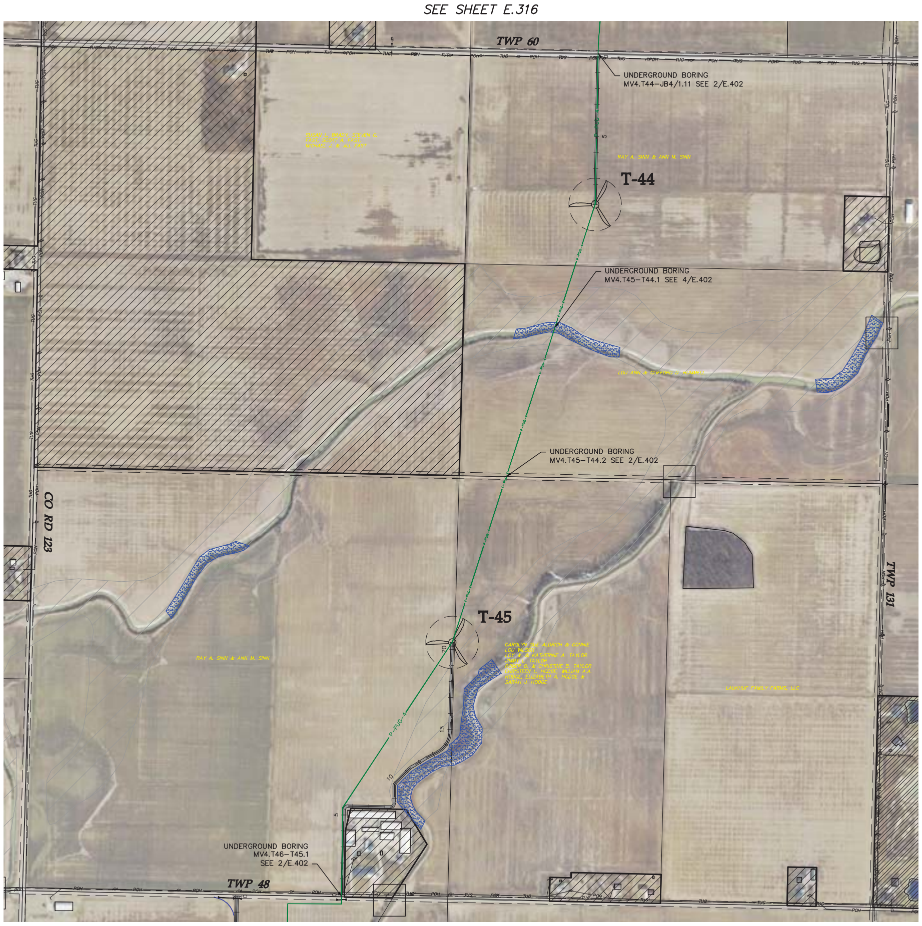
©2017 Westwood Professional Services, Inc.

SEE SHEET E.316

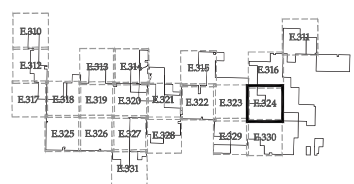
SEE SHEET E.323



SEE SHEET E.330

LEGEND

	TURBINE LOCATION
T-XX	TURBINE NUMBER
P-PUG-1	PROPOSED CIRCUIT 1
P-PUG-2	PROPOSED CIRCUIT 2
P-PUG-3	PROPOSED CIRCUIT 3
P-PUG-4	PROPOSED CIRCUIT 4
	DELINEATED WETLAND
	NON-PARTICIPATING PROPERTY



KEY MAP

Westwood
Phone (952) 937-5150 7699 Anagram Drive
Fax (952) 937-5822 Eden Prairie, MN 55344
Toll Free (888) 937-5150 westwoodps.com
Westwood Professional Services, Inc.

Designed: JRV
Checked: ANS
Drawn: JMC, JRG
As-Built Drawing:

Revisions:

#	DATE	DESCRIPTION
A	09/27/17	30% plans
B	10/03/17	Issued for Procurement – Revised
C	10/19/17	60% plans
D	10/30/17	90% plans

Prepared for:

WHITE an IEA company
3900 E. White Ave
Clinton, IN 47842

Trishe Wind Ohio, LLC
c/o Starwood Energy Group, LLC
5 Greenwich Office Park, 2nd Floor
Greenwich, CT 06831

0' 300' 600' 900'

Northwest Ohio Wind Project

Paulding County, Ohio

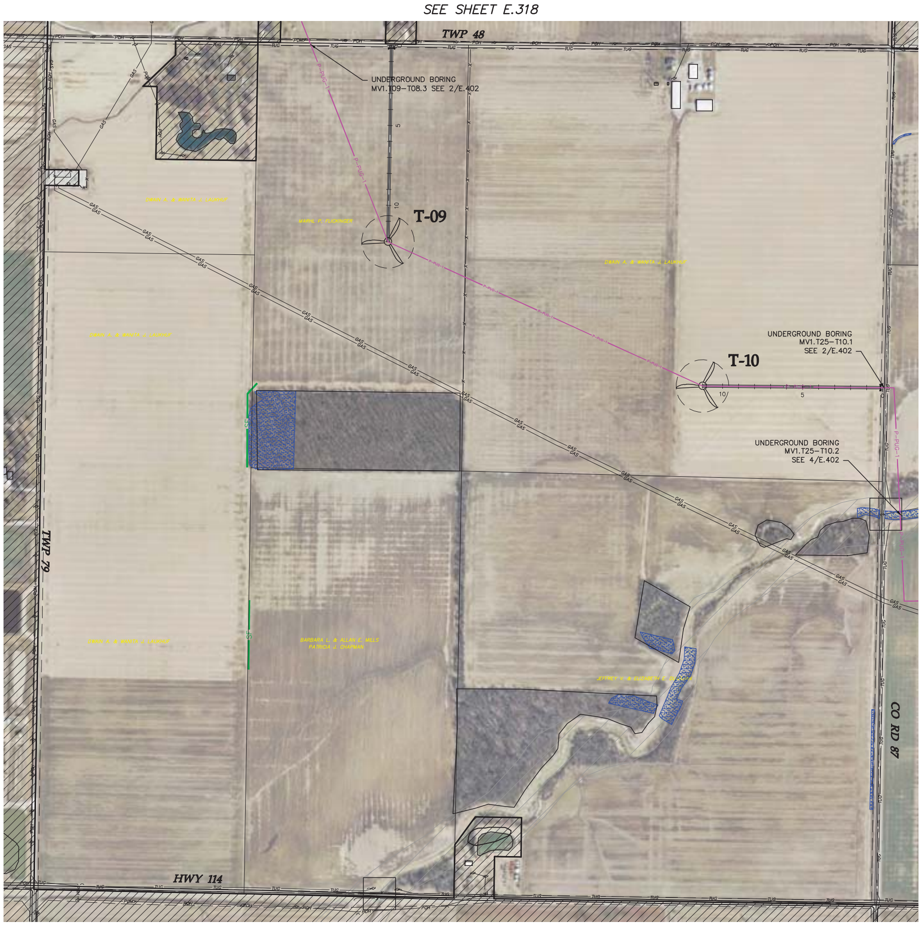
Electrical Site Plan

Not For Construction

Array Date: 09/14/2017
Date: 10/30/2017
Sheet: E.324

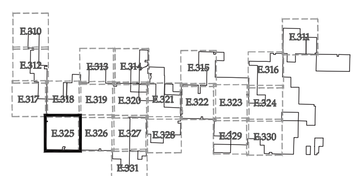
0007186_Electrical Site Plans.dwg

©2017 Westwood Professional Services, Inc.



LEGEND

(turbine symbol)	TURBINE LOCATION
T-XX	TURBINE NUMBER
P-PUG-1	PROPOSED CIRCUIT 1
P-PUG-2	PROPOSED CIRCUIT 2
P-PUG-3	PROPOSED CIRCUIT 3
P-PUG-4	PROPOSED CIRCUIT 4
(hatch)	DELINEATED WETLAND
(hatch)	NON-PARTICIPATING PROPERTY



KEY MAP

Westwood
Phone (952) 937-5150 7699 Anagram Drive
Fax (952) 937-5822 Eden Prairie, MN 55344
Toll Free (888) 937-5150 westwoodps.com
Westwood Professional Services, Inc.

Designed: JRV
Checked: ANS
Drawn: JMC, JRG
As-Built Drawing:

Revisions:

#	DATE	DESCRIPTION
A	09/27/17	30% plans
B	10/03/17	Issued for Procurement – Revised
C	10/19/17	60% plans
D	10/30/17	90% plans

Prepared for:

WHITE
an IEA company
3900 E. White Ave
Clinton, IN 47842

Trishe Wind Ohio, LLC
c/o Starwood Energy Group, LLC
5 Greenwich Office Park, 2nd Floor
Greenwich, CT 06831

0' 300' 600' 900'

Northwest Ohio Wind Project

Paulding County, Ohio

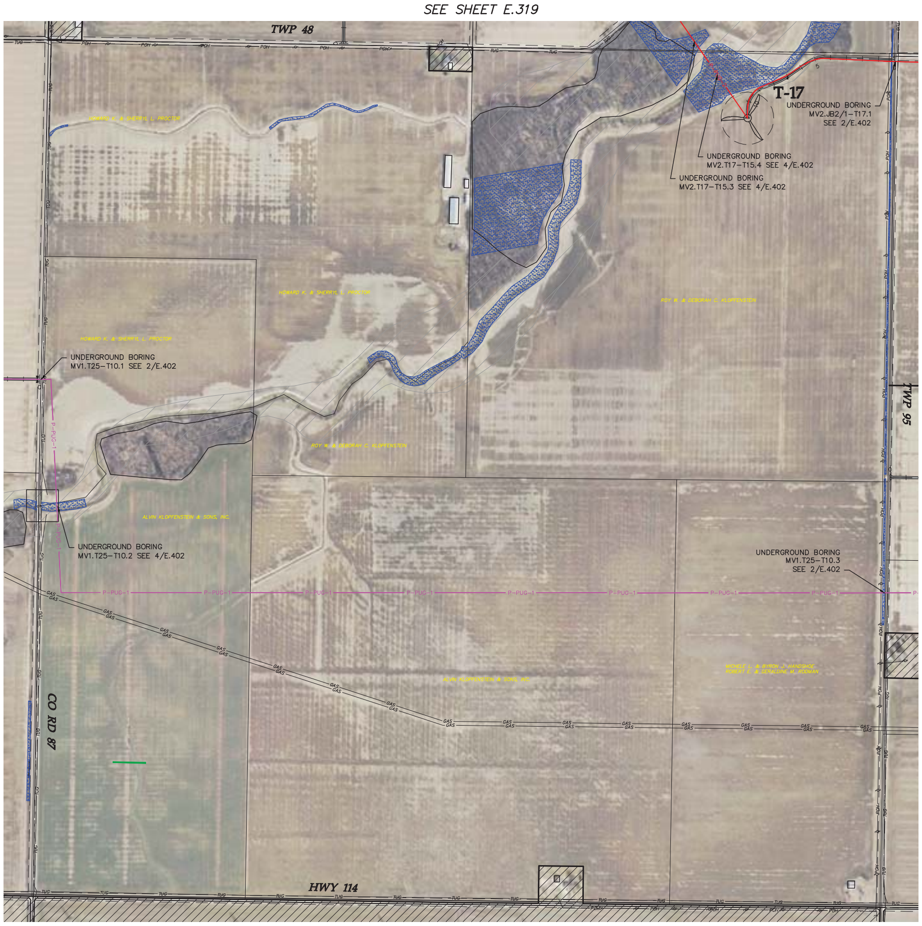
Electrical Site Plan

Not For Construction
Array Date: 09/14/2017
Date: 10/30/2017
Sheet: E.325
0007186_Electrical Site Plans.dwg

©2017 Westwood Professional Services, Inc.

1 2 3 4 5 6 7 8

SEE SHEET E.319

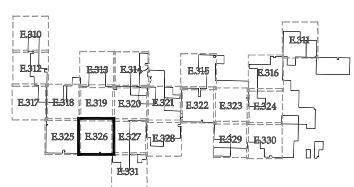


SEE SHEET E.325

SEE SHEET E.327

LEGEND

	TURBINE LOCATION
T-XX	TURBINE NUMBER
P-PUG-1	PROPOSED CIRCUIT 1
P-PUG-2	PROPOSED CIRCUIT 2
P-PUG-3	PROPOSED CIRCUIT 3
P-PUG-4	PROPOSED CIRCUIT 4
	DELINEATED WETLAND
	NON-PARTICIPATING PROPERTY



KEY MAP

Westwood
Phone (952) 937-5150 7699 Anagram Drive
Fax (952) 937-5822 Eden Prairie, MN 55344
Toll Free (888) 937-5150 westwoodps.com
Westwood Professional Services, Inc.

Designed: JRV
Checked: ANS
Drawn: JMC, JRG
As-Built Drawing:

Revisions:

#	DATE	DESCRIPTION
A	09/27/17	30% plans
B	10/03/17	Issued for Procurement - Revised
C	10/19/17	60% plans
D	10/30/17	90% plans

Prepared for:

WHITE

3900 E. White Ave
Clinton, IN 47842

Trishe Wind Ohio, LLC
c/o Starwood Energy Group, LLC
5 Greenwich Office Park, 2nd Floor
Greenwich, CT 06831

N

0' 300' 600' 900'

Northwest Ohio Wind Project

Paulding County, Ohio

Electrical Site Plan

Not For Construction

Array Date: 09/14/2017

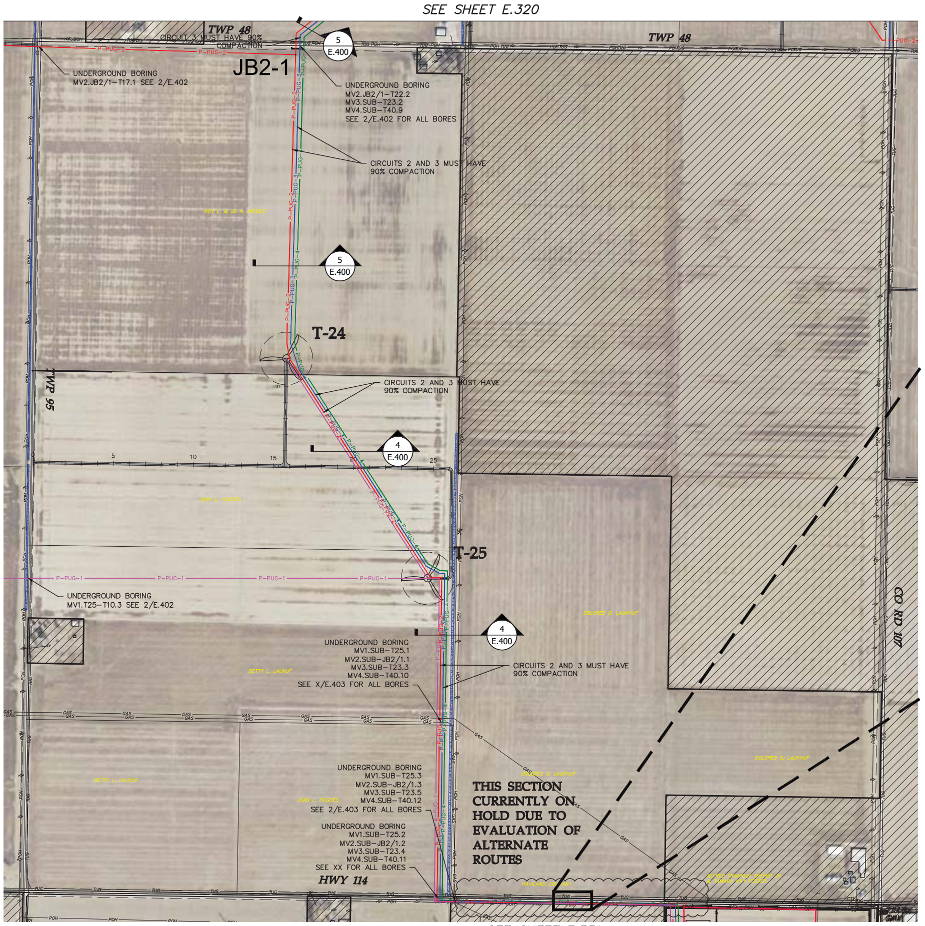
Date: 10/30/2017

Sheet: E.326

0007186_Electrical Site Plans.dwg

©2017 Westwood Professional Services, Inc.

SEE SHEET E.320



SEE SHEET E.326

SEE SHEET E.328

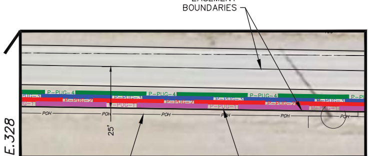
SEE SHEET E.331

LEGEND

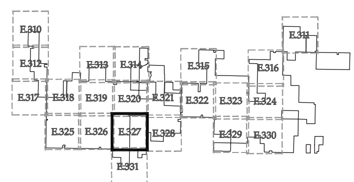
	TURBINE LOCATION
T-XX	TURBINE NUMBER
P-PUG-1	PROPOSED CIRCUIT 1
P-PUG-2	PROPOSED CIRCUIT 2
P-PUG-3	PROPOSED CIRCUIT 3
P-PUG-4	PROPOSED CIRCUIT 4
	DELINEATED WETLAND
	NON-PARTICIPATING PROPERTY

KEY NOTES

1. 34.5KV COLLECTOR CIRCUITS 1,2,3 AND 4 CONTAINED WITHIN 25' EASEMENT ON SOUTH SIDE OF HWY 114 FOR EAST TO WEST RUN.



