The Blimp Event of 2015

Description and Analysis of the Outages caused by a runaway blimp on PPL Electric Utilities Transmission System

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Introduction

In late October 2015, a blimp became untethered at a military base near Baltimore, Maryland and drifted north. As two Air Force F-16 fighter jets tracked its flight, the errant blimp began to descend as it slowly lost helium. [1] As it floated free over central Pennsylvania, its mile long tethering cable began to contact PPL Electric Utilities transmission lines.

The runaway blimp and the resulting power outages drew national media coverage. The blimp's tether contacted transmission lines ranging from 69 to 500kV, and damage to the lines was extensive, including broken poles and damaged conductors.

This **"**one-of-a-kind" event provided a unique opportunity for PPL to assess its digital monitoring equipment (DME) and fault location accuracy on the affected lines. This paper focuses on the transmission events attributed to the blimp's tether, associated damage, and post-fault analysis. Fault location systems utilized for the "blimp event" included relays event records, digital fault recorder (DFRs), distributed event recorders (DERs), and Traveling Wave. In addition, highlights of the JLENS blimp program and the event aftermath are presented in the paper.

System Event Overview

On October 28th 2015 at 11:54 EDT, a military blimp broke loose from its moorings at the Aberdeen Proving Grounds.[1] The blimp drifted due north at 60 mph with an initial altitude of 15,000 feet while trailing 6,700 feet of its mooring tether. As the blimp continued to descend, its tether began to contact PPL's transmission lines at 13:31 EDT. Within one hour, the blimp contacted 9 transmission lines that also impacted 32 distribution lines. The blimp traveled a total distance of 135 miles and remained airborne for nearly four hours (Table 1). Ultimately, over 40,000 customers were affected and most were restored in approximately two hours after the event.

While the weather was rainy, surface winds were generally from the southeast, averaging 15 to 25 mph. However, at altitudes above 5,000 feet, the winds were 50 mph and greater from the south. [2] This explains the blimp's trajectory of traveling due north and then changing to a northwest direction as it descended (Figure 2). The blimp slowed during the line contacts and significantly slowed when its tether began dragging on the ground. Via Google Earth, the blimp's tether contact locations and the nine transmission lines are shown in Figure 1.

Event Time (EDT)	location	Time Difference	Event or Line Contact	Line Ops	Distance	Estimated Speed
11:54:00		0:00	Blimp breaks loose in Aberdeen, Md			
13:29:51	A	94:09	Tuscarora 26-1 12kV circuit	TTLO	90 mi	57 mph
13:31:41	B	1:50	Frackville-Hauto-1 69kV	2 X	1.6 mi	53 mph
13:31:49	B	0:08	Frackville-Siegfried 230kV	2 X	0.03 mi	60 mph
13:36:53	C	5:04	Frackville-Shenandoah 69kV at 79/79	2 X	5 mi	60 mph
13:37:55	D	1:02	Frackville-Shenandoah 69kV at 04/15	TTLO	0.92 mi	60 mph
13:57:22	E	19:27	Sunbury-Susquehanna 500kV	LO	15 mi	46 mph
13:57:31	E	0:09	Sunbury-Susquehanna 230kV	1 X	0.04 mi	46 mph
14:00:53	F	03:22	Columbia-Berwick 69kV	TTLO	2.27 mi	39 mph
14:10:34	G	9:41	Columbia-Scott 69kV	TTLO	3.45 mi	22 mph
14:36:34	H	26:00	Montour-Susq T10 230kV	LO	5.24 mi	12 mph
14:36:56	H	0:22	Montour-Susquehanna 230kV	LO	0.01 mi	12 mph
15:45:00	I	68:04	Blimp down in Anthony Township, PA		10 mi	9 mph

