nationalgrid

Jennifer Brooks Hutchinson
Senior Counsel

February 3, 2012

VIA HAND DELIVERY & ELECTRONIC MAIL

Luly E. Massaro, Clerk
Rhode Island Division of Public Utilities & Carriers
89 Jefferson Boulevard
Warwick, RI 02888

RE: Division Docket No. D-11-94
National Grid Hurricane Irene Response Assessment
Responses to Division Data Requests (Set 2)
Section I. Engineering & Design

Dear Ms. Massaro:

Enclosed are one original and five (5) copies of National Grid's[1] responses to the Division's Second Set of Data Requests concerning Section I. Engineering & Design.

Thank you for your attention to this transmittal. If you have any questions, please feel free to contact me at (401) 784-7288.

Very truly yours,

Jennifer Brooks Hutchinson

Enclosures

cc: Steve Scialabba, Division
Leo Wold, Esq.

[1] The Narragansett Electric Company d/b/a National Grid ("Company").

I. Engineering & Design

Division 2-1

Request:

Provide National Grid's failure analysis summarizing the cause of Rhode Island structure failures from Hurricane Irene.

Response:

National Grid experienced one transmission structure failure during Irene. Please refer to Attachments DIV 2-11-1 and DIV 2-11-2: I. Engineering and Design, for a discussion of that failure.

Prepared by or under the supervision of Mark Browne

I. Engineering & Design

Division 2-2

Request:

Refer to the picture shown on Page 3 in National Grid's Report on Tropical Storm Irene Preparedness Report. Discuss the details of the pole failure, restoration, and cause, since apparently the transmission pole pictured was broken with no obvious tree problems.

Response:

Please refer to Attachment DIV 2-11: I. Engineering and Design, for a discussion of the failure of the pole pictured.

Due to excessive wind speeds on Sunday, August 28, the day Irene impacted the region, the repair was made the following day on Monday, August 29. Standard repair techniques were used, including a crane, bucket trucks and qualified line workers. The broken pole was lifted off the line that was undamaged, the undamaged line was re-energized and the broken pole was replaced.

Prepared by or under the supervision of: Fred Raymond and Mark Browne

I. Engineering & Design

Division 2-3

Request:

Provide a copy of all pole and line strength calculations for the transmission structure that failed.

Response:

National Grid does not possess original design documents for the structure that failed. For an analysis showing compliance of this structure with the original design code, please refer to Attachment DIV 2-11: I. Engineering and Design.

Prepared by or under the supervision of: Mark Browne

I. Engineering & Design

Division 2-4

Request:

Discuss the pole line engineering design criteria and NESC factors, such as wind loading, gust factor, factor of safety, and loading district, that National Grid uses to design and construct transmission facilities since 45 to 55 mph winds should never result in transmission structure failures from wind alone. Include in the explanation what edition of the NESC was used for the line design.

Response:

The Company utilizes the *National Electrical Safety Code* ("NESC") engineering design criteria and factors to design and construct its transmission facilities. The 2012 NESC engineering design criteria and factors are as follows:

- Rule 250B – Combined Ice and Wind District Loading
  - Structures are designed to withstand the load resulting from a ½" thick coating of ice on all wires concurrent with a 4 psf (40 mph) wind.
  - Gust Factors
    - There are no gust factors for this case
  - Factors of Safety
    - Loads resulting from wind are increased by 150%
    - Loads resulting from wire tension are increased by 65%
    - Loads resulting from material weight are increased by 50%
    - Design wood pole strength is reduced by 35%
    - Design guy wire strength is reduced by 10%
- Rule 250C – Extreme Wind Loading
  - Structures are designed to withstand the load resulting from a design 3-second gust wind speed as given in ASCE 7-05 "Minimum Design Loads for Buildings and Other Structures". In the State of Rhode Island, this varies from 100 mph to 120 mph depending upon proximity to the coast.

Division 2-4 (continued, p2)

- Gust Factors
    - Design wind pressure is multiplied by the velocity pressure coefficient k_z, a function of height above grade, in the range of 0.85 to 2.01.
    - Design wind pressure is multiplied by the gust response factor G_{RF}, a function of height above grade and span length, in the range of 0.63 to 1.02
- Factors of Safety
    - Design wood pole strength is reduced by 25%
    - Design guy wire strength is reduced by 10%

- Rule 250D – Extreme Ice with Concurrent Wind Loading
    - Structures are designed to withstand the load resulting from a 50-year recurrence interval uniform ice thickness with concurrent 3-second wind gust. In the State of Rhode Island, this requires design for a ¾” thick coating of ice concurrent with a 6.4 psf (50 mph) wind gust.
    - Gust Factors
        - There are no gust factors for this case
    - Factors of Safety
        - Design wood pole strength is reduced by 25%
        - Design guy wire strength is reduced by 10%

Based on available records, it appears the 1977 edition of the NESC was used for the design of the L14 Line. The 1977 criteria and factors are as follows:

- Rule 250B – Combined Ice and Wind District Loading
    - Structures are designed to withstand the load resulting from a ½” thick coating of ice on all wires concurrent with a 4 psf (40 mph) wind.
    - Gust Factors
        - There are no gust factors for this case

Division 2-4 (continued, p3)

- Factors of Safety
    - All loads are multiplied by an overload factor of 4.0

- Rule 250C – Extreme Wind Loading
    - Structures are designed to withstand the load resulting from a 50-year recurrence interval wind pressure. In the State of Rhode Island, this varies from 16 psf to 21 psf depending upon proximity to the coast.
    - Gust Factors
        - There are no gust factors for this case
    - Factors of Safety
        - There are no factors of safety for this case

Please refer to response provided in Division 2-11: I. Engineering and Design, for a discussion of the one transmission structure which failed during Irene.

