



**Root Cause Analysis
for
327 East New York Street
Network Event on
November 24, 2014**

Prepared by T&D Transmission Field Operations
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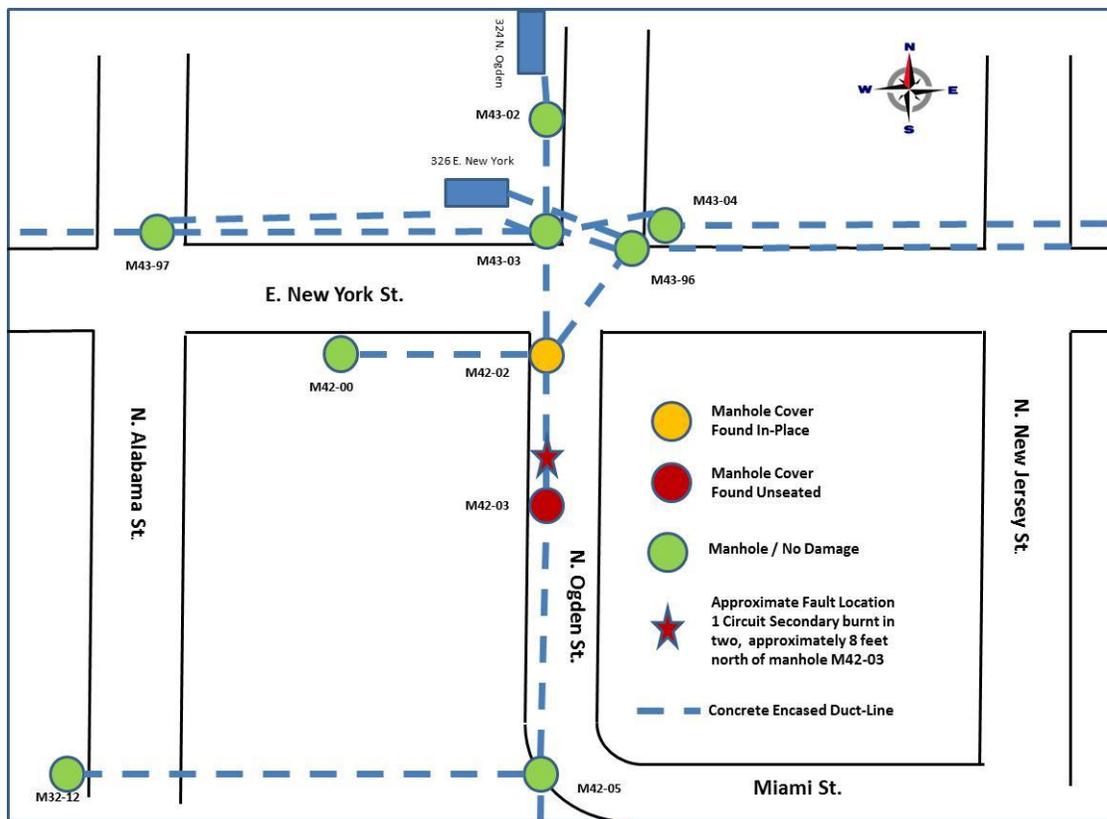
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1.0 Introduction

On Monday, November 24, 2014 at 8:32 AM EST Indianapolis Power & Light Company (IPL) received a call from the Indianapolis Fire Department (IFD) reporting a manhole cover off its ring at 321 East New York Street. This location is in the IPL Edison East secondary network. The event involved a secondary network cable failure with one manhole cover becoming dislodged/ajar. There was no property damage or injuries to the public. The secondary cable fault cleared itself as designed in approximately 2 minutes. It was not necessary to de-energize the Edison East secondary network to electrically isolate the faulted cable. When IPL personnel arrived on-site they found manhole M42-03 cover unseated on its ring.

Exhibit 1 below shows the layout of IPL facilities in the area of the event.



2.0 Background

In July of 2014, manhole M42-03 was inspected and no issues were found that would contribute to the event on November 24th. Similarly, in June of 2014, manhole M42-02 was inspected and no issues were found that would have contributed to the aforementioned event.

The ambient weather condition on the morning of November 24, 2014 at the time of the event was cloudy and spotty showers with a 52° F temperature. There was heavy rain on November 23rd. The Table below provides an insight to the weather conditions leading up to the November 24th event.

Date	Mean Temperature	Precipitation	Average Humidity
11/20/2014	24° F	Trace	62%
11/21/2014	23° F	0.0”	56%
11/22/2014	43° F	0.02”	66%
11/23/2014	50° F	1.91” *	81%
11/24/2014	46° F	0.18”	82%

* The 1.91” of rain on 11/23/2014 is reported as a single day record for November 23rd.



