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**E-FILE**

October 1, 2020

Rosemary Chiavetta, Secretary  
Pennsylvania Public Utility Commission  
Commonwealth Keystone Building  
400 North Street  
Harrisburg, Pennsylvania 17105-3265

**Re: PPL Electric Utilities Corporation  
Biennial Inspection, Maintenance, Repair and Replacement Plan  
For the Period January 1, 2022 – December 31, 2023  
Docket No. M-2009-2094773**

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Dear Ms. Chiavetta:

Enclosed for filing on behalf of PPL Electric Utilities Corporation ("PPL Electric") an original of PPL Electric's Biennial Inspection, Maintenance, Repair and Replacement Plan for the Period January 1, 2022 – December 31, 2023 ("I&M Plan"). PPL Electric's I&M Plan is being filed pursuant to the Commission's regulations at 52 Pa. Code §§ 57.198.

Pursuant to 52 Pa. Code § 1.11, the enclosed document is to be deemed filed on October 1, 2020, which is the date it was submitted electronically via the Commission's E-Filing system.

If you have any questions, please call me or Dave Gladey, PPL Electric's Director – Distribution Asset Management at (610) 774-6580.

Very truly yours,

A handwritten signature in blue ink, appearing to read "Michael J. Shafer", is written over a light blue horizontal line.

Michael J. Shafer

Enclosures

cc: Mr. Paul Diskin  
Mr. David Washko

Tanya J. McCloskey, Esquire  
Mr. John R. Evans

# PPL Electric Utilities Corporation

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## Biennial Inspection, Maintenance, Repair and Replacement Plan of PPL Electric Utilities Corporation

For the Period of January 1, 2022 – December 31, 2023

Submitted by:

  
David Gladey (Sep 30, 2020 10:42 EDT)

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Dated: October 1, 2020

# PPL Electric Utilities Corporation

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### **Introduction**

PPL Electric Utilities Corporation (“PPL Electric” or “Company”) is firmly committed to maintaining high levels of customer satisfaction. Customer surveys show that high levels of customer satisfaction are achieved by providing reliable performance at a reasonable cost. PPL Electric has established a strong, long-term record of customer satisfaction and electric reliability. PPL Electric has earned 26 J. D. Power customer satisfaction awards – more than any other investor-owned utility in the country – since J. D. Power began studying customer satisfaction among electric utility customers. PPL Electric has ranked highest among large electric utilities in the eastern United States in J. D. Power annual study of residential customer satisfaction 16 times: in 1999 and from 2001-2007 and 2012-2019.

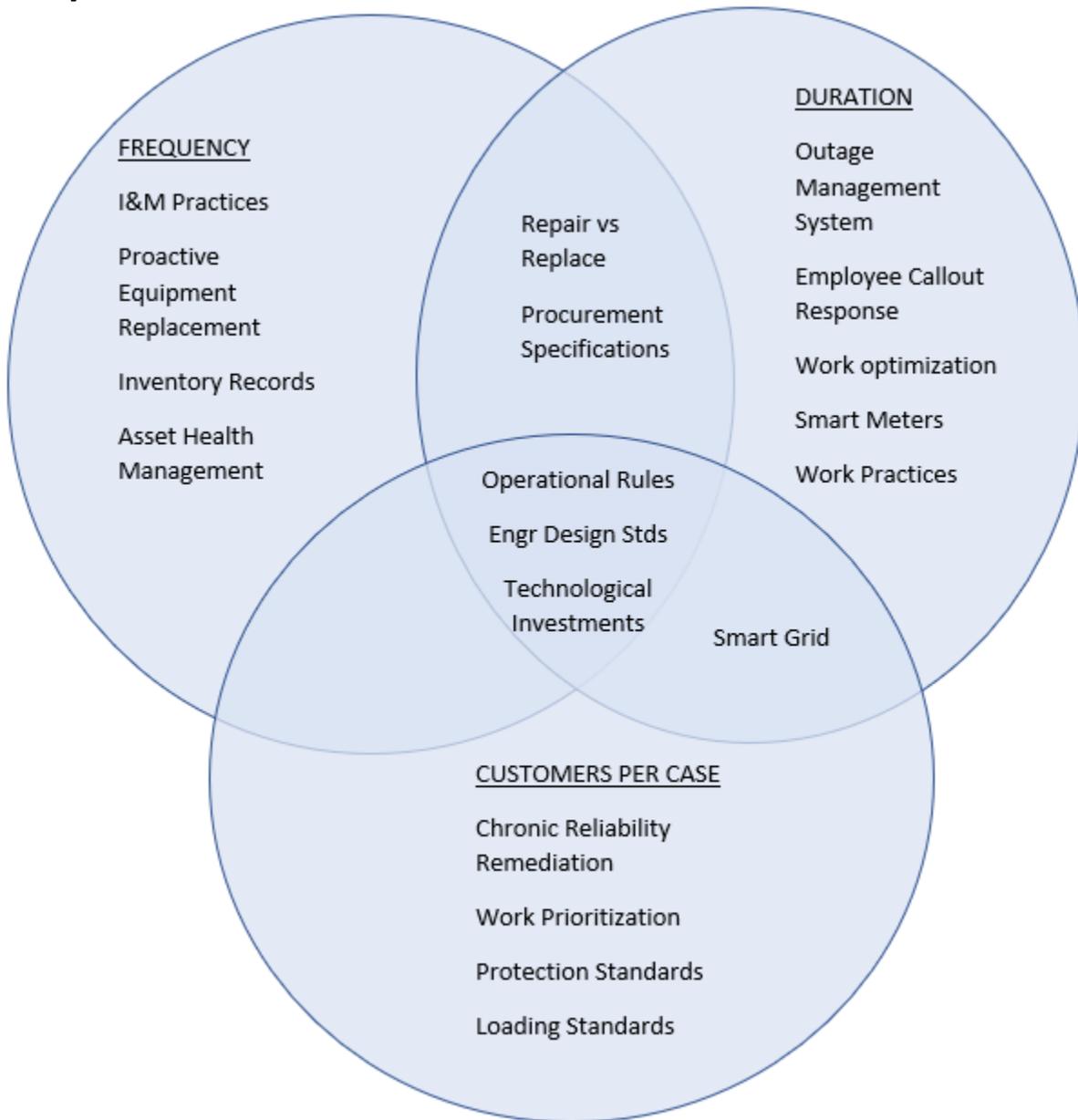
Ultimately, all of the costs of maintaining reliability are borne by the ratepayers. Therefore, managing finite resources to produce optimal results is essential in order to deliver excellence in customer satisfaction. The criteria for program inclusion is not whether any given activity produces a positive reliability result, but, rather, what portfolio of activities produces the best result for a given expenditure of resources given the specific reliability challenges faced by PPL Electric at this point in time, and for the foreseeable future. PPL Electric’s goal is focused on results (i.e., the reliability experienced by customers), not the rote execution of particular tasks.

Reliability performance is driven by a mixture of manageable and unmanageable factors. The most impactful of the unmanageable factors is the frequency and severity of weather events, which can vary

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dramatically over time and geography. The manageable factors have an effect on service interruption frequency, duration, or number of customers affected, or a combination of all three. The figure below depicts a portfolio of manageable factors with inspection and maintenance (“I&M”) practices being one of many.



