BEFORE THE
PENNSYLVANIA PUBLIC UTILITY COMMISSION

Petition of PPL Electric Utilities Corporation	:	
for Approval of Tariff Modifications and	:	
Waivers of Regulations Necessary to	:	Docket No. P-2019-3010128
Implement its Distributed Energy Resources	:	
Management Plan	:	

DIRECT TESTIMONY OF WANDA REDER

PPL Electric Statement No. 2

December 11, 2019

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Q. PLEASE STATE YOUR NAME AND BUSINESS ADDRESS.

A. My name is Wanda Reder, and my business address is 34W676 Country Club Road, Wayne, Illinois 60184.

Q. BY WHOM ARE YOU EMPLOYED AND IN WHAT CAPACITY?

A. I am the President and CEO of Grid-X Partners, LLC ("Grid-X").

Q. WOULD YOU PLEASE DESCRIBE GRID-X?

A. Grid-X Partners, LLC is a certified Women Business Enterprise (WBE) consulting firm that provides insight and direction for electric utility grid transformation. Grid-X brings a unique balance of technical, strategic and practitioner experience in the delivery of engagements. It assists utilities and their stakeholders in developing and executing plans to address the complex challenges confronted by utilities in an ever-changing industry landscape.

Q. WHAT ARE YOUR DUTIES AS PRESIDENT AND CEO OF GRID-X?

A. As CEO, my primary responsibilities include making major corporate decisions, managing the overall operations and resources of the company, acting as the main point of communication between the consultants and our clients and being the public face of the Company. Management and viability of the vision, brand, clients, portfolio, finances and risk tolerance are all my ultimate responsibility.

Q. WHAT IS YOUR EDUCATIONAL BACKGROUND?

A. I earned a Master of Business Administration with emphasis in New Ventures from the University of St. Thomas in St. Paul, Minnesota, and a Bachelor of Science in Engineering from South Dakota State University.

Q. PLEASE DESCRIBE YOUR PROFESSIONAL EXPERIENCE.

A. I have over 30 years of experience in the electric utility industry with much of my career aimed at grid modernization thought leadership and transformation for electric utilities. Before founding Grid-X Partners, I served as Chief Strategy Officer and Vice President of Power Systems Services for S&C Electric Company ("S&C") from 2004 to 2018. There, I developed consulting, engineering, field services and project management capability to address global service needs. Among many offerings we designed, integrated and commissioned grid-scale wind-power, solar and storage projects for utilities and developers. Prior to S&C, I was a Vice President for Exelon Energy Delivery responsible for several areas such Asset Management, Engineering and Planning. My group of over 1,000 employees defined the transmission and distribution work portfolio that exceeded $1 billion annually, managed the budget, prepared the work and scheduled it. Before Exelon, starting in 1987, I served in various capacities for Northern States Power (now Xcel) in executive and engineering roles leading business planning and technology implementation for automated meter reading, distribution automation, distribution management and demand-side management to name a few. I am an Institute of Electrical and Electronics Engineers ("IEEE") Fellow, was the President of the IEEE Power & Energy Society ("PES") from 2008 to 2009, was appointed to the U.S. Department of Energy ("DOE") Electricity Advisory Committee from 2011 to 2017 and again as vice chair starting in 2018 by the U.S. Secretary of Energy, and was invited and became a member of the National Academy of Engineers in 2016 "for leadership in electric power delivery and workforce development."

Q. HAVE YOU PREVIOUSLY TESTIFIED AS A WITNESS BEFORE THE PENNSYLVANIA PUBLIC UTILITY COMMISSION ("COMMISSION")?

A. No.

Q. HAVE YOU BEEN RETAINED BY PPL ELECTRIC UTILITIES CORPORATION ("PPL ELECTRIC" OR THE "COMPANY") TO TESTIFY ON BEHALF OF THE COMPANY IN SUPPORT OF THE ABOVE-CAPTIONED PETITION?

