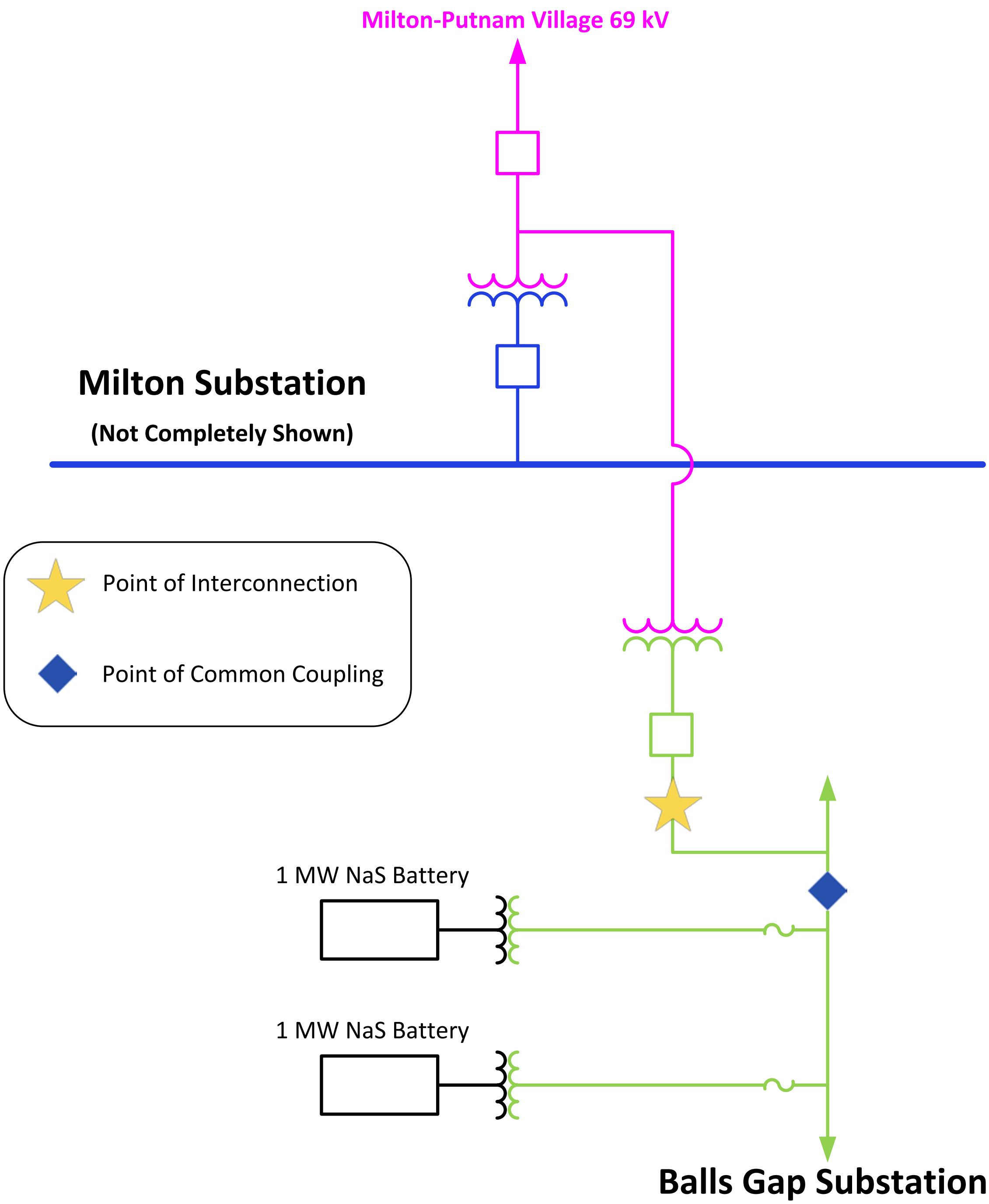

Figure 2 – Single Line Diagram

Part II – Transmission Planning Analysis and Results

Network Impacts

The Queue Project AB1-055 was studied as a 2.0 MW energy only injection at the Balls Gap 34.5 kV substation in the AEP area. Project AB1-055 was evaluated for compliance with applicable reliability planning criteria (PJM, NERC, NERC Regional Reliability Councils, and Transmission Owners). Project AB1-055 was studied with a commercial probability of 100%. Potential network impacts were as follows:

Summer Peak Analysis - 2019

Generator Deliverability

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

None

Multiple Facility Contingency

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

None

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

Steady-State Voltage Requirements

(Results of the steady-state voltage studies should be inserted here)

None

Delivery of Energy Portion of Interconnection Request

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.

Only the most severely overloaded conditions are listed. 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 will study all overload conditions associated with the overloaded element(s) identified.

None

Light Load Analysis - 2018

Not required

System Reinforcements

New System Reinforcements

(Upgrades required to mitigate reliability criteria violations, i.e. Network Impacts, initially caused by the addition of this project generation)

None

Contribution to Previously Identified System Reinforcements

(Overloads initially caused by prior Queue positions with additional contribution to overloading by this project. This project may have a % allocation cost responsibility which will be calculated and reported for the Impact Study)

(Summary form of Cost allocation for transmission lines and transformers will be inserted here if any)

None

Short Circuit

(Summary form of Cost allocation for breakers will be inserted here if any)

None

Stability and Reactive Power Requirement

(Results of the dynamic studies should be inserted here)

Not required