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1.0 APPLICATION SUMMARY

PPL Electric Utilities Corporation ("PPL Electric") is seeking approval from the Pennsylvania Public Utility Commission ("Commission") to rebuild the existing single-circuit Breinigsville-Alburtis 500kV Transmission Line to a double-circuit configuration (the "Project"). The Breinigsville-Alburtis 500kV Transmission Line extends approximately 6 miles from the Breinigsville 500kV substation in Upper Macungie Township, Lehigh County to the Alburtis 500kV substation in Lower Macungie Township, Lehigh County.

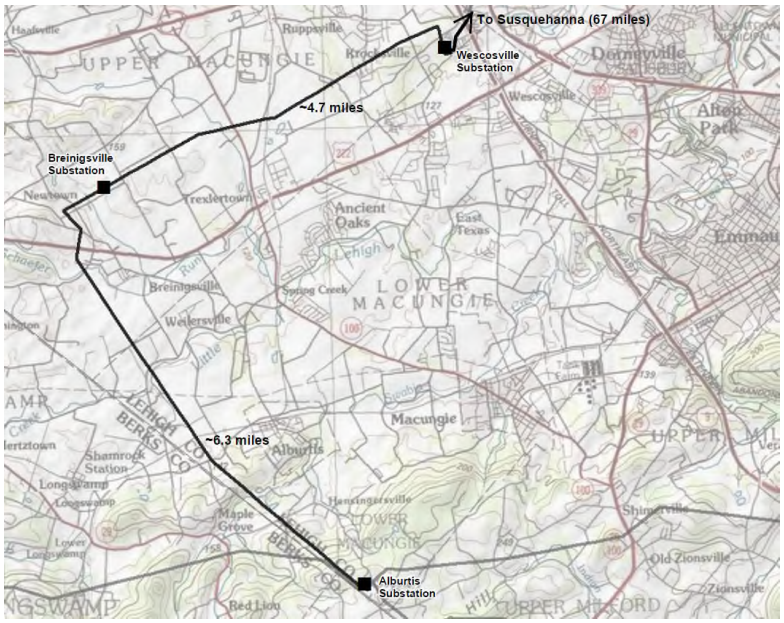

Figure 1-1: Current System Configuration

The Project is required to comply with:

1. North American Electric Reliability Corporation ("NERC") reliability standards approved by the Federal Energy Regulatory Commission ("FERC"),

2. PPL Electric and PJM Interconnection, LLC ("PJM") planning standards, and

3. Good utility practice and responsibility to serve customers while minimizing equipment damage and extended loss of power to customer homes and businesses.

Once the Project is complete, the new double-circuit 500kV line will be designated the Breinigsville-Alburtis #1 & #2 500kV Transmission Line. Failure to construct this Project will prevent PPL Electric from complying with its transmission planning criteria and NERC standards as well as negatively impact the reliability of the bulk electric system in Pennsylvania by subjecting customers to potential extended outages.

Pending the Commission's approval, construction will begin May 2020 with a Project in service date of April 2021. The total estimated cost of the Project is $33 million.[1]

2.0 BACKGROUND

PPL Electric's planning process requires it to consider reliability standards from three sources: NERC standards, PJM standards, and PPL Electric standards.

- NERC is a not-for-profit international regulatory authority whose mission is to assure the effective and efficient reduction of risks to the reliability and security of the North American power grid. NERC is subject to oversight by FERC and has the legal authority to enforce its reliability standards with monetary fines and increased oversight. NERC standards require PPL Electric to annually review the performance of its transmission system.

- PJM is a regional transmission organization responsible for certain planning functions. PJM incorporates NERC standards into its planning process and analyzes thermal, voltage, short circuit, and stability limits on the transmission system.

- PPL Electric also incorporates NERC standards in its internal planning and must also address utility-specific needs such as providing reliable electric service to load and planning for long-term reliability and resiliency issues.

The transmission system is the backbone of the electric grid. Failure to plan, design, and operate the transmission system to NERC reliability standards would create compliance issues for PPL Electric, and increase the risk of cascading outages for the regional or eastern-interconnection electric grid.