NO SCALE



KEY MAP

Westwood
Phone (952) 937-5150 7699 Anagram Drive
Fax (952) 937-5822 Eden Prairie, MN 55344
Toll Free (888) 937-5150 westwoodps.com
Westwood Professional Services, Inc.

Designed: JRV
Checked: ANS
Drawn: JMC, JRG
As-Built Drawing:

Revisions:

#	DATE	DESCRIPTION
A	09/27/17	30% plans
B	10/03/17	Issued for Procurement - Revised
C	10/19/17	60% plans
D	10/30/17	90% plans

Prepared for:

WHITE an IEA company
3900 E. White Ave
Clinton, IN 47842

Trishe Wind Ohio, LLC
c/o Starwood Energy Group, LLC
5 Greenwich Office Park, 2nd Floor
Greenwich, CT 06831

N

0' 300' 600' 900'

Northwest Ohio Wind Project
Paulding County, Ohio

Electrical Site Plan

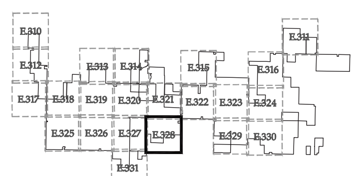
Not For Construction
Array Date: 09/14/2017
Date: 10/30/2017
Sheet: E.327

0007186_Electrical Site Plans.dwg

©2017 Westwood Professional Services, Inc.

LEGEND

	TURBINE LOCATION
T-XX	TURBINE NUMBER
P-PUG-1	PROPOSED CIRCUIT 1
P-PUG-2	PROPOSED CIRCUIT 2
P-PUG-3	PROPOSED CIRCUIT 3
P-PUG-4	PROPOSED CIRCUIT 4
	DELINEATED WETLAND
	NON-PARTICIPATING PROPERTY



KEY MAP

Westwood
Phone (952) 937-5150 7699 Anagram Drive
Fax (952) 937-5822 Eden Prairie, MN 55344
Toll Free (888) 937-5150 westwoodps.com
Westwood Professional Services, Inc.

Designed: JRV
Checked: ANS
Drawn: JMC, JRG
As-Built Drawing:

Revisions:

#	DATE	DESCRIPTION
A	09/27/17	30% plans
B	10/03/17	Issued for Procurement – Revised
C	10/19/17	60% plans
D	10/30/17	90% plans

Prepared for:

WHITE an IEA company
3900 E. White Ave
Clinton, IN 47842

Trishe Wind Ohio, LLC
c/o Starwood Energy Group, LLC
5 Greenwich Office Park, 2nd Floor
Greenwich, CT 06831

N

0' 300' 600' 900'

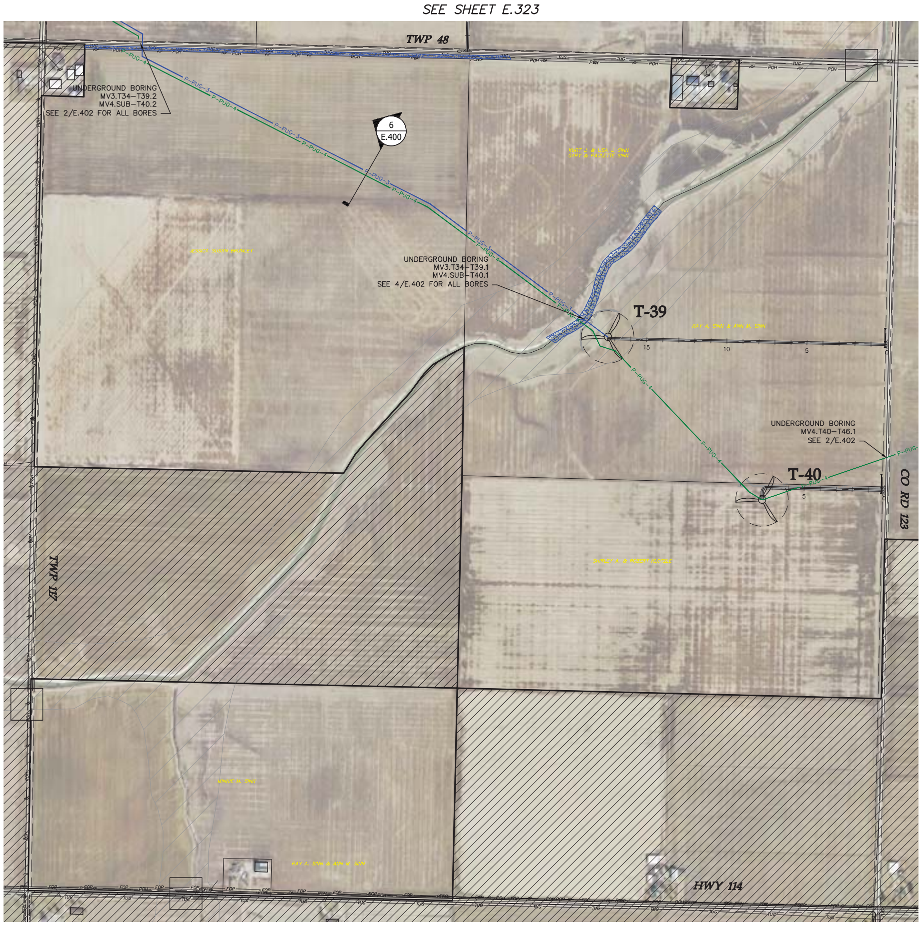
Northwest Ohio Wind Project
Paulding County, Ohio

Electrical Site Plan

Not For Construction
Array Date: 09/14/2017
Date: 10/30/2017
Sheet: E.328

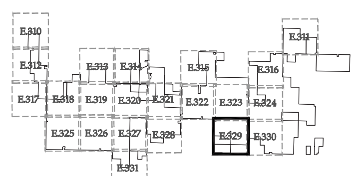
0007186_Electrical Site Plans.dwg

©2017 Westwood Professional Services, Inc.



LEGEND

(turbine symbol)	TURBINE LOCATION
T-XX	TURBINE NUMBER
P-PUG-1	PROPOSED CIRCUIT 1
P-PUG-2	PROPOSED CIRCUIT 2
P-PUG-3	PROPOSED CIRCUIT 3
P-PUG-4	PROPOSED CIRCUIT 4
(dotted fill)	DELINEATED WETLAND
(hatched fill)	NON-PARTICIPATING PROPERTY



KEY MAP

Westwood

Phone (952) 937-5150 7699 Anagram Drive
Fax (952) 937-5822 Eden Prairie, MN 55344
Toll Free (888) 937-5150 westwoodps.com

Westwood Professional Services, Inc.

Designed: JRV
Checked: ANS
Drawn: JMC, JRG
As-Built Drawing:

Revisions:

#	DATE	DESCRIPTION
A	09/27/17	30% plans
B	10/03/17	Issued for Procurement – Revised
C	10/19/17	60% plans
D	10/30/17	90% plans

Prepared for:

WHITE an IEA company

3900 E. White Ave
Clinton, IN 47842

Trishe Wind Ohio, LLC
c/o Starwood Energy Group, LLC
5 Greenwich Office Park, 2nd Floor
Greenwich, CT 06831

N

0' 300' 600' 900'

Northwest Ohio Wind Project

Paulding County, Ohio

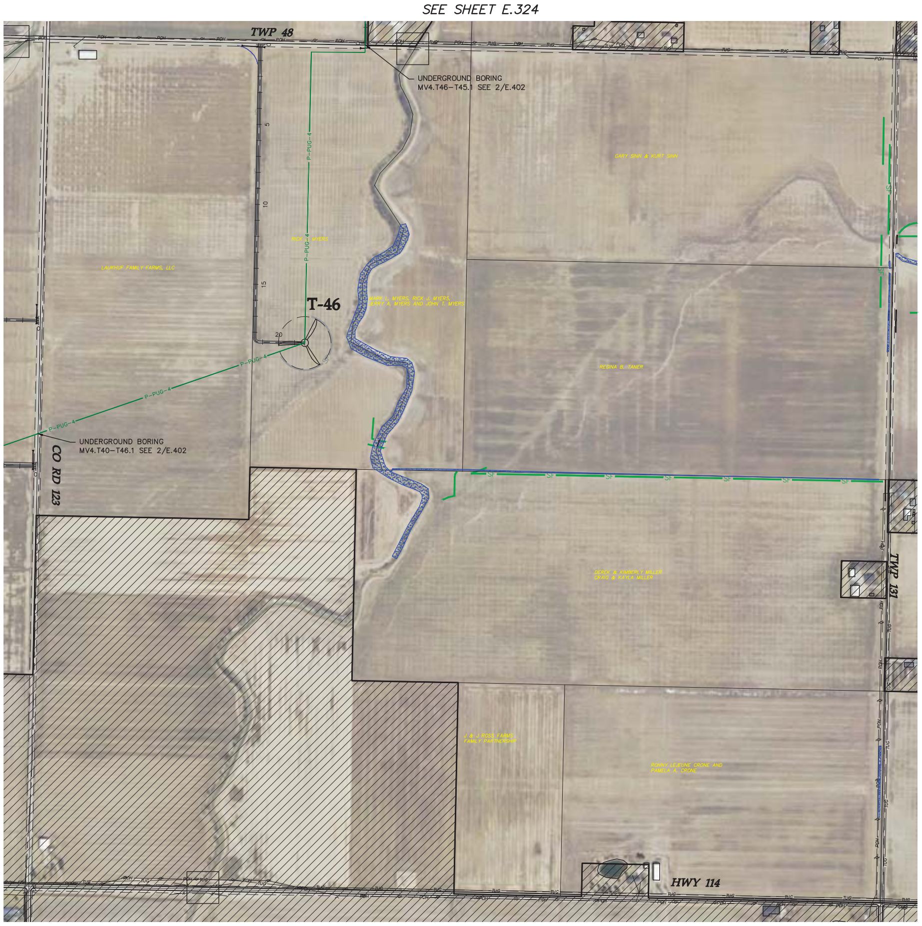
Electrical Site Plan

Not For Construction

Array Date: 09/14/2017
Date: 10/30/2017
Sheet: E.329

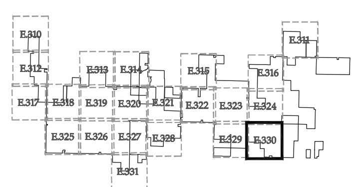
0007186_Electrical Site Plans.dwg

©2017 Westwood Professional Services, Inc.



LEGEND

(symbol)	TURBINE LOCATION
T-XX	TURBINE NUMBER
P–PUG–1	PROPOSED CIRCUIT 1
P–PUG–2	PROPOSED CIRCUIT 2
P–PUG–3	PROPOSED CIRCUIT 3
P–PUG–4	PROPOSED CIRCUIT 4
(pattern)	DELINEATED WETLAND
(hatch)	NON–PARTICIPATING PROPERTY



KEY MAP

Westwood

Phone (952) 937-5150 7699 Anagram Drive
Fax (952) 937-5822 Eden Prairie, MN 55344
Toll Free (888) 937-5150 westwoodps.com
Westwood Professional Services, Inc.

Designed: JRV
Checked: ANS
Drawn: JMC, JRG
As-Built Drawing:

Revisions:

#	DATE	DESCRIPTION
A	09/27/17	30% plans
B	10/03/17	Issued for Procurement – Revised
C	10/19/17	60% plans
D	10/30/17	90% plans

Prepared for:

WHITE
an IEA company

3900 E. White Ave
Clinton, IN 47842

Trishe Wind Ohio, LLC
c/o Starwood Energy Group, LLC
5 Greenwich Office Park, 2nd Floor
Greenwich, CT 06831

0' 300' 600' 900'

Northwest Ohio Wind Project

Paulding County, Ohio

Electrical Site Plan

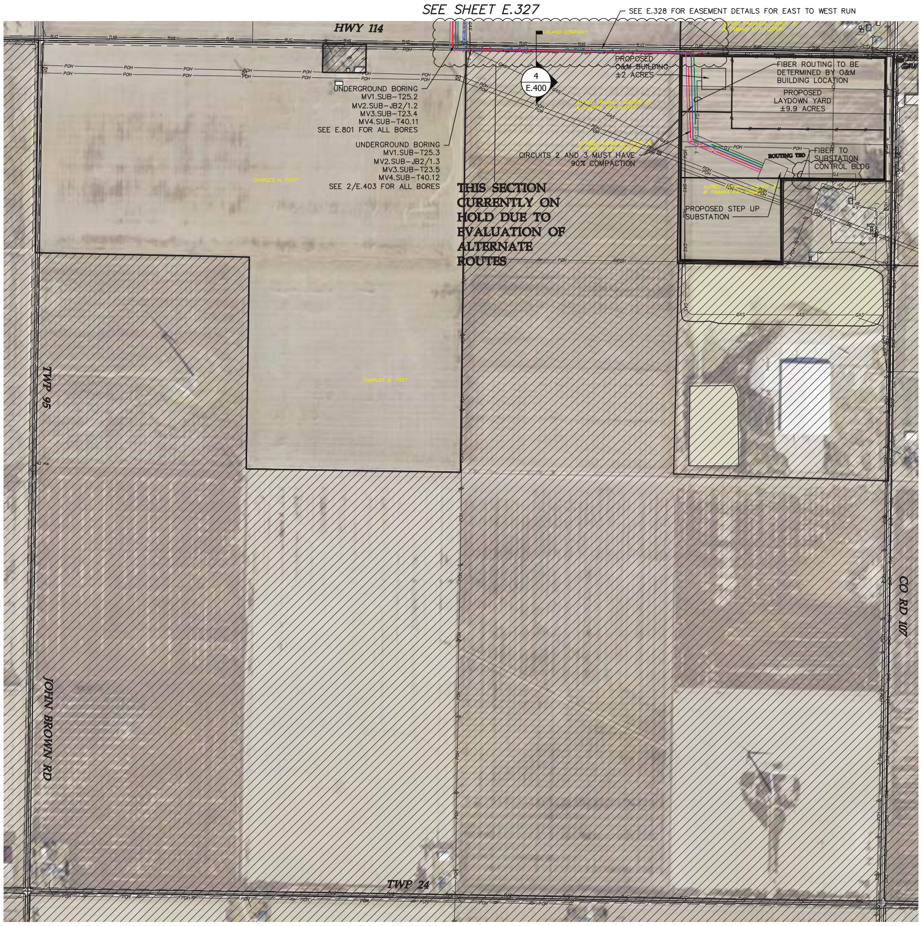
Not For Construction

Array Date: 09/14/2017
Date: 10/30/2017
Sheet: E.330

0007186_Electrical Site Plans.dwg

©2017 Westwood Professional Services, Inc.

SEE SHEET E.327

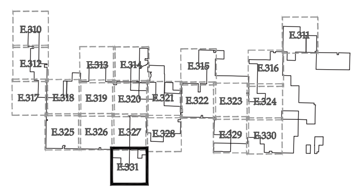


LEGEND

T-XX	TURBINE LOCATION
T-XX	TURBINE NUMBER
P-PUG-1	PROPOSED CIRCUIT 1
P-PUG-2	PROPOSED CIRCUIT 2
P-PUG-3	PROPOSED CIRCUIT 3
P-PUG-4	PROPOSED CIRCUIT 4
	DELINEATED WETLAND
	NON-PARTICIPATING PROPERTY

GENERAL NOTES

1. FIBER OPTIC RUN BETWEEN COLLECTOR SUBSTATION CONTROL BUILDING AND AEP HAVILAND SUBSTATION CONTROL BUILDING TO CONSIST OF TWO SEPARATE BURIED FIBER OPTIC CABLES INSTALLED IN 1.5" HDPE INNERDUCT. MINIMUM SPACING BETWEEN CABLES TO BE 10'.



KEY MAP

Westwood
Phone (952) 937-5150 7699 Anagram Drive
Fax (952) 937-5822 Eden Prairie, MN 55344
Toll Free (888) 937-5150 westwoodps.com
Westwood Professional Services, Inc.

Designed: JRV
Checked: ANS
Drawn: JMC, JRG
As-Built Drawing:

Revisions:

#	DATE	DESCRIPTION
A	09/27/17	30% plans
B	10/03/17	Issued for Procurement – Revised
C	10/19/17	60% plans
D	10/30/17	90% plans

Prepared for:

WHITE an EDEA company
3900 E. White Ave
Clinton, IN 47842

Trishe Wind Ohio, LLC
c/o Starwood Energy Group, LLC
5 Greenwich Office Park, 2nd Floor
Greenwich, CT 06831

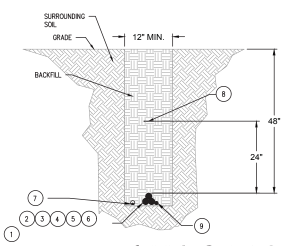
N
0' 300' 600' 900'

Northwest Ohio Wind Project
Paulding County, Ohio

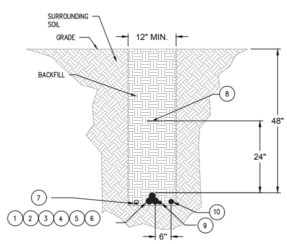
Electrical Site Plan

Not For Construction
Array Date: 09/14/2017
Date: 10/30/2017
Sheet: E.331
0007186_Electrical Site Plans.dwg

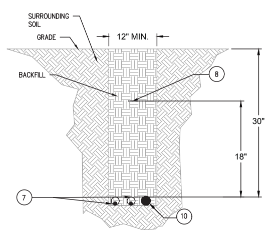
©2017 Westwood Professional Services, Inc.