Prepared by or under the supervision of: Mark Browne

I. Engineering & Design

Division 2-5

Request:

Does National Grid have a program to evaluate the performance of its transmission and sub-transmission line structures in Rhode Island under worst case wind/ice conditions?

Response:

National Grid designs its transmission and sub-transmission line structures in accordance with the requirements of the *National Electrical Safety Code* (NESC), which includes provisions to account for severe ice and wind conditions.

Prepared by or under the supervision of: Mark Browne

I. Engineering & Design

Division 2-6

Request:

Does National Grid have a transmission and sub-transmission inspection and maintenance program? If so, what is the inspection interval? Considering that the average pole age for National Grid is 36 years, does the program include any life cycle replacement considerations? Also, provide a copy of the latest inspection details for the line sections that failed during Irene in Rhode Island.

Response:

National Grid has an Inspection and Maintenance program for transmission and sub-transmission assets. The transmission program consists of helicopter visual patrols twice per year and an Infra-red patrol once per year. In addition, a ground based visual patrol is scheduled every five (5) years. The sub-transmission program consists of a helicopter visual patrol once per year.

National Grid does not replace assets based on a life-cycle, but rather, replacements are based on condition-based assessments of the inspectors or follow-up evaluations by the Transmission Line Engineering Department. Further, if inspection results indicate deterioration of the overall line, a refurbishment project will be initiated where all of the assets are evaluated for replacement.

There were no issues identified during the most recent sub-transmission aerial patrol on sections that failed during Hurricane Irene. Please note that inspection results are based on "exception reporting", that is, reports are only generated for identified issues.

There were no issues identified during the most recent transmission foot or aerial patrols on sections that failed during Hurricane Irene. Please note that inspection results are based on "exception reporting", that is, reports are only generated for identified issues.

Prepared by or under the supervision of: Peter Altenburger

I. Engineering & Design

Division 2-7

Request:

Does National Grid have any hardening programs for transmission or sub-transmission structures?

Response:

National Grid does not have a specific hardening program for transmission or sub-transmission structures. Instead, asset replacement and/or maintenance work is identified during periodic inspections as described in the Company's response to Division 2-6- I. Engineering & Design.

Prepared by or under the supervision of: Peter Altenburger

I. Engineering & Design

Division 2-8

Request:

For the State of Rhode Island, discuss the Engineering process and criteria for allowing third party attachers on poles, including which utility is responsible for the determination of "Make Ready" work and increased strength required based on greater pole loading?

Response:

Responsibility for identification of "Make Ready" work required to allow new third party attachments is a shared responsibility of the joint pole owners. National Grid uses a combination of internal and contracted resources to process third party pole applications. At a high level the engineering process involves an application, survey, engineering, and make ready estimate. The third party requesting access to National Grid's pole plant must submit an application detailing to which poles they want to attach and the type of equipment they are applying to install. A field survey is conducted, collecting current condition and physical data on the existing pole and span conditions. The collected data is used to engineer a scope of work required to allowing the third party to attach. The final output is a "Make Ready" scope of work and cost estimate for required modifications to National Grid's poles allowing the new attachment.

The engineering criteria used for allowing third party attachers access to our poles are in compliance with the NESC, National Grid Standards and Joint Ownership Agreements with Verizon. This requires a comprehensive review of the entire pole and in-span clearance requirements.

National Grid requires that pole loading be reviewed as part of a third party application. The review is conducted using a finite element computer program; National Grid recommends use of "OCalc" or "PLS Pole". In the event that the pole loading assessment conducted during data collection identifies poles that may have limited remaining load capacity or which may be currently overloaded, such poles are required to be addressed through replacement or further analysis by a registered professional engineer. Specifically, pole loading assessments use the NESC Heavy and any other applicable NESC loading criteria.

Prepared by or under the supervision of: Robert Brawley

I. Engineering & Design

Division 2-9

Request:

Refer to the pole failure shown in the picture contained in article ***National Grid Learns Lessons from Irene*** (The Providence Journal; Date: Dec 18, 2011. See attachment emailed with data request). The pole shows a large conductor laying on a crossarm detached from the insulators with the pole leaning significantly, the insulators appeared not to be broken and pins appeared not to be bent. Discuss the details of pole failure, restoration, and cause. How is the conductor tied onto an insulator to allow this to happen with only 55 mph winds? Has National Grid made a determination if the conductors breaking loose from insulators are a design defect, an installation defect, or some other defect?

Response:

National Grid's review of Damage Appraisal information indicates these poles were damaged as the result of tree falling into the Company's pole line on Grand Avenue in Cranston between Poles 13 and 14. The poles broke under the stress applied by the tree, not by storm winds. The poles were replaced as part of restoration activities. The poles that failed were Jointly Owned 40' Class 3 poles set in 1992. The conductors normally rest on top of the insulators and are held on the insulators with tie wires, which are tied around the top of the insulator and along the conductors in either direction from the insulator. This arrangement holds the conductor to the top of the insulators for all design conditions. The fact that these tie wires broke under the impact of a tree is not the result of a design or an installation defect.