A. Yes.

Q. WOULD YOU PLEASE DESCRIBE THE SUBJECT MATTER OF YOUR TESTIMONY?

A. My testimony will address questions concerning the applicable IEEE and Underwriters Laboratories ("UL") standards under the Company's proposed Distributed Energy Resources ("DER") Management Plan. I also have provided examples of other utilities operating domestically and globally that have experienced grid challenges from DER penetration that could have been avoided if they would have acted proactively as is the case with PPL Electric and its proposed DER Management Plan.

Q. ARE YOU SPONSORING ANY EXHIBITS WITH YOUR TESTIMONY?

A. No.

A. IEEE AND UL STANDARDS

Q. WOULD YOU PLEASE DESCRIBE THE IEEE AND UL STANDARDS THAT ARE IMPLICATED BY PPL ELECTRIC'S PROPOSAL?

A. In PPL Electric's DER Management Petition, the Company has requested to proactively implement the 2018 revisions to IEEE Standard 1547, "Standard for Interconnection and Interoperability of Distributed Energy Resources with Associated Electric Power Systems Interfaces" ("IEEE Standard 1547" or "IEEE 1547-2018") and the related, forthcoming revisions to UL Standard 1741, "Inverters, Converters and Controllers for use in Independent Power Systems" ("UL Standard 1741"). As Mr. Salet explains in his direct testimony (PPL Electric Statement No. 1), the Company's proposal would require new customers applying to interconnect new DERs with PPL Electric's distribution system to: (1) use Company-approved smart inverters that are compliant with IEEE 1547-2018 and forthcoming UL Standard 1741 (or until that standard is finalized, UL Standard 1741 SA); and (2) install devices that enable PPL Electric to monitor and proactively manage DERs.

Q. COULD YOU PROVIDE US WITH SOME BACKGROUND OF IEEE STANDARD 1547?

A. IEEE Standard 1547 is formally identified as "IEEE Standard for Interconnection and Interoperability of Distributed Energy Resources with Associated Electric Power Systems

Interfaces." This standard outlines technical requirements concerning the interconnection and interoperability performance of DERs, including operation and testing, safety, maintenance, and security requirements. The standard also specifies that a DER must be equipped with additional grid support functions.

The IEEE 1547 series of standards has helped shape the way utilities and other businesses have worked together to realize increasing amounts of DERs interconnected with the distribution grid. The IEEE 1547 family of standards provides the critical foundation for interconnecting DERs to electric utility distribution grids by establishing mandatory functional technical requirements and specifications, as well as flexibility and choices, about equipment and operating details. It has been the de-facto standard for DER interconnections in the United States since it was originally published in 2003.

Since that time, however, a lot has changed in the distributed generation area; increasing technological and economic advances have elevated the levels of penetration the grid experiences, resulting in a continual evolution of IEEE 1547. As a result, in April 2018, IEEE Standard 1547 was revised to transform how DERs interact with and function on the electrical distribution system. The revised IEEE Standard 1547 standardized inverter capability requirements, incorporated improved communication interface standards, expanded grid support functions (such as requiring the capability to actively regulate voltage, ride through abnormal voltage/frequency conditions, and provide frequency response), and improved anti-islanding protections. The original version of IEEE Standard 1547 (adopted in 2003) was limited to electrical requirements. However, IEEE 1547-2018 includes both electrical as well as interoperability and communication requirements.

DERs interconnecting with the distribution system in the coming years are expected to be inverter-based, specifically equipped with "smart inverters" that comply with IEEE 1547-2018 and provide grid support functionality relating to voltage, frequency, communication, and controls. When widely used and adopted, IEEE 1547-2018 will enable a higher saturation of DERs on the distribution system, while maintaining grid safety and reliability and providing new benefits for the grid and customers.