Table 1 – Blimp Event Timeline

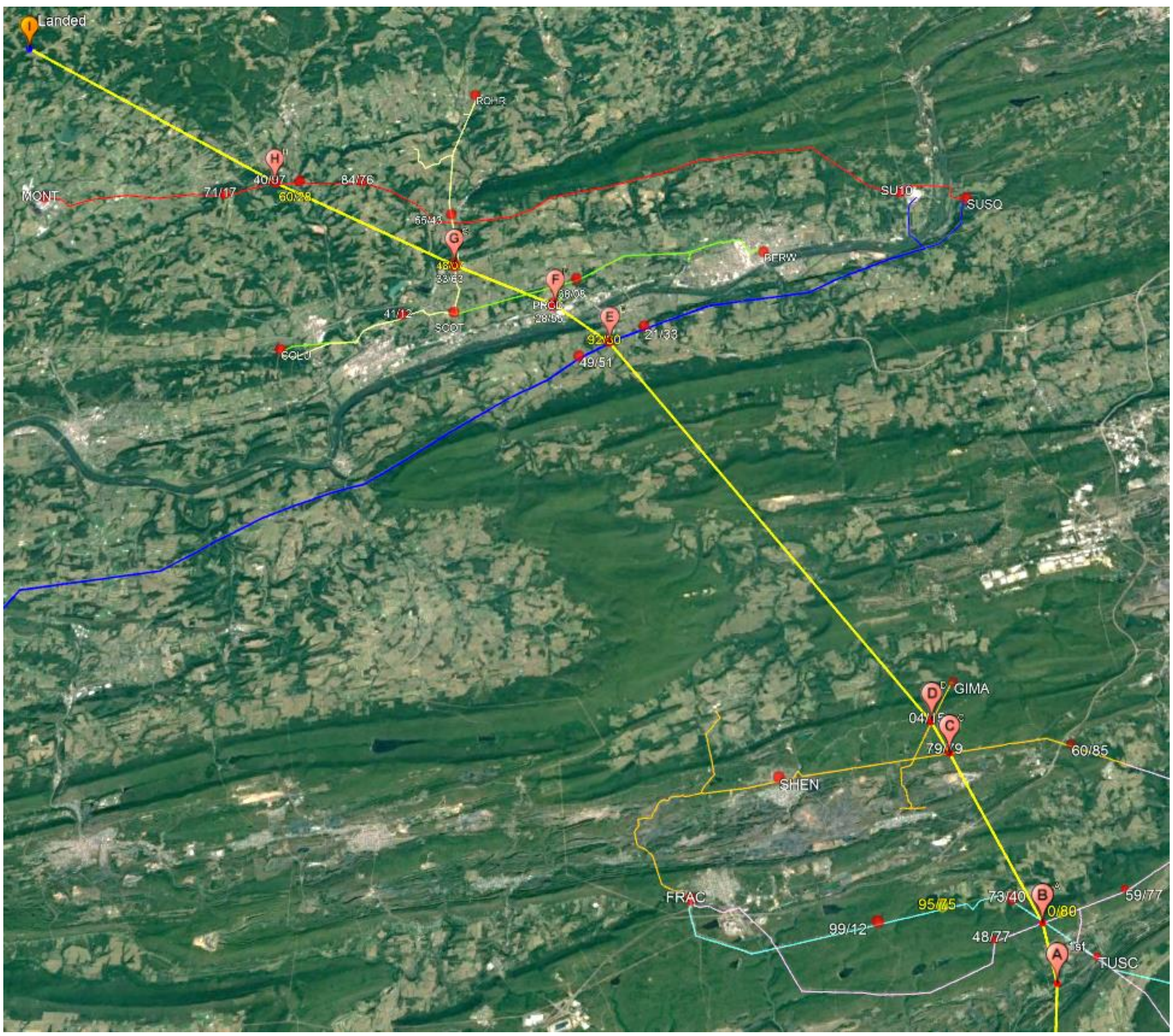

Figure 1 – Blimp Tether Contact Locations

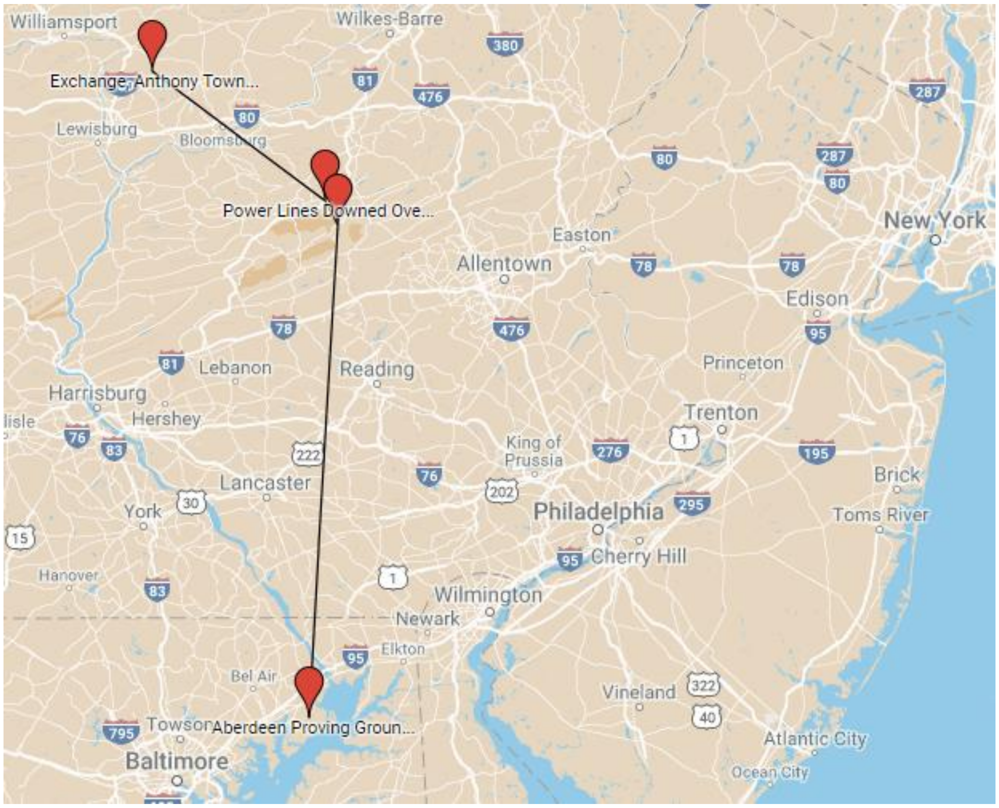

Figure 2 – Flight Path of Blimp *(courtesy of TamaquaArea.com)*

For this system wide event, PPL utilized a 4 mile patrol range, +/- 2 miles from the estimated fault location for each line. Typically, the patrol range varies depending on the fault data and geographical circumstances. In addition, ground patrols were initiated due to the weather conditions. Helicopter patrols were performed the following day.