Prepared by or under the supervision of: Robert Brawley

I. Engineering & Design

Division 2-10

Request:

The photographs and information from the storm indicate a pole line design strength concern. Items such as failed transmission poles, severely leaning distribution poles and broken distribution poles raise a concern that lines are not designed to the NESC standards. How is line design strength assessed during the National Grid inspection processes associated with prior hardening programs, reliability programs, and I&M programs?

Response:

Distribution:
The Company's construction standards and design practices ensure that the Company's lines meet or exceed the strength requirements of the NESC. The Company's distribution construction standards make conservative assumptions about conductor sizes, line angles and equipment weights and sizes. This ensures that all distribution poles meet NESC strength requirements and that most distribution poles exceed those requirements.

The distribution Inspection and Maintenance ("I&M") program qualitatively evaluates the condition of poles through visual inspection and mechanical "sounding" with a hammer for signs of interior degradation.

Transmission:
The Company's transmission poles are designed applying good engineering practice to meet all NESC strength requirements and other additional load cases developed through experience by the company. These practices ensure that all transmission poles meet or exceed the NESC strength requirements.

Through various components of the Company's I & M program, poles and towers are assessed for signs of degradation. This includes visual inspection above and below grade, and sounding and boring of wood poles.

Prepared by or under the supervision of: Rob Sheridan

I. Engineering & Design

Division 2-11

Request:

Has National Grid completed a line design and strength assessment based on the failures which occurred during Irene? If it has, provide a copy of each assessment completed.

Response:

National Grid experienced one transmission structure failure during Irene. Please see the document entitled "Analysis of L14 Pole 54 Failure" in Attachment DIV 2-11-1 and the engineering and design calculation in Attachment DIV 2-11-2 for additional details regarding this failure.

Prepared by or under the supervision of: Mark Browne

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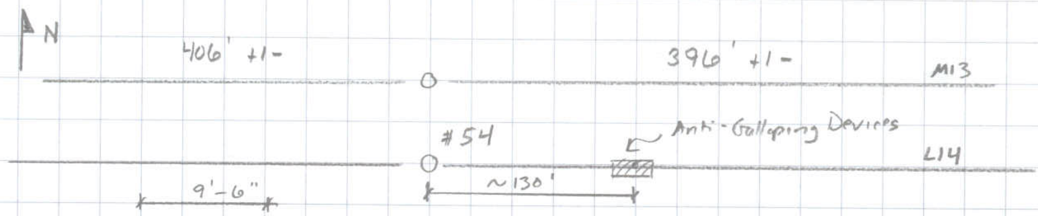
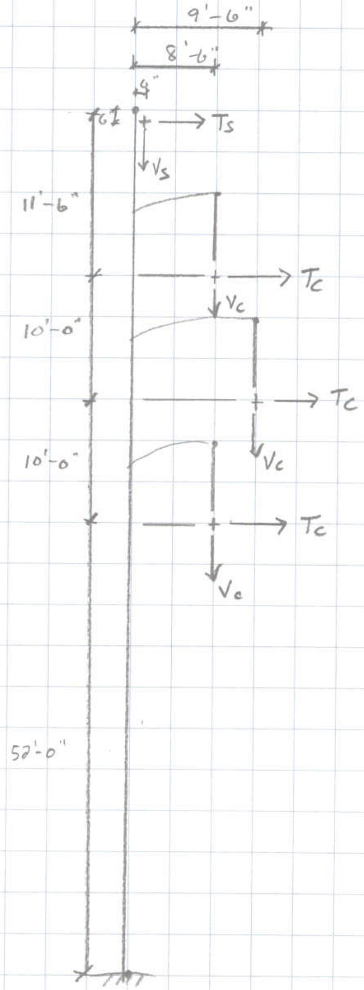
SUBJECT L14 Failure Analysis

SHEET NO. 1 OF 4
DATE 01/23/12
INDEX OR FILE NO.
PREPARED BY JLC
CHECKED BY PAW



Type	636 AAC	3 #6 AW
Dia.	0.918 in.	0.349 in
Weight	0.597 lb/ft	0.178 lb/ft



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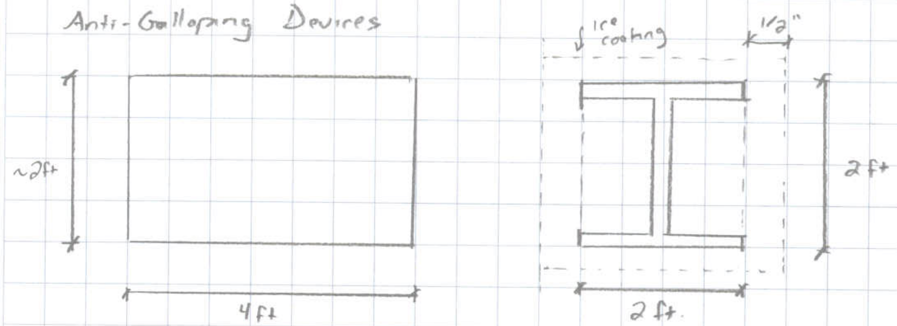
SUBJECT: L14 Failure Analysis	SHEET NO.	2	OF 4
	DATE	01/23/12	
	INDEX OR FILE NO.		
	PREPARED BY	JLC	
	CHECKED BY	PAW	