Of specific importance to PPL Electric and DER customers is the new requirement for DER inverters to be "smart," *i.e.*, capable of providing grid support functionality and communications using revised specifications. IEEE 1547-2018 states that DERs must provide the local electric distribution utility with a standardized local interface for the monitoring and management of the DER. Section 10.2 of IEEE 1547-2018 specifies that DERs "shall use a unified information model, and non-proprietary protocol encodings based on international standards or open industry specifications as described in 10.7." Section 10.7 then specifies that the DER must offer either an Ethernet or a Serial (RS-485) interface that uses one of three standardized protocols: (1) SunSpec Modbus; (2) DNP3 (IEEE 1815); or (3) SEP2 (IEEE 2030.5). The more sophisticated and standardized communications specified by IEEE 1547-2018 will enable DERs to convey performance data, so the Company will have increased situational awareness and can more quickly diagnose and address any operational or maintenance issues.

By implementing IEEE 1547-2018, a significant and longstanding impediment to the development of replicable and scalable DER management has been resolved—inverter protocol standardization. Now, inverter manufacturers will have standardized information models detailing read/write protocols. This will enable electric utilities to use standardized system programming to interface with DERs instead of creating custom programs for each inverter type.

Q. WOULD YOU PLEASE PROVIDE BACKGROUND INFORMATION ON UL STANDARD 1741 AND HOW IT INTERACTS WITH IEEE 1547-2018?

A. UL Standard 1741 also applies to DERs and governs the physical testing procedures that manufacturers must perform to certify that a DER inverter meets IEEE 1547-2018. Based upon the recent update of IEEE Standard 1547 in 2018, UL Standard 1741 is currently under revision, with an expected release sometime in the first half of 2020. Once the updated UL Standard 1741 is published, organizations that adopt it will require DER equipment manufacturers to comply with the new UL Standard 1741 and IEEE Standard 1547. Typically, manufacturers are provided time to change their production operations and processes before they must manufacture their products to meet the new standards. Most recently, California provided manufacturers one year to update their products to the new standards imposed through California Senate Bill 1, "Guidelines for California's Solar Electric Incentive Programs." As such, all DER inverter and communication devices are expected to be certified in 2020 under IEEE 1547-2018, using the new UL Standard 1741.

In sum, UL Standard 1741 certifies performance, ensuring that every inverter is manufactured, programmed, and tested to adhere to the interconnection standard and is the standard to which all inverters must be listed. UL Standard 1741 is harmonized with IEEE Standard 1547 and IEEE 1547.1 (the testing standard).

Q. WHAT IS IEEE 1547.1 AND HOW IS IT DIFFERENT THAN IEEE STANDARD 1547?

A. While IEEE 1547 provides specifications and requirements for the interconnect tests, it does not provide test procedures. IEEE 1547.1 defines the type, production and commissioning tests that shall be performed to demonstrate conformance with the technical requirements in IEEE 1547. IEEE 1547.1 is currently under revision, has gone to ballot, and is expected to be approved early in 2020. In the meantime, UL Standard 1741 SA is being used as an interim standard until the IEEE 1547.1 revisions are completed and adopted.

Q. WHAT IS UL STANDARD 1741 SA?

A. UL Standard 1741 SA refers to Supplement A of the UL Standard 1741, which, in addition to UL Standard 1741, allows for limited testing of advanced inverter functions and implemented before the IEEE 1547.1 revision is available. The requirements for functionality under UL Standard 1741 SA are set in a "Source Requirements Document," *e.g.*, California Rule 21 or HECO Rule 14H requirements, published in September 2016. The Company has informed me that PPL Electric already requires inverters to be compliant with UL 1741 SA, which provides testing and certification of limited autonomous inverter functions.

B. TIMING AND BENEFITS OF THE COMPANY'S PROPOSAL

Q. THE REVISIONS TO UL STANDARD 1741 AND IEEE 1547.1 HAVE NOT BEEN FINALIZED YET, SO DOES THE COMPANY NEED TO WAIT UNTIL THOSE REVISIONS ARE FINALIZED BEFORE IT CAN MOVE AHEAD WITH ITS PROPOSED DER MANAGEMENT PLAN?