### Reliability Programs and Policies

PPL Electric’s philosophy is that the first step in improving reliability is to prevent outages altogether. The primary focus is, therefore, on the manageable factors that reduce the frequency (number) of cases. Efforts that typically overlap are those designed to minimize the number of customers affected should an outage occur. Realizing that not all outages are preventable, PPL Electric also directs rigorous efforts

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designed to reduce the duration of the outages that do occur. Examples of PPL Electric initiatives addressing each of the three reliability sectors, frequency (number of cases), customers affected per case, and duration are addressed below.

### **Frequency (number of cases)**

- **Inspection and maintenance practices and programs:** PPL Electric remains focused on equipment performance and service interruption avoidance through the application of effective inspection and maintenance practice and programs. A comprehensive discussion has been provided to the Pennsylvania Public Utility Commission (“PUC” or “Commission”) via PPL Electric’s I&M filing on a biennial basis since the initial report in 2010. The scope of these programs, procedures and activities covers all areas of the electrical infrastructure to include transmission, substations, distribution, and vegetation.

#### **Transmission**

Transmission inspection programs include aerial patrols and structure inspections, treatments, and replacements. The patrols focus on comprehensive inspections, routine inspections, stop-go inspections, and identification of emergency work. The inspections encompass all equipment, including poles, arms, line switches, interrupters, arresters, grounding, guying, anchors, and other key transmission components.

#### **Substation**

Substation maintenance programs include inspections, condition testing, and preventative maintenance of equipment, such as power transformers, circuit breakers, disconnects, power cables, and security equipment. Some equipment is maintained on a time basis; other equipment is condition monitored. These two methods help ensure that maintenance work is performed in a timely manner. In addition to time and condition-based maintenance, thermographic inspections help to ensure that substation equipment does not operate at elevated temperature levels, which could lead to premature failures.

#### **Distribution**

Distribution encompasses many maintenance aspects similar to transmission and substations, and also includes load surveys that assist in determining peak load requirements, and circuit analyses that help identify lines requiring maintenance work, voltage relief, or other capital improvements. Overhead line inspections identify the weak links in the system so that damaged or deteriorated equipment can be repaired or replaced. In addition, distribution maintenance includes inspections of poles, voltage regulators, line switches, capacitors, and other key distribution equipment. PPL Electric also tests underground cable for integrity to determine if the cable needs to be replaced or repaired.

#### **Vegetation**

The vegetation on PPL Electric’s transmission and distribution rights-of-way is maintained using a combination of several management techniques. These include

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reclearing, ground-to-sky trimming, hazard tree removal, tree pruning, and herbicide application. The work is prioritized based on the conditions observed and past performance.

Each of these programs is more fully described in Appendices A through D.

- **Asset Optimization Strategy (“AOS”):** Since 2018, PPL Electric has developed several data-driven failure probability models based on relevant failure modes. These data model projects were initiated to drive smarter, targeted asset investment strategies throughout the portfolio and to address the challenges created by the Company’s aging infrastructure. As a result, several asset investment strategies across multiple asset classes have been revised to address these challenges. PPL Electric conducts effectiveness reviews of the various programs comprising this strategy to ensure that aging infrastructure continues to be appropriately addressed.
- **Asset Health Assessment:** PPL Electric is continuously expanding its use of data-driven decision making. Where feasible, asset health and criticality scores are captured and employed to refine programs to deliver the most effective reliability impact per dollar invested. PPL Electric continuously monitors the accuracy and effectiveness of these asset health and criticality scores, and in early 2018 began an initiative to develop predictive failure models of vital assets with the intention of continuously improving the health and criticality scores. These continued health calculation efforts enable PPL Electric to mitigate risk and optimize reliability more effectively. Among the areas where health and criticality scores are employed are substation and Low Tension Network equipment, reclosers, and underground cables.
- **Long Term Infrastructure Improvement Plan:** In January 2018, the Commission approved PPL Electric’s second Long Term Infrastructure Improvement Plan (“LTIIIP”). This Plan was submitted pursuant to the requirements of Subchapter B, Distribution Systems, of the Public Utility Code, 66 Pa.C.S. §§ 1350-1360, and the PUC’s Implementation Order for Establishment of a Distribution System Improvement Charge (“DSIC”). The Plan is a continuation of AOS infrastructure replacements in addition to prudent capital investments such as the proactive installation of animal guards, new sectionalizing devices, distribution automation, asset life extension methods, replacement of deteriorated equipment, and capital projects aimed at addressing worst performing circuits (“WPCs”).

**Reliability Preservation Program:** In 2019, the legacy Customers Experiencing Multiple Interruptions (“CEMI”) and MAIFI Programs were combined with the Reliability Preservation Program. This was strategically done to ensure all reliability-based projects were prioritized and addressed together for efficiency and timeliness of remediation. All projects are vetted and prioritized against a common prioritization methodology to ensure consistency and systematic benefits are quantified across the portfolio. Reliability performance of PPL Electric’s circuits are reviewed on a quarterly basis to ensure investment plans are optimized.

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- **Proactive Circuit Analysis (“PCA”):** PCAs are performed on each circuit on a four-year cycle. The review analyzes and addresses both operational and reliability characteristics of each circuit. Voltage support, phase balancing, protection coordination, power factor maintenance and loading issues are addressed from an operational perspective. Service outage analysis, exposure analysis and field checks address reliability and power quality.
- **Reliability Principles and Practices (“P&P”) Revisions:** The P&P sets forth a set of principles that PPL Electric follows to plan, protect, and operate the Electrical Distribution System (“EDS”). These principles are implemented through a set of standard practices that are used as guidelines in designing the EDS. These practices are reviewed regularly to ensure they remain reasonable and acceptable and align well in accordance with good utility practices. Additional revisions to PPL Electric’s P&P are underway to reduce the overall impact to our customers as the Company implements smart grid strategies.

### Duration (minutes/case)

- **Distribution Automation:** In 2010, PPL Electric launched a “smart grid” pilot project that enables the Company to react rapidly to changes on the delivery system, and to automatically re-route power around problems that occur. The project initially focused on the Harrisburg, Pa. area, but has since been expanded to cover all of our service territory. The project included the implementation of an advanced Distribution Management Systems (“DMS”), which was a breakthrough technology that enables our operators to see the status of our distribution network in real-time. In 2016, PPL Electric completed a system wide rollout of FISR (Fault Isolation and Service Restoration) technology. FISR identifies faulted sections and quickly develops an optimized restoration plan, then automatically executes that plan. Customers typically can be restored within five minutes from the start of the outage. This milestone is an industry first and looks to significantly reduce overall outage durations. Over 8,600 automated smart devices have been installed to date. Such installations allow for remote operation and monitoring of circuit sectionalizing equipment, and advanced fault location technology. The goals of these improvements are threefold:
  - Reduce the number of upstream customers affected by a service outage.
  - Reduce the time necessary to restore customers by transferring circuit sections to alternate sources and limiting long-duration service outages to smaller circuit sections involving fewer customers.
  - Facilitate fault location and reduce the time necessary for repair and restoration.

The end-result will be a delivery system that operates more efficiently, recognizes problems immediately, and responds in seconds to restore the service for many customers who otherwise need to wait for crews to physically respond to an outage.

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### **PPL Electric Reliability Results**

The reliability planning and investment process employed by PPL Electric have been very effective, as evidenced by its reliability performance. This has been accomplished while preserving a reasonable cost of providing service.

