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79NC59
PO Box 9239
Newark, DE 19714-9239

March 31, 2014

VIA Overnight Delivery

Mr. Robert Howatt
Executive Director
Delaware Public Service Commission
861 Silver Lake Blvd., Suite 100
Dover, DE 19904

Re: Delmarva Power 2014 Reliability Planning and Studies Report

Dear Mr. Howatt:

Enclosed for filing with the Commission are the original and 10 copies of the Delmarva Power 2014 Reliability Planning and Studies Report. This report is filed in compliance with Section 9.2 of Regulation Docket No. 50. Page 16 of the report reflects the contents of the CD ROM Document Index for the 2013 PJM Regional Transmission Expansion Plan. Included with the printed materials is a CD which contains electronic documents referenced in the Report.

Please contact me or Todd Goodman with any questions relating to the above referenced matter.

Sincerely Yours,

Heather G. Hall

Heather G. Hall

CC:
Kevin Neilson, DPSC
Jerry Platt, DPSC
David Bonar, DPA
William Gausman, DP
Michael Maxwell, DP
Bryan Clark, DP
Daniel Guy, DP
Mindy Herman, DP
Todd Goodman, DP
Joanne Sheridan, DP

STATE OF DELAWARE

Delaware Public Service Commission

Electric Service Reliability and Quality Standards

Delmarva Power 2014 Reliability Planning and Studies Report

As stated in the Delaware Public Service Commission (DE-PSC) Regulation Docket No. 50, each electric distribution company (EDC) shall annually submit a reliability planning and studies report to the DE-PSC by March 31. The report requirement is contained in Section 9 of the Commission order. This document is presented as Delmarva Power's 2014 Reliability Planning and Studies Report. Section 9 of the Commission order is reproduced in the report with Delmarva Power's response inserted after each sub-section.

9.0 Planning and Studies Report

9.1. Prior to May 31 of each year, each EDC shall convene a stakeholder meeting offering opportunity for interested parties to discuss electric service reliability or quality concerns within Delaware. Such meeting shall be limited to discussion of publicly available information and at a minimum be open to generation companies, electric suppliers, municipals or other EDCs, PJM, state agencies and wholesale/retail consumers. Each EDC shall consider the resulting issues and include mitigation efforts in annual plans as appropriate.

Response 9.1: Stakeholders meeting completed as follows:

The stakeholder meeting required in 2013 was held Thursday, May 29th at Delmarva Power's Conference Center at 4100 South Wakefield Drive, Newark, Delaware. The meeting was convened at 10:00 AM and attended by members of the Delaware Public Commission Staff, the Division of the Public Advocate, and Delmarva Power. Notice for this meeting was published in the News Journal. The agenda followed at this meeting is attached and labeled as Attachment No. 1.

9.2. By March 31 of each year, each EDC shall submit a reliability planning and studies report to the Commission for review. The report will identify current reliability objectives, load study results and planned actions, projects or programs designed to maintain the electric service reliability and quality of the delivery facilities.

Response 9.2:

This document is presented as Delmarva Power's 2014 Reliability Planning and Studies Report.

9.3. The report shall include the following information:

9.3.1. Objective targets or goals in support of reliable electric service and descriptions of planned actions to achieve the objectives;

Response 9.3.1:

Delmarva Power reliability programs are designed to maintain a minimum (and improve upon wherever possible) performance level of 295 minutes as measured by the System Average Interruption Duration Index (SAIDI) in accordance with paragraph 4.3 of the Electric Service Reliability and Quality Standards set forth in Regulation Docket No. 50. Planning studies are conducted to determine where new equipment should be installed to maintain or improve service.

In addition to the identified capital improvements listed in Section 9.3.3, the following priority feeder program is in place to support improvement in reliable electric service:

All Delmarva Power distribution feeders were ranked by relative performance using a composite performance indexing method that considers number of interruptions, duration, System Average Interruption Frequency Index (SAIFI), and System Average Interruption Duration Index (SAIDI) in the ranking calculation. For the 2014 program, feeders were ranked using performance values for the period October 1, 2012 to September 30, 2013. Ten of the least reliable feeders in Delaware were selected to receive a technical evaluation (consisting of a historical outage review, feeder analysis, design review, and field inspection), and modifications (in most cases) based on the evaluation. Feeder modifications are now being designed and are planned to be performed by December 31, 2014. See Table A (Priority Feeder Budget) of this section, for the 2014 budget for these planned projects. The Annual Performance Report, to be issued by April 30, 2014, will provide more detail on the composite performance ranking method used in the priority feeder program. In addition, all identified feeders will be inspected for the necessary vegetation management work.

All other reliability inquires and issues (aside from the ten least performing feeders) are investigated and addressed. Based on the technical evaluation of the reliability issues, feeder improvements to the service reliability are recommended, if needed. These recommendations are then evaluated and improvement projects are implemented as required. See Table B (Feeder Improvement Budget) of this section for the 2014 budget for these type projects.

Delmarva Power has other programs in place to support reliability as noted in this document. Section 9.3.4 contains the power quality program guideline. The maintenance program is presented in Section 9.3.5 and Section 9.3.7 includes information on the company's participation in organizations that establish reliability standards. All customer reliability inquiries are investigated and addressed.

Table A
Priority Feeder Budget

Project Number	Description	Estimated Cost
UDLBRM4MF	Millsboro - Priority Feeder Improvements	$2,500,000
UDLNRM4CF	Christiana - Priority Feeder Improvements	$2,508,191

Table B
Feeder Improvement Budget

Project Number	Description	Estimated Cost
UDLBRM63M	MI FEEDER RELIABILITY IMPROVEMNT	$3,776,001.00
UDLNRM63C	CHRISTIANA FEEDER RELIABILITY IMPROVEMNT	$2,385,214.00
UDLBRM4MC	Millsboro District-Replace Deteriorated BD Cable	674,033.00
UDLBRM4MD	Millsboro - Planned URD Cable Replacements	1,400,000.00
UDLNRM4CC	Christiana - Replace Failed Cable	980,136.00
UDLNRM4CD	Christiana - Planned URD Cable Replacements	1,200,000.00
UDLNRDA1C	DIST AUTOMATION CHRISTIANA DISTRICT	426,103.00
UDSBRDA1D	BAY SUBST DISTRIBUTION AUTOMATION - DE	433,659.00

9.3.2. Delivery load study results as described in Section 8, to include at a minimum the information for both year b and year c as specified in Section 8, Paragraph 3;

Section 8 is reproduced here for reference:

8.0 Delivery Facility Studies

8.1. Each EDC shall perform system load studies to identify and examine potential distribution circuit overloads, distribution substation and distribution substation supply circuit single contingencies and all transmission system single and double contingencies as specified by NERC, Reliability First Corp. and PJM or successor requirements. Double contingency analysis should include supply service contingencies that may cause overloads or outages on the EDC's system. Where NERC, Reliability First Corp or PJM requirements are not applicable, the EDC shall at a minimum examine circuit and equipment overloads under normal and single contingency conditions at peak load, with and without ALM or other demand response mechanisms. The EDC shall identify all projects and/or corrective actions that are planned to mitigate reliability loading issues identified in the study.

8.2. Delivery facility planning studies will be performed annually under conditions specified by NERC, Reliability First Corp. and PJM or their successor organization's planning requirements, or as specified in 8.1. Studies shall identify required projects and/or planned corrective actions. For any study resulting in a thermal overload or an out-of-range voltage level, the study shall be performed again after the implementation of Active Load Management (ALM), system switching or reconfiguration.

8.3. Each EDC shall perform the electric delivery facility system planning studies as described herein in the fall of each year (year a) for the upcoming summer period (year b) and for the summer period two years later (year c). The planning studies will include all delivery facility enhancements planned to be in-service during the applicable summer peak and shall identify those delivery facilities that are anticipated to be overloaded during the peak demand period.

Response 9.3.2:

The results of the system planning studies are included in the project list in Section 9.3.3.

The PJM 2013 Regional Transmission Expansion Plan (RTEP) <u>2013 Regional Transmission Expansion Plan</u>, issued February 28, 2014, satisfies this requirement. This report includes all planning studies through a five-year period with identified system reinforcements. The report is available at the PJM web site. You may access the report by holding down the Control (Ctrl) Key and Mouse Click on the highlighted text. Also see response to Section 9.3.6. The RTEP table of contents is included at the end of this report.

9.3.3. Description and estimated cost of capital projects planned to mitigate loading or contingent conditions identified in load studies or required to manage hours of congestion;

Response 9.3.3:

Reliability and Load Driven Projects in Delaware Approved 2014 - 2018 Budget with Expenditures in 2014)				
Project Number	Description	ISD	Estimated Total Cost (thousands)	Driver
UTLNRM5DD1	23030 Red Lion-Cedar Creek Rebuild	12/31/2016	$330	Reliability
UTSBLCN3	Bethany Relay Upgrades for Cedar Neck	5/31/2015	$146	Load
UTSBPN7BV	Bridgeville - Install 69kV Capacitor Bank	5/30/2014	$959	PJM
UTLBRM5DD	Cedar Creek/Milford - Upgrade 230kV Line	12/31/2017	$268	Reliability
UTLBPN78F	DuPont Seaford - Laurel (6736) - Rebuild	12/31/2016	$65	PJM
UTLNRM5D1	Edgemoor - GM: Upgrade 6802	5/31/2014	$94	Reliability
UTLNPGC1	Glasgow - Cecil Reconductor 13810	5/31/2015	$3,436	PJM
UTLNRM8SF	Hay Rd - Red Lion Insulator Replacement	12/31/2014	$216	Reliability
UTSNPN74B	Keeney EHV Sub: Replace AT50 and AT51	12/31/2014	$14,496	Reliability
UTLBPN78D	Laurel - Short ckt 6706 - 1 Rebuild	5/31/2016	$49	PJM
UTSBRD9SM	Milford - Replace AT20	5/31/2014	$1,586	Reliability
UTLNCM7D	Misc Transm Ln Upgrade Reimbursable-DE	12/31/2018	$37	Customer
UTSBPN7BV1	N. Seaford L6737 Relay Upgrade for Bridgeville Cap Bank	5/30/2014	$63	Load
UTSNPN73R	NC Substation Reactor 2014 - NC substation 40 MVAR	12/31/2014	$2,990	PJM
UTSBCD8SF	Nelson Substation - Install 69kV Terminal	5/31/2015	$647	Customer
UTSBLCN2	Rehoboth Relay Upgrades for Cedar Neck	5/31/2015	$177	Load
UTLBPN7BV1	Relocate Circuits 6737 & 6738 at Bridgeville Sub.	5/30/2014	$40	PJM
UTSBPN7BV2	S. Harrington L6738 Relay Upgrade for Bridgeville Cap Bank	5/30/2014	$66	Load
UTLBRM5DD1	South Harrington-Bridgeville Rebuild	6/1/2016	$167	PJM
UTLBPTC1	Townsend - Church 13833 Rebuild	5/31/2014	$7,644	PJM
UTLNCMD1	Townsend - Middletown: Const. New 138 kV Line	12/31/2015	$32	Customer
UTSNCMD2	Townsend Sub. - 138kv Terminal to Middletown	12/31/2015	$43	Customer
UTSNPTC2	Townsend Sub: Relay and Term Upgrades 13833 to Church	6/1/2014	$280	PJM
UTLBRM5DD2	Wells-Harrington Rebuild 6784	12/31/2015	$202	Reliability
UTLBLCN4	Cedar Neck Sub: Construct two 69kV Lines	5/31/2015	$171	Load
Reliability and Load Driven Projects in Delaware				