A. No. IEEE 1547-2018, which defines technical requirements, was approved in 2018. Approval of IEEE 1547.1, which will provide the complete testing provisions for IEEE 1547-2018, is expected to occur by the end of the first quarter of 2020. The IEEE 1547.1 standard has been balloted and is in review. In all likelihood, publication will occur well before the end of this proceeding. When IEEE 1547.1 is published, the harmonized UL Standard 1741 provisions will be made available.

I recognize that there is some uncertainty on exactly when the standard will be published and a certified product available. IEEE is a volunteer-based organization having over 400,000 members in 160 countries. One of its functions is to develop global standards for a broad range of industries using a process that is balanced, open, and fair and is based upon consensus. Because of the IEEE construct, there are schedule uncertainties in the IEEE standards approval process. Additionally, even though manufacturers have had insight and input to the standards throughout the development process, they will likely need a few months to make design and supply chain changes before compliant products are available for purchase in the marketplace.

However, because of these uncertainties, PPL Electric has developed an interim plan that can be used for testing, if it is needed, to bridge the gap between when the Company's Petition may be approved and when certified IEEE 1541.1 / UL Standard

1741 equipment is available in the marketplace. Specifically, the interim approach would require compliance with UL Standard 1741 SA and would also require compliance with the communication technical requirements specified in section 10.7 of IEEE 1547-2018.

Q. DO YOU BELIEVE THEN THAT THE COMPANY'S DER MANAGEMENT PLAN IS PREMATURE?

A. Absolutely not. Like the Company, I believe that an expedited process to incorporate IEEE 1547-2018 is warranted and that PPL Electric should be allowed to proactively implement IEEE 1547-2018 to begin achieving the benefits of the new inverter technology. Doing so reduces the time to implement IEEE 1547-2018 once the revised UL Standard 1741 standard becomes effective. Indeed, although the finalization of updates to UL Standard 1741 is still pending, there are currently-available inverters that meet IEEE 1547-2018 and UL Standard 1741 SA.

In fact, PPL Electric's timing is impeccable. Through its Petition, the Company is proactively moving forward to utilize newly available standards and technology to monitor and manage interconnected DERs to satisfy its obligation to serve reliably, affordably, and safely. By proceeding with the PPL Electric's DER Management Petition at this juncture, before there are significant DER installations, PPL Electric will be placed in the best position possible to act responsibly, thereby avoiding many of the grid problems that other utilities who lack appropriate visibility and management of DERs have realized after encountering significant DER penetration.

In sum, smart inverter technology is available, IEEE 1547-2018 is approved, the remaining testing standard IEEE 1547.1 will be published imminently, and the Company has developed a viable interim solution in case the revisions to these standards are not finalized by the end of this proceeding. Therefore, the Company's Petition is not premature.

Q. ARE THERE ANY BENEFITS TO IMPLEMENTING THE COMPANY'S PROPOSAL NOW VERSUS WAITING FOR THOSE STANDARDS TO BE FINALIZED?

A. Definitely. Proactive implementation permits new DERs to utilize the smart inverters and communication devices and take advantage of the functionalities provided by those devices. Overall, consistent adherence to the updated standards will maintain or increase the stability, reliability, and efficiency of the distribution system over time as DER penetration levels increase. It also will improve distribution system management capabilities, streamline the interconnection process for new DERs by reducing the protocols the Company will need to manage and maintain, provide increased DER interconnection potential, and could reduce utility investments supporting DER interconnection. As the installation rate of DER installations are rapidly increasing, PPL Electric seeks to enable the movement. The Company's customers deserve the opportunity to fully benefit from the technology that is unleashed by acceptance and adoption of the new IEEE 1547 and UL 1741 standards.

Indeed, by proceeding with the PPL Electric's DER Management Petition at this juncture, before there are significant DER installations, PPL Electric will be placed in the best position possible to act responsibly, thereby avoiding many of the grid problems that other utilities who lack appropriate visibility and management of DERs have realized after encountering significant DER penetration.