Anti-Galloping Devices



Assumed self weight $(170\ lb/ft^3)(6ft)(1in)(4ft) = 340\ lbs. = V_{AGC}$

Assumed Ice weight $[(25in)^2 - (24in)^2](57\ lb/ft^3)(48in) = 78\ lbs. = V_{AGCI}$

Wind load with ice (250B) $(4psf)(49in)(25in) = 34\ lbs. = T_{AGC}$

Wind load w/o ice (250C) $(21psf)(48in)(24in) =$ ~~192 lbs.~~ $168\ lbs. = T_{AGC}$

Equipment Weights

Insulator String ~ 135 lbs.

8' Davit Arm ~ 120 lbs.

9' Davit Arm ~ 135 lbs

Struts ~ 150 lbs.

Pole Parameters (based on min. dimensions)

$A = \pi(9.94in)^2 = 310.15\ in^2$

$I = 7655\ in^4$

$S = 770\ in^3$

AT GROUNDLINE

Projected Area = 130.54 sq ft

Centroid = 37.04 ft

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SUBJECT L14 Failure Analysis

SHEET NO. 3 OF 4
DATE 1/24/12
INDEX OR FILE NO.
PREPARED BY JLC
CHECKED BY PAW

250B Loading

$V_C = [1.2435(0.5)(0.918+0.5)+0.597](401) = 593$ lbs

$V_S = [1.2435(0.5)(0.349+0.5)+0.178](401) = 284$ lbs

$T_C = (4psf)(1.918/12)(401) = 257$ lbs

$T_S = (4psf)(1.349/12)(401) = 180$ lbs

$M_{TRANSVERSE} = [T_S Z_S + (T_C + T_{AGC})(Z_1 + Z_2 + Z_3)](OCF)$
$= [(180)(83) + (257+34)(72+62+52)](4.0)$
$= 276,264$ ft·lb

$M_{VERTICAL} = [V_S Y_S + (V_C + V_{AGC1} + V_{INS} + V_{STRUT}/2)(Y_{C1} + Y_{C2} + Y_{C3})$
$+ V_{ARM1}(Y_{C1}/2 + Y_{C3}/2) + V_{ARM2}(Y_{C2}/2)](4.0)$
$= [(284)(0.5) + (593 + 418 + 135 + 150/2)(8.5 + 9.5 + 8.5)$
$+ 120(4.25 + 4.25) + 135(4.75)](4.0)$
$= 136,639$ ft·lb

$M_{WIND ON POLE} = (4psf)(130.54)(37.04)(4.0) = 61,362$ ft·lb

$P = [2V_{ARM1} + V_{ARM2} + 3V_{INS} + 3V_{STRUT} + 3V_{AGC1} + 3V_C + V_S + V_{pole}](OCF)$
$= [2(120) + 135 + 3(135) + 3(150) + 3(418) + 3(593) + 284 + 6205](4.0)$
$= 43008$ lbs

$\sigma = \frac{(276264 + 136639 + 61362)(12)}{770} + \frac{43008}{310.15} = 7530$ psi < 8000 psi

OK

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SUBJECT

SHEET NO. 4 OF 4
DATE 1/24/12
INDEX OR FILE NO.
PREPARED BY JLC
CHECKED BY

250C Loading

$V_C = (0.597)(401) = 240$ lbs.

$V_S = (0.178)(401) = 72$ lbs.

$T_C = (21 psf)(0.918/12)(401) = 645$ lbs.

$T_S = (21 psf)(0.349/12)(401) = 245$ lbs

$M_{TRANSVERSE} = [T_S Z_S + (T_C + T_{AGC})(Z_{C1} + Z_{C2} + Z_{C3})](OCF)$

$= [(245)(83) + (645 + 168)(72 + 62 + 52)](1.0)$

$= 171,553$ ft·lb

$M_{VERTICAL} = [V_S Y_S + 2(V_C + V_{AGC} + V_{INS} + V_{STRUT}/2)(Y_{C1}) + (V_C + V_{AGC} + V_{INS} + V_{STRUT}/2)(Y_{C2}) + 2(V_{ARM1})(Y_{C1}/2) + (V_{ARM2})(Y_{C2}/2)](OCF)$

$= [(72)(0.5) + 2(240 + 340 + 135 + 150/2)(8.5) + (240 + 340 + 135 + 150/2)(9.5) + 2(120)(4.25) + (135)(4.75)](1.0)$

$= 22,633$ ft·lb

$M_{WIND\ ON\ POLE} = (21 psf)(130.54\ sqft)(37.04\ ft) = 101,540$ ft·lb

$P = [2V_{ARM1} + 1V_{ARM2} + 3V_{INS} + 3V_{STRUT} + 3V_{AGC} + 3V_C + V_S + V_{pole}](OCF)$

$= (2(120) + 135 + 3(135) + 3(150) + 3(340) + 3(240) + 72 + 6205)(1.0)$

$= 9247$ lbs.