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Approved 2014 - 2018 Budget with Expenditures in 2014)				
Project Number	Description	ISD	Estimated Total Cost (thousands)	Driver
UDSBLM76A	Cedar Neck Substation: Install 2nd 69/12kV Transformer	5/31/2015	$3,577	Load
UDSNRD9SU	Chestnut Run T2 Replacement	12/31/2015	$475	Reliability
UDSNRD9SR	Chestnut Run T3 Replacement	12/31/2014	$450	Reliability
UTSBRD9SX3	Harbeson Substation - Line 6742 Relay Upgrade	12/31/2014	$119	Reliability
UDSNRD9A	IR Roger Road Substation. Clean up and retire	12/3/2014	$285	Reliability
UDSNRD9SM	Kiamensi T2: Replace Transformer	12/31/2014	$1,475	Reliability
UTSBRD9SX4	Laurel Substation - Line 6722 Relay Upgrade	12/31/2014	$140	Reliability
UDSBLM73B	Midway - Add a 2nd Transformer	5/31/2016	$17	Load
UDSNRD9SQ	Milford Crossroads T1: Replace XFMR	6/30/2015	$400	Reliability
UDLNLMTP3	Mt. Pleasant: Construct New Feeder	5/31/2015	$1,000	Load
UDSNRD9SV	Naamans Rd - Replace T1	12/31/2014	$800	Reliability
UDSNRD9ST	Naamans Rd - Replace T2	12/31/2014	$800	Reliability
UDSBRD9SG	North Seaford - Replace T2 & T3 with One Transformer	12/31/2014	$475	Reliability
UDSNRD8RA	North Wilmington Sub. Cleanup and retire	12/3/2014	$298	Reliability
UDSNLOGT1	Ogletown Area Substation - Land Purchase	12/31/2015	$200	Load
UDLNRM8BC	Silverside: 4-12kV Conversion	12/31/2014	$300	Reliability
UDSBRD9SX1	Sussex - Replace T2 Transformer	12/31/2014	$1,354	Reliability
UTSBRD9SX2	Sussex Substation 69kV Bus Upgrade	12/31/2014	$1,412	Reliability
UDSNRD9SL	West Sub. Replace T-5 69/34 kV transformer	12/31/2014	$1,280	Reliability
UDLNRM4CR	Wilmington Network Upgrade.	5/31/2017	$596	Reliability
UDSBRD9SF	Millsboro – Replace T1	12/31/2013	$175	Reliability
UDSBRD8RB	Greenwood Substation – Retire/Remove 4 kV	12/31/2013	$119	Reliability
UDLNRMT1	Milltown Rd – Move DE0640 from T1 to T3	12/31/2014	$15	Reliability
UDSBLM73C	Harbeson Substation Upgrade T1	5/31/2013	$51	Load

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9.3.4. The EDC's power quality program and any amendments as required in Section 6;

Section 6 is reproduced here for reference:

6.0 Power Quality Program

6.1. Each EDC shall maintain a power quality program with clearly stated objectives and procedures designed to respond promptly to customer reports of power quality concerns.

6.2. Each EDC shall consider power quality concerns in the design, construction and maintenance of its transmission and distribution power delivery system components to mitigate, using reasonable measures, power quality disturbances that adversely affect customers' equipment.

6.3. Each EDC shall maintain records of customer power quality concerns and EDC response. These records shall be made available to the Commission Staff upon request with 30 days notice.

Response 9.3.4:

The power quality program policy guideline is included with this document as Attachment No. 2 and remains unchanged from the 2013 Reliability Planning and Studies Report.

9.3.5. The EDC's inspection and maintenance program, any amendments as required in Section 7, and any specific actions aimed at reducing outage causes;

Section 7 is reproduced here for reference:

7.0 Inspection and Maintenance Program

7.1. Each EDC shall have an inspection and maintenance program designed to maintain delivery facilities performance at an acceptable reliability level. The program shall be based on industry codes, national electric industry practices, manufacturer's recommendations, sound engineering judgment and past experience.

7.2. As a maintenance minimum, each EDC shall inspect and maintain as necessary its power transformers, circuit breakers, substation capacitor banks, automatic 3-phase circuit switches and all 600 amp or larger manually operated, gang transmission circuit tie switches at least once every two (2) years.

7.3. As a maintenance minimum, each EDC shall inspect all right-of-way vegetation at least once every four (4) years and trim or maintain as necessary, according priorities to circuits that have had significant numbers of vegetation-related outages, while not unduly delaying the trimming of other circuits that inspections indicate currently need trimming. Vegetation management practices should be applied at least once every four (4) years except where growth or other assessments deem it unnecessary.

7.4. Each EDC shall maintain records of inspection and maintenance activities. Compliance with this requirement may be established by a showing of substantial compliance without regard for a single particular facility maintenance record. These records shall be made available to Commission Staff upon request with 30 days notice.

Response 9.3.5:

Delmarva Power has an established Reliability Centered Maintenance (RCM) program which is based on industry codes, national electric industry practices, manufacturer's recommendation, sound engineering judgment and past experience. This program provides the inspection and maintenance intervals, and reliability and quality standards for electric distribution equipment. Any new commission standards and intervals shall override the existing RCM program. All inspection and maintenance activity records for this program are held at the regional operation facilities.

Substation

Circuit Breakers

Description	**Vacuum Circuit Breakers**	**Air Circuit Breakers**	**SF-6 Breakers**	**Oil Circuit Breakers**	**Oil Circuit Breakers**	**SF-6 Breakers**
	4,12,25, & 34 kV	**4,12,25,& 34kV**	**12, 25, & 34kV**	**4,12, 25, & 35kV**	**69, 138, & 230kV**	**69,138, 230, & 500 kV**
External Testing/ Maintenance Cycle	6-10 yrs.	8-10yrs	8yrs	6-10yrs	6-10yrs	8yrs
Infrared Inspection	Annually	Annually	Annually	Annually	Annually	Annually
Internal Inspection	Based on test results	Based on test results	Based on test results	8 yrs./Based on test results	Based on test results	Based on test results
Test Requirements						
Gas Pressure Test	No	No	No	No	No	Yes
Dissolved Gas in Oil Test	No	No	No	No	Yes	No
Doble Power Factor (PF) Test	No	12,23,& 34kV only	Yes	Yes	Yes	Yes
Ductor	Yes	Yes	Yes	Yes	Yes	Yes
Hi-Pot Vacuum Bottles	Yes	N/A	N/A	N/A	N/A	N/A
Analyze/Timing Test	Standalone breakers only	N/A	Yes	Yes	Yes	Yes
Oil Power Factor (ASTM D924)	N/A	N/A	N/A	Yes	Yes	N/A
Dielectric Breakdown (ASTM D-877)	N/A	N/A	N/A	Yes	Yes	N/A

Substations

Power Transformers

Description	Power Transformers	Mobile Unit Transformers	Load Tap Changers
Testing/Maintenance	6-12 yrs	annual external inspection	6-12 yrs or condition based
Infrared Inspection	Annually		Annually
Doble Power Factor Testing			N/A
Overall Insulation Test	Yes	Yes	N/A
Bushing Tests: C1 & C2	Yes	Yes	N/A
Hot Collar Test - W/O PF Tap	Yes	Yes	N/A
Excitation Test	at existing tap setting	at existing tap setting	N/A
LTC Position (16L, 16R)	Yes	Yes	N/A
Limited TTR	at existing tap setting	at existing tap setting	N/A
LTC Tap Position (16L, 1L,N, 16R)	if applicable	N/A	N/A
Dissolved Gas in Oil/Oil Quality Checks			
Dissolved Gas Analysis	Annually	Annually	Annually
Dielectric Breakdown	Annually	Annually	Annually
Acid Number (ASTM D-1534)	Annually	Annually	Annually
Color (ASTM D-1534)	Annually	Annually	Annually
Moisture	Annually	Annually	Annually
Oil Power Factor test	Yes	Yes	Yes
Supplemental Tests			
Ductor (Resistance test)	W/Doble PF Test	W/Doble PF Test	N/A
Meggar Test	W/Doble PF Test	W/Doble PF Test	N/A
Doble Hot Collar-Bushing with Power Factor (PF) Tap	W/Doble PF Test	W/Doble PF Test	N/A

Substations

Switches

Description	Motor Operated Disconnect Switches w/ Relay Scheme	Circuit Switchers
Maintenance	N/A	Operate with other equipment maintenance outages
Cycle		Annual External Inspection
Infrared Inspection	Annually	Annually
Maintenance performed in conjunction with other equipment	Yes	Yes
Test Requirements	Per Manufacturer Recommendations	Per Manufacturer Recommendations

Miscellaneous Equipment

Description	Lightning Arresters	Potential Current Transf.	Potential Current Transf.	Relay/Communication Transmission	Relay/Communication Distribution
		<= 34.5 kV	>=69kV		
Maintenance Cycle	N/A	N/A	N/A	4 yrs.	8 yrs. (4 yrs UV & UF)
Battery System	N/A	N/A	N/A	Annually	Annually
Infrared Inspection	Yes	Yes	Yes	N/A	N/A
Visual Inspection	Yes	Yes	Yes	N/A	N/A
Maintenance performed in conjunction with other equipment	Yes	Yes	Yes	Yes	Yes
Doble Power Factor Test	Condition Based	Condition Based	Condition Based		

Transmission Maintenance Plan Summary

- Transmission wood pole inspection	12 to 18 year cycle
- Transmission infrared inspection	Annually
- Transmission vegetation management Aerial inspection done semi-annually	4-year Maintenance Program
- High Pressure Oil or Gas Filled Cable Systems	Annually
- Communication / Tower Aviation Warning Lights	Annually
- Visual check of navigable water crossings	5 year cycle
- Transmission aerial inspection, "fly by"	3 year cycle
- Transmission aerial inspection, comprehensive	Bulk supply lines – 6 year cycle

Distribution Maintenance Plan Summary

- Street Light Group Replacement	6 year cycle
- Inspection of Switch Capacitor Banks	Annually
- Inspection of Fixed Capacitor Banks	Annual visual inspection
- Full operational check of Reclosers and Sectionalizers	Electronic Controls tested every 3 – 6 years
- Visual inspection electronically controlled reclosers	Annually
- Distribution wood pole inspections	12 to 18 year cycle
- Inspection of Pad Mounted Distribution Facilities	10 to 20 Year cycle
- Distribution Vegetation Management	Reliability based program
- Distribution infrared inspection	5 year cycle
- Visual check of navigable water crossings	5 year cycle

9.3.6. Copies of all recent delivery facility planning studies and network capability studies (including CETO and CETL results) performed for any delivery facilities owned by the utility; and

Response 9.3.6:

The information is available at the PJM Web Site. The web site address is:

<u>2013 Regional Transmission Expansion Plan</u> issued February 28, 2014.

The documents are also included on the enclosed CD – ROM. The RTEP table of contents is included at the end of this report.

9.3.7. Summaries of any changes to reliability related requirements, standards and procedures at PJM, First Reliability Corporation, NERC or the EDC.

Response 9.3.7:

"Control - Click" on any web page link to access that document or web page.

PJM Reliability Standards:

Refer to the PJM Manual 14B:

PJM Regional Transmission Planning Process, Revision 25, October 24, 2013 at the PJM Web Site.