3.0 TRANSMISSION SYSTEM PLANNING PROCESS

PPL Electric's process for transmission planning ensures that the transmission grid can:

- Accommodate forecasted system flows during summer and winter peak load;

[1] The estimated cost for the Project is developed using averages of costs for recent similar projects and does not incorporate an in-depth analysis of field conditions. The estimated cost is expected to change as the constructability of the Project, sequence of construction, and other factors are identified and analyzed as the Project progresses. The entire cost for this Project will be paid by PPL Electric. Cost recovery of the Project is subject to the jurisdiction of FERC.

- Adequately serve each customer's need with regard to capacity, voltage and reliability for all load levels throughout the daily load cycle;

- Sustain probable contingencies and disturbances with minimal customer service interruptions; and

- Maintain compliance with NERC, PJM, and PPL Electric's transmission planning criteria for all normal and emergency operating conditions.

The transmission planning process requires PPL Electric and PJM to study the transmission system and individual transmission facilities in their expected future state at periods of 5 to 10 years in the future. The goal is to identify and proactively correct NERC, PJM, and PPL Electric planning standard compliance deficiencies.

4.0 THE NEED FOR THE PROJECT

4.1 Project Background

During the transmission planning process, PPL Electric identified low voltage and voltage drop concerns on its 138kV and 69kV lines at the Wescosville 500kV substation. The 138kV and 69kV lines directly serve residential and industrial customers. Operational switching procedures were utilized as a temporary solution. However, a permanent solution was needed to resolve the voltage concerns. To address this, in 2015, a Supplemental/PPL Electric driven project was initiated to re-configure the Wescosville substation to allow for removal of a line-tapped transformer and upgrade the capacity of the 500kV transmission line between the Breinigsville and Alburtis substations. The proposed project was reviewed at the PJM Transmission Expansion Advisory Committee ("TEAC") meeting in April 2015 and designated Supplemental project s0864.

The substation and line upgrades were required to not only solve the problems at the Wescosville substation, but to keep similar voltage problems from propagating to the Breinigsville substation. The project was originally expected to be completed in 2017. Reconfiguration of the Wescosville substation and removal of the line-tapped transformer have been completed. Upgrade of the Breinigsville to Alburtis 500kV line has not been completed and is the cause of voltage problems at the Breinigsville substation which is the subject of this Application. Since the full scope of the Supplemental project was not completed as planned by 2017, voltage problems at the Breinigsville substation, if left unmitigated, will become a violation of PPL Electric transmission planning criteria and NERC reliability standards[2].

[2] Under normal circumstances, a violation of NERC TPL-001-4 would trigger a "715 project or Baseline project" where PJM would recognize a violation of PPL Electric's transmission planning criteria and instruct PPL Electric to complete the project as part of PJM's Regional Transmission Expansion Plan ("RTEP"). See PJM Operating

PPL Electric analyzes its transmission system based on transmission planning criteria developed to comply with NERC reliability standard TPL-001-4, "Transmission System Planning Performance Criteria". This standard was established by NERC to ensure the Bulk Electric System ("BES") will operate reliably over a broad spectrum of system conditions and following a wide range of probable contingencies (defined as events to which the BES must be able to respond and support). Specifically, this standard requires PPL Electric to study the BES, proactively identify when issues would occur and develop and pursue implementation of corrective actions to resolve identified issues.

4.2 Existing System Configuration

The existing power feed to the Breinigsville substation is served by a single circuit 500kV line originating from the Wescosville 500kV substation and a single circuit 500kV line out of the Alburtis 500 kV substation (see **Figure 1-1**). This 500kV system provides voltage support to the Breinigsville substation. In the current configuration, when a 500kV outage event at Breinigsville occurs, PPL Electric's ability to resolve the resulting low voltage conditions is limited to reducing substation loading, *i.e.*, shedding customer load.

The Breinigsville 500kV substation feeds both industrial customers and residential customers. The industrial customers include Air Products, Tek Park, Amazon, Nestle Foods, and Coca Cola Bottling. Thus, a voltage issue could have a significant regional economic impact. The Breinigsville 500kV substation also serves important communication facilities, county and township offices, healthcare facilities, schools, sewage treatment facilities, and UGI gas facilities. Finally, this substation provides electric service to approximately 10,000 residential customers. In the event of a 500kV outage, customers would be subject to line repair periods ranging from ten hours to multiple days before service could be restored. Outage durations would be even longer in the event of unusually severe damage, caused by a weather event or security attack.