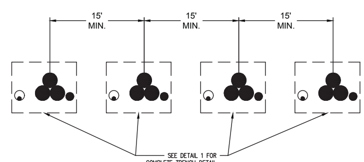
1 Typical MVAC & FO Trench
NTS



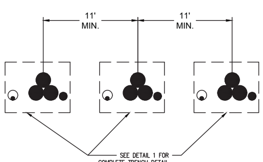
2 MVAC, FO AND LVAC TRENCH
NTS



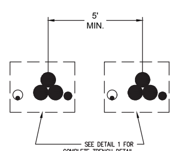
3 FO AND LVAC TRENCH
NTS



4 TRENCH SPACING - FOUR CIRCUITS
NTS



5 TRENCH SPACING - THREE CIRCUITS
NTS



6 TRENCH SPACING - TWO CIRCUITS
NTS

MATERIAL LIST

ITEM	QTY	UNIT	DESCRIPTION		
1	A/R	FT	CABLE, 35 KV MV-90 1/0 AWG AL, 2/3 CN – 11 #14 CU		
2	A/R	FT	CABLE, 35 KV MV-90 4/0 AWG AL, 1/2 CN – 16 #14 CU		
3	A/R	FT	CABLE, 35 KV MV-90 500 KCMIL AL, 1/3 CN – 16 #12 CU		
4	A/R	FT	CABLE, 35 KV MV-90 750 KCMIL AL, 1/6 CN – 19 #14 CU		
5	A/R	FT	CABLE, 35 KV MV-90 1000 KCMIL AL, 1/6 CN – 16 #12 CU		
6	A/R	FT	CABLE, 35 KV MV-90 1250 KCMIL AL, 1/6 CN – 20 #12 CU		
7	A/R	FT	CABLE, 12 COUNT SM (9/125) FIBER OPTIC, IN 1.5" INNERDUCT, NON-ARMORED		
8	A/R	FT	UG UTILITY RED WARNING TAPE		
9	A/R	FT	7#7 COPPER CLAD STEEL, 40% CONDUCTIVITY		
10	A/R	FT	CABLE, 600V, TYPE TC		

GENERAL NOTES

1. EACH CIRCUIT CONSISTS OF 3-1/0 AWG AL, 4/0 AWG AL, 500 KCMIL AL, 750 KCMIL AL, 1000 KCMIL AL, OR 1250 KCMIL AL MEDIUM VOLTAGE CABLES (1 PER PHASE).
2. EXCLUDE HEAVY STIFF CLAY, ROCKS, OR OTHER UNDERSTANDABLE BACKFILL WITHIN 12 INCHES OF CABLES
3. POWER CABLES INSTALLED IN TRIPLEX CONFIGURATION.
4. COMPACT NATIVE SOIL TO BE (TBD) STANDARD PROCTOR DENSITY FOR ALL TRENCH WORK UNLESS OTHERWISE SPECIFIED.
5. NO ENGINEERED BACKFILL REQUIRED.
6. WARNING TAPE TO HAVE WHITE TEXT STATING "CAUTION BURIED HIGH VOLTAGE LINE BELOW".
7. REQUIRED TRENCH BACKFILL COMPACTION TO BE 85% STANDARD PROCTOR EXCEPT FOR THE FOLLOWING, WHICH REQUIRE 90% STANDARD PROCTOR:
   MV CABLE SECTIONS: MV2.SUB-JB2/1, MV3.SUB-T23

Westwood
Phone (952) 937-5150 7699 Anagram Drive
Fax (952) 937-5822 Eden Prairie, MN 55344
Toll Free (888) 937-5150 westwoodps.com
Westwood Professional Services, Inc.

Designed: JRV
Checked: ANS
Drawn: JMC, JRG
As-Built Drawing:

Revisions:

#	DATE	DESCRIPTION
A	09/27/17	30% plans
B	10/03/17	Issued for Procurement – Revised
C	10/19/17	60% plans
D	10/30/17	90% plans

Prepared for:

WHITE
an EIEA company

3900 E. White Ave
Clinton, IN 47842

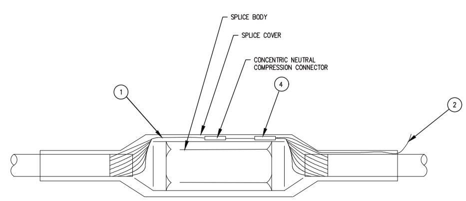
Trishe Wind Ohio, LLC
c/o Starwood Energy Group, LLC
5 Greenwich Office Park, 2nd Floor
Greenwich, CT 06831

Northwest Ohio Wind Project
Paulding County, Ohio

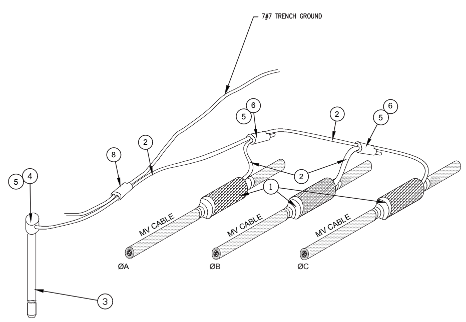
Medium Voltage Trench Details

Not For Construction
Array Date: 09/14/2017
Date: 10/30/2017
Sheet: E.400
0007186_E400_Trench Details.dwg

©2017 Westwood Professional Services, Inc.



1 Splice Detail
NTS



2 SPLICE ARRANGEMENT DETAIL
NTS

MATERIAL LIST

ITEM	QTY	UNIT	DESCRIPTION		
1A		EA	SPLICE KIT, CABLE, 1/0 AWG AL, 345 MIL, 35 KV		
1B		EA	SPLICE KIT, CABLE, 4/0 AWG AL, 345 MIL, 35 KV		
1C		EA	SPLICE KIT, CABLE, 500 KCMIL AL, 345 MIL, 35 KV		
1D		EA	SPLICE KIT, CABLE, 750 KCMIL AL, 345 MIL, 35 KV		
1E		EA	SPLICE KIT, CABLE, 1000 KCMIL AL, 345 MIL, 35 KV		
1F		EA	SPLICE KIT, CABLE, 1250 KCMIL AL, 345 MIL, 35 KV		
2		FT	WIRE, 2 AWG, SOLID CU, BARE		
3		EA	GROUND ROD, 5/8" X 8', 13 MIL COPPER CLAD		
4		EA	COMPRESSION CONNECTOR, CN TO CN		
5		EA	COMPRESSION CONNECTOR 2 AWG CU TO 5/8"" X 8' GROUND ROD		
6		EA	COMPRESSION CONNECTOR, 2 AWG TO 2 AWG CU		
7		EA	UNDERGROUND UTILITY MARKER BALL LOCATOR		
8		EA	COMPRESSION CONNECTOR, #2 AWG CU TO 7#7 CCS		
9		EA	MARKER BALL		

GENERAL NOTES

1. SPLICE KIT INCLUDES SPLICE BODY, SPLICE COVER AND COMPRESSION CONNECTOR.
2. PERFORM ALL SPLICES USING MANUFACTURER'S INSTRUCTIONS.
3. PLACE MARKER BALL ABOVE SPLICE AT 30" DEPTH.
4. SPLICE LOCATION TO BE COMPLETED PER GENERAL TRENCH COMPACTION SPEC.

Westwood
Phone (952) 937-5150 7699 Anagram Drive
Fax (952) 937-5822 Eden Prairie, MN 55344
Toll Free (888) 937-5150 westwoodps.com
Westwood Professional Services, Inc.

Designed: JRV
Checked: ANS
Drawn: JMC, JRG
As-Built Drawing:

Revisions:

#	DATE	DESCRIPTION
A	09/27/17	30% plans
B	10/03/17	Issued for Procurement – Revised
C	10/19/17	60% plans
D	10/30/17	90% plans

Prepared for:

WHITE an IEA company

3900 E. White Ave
Clinton, IN 47842

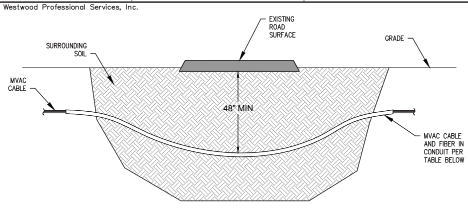
Trishe Wind Ohio, LLC
c/o Starwood Energy Group, LLC
5 Greenwich Office Park, 2nd Floor
Greenwich, CT 06831

Northwest Ohio Wind Project
Paulding County, Ohio

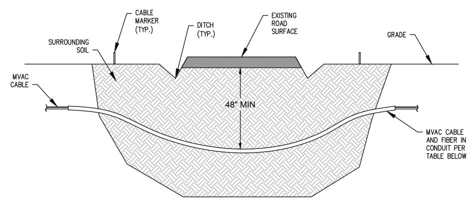
Medium Voltage Underground Cable Splice

Not For Construction
Array Date: 09/14/2017
Date: 10/30/2017
Sheet: E.401
0007186_E400_MV Details and Crossing.dwg

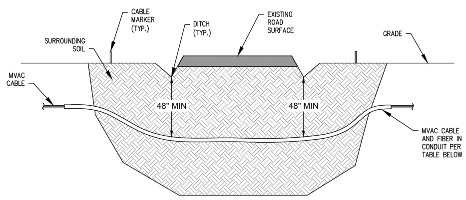
©2017 Westwood Professional Services, Inc.



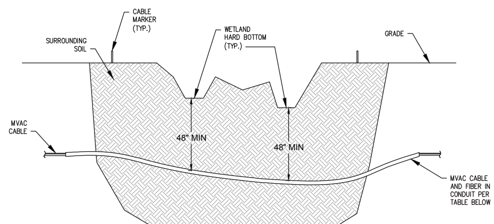
1 Typical MVAC Crossing Access Road Boring Detail
NTS



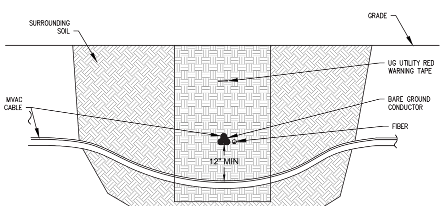
2 Typical MVAC Crossing County Road Boring Detail
NTS



3 Typical MVAC Crossing State Highway Boring Detail
NTS



4 Typical MVAC Crossing Wetland Boring Detail
NTS



5 Typical MVAC Crossing MVAC Trench Detail
NTS

CONDUIT TABLE					
MV CABLE SIZE	1/0 AWG	4/0 AWG	500 kCMIL	1000 kCMIL	1250 kCMIL
MIN. CONDUIT SIZE	6" HDPE DR17	6" HDPE DR17	8" HDPE DR17	8" HDPE DR17	8" HDPE DR17

GENERAL NOTES

1. SEAL ALL CONDUITS WITH FOAM AFTER CABLE INSTALLATION.
2. EXISTING PIPELINE LOCATIONS & DEPTHS TO BE DETERMINED BY OTHERS WITH ELECTRONIC MEANS IN ADVANCE OF CONSTRUCTION.
3. INSTALL EROSION CONTROL MEASURES BEFORE LAND DISTURBANCE BEGINS AROUND WETLANDS.
4. CROSS WETLANDS IN AREAS THAT MINIMIZE THE EXTENT AND DEGREE OF DISTURBANCE AND IS AS PERPENDICULAR TO BANKS AS POSSIBLE. FOLLOW STREAM AND WATERWAY CROSSING PERMIT REQUIREMENTS.
5. LOCATE ALL SOIL STOCKPILES OUTSIDE OF EMBANKMENTS OF WATER BODIES, DITCHES OR OTHER CONVEYANCE SYSTEMS, OR AS REQUIRED BY PERMITS.
6. DO NOT STORE EQUIPMENT SOLID WASTE, OR PETROCHEMICAL PRODUCTS BELOW THE ORDINARY HIGH WATER MARK OF ANY DITCH OR STREAM.
7. UPON COMPLETION OF THE WORK, ALL AREAS ON OR ALONG THE BANKS OF STREAMS MUST BE SEEDED TO NATIVE GRASS.
8. FOR BORE LOCATION WITH MULTIPLE CIRCUITS, SEE BORE SCHEDULE E.801 FOR REQUIRED BORE SPACING.

Westwood
Phone (952) 937-5150 7699 Anagram Drive
Fax (952) 937-5822 Eden Prairie, MN 55344
Toll Free (888) 937-5150 westwoodps.com
Westwood Professional Services, Inc.

Designed: JRV
Checked: ANS
Drawn: JMC, JRG
As-Built Drawing:

Revisions:

#	DATE	DESCRIPTION
A	09/27/17	30% plans
B	10/03/17	Issued for Procurement – Revised
C	10/19/17	60% plans
D	10/30/17	90% plans

Prepared for:

WHITE an IEA company
3900 E. White Ave
Clinton, IN 47842

Trishe Wind Ohio, LLC
c/o Starwood Energy Group, LLC
5 Greenwich Office Park, 2nd Floor
Greenwich, CT 06831

Northwest Ohio Wind Project
Paulding County, Ohio

Medium Voltage & FO Crossing Details

Not For Construction
Array Date: 09/14/2017
Date: 10/30/2017
Sheet: E.402
0007186_E400_MV Details and Crossing.dwg

©2017 Westwood Professional Services, Inc.

GENERAL NOTES - TRANSCANADA PIPELINE CROSSINGS

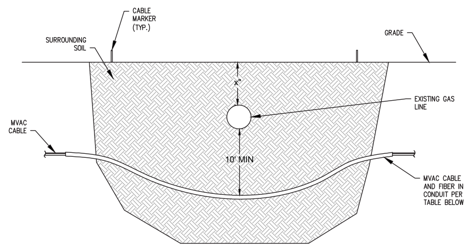
1. THE TOP SIDE OF ALL TRANSCANADA PIPELINES OR BURIED FACILITIES MUST BE EXPOSED BY HAND DIGGING OR HYDROVAC.
2. SIGHT HOLES MUST BE EXCAVATED AT A MIN. OF 5 FEET FROM THE SIDE (NEAREST TO THE DRILL) OF EACH BURIED FACILITY, AND PARALLEL TO THE EXISTING TRANSCANADA BURIED FACILITY.
3. BORE PITS REQUIRING SETUP AND STAGING OF EQUIPMENT SHALL BE OUTSIDE OF TRANSCANADA BURIED FACILITY RIGHT OF WAY.
4. THE NEW CROSSING FACILITY SHOULD MAINTAIN A CONTINUOUS DEPTH OR CONSISTENT PROFILE AND STRAIGHT HORIZONTAL ALIGNMENT ACROSS THE FULL LENGTH OF THE RIGHT OF WAY.
5. CROSSING MUST PASS TRANSCANADA FACILITY WITH A MIN. CLEARANCE OF 8 FEET.
6. CABLE CROSSING SHOULD BE CLEARLY AND PERMANENTLY MARKED ON EACH SIDE OF THE RIGHT OF WAY.
7. NO GROUND DISTURBANCE SHALL BE MADE WITHIN TRANSCANADA REPRESENTATIVE. TRANSCANADA WILL ARRANGE FOR A REPRESENTATIVE TO BE ONSITE WHEN WORK IS OCCURRING ON OR NEAR RIGHT OF WAY OR WITHIN 25 FEET OF PIPELINES. AFTER HOURS CALL 800-447-8066.
8. NOTICE OF AT LEAST 72 HOURS IN ADVANCE OF CONSTRUCTION MUST BE PROVIDED. NORTHWEST OHIO WIND PROJECT MUST CONTACT TRANSCANADA REPRESENTATIVE TODD FLORY 419-438-0208.

GENERAL NOTES - PANHANDLE PIPELINE CROSSINGS

1. UNDERGROUND LINE CROSSINGS MUST CROSS AT OR NEAR 90° TO THE PIPELINE.
2. A MINIMUM OF 10' CLEARANCE SHALL BE MAINTAINED FOR THE WIDTH OF THE PIPELINE RIGHT OF WAY.
3. POTHOLES SHALL BE EXCAVATED ON THE APPROACH SIDE OF THE BORE. THE DEPTH OF THE POTHOLE SHALL BE TO A MINIMUM OF 2' BELOW THE BOTTOM OF THE PIPELINE AND IN THE DIRECT PATH OF THE APPROACHING BORE TOOL TO ALLOW VISUAL CONFIRMATION THAT THE BORE TOOL DOES NOT IMPACT THE PIPELINE.
4. POWER LINE CROSSINGS MUST BE CLEARLY MARKED AND IDENTIFIED ON EACH SIDE OF THE PIPELINE EASEMENT.

GENERAL NOTES - DOMINION PIPELINE CROSSINGS

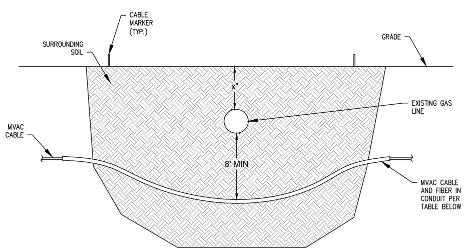
1. ALL BORING MUST MAINTAIN A MIN. OF 1 FOOT CLEARANCE AND POTHOLED.