The operations were analyzed by review of the relay event reports, and associated DME. Short circuit simulations were performed to determine and/or verify fault distance estimations for the affected transmission lines.

Lines 1 & 2 – Hauto-Frackville-1 69kV / Siegfried-Frackville 230kV

At 13:31:41 EDT, the first transmission fault occurred on the Hauto-Frackville-1 69kV line. The line first tripped by an A-phase-to-ground fault with a magnitude of 2,170A. The line reclosed in 1.5 seconds and then tripped again via an A-to-C-phase fault with a magnitude of 3,130A and reclosed 15 seconds later. Then at 13:31:49 EDT, the Siegfried-Frackville 230kV tripped and reclosed twice via an A-phase-to-ground fault. Both lines are protected with electromechanical schemes.

Investigation, Analysis, and Patrol Results

Utilizing short circuit simulations, both the ground and phase-to-phase fault values from the distributed event recorder (DER) on the Hauto-Frackville-1 line yielded an estimated fault location of 11.8 miles from Frackville at structure 46870s53080 (70/80). The patrol area was from 48/77 to 59/77 and included the Tuscarora Tap (Figure 3).

Utilizing fault values from the Frackville DFR, the estimated fault location for Siegfried-Frackville 230kV line was 8.0 miles from Frackville at structure 415195s53075 (95/75). The patrol area was from 99/12 to 73/40 (Figure 3). The helicopter patrol, performed the following day, did not discover any findings for either the line in the listed patrol areas.

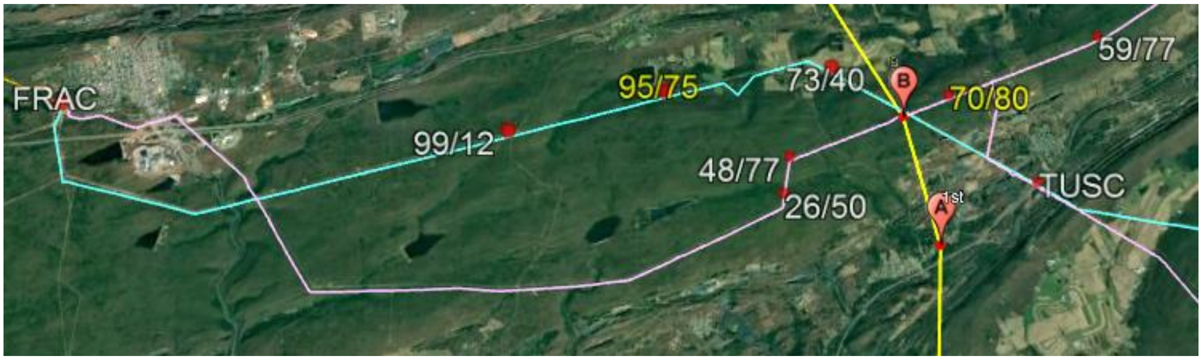

Figure 3 – Hauto-Frackville-1 (pink) and Frackville-Siegfried (light blue) Lines

<u>Post Analysis</u>

After the helicopter patrol, these two lines were re-evaluated. Since the operations between the 69kV and 230kV were 8 seconds apart, the fault location must be near an intersection of the two lines. At the time of issuing the patrols, different people were analyzing each fault. The possibility of the fault location occurring near the intersection of the two lines was not initially recognized.

This location must be one where the 69kV line was contacted first, then the 230kV line and neither line contacted again. Per Google Earth, the most probable location is noted by Placemark B in Figure 2. This distance from Frackville is 11.3 miles for the 69kV line and 10.5 miles for the 230kV line. For the 69kV line, the conductor phasing arrangements south to north are A-C-B from structure 26/50 to the Tuscarora Tap. So, the A-to-C-phase fault on its second operation could have only occurred in that area. Additionally, 12kV circuit Tuscarora 26-1 was contacted at 13:29:51 EDT, about 2 minutes before the 69kV line was contacted. Downed conductors and broken cross arms were reported at location 46853s52169, noted by Placemark A. This damage was due south of the intersection and further supports the probable fault location.