A map of the existing system is provided as **Figure 1-2**.

4.3 System Performance Review and Reliability Risks

PPL Electric's system planning studies and analysis identified that N-1-1 (N minus 1 minus 1) contingency conditions (unacceptable low voltage and voltage drop) would be present at the Breinigsville substation, beginning in 2019. These studies are required by PPL Electric's transmission planning requirements and NERC Standards. An N-1-1 contingency involves the loss of one system element followed by transmission system operators making manual system

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Agreement, Schedule 6. In this case, the Project was planned using different drivers and had already been presented to PJM as a Supplemental project. See Transmission Expansion Advisory Committee presentation, Apr. 9, 2015, at p. 30, https://pjm.com/-/media/committees-groups/committees/teac/20150409/20150409-reliability-analysis-update.ashx.

readjustments, and then the loss of a second system element, *e.g.*, outage of one transmission line followed by switching moves and then the loss of a second transmission line.

At the Breinigsville 500kV substation, a loss of both of the 500kV lines, the Susquehanna-Wescosville 500kV line and the Breinigsville-Alburtis 500kV line, creates an unacceptable voltage drop[3] and low voltage[4] on the 138kV and 69kV transmission lines supplied by the Wescosville, and Breinigsville 500kV substations. The Breinigsville substation would experience a 13.8% voltage drop, which exceeds PPL Electric's transmission criteria limit of 8% and a minimum voltage of 57.2kV, which is below the transmission criteria limit of 62.1kV. The low voltage and voltage drop experienced at the Breinigsville substation 138kV and 69kV lines directly lowers distribution system voltage to below allowable limits. When a low voltage or voltage drop event would occur, customers would experience low voltage and PPL Electric system operators would be required to reduce substation load by shedding 10,000 customers from service in the Breinigsville area to protect the power grid from the risk of cascading outage and blackout events and to protect distribution customers from equipment damage caused by the low voltage. During this event, the Commission's requirements[5] for voltage range and deviations on PPL Electric's distribution systems would be exceeded.

NERC standards require utilities to proactively plan for voltage drop conditions, which is why both PJM and PPL Electric include voltage drop criteria in their transmission planning standards.[6] Because utilities regularly plan to mitigate voltage drop and other events on the high voltage system, unplanned outages that result in unacceptable voltage drop at the 500kV level are rare.[7] Although the probability that the two relevant lines would go out of service at the same time is low, NERC requires PPL Electric to plan for this event to maintain the reliability of the BES.

NERC Standard TPL-001-4 requires the transmission planners (PJM and PPL Electric) to study this contingency event, develop criteria to ensure that during such an event, reliable system

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[3] PPL Electric's transmission planning standard criteria does not allow, more than an 8% voltage drop on the 138kV Transmission System post an N-1-1 contingency event. Similarly, more than a 7.5% voltage drop is not allowed on the 69kV system post an N-1-1 contingency event. PPL Electric's planning standards and criteria are detailed and publicly available in FERC Form 715. A copy is available at http://www.pjm.com/~/media/planning/plan-standards/private-ppl/point-of-contact-requirements.ashx. Table 4.2-2 on page 15 shows the PPL Electric Voltage Drop Criteria.

[4] PPL Electric planning standards do not permit lower than 0.92 and 0.90 per unit voltage on 138kV and 69kV systems, respectively, post a N-1-1 contingency event.

[5] 52 Pa. Code 57.14 (b) Allowable voltage variation (primary lightning)

[6] In addition to the potential impact on customers, failing to correct the voltage drop conditions may eventually result in compliance violations for PPL Electric. Specifically, PPL Electric would be subject to potential fines or other corrective action from its NERC delegated Regional Entity, Reliability First Corporation.

[7] PPL Electric has an average of 0 unplanned and 22 planned outages on the 500kV lines involved in the subject N-1-1 contingency, per year. System wide, PPL Electric has had an average of 8 unplanned outages and 128 planned outages per year on its 500kV system. PPL Electric has not had an occurrence where the two lines were out of service at the same time.

operation is maintained and mitigate any identified deficiencies. The subject N-1-1 scenario exceeding voltage parameters is an identified deficiency and PPL Electric must develop a solution and plan to resolve the deficiency it in order to be in compliance with NERC standards.