Additional information on planning parameters may be reviewed at:

RPM Planning Parameters 2017/2018

Also, select Delivery Year 2017/2018 after navigating to the link below:

http://www.pjm.com/markets-and-operations/rpm/rpm-auction-user-info.aspx

MAAC Reliability Standards:

The following web site lists the status of all MAAC Reliability Standards including those that were retired on June 18, 2007, October 25, 2007, March 19, 2008, May 14, 2009, and November 1, 2011 due to obsolescence and/or replacement. There have been no revisions to the MAAC Reliability Standards since 2005. Two of the three remaining legacy MAAC Reliability Standards were retired on October 1, 2013. The remaining standard will be retired when NERC standard PRC-024-1 becomes effective.

The legacy MAAC Reliability Standards are being replaced by Reliability*First* Criteria or NERC Standards.

Reliability*First* Corp. – Disposition of Legacy Documents (pages 2-3)

The following web site provides the MAAC Reliability Standard documents that were retired on March 7, 2014:

Retired MAAC Standards

ReliabilityFirst Reliability Standards:

Presently there are no Reliability*First* Reliability Standards that apply to Delmarva Power

NERC Reliability Standards:

subject to enforcement.

NERC Reliability Standards – BOT and FERC Approved

Those standards having a 2013 enforcement date were added or revised.

The following web site includes a list of NERC Reliability Standards that were retired and are now inactive. The Inactive Reliability Standards Report must be selected at the top of this page

NERC Reliability Standards – Retired/Inactive

Those standards having a 2013 inactive date were retired in 2013. In most if not all cases, the retired standards were replaced by a newer version or combined with another standard.

Those NERC and Reliability*First* Reliability Standards or Requirements that list Transmission Owner, Distribution Provider, Load Serving Entity, or Purchasing-Selling Entity as the applicable entity apply to Delmarva Power.

Those NERC Standards or Requirements that list Transmission Operator as the applicable entity apply to PJM. For a subset of the NERC Requirements that apply to Transmission Operators, PJM has assigned tasks to member Transmission Owners including Delmarva Power. The following web site provides a list of PJM TOP assigned tasks. Those Standards and Requirements having a 2013 start date were added or revised.

PJM TO/TOP Matrix of Shared or Assigned Tasks– Version 7

The NERC Reliability Standard numbering convention has three parts:

1. A three-letter acronym denoting the general topical area of the standard.
2. The standard number within that topical area, beginning with 1 and increasing sequentially.
3. The version of that standard.

Example: BAL-001-1 (Balancing – Standard 001 – Version 1)

The version number is changed when changes are made to the standard through the standards development process.

The web page links are provided here:

NERC Standards Processes Manual

Reliability*First* Reliability Standards Development Procedure

9.3.8. Summary of any issues that resulted from the EDC stakeholder meeting and any projects or planning changes that may have been incorporated as a result of such meeting.

Response 9.3.8:

The last EDC stakeholder meeting was held May 29, 2013. There were no issues or projects/planning changes as a result of the EDC stakeholder meeting.

PJM 2014 RTEP 02/28/2014

CD-ROM[1] Table of Contents

[1] All data contained on the CD-ROM is also available at www.pjm.com

Attachment No. 1
Stakeholder Meeting Agenda

Regulation Docket No. 50
Annual Stakeholders Meeting
Wednesday, May 29, 2013

Delmarva Power
Newark, Delaware
NCRO Conference Room 1A/1B
10:00 A.M.

Agenda

Introduction and welcome – Heather Hall, Manager, Regulatory Affairs, External Issues and Compliance, Delmarva Power

Power Point Reliability Presentation – Bryan L. Clark, Manager – Asset Performance & Reliability, Delmarva Power

To include: Distribution Reliability Update

- Reliability Performance summary: SAIFI, SAIDI & CAIDI
- Major Event Days – 2012
- Major Causes of Outage Interruptions – 2012
- Distribution Automation

Wholesale Reliability Update

General Discussion and Questions & Answers

QUALITY OF DELIVERY VOLTAGE GUIDELINES

Purpose

The purpose of this section is to provide technical information and a process for the resolution of customer power quality complaints. Power quality (PQ) has become a concern for many of our customers and for Atlantic City Electric & Delmarva Power. Voltage variations that once were considered normal can cause today's electronic equipment to trip off line or even fail.

Requirements

Although the state rules vary, overall the standards are loosely defined. Atlantic City Electric & Delmarva Power's internal design philosophy exceeds all state requirements throughout the service territory.

The information in this section was condensed from the Quality of Delivery Voltage Guidelines (full report), Power Quality Guidelines, and the following documents in four states:

Delaware: from "Regulations Governing Service Supplied by Electric Utilities," Rule 16 Voltage (Sections A2, A3, B and F). This document was written in 1952 and has not changed since then.

Maryland: from "Code of Maryland Regulations", Title 20, Subtitle 50, Chapter 07. This chapter was written in 1942 with the last update made in 1965. The commission staff in 1997 did not anticipate any modifications to this chapter.

New Jersey: from "New Jersey Administrative Code" (NJAC), 1980, Sections 14:5 – 2.3 Adequacy of Services and 14:5 – 7.5 Power Quality.

Virginia: from "Virginia Rules and Regulations" in Atlantic City Electric & Delmarva Power's Tariff Section XI - Customer Use of Service. These rules and regulations for the Virginia service territory meet the requirements of the state. Virginia staff members reported in 1997 that these rules have been on the books for decades and there are no plans to change this section.

Information Resource

For additional assistance, questions, or customer consultations, contact a Power Quality Contractor.

Table I Voltage Limitations Defined by State

State	Steady State Criteria	Transient Voltage Fluctuations	Flicker Limitations	Maximum Harmonic Distortion	Maximum Voltage Unbalance
Delaware	±5%	Undefined	Continuous fluctuations not to exceed ±3% change in one second or less	Undefined	Undefined
Maryland	+5%, -10% for secondary service ±7.5% for primary service	Undefined Undefined	Undefined Undefined	Undefined Undefined	Undefined Undefined
New Jersey	±4%	Undefined	Undefined	Undefined	Undefined
Virginia	±5% for urban residential areas ±7.5% for non-urban and all others	Undefined Undefined	Undefined Undefined	Undefined Undefined	Undefined Undefined

[1]It should be noted that there will be exceptions to the voltage requirements. A typical definition of these exceptions is defined in the Maryland Regulations under Title 20.50.07.02 Voltage Limits... "It will **not** be considered a violation when voltages outside of the prescribed limits are caused by any of the following:

1. Action of the elements
2. Service interruptions
3. Temporary separation of parts of the system from the main system
4. Infrequent fluctuations not exceeding 5 minutes duration
5. Other causes beyond the control of the utility

NORMAL, STEADY STATE VOLTAGE

Definition of Normal Voltage Ranges

All four state jurisdictions define acceptable variations in steady state voltage. Only the State of Maryland Regulations, among the states served by Atlantic City Electric & Delmarva Power, define nominal acceptable secondary voltages.

The following paragraphs and Table II are adopted from ANSI-C84.1-1989 which defines nominal system voltages and voltage ranges. It is worth noting that on Table II the limits of Range A and Range B apply to steady state voltage levels and not to momentary voltage excursions that may result from such causes as switching operations, motor starting currents, etc.

RANGE A - SERVICE VOLTAGE... Electric supply systems shall be so designed and operated that most service voltages will be within the limits specified for Range A. The occurrence of voltages outside of these limits should be infrequent. Service voltage is defined as the voltage at the point where the electrical system of the supplier and the electrical system of the user are connected.

RANGE A - UTILIZATION VOLTAGE... User systems shall be so designed and operated that, with service voltages within Range A limits, most utilization voltages will be within the limits specified for this range. Utilization equipment shall be designed and rated to give fully satisfactory performance throughout this range.

RANGE B - SERVICE AND UTILIZATION VOLTAGES... Range B includes voltages above and below Range A limits that necessarily result from practical design and operating conditions on supply or user systems, or both. When they occur, corrective measures shall be undertaken within a reasonable time to improve voltages to meet Range A requirements. Equipment shall be designed to give acceptable performance in the extremes of the range of utilization voltages, although not necessarily as good performance as Range A. When voltages occur outside the limits of Range B, prompt corrective action shall be taken.

If information is needed for nominal voltages and acceptable operating ranges for systems above 230 kV refer to ANSI-C92.2-1987.

Table 1— Standard Nominal System Voltages and Voltage Ranges

(Preferred system voltages in bold-face type)

VOLTAGE CLASS	NOMINAL SYSTEM VOLTAGE (Note a)			Nominal Utilization Voltage (Note i)	VOLTAGE RANGE A (Note b)			VOLTAGE RANGE B (Note b)		
					Maximum	Minimum		Maximum	Minimum	
	Two-wire	Three-wire	Four-wire	Two-wire Three-wire Four-wire	Utilization and Service Voltage (Note c)	Service Voltage	Utilization Voltage	Utilization and Service Voltage	Service Voltage	Utilization Voltage
Low Voltage (Note 1)	Single-Phase Systems									
	120			115	126	114	110	127	110	106
		120/240		115/230	126/252	114/228	110/220	127/254	110/220	106/212
	Three-Phase Systems									
			208Y/120 (Note d)	200	218Y/126	197Y/114	191Y/110	220Y/127	191Y/110 (Note 2)	184Y/106 (Note 2)
			240/120	230/115	252/126	228/114	220/110	254/127	220/110	212/106
		240		230	252	228	220	254	220	212
			480Y/277	460	504Y/291	456Y/263	440Y/254	508Y/293	440Y/254	424Y/245
		480		460	504	456	440	508	440	424
		600 (Note e)		575	630 (Note e)	570	550	635 (Note e)	550	530
Medium Voltage		2400			2520	2340	2160	2540	2280	2080
			4160Y/2400		4370/2520	4050Y/2340	3740Y/2160	4400Y/2540	3950Y/2280	3600Y/2080
		4160			4370	4050	3740	4400	3950	3600
		4800			5040	4680	4320	5080	4560	4160
		6900			7240	6730	6210	7260	6560	5940
			8320Y/4800		8730Y/5040	8110Y/4680	(Note f)	8800Y/5080	7900Y/4560	(Note f)
			12000Y/6930		12600Y/7270	11700Y/6760		12700Y/7330	11400Y/6580	
			12470Y/7200		13090Y/7560	12160Y/7020		13200Y/7620	11850Y/6840	
			13200Y/7620		13860Y/8000	12870Y/7430		13970Y/8070	12504Y/7240	
			13800Y/7970		14490Y/8370	13460Y/7770		14520Y/8380	13110Y/7570	
		13800			14490	13460	12420	14520	13110	11880
			20780Y/12000		21820Y/12600	20260Y/11700	(Note f)	22000Y/12700	19740Y/11400	(Note f)
			22860Y/13200		24000Y/13860	22290Y/12870		24200Y/13970	21720Y/12540	
		23000			24150	22430		24340	21850	
			24940Y/14400		26190Y/15120	24320Y/14040		26400Y/15240	23690Y/13680	
			34500Y/19920		36230Y/20920	33640Y/19420		36510Y/21080	32780Y/18930	
		34500			36230	33640		36510	32780	
					Maximum Voltage					
		46000			(Note g) 48300					
		69000			72500					
High Voltage		115000			121000					
		138000			145000					
		161000			169000					
		230000			242000					
		(Note h)								
Extra-High Voltage		345000			362000					
		500000			550000					
		765000			800000					
Ultra-High Voltage		1100000			1200000					

NOTES: (1) Minimum utilization voltages for 120-600 volt circuits not supplying lighting loads are as follows:

Nominal System Voltage	Range A	Range B
120	108	104
120/240	108/216	104/208
(Note 2) 208Y/120	187Y/108	180Y/104
240/120	216/108	208/104
240	216	208
480Y/277	432Y/249	416Y/240
480	432	416
600	540	520

(2) Many 220 volt motors were applied on existing 208 volt systems on the assumption that the utilization voltage would not be less than 187 volts. Caution should be exercised in applying the Range B minimum voltages of Table 1 and Note (1) to existing 208 volt systems supplying such motors.