The initial estimated location for the 230kV line was 2.5 miles away and the patrol was short of this location, but the estimated fault location for Hauto-Frackville-1 was about 0.5 miles east of the intersection and its patrol covered this area. For the absence of verified line contact, minor conductor arcing was suspected to have occurred. Helicopter patrols, especially ones of significant patrol length, have difficulty with locating superficial arcing conductor damage, particularly if the contact is on the side of the conductor. Comprehensive Visual Inspections (CVI) patrol of both lines occurred in early 2016, but nothing new was discovered for the probable fault location.

The Siegfried-Frackville line is untransposed for its entire 40.26 mile length with 795 ACSR conductor on lattice towers. This could have impacted the short circuit simulation; however, the phasing arrangement of the line was entered correctly into the short circuit model. The previous fault on this line occurred in May 2011 with no subsequent faults since the blimp. The relays for this line will be upgraded in late 2018 and more fault information will be available for this line.

Line 3 - Frackville-Shenandoah 69kV Line

At 13:36:53 EDT, the next fault occurred on the Frackville-Shenandoah 69kV line while carrying a portion of the Hauto-Frackville-3 69kV line for scheduled work. This contact was located 5 miles (line of sight) from previous fault location (Figure 4).

The line initially tripped and reclosed via a B-phase-to-ground fault with a magnitude of 2131A. Then 62 seconds later, the line tripped four times to lockout. The first two faults were C-phase-to-ground with a magnitude of 2120A and last the two were A-to-B-to-ground with a magnitude of 3192A.

Investigation, Analysis, and Patrol Results

With short circuit simulations, both the ground and phase-to-phase-ground faults yielded the same approximate location, 12 miles from Frackville at structure 45179/S55279 (79/79) and 44904s55715 (04/15) on the Girard Manor Tap. There were two possible fault locations, both with a distance of 12 miles from Frackville. The patrol areas were from 30/51 to Girard Manor (GIMA) sub and from 30/51 to 93/80 (Figure 4).

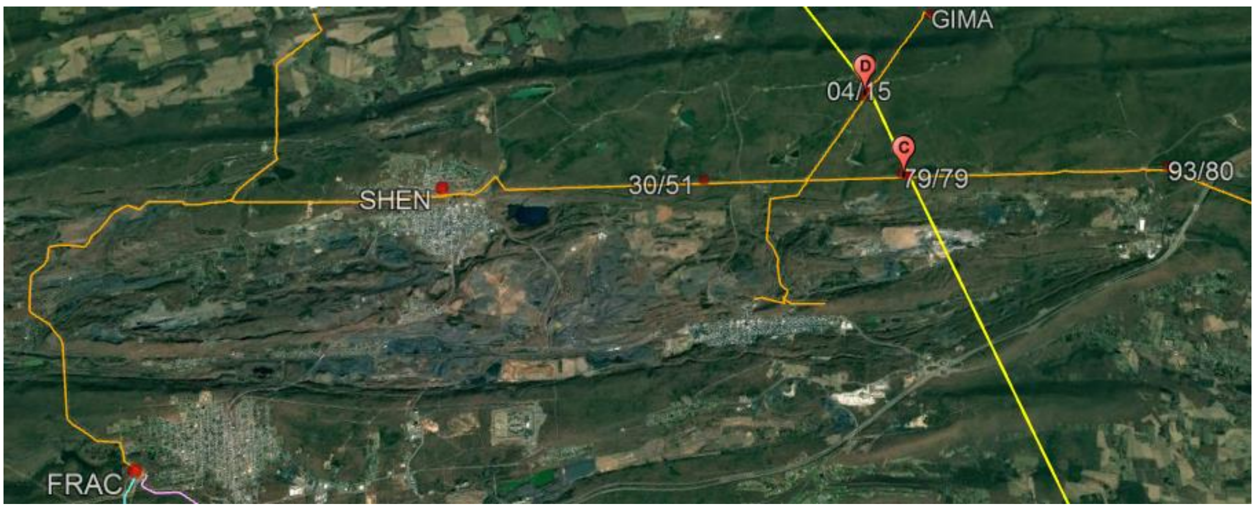

Figure 4 – Frackville-Shenandoah Line

The foot patrol, performed a few hours after the operation, discovered structures with broken overhead ground wire (OHGW), conductor, and pole damage around structure 04/15 (Placemark D) on Girard Manor Tap (11.7 miles from Frackville). Helicopter patrol found nothing additional in the other patrol area for structure 79/79 (Placemark C). In order to restore power quickly, temporary repairs were made that night. The following permanent repairs were completed in July 2016 when outage conditions allowed:

- Replacement of OHGW between structures 44905s55715 and 44868s55628 (4 spans)
- Repair of the pole top damage at structure 44894s55687
- Replacement of middle phase conductor (2,800 feet) between 44905s55715 and 44894S55687

Figure 5 –Damages on Structures: 44894s55687, 44904s55715, 44868s55628, and 44879s55657

Post Analysis

The actual fault distance of 11.7 miles compared favorably with the estimated of 12 miles. The short circuit simulations provided a distance differing from the relay. However, this is not unusual, since line segments can have different conductor types, line arrangements, and varying structures. The relay event records listed fault distances of 10.11 miles for the entire line-to-ground fault, but listed 7.34 miles for the double-line-to-ground fault. The explanation for the difference in fault distances from the relay could not be determined. For the contact suspected at 79/79, minor conductor arcing was suspected to have occurred and the helicopter patrol was unable to detect the damage.