$\sigma = \frac{(171553 + 22633 + 101540)(12)}{770} + \frac{9247}{318.15} = 4640\ psi < 8000\ psi$

OK

Analysis of L14 Pole 54 Failure

Prepared by Jeremy Cote

1.0 In August 2011 during Tropical Storm Irene, pole 54 of the L14 line failed, causing the line to fall into the adjacent M13 circuit, resulting in outages on both circuits and significant lost customer minutes. The pole failed well above the ground line, under winds believed to be in the range of 45 to 55 mph.

2.0 This analysis will assess the likely cause of the failure. First, the pole will be analyzed for compliance with the 1977 edition of the National Electrical Safety Code to verify proper design. Second, although not required, the pole will be analyzed using modern methods for determining the load effects of high wind storms on transmission structures, in order to assess the likelihood that the pole could have failed without the existence of prior damage.

3.0 As it appears the line was constructed in or around 1978, the line would be governed by the 1977 edition of the NESC[1]. Under this code, the pole would have been designed for two load cases:

3.1 Rule 250B – design the pole such that it can endure the load resulting from a ½" thick ice coating on all wires and a 4 psf wind perpendicular to the wires, with an overload capacity factor of 4.0, without exceeding the designated fiber strength at the ground line given in ANSI O5.1-1972.

3.2 Rule 250C – design the wood pole such that it can endure the load resulting from a 50-year mean recurrence interval wind storm without exceeding the designated fiber strength at the ground line given in ANSI O5.1-1972.

4.0 For Rhode Island, the extreme wind pressure is 21 psf in the 1977 code, corresponding roughly to a 90 mph wind. For southern yellow pine poles, a fiber strength of 8000 psi is used.

5.0 As shown in the attached calculations, the maximum stress occurring at the ground line for Rule 250B loading is approximately 7,530 psi. For Rule 250C loading, the maximum stress at the ground line is approximately 4,640 psi. Therefore, the pole was properly designed for the 1977 edition of the NESC.

6.0 Calculating the design wind pressure under the 2012 NESC is slightly more complicated, and requires the following steps

6.1 Determine the design wind speed from Figure 250-2(b)

6.2 Calculate the velocity pressure exposure coefficient k_z, a function of height above ground, using Table 250-2

6.3 Calculate the gust response factor G_{RF}, a function of height and span length, using Table 250-3

6.4 Calculate loads resulting from wind applied to structure and wires (using PLS-POLE)

7.0 Wood pole strength is highly variable. According to ANSI O5.1.2008, southern yellow pine poles have an average ground line fiber strength of 8000 psi, and a coefficient of variation of 20%. In addition, the fiber strength varies depending

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[1] National Grid does not possess the original design documentation for this circuit

upon the distance from the ground line. To assess the probability of overload without the presence of damage in the pole, the following steps are followed

7.1 Identify the maximum stress, and the location of the maximum stress, using PLS-POLE

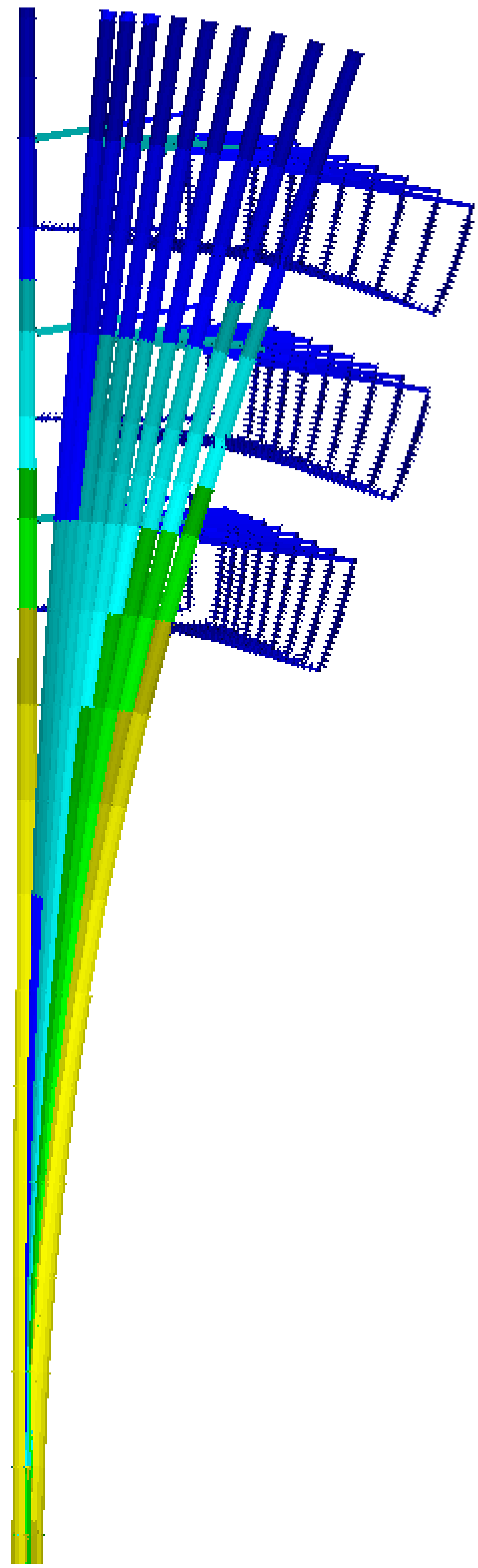
7.2 Calculate the probability of overload under this stress for an undamaged pole using the wood pole properties presented in ANSI O5.1.2008 and assuming wood pole strength variation is normally distributed

8.0 The results of the analysis are shown below. For the wind speeds observed during Tropical Storm Irene, the probability of overload for an undamaged pole is quite low. Therefore, it can be concluded with a high degree of certainty that the primary cause of failure was pre-existing damage, deterioration or defect, and not inadequate design.