### **PPL Electric Reliability Planning Process**

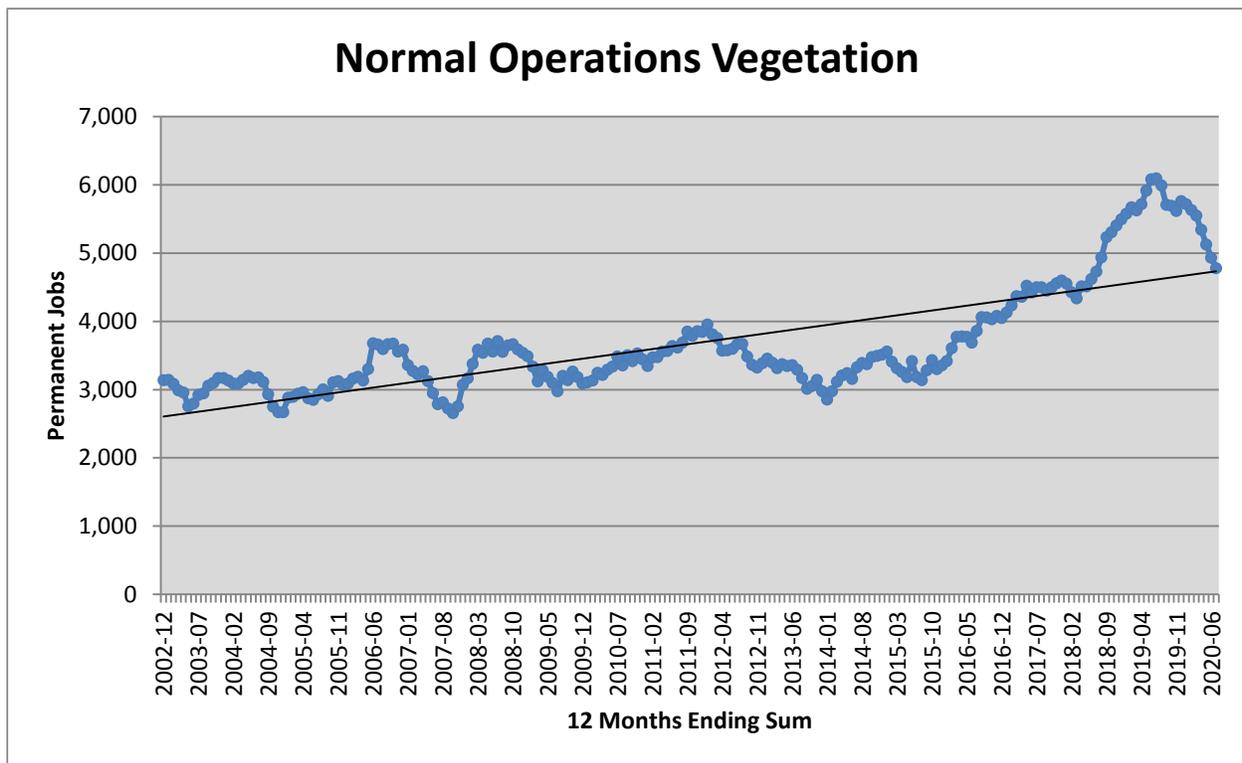
PPL Electric's process is forward-looking and proactive. It consists of the following:

- Analyze the historical trends of causes of service outages and other power service problems.
- Identify the drivers of those trends.
- Forecast future reliability metrics (SAIDI, SAIFI, CAIDI, and MAIFI) given existing mitigation programs' effect on the identified drivers.
- Identify new programs, policies, and activities to add to or substitute for existing mitigation programs to avoid any forecasted gaps between future reliability and the desired levels.
- Identify, evaluate, and implement new technologies that enhance its condition monitoring strategy
- Continually evaluate and adjust programs, policies and activities to produce the desired future results.
- The resulting portfolio of existing and new programs, policies and activities are incorporated into PPL Electric's I&M plan.

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## PPL Electric Reliability Analysis

Identification and understanding of trends create the opportunity to plan programs to mitigate undesirable trends. Most of the year-to-year variation in service interruptions is explained by differences in storm experience. Therefore, PPL Electric generally removes all declared-storm caused service outages (though not all weather related outages) for internal analysis to identify other causal trends affecting reliability. Each data point in the following charts represents a 12-month ending value to eliminate the effect of seasonal variation.

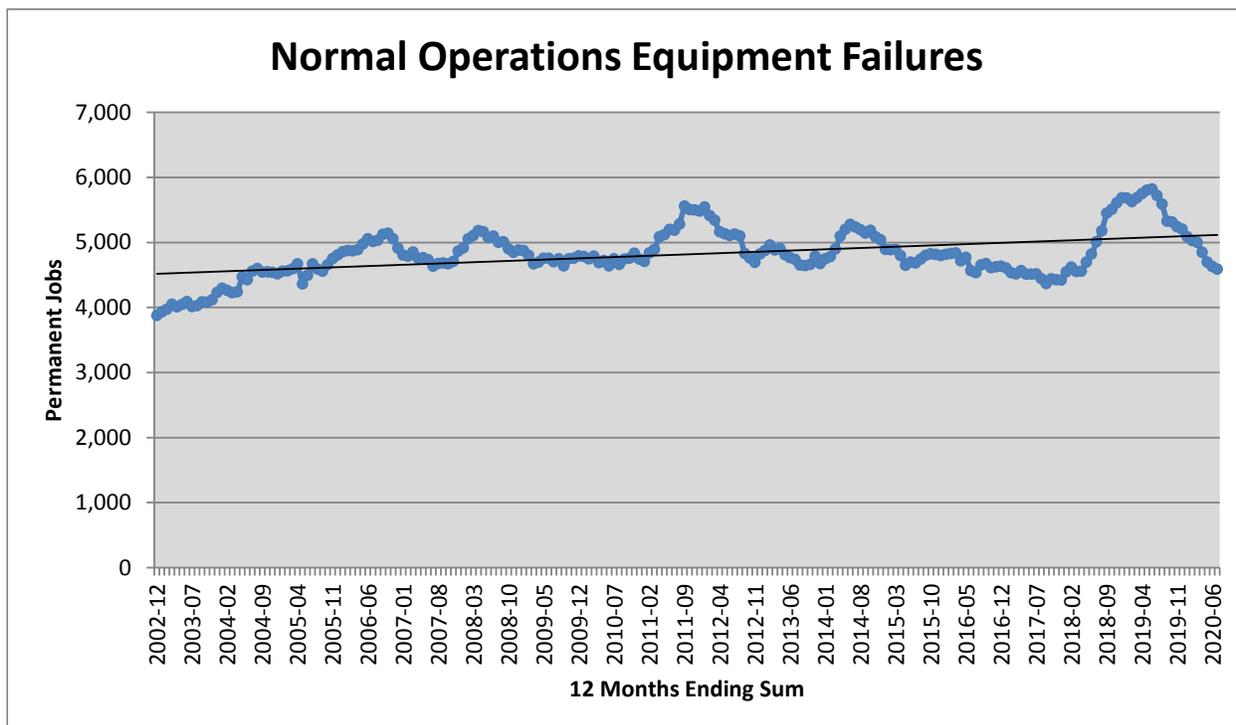


**Vegetation Related Service Interruption Cases**

PPL Electric is committed to continuing an aggressive Vegetation Management program to address the threat of tree related outages. It is worth noting that even when excluding major and PUC reportable storm events, 77% of vegetation related outages occur during adverse weather conditions. The strong storms and saturated ground conditions prevalent in 2018 and 2019 resulted in higher than normal occurrences of vegetation outages, including healthy trees toppling into overhead conductor.