Lines 4 & 5 - Sunbury-Susquehanna 230kV and 500kV lines

Approximately 20 minutes after the last line operation, the tether came in contact with Sunbury-Susquehanna 230kV and 500kV lines which are on separate towers but in the same right-of-way. The 500kV line was contacted first at 13:57:22 EDT and did not reclose while the 230kV tripped once and reclosed at 13:57:31 EDT.

Figure 6 - Sunbury-Susquehanna 230kV line and 500kV lines

Investigation, Analysis, and Patrol Results

For the initial analysis, short circuit simulations were performed utilizing DFR records that were accessed remotely from both substations. The estimated fault location was 30 miles from Sunbury at structure 39049n30851 (49/51). The patrol area was from 24/79 to 21/33 (Figure 6). At 17:10 EDT, field crews reported that portions of the tether were entangled around both lines and remnants were on the ground at structure 92/30 which was 31.44 miles from Sunbury (Placemark E) as shown in Figure 7. The following day, the sections of tether from both lines were removed during the helicopter inspection.

Figure 7 - Tether entangled on Sunb-Susq conductors, 500kV on left and 230kV on right

An additional helicopter visual inspection was performed on 11/1/15 which identified damage to the 500kV conductor, overhead ground wire (OHGW), and line hardware, as shown in Figures 8 and 9. Speed grip style bundle spacers moved along the conductor. Vibration dampers on both OHGWs were bent and deformed. National Electric Energy Research Testing and Applications Center (NEETRAC) performed further analysis and confirmed the damage. With the tether found on the ground and the available fault current, it is likely that arcing from the fault severed the blimp's tether.

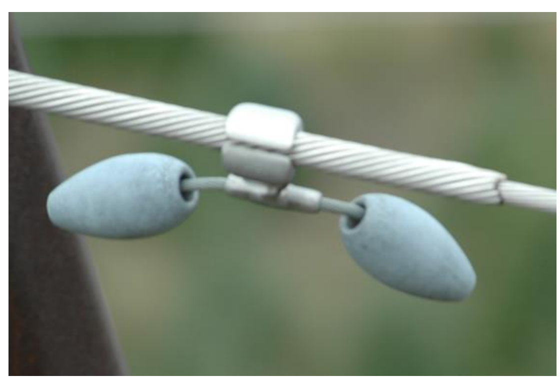

Figure 8 – Left - Moved bundle spacer on 500kV line, Right – Deformed vibration damper on 500kV line

Figure 9 – Left - Conductor damage, Right – Static wire damage

Permanent repairs occurred via helicopter repair crew in April 2016 during a line outage and included the following repairs to restore the line to its configuration prior to the incident:

- New bundled conductor spacers (qty 3) were installed
- OHGW vibration dampers (qty 2) were replaced
- Conductor vibration dampers (qty 6) were replaced
- Armor rod (patch rod) was installed over damaged OHGW and conductor strands

Post Analysis

These two lines provided an opportunity to compare the fault location estimate from all its relays and other fault location methods. The 230kV and 500kV lines have similar lengths, 43.92 and 43.54 miles, respectively. Table 2 lists each relay's fault distance along with the fault values. The SEL-421 and SEL-411L's utilized mutli-ended calculation for fault distance. Although the distance values from the relays were respectable, the traveling wave distances were closest to the actual distances of 31.44 miles from Sunbury and 12.10 miles from Susquehanna as listed in Table 2.

		Sunbury			Susquehanna			
Line	**Source**	**Relay**	**Distance**	**Current**	**Current**	**Distance**	**Relay**	**Length**
230kV Line	Primary	SEL-421	31.16 mi	2527A	6343A	12.25 mi	SEL-421	43.92 mi
	Backup	GE D60	30.60 mi	2725A	6527A	13.22 mi	LFZP	
500kV Line	Primary	SEL-411L	29.01 mi	4682A	8929A	11.18 mi	SEL-411L	43.54 mi
	Backup	SEL-411L	29.22 mi	4862A	8915A	11.25 mi	SEL-411L	
	Travel Wave	411L Pri	31.29 mi			12.14 mi	411L Pri	

Table 2 – Sunbury-Susquehanna Fault Distance Comparison

Traveling Wave (TW) was activated in the 500kV SEL-411Ls; however, the GPS clock at Susquehanna 500kV was discovered not to have the required high accuracy IRIG for TW. Without the high time accuracy, the relays could not automatically generate a TW fault location; however, the relays still captured the traveling wave data which allows for manual TW calculation. The TW fault location was manually calculated utilizing the Bewley lattice diagram provided by the SEL analysis software.