Notes:

a) Three-phase three-wire systems are systems in which only the three-phase conductors are carried out from the source for connection of loads. The source may be derived from any type of three-phase transformer connection, grounded or ungrounded. Three-phase four-wire systems are systems in which a grounded neutral conductor is also carried out from the source for connection of loads. Four wire systems in Table II are designated by the phase-to-phase voltage, followed by the letter Y (except for 240/120 volt delta system), a slant line, and the phase-to-neutral voltage. Single-phase services and loads may be supplied from either single-phase or three-phase systems.

b) The voltage ranges in this table are illustrated in the full ANSI Standard, Appendix B.

c) For 120-600 volt nominal systems, voltages in this column are maximum service voltages. Maximum utilization voltages would not be expected to exceed 126 volts for the nominal system voltage of 120, nor appropriate multiples thereof for other nominal voltages through 600 volts.

d) A modification of this three-phase, four-wire system is available as a 120/208 Y volt service for single-phase, three-wire, open-wye applications.

e) Certain kinds of control and protective equipment presently available have a maximum voltage limit of 600 volts, the manufacturer or power supplier or both should be consulted to assure proper application.

f) Utilization equipment does not generally operate directly at these voltages. For equipment supplied through transformers refer to limits for nominal system voltage of transformer output.

g) For these systems, Range A and Range B limits are not shown because, where they are used as service voltages, the operating voltage level on the user's system is normally adjusted by means of voltage regulators to suit their requirements.

h) Standard voltages reprinted from American National Standard C92.2-1981 for convenience only. Reference this standard for more detailed information.

i) Nominal utilization voltages are for low-voltage motors and control. See Appendix C in the full ANSI Standard for other equipment nominal utilization voltages (or equipment nameplate voltage ratings).

Causes of Voltage Variations

Steady state service voltages, designed to be within a certain range, are affected by many variables. These variables include such items as the following:

- Transmission system voltage requirements
- Step-down transformer voltage ratios including any tap setting used
- Step-down transformer impedance
- Load tap changing or regulator use and settings
- Equipment failure or improper operation
- Distribution circuit design and the customer location on the circuit
- Cyclical load patterns on the system and the addition of load by customers
- Application of voltage reductions during emergency conditions by the supplying utility.
- Capacitor bank switching
- Circuit switching that temporarily reconfigures the system due to maintenance or system outages.
- Shunt reactors
- Static Var Compensators

Recommendations

It is recommended that Atlantic City Electric & Delmarva Power design to the nominal system voltages ±5% in the Bay & New Castle Regions and ±4% in the Atlantic Region, except for EHV, as defined in ANSI C84.1-1989. It should be noted that the minimum service voltages defined by ANSI C84.1-1989 in some cases are -2.5%. In those cases, Atlantic City Electric & Delmarva Power will continue to design to a minimum voltage as stated above.

TRANSIENT AND SHORT DURATION VOLTAGE VARIATIONS

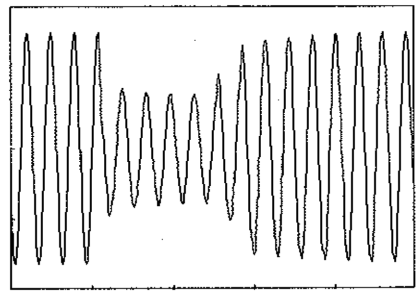
Definition

The following terms are selected as being the most important for discussing power quality phenomena. Electricity is normally generated, transmitted, and delivered to the customer as a 60 Hz sinusoidal wave. The term "power quality" broadly refers to maintaining the near sinusoidal voltage waveform at rated voltage magnitude and frequency. Some examples of basic voltage variations which alter the sinusoidal wave follow:

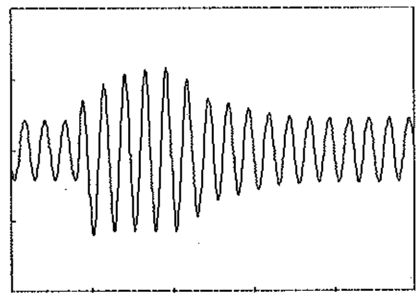
Transient — A sub-cycle disturbance in the ac voltage which is evidenced by a sharp brief discontinuity of the waveform. May be of either polarity and may be additive or subtractive from the normal voltage waveform.

Short Duration Variations

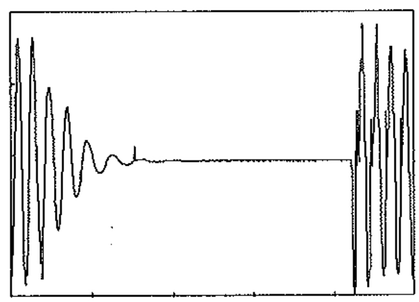
Sag — A decrease in the voltage or current, at the power frequency, for durations from 0.5 cycle to 1 minute.[18].



Swell — An increase in rms voltage or current at the power frequency, for durations from 0.5 cycle to 1 minute[18].



Interruption — The complete loss of voltage for a period of time:
Momentary (0.5 cycles - 3 seconds)
Temporary (3 seconds to 1 minute)
Sustained (>1 minute).



Harmonics — Harmonics are voltages or currents with frequencies that are integer multiples of the fundamental power frequency of 60 Hz. For example, if the fundamental frequency is 60 Hz, then the second harmonic is 120 Hz, the third is 180 Hz, etc.

Table 5.1

Categories and Typical Characteristics of Power System Electromagnetic Phenomena

CATEGORIES	SPECTRAL CONTENT	TYPICAL DURATION	TYPICAL MAGNITUDES
1. Transients			
Impulsive			
Nanosecond	5 ns rise	< 50 ns	
Microsecond	1 μs rise	50 ns - 1 ms	
Millisecond	0.1 ms rise	> 1 ms	
Oscillatory			
Low Frequency	< 5 kHz	.3 - 50 ms	0 - 4 pu
Medium Frequency	5 -500 kHz	20 μs	0 - 8 pu
High frequency	0.5 - 5 Mhz	5 μs	0 - 4 pu
2. Short Duration Variations			
Instantaneous			
Sag		0.5 - 30 cycles	0.1 - 0.9 pu
Swell		0.5 - 30 cycles	1.1 - 1.8 pu
Momentary			
Interruption		0.5 cycles - 3 s	< 0.1 pu
Sag		30 cycles - 3 s	0.1 - 0.9 pu
Swell		30 cycles - 3 s	1.1 - 1.4 pu
Temporary			
Interruption		3 s - 1 min	< 0.1 pu
Sag		3 s - 1 min	0.1 - 0.9 pu
Swell		3 s - 1 min	1.1 - 1.2 pu
3. Long Duration Variations			
Interruption, Sustained		>1 minute	0.0 pu
Undervoltage		>1 minute	0.8 - 0.9 pu
Overvoltage		>1 minute	1.1 - 1.2 pu
4. Voltage Imbalance		steady state	0.5 - 2%
5. Waveform Distortion			
DC Offset		steady state	0 - 0.01%
Harmonics	0 - 100th H	steady state	0 - 20%
Inter-Harmonics	0 - 6 kHz	steady state	0 - 2%
Notching		steady state	
Noise	broad-band	steady state	0 - 1%
6. Voltage Fluctuations	< 25 Hz	intermittent	0.1 - 7%
7. Power Frequency Variations		< 10 s	

Causes

Transients and short duration voltage variations can result from events, which occur on the utility system, or within the customer's facility, or as a result of the electrical parameters of the combined system. In general there are two classes of disturbances, which may effect the operation of sensitive electronic equipment, those which are conducted and those which are radiated. For the purposes of this discussion, only conducted disturbances will be considered. It is worthy of note that these disturbances, like all electrical phenomena, obey the basic laws of physics and thus the location of the revenue meter has no specific consequence in their analysis. The following list indicates events that generate conducted disturbances which may disrupt the operation of sensitive electronic equipment:

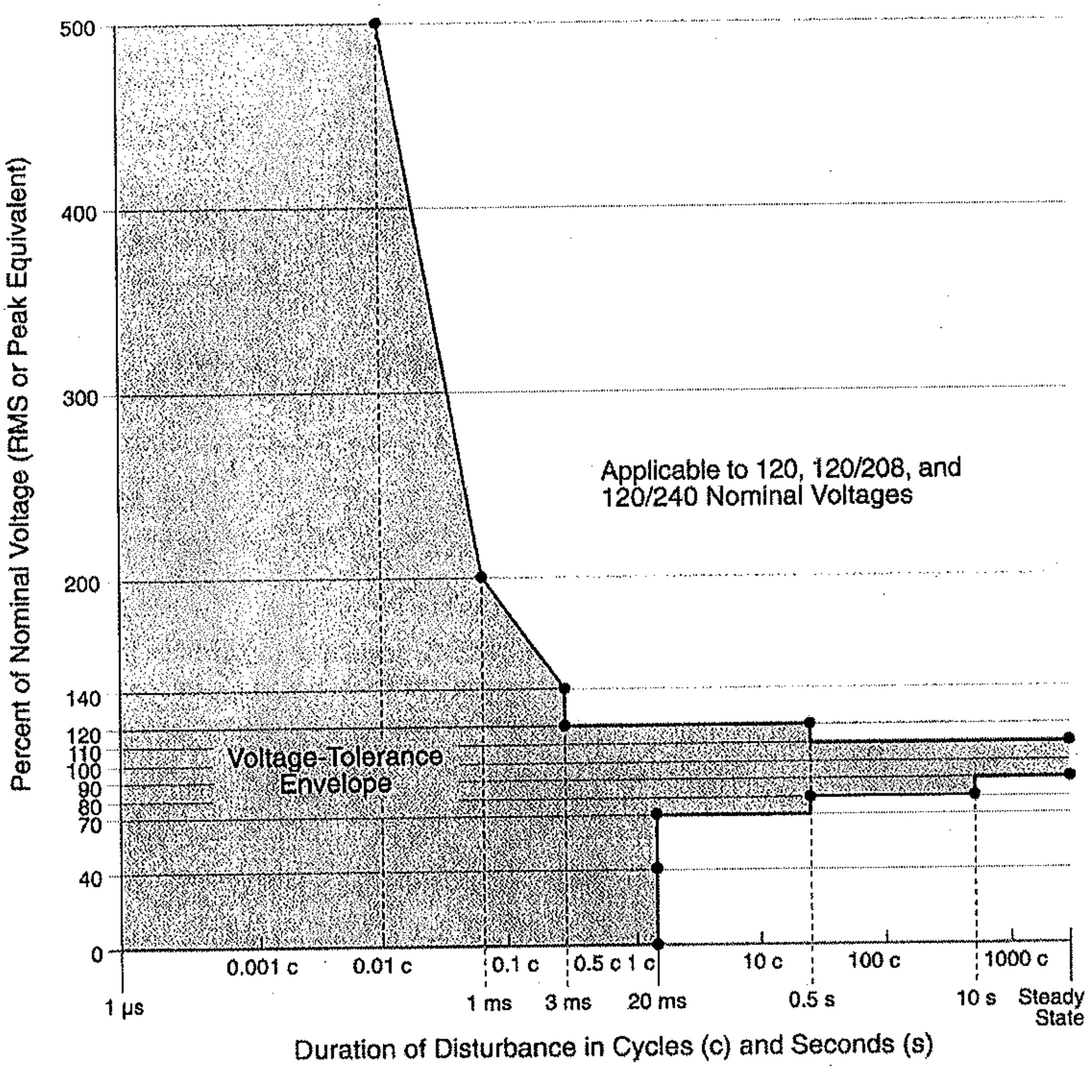
- Load switching
- Faults or short circuits
- Capacitor bank switching
- Arcing or loose connections
- Motor starting/stopping
- Operation of Silicon Control Rectifier (SCR) devices
- Operation of rectifier type loads
- Inappropriate wiring or grounding practices
- Lightning
- Solar Magnetic Disturbances

Effects

The increased use of computer technology for process control and business operations has begun to change the utility customer's perception of quality electric service. The ability to tolerate the impact of transients and voltage variations frequently depends on a variety of factors including the criticality of the function or process, the design and configuration of the power system supplying the critical load, and the design of the critical load itself.