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A significant risk to PPL Electric's ability to meet reliability benchmarks is the large portion of distribution facilities, which were installed in the 1960's and 1970's, that are now beyond or nearing the end of their design lifetime. The resultant effect on non-storm-related equipment failure is illustrated by the chart below.



### Equipment Failure Service Interruption Cases

The annual number of outages due to equipment failure was generally stable or declining from 2005 through 2018. Beginning in July of 2018, a period of severe weather brought about a spike in failed equipment that is just now rolling out of the 12-month rolling window.

Initiatives contributing to the reversal of the failed equipment trend include equipment replacements identified through Expanded Operational Reviews of 25% of circuits annually, aggressive worst performing circuit remediation, implementation of PPL Electric's Asset Optimization Strategy, enhanced pole inspection and treatment, distribution automation, and infrared inspections.

Although these programs have successfully reversed equipment failure growth rates in the short-term, PPL Electric faces a long-term challenge regarding aging infrastructure. PPL Electric is committed to mitigating the aging infrastructure challenge through effective use of proactive replacement programs and data-driven failure probability models. Scheduled replacement of that infrastructure is necessary to avoid accelerating failure rates due to end of life fatigue.

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Reliability is the largest contributor to overall customer satisfaction. Satisfaction levels vary depending upon the amount of information provided to the customer regarding their outage. Providing customers with accurate information about their outage is increasingly important. Customers are more understanding of storm and weather-related service outage impacts than they are of other outage causes, such as utility equipment failures.

If it is more cost-effective to offset an increase in equipment failure cases with a program to reduce vegetation-related cases, the customer is better served by this cost-effective choice. Similarly, if a program that reduces the average number of customers affected by each service outage is more cost-effective than a program to reduce the gross number of service outages, the more cost-effective program should be chosen. The management challenge is to maintain reliability within acceptable parameters in the most cost-effective manner, while keeping customer satisfaction levels high.

***52. Pa. Code § 57.198 (b) Plan Consistency.*** *The plan must be consistent with the National Electrical Safety Code, Codes and Practices of the Institute of Electrical and Electronic Engineers, Federal Energy Regulatory Commission Regulations and the provisions of the American National Standards Institute, Inc.*

PPL Electric's I&M Plan is consistent with the National Electric Safety Code ("NESC"), Codes and Practices of the Institute of Electrical and Electronic Engineers ("IEEE"), Federal Energy Regulatory Commission Regulations ("FERC") and the provisions of the American National Standards Institute, Inc. ("ANSI").

***52. Pa. Code § 57.198 (c) Requested Deviations*** *The plan must comply with the inspection and maintenance standards in subsection (n). A justification for the inspection and maintenance time frames selected shall be provided, even if the time frame falls within the intervals prescribed in subsection (n). However, an EDC may propose a plan that, for a given standard, uses intervals outside the Commission standard, provided that the deviation can be justified by the EDC's unique circumstances or a cost/benefit analysis to support an alternative approach that will still support the level of reliability required by law.*

PPL Electric is again requesting acceptance of the following deviations from the intervals in the Commission standard as were included in the five previous I&M reports (2012-2013, 2014-2015, 2016-2017, 2018-2019, and 2020-2021):

- Section 57.198 (n)(2). Pole Inspections. (vi) A load calculation.
- Section 57.198 (n)(4). Distribution overhead line inspections.
- Section 57.198 (n)(6). Distribution transformer inspections.

PPL Electric is again requesting acceptance of the following deviations from the intervals in the Commission standard as were included in the three previous I&M reports (2016-2017, 2018-2019, 2020-2021):

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- Section 57.198 (n)(7). Recloser inspections.

PPL Electric is again requesting acceptance of the following deviation from the intervals in the Commission standard as were included in the two previous I&M reports (2018-2019, 2020-2021):

- Section 57.198(n)(8). Substation inspections.

***52. Pa. Code § 57.198 (m) Recordkeeping(m)*** *An EDC shall maintain records of its inspection and maintenance activities sufficient to demonstrate compliance with its distribution facilities inspection, maintenance, repair and replacement programs as required by subsection (n). The records shall be made available to the Commission upon request within 30 days. Examples of sufficient records include: (1) Date-stamped records signed by EDC staff who performed the tasks related to inspection. (2) Maintenance, repair and replacement receipts from independent contractors showing when and what type of inspection, maintenance, repair or replacement work was done.*

Inspection and maintenance activities performed by PPL Electric employees are tracked by electronic work requests in the Company's Work & Asset Management System (WAM) software application which date-stamps transactions and captures an electronic signature of the employee certifying completion.

Inspection and maintenance activities performed by PPL Electric contractors are documented with itemized records, which identify when and what type of work was performed, before invoices for the work are paid.

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**52. Pa. Code § 57.198 (n)(1). Vegetation Management.** *The Statewide minimum inspection and treatment cycle for vegetation management is between 4-8 years for distribution facilities. An EDC shall submit a condition-based plan for vegetation management for its distribution system facilities explaining its treatment cycle.*

### Program Description

PPL Electric employs a condition-based five-year inspection and maintenance cycle for its distribution circuits where trimming, hazard tree removals and brush control are performed. All Transmission lines have two complementary condition-based maintenance programs performed on four-year cycles. One focuses on herbicide application to manage vegetation on the floor of the corridor and the other focuses on trimming along the edge of the corridor. Inspections for and removals of hazard trees occur on both cycles. Each program is offset by two years, so each line receives a physical inspection and maintenance every two years. Additionally, an aerial LiDAR inspection is performed annually to verify clearances of vegetation from Transmission facilities. Based on conditions the cycle schedule may be modified, but not beyond established regulations.

- Purpose

To safeguard the reliability of its electric distribution system, PPL Electric has developed a comprehensive program to manage vegetation around power lines. Keeping trees and other vegetation away from high-voltage lines is important. Tree contacts can result in short-circuits and subsequent service outages.

Taller species of trees that are permitted to grow under power lines eventually will contact the wires, causing service interruptions and unsafe conditions. It is necessary for PPL Electric to trim or remove these trees to continue safe and reliable electric service.

- Process

### Distribution

Multi-phase lines will be pruned to the full extent of the established tree line, not to exceed 25' from centerline and ground to sky pruning will be utilized.

Single-phase lines will be pruned to the full extent of the established tree line, not to exceed 15' from centerline and to a distance of 15' above the line. All dead or structurally weak limbs which could fall or blow into the conductor are removed regardless of their distance above the conductor.

Exceptions: Trees on the opposite side of any thoroughfare, where normal line construction exists (not alley arms), should be considered for proper lateral pruning using the centerline of the thoroughfare as a guideline. Fast growing tree species may need more aggressive pruning.

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Another enhancement is hazard tree removal. “Hazard trees” are those trees outside the right of way that may be leaning, diseased, or otherwise pose a threat of falling on a distribution line. PPL Electric bears all costs of removing hazard trees and conducts the removal either based on right of way agreements or with property owner permission.

### Transmission

PPL Electric Utilities operates thousands of miles of high-voltage transmission lines. The Company’s vegetation management program is designed to promote the safe and reliable operation of the electric grid, while considering the concerns of property owners and our obligations to electric customers. Low-growing grasses and other compatible species are permitted within the wire zone. In the remainder of the right-of-way, certain compatible trees and shrubs are allowed if they do not pose a reliability risk.