4.4 Public Health and Safety

During the preliminary engineering phase of this Project PPL Electric identified a safety concern with the Breinigsville-Alburtis 500kV Transmission Line. The existing line does not meet current National Electric Safety Code ("NESC") requirements, specifically the 5mA rule. This rule caps at 5mA the maximum induced current a transmission facility can cause on a large metal object, such as a tractor trailer parked under the line. Induced current in excess of 5mA creates the potential for individuals to be shocked. According to the Occupational Safety and Health Administration, current of 5mA or greater through the human body can lead to injury.

While the line met safety standards in effect when constructed, PPL Electric is required to comply with new and revised standards for any new or rebuilt transmission lines. Inspection determined that 12 of the 28 spans on the line do not meet contemporary standards. During Project development, PPL Electric also learned that there was an increased safety clearance risk with the existing line. A property owner routinely operates agricultural equipment under existing transmission structures within close proximity of the line. Rebuilding and raising the height of the transmission line will eliminate this safety concern.

5.0 Functional Alternatives

PPL analyzed six alternatives to resolve the transmission planning criteria violation and the health and public safety requirement (NESC 5mA rule) described above. PPL concluded that rebuilding the existing single-circuit Breinigsville-Alburtis 500kV Transmission Line provides the best solution to prevent the NERC violation from occurring and address the safety concern. The six alternatives considered included:

1) Rebuilding the Breinigsville-Alburtis Transmission Line to double circuit,

2) Installation of capacitor banks at Wescosville and Breinigsville substations,

3) Installation of a Special Protection Scheme ("SPS"),

4) Rebuilding the Susquehanna-Wescosville 500kV Transmission Line to double circuit,

5) Addition of a new 500kV green field circuit, and

6) Addition of a new 138 kV green field circuit.

Analysis of each alternative is provided below.

5.1 Rebuilding the Breinigsville-Alburtis Transmission Line to double circuit

The Breinigsville-Alburtis 500kV Transmission Line is presently a single circuit line that runs from the Breinigsville substation to the Alburtis substation. This line is approximately 6 miles long and will cost approximately $33M to rebuild. Rebuilding the Breinigsville-Alburtis 500kV Transmission Line will resolve the N-1-1 contingency conditions and address the NESC 5mA rule. PPL Electric determined that rebuilding the Breinigsville-Alburtis Transmission Line is an effective and acceptable solution because it:

- Permanently resolves the NERC contingency conditions regardless of system loading changes,
- Requires no new right of way, which minimizes environmental impact,
- Resolves the NESC safety concern,
- Improves customer reliability,
- Will accommodate long term system growth, and
- Minimizes the need for future capital improvements in this area.

5.2 Installation of capacitor banks at Wescosville and Breinigsville

PPL Electric studied the installation of capacitor banks[8] at the Wescosville and Breinigsville substations to provide voltage support during the N-1-1 contingency event. For this to be a viable solution, capacitor banks must be available prior to the contingency event occurring on the 500kV system under all operational and system loading conditions. Capacitor banks cannot be operated 24/7 year-round due to system operating and capacitor equipment performance constraints and therefore would only be partially effective in preventing the NERC N-1-1 conditions from occurring. Additionally, load growth around the Breinigsville substation has increased by 17 MW in the past three years and is projected to increase an additional 18 MW in the next three years.[9] Installation of capacitors to correspond with load growth would require capacitors of a size that would exceed PPL Electric's criteria for allowable voltage rise during capacitor switching operations. For these reasons, use of capacitors is not an acceptable solution.

5.3 Installation of a Special Protection Scheme (SPS)

NERC reliability standards allow the use of load drop as a solution to an N-1-1 contingency. However, load drop must be "automatic" (not by system operator manual intervention after low

[8] Capacitor banks are electrical devices that provide a fixed level of voltage increase under steady state conditions.

[9] One megawatt serves the equivalent of approximately 200 residential homes.

voltage occurs). Automatic load drop could be accomplished by designing and installing a SPS. PJM and PPL Electric do not consider SPS schemes as permanent solutions to reliability standard violations. PJM Manual 7 states "SPS's **should not** be installed as a substitute for good system design or operating practices. The implementation of SPS schemes are generally limited to temporary conditions involving the outage of critical equipment". These schemes are designed and intended to automatically and instantaneously de-energize transmission facilities in the event of a system contingency. SPS schemes involve complex relaying equipment and logic. Historically, they have been prone to mis-operation and increased outage risk. If a mis-operation were to occur, the same 10,000 customers would lose service. PPL Electric determined that this alternative is not an acceptable solution.