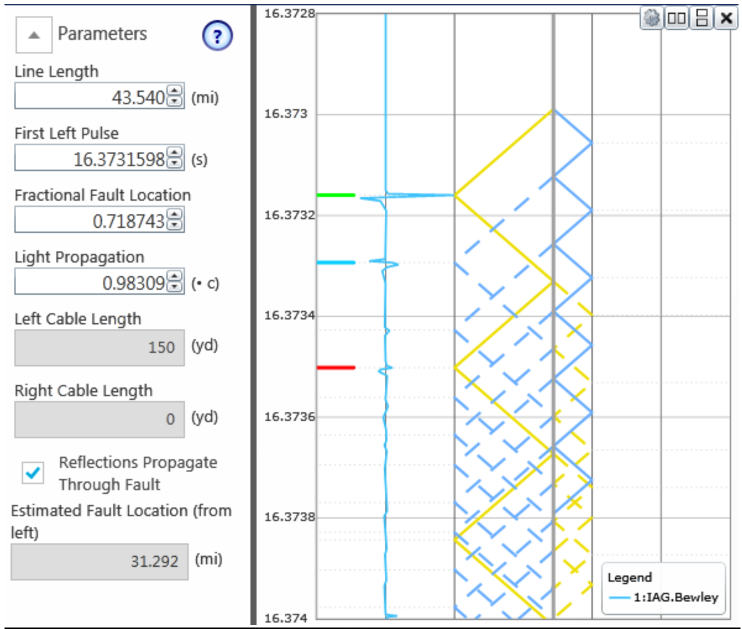

Figure 10 - Bewley diagram for Sunbury 500kV end

The Bewley diagram shows the TW propagation path along the transmission line and the reflections from the fault to Sunbury terminal (Figure 10). The fault location is represented by the vertical gray bar. The single-end TW calculation uses the time difference between the first TW from the fault and the first reflection from the fault. TW (yellow curve) launched at the fault point arrives at Sunbury, noted by the green cursor. It travels back toward the fault (gray bar), reflects back from the fault, and then returns back to Sunbury. The red cursor was aligned with the first reflection to establish the fault location. During the time interval between those two points, the TW traveled twice the fault distance. The program uses that time interval and the other parameters listed in the Bewley diagram to calculate the fault distance. Blue cursor was aligned with first full-line-traversal peak (blue curve) to refine the location which adjusted to the light propagation velocity from 0.98 to 0.98309pu.

The TW distance of 31.292 miles was within one span of the 31.44 miles fault location from Sunbury. The single-end TW calculation for other end resulted in 12.241 miles from Susquehanna. Even with the standard TW parameters utilized in the relay, the fault location values were quite good. With the standard light propagation of 0.98pu, the calculated distance was 31.194 miles.

Lines 6 & 7 - Columbia - Berwick 69kV and Columbia - Scott 69kV Lines

At 14:00:53 EDT, the Columbia-Berwick 69kV Line tripped to lockout. Unfortunately, there was no remote relay communications available at the Berwick end. At Columbia, electromechanical relays are utilized with no external fault recording capability. Ten minutes later at 14:10:34 EDT, the Columbia-Scott 69kV Line tripped to lockout via B-phase-to-ground fault with a magnitude of 3163A.

Investigation, Analysis, and Patrol Results

The event record from the Columbia-Scott relay listed a B phase-to-ground fault with a magnitude of 3163A and a fault distance 6.74 miles. Short circuit simulations estimated a fault distance of 7.4 miles from Columbia substation at structure 36848n32307 (48/07). The patrol area was from 41/12 to 55/43, as listed in Figure 11.

Noting the proximity of the lines, the blimp's tether should have contacted Columbia-Berwick at a similar fault location as Columbia-Scott. Based on that assumption, the patrol area was from 41/12 to 38/08 including Products Tap (Figure 11).

Figure 11 - Columbia – Berwick (green line) and Columbia - Scott (yellow line)

For Columbia-Scott, the foot patrol identified a broken pole at 36833n32363 (33/63), 7.6 miles from Columbia (Placemark F), as shown in Figure 12. Helicopter patrol, performed the following day, noted the broken pole identified by the ground crew; no additional findings were discovered. The broken wood pole was repaired with spare parts. The pole was replaced in early 2016.

For Columbia-Berwick, foot patrol identified the static wire down on Products tap at 38528n31755 (28/55) which was 9.8 miles from Columbia and 7.8 miles from Berwick (Placemark G) as listed in Figure 11. The static wire sustained significant damage as shown in Figure 13. Helicopter patrol discovered no findings in addition to downed static wire; repairs were completed the following day. The relay event record from Berwick was retrieved weeks after the event. The relay record listed a B-phase-to-ground fault with a magnitude of 1,356A and a fault distance 9.30 miles. Short circuit simulation provided an estimated fault distance of 8.2 miles from Berwick.