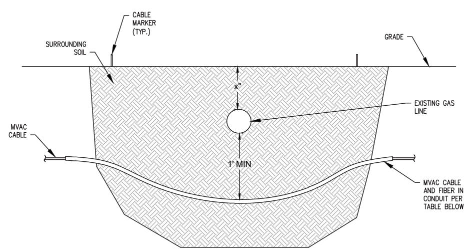
2 Panhandle MVAC Crossing Gas Pipeline Boring Detail
NTS

GENERAL NOTES

1. SEAL ALL CONDUITS WITH FOAM AFTER CABLE INSTALLATION. SEE SHEET E500 FOR MORE INFORMATION.
2. PIPE LINE UTILITY MUST BE CONTACTED AT LEAST 72 HOURS PRIOR TO CONSTRUCTION UNDER
3. EXISTING PIPELINE LOCATIONS & DEPTHS TO BE DETERMINED BY OTHERS WITH ELECTRONIC MEANS IN ADVANCE OF CONSTRUCTION.
4. INSTALL EROSION CONTROL MEASURES BEFORE LAND DISTURBANCE BEGINS AROUND WETLANDS.
5. LOCATE ALL SOIL STOCKPILES OUTSIDE OF EMBANKMENTS OF WATER BODIES, DITCHES OR OTHER CONVEYANCE SYSTEMS, OR AS REQUIRED BY PERMITS.
6. DO NOT STORE EQUIPMENT SOLID WASTE, OR PETROCHEMICAL PRODUCTS BELOW THE ORDINARY HIGH WATER MARK OF ANY DITCH OR STREAM.
7. UPON COMPLETION OF THE WORK, ALL AREAS ON OR ALONG THE BANKS OF STREAMS MUST BE SEEDED TO NATIVE GRASS.
8. FOR BORE LOCATION WITH MULTIPLE CIRCUITS, SEE BORE SCHEDULE E.801 FOR REQUIRED BORE SPACING.



1 TransCanada MVAC Crossing Gas Pipeline Boring Detail
NTS



3 Dominion MVAC Crossing Gas Pipeline Boring Detail
NTS

CONDUIT TABLE					
MV CABLE SIZE	1/0 AWG	4/0 AWG	500 kCMIL	1000 kCMIL	1250 kCMIL
MIN. CONDUIT SIZE	6" HDPE DR17	6" HDPE DR17	8" HDPE DR17	8" HDPE DR17	8" HDPE DR17

Westwood
Phone (952) 937-5150 7699 Anagram Drive
Fax (952) 937-5822 Eden Prairie, MN 55344
Toll Free (888) 937-5150 westwoodps.com
Westwood Professional Services, Inc.

Designed: JRV
Checked: ANS
Drawn: JMC, JRG
As-Built Drawing:

Revisions:

#	DATE	DESCRIPTION
A	09/27/17	30% plans
B	10/03/17	Issued for Procurement – Revised
C	10/19/17	60% plans
D	10/30/17	90% plans

Prepared for:

WHITE an IEA company
3900 E. White Ave
Clinton, IN 47842

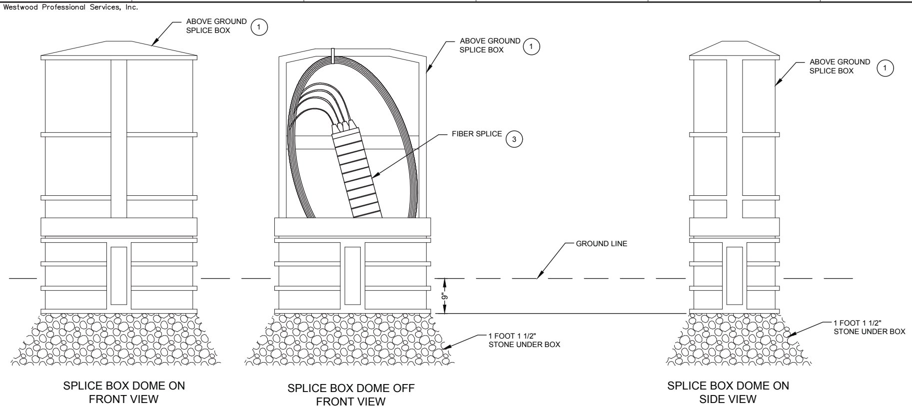
Trishe Wind Ohio, LLC
c/o Starwood Energy Group, LLC
5 Greenwich Office Park, 2nd Floor
Greenwich, CT 06831

Northwest Ohio Wind Project
Paulding County, Ohio

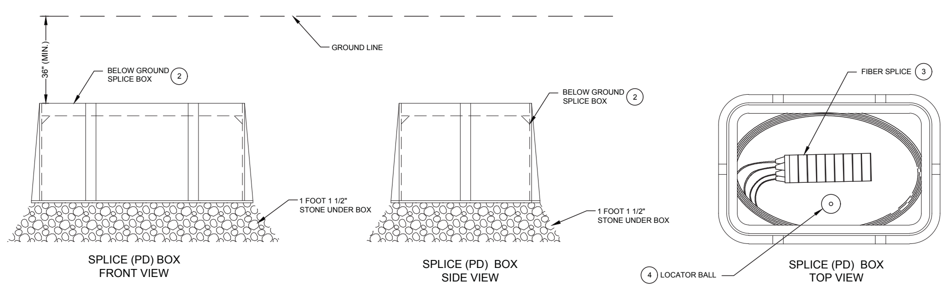
Medium Voltage & FO Crossing Details (2)

Not For Construction
Array Date: 09/14/2017
Date: 10/30/2017
Sheet: E.403
0007186_E400_MV Details and Crossing.dwg

©2017 Westwood Professional Services, Inc.



1 Above Ground Splice Box
NTS



2 Below Ground Splice Box
NTS

MATERIAL LIST

ITEM	QTY	UNIT	DESCRIPTION	MFG.	PART #
1	A/R	EA	ABOVE GROUND FIBER OPTIC SPLICE BOX	X	
2	A/R	EA	BELOW GRADE FIBER SPLICE BOX 24"X36"PD BOX	X	
3	A/R	EA	FIBER SPLICE ENCLOSURE WITH 4 PORT END-PLATE KIT	X	
4	A/R	EA	UNDERGROUND UTILITY MARKER BALL LOCATOR	X	

GENERAL NOTES

1. LEAVE EXTRA 100 FEET OF CABLE IN SPLICE BOX.
2. DO NOT EXCEED THE MINIMUM BEND RADIUS OF 6 INCHES UNDER LOAD AND 4 INCHES WITH NO LOAD.
3. SIZE OF GROMMETS AND CLOSURE ACCESSORIES TO MEET CABLE SIZE AND QUANTITY.
4. BRING CABLE INNER DUCT INTO SPLICE BOX 3 INCHES ABOVE GRAVEL FILL.
5. SEAL ALL CONDUITS WITH FOAM AFTER CABLE INSTALLATION.
6. FILL BOTTOM OF BOXES WITH 9 INCHES PEA GRAVEL TO PREVENT RODENT ENTRY.
7. TAPE OVER BURIED LID SCREWS.

Westwood
Phone (952) 937-5150 7699 Anagram Drive
Fax (952) 937-5822 Eden Prairie, MN 55344
Toll Free (888) 937-5150 westwoodps.com
Westwood Professional Services, Inc.

Designed: JRV
Checked: ANS
Drawn: JMC, JRG
As-Built Drawing:

Revisions:

#	DATE	DESCRIPTION
A	09/27/17	30% plans
B	10/03/17	Issued for Procurement – Revised
C	10/19/17	60% plans
D	10/30/17	90% plans

Prepared for:

WHITE
3900 E. White Ave
Clinton, IN 47842

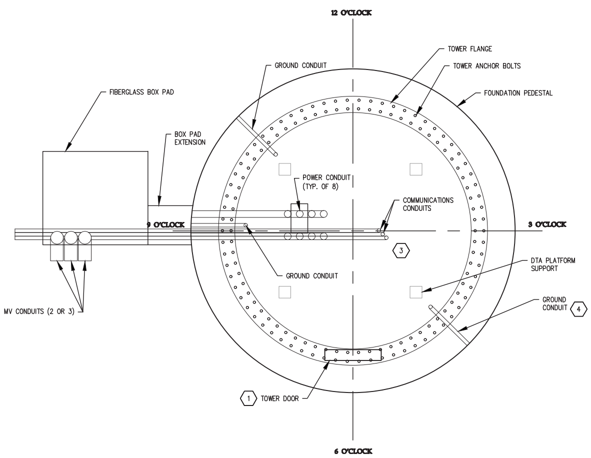
Trishe Wind Ohio, LLC
c/o Starwood Energy Group, LLC
5 Greenwich Office Park, 2nd Floor
Greenwich, CT 06831

Northwest Ohio Wind Project
Paulding County, Ohio

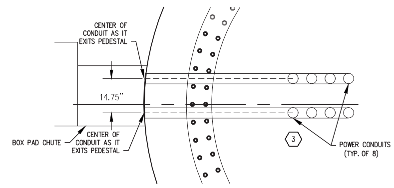
Fiber Splice Box

Not For Construction
Array Date: 09/14/2017
Date: 10/30/2017
Sheet: E.404
0007186_E400_MV Details and Crossing.dwg

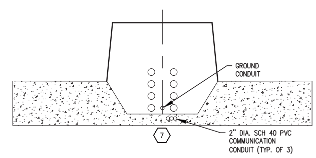
©2017 Westwood Professional Services, Inc.



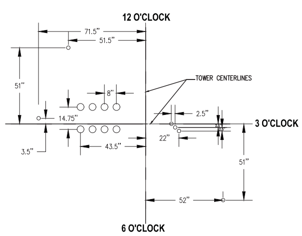
1 Plan View - Turbine Conduits
NTS



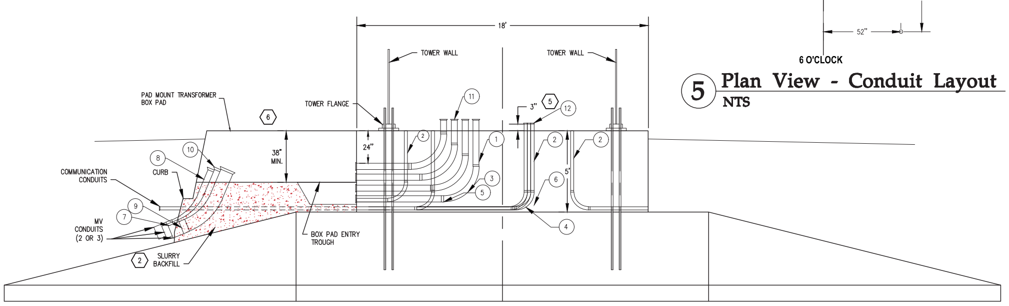
3 Power Conduit Exit From Pedestal
NTS



4 Power Conduit Exit From Pedestal
NTS



5 Plan View - Conduit Layout
NTS



2 Section View - Foundation Elevation
NTS

MATERIAL LIST

ITEM	QTY	UNITS	DESCRIPTION		
1	55	FT	4" PVC CONDUIT SCH. 40		
2	100 OR 75	FT	2" PVC CONDUIT SCH. 40		
3	8	EA	4" PVC CONDUIT SCH. 40, 90 DEGREE SWEEP, 24" RADIUS		
4	5 OR 6	EA	2" PVC CONDUIT SCH. 40, 90 DEGREE SWEEP, 12" RADIUS		
5	16	EA	4" PVC COUPLING		
6	10 OR 12	EA	2" PVC COUPLING		
7	12	FT	8" PVC CONDUIT SCH. 40		
8	3	EA	8" PVC CONDUIT SCH. 40, 45 DEGREE SWEEP, 36" RADIUS		
9	2 OR 3	EA	8" PVC COUPLING		
10	2 OR 3	EA	8" PVC BELL END, SCH. 40		
11	16	EA	4" PVC BELL END, SCH. 40		
12	6	EA	2" PVC BELL END, SCH. 40		

GENERAL NOTES

1. PREVENT CONCRETE FROM ENTERING ALL OPEN CONDUIT ENDS BY INSTALLATION OF CAPS..
2. ALL SPARE CONDUITS SHOULD BE SEALED WITH FLAME RETARDED FOAM AND CAPPED. ALL FLOATING CONDUCTORS IN CONDUIT SHALL BE ENCAPSULATED IN FLAME RETARDANT FOAM TO PREVENT RODENT AND MOISTURE DAMAGE. FOAM SHALL BE INSTALLED IN A NEAT AND WORKMAN LIKE MANNER.
3. ALL POWER AND CONTROL CONDUIT ENDS TO BE FITTED WITH BELL ENDS.
4. LOW VOLTAGE POWER FROM PAD MOUNT TRANSFORMER TO MET STATION AT WTG-04 ONLY.

KEY NOTES

1. CENTER OF TOWER DOOR AT 6 O'CLOCK POSITION (FACING ACCESS ROAD).
2. SLURRY BACKFILL – 2000 PSI, 8 INCH SLUMP. FILL TO 2 INCHES ABOVE BOX PAD FLANGE.
3. RUN ONE SET PHASE CONDUCTORS A,B,C, AND NEUTRAL IN EACH OF THE EIGHT 4 INCH CONDUITS.
4. SEE TURBINE GROUNDING SHEET E.411 FOR GROUNDING INSTRUCTIONS.
5. THE CONDUITS SHALL BE TRIMMED TO WITHIN 3 INCH OF THE TOP OF THE CONCRETE SURFACE NO LATER THAN 2 DAYS AFTER THE INSTALLATIONS OF CONCRETE. DEBUR THE ENDS OF THE CONDUIT. SLOPE ALL CONDUIT TOWARDS THE OUTSIDE OF THE FOUNDATION AT APPROXIMATELY A 2% SLOPE.
6. THE TRANSFORMER BOX PAD SHALL BE SET SO THAT THE FACE OF THE EXTENSION IS FLUSH WITH THE TOP EDGE OF THE PEDESTAL.
7. COMMUNICATION CONDUITS INSTALLED IN SLURRY BACKFILL. TWO COMMUNICATION CONDUITS TYPICALLY REQUIRED. THREE CONDUITS REQUIRED AT TURBINES 07, 15, 22, 25, 28, 33, 34 AND 49.

Westwood
Phone (952) 937-5150 7699 Anagram Drive
Fax (952) 937-5822 Eden Prairie, MN 55344
Toll Free (888) 937-5150 westwoodps.com
Westwood Professional Services, Inc.

Designed: JRV
Checked: ANS
Drawn: JMC, JRG
As-Built Drawing:

Revisions:

#	DATE	DESCRIPTION
A	09/27/17	30% plans
B	10/03/17	Issued for Procurement – Revised
C	10/19/17	60% plans
D	10/30/17	90% plans

Prepared for:

WHITE an IEA company
3900 E. White Ave
Clinton, IN 47842

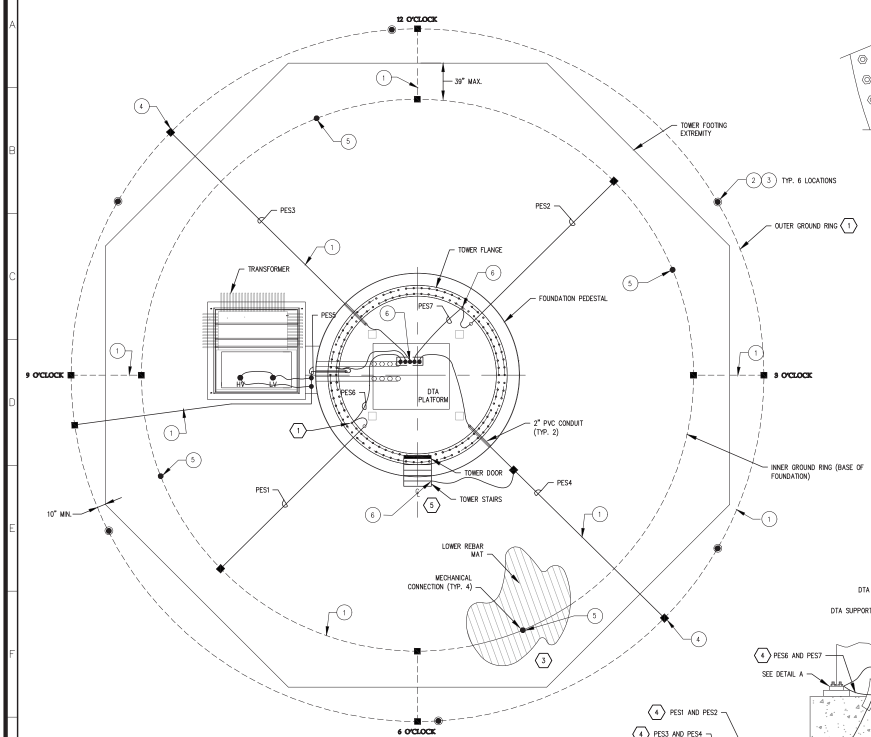
Trishe Wind Ohio, LLC
c/o Starwood Energy Group, LLC
5 Greenwich Office Park, 2nd Floor
Greenwich, CT 06831

Northwest Ohio Wind Project
Paulding County, Ohio

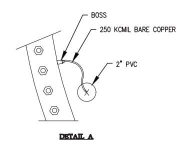
Below Grade Work GE 2.5-116 Turbines

Not For Construction
Array Date: 09/14/2017
Date: 10/30/2017
Sheet: E.410
0007186_E400_Turbine Conduit and Gnd.dwg

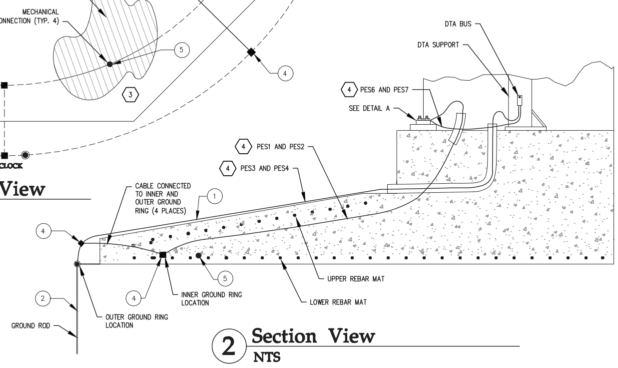
©2017 Westwood Professional Services, Inc.