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**52. Pa. Code § 57.198 (n)(2). Pole Inspections.** *Distribution poles shall be inspected at least as often as every 10-12 years except for the new southern yellow pine creosoted utility poles which shall be initially inspected within 25 years, then within 12 years annually after the initial inspection. Pole inspections must include:*

- (i) Drill tests at and below ground level.*
- (ii) A shell test.*
- (iii) Visual inspection for holes or evidence of insect infestation.*
- (iv) Visual inspection for evidence of unauthorized backfilling or excavation near the pole.*
- (v) Visual inspection for signs of lightning strikes.*
- (vi) A load calculation.*

### Program Description

- Cycle

Every twelve years.

- Purpose

Distribution poles are inspected to identify and measure the extent of decay and defects that may adversely affect safety or service reliability.

- Process

PPL Electric conducts a full excavation program, in which each pole over the age of twenty-five years that is not set in concrete, asphalt or with a riser is fully excavated to a depth of 18 inches. The pole is inspected visually, sounded and bored above ground in addition to the full excavation. All measurable decay is entered into the contractor's engineering-based software program to determine the percentage of remaining strength, taking into consideration ANSI and NESC standards. Poles younger than twenty-five years are visually inspected only.

Based upon the inspection and testing results, the pole is treated with a preservative, reinforced (by truss or fiber wrap) or replaced.

- Justification for waiver

PPL Electric's pole inspection program generally complies with the intervals set forth in 52. Pa. Code §57.198 (n)(2), NESC rules and is consistent with industry practices. PPL Electric proposes a continuance of the deviation from the requirement for a load calculation to be performed for each pole inspected. The design of PPL Electric's lines is based on its Distribution Engineering Instructions which are based upon NESC heavy loading conditions. These instructions provide adequate safety factors such that the allowable percentage of strength reduction does not compromise the ability of the pole to support the load. PPL Electric requires entities attaching facilities to its poles to perform

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their own load calculations before making the attachment. Load calculations are performed on every pole where new attachments are requested by third parties.

PPL Electric does not track service outages caused by pole equipment failure as a discrete category. Poles are contained within a category that includes poles arms, brackets, guys, push braces, pole top extensions and any other mounting hardware. In 2017, equipment failures requiring replacement in this category amounted to 374 (7.6% of total cases), of which only a small fraction are poles. Excluding pole fires, only 9 cases (0.3% of total cases) suggest broken PPL Electric-owned poles. (Nine poles represent 1/1000 of one percent of PPL Electric's 885,000 wood distribution pole inventory.) Most of the limited numbers of pole failures are aggravated by weather conditions such as trees being blown into lines, so the potential risk reduction through a load calculation is insignificant.

Beginning in 2010, the Company's wood pole maintenance program was enhanced from an inspection-only process to an inspection and treat program, whereby all poles passing the inspection are chemically treated to arrest decay at the same visit. The preservative treatment permits the next inspection to be at a uniform twelve years, rather than the former one to nine-year cycle after original inspection applied to individual poles. Changing to a uniform twelve-year cycle will enable more economic geographic-based inspections where all poles in a defined area are inspected, rather than the current method of inspecting scattered poles with individually specified intervals which maximizes the employee travel involved.

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**52. Pa. Code § 57.198 (n)(3). Pole inspection failure.** *If a pole fails the groundline inspection and shows dangerous conditions that are an immediate risk to public or employee safety or conditions affecting the integrity of the circuit, the pole shall be replaced within 30 days of the date of inspection.*

### Corrective Maintenance

- PPL Electric obtains pole replacement data weekly. Critical poles, those that pose an immediate safety concern, are reinforced or replaced as soon as possible, and not later than 30 days after notification. Other non-restorable rejected poles generally are replaced within one year of identification. Pole strength is provided for each rejected pole to assist in reinforce versus replace decisions and schedule prioritization. Reinforcement by steel C-Truss, a galvanized steel truss which is banded around the pole in order to regain the pole's original strength or fiber wrap, several layers of high-strength fiberglass wrapped onto the pole and saturated with resin is generally completed within 180 days of identification. The method of reinforcement is determined by the circumstances and/or location of the pole.

**52. Pa. Code § 57.198 (n)(4). Distribution overhead line inspections.** *Distribution lines shall be inspected by ground patrol a minimum of once every 1-2 years. A visual inspection must include checking for:*

- Broken insulators.*
- Conditions that may adversely affect operation of the overhead transformer.*
- Other conditions that may adversely affect operation of the overhead distribution line.*

### Program Description

- Cycle

Infrared inspection: Multi-phase overhead lines adjacent to roadways every two years.

Visual inspection: Condition based – selected line segments. Inspections are scheduled under various conditions to include CEMI and WPC circuits, if warranted based on Proactive Circuit Reviews, and/or if power quality issues are experienced. Additional patrols are conducted to ensure continued reliability include those in support of distribution construction projects as well as summer and winter readiness patrols.

Pole inspection: Every twelve years.

- Purpose

The objective of an overhead line inspection is to identify and correct hardware or equipment defects that may lead to a future service interruption or pose a safety hazard. Defects are identified by inspection, prioritized and scheduled for repair.

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- Process

Infrared: Multi-phase distribution lines adjacent to roadways are scanned from vehicles. A roof-mounted infrared camera is employed to capture a thermal image of components carrying electrical current. Heat emission measurements are compared to reference temperatures. Probability of failure is estimated based upon the magnitude of temperature difference from reference. The method detects problems in current carrying components such as transformers, connections, splices, hot line clamps, disconnects, switches, lightning arresters, bridges disconnects, terminators, etc., whether or not there are visible defects. A detailed report of findings is prepared and at-risk items are prioritized and mitigated by repair or replacement.

Visual: An analysis of actual service interruptions is conducted on selected circuits (e.g., poor performing circuits as measured by PPL Electric's WPC process, circuits with higher CEMI customers, and circuits undergoing proactive circuit analysis.) If an analysis indicates a pattern of equipment failure exists, a visual line inspection is scheduled. In addition to looking for visible defects in current-carrying components, visual inspection looks for mechanical defects in anchors, guys, crossarms, insulators, offset brackets, grounding systems and poles.

Pole Inspection: As an integral part of the twelve-year pole inspection process, the wood poles are observed, with at-risk conditions of all pole attachments, specifically crossarms, braces, conductors, transformers, fuse cutouts, lightning arresters, reclosers, regulators, capacitors, switches, wildlife protection, vegetation encroachment, guys, anchors, ground wires and rods noted and reported.

- Justification for waiver

PPL Electric hereby proposes a continued deviation from the 1-2 year inspection cycle on the basis of an effectiveness evaluation and cost benefit analysis in favor of the program described herein. Resources that would be applied to shorter visual cycles than this proposal would reduce the resources applied to other more cost-effective reliability programs described in this plan.

PPL Electric conducted a trial of infrared inspections of multi-phase lines in 2006. The trial inspections cost \$122,500 and identified repairs costing \$100,000, saving an estimated 1,460,000-2,600,000 Customer Minutes Interrupted ("CMI"), at a cost of \$0.09 to \$0.15 per CMI saved. PPL Electric restructured the infrared service contract gaining further efficiencies in 2014. The cost benefit as calculated by the 2018 program effectiveness review suggested that the two programs, at a yearly cost of \$327,000, save an estimated 719,000 CMI, at a cost of \$0.45 per CMI saved.