Out of a concern for developing industry accepted operating criteria, the Computer Business Equipment Manufacturers Association (CBEMA) has adopted an equipment tolerance envelope. This set of curves (Figure 5.3[2]) illustrates typical design goals for the power conscious computer manufacturer.

CBEMA Curve



Revised 1996

Figure 5.3 "Safe" Operating Envelope for Computer Power

Appendix A provides an excerpt from ANSI/IEEE Std. 446-1987 which gives a partial description of voltage variations based on their duration. It should be noted that since this book was written in 1987, advances have been made in industry accepted terminology. For that reason, some of the terms as well as the time divisions used in this excerpt, differ from those discussed above. The concepts, however, are of value. It is readily apparent from a comparison of these disturbances with Figure 5.3, why some affect equipment operation while others do not.

The net effect of these transients and voltage variations at the point of end use, can be damaged equipment, lost productivity or inconvenience. The effects have increased utility customers' sensitivity and awareness of the existence of such disturbances. In many cases, even though the utility is not the source of the disturbance, since it is electric power related, it is perceived as an electric utility problem.

The industry, including utilities, equipment manufacturers, and end users, are only now beginning to address the issue of compatibility between customer equipment and the power source.

Recommendations

Atlantic City Electric & Delmarva Power should respond promptly to all customer concerns about transients and voltage variations. Because the causes and consequences of these phenomena are so diverse, there is no universal solution for these problems. Atlantic City Electric & Delmarva Power, however should work with the customer using mutual discussion, outage records, observation, and recording instrumentation to identify the nature and source of the disturbance and recommend possible solutions. See Power Quality Procedures below.

FLICKER

Definition

For many decades "voltage flicker" or "lamp flicker" has been defined as a perceptible change in the light output of incandescent lamps produced by chronic repetitive sudden changes in supply voltage. Most often the transient voltage causing flicker persists for a number of cycles or longer.

Traditionally two levels of flicker have been defined.[3] One is designated "minimum threshold of perception" or "borderline of visibility". The other is designated "tolerance threshold" or "borderline of irritation." Studies were conducted many years ago to measure the reaction of a large number of people to changes in light intensity produced by voltage fluctuations of various magnitudes and frequencies of occurrence. Curves were then plotted showing the two "borderlines" and how annoyance is effected by changes in the above two parameters (See Figure 6.1).

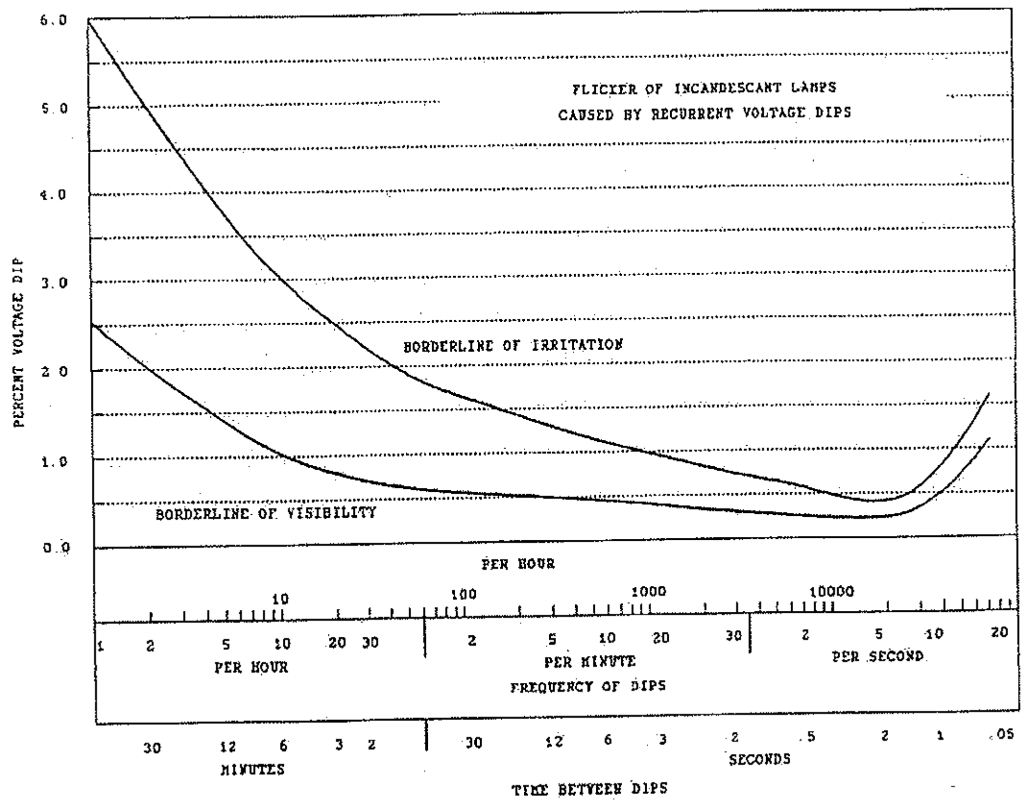


Figure 6.1 Flicker Annoyance Levels

Causes

Flicker may be created by a variety of conditions on the power supply system. Motor starting, heavy intermittent loads such as arc-welders, arc furnaces and spot welders, and loose connections are common sources of flicker.

Effects

Rapid changes in voltage create corresponding changes in light output. These changes are most readily perceived in incandescent lamps.

The net effect of this flicker then most often becomes a human psychological objection to the perceived discomfort caused by it. Most often this objection manifests itself in a real concern about fire or physical hazards. Some sources generate flicker that is perceived only at the customer's site where it is produced while others may effect nearby customers.

Recommendations

Because of the wide variation in individual response to a given level of flicker it then becomes necessary to define a reasonable level of flicker above which corrective action is necessary.

Defining a "tolerance threshold" is desirable from a utility standpoint, because it establishes a reasonable level of service and influences the design, operation, and maintenance of an electrical system.

The level of flicker that Atlantic City Electric & Delmarva Power defines as acceptable for normal system operation is the "Borderline of Irritation" as described by the curve of Figure 6.1. This curve is being used by nearly 70% of utilities responding to a 1985 IEEE survey for this same purpose.[5] Atlantic City Electric & Delmarva Power will initiate corrective action or advise the customer to do so for flicker above the Borderline of Irritation level. Flicker below this threshold, resulting in customer dissatisfaction, will be investigated on a case-by-case basis and corrective action may be taken.

HARMONIC DISTORTION

Definition

Harmonics — Any periodic waveform can be described mathematically as a series of sinusoids summed together as is illustrated in Figure 6.1. The sinusoids are integer multiples of the fundamental periodic cycle, which vary in magnitude and phase angle. Each term in the series is referred to as a "harmonic" of the fundamental frequency. The term having the same frequency as the fundamental is the first harmonic and is also referred to as simply the fundamental. The term having twice the fundamental frequency is the second harmonic, and so on. Figure 7.1 below illustrates the sum of the fundamental, 3rd, 5th, 7th and 9th harmonics of varying magnitudes to form an approximate square wave.

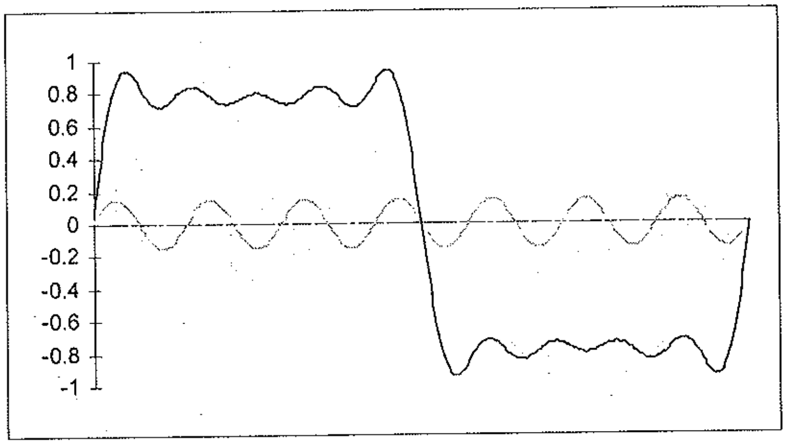


Figure 7.1 Harmonic Components of a Square Wave

I. Harmonic Distortion

The more harmonics present in a waveform the more "distorted" that waveform becomes when compared to the pure fundamental sinusoid. The following terms, expressed in percent distortion, are frequently used to quantify the level of harmonics present in a particular system.

J. Individual Harmonic Distortion

This term is used to quantify the magnitude of a single harmonic frequency voltage or current in the power system. It is expressed as a ratio of the RMS value of a single harmonic frequency quantity to the RMS value of the fundamental.

$$\frac{I_h(RMS)}{I_1(RMS)} \times 100\% \quad \text{or} \quad \frac{V_h(RMS)}{V_1(RMS)} \times 100\%$$

K. Total Harmonic Distortion (THD)

Total harmonic distortion is used to quantify the total magnitude of harmonics present in the power system voltage waveform. It is expressed as a percent of the fundamental voltage and is defined as:

$$THD = \sqrt{\frac{Sum\ of\ Squares\ of\ Amplitude\ of\ all\ Harmonic\ Voltages}{Square\ of\ Amplitude\ of\ Fundamental\ Voltage}} \times 100\%$$

or

$$THD = \frac{\sqrt{Sum\ of\ Squares\ of\ RMS\ Value\ of\ all\ Harmonic\ Voltages}}{RMS\ Value\ of\ Fundamental\ Voltage} \times 100\%$$

Harmonics from 2 through 50 times fundamental frequency are normally considered.

L. Total Demand Distortion (TDD)

Total demand distortion is used to quantify the total magnitude of harmonics present in the power system current waveform. It is expressed as a percent of the fundamental frequency maximum demand load current (15 or 30 minute demand interval) and is defined as:

$$TDD = \frac{\sqrt{Sum\ of\ Squares\ of\ RMS\ Value\ of\ all\ Harmonic\ Currents}}{RMS\ Value\ of\ Fundamental\ Frequency\ Maximum\ Demand} \times 100\%$$

Harmonics from 2 through 50 times fundamental frequency are normally considered.

Causes

In a power system, harmonic distortion is caused by non-linear elements in circuits. Non-linear elements are characterized by a relationship in which voltage is not proportional to current. This relationship results in a waveform that becomes non-sinusoidal and thereby generates harmonics on the system.

In the power system, this non-linear load can be represented as a load to the 60 Hz (fundamental) component of current and as a source of current for the harmonic current components. These harmonic currents, generated at the non-linear load, flow toward the source of the fundamental through the paths of least resistance. The voltage distortion experienced by the fundamental is a function of the voltage drops in components of the power system at the harmonic frequencies as these harmonics flow through the power system.