Wind Speed (mph)	Applied Stress (ksi)	Distance from Top (ft)	Average Fiber Strength (ksi)	Standard Deviation (ksi)	Probability of Overload
40	1.9	26.8	6.8	1.4	0.02%
50	2.1	41.5	6.8	1.4	0.03%
60	2.5	41.5	6.8	1.4	0.08%
70	3.1	46.5	6.9	1.4	0.27%
80	3.8	51.5	7.1	1.4	0.95%
90	4.5	56.5	7.2	1.4	3.18%
100	5.3	56.5	7.2	1.4	9.59%
110	6.3	61.5	7.4	1.5	23.73%
120	7.3	61.5	7.4	1.5	46.61%

9.0 The broken pole was not retained, and no photographs of the broken area of the pole were taken, so any discussion of the specific type of damage present would be speculative at best. Given that the failure occurred well above the ground line, decay seems unlikely. Fatigue stress on the pole due to repeated wind loading cycles may be possible. Acute mechanical damage due to wood pecker nesting or some other cause could also be possible.

Figure 1 Model of Structure Behavior Under Various Wind Loads



I. Engineering & Design

Division 2-12

Request:

Provide a copy of an example pole strength calculation for one of the joint use poles that blew over or failed and include any "make ready" work order documentation that exists.

Response:

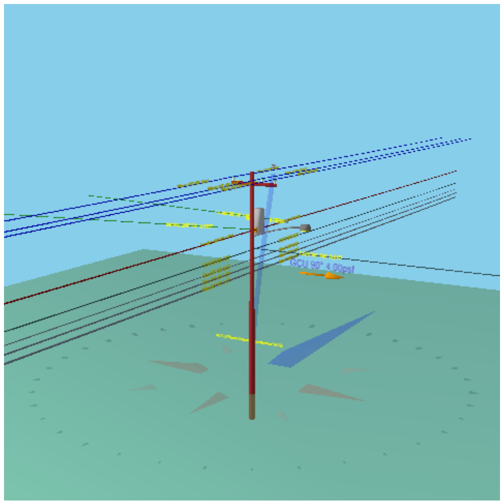
Please see the document entitled "O-Calc® Pro Analysis Report" in Attachment DIV 2-12 as an example of a pole strength calculation for Pole 15 at Grand Avenue, Cranston. National Grid is not aware of any associated "make ready" documentation for this location.

Prepared by or under the supervision of: Robert Brawley

O-Calc® Pro *Analysis Report*

Wednesday, January 25, 2012 4:48:56 PM

File Name:	**pole15(grandave).pplx**	Pole Length / Class:	**40 / 3**	Code:	**NESC**	Structure Type:	**Jnguyed**
Pole Num:	**Unset**	Pole Species:	**SOUTHERN PINE**	NESC Rule:	**Rule 250B**	Status:	**At Installation**
Related	**N/A**	Setting Depth (ft):	**6.00**	Construction Grade:	**B**	Strength Factor:	**0.65**
Aux Data	**Unset**	G/L Circumference (in):	**36.00**	Loading District:	**Heavy**	Transverse Wind LF:	**2.50**
Aux Data	**Unset**	G/L Fiber Stress (psi):	**8,000**	Ice Thickness (in):	**0.50**	Wire Tension LF:	**1.10**
Aux Data	**Unset**	Allowable Stress (psi):	**5,200**	Wind Speed (mph):	**39.53**	Vertical LF:	**1.50**
Aux Data	**Unset**	Fiber Stress Ht. Reduction:	**No**	Wind Pressure	**4.00**		



Pole Capacity Utilization		Height	Wind Angle
Maximum:	**66.7%**	0.0 ft	90.0°
Groundline:	**66.7%**	0.0 ft	90.0°
Vertical:	**20.2%**	22.4 ft	90.0°

Pole Moments		Load Angle	Wind Angle
Max Capac. Util:	**42,158 ft-lb**	87.8°	90.0°
Groundline:	**42,158 ft-lb**	87.8°	90.0°

Pole ID: pole15(grandave).pplx (Unset) **O-Calc® Pro *Analysis Report*** Wednesday, January 25, 2012 4:48:57 PM

GROUNDLINE LOAD SUMMARY:*Wind at 90.0°, Applied Moment 42,158 ft-lb at 87.8°, Allowable Moment 64,015 ft-lb