On New York Street looking south down Ogden Street – IPL Crew working at Manhole M42-03



Southwest corner of New York Street and Ogden Street – IPL Manhole M42-02 is in the foreground and M42-03 is shown in the back ground

3.0 Sequence of Events

The following sequence of events has been developed using information from IPL logs and records.

Network Event on November 24, 2014					
327 East New York Street - Edison East Secondary Network					
Sequence of Events					
Date/Time	Event Description				
11/24/2014 08:15	Pre-Event				
	Network SCADA Network Protector Status	Transformer KVA	Low side current rating		
	202 East New York - UG 422	750	2,084	Protector is CLOSED with Normal Analog Values	
	223 North New Jersey - UG 412	1,000	2,779	Protector is CLOSED with Normal Analog Values	
	223 North New Jersey - UG 422	1,000	2,779	Protector is CLOSED with Normal Analog Values	
	237 East Miami - UG 412	1,000	2,779	Protector is CLOSED with Normal Analog Values	
	237 East Miami - UG 462	1,000	2,779	Protector is CLOSED with Normal Analog Values	
	324 North Ogden - UG 422	1,000	2,779	Protector is CLOSED with Normal Analog Values	
	324 North Ogden - UG 462	1,000	2,779	Protector is CLOSED with Normal Analog Values	
	326 East New York - UG 412	500	1,390	Protector is CLOSED with Normal Analog Values	
	326 East New York - UG 442	500	1,390	Protector is CLOSED with Normal Analog Values	
	333 Massachusetts - UG 412	1,000	2,779	Protector is CLOSED with Normal Analog Values	
	333 Massachusetts - UG 422	1,000	2,779	Protector is CLOSED with Normal Analog Values	
	333 Massachusetts - UG 442	1,000	2,779	Protector is CLOSED with Normal Analog Values	
	425 East Vermont - UG 422	300	834	Protector is CLOSED with Normal Analog Values	
	425 East Vermont - UG 442	300	834	Protector is CLOSED with Normal Analog Values	
11/24/2014 08:32	IPL receives a call from IFD reporting a manhole cover off at 321 East New York Street IPL dispatches network crews to the 321 East New York Address				
	There were not any alarm indications during the time period associated with the event.				
11/24/2014 08:35	Post-Event				
	Network SCADA Network Protector Status	Transformer KVA	Low side current rating		
	202 East New York - UG 422	750	2,084	Protector is CLOSED with Normal Analog Values	
	223 North New Jersey - UG 412	1,000	2,779	Protector is CLOSED with Normal Analog Values	
	223 North New Jersey - UG 422	1,000	2,779	Protector is CLOSED with Normal Analog Values	
	237 East Miami - UG 412	1,000	2,779	Protector is CLOSED with Normal Analog Values	
	237 East Miami - UG 462	1,000	2,779	Protector is CLOSED with Normal Analog Values	
	324 North Ogden - UG 422	1,000	2,779	Protector is CLOSED with Normal Analog Values	
	324 North Ogden - UG 462	1,000	2,779	Protector is CLOSED with Normal Analog Values	
	326 East New York - UG 412	500	1,390	Protector is CLOSED with Normal Analog Values	
	326 East New York - UG 442	500	1,390	Protector is CLOSED with Normal Analog Values	
	333 Massachusetts - UG 412	1,000	2,779	Protector is CLOSED with Normal Analog Values	
	333 Massachusetts - UG 422	1,000	2,779	Protector is CLOSED with Normal Analog Values	
	333 Massachusetts - UG 442	1,000	2,779	Protector is CLOSED with Normal Analog Values	
	425 East Vermont - UG 422	300	834	Protector is CLOSED with Normal Analog Values	
	425 East Vermont - UG 442	300	834	Protector is CLOSED with Normal Analog Values	
11/24/2014 08:40	IPL personnel arrive on-site (Tom Frank & Caesar Doyle)				
11/24/2014 08:47	IPL personnel arrive on-site (Mike Lee)				

IPL removed and replaced the faulted quadraplex cable between manholes M42-02 and M42-03 on the day of the incident. IPL also inspected the adjacent manholes and didn't find any other damage.

4.0 Investigation and Analysis

The investigation into the cause of the network event at 327 East New York Street began as soon as IPL crews arrived on site and it was deemed safe to enter the impacted manholes.