1 Plan View
NTS



DETAIL A



2 Section View
NTS

LEGEND

- ◉ GROUND ROD
- ■ COMPRESSION CONNECTION
- ● BOLTED CONNECTION TO REINFORCING STEEL
- – – – INNER AND OUTER GROUND RING WITH CONNECTIONS

MATERIAL LIST

ITEM	QTY	UNITS	DESCRIPTION		
1	590	FT	4/0 AWG BARE CU STR. CABLE, S.D.		
2	6	EA	GROUND ROD, 5/8" X 8', 13 MIL CU CLAD		
3	6	EA	COMPRESSION CONNECTOR 5/8" CU ROD TO 4/0 AWG BARE CU		
4	16	EA	COMPRESSION CONNECTOR 4/0 AWG BARE CU TO 4/0 AWG BARE CU		
5	4	EA	BOLTED CONNECTOR, #10 REBAR TO 4/0 AWG BARE CU		
6	8	EA	COMPRESSION LUG, 4/0 AWG CU TO 1 HOLE		

GENERAL NOTES

1. PROVIDE SUFFICIENT CONDUCTOR LENGTH SO CONNECTORS CAN BE MADE WITH SLACK.
2. INSTALL GROUND GRID AS SHOWN. OUTER GROUND RING TO BE INSTALLED AT BASE OF FOUNDATION. PROVIDE EXOTHERMIC WELD CONNECTIONS FOR ALL GROUND ROD AND GROUNDING CABLE CONNECTIONS EXCEPT WHERE NOTED.
3. AFTER INSTALLATION OF GRID AND PRIOR TO CONNECTION OF COLLECTOR CABLES, MEASURE GROUND/EARTH GRID RESISTANCE. IF RESISTANCE IS GREATER THAN 10 OHMS, INSTALL ADDITIONAL GROUND GRID IN 10 FEET SUCCESSIVE STEPS CONCENTRIC FROM PREVIOUS GRID. CONNECT TO PREVIOUS SECTION AT FOUR LOCATIONS AND INSTALL FOUR GROUND RODS WITH EACH SECTION.
4. REMOVE PAINT COATINGS, IF PRESENT, AT ALL GROUND CONNECTION LOCATIONS.
5. CONDUIT STUB OUTS NEAR TOWER FLANGE TO BE 6 INCH FROM FLANGE (EDGE TO EDGE).
6. GROUND CABLE IS PERMITTED TO LAY ON FOUNDATION.

KEY NOTES

1. GROUNDING CABLE CONNECTING INNER GROUND LOOP TO INTERIOR TOWER FLANGE – TYPICAL 2 LOCATIONS (SEE DETAIL A).
2. ALL GROUNDING CABLES SHALL BE 250 KCMIL BARE COPPER.
3. MECHANICALLY BOLT INNER GROUNDING RING TO BOTTOM REINFORCING STEEL MAT OF FOUNDATION (NO EXOTHERMIC WELDS). USE FOUR EQUALLY SPACED CONNECTIONS.
4. PES1 AND PES2:
   CONNECTS THE GROUNDING RING INSIDE THE FOUNDATION (CONNECTED TO THE BOTTOM REINFORCING BARS) TO THE INTERIOR TOWER BASE FLANGE BOSSES.
   PES3 AND PES4:
   CONNECTS THE DTA PLATFORM BUS BAR TO THE OUTER GROUND RING LOCATED IN THE SOIL. ISOLATE PES3 AND PES4 FROM THE CONCRETE AND REINFORCING BARS BY INSTALLING THEM INSIDE 2" SCH. 40 PVC DUCTS.
   PES5:
   CONNECTS THE GROUND RING, PADMOUNT TRANSFORMER GROUND BUS, AND THE DTA PLATFORM BUS BAR.
   PES6 AND PES7:
   CONNECTS THE DTA PLATFORM BUS BAR TO TOWER INTERIOR BOTTOM FLANGE.
5. BOND TOWER STAIRS TO GROUNDING RING.

Westwood
Phone (952) 937-5150 7699 Anagram Drive
Fax (952) 937-5822 Eden Prairie, MN 55344
Toll Free (888) 937-5150 westwoodps.com
Westwood Professional Services, Inc.

Designed: JRV
Checked: ANS
Drawn: JMC, JRG
As-Built Drawing:

Revisions:

#	DATE	DESCRIPTION
A	09/27/17	30% plans
B	10/03/17	Issued for Procurement – Revised
C	10/19/17	60% plans
D	10/30/17	90% plans

Prepared for:

WHITE an IEA company
3900 E. White Ave
Clinton, IN 47842

Trishe Wind Ohio, LLC
c/o Starwood Energy Group, LLC
5 Greenwich Office Park, 2nd Floor
Greenwich, CT 06831

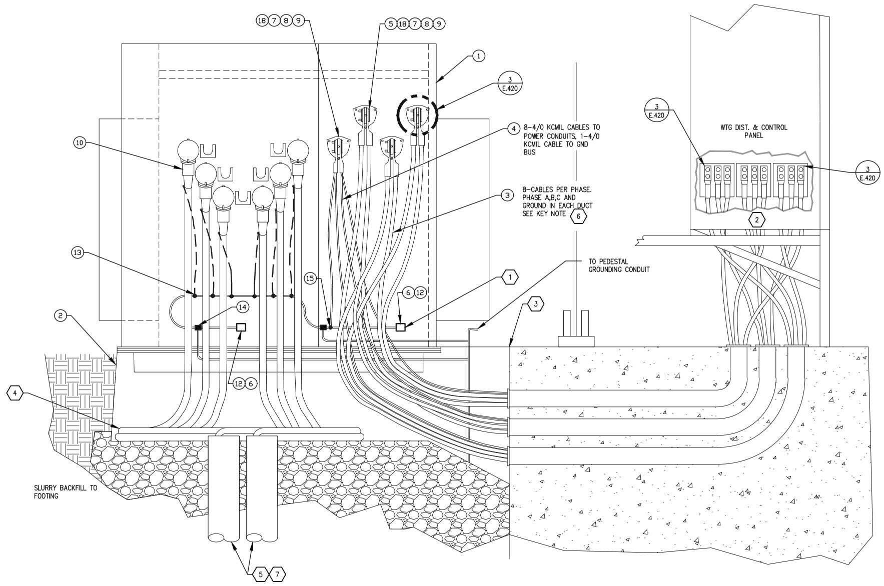
Northwest Ohio Wind Project
Paulding County, Ohio

Turbine Grounding - Spread Foundation GE 2.5-116

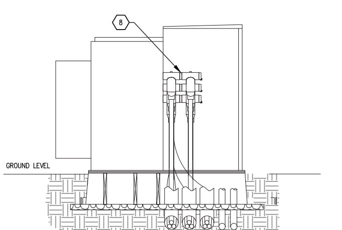
Not For Construction
Array Date: 09/14/2017
Date: 10/30/2017
Sheet: E.411

0007186_E400_Turbine Conduit and Gnd.dwg

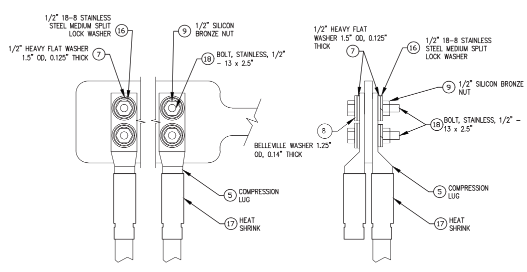
©2017 Westwood Professional Services, Inc.



1 Step-Up Transformer - Front View
NTS



2 Step-Up Transformer - Side View
NTS



3 Termination Detail
NTS

MATERIAL LIST

ITEM	QTY	UNIT	DESCRIPTION	MFG.
1	1	EA	PAD MOUNTED TRANSFORMER, 2750kVA	–
2	1	EA	BOX PAD ## INCH X ## INCH X 36 INCH	–
3	###	FT	1000 KCMIL AL STR. CABLE, 2 KV, RHW-2	–
4	###	FT	4/0 AWG BARE CU STR. CABLE, S.D.	–
5	64	EA	CONNECTOR, CP, AL, 2H LUG 1000 KCMIL (TURBINE AND TRANSFORMER)	–
6	4	EA	1/2"-13 X 2-1/2" 316 STAINLESS STEEL HEX CAP SCREW	–
7	128	EA	1/2" 18-8 STAINLESS STEEL SMALL OD EXTRA THICK FLAT WASHER	–
8	64	EA	1/2" 18-8 S/S BELLEVILLE WASHER 4700 LBS	–
9	64	EA	1/2-13 HEAVY HEX NUTS, SILICON BRONZE	–
10a	3	EA	600A DEAD BREAK CONNECTOR WITH SEALING KIT, 35 KV 1250 MCM	–
10b	3	EA	600A DEAD BREAK CONNECTOR WITH SEALING KIT, 35 KV 1000 MCM	–
10c	3	EA	600A DEAD BREAK CONNECTOR WITH SEALING KIT, 35 KV 750 MCM	–
10d	3	EA	600A DEAD BREAK CONNECTOR WITH SEALING KIT, 35 KV 500 MCM	–
10e	3	EA	600A DEAD BREAK CONNECTOR WITH SEALING KIT, 35 KV 4/0 AWG	–
10f	3	EA	600A DEAD BREAK CONNECTOR WITH SEALING KIT, 35 KV 1/0 AWG	–
11	.25	EA	CABLE CLEANING KIT, SPECIALIZED PADS CLEAN CABLE INSULATION, COMES W/ 3EA SATURATED PADS/KIT & CASE	–
12	##	EA	CONNECTOR, CP, CU, 2H LUG	–
13	##	EA	CONNECTOR,CP, CU GRD. TAP "C",GROUND TAP "C", HYTAP 2/0 TO #1 AWG CU RUN TO TAP #8-#4 STR CU	–
14	##	EA	CONNECTOR,CP, CU GRD. TAP "C", 7#7 CCS RUN TO 7#7 CCS TAP. CU WIRE/BAR	–
15	#	EA	CONNECTOR,CP, TIN PLATED "C", HYTAP , 2 AWG – 250 KCMIL RUN TO 2 AWG- 250 KCMIL TAP	–
16	64	EA	1/2" 18-8 STAINLESS STEEL MEDIUM SPLIT LOCK WASHER	–
17	A/R	FT	HEAT SHRINK, 1000V	–
18	64	EA	BOLT, STAINLESS STEEL, 1'2" – 13 X 2.5"	–

GENERAL NOTES

1. PREVENT CONCRETE FROM ENTERING ALL OPEN CONDUIT ENDS.
2. ALL SPARE CONDUITS SHOULD BE SEALED WITH FLAME RETARDANT FOAM AND CAPPED. ALL FLOATING CONDUCTORS IN CONDUIT SHALL BE ENCAPSULATED IN FLAME RETARDANT FOAM TO PREVENT RODENT AND MOISTURE DAMAGE. FOAM SHALL BE INSTALLED IN A NEAT AND WORKMAN LIKE MANNER.
3. MARK EACH CIRCUIT WITH DESTINATION.
4. MARK EACH CABLE

PHASE	34.5 kV	SECONDARY
A	RED	BROWN
B	WHITE	ORANGE
C	BLUE	YELLOW

KEY NOTES

1. BOND 4/0 AWG COPPER GROUND BUS TO TRANSFORMER GROUNDING PAD. CONNECT TO GROUND GRID WITH 4/0 AWG COPPER.
2. CONNECT GROUNDING CONDUCTORS TO GROUND BUS IN WTG DIST. PANEL
3. TOP OF PEDESTAL AND BOX PADS TO BE AT SAME ELEVATION. CAULK THE JOINT BETWEEN THE BOXPAD AND PEDESTAL.
4. SLACK COIL (FOR ONE EXTRA TERMINATION)
5. SEAL ALL CONDUITS WITH FOAM AFTER CABLE INSTALLATION.
6. ALL TURBINE POWER CABLES SHALL BE EQUAL IN LENGTH.
7. EXTEND ELECTRICAL CONDUITS FOR MV CABLE AND GROUNDS INTO NATIVE SOIL BEDDING WITH 45 AND 90 DEG SWEEPS AS REQUIRED.
8. ELBOW TO ELBOW (PIGGYBACK) CONNECTOR KIT REQUIRED.

Westwood
Phone (952) 937-5150 7699 Anagram Drive
Fax (952) 937-5822 Eden Prairie, MN 55344
Toll Free (888) 937-5150 westwoodps.com
Westwood Professional Services, Inc.

Designed: JRV
Checked: ANS
Drawn: JMC, JRG
As-Built Drawing:

Revisions:

#	DATE	DESCRIPTION
A	09/27/17	30% plans
B	10/03/17	Issued for Procurement – Revised
C	10/19/17	60% plans
D	10/30/17	90% plans

Prepared for:

WHITE an IEA company
3900 E. White Ave
Clinton, IN 47842

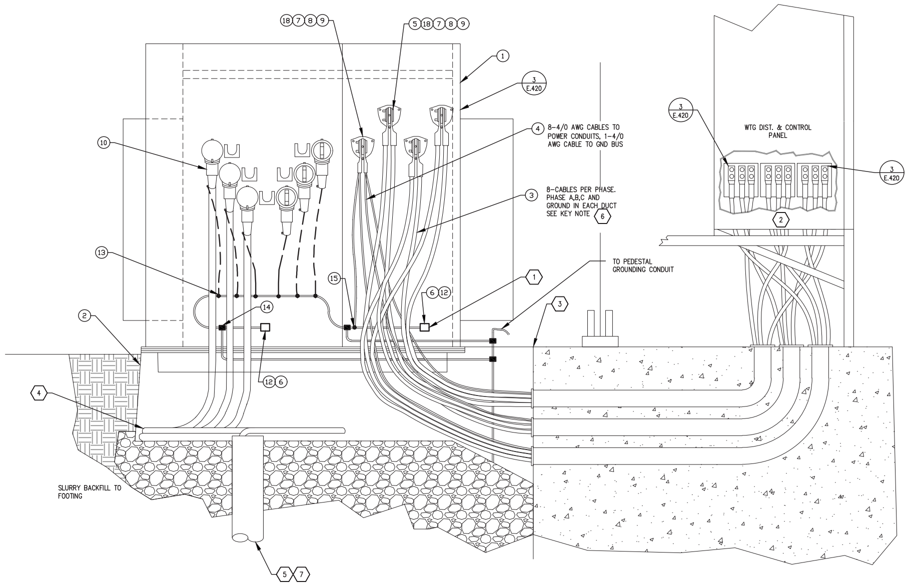
Trishe Wind Ohio, LLC
c/o Starwood Energy Group, LLC
5 Greenwich Office Park, 2nd Floor
Greenwich, CT 06831

Northwest Ohio Wind Project
Paulding County, Ohio

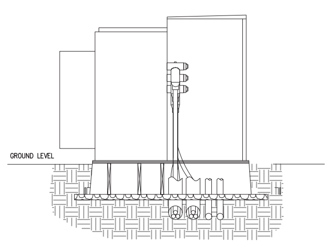
Padmount Transformer Feedthrough

Not For Construction
Array Date: 09/14/2017
Date: 10/30/2017
Sheet: E.420
0007186_E400_Padmount Transformer Details.dwg

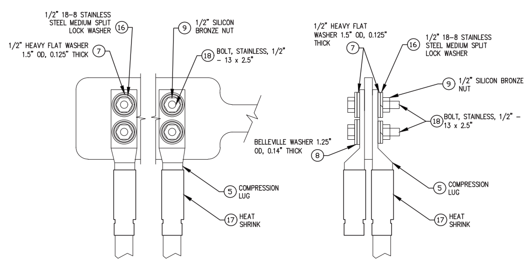
©2017 Westwood Professional Services, Inc.