	Shear Load (lbs)*	Percent Applied Load	Bending Moment (ft-lb)	Percent of Applied Moment**	Percent of Pole Capacity	Bending Stress (+/-psi)	Vertical Load (lbs)	Vertical Stress (psi)	Total Stress (psi)	Percent of Pole Capacity
Powers:	-1,470	-73.0	**-33,023**	12.7	**8.3**	**-2,683**	724	7	**-2,676**	**-51.5**
Comms:	3,087	153.2	**67,070**	8.8	**5.8**	**5,448**	925	9	**5,457**	**104.9**
Power Equipment:	78	3.9	**2,102**	5.0	**3.3**	**171**	960	9	**180**	**3.5**
Pole:	266	13.2	**4,188**	9.9	**6.5**	**340**	1,495	15	**355**	**6.8**
Crossarms:	3	0.2	**108**	0.3	**0.2**	**9**	75	1	**10**	**0.2**
Streetlights:	34	1.7	**1,180**	2.8	**1.8**	**96**	60	1	**96**	**1.9**
Insulators:	18	0.9	**534**	0.3	**0.2**	**43**	108	1	**44**	**0.9**
Pole Load:	2,015	100.0	**42,158**	100.0	**65.9**	**3,425**	4,348	42	**3,467**	**66.7**
Pole Reserve Capacity:			**21,857**		**34.1**	**1,775**			**1,733**	**33.3**

LOAD SUMMARY BY OWNER

	Shear Load (lbs)*	Percent Applied Load	Bending Moment (ft-lb)	Percent of Applied Moment**	Percent of Pole Capacity	Bending Stress (+/-psi)	Vertical Load (lbs)	Vertical Stress (psi)	Total Stress (psi)	Percent of Pole Capacity
<Undefined>:	1,749		**37,970**			**3,084**	2,853	28	**3,112**	**8.4**
Pole:	266		**4,188**			**340**	1,495	15	**355**	**6.8**
Unset:	0		**0**			**0**	0	0	**0**	**0.0**
Totals	2,015		**42,158**			**3,425**	4,348	42	**3,467**	**66.7**

Pole ID: pole15(grandave).pplx (Unset) **O-Calc® Pro *Analysis Report*** Wednesday, January 25, 2012 4:48:57 PM

Detailed Load Components

Powers:		Owner	Height (ft)	Horiz. Offset (in)	Cable Dia. (in)	Rotate Angle (deg)	Cable Weight (lbs/ft)	Lead/Span Length (ft)	Span Angle (deg)	Wire Length (ft)	Tension (lbs)	Tension Moment (ft-lb)*	Offset Moment (ft-lb)*	Wind Moment (ft-lb)*	Moment at GL (ft-lb)*
Primary	AAC 336.4 KCM 19 STRAND TULIP		32.92	44.45	0.6660	-	0.316	100.0	360.0	100.0	2,030	2,770	288	2,285	5,342
Primary	AAC 336.4 KCM 19 STRAND TULIP		32.92	44.45	0.6660	-	0.316	100.0	180.0	100.0	2,030	-2,770	288	2,285	-197
Primary	AAC 336.4 KCM 19 STRAND TULIP		32.92	19.06	0.6660	-	0.316	100.0	360.0	100.0	2,030	2,770	119	2,285	5,173
Primary	AAC 336.4 KCM 19 STRAND TULIP		32.92	19.06	0.6660	-	0.316	100.0	180.0	100.0	2,030	-2,770	119	2,285	-366
Primary	AAC 336.4 KCM 19 STRAND TULIP		32.92	44.45	0.6660	-	0.316	100.0	360.0	100.0	2,030	2,770	-285	2,285	4,770
Primary	AAC 336.4 KCM 19 STRAND TULIP		32.92	44.45	0.6660	-	0.316	100.0	180.0	100.0	2,030	-2,770	-285	2,285	-769
Secondary	TRIPLEX 1/0		25.00	7.71	1.0300	-	0.399	100.0	0.0	100.0		0	65	2,113	2,178
Service	Generic Span		24.96	120.25	0.5000	-	0.091	50.0	280.0	50.0	1,000	-24,154	1	26	-24,127
Secondary	TRIPLEX 1/0		25.00	7.71	1.0300	-	0.399	100.0	180.0	100.0		0	65	2,113	2,178
Service	Generic Span		25.00	7.71	0.5000	-	0.091	50.0	260.0	50.0	1,000	-27,243	17	19	-27,207
											Totals:	**-51,397**	**391**	**17,982**	**-33,023**