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PPL Electric employs a \$2.00 per CMI saved cost threshold<sup>1</sup> as a principal criterion for evaluating new projects for inclusion in the portfolio of reliability programs. Costs below that threshold are generally considered to be prudent investments, while those above typically provide less benefit for the cost. The cost threshold assists in applying finite resources to programs producing better results, thus enabling the most effective portfolio of programs. Because infrared costs per CMI saved are well below the threshold, PPL Electric instituted a two-year infrared cycle for accessible multi-phase lines.

PPL Electric also conducted an overhead line visual inspection cost benefit study in 2010. The study calculated a reliability benefit as a probability that inspections and the associated repairs will reduce equipment failure service interruptions. The overall probability is the product of (a) the probability that an equipment failure service outage is preceded by a visible condition, (b) the probability that the visible condition exists at the time of inspection, (c) the probability that an existing condition is detected and (d) the probability that the condition is repaired before a service interruption occurs. For seven of the thirteen overhead distribution component codes, actual inspection data established little likelihood of visible conditions preceding failure. For the remaining six component codes, subject matter experts were surveyed. The resulting probability estimates were applied to actual service outage data to estimate avoided CMI per mile. The inspection and repair cost per mile divided by CMI avoided per mile yielded an estimate of cost per CMI avoided. The graph below shows these costs per CMI for various inspection intervals.

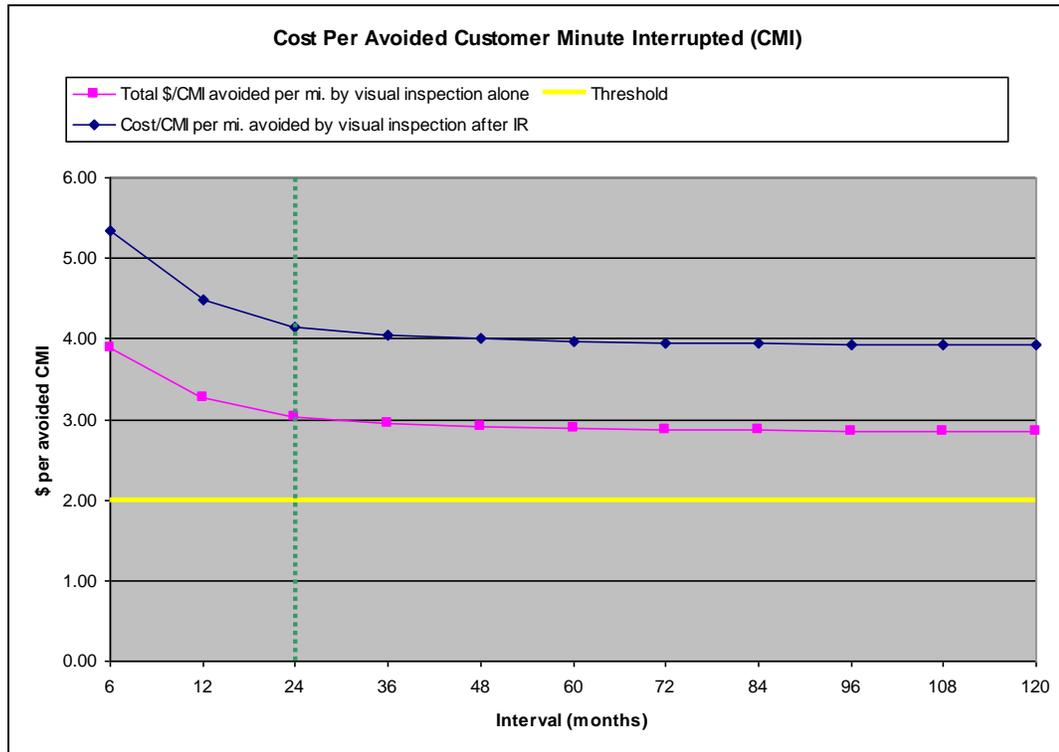
The study also estimated avoided CMI/mile for visual inspections that follow infrared inspections because there is significant overlap between the two methods: infrared identifies both visible and hidden defects in current carrying components, while visual inspection detects only visible defects in electrical and mechanical components. The second graph below shows these costs per CMI for various inspection intervals.

As the graphs below depict, given PPL Electric's reliability parameters, there is no interval for visual overhead inspections that meets the established cost threshold, particularly when performed in conjunction with infrared inspections. Visual inspections alone at two-year intervals are 50% above the threshold; two-year visuals done in conjunction with infrared are 100% above the threshold.

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<sup>1</sup> Cost threshold recommended by Richard E. Brown, Sr. Vice President and co-founder of Quanta Technology, a firm specializing in technical and management consulting for utilities. Dr. Brown has provided consulting services to most major utilities in the U.S. Dr. Brown has published more than 90 technical papers related to asset management and is the author of Electric Power Distribution Reliability, CRC Press, 2009.

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**Overhead Line Inspection Cost per Avoided CMI**

Although universal overhead visual inspections are not cost-effective, targeted visual inspections have more value. In a typical year, less than 15% of the circuits are responsible for 80% of equipment failure CMI. For the period 2002 to 2009, 30% of the circuits were responsible for 80% of equipment failure CMI.

Consequently, PPL Electric employs the condition-based visual inspection approach described above, combined with Expanded Operational Review field checks and overhead inspections in conjunction with pole inspections.

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**52. Pa. Code § 57.198 (n)(5). Inspection failure.** *If critical maintenance problems are found that affect the integrity of the circuits, they shall be repaired or replaced no later than 30 days from discovery.*

### Corrective Maintenance Description

- Infrared

Priorities for corrective maintenance are determined by the magnitude of the variance from normal operating temperature.

<b>Distribution Overhead Infrared Inspections Corrective Maintenance</b>		
	<b>Variance from Normal Operating Temp.</b>	<b>Days Allowed After Report Receipt for Service</b>
<b>Secondaries</b>	+20-60° C	8 weeks
	> +60° C	2 weeks
<b>Disconnect Switches</b>	+20-60° C	8 weeks
	> +60° C	2 weeks
<b>All Other Facilities</b>	+10-40° C	8 weeks
	> +40° C	2 weeks

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- Visual

The urgency for repairs is determined and an appropriate order of priority is assigned from four categories (Emergency, Priority, Unsatisfactory, and System Improvement) described below.

<b>Distribution Overhead Visual Inspections Corrective Maintenance</b>	
<b>Definition</b>	<b>I&amp;M Standard</b>
Emergency; Defects which: (1) Threaten the safety of the public or employees; or (2) Will cause a service interruption at any moment Scheduling Priority: 1	Corrective Action taken Immediately
Priority; Defects with a high probability of causing a service interruption if not corrected promptly. Scheduling Priority: 2	Corrective Action must be taken within 30 days.
Unsatisfactory; Defects with a lower probability of causing a service interruption if not corrected promptly. Scheduling Priority: 3	Corrective action must be taken within 3 months.
System Improvement; Conditions which could be altered to improve service reliability, with no immediate reduction of risk of service interruption. Scheduling Priority: 5	Corrective action may or may not be taken.

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**52. Pa. Code § 57.198 (n)(6). Distribution transformer inspections.** *Overhead distribution transformers shall be visually inspected as part of the distribution line inspection every 1-2 years. Above-ground pad-mounted transformers shall be inspected at least as often as every 5 years and below-ground transformers shall be inspected at least as often as every 8 years. An inspection must include checking for:*

- (i) Rust, dents or other evidence of contact.*
- (ii) Leaking oil.*
- (iii) Installation of fences or shrubbery that could adversely affect access to and operation of the transformer.*
- (iv) Unauthorized excavation or changes in grade near the transformer.*

### Program Description

- Cycle

Overhead: Overhead transformers are inspected as part of overhead visual line inspections, infrared inspections, and pole inspections. Additionally, load profiles are analyzed to identify and remedy overhead transformer locations that have consistent load demands exceeding design parameters.