After confirming the secondary fault was isolated, IPL crews prepared to enter and inspect manholes M42-02 and M42-03. Prior to entering the manholes both manholes required to have water pumped out.

Upon entering the manholes the IPL Crews observed indications of a secondary cable fault in a duct line between the M42-02 and M42-03. Three quadraplex secondary cables run north and south on Ogden Street between the two manholes. The phase conductors in each of the sets of quadraplex cable is 350MCM Paper Insulated Lead Cover (PILC) copper conductor and the neutral conductor is a single 4/0 Polyethylene copper wire. Each of the quadraplex cable configurations run in a separate duct line/conduit within the duct bank.

Only one of the quadraplex of cables between manholes M42-02 and M42-03 experienced a fault. Once the faulted cable electrically isolated itself, as designed, the audible sound and visible smoke would have ceased.

IPL crews removed and retained the fault cable section for inspection. The distance between manhole M42-02 and M42-03 is approximately 35'. The faulted cable was manufactured in 1980.

Two of the phase conductors and the neutral conductor sustained damage due the fault. One of the phase conductors melted into two sections. The cable fault occurred approximately 8' to the north of manhole M42-03.

It is thought the rapid heating and expansion of the air (over pressurization) caused the manhole cover to dislodge and become ajar in its supporting ring. Due to the water in the manholes from the previous day's significant rainfall the amount of rapid expansion of the air required to lift the manhole cover would have been greatly reduced due to the fact water is a non-compressible liquid.

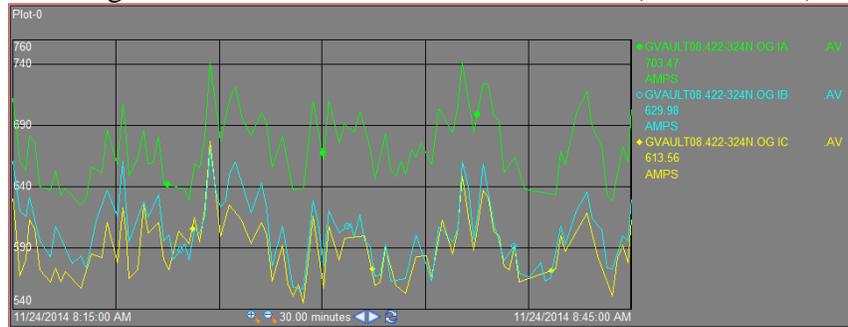
4.1 Downtown Network Supervisory Control and Data Acquisition

The next page contains charts of the three phase currents for the 120/208 Volt side of the following network transformers for the 30 minute time period from 08:15 to 08:45 on November 24th.

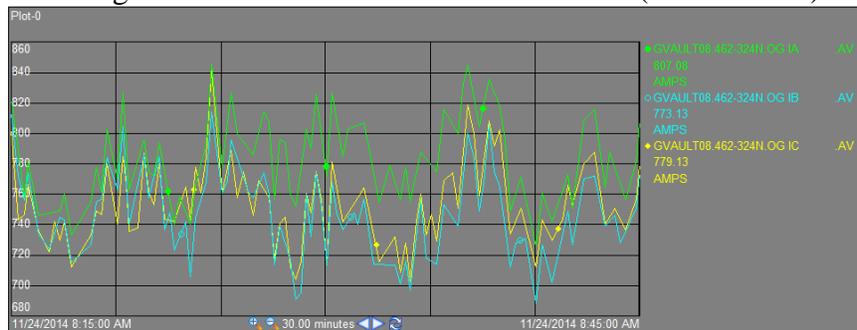
- 324 North Ogden UG 422
- 324 North Ogden UG 462
- 326 East New York UG 412
- 326 East New York UG 442

These transformers are electrical and physical the closest to the fault location. Therefore should be providing the most current during the event. By inspection of the charts you will note an increase of current at approximately 08:25. The maximum current observed is approximately 850 amps on the 1,000kVA transformers and 410 amps on the 500kVA transformers. These peak currents represent approximately 50% of full load rating. (i.e. not enough to trigger an alarm indication).