Q. COULD YOU PROVIDE SOME EXAMPLES OF GRID CHALLENGES THAT COULD HAVE BEEN MITIGATED WITH THE ABILITY TO MONITOR AND MANAGE DERS?

A. A prime example occurred on the system of Dominion Energy, which is headquartered in Virginia. Following the normal afternoon "fall off" of solar generation at approximately 6 PM one spring afternoon, *Real Time* contingency analysis identified a post contingency thermal overload, where the Emergency Rating on a 115 kV Transmission Line would be exceeded. The contingency event studied the loss of another 115 kV Transmission Line in the area, and the post contingency overload was not identified in the *Next Day* contingency analysis. The reason this was not identified was the solar generation in question that was on-line at the time the *Next Day* study was performed *masked the gross load* that was being served by the 115 kV Transmission Line. During this event, the system operators identified and performed a real time switching solution to mitigate the post contingency overload. Had a switching solution not been available, load curtailment would have been performed. This event highlights the importance of knowing the physical location of distributed generation, the real time & forecasted total gross load, and the total gross generation at the transmission bus. Additionally, understanding of net load is not sufficient, and DERs cannot simply be treated as a "load reducer." If real time monitoring of DERs were available to Dominion Energy, it would have provided the utility with the visibility needed to operate reliably and safely because real time gross load and generation would have been available. Without specific real-time information that comes from monitoring DERs, the load can be masked causing operational actions to be taken that can have unintended consequences.

In Germany, highly penetrated PV installations led to generation exceeding the annual peak load on parts of the distribution system. A region was separated from the main power grid, causing the frequency to increasing above 50.2 Hz; over-frequency settings in the DER inverters caused them to disconnect from the grid simultaneously. Subsequent analysis simulating similar effects across the country indicated a stability risk for Germany and its interconnections if they would have a sudden loss of capacity during peak feed-in times because there was not enough frequency control reserve available in the continental European control area to balance the system. To solve this, Germany manually retrofitted 300,000 DER systems with different ride-through settings which cost approximately $175 million Euros (approximately $190 million U.S. dollars) for utility customers. This expense could have been avoided if autonomous smart inverter settings could have been changed remotely with communication-equipped inverters. This is one utility story of many that are occurring domestically and internationally, where system challenges are occurring because utilities cannot monitor and manage DERs. As DER penetration increases, so does the utility's operational risk if it does not have the capability to monitor and manage. PPL Electric should be allowed to act, with all due haste, so the Company can move forward before DER penetration builds and the system challenges develop.

Q. DO EXPERIENCES IN OTHER STATES AND COUNTRIES SUPPORT THE COMPANY'S NEED TO TAKE ACTION NOW AND ADDRESS THE DEPLOYMENTS OF DERS?

A. Absolutely. In various capacities that I have held with IEEE, U.S. Department of Energy and as an executive with global reach, I have had the opportunity to participate and monitor transformation of the electric industry throughout the world. It has greatly accelerated over the last decade. While there have been many factors, the rapid increase in penetration of DERs has been a significant driver. Many utilities have been surprised by the DER adoption rates and were unprepared to deal with the impacts on the grid, primarily due to the lack of visibility of a new generation entrant that was dynamic, intermittent and distributed.

Over the years, tools, processes, standards and policies have evolved and are being adopted to better harmonize DER interconnections with grid operations. In the following sections, I provide some relevant lessons from experiences of utilities in California, Hawaii, Arizona, Australia, Japan, and Spain and highlight the influence that these findings have had on PPL Electric's DER Management Plan.

California

California has been and remains at the forefront of the United States DER revolution, having some of the most aggressive renewable energy goals in the United States. The state is required to obtain at least 33% of its retail electricity from renewable resources by 2020, 50% by 2030 (excluding large hydro), and 100% carbon-free energy by 2045. The California Energy Commission reports that approximately 30% of the state's electric energy currently comes from renewable energy sources. Further, in May

2017, the California Independent System Operator ("CAISO") reported a new instantaneous renewable energy record in the state, with non-hydro renewables providing 67.2% of the total electricity for the grid. Intermittent renewables have led to the well-known and widely used "duck curve," a graph that CAISO created in 2012 to convey renewable operational challenges due to the difference in peak demand and renewable energy production over the course of a day.