Pad-mount and below-ground: Inspections are scheduled when indicated by circuit performance and confirmed by an analysis of actual service interruptions that identifies underground failures addressable by visual inspection.

Pad-mount and below-ground transformers may be inspected as part of the underground residential development cable testing or replacement programs.

- Purpose

The objective of a transformer inspection is to identify and correct hardware or equipment defects that may lead to a future service interruption or pose a safety hazard. Defects are identified by inspection, prioritized and scheduled for repair.

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- Process

Overhead and underground transformers are visually inspected for damage (rust, dents, cracks, locking devices, broken bushings, etc.), integrity of connections and leaks. In addition, pad-mounts and below-ground transformers have cables and elbows inspected for deterioration, foundations and covers inspected and animals, nests, cobwebs, and vegetation removed.

- Justification for waiver

PPL Electric hereby proposes a continued deviation from the fixed inspection cycle for transformers in favor of the condition-based inspection program described herein.

The overhead line inspection cost benefit study described previously estimated that about 20,000 CMI annually could be saved via visual overhead transformer inspections. In 2016, the estimated cost to inspect those transformers every two years was \$1.3 million or \$65 per CMI avoided, well above the threshold employed by PPL Electric of \$2.00 per CMI saved for identifying prudent reliability investments.

Similarly pad-mount transformers only contribute 500,000 CMI on average to overall system reliability. An inspection and maintenance program for transformer condition would cost millions in expense for little improved reliability over other underground reliability improvement programs.

Resources that would be applied to shorter cycles than this proposal would reduce the resources applied to other more cost-effective reliability programs described in this plan.

**52. Pa. Code § 57.198 (n)(7). Recloser inspections.** *Three-phase reclosers shall be inspected on a cycle of 8 years or less. Single-phase reclosers shall be inspected as part of the EDC's individual distribution line inspection plan.*

### Program Description

- Cycle

PPL Electric has initiated an upgrade program to replace three-phase oil circuit reclosers (“OCRs”) with vacuum circuit reclosers (“VCRs”) based upon a review of the dominant failure modes and causes. The newer technology replaces oil with a vacuum as the interrupting media. This eliminates the OCR maintenance issues of carbonized oil, contact deterioration and the timing issues that sometimes occur with OCRs. In addition, the communication capabilities of the devices allow for PPL Electric to track data pertaining to the asset health which will allow PPL Electric to implement a more targeted, condition-based replacement strategy. PPL Electric received approval from the

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commission on January 3, 2014 to complete these replacements on a 10-year cycle starting in 2015.

Three-phase VCRs are subjected to infrared inspection on the same 2-year cycle as OCRs.

Three-phase OCR: 2-year infrared; 10-year replacement.

Single-phase OCRs: inspected as part of PPL Electric's distribution line inspection program.

- Purpose

The purpose of the recloser inspection program is to ensure the reliable operation of reclosers by replacing deteriorated equipment with new installations.

- Process

Three-phase oil and vacuum reclosers are included in the two-year infrared line inspection program.

- Justification for waiver

PPL Electric hereby proposes a continued deviation for reclosers in favor of the program described herein.

A recloser's function is to isolate faults while minimizing the number of customers affected by permanent service outages. Visual inspection of an OCR provides relatively little useful information about the unit's capability to perform its function compared to testing. Testing in place would require almost all of the same steps that are involved in replacement. Bench testing is preferable to testing in place and refurbishment requires the unit's removal from service. With the planned installation of these communicating vacuum units, the devices have a longer life expectancy, and inspections can be planned.

As PPL Electric has been replacing older oil reclosing three phased units, reliability has improved from the decreasing number of failed units. In addition, PPL Electric experienced close to a 50% improvement in reliability within the initial smart grid pilot area.

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**52. Pa. Code § 57.198 (n)(8). Substation inspections.** *Substation equipment, structures and hardware shall be inspected on a cycle of 5 weeks or less.*

## Program Description

- Cycle

	Visual	Infrared
<b>Distribution- Supervisory control and data acquisition (“SCADA”) Controlled</b>	Quarterly	Annual

- Purpose

Periodic substation inspections verify the integrity of station physical security, record and correct any security breaches, verify the proper fluid levels and gas pressures, and identify any leaks, verify the proper operation of essential station equipment and initiate any necessary corrective actions.

- Process

Inspection of substation equipment and recording abnormal conditions of the equipment. Equipment inspected includes, but is not limited to:

- Power transformers
- Circuit breakers
- Auxiliary equipment
- Batteries and chargers
- Control house
- Yard and perimeter

- Justification for waiver

In 2017, PPL Electric was granted a deviation from the five-week inspection cycle for substations in favor of the quarterly program described herein.

From 2016-2018, PPL Electric estimates that a yearly average of 826k CMI was avoided through repairs identified via the monthly substation inspection. The costs of inspection plus repair averaged \$1.24 million per year, or \$1.50 per CMI avoided, which is under the threshold employed by PPL Electric of \$2.00 per CMI saved for identifying prudent reliability investments.

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PPL Electric employs SCADA at every substation, which provides real-time telemetry of potential issues. The relay packages provide advanced health information about the breakers and signal when maintenance is required, negating the need for visual inspections of these assets. PPL Electric implemented an upgrade to the data historian software which allows the Company to be automatically alerted when substation abnormalities are detected, and automatically calculate remaining life on smart assets when operations occur.

Over the last four years, none of the repairs scheduled due to the monthly inspections have been critical repairs due to imminent failure risk. The repairs have been minor and could have waited 90 additional days to be identified.

Resources that would be applied to shorter cycles than this proposal would reduce the resources applied to other more cost-effective reliability programs described in this plan.

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## *Appendix A: Transmission Programs and Procedures*

<b>Program</b>	<b>Activity</b>
Helicopter Inspections – Stop-go	Aerial linemen perform annual routine transmission line patrols from a helicopter. They identify damaged or deteriorated equipment and any apparent vegetation issues. Engineers review the findings and develop plans for repair, replacement or remediation.
Helicopter Inspections – Comprehensive	Aerial linemen perform an overhead comprehensive inspection of transmission line facilities on a four-year or eight-year cycle. Detailed condition reports with close-up digital photos are prepared for each specific component problem found along the transmission line and right-of-way. Engineers review the findings and schedule corrective maintenance as needed.
Helicopter Inspections – Emergency	Aerial linemen perform patrols of transmission lines that operate abnormally. This inspection focuses on identifying damage that may have been caused by lightning, inclement weather, equipment failure or vandalism. Because of the nature of this work, corrective actions generally are expedited.
Steel Structures – Inspection, Treatment, Replacement, Reinforcement/Repair	Steel transmission structures are examined and measured for the degree of decay and deterioration. Any issues identified by the inspection are then categorized with a priority rating and are scheduled for follow-up actions based on the criticality. Follow-up actions may include remediation or replacement of steel members or foundations to extend the life of the asset.
Equipment Maintenance	During helicopter and foot patrols, equipment and facilities are identified that require repairs. Based on need and criticality, repairs are either scheduled or completed as soon as possible. Repairs are either completed by line crews or aerial line crews to ensure efficient and effective repairs.
Line Switches – Maintenance and Inspection	Line personnel inspect, maintain and perform operational tests on 138kV and 69kV line air break switches on an as-needed basis to assure proper operation. Corrective action is taken as needed.
Line Switch Upgrades	Line personnel install lightning arresters on 138kV and 69kV line switches to increase system reliability. Existing parallel break air breaks and load sectionalizing air breaks are being upgraded to motor operated load break air breaks to improve switching capabilities, outage restoration times, and sectionalizing ability. Corrective action is taken as needed.