In a power system almost all of the series impedances are linear. These impedances consist of lines, cables, and transformers. Nonlinear elements are normally connected in shunt with the power system. Transformers are a special case because they have both linear and nonlinear characteristics. The short circuit impedance (series impedance) is linear whereas the magnetizing impedance which is a shunt impedance is non-linear. Generators also produce harmonics but they are generally negligible. For the most part, harmonic production on a utility power system comes from loads connected to the system or specialized switching equipment. This specialized equipment can be Static Var Compensation (SVC) or High Voltage Direct Current (HVDC) line terminals.

There are three major classes of equipment that inject harmonics into the power system:

- Ferromagnetic Devices
- Electronic Power Converters
- Arcing Devices

Ferromagnetic Devices are most commonly represented by transformer and motors connected to the power system. A motor's magnetic characteristic is generally linear because of the air gap in the motor. A transformer's magnetizing current characteristic is very non-linear which results in a third harmonic about 50% of the fundamental. Delta windings reduce the magnitude of the third and ninth harmonics injected into the system. The fifth and seventh harmonics then become prevalent. Since a transformer's excitation current is 0.5% to 1.0% of the rated load current, harmonic injection contributions from transformers are generally not a problem. However, because of the large number of transformers on a power system, harmonic current injections can become significant. As applied voltage increases, such as during light load periods, saturation also increases thereby further contributing to harmonic current injection.

Electronic Power Converters can include rectifiers, inverters, adjustable speed motor drives, and light dimmers. Most of these types of equipment are dependent on the power system waveform to turn the thyristors or diodes in these devices off after they begin conducting. This is referred to as line commutation. The total harmonic distortion in the current waveform of line commutation devices is typically 10% to 30% of the load current. Devices that are force commutated switch the flow of current on or off at will. These devices can be designed to generate waveforms that do not contain problem harmonics.

The most common electronic power converters are single phase, fullwave rectifiers typically found in appliances and computers. The dominance of a third harmonic, which can be as high as 50% of the fundamental load current, has been documented by relating television viewing times to primary feeder voltage distortion.

Arcing devices include fluorescent lighting, sodium and mercury vapor lighting, electric arc furnaces, and electric arc welders. All these devices generate similar harmonic current injections. Electric arc furnaces have created the most harmonic problems because of the magnitude of the load that is concentrated at one point on the power system. Lighting presents a greater load but because the load is spread out across the system, the impact of the harmonics generated is reduced.[7]

Balanced three phase devices generally eliminate the third and ninth harmonics. This does not apply to arc furnaces since during scrap meltdown, the load is extremely erratic and unbalanced. Even harmonics are also found in electric arc furnaces due to erratic arcing that results in unequal conduction of current during positive and negative half cycles.

Effects

The effects of harmonics producing loads on Atlantic City Electric & Delmarva Power equipment and on other Atlantic City Electric & Delmarva Power customers are greatly dependent on the system characteristics. The fact that a load has a distorted current waveform is not a definite indication that there will be an adverse impact to either the power system or other power consumers. Power systems are capable of absorbing considerable harmonic currents without noticeable problems. Many of the problems have involved resonance resulting from the size and location of a nearby capacitor bank. Harmonic resonance can amplify voltage distortion and cause capacitor bank failure. Harmonic distortion can result in watt-hour meter error and cause interference in communication circuits.[7] In the case of watt-hour meters, the error is generally slight. When considering the effects of a harmonic producing load on other utility customers, the voltage distortion is the primary concern. The presence of a significant harmonic current does not mean that there will be significant voltage distortion. If the source impedance is low, the voltage distortion will be low and the other customers will be unaffected.

Most commonly, electronic equipment produces 3rd, 5th and 7th harmonic currents. When sufficient levels of these currents are present, adverse effects such as nuisance circuit breaker tripping, transformer and neutral conductor overheating, and capacitor fuse operations can be experienced. These symptoms typically occur on the customer's low voltage system before they effect the utility distribution system.

Although the harmonic currents do not directly affect other power consumers if the voltage distortion is low, they may have detrimental effects on other power system elements such as generators and transformers. Also, harmonic currents may be coupled to other electrical circuits such as communications that are in parallel with the power circuits. A power system may incur increased losses in transformers and generators. If the harmonic content is high enough, hot spots may develop which can result in insulation failure. Generally, current distortion seen by substation transformers and generators is small in relation to the total power system load which is linear or non-harmonic producing.

However, if the use of electric power converters continues to increase, such as adjustable speed motor drives for residential heat pumps, this may not be the case sometime in the future.

Recommendations

Atlantic City Electric & Delmarva Power should use IEEE Standard 519, "Recommended Practices and Requirements for Harmonic Control in Electric Power Systems" as a guide for controlling harmonics in the electrical system and as a reference for solving problems that may arise in terms of objectionable harmonics encountered in the system.

This industry standard describes the quality of electrical power that a utility should furnish the consumer in regard to harmonic distortion of the voltage waveform. It also describes the harmonic current injection limits that should apply to individual consumers of electrical energy. These recommendations were established with the goal of minimizing harmonic interference problems among both the utility and customer systems.

IEEE 519 refers to the Point of Common Coupling (PCC) as the point at which the customer interfaces with the utility and other users. This may be a metering point or point of service.

Table III shows the harmonic voltage limits that are recommended at the PCC defining the quality of voltage to be delivered to the customer by Atlantic City Electric & Delmarva Power.

Table III Harmonic Voltage Distortion Limits

Bus Voltage at PCC	Individual Harmonic Voltage Distortion (%)	Total Voltage Distortion THD (%)
Below 69 kV	3.0	5.0
69kV to 138 kV	1.5	2.5
138 kV and above	1.0	1.5

Note: High voltage systems can have up to 2.0% THD where the cause is an HVDC terminal that will attenuate by the time it is tapped for a user.

Tables IV, V, and VI show the harmonic current limits that are recommended to be the maximum harmonic current injections permitted into the Atlantic City Electric & Delmarva Power system at the PCC by a customer.

For shorter periods of time (less than one hour), during startups or unusual conditions, the limits may be exceeded by 50%.

The harmonic current limits are based on the size of the load with respect to the size of the power system to which the load is connected. The ratio I_{SC}/I_L is the ratio of the short circuit current available at the point of common coupling (PCC), to the maximum fundamental load current. It is recommended that the load current I_L be calculated as the average current of the maximum demand for the preceding twelve months. Thus as the size of the user load decreases with respect to the size of the system, the larger is the percentage of harmonic current the user is allowed to inject into the utility system. This protects other users on the same feeder as well as the utility which is required to furnish a certain quality of power to its customers.

Table IV. Harmonic Current Limits for Systems 120 Volts Through 69 kV

Maximum Harmonic Current Distortion in % Fundamental						
Harmonic Order (Odd Harmonics)						
I_{SC}/I_L	<11	$11\le h<17$	$17\le h<23$	$23\le h35$	$35\le h$	TDD
<20*	4.0	2.0	1.5	0.6	0.3	5.0
20<50	7.0	3.5	2.5	1.0	0.5	8.0
50<100	10.0	4.5	4.0	1.5	0.7	12.0
100<1000	12.0	5.5	5.0	2.0	1.0	15.0
>1000	15.0	7.0	6.0	2.5	1.4	20.0

Even harmonics are limited to 25% of the odd harmonic limits above.
Current distortions that result in a direct current offset, e.g., half wave converters are not allowed.
*All power generation equipment is limited to these values of current distortion regardless of actual I_{SC}/I_L.
Where I_{SC} = Maximum short circuit current at PCC
and I_L = Maximum demand load current (fundamental frequency) at PCC

Table V. Harmonic Current Limits for Systems 69 kV Through 161 kV

Maximum Harmonic Current Distortion in % Fundamental						
Harmonic Order (Odd Harmonics)						
I_{SC}/I_L	<11	11≤h<17	17≤h<23	23≤h35	35≤h	TDD
<20*	2.0	1.0	0.75	0.3	0.15	2.5
20<50	3.5	1.75	1.25	0.5	0.25	4.0
50<100	5.0	2.25	2.0	0.75	0.35	6.0
100<1000	6.0	2.75	2.5	1.0	0.5	7.5
>1000	7.5	3.5	3.0	1.25	0.7	10.0

Even harmonics are limited to 25% of the odd harmonic limits above.
*All power generation equipment is limited to these values of current distortion regardless of actual I_{SC}/I_L.
Where I_{SC} = Maximum short circuit current at PCC
and I_L = Maximum demand load current (fundamental frequency) at PCC

Table VI. Harmonic Current Limits for Systems above 161 kV and Privately Owned Generation at any Voltage Level

Maximum Harmonic Current Distortion in % Fundamental						
Harmonic Order (Odd Harmonics)						
I_{SC}/I_L	<11	11≤h<17	17≤h<23	23≤h35	35≤h	TDD
<50	2.0	1.0	0.75	0.3	0.15	2.5
□50	3.0	1.5	1.15	0.45	0.22	3.75

Even harmonics are limited to 25% of the odd harmonic limits above.

If the above recommended limits are exceeded or specific harmonic problems arise certain measures should be undertaken to identify and correct such occurrences. These measures may include:

- Performing harmonic measurements at selected points within the utility system including PCC's and attempt to determine sources of harmonic current injection. If the defined limits identified in this guideline are exceeded, then such measures as necessary should be taken to assure compliance (i.e., installing filters, static var compensators, reducing harmonic generation sources, etc.).
- Modifying the source impedance to allow the system to absorb more harmonics.
- Isolating the harmonic load on separate supply circuits.

PHASE VOLTAGE UNBALANCE IN THREE PHASE SYSTEMS

Definition

Several methods have been proposed to quantify the amount of phase voltage unbalance of a polyphase system, however the most generally accepted definition as presented by ANSI [9] & NEMA [10] is:

$$\%Voltage\ Unbalance = \frac{(Max\ Deviation\ from\ Avg\ Voltage)}{(Average\ Voltage)} \times 100$$

Example: With phase-to-phase voltages of 230 v, 232 v, and 225 v, the average is 229 v: the maximum deviation from average is 4 v; and the percentage unbalance is 100 x 4/229 = 1.75%.

This simplified method of calculation avoids the need to calculate actual negative sequence voltages or currents, which are the major cause of motor over-heating resulting from phase unbalance. (See Effect of Phase Voltage Unbalance)

Studies have demonstrated that for all practical purposes the magnitude of unbalance voltage in percent, calculated from the equation above, and the actual negative sequence voltage in percent, are essentially equal.

Causes

Certain events such as system faults, blown fuses, and open conductors can cause severe unbalance conditions to exist on the power system. These occurrences are considered abnormal and are beyond the control of the electric utility. However, continuous levels of unbalance caused by the diversity of single phase load on the three phase system can and must be controlled so as to ensure proper operation of connected equipment.

"Most utilities use four wire grounded wye primary distribution systems so that single phase distribution transformers can be connected phase to neutral to supply single phase load such as residences and street lights. Variations in single phase loading cause the currents in the three phase conductors to be different, producing different voltage drops and causing the phase voltages to become unbalanced. Normally the maximum phase voltage unbalance will occur at the end of the primary distribution system, but the actual amount will depend on how well the single phase loads are balanced between the phases on the system.

Perfect balance can never be maintained because the loads are continually changing, causing the phase voltage unbalance to vary continually."[12]

Effects

M. Phase Voltage Unbalance

Phase voltage unbalance can affect the operation of various types of electrical equipment, however, the most prevalent being polyphase induction motors.