To enable DER interconnection, California adopted Electric Rule 21, a tariff that describes DER interconnection, operating, and metering requirements that was supported by the Smart Inverter Working Group ("SIWG"). The SIWG was formed in 2013 to identify the development of advanced inverter functionality as an important strategy to mitigate the impact of high penetrations of DERs. The SIWG defined and pursued development of advanced inverter functionality over three phases. Phase 1 defined autonomous functions that all inverter-connected DERs in California must perform. Phase 2 defined the default protocols for communications between investor-owned utilities ("IOUs"), DERs, and DER aggregators. Phase 3 is considering additional advanced inverter functionality that may or may not require communications[1].

All three Californian utilities, Pacific Gas and Electric Company ("PG&E"), San Diego Gas and Electric ("SDG&E"), and Southern California Edison ("SCE") have conducted trials on Smart Inverters and documented its findings in a joint IOU report whitepaper.[2] This paper states that "DER interconnection rules requiring smart inverters,

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[1] *Smart Inverter Working Group*, CA.GOV, https://www.cpuc.ca.gov/General.aspx?id=4154 (last visited Dec. 10, 2019).

[2] "Enabling Smart Inverters for Distribution Grid Services" (October 2018), *available at* https://www.pge.com/pge_global/common/pdfs/about-pge/environment/what-we-are-doing/electric-program-investment-charge/Joint-IOU-SI-White-Paper.pdf.

such as California's Rule 21, can help the grid to host more DERs, can minimize the negative impact of DERs on grid power quality and can potentially lower interconnection costs."

This report further goes on to detail Autonomous and Active Control modes. The Active control relies on the inverter to be able to receive and execute remote commands to address dynamic grid conditions using a Distributed Energy Resource Management System ("DERMS")/Advanced Distribution Management System ("ADMS") platform. The function the smart inverter could perform is analogous to a grid operator using a Distribution Management System ("DMS") to remotely control a Supervisory Control and Data Acquisition ("SCADA") device such as a sectionalizer to rebalance loads.

PPL Electric has followed the development of the SIWG and is leveraging the lessons and developments in its DER Management Plan, where applicable. For example, the PPL Electric-qualified smart inverter list leverages the work that California has done to test and qualify units as described earlier in this testimony. As compared to California, where a wide variety of legacy DER installations have been deployed, PPL Electric benefits from being in a position to define the requirements for DERs earlier in the process, before significant system issues develop. For this reason, PPL Electric can leverage the lessons and technical developments that have come from California without needing to replicate their entire approach.

<u>Hawaii</u>

Hawaii has become the best-in-class example for how DERs at scale can transform a series of island grids powered by expensive imported oil. Hawaii, being isolated from the mainland, has no interconnections with neighboring grids to provide support, and the islands are not interconnected, which makes grid management extra challenging because the load and generation need to be perfectly balanced on each island at all times. Hawaii's Renewable Portfolio Standard has a target of 40% net electricity sales to come from renewable source by 2030 and 100% by 2045. The growth of distributed PV in Hawaiian households has been incentivized by high electricity prices, solar PV income tax credits, net-energy metering (now discontinued), utility incentives and strong solar resources. Hawaii currently has the highest distributed PV capacity of about 50% of peak load which is higher than any state in the US[3].

Experience in Hawaii has highlighted the challenges of integrating renewable resources without the back-up from a continental grid. A few of the challenges that the Hawaiian power grid faced from DER penetration has included steady-state voltage issues, islanding and transient voltage issues, and the deterioration of frequency response. Additionally, the lack of visibility and controllability of DER and grid-edge conditions and difficulties in changing settings of the legacy inverter fleet have proved to be a challenge due to cost, logistics and policy challenges.