5.4 Rebuilding the Susquehanna-Wescosville 500kV Transmission Line to double circuit

Another option to resolve the loss of one of the 500kV circuits into the Breinigsville substation would be to rebuild the Susquehanna-Wescosville 500kV Transmission Line and the Wescosville-Breinigsville 500kV Line. Both are currently single circuit transmission lines and combined are approximately 67 miles long. Initial evaluation of rebuilding this line indicated that the existing structures could not support the addition of another circuit and the entire line would need to be rebuilt. The cost to rebuild the entire transmission line would be in excess of $382M.

Rebuilding the Susquehanna-Wescosville and the Wescosville-Breinigsville 500kV line would be an effective solution to resolve the NERC contingency conditions. However, this alternative is not a preferred solution because of the high cost and it does not resolve the existing safety concerns on the Breinigsville-Alburtis 500kV line.

5.5 Building a new 500kV green field circuit into Breinigsville

An alternate solution to rebuilding the existing Breinigsville-Alburtis 500kV line is building a new 500kV green field line from Breinigsville to Alburtis. This option would require the expansion of existing or procurement of new rights of way resulting in increased impacts on the environment and the public in general. The cost of this option would be more than $35 million. This option also does not resolve the existing NESC safety concern on the Breinigsville-Alburtis 500kV line. For these reasons, building a new line is not a preferred solution.

5.6 Building a new 138kV Double Circuit Line between Wescosville and Breinigsville

Another alternative considered was building a new double circuit 138kV line from the Wescosville substation to the Breinigsville substation. This would resolve the current N-1-1 scenario and bring the voltage drop and low voltage values on the 138kV and 69kV systems in the Breinigsville area within acceptable limits. However, it would also create new and additional NERC contingency conditions. A new double circuit 138kV line will overload the Wescosville T3 transformer, creating new N-1 and N-1-1 NERC violations. Additionally, a third N-1-1 contingency condition, occurs from overloading the existing Hosensack-Wescosville 230kV line. Cost estimates to build a new double circuit 138kV lines range from $33M to $71M due to the

limited availability of new rights of way in the area. Additional costs of $16M would also be incurred to resolve the three new NERC contingency conditions. This option would require the procurement of new rights of way resulting in increased impacts on the environment and the public in general. Therefore, this alternative is not a preferred solution.

6.0 Proposed Solution

PPL Electric has determined that rebuilding the existing Breinigsville-Alburtis 500kV Transmission Line to double-circuit is the most effective and acceptable solution to resolve the NERC contingency conditions as well as the NESC safety concern.

To resolve the NERC N-1-1 contingency conditions and ensure compliance with NESC safety requirements, PPL Electric proposes to rebuild the single-circuit Breinigsville-Alburtis 500kV Transmission Line to a double-circuit configuration including a complete reconstruction of the existing line and new structures that meet modern clearances and design standards.

A map of the proposed Project is provided as **Figure 1-3**.

The Project will rebuild approximately 6 miles of line from the Breinigsville 500kV substation to the Alburtis 500kV substation as shown on Figure 1-2. The rebuilt double-circuit Breinigsville-Alburtis 500kV Transmission Line will be on the same structure alignment and in the same right-of-way as the existing single-circuit Breinigsville-Alburtis 500kV Transmission Line. This Project will not require the purchase of any additional land therefore offering a low environmental impact proposal. The existing 500kV conductor and structures are required to be replaced as a result of adding the new second 500kV circuit and to address the NESC safety concern by increasing the ground to line clearance. Detailed descriptions of the new structure types and locations are provided in **Attachments 2** and **3**.

This proposed second circuit will permanently resolve the low voltage and voltage drop conditions as required by the NERC TPL-001-4 standard described above, improve overall system reliability, and ensure compliance with NESC safety rules.

The Project is necessary to resolve violations of NERC, PJM and PPL Electric transmission planning standards criteria, improve system reliability, reduce the potential for and duration of outages, increase system operability and ensure safe operation of the Transmission system in Lehigh County. Upon completion, PPL Electric estimates a reduction in both the System Average Interruption Duration Index ("SAIDI") and System Average Interruption Frequency Index ("SAIFI") of outages by 10.36 minutes and 0.0072 occurrences respectively,[10] should the N-1-1 contingency event occur.