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<b>Program</b>	<b>Activity</b>
Circuit Analysis	Engineers analyze circuit loading and performance to identify areas needing increased line capacity or improved line reliability. Circuits are also reviewed based on operational performance and ranked yearly in a WPC list, with appropriate circuits identified for targeted reliability improvements.

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### *Appendix B: Substation Programs and Procedures*

<b>Program</b>	<b>Activity</b>
Load Survey	Automatic monitoring devices such as SCADA provide continuous, real-time loading information. Engineers review equipment loading and identify facilities and transfer capabilities approaching capacity limits. A portion of the load may be supplied from a different source, the existing facilities may be upgraded, new lines and equipment may be added, or a new substation may be built to address capacity deficiencies.
Substation Inspection/Repair	Electricians inspect substations for security and equipment reliability on a time-based maintenance cycle. They identify and correct potential equipment problems before a failure or service interruption occurs.
Equipment Service	Electricians perform operational tests on power transformers, load tap changers (“LTC”), voltage regulators, circuit breakers, circuit switchers, vacuum switches, air break switches and transformer protective switches on a time-based maintenance cycle to assure that equipment is operating within established parameters. Equipment serviced includes batteries, battery chargers, protective relays, high voltage fuses and high-speed automatic grounding switches. Depending on the type of equipment, “service” can include actions other than operational testing.
Inspection and Condition Assessment	Electricians inspect and perform condition assessments of circuit breakers, wave traps, ground switches, stick-operated disconnects, gang-operated disconnects and motor-operated disconnects on a time-based maintenance cycle to assure proper operation. Corrective action is taken as needed.
Insulation Testing	Technicians perform power factor testing on power transformers, potential transformers, lightning arresters, current transformers, select circuit breakers and power cables on a time-based maintenance cycle. Testing also includes other instrument transformers (capacitance coupled voltage transformer, coupling capacitors, potential devices, etc.). They also perform high-potential testing on 12kV oil, air and vacuum circuit breakers to assure proper operation.

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<b>Program</b>	<b>Activity</b>
Condition Monitoring of Station Equipment	Electricians/Technicians perform dissolved gas-in-oil analysis, dielectric, and physical properties oil tests for oil in power transformers, and impedance and select capacity tests on station batteries, to assure equipment is within normal parameters. Periodically, AC power factor tests, hi-potential tests, contact resistance tests and motion tests are performed on circuit breakers. Oil dielectric testing is conducted for oil circuit breakers.
Thermographic Inspections	Electricians perform infrared surveys of substation facilities to identify components operating at elevated temperature. Based on the findings, engineers develop plans to repair or replace the component(s) prior to failure.
Minor Improvements	Maintenance activities may identify conditions where additions or upgrades are needed to assure reliability. Engineers evaluate the need and develop action plans and schedules to complete the work.
DC Station Service Improvements	Repairmen and Testing identify deteriorated station batteries, battery chargers and battery components. Engineers schedule repair or replacement as necessary.
Capacitor Bank Protection	Engineers monitor the need for synchronous closing schemes on vacuum switches on 69kV capacitor banks. They plan and schedule installations as needed.
Area/Regional Supply	Engineers develop specific projects aimed at improving capacity shortfalls or replacing deteriorated or substandard station equipment.
SCADA Replacement	Engineers identify deteriorating substation SCADA equipment and develop plans to repair or replace it.

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### *Appendix C: Distribution Programs and Procedures*

<b>Program</b>	<b>Activity</b>
Load Survey – of equipment that is not continuously monitored	Line personnel measure the loading of facilities during peak periods. Engineers use this data for system studies.
Load Survey – by automatic monitoring devices	Automatic monitoring devices such as SCADA provide continuous, real-time loading information. Operators use this data to assure that loads do not exceed design limits. Engineers use this data for system studies.
Circuit Analysis	Engineers analyze circuit voltage profiles to balance loads and to identify areas requiring voltage support to maintain required voltage at the customer's facility.
Transformer Replacements	Engineers analyze customer usage data to identify overloaded transformers. Transformers that are heavily loaded are replaced with higher capacity units or portions of the load are transferred to other nearby transformers.
Wood Pole – Inspection, Maintenance, Reinforcement, Replacement	Wood poles are examined for deterioration and the degree of decay is measured. Based on the results, the pole may be treated with preservative to extend its life, treated and reinforced for extended life or replaced.
Overhead Line Inspection	Line inspection personnel examine overhead facilities to identify damaged, deteriorated or substandard equipment. Equipment examines include but is not limited to capacitors, regulators, switches, and reclosers. Line personnel repair or replace any defective equipment.
Circuit Performance Review	Engineers use PPL Electric's WPC score to ascertain the need for additional circuit reviews or inspections. The improved index looks at a circuit's overall impact to system SAIFI and circuit SAIDI. Actual service interruption history is analyzed to identify causal or geographic patterns.
Underground Primary Cable – Replacement	Based on a data-driven failure probability model and risk assessment, underground cable is identified for proactive replacements.
LTN Maintenance	Electricians inspect, service, maintain and overhaul LTN vaults, manholes, cables, transformers, low-voltage network protectors and primary transformer disconnect switches. Based on results, defective equipment is either repaired or replaced.

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<b>Program</b>	<b>Activity</b>
Public Damaged Facilities Review	A program aimed at identifying the locations of facilities that have been damaged by public contact more than once. Technicians evaluate those installations and, if relocation is deemed appropriate, schedule work to move the facilities.
Underground Service Cable	Engineers resolve customer service problems that are due to deteriorated underground service conductors.
Oil Circuit Reclosers	Line personnel replace in-service oil circuit reclosers conditionally.
Line Protection Equipment	Line personnel replace in-service three phase oil circuit reclosers with communicating vacuum devices conditionally.
Capacitor and Voltage Regulator Installation	Engineers perform voltage profiles to determine the need, location and size of any new voltage support equipment required to maintain adequate service voltage levels at customer facilities and provide needed reactive support for system stability. Line personnel install the required equipment.

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### *Appendix D: Vegetation Applications*

<b>Program</b>	<b>Activity</b>
Tree Pruning	Tree pruning is scheduled based on field conditions observed and/or a system prioritization process. All pruning is done in accordance with <u>American National Standard for Tree Care Operations-Tree, Shrub and Other Woody Plant Maintenance – Standard Practices (ANSI A300)</u> .
Hazard Tree Removal	Trees located outside the right-of-way that represent a threat to line performance/ safety are removed when it is feasible to do so.
Herbicide Application	Tall-growing, undesirable vegetation growing within the right-of-way corridors is selectively treated with herbicides. Low-growing vegetation that does not represent a hazard to the safe, reliable operation of PPL Electric’s facilities is preserved wherever possible.
Reclearing	Tall-growing, undesirable vegetation growing within the right-of-way corridors is selectively removed in those situations where herbicides cannot be utilized. Low-growing vegetation that does not represent a hazard to the safe, reliable operation of PPL Electric’s facilities is preserved wherever possible.