1 Step-Up Transformer - Front View
NTS



2 Step-Up Transformer - Side View
NTS



3 Termination Detail
NTS

MATERIAL LIST

ITEM	QTY	UNIT	DESCRIPTION	MFG.
1	1	EA	PAD MOUNTED TRANSFORMER, 2750kVA	–
2	1	EA	BOX PAD ## INCH X ## INCH X 36 INCH	–
3	###	FT	1000 KCMIL AL STR. CABLE, 2 KV, RHW-2	–
4	###	FT	4/0 AWG BARE CU STR. CABLE, S.D.	–
5	64	EA	CONNECTOR, CP, AL, 2H LUG 1000 KCMIL (TURBINE AND TRANSFORMER)	–
6	4	EA	1/2"-13 X 2-1/2" 316 STAINLESS STEEL HEX CAP SCREW	–
7	128	EA	1/2" 18-8 STAINLESS STEEL SMALL OD EXTRA THICK FLAT WASHER	–
8	64	EA	1/2" 18-8 S/S BELLEVILLE WASHER 4700 LBS	–
9	64	EA	1/2-13 HEAVY HEX NUTS, SILICON BRONZE	–
10a	3	EA	600A DEAD BREAK CONNECTOR WITH SEALING KIT, 35 KV 1250 MCM	–
10b	3	EA	600A DEAD BREAK CONNECTOR WITH SEALING KIT, 35 KV 1000 MCM	–
10c	3	EA	600A DEAD BREAK CONNECTOR WITH SEALING KIT, 35 KV 750 MCM	–
10d	3	EA	600A DEAD BREAK CONNECTOR WITH SEALING KIT, 35 KV 500 MCM	–
10e	3	EA	600A DEAD BREAK CONNECTOR WITH SEALING KIT, 35 KV 4/0 AWG	–
10f	3	EA	600A DEAD BREAK CONNECTOR WITH SEALING KIT, 35 KV 1/0 AWG	–
11	.25	EA	CABLE CLEANING KIT, SPECIALIZED PADS CLEAN CABLE INSULATION, COMES W/ 3EA SATURATED PADS/KIT & CASE	–
12	##	EA	CONNECTOR, CP, CU, 2H LUG	–
13	##	EA	CONNECTOR,CP, CU GRD. TAP "C",GROUND TAP "C", HYTAP 2/0 TO #1 AWG CU RUN TO TAP #8-#4 STR CU	–
14	##	EA	CONNECTOR,CP, CU GRD. TAP "C", 7#7 CCS RUN TO 7#7 CCS TAP. CU WIRE/BAR	–
15	#	EA	CONNECTOR,CP, TIN PLATED "C", HYTAP , 2 AWG – 250 KCMIL RUN TO 2 AWG– 250 KCMIL TAP	–
16	64	EA	1/2" 18-8 STAINLESS STEEL MEDIUM SPLIT LOCK WASHER	–
17	A/R	FT	HEAT SHRINK, 1000V	–
18	64	EA	BOLT, STAINLESS STEEL, 1'2" – 13 X 2.5"	–

GENERAL NOTES

1. PREVENT CONCRETE FROM ENTERING ALL OPEN CONDUIT ENDS.
2. ALL SPARE CONDUITS SHOULD BE SEALED WITH FLAME RETARDANT FOAM AND CAPPED. ALL FLOATING CONDUCTORS IN CONDUIT SHALL BE ENCAPSULATED IN FLAME RETARDANT FOAM TO PREVENT RODENT AND MOISTURE DAMAGE. FOAM SHALL BE INSTALLED IN A NEAT AND WORKMAN LIKE MANNER
3. MARK EACH CIRCUIT WITH DESTINATION.
4. MARK EACH CABLE

PHASE	34.5 kV	SECONDARY
A	RED	BROWN
B	WHITE	ORANGE
C	BLUE	YELLOW

KEY NOTES

1. BOND 4/0 AWG COPPER GROUND BUS TO TRANSFORMER GROUNDING PAD. CONNECT TO GROUND GRID WITH 4/0 AWG COPPER.
2. CONNECT GROUNDING CONDUCTORS TO GROUND BUS IN WTG DIST. PANEL
3. TOP OF PEDESTAL AND BOX PADS TO BE AT SAME ELEVATION. CAULK THE JOINT BETWEEN THE BOXPAD AND PEDESTAL.
4. SLACK COIL (FOR ONE EXTRA TERMINATION)
5. SEAL ALL CONDUITS WITH FOAM AFTER CABLE INSTALLATION.
6. ALL TURBINE POWER CABLES SHALL BE EQUAL IN LENGTH.
7. EXTEND ELECTRICAL CONDUITS FOR MV CABLE AND GROUNDS INTO NATIVE SOIL BEDDING WITH 45 AND 90 DEG SWEEPS AS REQUIRED.
8. ELBOW TO ELBOW (PIGGYBACK) CONNECTOR KIT REQUIRED.

Westwood
Phone (952) 937-5150 7699 Anagram Drive
Fax (952) 937-5822 Eden Prairie, MN 55344
Toll Free (888) 937-5150 westwoodps.com
Westwood Professional Services, Inc.

Designed: JRV
Checked: ANS
Drawn: JMC, JRG
As-Built Drawing:

Revisions:

#	DATE	DESCRIPTION
A	09/27/17	30% plans
B	10/03/17	Issued for Procurement – Revised
C	10/19/17	60% plans
D	10/30/17	90% plans

Prepared for:

WHITE an IEA company
3900 E. White Ave
Clinton, IN 47842

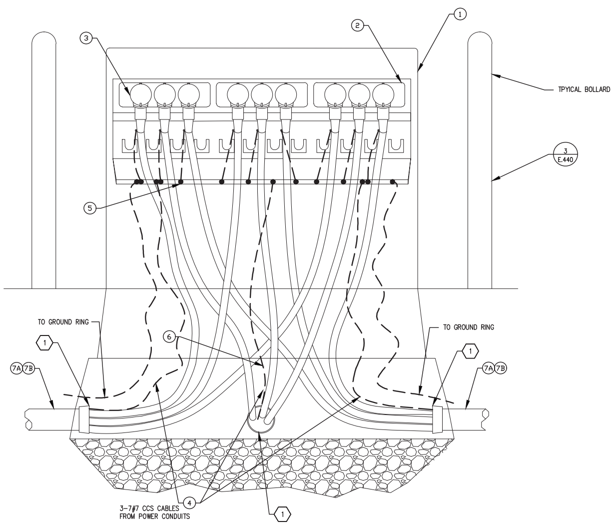
Trishe Wind Ohio, LLC
c/o Starwood Energy Group, LLC
5 Greenwich Office Park, 2nd Floor
Greenwich, CT 06831

Northwest Ohio Wind Project
Paulding County, Ohio

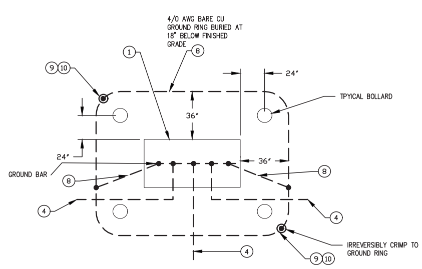
Padmount TransformerTerminal

Not For Construction
Array Date: 09/14/2017
Date: 10/30/2017
Sheet: E.421
0007186_E400_Padmount Transformer Details.dwg

©2017 Westwood Professional Services, Inc.



1 Sectionalizing Cabinet - Front View
NTS



2 Sectionalizing Cabinet - Grounding Detail
NTS

MATERIAL LIST

ITEM	QTY	UNIT	DESCRIPTION	MFG.	
1	1	EA	3-WAY JUNCTION BOX, 3-WAY 35KV, WITH GROUNDING BAR		
2	3	EA	JUNCTION, 600A, 35KV, W/MOUNTING HARDWARE		
3	9	EA	DEADBREAK ELBOWS, 600A, 40 KA		
4	###	FT	7#7 CCS STR. CABLE, 40% CONDUCTIVITY		
5	9	EA	CONNECTOR, CONCENTRICS TO JBOX GROUNDING		
6	3	EA	CONNECTOR, TRENCH GROUND TO JBOX GROUNDING		
7A	3	EA	8" PVC CONDUIT SCH. 40, 10FT LENGTH, BELL END		
7B	3	EA	6" PVC CONDUIT SCH. 40, 10FT LENGTH, BELL END		
8	60 OR 70	FT	4/0 AWG BARE CU STR. CABLE, S.D.		
9	2	EA	GROUND ROD, COPPER CLAD STEEL 3/4" x 10'		
10	2	EA	EXOTHERMIC CONNECTOR 3/4" STEEL ROD TO 4/0 AWG BARE CU		

GENERAL NOTES

1. PREVENT CONCRETE FROM ENTERING ALL OPEN CONDUIT ENDS.
2. ALL SPARE CONDUITS SHOULD BE SEALED WITH FLAME RETARDANT FOAM AND CAPPED. ALL FLOATING CONDUCTORS IN CONDUIT SHALL BE ENCAPSULATED IN FLAME RETARDANT FOAM TO PREVENT RODENT AND MOISTURE DAMAGE. FOAM SHALL BE INSTALLED IN A NEAT AND WORKMAN LIKE MANNER.
3. MARK EACH CIRCUIT WITH DESTINATION.
4. MARK EACH CABLE

PHASE	34.5 kV	SECONDARY
A	RED	BROWN
B	WHITE	ORANGE
C	BLUE	YELLOW

5. BOND MV CABLE CONCENTRIC NEUTRALS TO SECTIONALIZING CABINET GROUND.

KEY NOTES

1 SEAL ALL CONDUITS WITH FOAM AFTER CABLE INSTALLATION.

Westwood
Phone (952) 937-5150 7699 Anagram Drive
Fax (952) 937-5822 Eden Prairie, MN 55344
Toll Free (888) 937-5150 westwoodps.com
Westwood Professional Services, Inc.

Designed: JRV
Checked: ANS
Drawn: JMC, JRG
As-Built Drawing:

Revisions:

#	DATE	DESCRIPTION
A	09/27/17	30% plans
B	10/03/17	Issued for Procurement – Revised
C	10/19/17	60% plans
D	10/30/17	90% plans

Prepared for:

WHITE an IEA company
3900 E. White Ave
Clinton, IN 47842

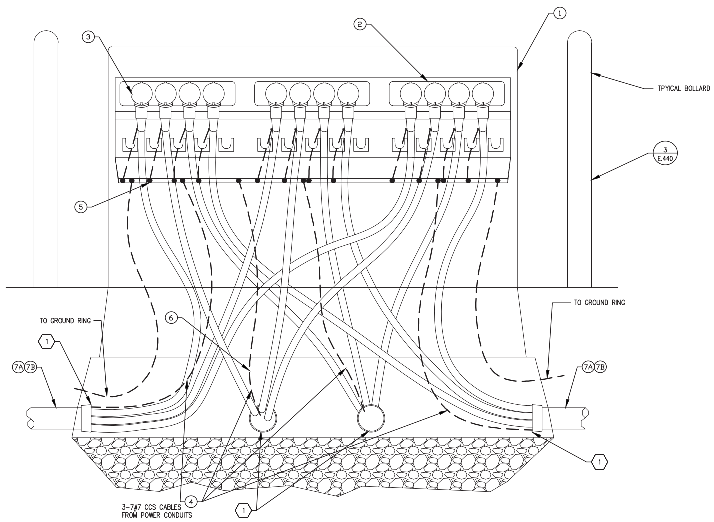
Trishe Wind Ohio, LLC
c/o Starwood Energy Group, LLC
5 Greenwich Office Park, 2nd Floor
Greenwich, CT 06831

Northwest Ohio Wind Project
Paulding County, Ohio

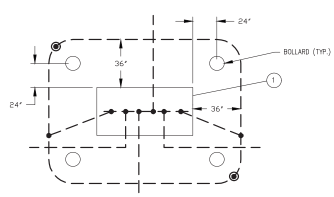
Sectionalizing Cabinet, 3 Way

Not For Construction
Array Date: 09/14/2017
Date: 10/30/2017
Sheet: E.422
0007186_E400_Padmount Transformer Details.dwg

©2017 Westwood Professional Services, Inc.



1 Sectionalizing Cabinet - Front View
NTS



2 Sectionalizing Cabinet - Grounding Detail
NTS

MATERIAL LIST

ITEM	QTY	UNIT	DESCRIPTION	MFG.	
1	1	EA	4-WAY JUNCTION BOX, 3-WAY 35KV, WITH GROUNDING BAR		
2	3	EA	JUNCTION, 600A, 35KV, W/MOUNTING HARDWARE		
3	12	EA	DEADBREAK ELBOWS, 600A, 40 KA		
4	###	FT	7#7 CCS STR. CABLE, 40% CONDUCTIVITY		
5	9	EA	CONNECTOR, CONCENTRICS TO JBOX GROUNDING		
6	3	EA	CONNECTOR, TRENCH GROUND TO JBOX GROUNDING		
7A	3	EA	8" PVC CONDUIT SCH. 40, 10FT LENGTH, BELL END		
7B	3	EA	6" PVC CONDUIT SCH. 40, 10FT LENGTH, BELL END		
8	60 OR 70	FT	4/0 AWG BARE CU STR. CABLE, S.D.		
9	2	EA	GROUND ROD, COPPER CLAD STEEL 3/4" x 10'		
10	2	EA	EXOTHERMIC CONNECTOR 3/4" STEEL ROD TO 4/0 AWG BARE CU		

GENERAL NOTES

1. PREVENT CONCRETE FROM ENTERING ALL OPEN CONDUIT ENDS.
2. ALL SPARE CONDUITS SHOULD BE SEALED WITH FLAME RETARDANT FOAM AND CAPPED. ALL FLOATING CONDUCTORS IN CONDUIT SHALL BE ENCAPSULATED IN FLAME RETARDANT FOAM TO PREVENT RODENT AND MOISTURE DAMAGE. FOAM SHALL BE INSTALLED IN A NEAT AND WORKMAN LIKE MANNER. INSTALL PERFORATED 6" SCH. 40 PVC SUMP SURROUNDED BY 6" OF CLEAN UNIFORM 2" WASHED STONE INSIDE OF GEOFABRIC.
3. MARK EACH CIRCUIT WITH DESTINATION.
4. MARK EACH CABLE

PHASE	34.5 kV	SECONDARY
A	RED	BROWN
B	WHITE	ORANGE
C	BLUE	YELLOW

KEY NOTES

1. SEAL ALL CONDUITS WITH FOAM AFTER CABLE INSTALLATION.

Westwood
Phone (952) 937-5150 7699 Anagram Drive
Fax (952) 937-5822 Eden Prairie, MN 55344
Toll Free (888) 937-5150 westwoodps.com
Westwood Professional Services, Inc.

Designed: JRV
Checked: ANS
Drawn: JMC, JRG
As-Built Drawing:

Revisions:

#	DATE	DESCRIPTION
A	09/27/17	30% plans
B	10/03/17	Issued for Procurement – Revised
C	10/19/17	60% plans
D	10/30/17	90% plans

Prepared for:

WHITE an IEA company
3900 E. White Ave
Clinton, IN 47842

Trishe Wind Ohio, LLC
c/o Starwood Energy Group, LLC
5 Greenwich Office Park, 2nd Floor
Greenwich, CT 06831

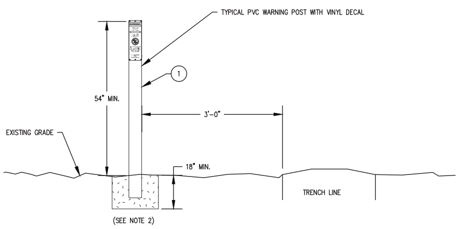
Northwest Ohio Wind Project
Paulding County, Ohio

Sectionalizing Cabinet, 4 Way

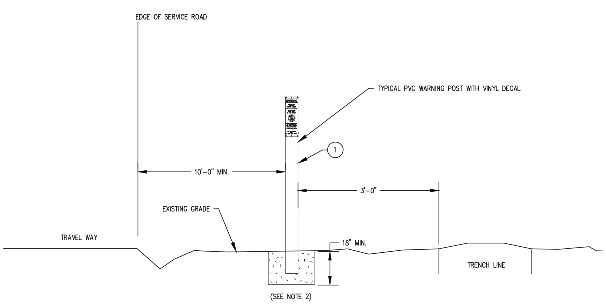
Not For Construction
Array Date: 09/14/2017
Date: 10/30/2017
Sheet: E.423

0007186_E400_Padmount Transformer Details.dwg

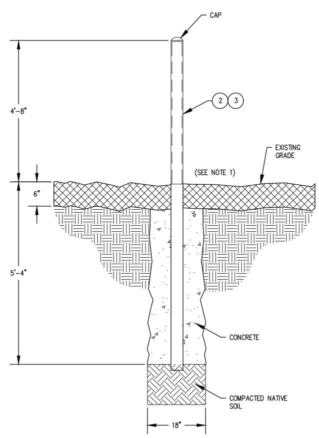
©2017 Westwood Professional Services, Inc.



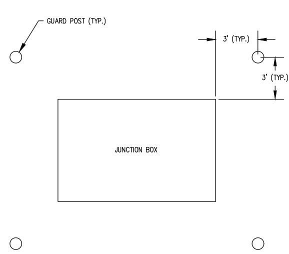
1 Marker Placement Along Trench Line
No Scale



2 Marker Placement Along Roadway
No Scale



3 Bollard (Guard Post) Detail
No Scale



4 Typical Guard Post Arrangement At Junction Boxes
No Scale

MATERIAL LIST

ITEM	QTY	UNITS	DESCRIPTION	MFG.	PART #
1	1	FT	UTILITY MARKER POLE, FLAT, RED, 72"		
2	4	EA	PIPE, GALVANIZED RIGID 4" X 10'		
3	4	EA	GUARD, BUMPER POST SLEEVE, SAFETY YELLOW, 4.75" ID, 56" HEIGHT		

GENERAL NOTES

1. ROUTE MARKER POLES SHALL BE PLACED ALONG THE COLLECTOR LINES EVERY 1000 FEET UNLESS DIRECTED OTHERWISE BY ELECTRICAL SUPERINTENDENT. THEY SHALL ALSO BE PLACED AT ALL ROUTING ANGLES, ROAD CROSSINGS, UTILITY CROSSINGS, AND CABLE SPLICES. ADDITIONAL MARKERS MAY BE ADDED AS REQUESTED BY THE OWNER.
2. COMPACT NATIVE SOIL.
3. ADDITIONAL MARKERS CAN BE ADDED DURING CONSTRUCTION AS REQUESTED BY CLIENT.

Westwood

Phone (952) 937-5150 7699 Anagram Drive
Fax (952) 937-5822 Eden Prairie, MN 55344
Toll Free (888) 937-5150 westwoodps.com

Westwood Professional Services, Inc.