To address legacy inverter ride-through challenges, Hawaii has emphasized the importance of defining voltage and frequency ride-through capability and relatively wide trip settings early in the process, to avoid future problems when more DERs come online. Inverters that are installed in Hawaii now require functionality for voltage and frequency ride-through, transient overvoltage mitigation, volt/volt-ampere reactive ("Volt/VAR") control, frequency-watt control, soft-start, ramp-rate control, volt-watt (optional) and remote upgrade capability.

[3] Andy Hoke, Ph.D, PE, "Smart Inverter Utility Experience in Hawaii," IEEE (August 4, 2019), *available at* https://www.nrel.gov/docs/fy19osti/74091.pdf.

In addition to establishing smart inverter standards for new installations, they worked with the inverter supplier to retroactively widen voltage and frequency trip settings for many legacy DERs. It was a major effort that was made possible by the manufacturer who had a communication solution to remotely change settings.

Here, the Company's DER Management Plan is trying to avoid the issues experienced in Hawaii by setting provisions before there is significant DER penetration. By allowing PPL Electric to proceed with the DER Management Plan now, the Company would avoid the challenges that Hawaii has faced with DER integration and be able to verify and change settings remotely to prudently manage the distribution system as conditions change.

Arizona

Arizona differs from other states in the country in that it does not have a 100% clean energy mandate. The Arizona Corporation Commission ended the state's net metering policies in 2016 in exchange for a set of lower rates for compensating solar exports. Arizona Public Service ("APS") responded with time-of-use rates for solar customers, which helped boost the case for solar-storage systems and has been running some of the country's most ambitious DER integration projects.

PPL Electric has learned from APS experiences where their field findings influenced the Keystone project scope. PPL has also gleaned understanding of how the mesh communication system can support smart inverters and has incorporated that knowledge into the requirements for the DER Management Plan.

Australia

In 2009, solar adoption in Australia boomed when feed-in tariffs were offered to homeowners of up to 60 cents per kilowatt-hour. The tariffs were designed to encourage households to invest in renewables which led to far more PV panels installations than anticipated. As a result, one in five Australian homeowners have installed solar energy panels, and in some areas nearly 40% of the owner-occupied dwellings have solar installed. In 2018, the Australian Energy Market Operator ("AEMO") launched a DER Program to provide a smooth transition from a one-way energy supply chain by sponsoring a number of demonstrations that developed a framework to better integrate DERs into the existing grid and to provide systems that would allow the AEMO access to real-time data from DERs, among other things.

In 2019, AEMO released a consultation paper titled "Technical Integration of Distributed Energy Resources,"[4] where the challenges that were identified parallel the issues that are being proactively addressed in PPL Electric's DER Management Plan. For example, AEMO recommended using DER performance standards to deliver affordable functionality that can optimize DER behavior during disturbances and ensure appropriate grid support, improve DER disturbance withstand capabilities consistent with IEEE 1547-2018 and expand the use of grid support control modes such as Volt/VAR, Volt-Watt, and Frequency-Watt. Among many benefits, this would improve the hosting capacity of feeders allowing more consumers to install DERs without additional network costs that would flow through to customers.

[4] "Technical Integration of Distributed Energy Resources," AEMO (April 2019), *available at* https://www.aemo.com.au/-/media/Files/Electricity/NEM/DER/2019/Technical-Integration/Technical-Integration-of-DER-Report.pdf.

Japan

Ten privately owned utilities serve the four major islands of Japan with a grid that operates on two different frequencies: Tokyo and the eastern side of Japan operate at 50 Hz, and Osaka and the western side of the country operate at 60 Hz.[5] Japan invested in DER alternatives long before other markets globally, even though solar was not a large part of the country's supply. The first solar cell was made in Japan in 1955, and the first solar panel was connected to the grid in 1978. After launching a rooftop solar PV program in 1992, Japan emerged as the global leader in solar production in 1999 and solar generation in 2004.