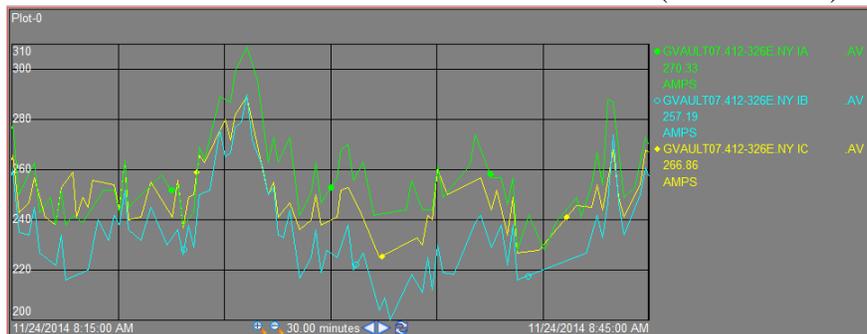
324 North Ogden – UG 422 Transformer – Low Side (120/208 volt) Current



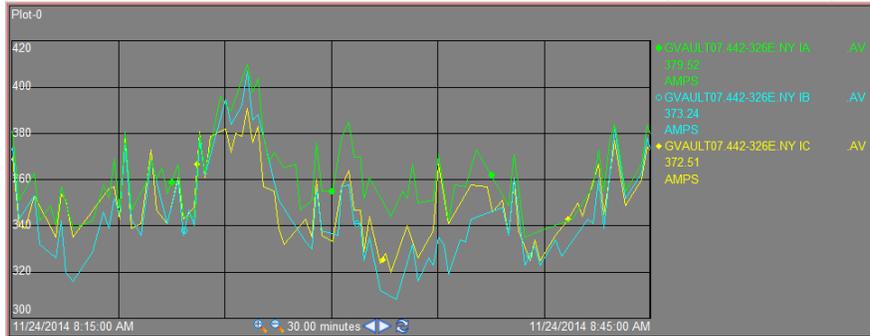
324 North Ogden – UG 462 Transformer – Low Side (120/208 volt) Current



326 East New York – UG 412 Transformer – Low Side (120/208 volt) Current



326 East New York – UG 442 Transformer – Low Side (120/208 volt) Current



4.2 Cable Observations Post Event

IPL retained Rick Leffler to perform a visual inspection of the faulted cable and to provide his opinion. The following information is provided by Rick Leffler:

Visual inspection of a 1000 volt paper insulated lead covered cable composed of 3-350mcm copper conductors and 1-4/0 polyethylene covered copper neutral conductor was performed December 16, 2014 in building B at Morris Street Service Center.

The section of cable is a proximately 6 feet long and contains the faulted area of the cable. This cable is normally quadraplexed cable. The short section would not allow for maintaining the original quadraplexed condition.

Initial inspection indicated approximately 3 feet of the lead jacket of 2 of the 3 conductors sustained damage during the fault condition. Lead had melted away on one side of this 3 feet of cable length exposing the paper insulation. This melted lead jacket was approximately 1/3 of the circumference on the each of the 2 conductors. One of the copper conductors appears to have melted and separated from the original circuit.

The neutral conductor polyethylene jacket is burnt away on half of the circumference. The remaining jacket appears to have melted and taken on a V shape formation. The formation may have occurred during the heating conditions in the V shape formed by the larger conductors and the 4/0 conductor would have laid in the V shaped form in the original quadraplexed cable condition.

The lead jacket was cleaned with cable cleaner and degreaser and rags. Small voids in the jacket approximately 1/8" in size were noted. These holes did not expose the paper insulation. 2 larger breaches in the jacket were noted approximately 12" from the end of the melted lead area. This breach was 2" long, 1/4" wide. The other breach was about 1/2" in diameter. Paper insulation was exposed at both locations. The longer breach may have been caused

mechanically. When the damage occurred is uncertain. Given the edges of the openings were not shiny before the cable cleaning and degreasing, this damage may have occurred when the cable was installed, not when cable was recently removed after the fault. See picture below.



This breach is located 180 degrees opposite in circumference from where the lead melted away at the fault location of this section of cable. Depending on the orientation of the conductor, it is plausible that oil may have escaped through the breach causing the paper insulation to dry thus degrading the insulation integrity of the paper resulting in the fault.

Length of the duct bank is 35'. Duct bank is composition is 9-4" F. (9 – 4" fiber conduits) The Damage described above in the lead jacket could have occurred before the cable was installed and not noticed during the installation.

5.0 Conclusions

The cable failure was due to the breach in the lead jacket. Over time the breach allowed insulating oil to seep out of the paper insulation. The paper insulation may have become dry over time and allowed water from the previous day's significant rainfall to enter the paper thus reducing the dielectric properties of the paper which was a catalyst to the secondary cable fault.

As a result of the previous day's significant rain fall the air space in the manholes was greatly reduced. This reduction of air space by a non-compressible liquid (water) reduced the amount of rapid expansion of the atmospheric air required to lift the manhole cover.