Designed: JRV
Checked: ANS
Drawn: JMC, JRG
As-Built Drawing:

Revisions:

#	DATE	DESCRIPTION
A	09/27/17	30% plans
B	10/03/17	Issued for Procurement – Revised
C	10/19/17	60% plans
D	10/30/17	90% plans

Prepared for:

WHITE an IEA company

3900 E. White Ave
Clinton, IN 47842

Trishe Wind Ohio, LLC
c/o Starwood Energy Group, LLC
5 Greenwich Office Park, 2nd Floor
Greenwich, CT 06831

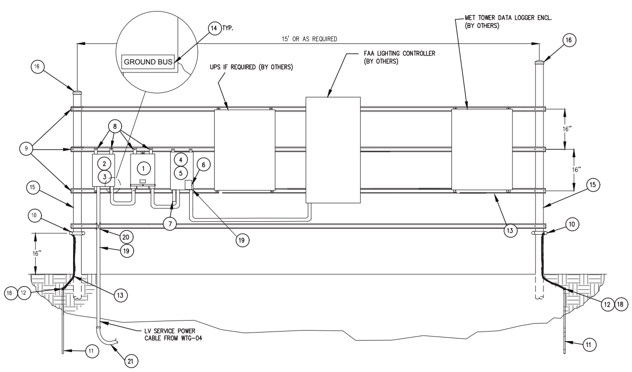
Northwest Ohio Wind Project
Paulding County, Ohio

Marker Poles and Bollards

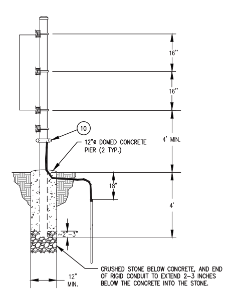
Not For Construction
Array Date: 09/14/2017
Date: 10/30/2017
Sheet: E.440

0007186_E440_Marker Poles.dwg

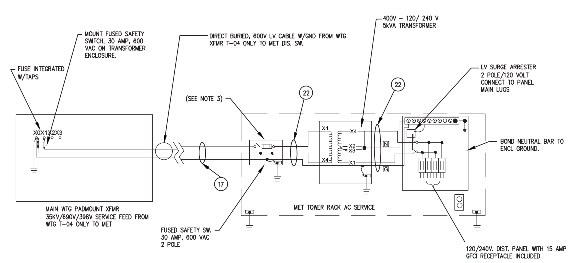
©2017 Westwood Professional Services, Inc.



1 MET Tower Rack - Front View
NTS



2 MET Tower Rack - Side View
NTS



3 MET Tower Wire Diagram
NTS

MATERIAL LIST

ITEM	QTY	UNIT	DESCRIPTION		
1	1	EA	TRANSFORMER, DRY TYPE, 5KVA, 380/400/415 V PRIMARY TO 120/240 V SECONDARY		
2	1	EA	SAFETY SWITCH., 20A, 600V, 3P, FUSIBLE		
3	1	EA	FS., FRS-R, 10A, 600V, 13/16 DIA, P HOLDER		
4	1	FT	120/240V AC LOADCENTER 70A W/SUBPANEL, 4SP, GFI SERVICE OUTLET NEMA 3R		
5	1	EA	MINIATURE CIRCUIT BREAKER STANDARD, 15A, 1-POLE, 120/240 VAC, 1-PHASE, 10KA		
6	1	EA	SECONDARY SURGE ARRESTOR		
7	1	EA	WEATHER PROOF GFCI RECEPTACLE, DUPLEX 20A		
8	8	FT	ENCLOSURE MOUNTING, 4 BRKT KIT FOR STRUT SYSTEM		
9	3	EA	1-5/8" X 1-5/8", 12 GAUGE, SLOTTED, 20'		
10	1	EA	BRONZE, TINNED POST CLAMP, 2 IN., #2/0 SOL		
11	1	EA	GROUND ROD, 5/8" X 8'0", 13-REA MIL CU-BONDED		
12	1=50X	EA	EXOTHERMIC MOLD, "X"-2/0 CU OR "T"-2/0 TO 5/8" X 8" GROUND ROD (USE WM#250)		
13	50	FT	CONDUCTOR, 1/0 CU BARE UNCOATED 19 STR S.D.		
14	7	EA	CONNECTOR, BOLT GROUNDING LUG, 2-20 SOL		
15	2	EA	PIPE, STL, 10 FT LONG		
16	2	EA	STEEL PIPE CAP, RIGID, 2" THREADLESS		
17	1150	FT	CABLE, AL #4 AWG CONDUCTOR, TRIPLEX URD, 600V		
18	2	EA	WELD SHOT 200		
19	-	-	CONDUIT, 2" SCH 80 PVC		
20	-	-	CONDUIT, 2" SCH 80 PVC		
21	-	-	CONDUIT, 3/4" LIQUID TIGHT		
22	-	-	CONDUCTOR, #8 AWG CU, XHHW-2		

GENERAL NOTES

1. PROVIDE 2 SPARE FUSES.
2. ELECTRICIAN TO FIELD CUT CHANNEL TO LENGTH & ADJUST SPACING TO FIT PANEL CONFIGURATION.
3. BOND NEUTRAL BAR TO ENCL. & OFF SET TOWER GROUND RING 36 INCH MIN FROM TOWER FOUNDATIONS ALL AROUND.
4. INSULATE ALL UNUSED TRANSFORMER TAPS.
5. SEAL CONDUITS, CABLES, AND INSTALL WARNING TAPE.

Westwood
Phone (952) 937-5150 7699 Anagram Drive
Fax (952) 937-5822 Eden Prairie, MN 55344
Toll Free (888) 937-5150 westwoodps.com
Westwood Professional Services, Inc.

Designed: JRV
Checked: ANS
Drawn: JMC, JRG
As-Built Drawing:

Revisions:

#	DATE	DESCRIPTION
A	09/27/17	30% plans
B	10/03/17	Issued for Procurement - Revised
C	10/19/17	60% plans
D	10/30/17	90% plans

Prepared for:

WHITE an IEA company
3900 E. White Ave
Clinton, IN 47842

Trishe Wind Ohio, LLC
c/o Starwood Energy Group, LLC
5 Greenwich Office Park, 2nd Floor
Greenwich, CT 06831

Northwest Ohio Wind Project
Paulding County, Ohio

Met Tower

Not For Construction
Array Date: 09/14/2017
Date: 10/30/2017
Sheet: E.450
0007186_E450_Met Tower.dwg

©2017 Westwood Professional Services, Inc.

MVAC WIRING SCHEDULE

CONDUCTOR LOCATION CODE	ORIGINATING EQUIPMENT	TERMINATING EQUIPMENT	Rated Vac (kV)	Iac (A)	# OF TUBRINES	LENGTH (FT)	CONDUCTOR SIZE	CONDUCTOR MATERIAL	# OF PARALLEL CONDUCTORS	GROUND CONDUCTOR SIZE	GROUND CONDUCTOR MATERIAL	DRAWING REFERENCE	CONDUCTOR SPECIFICS
MV1.SUB-T25	SUB	T25	34.5	516	10	4,616	3#1250 KCMIL	AL	1	7#7	Copper Clad Steel	E.200	35kV, (3) 1/C, 100% Insulation, 1/6 Cu CN, Type MV-90
MV1.T25-10	T25	T10	34.5	412.8	8	10,172	3#1000 KCMIL	AL	1	7#7	Copper Clad Steel	E.200	35kV, (3) 1/C, 100% Insulation, 1/6 Cu CN, Type MV-90
MV1.T10-09	T10	T09	34.5	361.2	7	2,161	3#750 KCMIL	AL	1	7#7	Copper Clad Steel	E.200	35kV, (3) 1/C, 100% Insulation, 1/6 Cu CN, Type MV-90
MV1.T09-08	T09	T08	34.5	309.6	6	3,297	3#500 KCMIL	AL	1	7#7	Copper Clad Steel	E.200	35kV, (3) 1/C, 100% Insulation, 1/3 Cu CN, Type MV-90
MV1.T08-05	T08	T05	34.5	258	5	2,679	3#500 KCMIL	AL	1	7#7	Copper Clad Steel	E.200	35kV, (3) 1/C, 100% Insulation, 1/3 Cu CN, Type MV-90
MV1.T05-04	T05	T04	34.5	206.4	4	1,991	3#4/0 AWG	AL	1	7#7	Copper Clad Steel	E.200	35kV, (3) 1/C, 100% Insulation, 1/2 Cu CN, Type MV-90
MV1.T04-03	T04	T03	34.5	154.8	3	1,777	3#4/0 AWG	AL	1	7#7	Copper Clad Steel	E.200	35kV, (3) 1/C, 100% Insulation, 1/2 Cu CN, Type MV-90
MV1.T03-02	T03	T02	34.5	103.2	2	1,878	3#1/0 AWG	AL	1	7#7	Copper Clad Steel	E.200	35kV, (3) 1/C, 100% Insulation, 2/3 Cu CN, Type MV-90
MV1.T02-01	T02	T01	34.5	51.6	1	2,213	3#1/0 AWG	AL	1	7#7	Copper Clad Steel	E.200	35kV, (3) 1/C, 100% Insulation, 2/3 Cu CN, Type MV-90
MV1.T25-24	T25	T24	34.5	51.6	1	1,633	3#4/0 AWG	AL	1	7#7	Copper Clad Steel	E.200	35kV, (3) 1/C, 100% Insulation, 1/2 Cu CN, Type MV-90
MV2.SUB-JB2/1	SUB	JB2/1	34.5	567.6	11	8,109	3#1250 KCMIL	AL	1	7#7	Copper Clad Steel	E.200	35kV, (3) 1/C, 100% Insulation, 1/6 Cu CN, Type MV-90
MV2.JB2/1-T22	JB2/1	T22	34.5	103.2	2	2,964	3#4/0 AWG	AL	1	7#7	Copper Clad Steel	E.200	35kV, (3) 1/C, 100% Insulation, 1/2 Cu CN, Type MV-90
MV2.T22-29	T22	T29	34.5	51.6	1	4,171	3#1/0 AWG	AL	1	7#7	Copper Clad Steel	E.200	35kV, (3) 1/C, 100% Insulation, 2/3 Cu CN, Type MV-90
MV2.T22-21	T22	T21	34.5	103.2	2	1,417	3#1/0 AWG	AL	1	7#7	Copper Clad Steel	E.200	35kV, (3), (3) 1/C, 100% Insulation, 2/3 Cu CN, Type MV-90
MV2.T21-20	T21	T20	34.5	51.6	1	3,551	3#1/0 AWG	AL	1	7#7	Copper Clad Steel	E.200	35kV, (3), (3) 1/C, 100% Insulation, 2/3 Cu CN, Type MV-90
MV2.JB2/1-T17	JB2/1	T17	34.5	206.4	4	2,718	3#750 KCMIL	AL	1	7#7	Copper Clad Steel	E.200	35kV, (3) 1/C, 100% Insulation, 1/6 Cu CN, Type MV-90
MV2.T17-15	T17	T15	34.5	154.8	3	4,579	3#500 KCMIL	AL	1	7#7	Copper Clad Steel	E.200	35kV, (3) 1/C, 100% Insulation, 1/3 Cu CN, Type MV-90
MV2.T15-14	T15	T14	34.5	103.2	2	3,770	3#1/0 AWG	AL	1	7#7	Copper Clad Steel	E.200	35kV, (3) 1/C, 100% Insulation, 2/3 Cu CN, Type MV-90
MV2.T14-13	T14	T13	34.5	51.6	1	1,517	3#1/0 AWG	AL	1	7#7	Copper Clad Steel	E.200	35kV, (3) 1/C, 100% Insulation, 2/3 Cu CN, Type MV-90
MV2.T15-07	T15	T07	34.5	103.2	2	2,790	3#4/0 AWG	AL	1	7#7	Copper Clad Steel	E.200	35kV, (3) 1/C, 100% Insulation, 1/2 Cu CN, Type MV-90
MV2.T07-06	T07	T06	34.5	51.6	1	1,388	3#1/0 AWG	AL	1	7#7	Copper Clad Steel	E.200	35kV, (3) 1/C, 100% Insulation, 2/3 Cu CN, Type MV-90
MV2.T07-16	T07	T16	34.5	51.6	1	3,068	3#1/0 AWG	AL	1	7#7	Copper Clad Steel	E.200	35kV, (3) 1/C, 100% Insulation, 2/3 Cu CN, Type MV-90
MV3.SUB-T23	SUB	T23	34.5	567.6	11	12,285	3#1250 KCMIL	AL	1	7#7	Copper Clad Steel	E.201	35kV, (3) 1/C, 100% Insulation, 1/6 Cu CN, Type MV-90
MV3.T23-28	T23	T28	34.5	154.8	3	2,947	3#1250 KCMIL	AL	1	7#7	Copper Clad Steel	E.201	35kV, (3) 1/C, 100% Insulation, 1/6 Cu CN, Type MV-90
MV3.T28-27	T28	T27	34.5	103.2	2	1,703	3#1/0 AWG	AL	1	7#7	Copper Clad Steel	E.201	35kV, (3) 1/C, 100% Insulation, 2/3 Cu CN, Type MV-90
MV3.T27-26	T27	T26	34.5	51.6	1	1,780	3#1/0 AWG	AL	1	7#7	Copper Clad Steel	E.201	35kV, (3) 1/C, 100% Insulation, 2/3 Cu CN, Type MV-90
MV3.T28-33	T28	T33	34.5	154.8	3	5,853	3#750 KCMIL	AL	1	7#7	Copper Clad Steel	E.201	35kV, (3) 1/C, 100% Insulation, 1/6 Cu CN, Type MV-90
MV3.T33-32	T33	T32	34.5	103.2	2	1,314	3#1/0 AWG	AL	1	7#7	Copper Clad Steel	E.201	35kV, (3) 1/C, 100% Insulation, 2/3 Cu CN, Type MV-90
MV3.T32-31	T32	T31	34.5	51.6	1	5,205	3#1/0 AWG	AL	1	7#7	Copper Clad Steel	E.201	35kV, (3) 1/C, 100% Insulation, 2/3 Cu CN, Type MV-90
MV3.T33-34	T33	T34	34.5	154.8	3	1,674	3#4/0 AWG	AL	1	7#7	Copper Clad Steel	E.201	35kV, (3) 1/C, 100% Insulation, 1/2 Cu CN, Type MV-90
MV3.T34-36	T34	T36	34.5	103.2	2	3,312	3#1/0 AWG	AL	1	7#7	Copper Clad Steel	E.201	35kV, (3) 1/C, 100% Insulation, 2/3 Cu CN, Type MV-90
MV3.T36-37	T36	T37	34.5	51.6	1	1,301	3#1/0 AWG	AL	1	7#7	Copper Clad Steel	E.201	35kV, (3) 1/C, 100% Insulation, 2/3 Cu CN, Type MV-90
MV3.T34-39	T34	T39	34.5	51.6	1	5,680	3#1/0 AWG	AL	1	7#7	Copper Clad Steel	E.201	35kV, (3) 1/C, 100% Insulation, 2/3 Cu CN, Type MV-90
MV4.SUB-T40	SUB	T40	34.5	516	10	29,905	3#1250 KCMIL	AL	1	7#7	Copper Clad Steel	E.201	35kV, (3) 1/C, 100% Insulation, 1/6 Cu CN, Type MV-90
MV4.T40-46	T40	T46	34.5	309.6	6	2,581	3#1000 KCMIL	AL	1	7#7	Copper Clad Steel	E.201	35kV, (3) 1/C, 100% Insulation, 1/6 Cu CN, Type MV-90
MV4.T46-45	T46	T45	34.5	258	5	3,997	3#1000 KCMIL	AL	1	7#7	Copper Clad Steel	E.201	35kV, (3) 1/C, 100% Insulation, 1/6 Cu CN, Type MV-90
MV4.T45-44	T45	T44	34.5	206.4	4	2,881	3#750 KCMIL	AL	1	7#7	Copper Clad Steel	E.201	35kV, (3) 1/C, 100% Insulation, 1/6 Cu CN, Type MV-90
MV4.T44-JB4/1	T44	JB4/1	34.5	154.8	3	3,486	3#500 KCMIL	AL	1	7#7	Copper Clad Steel	E.201	35kV, (3) 1/C, 100% Insulation, 1/3 Cu CN, Type MV-90
MV4.JB4/1-T42	JB4/1	T42	34.5	154.8	3	30	3#4/0 AWG	AL	1	7#7	Copper Clad Steel	E.201	35kV, (3) 1/C, 100% Insulation, 1/2 Cu CN, Type MV-90
MV4.T42-49	T42	T49	34.5	103.2	2	6,471	3#4/0 AWG	AL	1	7#7	Copper Clad Steel	E.201	35kV, (3) 1/C, 100% Insulation, 1/2 Cu CN, Type MV-90
MV4.T49-48	T49	T48	34.5	51.6	1	1,717	3#1/0 AWG	AL	1	7#7	Copper Clad Steel	E.201	35kV, (3) 1/C, 100% Insulation, 2/3 Cu CN, Type MV-90
MV4.T49-50	T49	T50	34.5	51.6	1	1,661	3#1/0 AWG	AL	1	7#7	Copper Clad Steel	E.201	35kV, (3) 1/C, 100% Insulation, 2/3 Cu CN, Type MV-90
MV4.JB4/1-T43	JB4/1	T43	34.5	51.6	1	1,349	3#1/0 AWG	AL	1	7#7	Copper Clad Steel	E.201	35kV, (3) 1/C, 100% Insulation, 2/3 Cu CN, Type MV-90
MV4.JB4/1-T41	JB4/1	T41	34.5	51.6	1	1,386	3#1/0 AWG	AL	1	7#7	Copper Clad Steel	E.201	35kV, (3) 1/C, 100% Insulation, 2/3 Cu CN, Type MV-90

NOTES

1. DISTANCES SHOWN ARE POINT TO POINT DISTANCES MEASURED IN CAD. THEY DO NOT ACCOUNT FOR VERTICAL LENGTHS. ALL LENGTHS TO BE FIELD VERIFIED.
2. REFER TO MVAC SITE PLANS FOR WIRING ROUTING.

Westwood

Phone (952) 937-5150 7699 Anagram Drive
Fax (952) 937-5822 Eden Prairie, MN 55344
Toll Free (888) 937-5150 westwoodps.com

Westwood Professional Services, Inc.