Figure 12 –Broken Pole on Colu-Scott

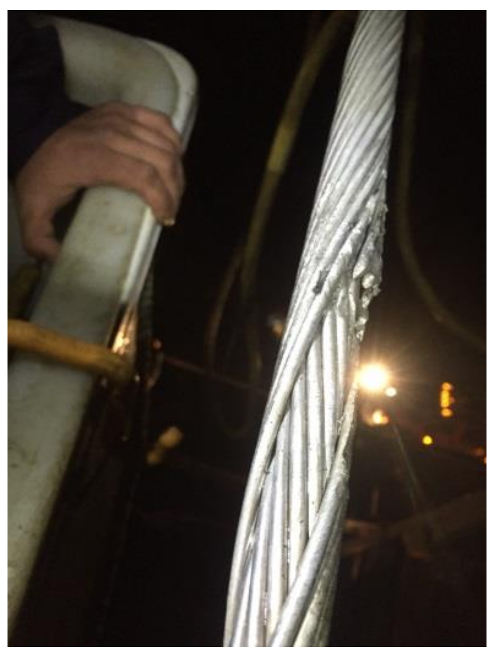

Figure 13 –Static wire damage on Colu-Berw

Lines 8 & 9 - Montour-Susquehanna and Montour-Susq T10 230kV lines

At 14:36:34 and 14:36:56 EDT, the tether made contact with Montour-Susquehanna T10 and Montour-Susquehanna 230kV lines, respectively. Both lines did not reclose and both occupy same steel lattice tower structure. At this point, the blimp significantly slowed down.

Figure 14 - Montour-Susq T10 and Montour-Susquehanna 230kV lines

Investigation, Analysis, and Patrol Results

At the time, only DFR data was available for initial analysis. Incidentally, the circuit breakers for the Montour-Susquehanna line were open at Montour for scheduled maintenance work. Thus, no DME from Montour was available for this line's analysis.

For both lines, short circuit simulation using the DFR fault values resulted in a fault distance of 8 miles from Montour substation at structure 60/28. The patrol area was from 71/17 to 84/76 (Figure 14). Helicopter patrol found a piece of the tether attached to the line extending to the ground near structure 40/97 which was 7.3 miles from Montour (Placemark H) as shown in Figure 15. No foot patrol was performed on this line.

Figure 15 - Tether hanging on Montour-Susquehanna

On 10/29/15, the helicopter removed remaining tether from the Montour-Susquehanna line and the line was returned to service at 18:27 EDT. The Montour-Susq T10 line, which was out for clearance while removing the tether on the Montour-Susquehanna line, was returned to service at 18:23.

An additional helicopter visual inspection was performed on 11/01/2015 and identified evidence of conductor damage. NEETRAC noted that no damage was observed to either of the structures or the suspension hardware, but damage occurred to the conductor strands. At one place, three individual strands were significantly compromised, as shown in Figure 16. Helicopter repair crew installed armor rod (patch rod) over the damaged conductor strands during an outage in 2016.


Figure 16 – Left - Mont-Susq conductor damage, Right – Close up of the conductor's damaged strands

Post Analysis

The actual fault distance of 7.3 miles compared favorably with the estimated distance of 8 miles. For the Montour-SusqT10 line (28.63 mile length), the relays listed fault distances of 6.6 and 21.7 miles from Montour and SusqT10, respectively. For the Montour-Susquehanna line, the backup relay at Susquehanna listed a fault distance 23.7 miles for the 30.91 mile line. The primary relay is an early vintage of microprocessor relay and does provide fault distance or oscillography. As stated earlier, the circuit breakers for the Montour-Susquehanna line were open at Montour for scheduled work.

Blimp Down

After the last transmission line contact, the blimp significantly slowed. There were reports of the blimp skimming treetops, damage to residential property damage, and tether marks. Around 15:45 EDT, Pennsylvania State Police reported that the blimp was brought down in a group of trees near a field in Anthony Township [3] (Figure 17), which is 10 miles from the last line contact. When the blimp went down, helium was still in the blimp's nose. The state troopers fired shotgun rounds at the fallen blimp for it to fully deflate. [4] Local authorities secured the area and a military recovery team removed onboard electronics from the blimp. [4]


Figure 17 – Blimp Down in Anthony Township, PA *(photos courtesy of WNEP)*

JLENS Blimp Program

The runaway blimp was one of two airships utilized for the JLENS program, which is short for Joint Land Attack Cruise Missile Defense Elevated Netted Sensor System. The blimps have radar that detect and track objects like missiles and aircraft up to 340 miles away. [4] The JLENS blimp is actually an aerostat, which means it is a large, helium-filled balloon tethered to the ground. The tether is made of Vectran, a substance similar to Kevlar, is 1 $^{1/8}$ inches thick, and is designed to withstand 100 mph winds. [5] The tether is comprised of four layers of the Vectran material wrapped around cables that transmit data and provide power to the blimp. [7] The 242-foot long aerostats are designed to operate at altitudes of up to 10,000 feet, and can stay aloft for up to 30 days at a time before being retrieved for maintenance (Figure 18). [5] The aerostats were in a three year operational exercise to assess its ability to detect potential air threats to the greater Washington DC area. [6]

Figure 18 – JLENS blimp at Aberdeen Proving Grounds *(photo courtesy of Baltimore Sun)*