Performance of polyphase induction motors under unbalanced voltage conditions is discussed in NEMA MG 1-1993:

"When the line voltages applied to a polyphase induction motor are not equal, unbalanced currents in the stator windings will result. A small percentage voltage unbalance will result in a much larger percentage current unbalance. Consequently, the temperature rise of the motor operating at a particular load and percentage voltage unbalance will be greater than for the motor operating under the same conditions with balanced voltages.

The effect of unbalanced voltages on polyphase induction motors is equivalent to the introduction of negative sequence voltage having a rotation opposite to that occurring with balanced voltages. This negative sequence voltage produces in the air gap a flux rotating against the rotation of the rotor, tending to produce high currents. A small negative sequence voltage may produce in the windings currents considerably in excess of those present under balanced voltage conditions.

The locked-rotor torque and breakdown torque are decreased when the voltage is unbalanced. If the voltage unbalance should be extremely severe, the torques might not be adequate for the application.

The full-load speed is reduced slightly when the motor operates at unbalanced voltages.

The locked-rotor current will be unbalanced to the same degree that the voltages are unbalanced but the locked-rotor kVA will increase only slightly.

The currents at normal operating speed with unbalanced voltages will be greatly unbalanced in the order of approximately 6 to 10 times the voltage unbalance."[10]

The rated load capability of polyphase equipment is normally reduced by voltage unbalance. A common example is the derating factor, shown in Fig. 8.1 in tabular form, used in the application of polyphase induction motors to reduce the possibility of damage due to over-heating. (See Section 14.35 of NEMA MG1-1993 for more complete information.)

	Percent Voltage Unbalance										
	0.0%	0.5%	1.0%	1.5%	2.0%	2.5%	3.0%	3.5%	4.0%	4.5%	5.0%
Derating Factor	1.00	0.99	0.98	0.97	0.96	0.93	0.90	0.87	0.84	0.79	0.76

Figure 8.1 Derating Factor

Other equipment, including such electronic devices as computers may also be affected by phase voltage unbalance. Individual equipment manufacturers should be consulted for necessary information regarding performance under unbalance conditions.[12]

N. Phase Current Unbalance

By restricting voltage unbalance, the Atlantic City Electric & Delmarva Power supply system can be held to a quantifiable level of service voltage quality which can be expected by its customers. Although not a quality of service issue, current unbalance must also be controlled due to its detrimental effects on rotating equipment.

Of particular interest when discussing phase current unbalance in polyphase systems is the effect of such a condition on generators. An unbalanced system can be represented by balanced positive, negative, and zero phase sequence components. It is the negative phase sequence current which has a detrimental effect on the rotating equipment.

"The negative sequence current (I_2) flows in the stator windings producing a magnetic flux that has the same rotational speed as the rotor flux but in the opposite direction. This flux is cut by the rotor at twice the rotational speed, and induces rotor currents at double the system frequency. These high frequency eddy currents flow in the rotor surface iron, brass slot wedges and retaining rings resulting in the heating of the rotor surface.

The effect of this heating is dependent on the negative sequence current and the duration of exposure. Sustained high levels of negative sequence current can soften brass slot wedges to the point of being extruded by centrifugal force until they stand out from the rotor and strike the stator. Less severe heating reduces the generators useful life by accelerating the deterioration of the insulation."[13]

ANSI C50.12-1982, C50.13-1989, and C50.14-1977 specify the required I_2 ratings for various types of generators. The short-term rating, generally expressed as $(I_2)^2t$, is of concern when considering the effects of faults on the generator. The protection of generators for excessive I_2 created by the unbalance due to faults is provided by applying appropriate relays in the generator protective relay schemes.

ANSI C50.13-1989 states: "A generator shall be capable of withstanding without injury the effects of a continuous current unbalance corresponding to a negative phase sequence current of the following values, providing the rated kVA is not exceeded and the maximum current does not exceed 105 percent of rated current in any phase."[14] Negative phase sequence current is expressed as a percentage of rated stator current.

Type of Generator	Permissible I_2 (Percent)
Cylindrical rotor generators[14]	
Indirectly cooled	10
Directly Cooled to 960 MVA	8
961 to 1200 MVA	6
1201 to 1500 MVA	5
Salient pole synchronous generators and generator/motors for hydraulic turbine applications[16]	
Machines with connected amortisseur windings	10

*Machines with non-connected amortisseur windings	5

*It should be noted that continuous performance with non-connected amortisseur windings is not readily predictable. Therefore, if unbalanced conditions are anticipated, machines with connected amortisseur windings should be utilized.

Recommendations

Consistent with ANSI C84.1-1989, Atlantic City Electric & Delmarva Power shall design and operate its system to limit the maximum steady state voltage unbalance to 3% at our delivery point under no load conditions. Expectations are that the customer's load must be reasonably well balanced resulting in no appreciable voltage unbalance increase under full load. In some cases, restrictions may be imposed on the connection of "large" single phase loads which would cause the voltage unbalance of the supply system to exceed 3% or which would cause the negative sequence current of any interconnected generator to exceed 10% of its rated stator current. When voltage unbalances in excess of 3% are found, local load balance shall be measured to determine the cause. Under specific conditions, the following actions will be taken.

- If local loads are reasonably balanced, Atlantic City Electric & Delmarva Power will analyze its system to determine the cause and correct it.
- If an unbalanced customer load is the cause, but the resulting condition only affects that one customer, Atlantic City Electric & Delmarva Power will notify the customer of the condition and recommend corrective action.
- If the load unbalance of one customer affects the voltage of other customers adversely, Atlantic City Electric & Delmarva Power will require that the customer correct the problem.

It is the customer's responsibility to install appropriate unbalance limit controls to protect their equipment from open phase conditions or other severe voltage or current unbalance conditions which may be hazardous to their equipment.

Power Quality Procedures

District Engineering Receives Customer Complaint

The customer complaint may come into District Engineering from a variety of sources – Call Center, Marketing, Consultant, Customer, etc.

Initial Investigation

District Engineering promptly contacts the customer to determine the nature of the complaint. If the customer's concern requires further investigation as a power quality issue, then a Power Quality Questionnaire should be completed. This may be completed over the phone if the customer has the time or mailed out to the customer for completion.

The timing and priority of the response shall depend upon the nature of the complaint made, the alleged effect of the power quality issue or the customer's service, whether any safety issues have been raised or known by the Company, and the engineering judgement of the District Engineering personnel assigned to handle the complaint.

For large power accounts, the major accounts representative should be kept informed of the situation.

For radio or TV interference, contact the appropriate Electrical Maintenance Group to investigate the situation.

Power Quality Questionnaire

The questionnaire is a useful tool in assessing the customer's concern. It should be filled out as completely as possible. The Case Number is intended to be unique to each District. The number should include the District Name, the year and the case number. For example: The 12th customer inquiry in 1999 for the Winslow District would have a case number of Winslow - 99 – 12. Each District should keep a log of all questionnaires completed. The questionnaires and resulting investigation data could be used as a basis for future system improvement projects.

Develop Investigation Plan

The plan for conducting a power quality investigation should be well thought out and provide an outline for conducting the investigation. The

plan should be flexible and allow for change as new data and information is gathered during the inspection and monitoring portions of the survey. The plan also serves to gain commitment for both personnel and equipment. It is a plan as to what is to be done, when, and by whom, equipment and resource requirements, and expected results.
The scope of activities should determine if power quality monitoring equipment is needed and, if so, what should be monitored. In developing the scope of activities, it may be necessary to preview the site prior to completing the plan.

Support or Assistance

If support or assistance is needed, contact Distribution Design, System Protection, Distribution Assets, or a Power Quality Contractor.

Investigate and Determine Source of Problem

The investigation typically is composed of several activities. A visual and physical inspection of our equipment and the customer's equipment is required. When on the customer's premises use extreme caution around the customer's equipment, having the customer or the customer's electrician remove panel covers and other access panels. Install monitoring equipment as appropriate.

Submit Report to Customer with Recommended Solution

Prepare a detailed report in conjunction with the involved PQ specialist noting the nature of the customer's concern, results of the investigation, and the recommended solution. The recommended solution should be clear as to what Atlantic City Electric & Delmarva Power and the customer should do to resolve the problem. Present the report to the customer after the District Supervisor of Planning & Design approves and signs the report.

After customer agrees with the work needed, issue work order to complete the required work to Atlantic City Electric & Delmarva Power's plant. Determine when the customer might complete any necessary work to their equipment.

Follow-up with the customer(s) after the recommended work is complete to see if the customer is now satisfied.

Appendix A

From ANSI/IEEE STD 446-1995

Short Duration Disturbances

Most disturbances on a power system are of short duration. Studies show that 90% are less than one second. Voltage disturbances of more than one cycle duration are usually expressed in rms values. Those of less than one cycle are expressed in terms of the fundamental peak value.

Less Than 1 Cycle – Transient

Transients result from disturbance of all kinds. The most severe subcycle disturbances are natural lightning, electrostatic discharge, load switch, and short-duration faults.

Half Cycle to a Few Seconds – Swell or Sag

Swells (increased voltage) or sags (decreased voltage) usually result from faults on the system with subsequent fuse or high speed circuit breaker action and reclosing. On the loaded phases this results in a sag, on the unloaded phases the result may be a swell.

More Than a Few Seconds – Overvoltage or Undervoltage

Overvoltage and undervoltage, usually attributed to severe faults accompanied by 50-100% voltage loss on one or more phases, often result in an outage in some circuit. Faults often involve all three phases and may be the result of a downed pole, a tree, or a crane on the line, a breaker lockout, or an in-line fuse blowing. If the critical load is on the cleared side of the fuse, the disturbance becomes an outage. If it is on the power source side of the fault clearing device, the normal voltage may be restored.

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Power Quality Questionnaire

Case ____________________

Date: ____________________

ACE/DPL Representative: ____________________ Phone: ____________________

Customer: ____________________ Account #: ____________________

Company: ____________________ Res. / Comm. / Ind.

Address: ____________________

City: ____________________ State: __________ Zip Code: ____________________

Contact: ____________________ Phone: ____________________

Contact: ____________________ Phone: ____________________

Site Description: ____________________ Age of Site: ____________________

Transformer Size: ______________ kVA Voltage: ____________________ POLE / PAD

Transformer Coordinate Number: ______________ / ______________ Circuit Number: ____________________

Service Size: ____________________ Length: ______________
feet

1. Description of Problem (include dates & times; Equipment affected)

____

____

2. Trouble / Serviceman been to site? Yes / No Work Order / TT#: ____________________
Remarks:

____

____

3. Why does the customer think the disruption is due to power disturbances?

____Operator error ruled out or not considered likely
____Equipment failure for non-power reasons ruled out
____Wiring / ground verification completed
_____Surge / transient protection survey completed
_____Power monitoring data available from customer
_____Customer / consultant investigated problem

____Other: ____________________

4. What are the symptoms of the problem?

____Lights off or blinking
____Loss of power for extended periods
____Known harmonic or phone problems
____System lock-ups or random computer re-boots
____Stops or unready lamps lit
____Machine resets

Line recloser before customer: Yes / No
Recent outages: Yes / No
Capacitor bank on feeder Yes / No
____Errors / Data loss
____Inconsistent results
____Electronic equipment problems

____Other: ____________________

5. Has there been equipment or product damage? Yes / No

____Circuit breakers tripped
____Transformers overheated
____Arcing or evidence of flashover
____Circuit breakers overheated
____Charred insulation or burned areas
____Other: ____________________

6. Frequency and duration. (Enter a number next to one of the following):

______per day ______per month ______per quarter ______per year

7. How long are operations disrupted during a typical occurrence?________________________

8. Does the problem occur at a specific time of day or work shift? Yes / No
If Yes, specify when and with what regularity, including other activities with which the problem correlates:

____

____

____

9. Is the problem associated with any unusual weather conditions? Yes/ No

____

____

10. Have any of the following been done on the system (unrelated to the problem) by contractors or the customer's facility engineers?