Comms:		Owner	Height (ft)	Horiz. Offset (in)	Cable Dia. (in)	Rotate Angle (deg)	Cable Weight (lbs/ft)	Lead/Span Length (ft)	Span Angle (deg)	Wire Length (ft)	Tension (lbs)	Tension Moment (ft-lb)*	Offset Moment (ft-lb)*	Wind Moment (ft-lb)*	Moment at GL (ft-lb)*
CATV	0.50IN CATV + 6.6M STRAND		22.00	6.89	0.8100	-	0.214	100.0	0.0	100.0	2,195	2,000	44	1,658	3,702
CATV	0.50IN CATV + 6.6M STRAND		22.00	6.89	0.8100	-	0.214	100.0	180.0	100.0	2,195	-2,000	44	1,658	-298
CATV	0.50IN CATV + 6.6M STRAND		22.00	6.89	0.8100	-	0.214	100.0	90.0	100.0	2,195	53,069	44	0	53,113
Telco	BELOPTIX AT072 - 72 FIBERS - ARMORED (0.657)		20.50	6.98	0.6570	-	0.190	100.0	0.0	100.0		0	40	1,414	1,454
Telco	BELOPTIX AT072 - 72 FIBERS - ARMORED (0.657)		20.50	6.98	0.6570	-	0.190	100.0	180.0	100.0		0	40	1,414	1,454
Telco	BELOPTIX MT144 - 144 FIBERS - STRANDED (1.19)		19.50	7.04	1.1900	-	0.339	100.0	0.0	100.0		0	61	1,778	1,839
Telco	BELOPTIX MT144 - 144 FIBERS - STRANDED (1.19)		19.50	7.04	1.1900	-	0.339	100.0	180.0	100.0		0	61	1,778	1,839
Telco	19 GA 100 PR (1.44)		18.50	7.10	1.4400	-	1.120	100.0	0.0	100.0		0	103	1,879	1,983
Telco	19 GA 100 PR (1.44)		18.50	7.10	1.4400	-	1.120	100.0	180.0	100.0		0	103	1,879	1,983
											Totals:	**53,069**	**541**	**13,460**	**67,070**

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PowerEquipments:		Owner	Height (ft)	Horiz. Offset (in)	Offset Angle (deg)	Rotate Angle (deg)	Unit Weight (lbs)	Unit Height (in)	Unit Depth (in)	Unit Diameter (in)	Unit Length (in)	Tension Moment (ft-lb)*	Offset Moment (ft-lb)*	Wind Moment (ft-lb)*	Moment at GL (ft-lb)*
Transformer	1PH-50KVA		26.00	22.15	0.0	0.0	640.00	47.00	-	24.00	-	-	67	2,035	2,102
											Totals:	**0**	**67**	**2,035**	**2,102**

Crossarms:		Owner	Height (ft)	Horiz. Offset (in)	Offset Angle (deg)	Rotate Angle (deg)	Unit Weight (lbs)	Unit Height (in)	Unit Depth (in)	Unit Diameter (in)	Unit Length (in)	Tension Moment (ft-lb)*	Offset Moment (ft-lb)*	Wind Moment (ft-lb)*	Moment at GL (ft-lb)*
Normal	CROSSARM 3-1/2 X 4-1/2 X 8		32.00	6.28	0.0	0.0	50.00	6.00	5.00	-	96.00	-	1	107	108
											Totals:	**0**	**1**	**107**	**108**

Streetlights:		Owner	Height (ft)	Horiz. Offset (in)	Offset Angle (deg)	Rotate Angle (deg)	Unit Weight (lbs)	Unit Height (in)	Unit Depth (in)	Unit Diameter (in)	Unit Length (in)	Tension Moment (ft-lb)*	Offset Moment (ft-lb)*	Wind Moment (ft-lb)*	Moment at GL (ft-lb)*
General	Streetlight		24.00	4.27	90.0	90.0	40.00	0.00	-	0.00	-	-	371	809	1,180
											Totals:	**0**	**371**	**809**	**1,180**

Insulators:		Owner	Height (ft)	Horiz. Offset (in)	Offset Angle (deg)	Rotate Angle (deg)	Unit Weight (lbs)	Unit Height (in)	Unit Depth (in)	Unit Diameter (in)	Unit Length (in)	Tension Moment (ft-lb)*	Offset Moment (ft-lb)*	Wind Moment (ft-lb)*	Moment at GL (ft-lb)*
Pin	Insulator, 15 kV		32.25	44.00	81.9	0.0	8.99	8.00	-	5.00	-	-	50	90	139
Pin	Insulator, 15 kV		32.25	18.00	70.8	0.0	8.99	8.00	-	5.00	-	-	20	90	110
Pin	Insulator, 15 kV		32.25	-44.00	278.1	0.0	8.99	8.00	-	5.00	-	-	-49	90	41
Spool	Insulator, 15 kV		25.00	4.21	90.0	90.0	8.99	8.00	-	5.00	-	-	9	69	78
Bolt	Insulator, 15 kV		22.00	4.39	90.0	0.0	8.99	8.00	-	3.00	-	-	8	37	44
Bolt	Insulator, 15 kV		20.50	4.48	90.0	0.0	8.99	8.00	-	3.00	-	-	8	34	42
Bolt	Insulator, 15 kV		19.50	4.54	90.0	0.0	8.99	8.00	-	3.00	-	-	8	32	40
Bolt	Insulator, 15 kV		18.50	4.60	90.0	0.0	8.99	8.00	-	3.00	-	-	8	31	39
											Totals:	**0**	**61**	**473**	**534**

Pole Buckling

Buckling Constant	Buckling Column Hgt (ft)	Buckling Section Height (% Buckling Col. Hgt.)	Buckling Section Diam. (in)	Min. Buckling Diam. at GL (in)	Diameter at Tip (in)	Diameter at GL (in)	Modulus of Elasticity (psi)	Pole Density (pcf)	Ice Density (pcf)	Pole Tip Height (ft)	Buckling Load Capacity at Hgt. (lbs)	Buckling Load Applied at Hgt. (lbs)	Buckling Load Factor of Safety
2.00	22.42	33.57	10.54	16.83	7.32	11.46	1,600,000	60.00	57.00	34.00	21,501	**4,348**	**4.95**