[10] SAIDI is a measure of the duration of electric outages and SAIFI is a measure of the frequency of outages. For example, a SAIFI of 1.0 would mean that within the previous year, a typical customer would experience one outage.

Figure 1-2: Existing System Map

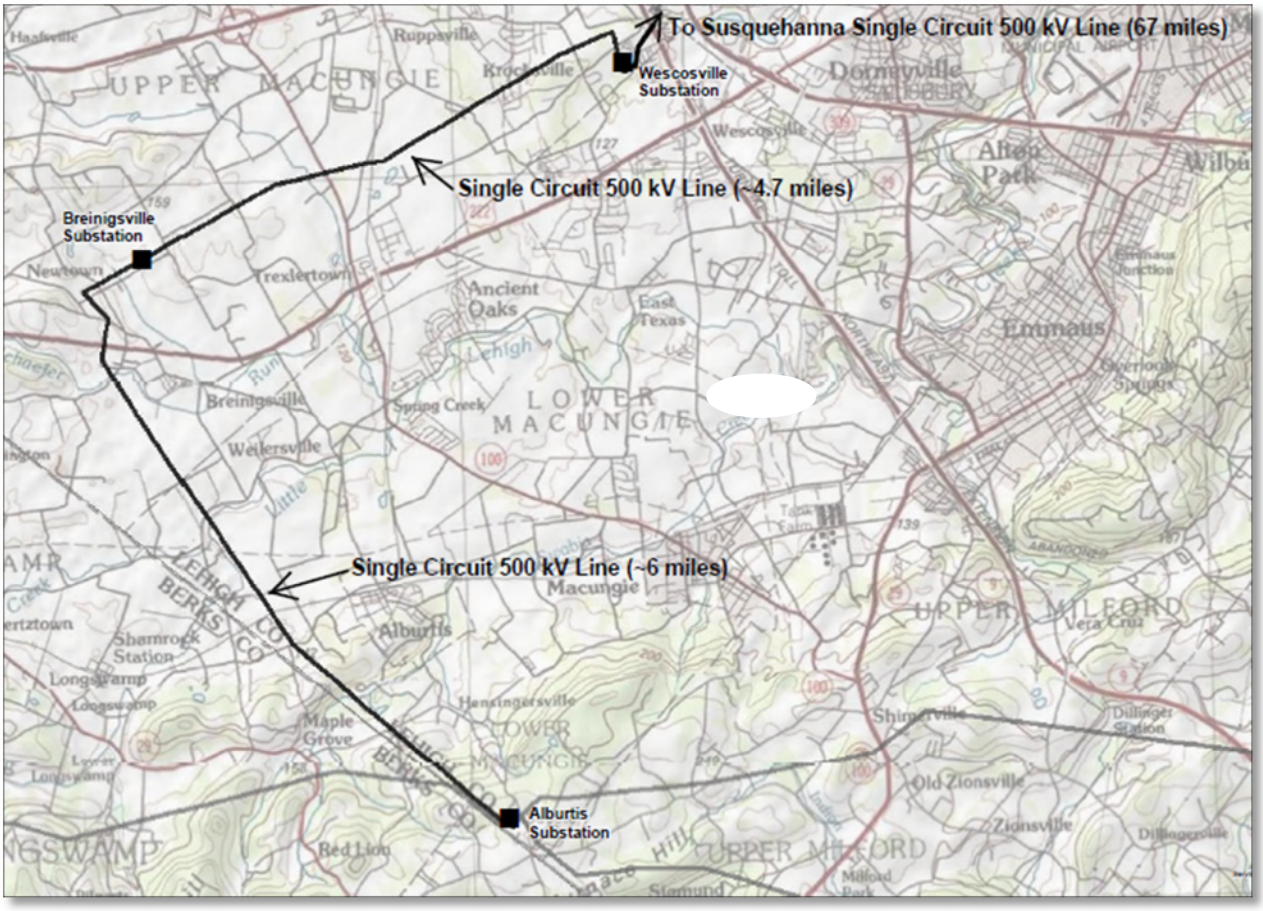

Figure 1-3: Proposed System Map