In 2012, after the nuclear event at Fukushima, new renewable feed-in tariffs were offered to solar power producers at ¥42 per kWh over the next 20 years, which was among the highest in the world. The incentive resulted in 1,718 MW of solar power addition that year alone. Since the Fukushima Daiichi nuclear event, steps have been made to liberalize the electricity supply market. In April 2016, domestic and small business voltage customers became eligible to select from over 250 supplier companies competitively selling electricity. In 2020, transmission and distribution infrastructure access will be made more open, which will increase pressure to harmonize central and distribution power sources.

The pace of planned deregulation reforms is opening up opportunities to tap diverse DERs, beyond commercial and industrial contributions, to help solve balancing challenges and grid constraints in Japan. This balancing act is multifaceted and requires automation and controls capable of sensing and optimizing both large and small resources,

[5] "Deregulation Drives Virtual Power Plant Expansion in Japan," Navigant Research (2019), *available at*https://cdn2.hubspot.net/hubfs/1537427/Navigant%20JapanWP%232.pdf.

renewables, fossil-fueled technologies, and nuclear power. A paper released by Navigant Research notes the need for flexibility as the DER portfolio grows; the notion is that thousands, if not millions, of diverse DER assets can be fine-tuned in real time to offer bidirectional value to both asset owners and the larger grid. Over time, as the country's DER portfolio grows, flexibility will help balance both distribution and transmission systems. Advanced active power management capabilities inherent in the concept of DERMS will come into play as DER penetration increases. These systems will target voltage hotspots and feeder-level issues, ideally with the same platform used to balance the transmission system.[6]

The vision that Japan holds for DER management parallels the Company's DER Management Plan, which would enable utility management and monitoring of DER smart inverters via a DERMS system.

Spain

Spain was one of the first countries to deploy large scale solar photovoltaics. In 2018, the cumulative total solar power installed was 7,011 MW, consisting of PV and concentrated solar power installations. The country initially had a leading role in the development of solar power and offered generous prices for grid connected solar to encourage the industry. Solar power installations were greater than anticipated; however, the interconnection prices did not provide for a maintainable market leading to a fast, but unsustainable, boom. Between 2012 and 2016, new installations stagnated in Spain while

[6] Robert Walton, *Autogrid's Japan project could be world's largest virtual power plant, company says*, UTILITY DIVE (June 25, 2019), *available at* https://www.utilitydive.com/news/autogrids-japan-project-could-be-worlds-largest-virtual-power-plant-comp/557550/.

growth accelerated in other leading countries, thereby leaving Spain to lose much of its world leading status in solar to countries such as Germany and Japan.

Spain is representative of many countries across the globe that has incented an unsustainable DER boom. Spain's experiences demonstrate that technical infrastructure and interconnection rules are needed to appropriately integrate renewables to achieve long-term clean energy targets. PPL Electric is learning from this and taking proactive measures with its DER Management Plan to enable DER interconnections and be successfully positioned to operate the distribution system safely and reliably as penetration increases.

With the Company's proactive approach proposing the DER Management Plan and their proven capability to innovate, this can be an industry model of how grid transformation should occur. Unlike the journeys of the early DER adopters, PPL Electric will have the opportunity to facilitate a smooth transformation of the electric grid that will enable DER penetration in a way that is benefits its customers, citizens and stakeholders.

Q. DOES THIS CONCLUDE YOUR DIRECT TESTIMONY AT THIS TIME?

A. Yes, although I reserve the right to supplement my direct testimony.

VERIFICATION

I, WANDA REDER, being the President and CEO of Grid-X Partners, LLC, hereby state that the facts above set forth are true and correct to the best of my knowledge, information and belief and that I expect PPL Electric Utilities Corporation to be able to prove the same at a hearing held in this matter. I understand that the statements herein are made subject to the penalties of 18 Pa.C.S. § 4904 relating to unsworn falsification to authorities.

Date: December 10, 2019

Wanda Reder