JLENS Investigation

In February 2016, the Army investigation had found that the pitot tube, a narrow 18-inch-long device that measures air pressure within the blimp, malfunctioned. Ordinarily, fans within the blimp would activate in response to a change in atmospheric conditions, such as increased winds. Due to the failed pitot tube, the fans did not operate and air pressure within the blimp started to drop. [8]

This caused the aircraft to turn perpendicular to the prevailing wind at a time when gusts were reaching nearly 70 mph. The aerostats tail fins began to warp under the strain from the winds, increasing the aircraft's instability. This placed extreme stress on the tether and caused it to break near its mooring. [9] At the time, both aerostats were aloft at 6,800 feet. [10] The blimp was equipped with an automated safety device that should have caused it to deflate and return to ground within a few miles. The device failed to activate because batteries had not been installed in the aerostat as a backup power source. [9]

Summary Lessons Learned and Conclusions

The errant military blimp caused significant damage to a number of PPL transmission lines, and all outages were restored by early next morning. The blimp caused damage equivalent to a significant storm. It caused five transmission lines to lock out of service, and caused additional damage to distribution system equipment.

This unusual event provided an opportunity for PPL to assess its DME and fault locating abilities over a wide area. The analysis of the relay events and the DFR records verified correct relay operations for all the affected lines. The estimated fault distances were reasonably close to the actual fault distances. The short circuit simulations provided marginally better fault distances than the relays. Summary of the transmission line operations along with the estimated and actual fault distances are listed in Table 4. The fault location provided a valuable tool to locate the line damage and enable quick restoration to the nine transmission lines during this significant event. The post-mortem analysis provided a complete picture of the entire event including the blimp's flight path and the line operations.

Line Name	operation time (EDT)	ops	faulted phase(s)	Fault Distance			Line		
				estimated	from	actual	Length	Damage	Restored in
Frac-Haut 1 69kV	13:31:41	2x	A, A-C	12 mi	Frack	11.3 mi*	34.53 mi^	no damage found	n/a
Sieg-Frac 230kV	13:31:49	2x	A	8 mi	Frack	10.5 mi*	40.26 mi	no damage found	n/a
Frac-Shen 69kV (79/79)	13:36:53	2x	B	12 mi	Frack	12.0 mi*	18.17 mi^	no damage	n/a
Frac-Shen 69kV (04/15)	13:37:55	LO	C, A-B	12 mi	Frack	11.7 mi	18.17 mi^	OHGW, conductor	2hr 3min
Sunb-Susq 500kV	13:57:22	LO	A	30 mi	Susq	31.4 mi	43.54 mi	OHGW, conductor, hardware	17hr 32min
Sunb-Susq230kV	13:57:31	1x	B	30 mi	Susq	31.4 mi	43.92 mi	no damage	n/a
Colu-Berw 69kV	14:00:53	LO	C	7.4 mi	Colu	9.8 mi	15.8 mi	static wire	6hr, 0min
Colu-Scot 69kV	14:10:34	LO	B	7.4 mi	Colu	7.6 mi	18.35 mi^	broken pole	2hr 5min
Mont-SuT10 230kV	14:36:34	LO	A	8 mi	Mont	7.3 mi	28.63 mi	no damage	27hr 13min
Mont-Susq 230kV	14:36:56	LO	A	8 mi	Mont	7.3 mi	30.91 mi	conductor	27hr 13min

Table 4 - Summary of Line Operations (* no damage found, ^ radial line)

Biography

Glenn Bray, PPL Electric Utilities

Glenn Bray joined PPL EU in 2000. He is a Senior Engineer in Real Time Operations Analysis, where he is responsible for the analysis of transmission and distribution system disturbances. Previously, he worked in the Protection & Analysis and Relay Test Departments. Glenn began his career with Pepco in Washington, DC. He received a Bachelor of Science degree in Electrical Engineering from the University of Pittsburgh. He is a member of IEEE and a registered Professional Engineer in PA and DC.

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[1] Baltimore Sun (October 28, 2015) "JLENS blimp returns to Earth in Central Pennsylvania; military recovery in progress" by Matthew Hay Brown and Ian Duncan

[2] Just in Weather (October 28, 2015) JLENS Blimp Downed In Bloomsburg PA Power Lines

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[4] Associated Press (October 28, 2015) “Pennsylvania State police using shotguns to deflate wayward blimp” by Michael Rubinkam

[5] Baltimore Sun (October 30, 2015) “Blimp on the loose: What does it do?”

[6] Norad.mil (December 4, 2014) “Joint Land Attack Cruise Missile Defense Elevated Netted Sensor System JLENS”

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[8] Los Angeles Times (February 14, 2016) “Missing batteries among issues that caused Army's runaway blimp” by David Willman

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Acknowledgements

The author would like to thank System Maintenance Engineering, Relay Test and Real Time Operations Analysis Departments at PPL EU for contributing data and information pertinent to the event. Without this information and their assistance, this paper would not be possible.