____New work
____Changes
____Additions

Describe:____

____

11. What has the customer done towards solving the problem?

____Hired a consultant
____Conducted a wiring/grounding verification
____Installed wiring/grounding retrofit
____Installed power conditioning equipment
____Hired an electrical contractor
____Monitored power
____Installed surge/transient protection retrofit

Other:____

____

12. Other relevant information:

____

____

____

Is a Power Quality Investigation recommended? Yes / No

Record recommendations made to customer and/or company action taken:________________

____

____

____

____

Completed By:____ Date:____________________

Power Quality Plan of Action

Physical Inspection — Safety Always - Wear Your Personal Protective Equipment

1. Tour the plant examining all electrical equipment.
2. Determine how the equipment is electrically connected / fed.
3. Determine exactly what equipment is affected.
4. Determine how the affected equipment is electrically connected / fed.

   - ❑ Straight feed from the panel board.
   - ❑ Feed from electronic device (Example: Motor frequency drives)
   - ❑ Determine what other equipment is fed by same internal circuit.
   - ❑ Nominal service voltage
   - ❑ Equipment utilization voltage rating.

5. Check electrical conduits for mechanical connection and excessive warmth.

6. Inspect all associated electrical panelboards and record the following information and measurements:

   Location: ____________________

   Panelboard Number: ____________________

   Manufacturer & Model Number: ____________________

   Type / Rating: ____________________

   Pole Positions: ____________________

   Phase Amperage: ____________________

   Neutral Amperage: ____________________

   Ground Bus: ____________________

   Isolated Ground Bus: ____________________

   Voltage Measurements

A – N ________	A – B ________	A – G ________
B – N ________	B – C ________	B – G ________
C – N ________	C – A ________	C – G ________
		N – G ________

   Does any phase voltage vary 5% or more? * Yes _____ No _____

   Does any phase to neutral voltage vary more than 2% from phase to ground voltages? ** Yes _____ No _____

   Does neutral to ground voltage exceed 2 volts? *** Yes _____ No _____

   Current Measurements

A ____________ B ____________ C ____________

N ____________ G ____________

Is the current for any conductor 80% or greater than the amperage rating of the wire or circuit breaker? Yes ______ No ______

Which wire or breaker position? (Note & mark for repair)

1 ____________	4 ____________	7 ____________	10 ____________
2 ____________	5 ____________	8 ____________	11 ____________
3 ____________	6 ____________	9 ____________	12 ____________

Are any ground currents excessive? Yes ______ No ______
Which wires? (Note & mark for repair)

1 ____________	4 ____________	7 ____________	10 ____________
2 ____________	5 ____________	8 ____________	11 ____________
3 ____________	6 ____________	9 ____________	12 ____________

Does the IR drop across any breaker exceed 0.1 volt? Yes ______ No ______

Does the temperature of any breaker exceed 40^0 C? Yes ______ No ______
Which breaker position? (Note & mark for repair)

1 ____________	4 ____________	7 ____________	10 ____________
2 ____________	5 ____________	8 ____________	11 ____________
3 ____________	6 ____________	9 ____________	12 ____________

Comments: ____

____

____

____

____

* Check cause of voltage variation
** Check transformer grounding and neutral
*** Check transformer neutral to ground bond

7. Inspect all transformers and record the following information and measurements.

Location ____

Transformer ______________________________

Manufacturer ______________________________

Impedance ______________________________

Type ______________________________

kVA ______________________________

Voltage ______________________________

Voltage Measurements

H1-G ________	X1-N ________	X1-X2 ________
H2-G ________	X2-N ________	X2-X3 ________
H3-G ________	X3-N ________	X3-X1 ________
	X1-G ________	X0-N ________
	X2-G ________	N0-G ________
	X3-G ________	

Does any phase voltage vary 5% or more? * Yes ______ No ______

Does any phase to neutral voltage vary more Than 2% from phase to ground voltages? ** Yes ______ No ______

Does neutral to ground exceed 0.2 volts? *** Yes ______ No ______

Current Measurements

H1 ______________	N ______________
H2 ______________	G ______________
H3 ______________	X0 ______________
X1 ______________	X0 To Building ______________
X2 ______________	X0 To Enclosure ______________
X3 ______________	

Observations

Does X0 to enclosure current exceed 2 amperes? Yes ______ No ______
(Larger current levels can mean wiring errors)

Does X0 current equal neutral current? Yes ______ No ______
(X0 current larger than neutral means wiring errors)

Is X0 reference a conductor? Yes _______ No _______
(Wire conductors are preferred)

Is safety ground conductor parity to phase conductors? Yes _______ No _______
(Parity conductor sizing is preferred)

Is safety ground parallel in power feeders? Yes _______ No _______
(NEC recommends symmetrical power feeders)

Comments: ____

____

____

* Check cause of voltage variation
** Check transformer grounding
*** Check transformer neutral to ground bond

8. Inspect service entrance and record the following information and measurements:

Location: ______________________________

Panelboard Number: ______________________________

Manufacturer & Model Number: ______________________________

Type / Rating: ______________________________

Pole Positions: ______________________________

Phase Amperage: ______________________________

Neutral Amperage: ______________________________

Ground Bus: ______________________________

Isolated Ground Bus: ______________________________

Voltage Measurements

A – N ____________	A – B ____________	A – G ____________
B – N ____________	B – C ____________	B – G ____________
C – N ____________	C – A ____________	C – G ____________
		N – G ____________

Does any phase voltage vary 5% or more? * Yes _______ No _______

Does any phase to neutral voltage vary more than 2% from phase to ground voltages? ** Yes _______ No _______

Does any neutral to ground voltage exceed 0.2 volts? *** Yes _______ No _______

Current Measurement

A ______________ B ______________ C ______________

N ______________ G ______________

Is the current for any conductor 80% or greater than the amperage rating of the wire or circuit breaker? Yes ______ No ______

Which wire or breaker position? (Note & mark for repair)

1 ____________________ 3 ____________________ 5 ____________________

2 ____________________ 4 ____________________ 6 ____________________

Is the current in any service grounding connections excessive? Yes ______ No ______

Which wires? (Note & mark for repair)

Earth electrode ______________________ Water pipe ______________________

Building steel ______________________ Neutral to Ground Bond**** ______________

Is current in any feeder grounding conductor excessive? Yes ______ No ______

Which wire or breaker position? (Note & mark for repair)
1 ____________________ 3 ____________________ 5 ____________________

2 ____________________ 4 ____________________ 6 ____________________

Comments: ____

____

____

*	Check cause of voltage variation
**	Check transformer grounding
***	Check the water meter for bond and for bypass jumper
****	Large amounts of current indicates either a wiring error or a parallel bond in the supply transformer

II Power Monitoring

If the data gathered during the physical inspection indicates that power monitoring is needed then the monitoring will be executed as follows:

1. Outside of the Facility

- ☐ Look for construction, facility damage, power lines, the type of load, equipment being used around the exterior, etc.

- ❑ Listen for arcing or other noises (possibly at the utility transformer).
- ❑ Smell the air for anything out of the ordinary (burning, arcing).

2. Inside the Facility

- ❑ Look for construction, facility damage, the type of load equipment being used within the facility, etc.
- ❑ Listen for noises out of the ordinary.
- ❑ Smell the air for anything out of the ordinary (burning, arcing).

3. Check the Appropriate Panel Boards and Receptacles – BE SAFE

- ❑ Look for physical damage, improper wiring, signs of wear, etc.
- ❑ Listen for arcing or other noises.
- ❑ Smell for burnt insulation or other odors.
- ❑ Feel the panels and so forth for signs of overheating.
- ❑ Measure the voltage and current in the conductors.

4. Decide on the Monitoring Location

- ❑ At the malfunctioning equipment
- ❑ At the power source – service entrance or transformer.
- ❑ At the panel or corrective device output.

5. Decide on your Monitoring Plan

- ❑ How long will you monitor (1 day, 1 week, 1 month, etc.)?
- ❑ How often will you collect data from the monitor?
- ❑ What are the appropriate thresholds?
- ❑ Will you need to change thresholds of monitoring locations?

6. Set Up and Install Monitoring Equipment

- ❑ Synchronize the unit(s) with the Customer's failure log clock.
- ❑ Properly setup full configuration (use the same if using more than one unit).

7. Once you have Completed Your Monitoring Plan

- ❑ Review the data you have collected.
- ❑ Categorize the disturbances according to type, duration, magnitude, and whether it caused a failure or not.
- ❑ Report on the data.

8. Help Decide the Corrective Action and Plan

- ❑ Will rewiring be required?
- ❑ Should a corrective device be added or removed?
- ❑ Must the Customer move the failing device or source?
- ❑ Doe the Customer want your involvement in the corrective action or is corrective action even required?

9. Monitor after the Corrective Action was Done

- ❑ To verify the action taken was appropriate.

- To see if there is more than one problem.
- To finalize the monitoring process.

Important Notes - Keep These Points in Mind

- Most problems are simple and can be solved without sophisticated monitoring.
- What you are monitoring will always be affected by the monitoring equipment - therefore, minimize your impact. (Ground loops, etc.)
- A picture, literally, can be worth a thousand words.
- Verifying that an issue is not a problem is just as valid as showing it.
- A monitoring device is only as good as the experience and knowledge of the user.
- Problems usually exist like layers of an onion - peel away one layer and there may be another underneath.

- Be extra careful while in the customer's facility. Follow all of the customer's safety rules as well as all of Atlantic City Electric & Delmarva Power's safety rules. Some of these guidelines call for opening panels and switchgear, if you are not qualified , trained, or do not feel comfortable to do so, then do not perform the action. Ask the customer to do it if it is their equipment or request assistance from a qualified Atlantic City Electric & Delmarva Power employee. Your personal safety and the safety of those on site with you must always have the highest priority.

Interpretation of Monitoring Data: Some Rules of Thumb

In General,

- Impulses have a faster rise time the closer you are to the source.
- No "pure" load exists, rather it is some combination of those listed below.

Capacitive Components

- Disturbances generally occur near the peak of the sine wave, opposite in wave directions, as they take energy out.
- They typically have a "ringing" characteristic.
- Power supplies, single phase capacitive start motors and power factor correction capacitors switched on can cause these types of disturbances.
- An instantaneous upward or downward sustained voltage change can usually relate to capacitor switching.

Inductive Components

- Disturbances generally occur near the zero crossing of the sine wave as thy try to add energy back into the line.
- Typically, contact arcing is evident when disturbances occur.
- Motors being switched off can cause these types of disturbances.

Resistive Components

- Disturbances generally occur near the peak of the sine wave, opposite in wave direction, as they take energy out.
- Similar to capacitive disturbances, but they do not have a "ringing" characteristic (unless reactive components exist on the line also).
- Incandescent lights and heaters switched on can cause these types of disturbances.

Voltage Recorders

- An arcing voltage can create little bursts or voltage spikes as it arcs.
- A bad or defective neutral connection can cause the voltage recording to appear like a mirror image because of a neutral shift. One leg will go up and another will go down at the same time by the same amount. For example, on a nominal 120/240 volt, 3 wire service; you might find a voltage recording of 112/128/240 volts, which could be a bad neutral connection.
- A motor starting can produce a large voltage dip. The voltage dip or flicker may impact the one customer or many customers.
- A highly resistive connection can cause excessive voltage drop on that phase as well as heating up the connection.