Designed: JRV
Checked: ANS
Drawn: JMC, JRG
As-Built Drawing:

Revisions:

#	DATE	DESCRIPTION
A	09/27/17	30% plans
B	10/03/17	Issued for Procurement – Revised
C	10/19/17	60% plans
D	10/30/17	90% plans

Prepared for:

WHITE an GEA company

3900 E. White Ave
Clinton, IN 47842

Trishe Wind Ohio, LLC
c/o Starwood Energy Group, LLC
5 Greenwich Office Park, 2nd Floor
Greenwich, CT 06831

Northwest Ohio Wind Project

Paulding County, Ohio

MVAC Wiring Schedule

Not For Construction

Array Date: 09/14/2017
Date: 10/30/2017
Sheet: E.800

0007186_E800 Schedules.dwg

©2017 Westwood Professional Services, Inc.

Bore ID	Circuit	Sheet #	Bore Type	From	To	Cable Size	Multi-Ckt Separation (center-center) (ft)
MV1.T02-T01.1	MV1	E.310 & E.312	COUNTY RD	T02	T01	1/0 AWG	N/A
MV1.T03-T02.1	MV1	E.312	WETLAND	T03	T02	1/0 AWG	N/A
MV1.T05-T04.1	MV1	E.312 & E.317	COUNTY RD	T05	T04	4/0 AWG	N/A
MV1.T08-T05.1	MV1	E.317 & E.318	COUNTY RD	T08	T05	500 MCM	N/A
MV1.T09-T08.1	MV1	E.318	GAS PIPELINE	T09	T08	500 MCM	N/A
MV1.T09-T08.2	MV1	E.318	WETLAND	T09	T08	500 MCM	N/A
MV1.T09-T08.3	MV1	E.318 & E.325	COUNTY RD	T09	T08	500 MCM	N/A
MV1.T25-T10.1	MV1	E.325 & E.326	COUNTY RD	T25	T10	1000 MCM	N/A
MV1.T25-T10.2	MV1	E.325 & E.326	WETLAND	T25	T10	1000 MCM	N/A
MV1.T25-T10.3	MV1	E.326 & E.327	COUNTY RD	T25	T10	1000 MCM	N/A
MV1.SUB-T25.1	MV1	E.327	GAS PIPELINE	SUB	T25	1250 MCM	23' (76' ROW)
MV1.SUB-T25.2	MV1	E.327 & E.331	STATE HWY	SUB	T25	1250 MCM	23' (76' ROW)
MV1.SUB-T25.3	MV1	E.327 & E.331	GAS PIPELINE	SUB	T25	1250 MCM	23' (76' ROW)
MV2.T15-T14.1	MV2	E.313 & E.319	COUNTY RD	T15	T14	1/0 AWG	N/A
MV2.T15-T07.1	MV2	E.318 & E.319	COUNTY RD	T15	T07	4/0 AWG	3' (10' ROW)
MV2.T07-T16.1	MV2	E.319	WETLAND	T07	T16	1/0 AWG	N/A
MV2.T07-T16.2	MV2	E.318 & E.319	COUNTY RD	T07	T16	1/0 AWG	3' (10' ROW)
MV2.T17-T15.1	MV2	E.319	WETLAND	T17	T15	500 MCM	N/A
MV2.T17-T15.2	MV2	E.319	COUNTY RD	T17	T15	500 MCM	N/A
MV2.T17-T15.3	MV2	E.319 & E.326	WETLAND	T17	T15	500 MCM	N/A
MV2.T17-T15.4	MV2	E.319 & E.326	WETLAND	T17	T15	500 MCM	N/A
MV2.JB2/1-T17.1	MV2	E.326 & E.327	COUNTY RD	JB2/1	T17	750 MCM	N/A
MV2.JB2/1-T22.1	MV2	E.320	WETLAND	JB2/1	T22	4/0 AWG	12' (28' ROW)
MV2.JB2/1-T22.2	MV2	E.320 & E.327	COUNTY RD	JB2/1	T22	4/0 AWG	18' (40' ROW)
MV2.T22-T29.1	MV2	E.321 & E.328	COUNTY RD	T22	T29	1/0 AWG	N/A
MV2.T22-T29.2	MV2	E.320 & E.321	COUNTY RD	T22	T29	1/0 AWG	N/A
MV2.T21-T20.1	MV2	E.314 & E.320	COUNTY RD	T21	T20	1/0 AWG	N/A
MV2.T21-T20.2	MV2	E.320	WETLAND	T21	T20	1/0 AWG	N/A
MV2.T21-T20.3	MV2	E.320	WETLAND	T21	T20	1/0 AWG	N/A
MV2.SUB-JB2/1.1	MV2	E.327	GAS PIPELINE	SUB	JB2/1	1250 MCM	23' (76' ROW)
MV2.SUB-JB2/1.2	MV2	E.327 & E.331	STATE HWY	SUB	JB2/1	1250 MCM	23' (76' ROW)
MV2.SUB-JB2/1.3	MV2	E.327 & E.331	GAS PIPELINE	SUB	JB2/1	1250 MCM	23' (76' ROW)

Bore ID	Circuit	Sheet #	Bore Type	From	To	Cable Size	Multi-Ckt Separation (center-center) (ft)
MV3.T32-T31.1	MV3	E.315	WETLAND	T32	T31	1/0 AWG	N/A
MV3.T32-T31.2	MV3	E.315 & E.322	COUNTY RD	T32	T31	1/0 AWG	N/A
MV3.T34-T36.1	MV3	E.322 & E.323	COUNTY RD	T34	T36	1/0 AWG	N/A
MV3.T34-T39.1	MV3	E.329	WETLAND	T34	T39	1/0 AWG	3' (10' ROW)
MV3.T34-T39.2	MV3	E.323 & E.329	COUNTY RD	T34	T39	1/0 AWG	3' (10' ROW)
MV3.T34-T39.3	MV3	E.322 & E.323	COUNTY RD	T34	T39	1/0 AWG	3' (10' ROW)
MV3.T28-T33.1	MV3	E.321 & E.322	STATE HWY, GAS PIPE	T28	T33	750 MCM	3' (10' ROW)
MV3.T28-T33.2	MV3	E.321	WETLAND	T28	T33	750 MCM	3' (10' ROW)
MV3.T23-T28.1	MV3	E.320 & E.321	COUNTY RD	T23	T28	1250 MCM	3' (10' ROW)
MV3.T23-T28.2	MV3	E.320	MVAC FDR2	T23	T28	1250 MCM	15' (20' ROW)
MV3.SUB-T23.1	MV3	E.320	WETLAND	SUB	T23	1250 MCM	12' (28' ROW)
MV3.SUB-T23.2	MV3	E.320 & E.327	COUNTY RD	SUB	T23	1250 MCM	18' (40' ROW)
MV3.SUB-T23.3	MV3	E.327	GAS PIPELINE	SUB	T23	1250 MCM	23' (76' ROW)
MV3.SUB-T23.4	MV3	E.327 & E.331	STATE HWY	SUB	T23	1250 MCM	23' (76' ROW)
MV3.SUB-T23.5	MV3	E.327 & E.331	GAS PIPELINE	SUB	T23	1250 MCM	23' (76' ROW)
MV4.T49-T50.1	MV4	E.311	WETLAND	T49	T50	1/0 AWG	N/A
MV4.T49-T50.2	MV4	E.311	WETLAND	T49	T50	1/0 AWG	N/A
MV4.T49-T48.2	MV4	E.311	WETLAND	T49	T48	1/0 AWG	N/A
MV4.T42-T49.1	MV4	E.311 & E.316	COUNTY RD	T42	T49	4/0 AWG	N/A
MV4.T42-T49.2	MV4	E.316	COUNTY RD	T42	T49	4/0 AWG	N/A
MV4.T44-JB4/1.1	MV4	E.316 & E.324	COUNTY RD	T44	JB4/1	500 MCM	N/A
MV4.T46-T45.1	MV4	E.324 & E.330	COUNTY RD	T46	T45	1000 MCM	N/A
MV4.T45-T44.1	MV4	E.324	WETLAND	T45	T44	750 MCM	N/A
MV4.T45-T44.2	MV4	E.324	COUNTY RD	T45	T44	750 MCM	N/A
MV4.T40-T46.1	MV4	E.329 & E.330	COUNTY RD	T40	T46	1000 MCM	N/A
MV4.SUB-T40.1	MV4	E.329	WETLAND	SUB	T40	1250 MCM	3' (10' ROW)
MV4.SUB-T40.2	MV4	E.323 & E.329	COUNTY RD	SUB	T40	1250 MCM	3' (10' ROW)
MV4.SUB-T40.3	MV4	E.322 & E.323	COUNTY RD	SUB	T40	1250 MCM	3' (10' ROW)
MV4.SUB-T40.4	MV4	E.321 & E.322	STATE HWY	SUB	T40	1250 MCM	3' (10' ROW)
MV4.SUB-T40.5	MV4	E.321	WETLAND	SUB	T40	1250 MCM	3' (10' ROW)
MV4.SUB-T40.6	MV4	E.320 & E.321	COUNTY RD	SUB	T40	1250 MCM	3' (10' ROW)
MV4.SUB-T40.7	MV4	E.320	MVAC FDR2	SUB	T40	1250 MCM	15' (20' ROW)
MV4.SUB-T40.8	MV4	E.320	WETLAND	SUB	T40	1250 MCM	12' (28' ROW)
MV4.SUB-T40.9	MV4	E.320 & E.327	COUNTY RD	SUB	T40	1250 MCM	18' (40' ROW)
MV4.SUB-T40.10	MV4	E.327	GAS PIPELINE	SUB	T40	1250 MCM	23' (76' ROW)
MV4.SUB-T40.11	MV4	E.327 & E.331	STATE HWY	SUB	T40	1250 MCM	23' (76' ROW)
MV4.SUB-T40.12	MV4	E.327 & E.331	GAS PIPELINE	SUB	T40	1250 MCM	23' (76' ROW)

Westwood
Phone (952) 937-5150 7699 Anagram Drive
Fax (952) 937-5822 Eden Prairie, MN 55344
Toll Free (888) 937-5150 westwoodps.com
Westwood Professional Services, Inc.

Designed: JRV
Checked: ANS
Drawn: JMC, JRG
As-Built Drawing:

Revisions:

#	DATE	DESCRIPTION
A	09/27/17	30% plans
B	10/03/17	Issued for Procurement – Revised
C	10/19/17	60% plans
D	10/30/17	90% plans

Prepared for:

WHITE an IEA company
3900 E. White Ave
Clinton, IN 47842

Trishe Wind Ohio, LLC
c/o Starwood Energy Group, LLC
5 Greenwich Office Park, 2nd Floor
Greenwich, CT 06831

Northwest Ohio Wind Project
Paulding County, Ohio

Boring Schedule

Not For Construction
Array Date: 09/14/2017
Date: 10/30/2017
Sheet: E.801
0007186_E800 Schedules.dwg

©2017 Westwood Professional Services, Inc.

FIBER OPTIC POWER LOSSES

	MINIMUM	# of FUSION SPLICES	# of CONNECTORS
		3	6

CIRCUIT	CO-LOCATED FIBER CABLE (12-STRAND S1)	ADDITIONAL SPLICES	ADDITIONAL CONNECTORS	FIBER CABLE LENGTH (FT)	FIBER CABLE LENGTH (kM)	POWER LOSS (dB)
1	FO.SUB-T25	0	0	4616	1.407	6.79243488
1	FO.T25-10	0	0	10172	3.100	7.38514896
1	FO.T10-08	2	2	5458	1.664	8.08225944
1	FO.T08-04	2	2	3297	1.005	7.85172396
1	FO.T04-03	2	2	2679	0.817	7.78579572
1	FO.T03-01	2	2	1991	0.607	7.71239988
1	FO.T01-02	0	0	1777	0.542	6.48957036
1	FO.T02-MET.1	2	2	1878	0.572	7.70034504
1	FO.MET.1-05	2	2	2213	0.675	7.73608284
1	FO.T05-09	2	2	5976	1.821	8.13751968
1	FO.T09-24	4	4	13966	4.257	10.18989288
1	FO.SUB-24	0	0	6249	1.905	6.96664332
1	FO.T25-24	2	2	1633	0.498	7.67420844
2	FO.SUB-T22	0	0	11073	3.375	7.48126764
2	FO.T22-29	0	0	4171	1.271	6.74496228
2	FO.T29-20	4	4	9139	2.786	9.67494852
2	FO.T20-21	0	0	3551	1.082	6.67882068
2	FO.T21-15	6	6	11678	3.559	11.14580904
2	FO.T15-13	2	2	5287	1.611	8.06401716
2	FO.T13-14	0	0	1517	0.462	6.46183356
2	FO.T14-07	2	2	6560	1.999	8.1998208
2	FO.T06-16	2	2	4456	1.358	7.97536608
2	FO.T16-SUB	8	8	21264	6.481	13.36844352
3	FO.SUB-T23	0	0	12285	3.744	7.6105638
3	FO.T23-28	0	0	2947	0.898	6.61438596
3	FO.T28-26	2	2	3483	1.062	7.87156644
3	FO.T26-27	0	0	1780	0.543	6.4898904
3	FO.T27-33	2	2	7556	2.303	8.30607408
3	FO.T33-31	2	2	6519	1.987	8.19544692
3	FO.T31-32	0	0	5205	1.586	6.8552694
3	FO.T32-34	2	2	2988	0.911	7.81875984
3	FO.T34-37	2	2	4613	1.406	7.99211484
3	FO.T37-36	0	0	1301	0.397	6.43879068
3	FO.T36-39	2	2	8992	2.741	8.45926656
3	FO.T36-SUB	6	6	28439	8.668	12.93387252
4	FO.SUB-T46	2	2	32486	9.902	10.96560648
4	FO.T46-44	2	2	6878	2.096	8.23374504
4	FO.T44-49	4	4	9987	3.044	9.76541316
4	FO.T49-48	0	0	1717	0.523	6.48316956
4	FO.T48-50	2	2	3378	1.030	7.86036504
4	FO.T50-42	2	2	8132	2.479	8.36752176
4	FO.T42-43	2	2	1379	0.420	7.64711172
4	FO.T43-41	2	2	2735	0.834	7.7917698
4	FO.T41-45	4	4	7753	2.363	9.52709004
4	FO.T45-40	2	2	6578	2.005	8.20174104
4	FO.J40-SUB	0	0	29905	9.115	9.4902654

	(ft)	(kM)	(dB)
Total	337,637	102.91	
Max	32,486	9.90	13.37
Min	1,301	0.40	6.44

GENERAL NOTES

1. SEE FIBER OPTIC POWER LOSSES TABLE BELOW FOR DB LOSSES FOR EACH FIBER LINK. LOSSES CALCULATED AT 0.35 DB PER KM, 0.1 DB PER SPLICE, 0.5 DB PER CONNECTOR, AND INCLUDE 3DB ADDITIONAL MARGIN.

Westwood
Phone (952) 937-5150 7699 Anagram Drive
Fax (952) 937-5822 Eden Prairie, MN 55344
Toll Free (888) 937-5150 westwoodps.com
Westwood Professional Services, Inc.

Designed: JRV
Checked: ANS
Drawn: JMC, JRG
As-Built Drawing:

Revisions:

#	DATE	DESCRIPTION
A	09/27/17	30% plans
B	10/03/17	Issued for Procurement – Revised
C	10/19/17	60% plans
D	10/30/17	90% plans

Prepared for:

WHITE
an GIEA company

3900 E. White Ave
Clinton, IN 47842

Trishe Wind Ohio, LLC
c/o Starwood Energy Group, LLC
5 Greenwich Office Park, 2nd Floor
Greenwich, CT 06831

Northwest Ohio Wind Project

Paulding County, Ohio

Fiber Optic Schedule

Not For Construction
Array Date: 09/14/2017
Date: 10/30/2017
Sheet: E.802
0007186_E800 Schedules.dwg

HARMONICS STUDY

Northwest Ohio Wind Project

Paulding, Ohio
October 20, 2017

Prepared for:
WHITE
an IEA company

Prepared by:
Westwood

Westwood

Project Name: NW OH Wind Project	
Title	**J.O. or W.O. Number**
Harmonics Study	0007186.00

Approvals		**Revision Number**	**Date**	**Description**
Preparer(s) Name	**Reviewer(s) Name**			
Josh Venden	Drew Szabo	0	10/20/2017	Original Release

Westwood

TABLE OF CONTENTS

INTRODUCTION

NW OH Wind Project is a 100 MW wind generation installation in Paulding, OH consisting 42 of GE 2.5 MW wind turbines. The turbines are grouped into four medium voltage (MV) feeders with 10 turbines on Feeders 1 and 4 and 11 turbines on Feeders 2 and 3. The feeders are connected to a main power transformer that steps the voltage up to 138kV where it interconnects with the AEP transmission system via a short overhead line segment.

OBJECTIVE

The objectives of this study are to identify the natural resonance of the collector system for various operating configurations as well as determine the total harmonic distortion (THD) for the current and voltage at the point of interconnection (POI). Frequency scan analysis for several collector system configurations will be performed to identify the natural resonant frequencies with different components of the collector system in-service to represent a range of operating conditions. Resonance at the 3rd, 5th, 7th, 11th, or 13th harmonics typically cause the greatest problems for power system equipment. An analysis of the voltage and current waveforms within the plant and at the POI will determine if there are any harmonic resonance issues due to the PV plant being interconnected at the proposed location. Verify that harmonic distortion levels within the plant and at the POI are within the acceptable ranges defined in the IEEE 519 standard. Voltage distortion due to harmonics can cause excessive heating of rotating machines, failure of capacitor banks and other increased wear and tear on equipment. Current distortion can be less of an issue but is still important to identify and mitigate for operation of the PV plant without adverse effects on the plant, power system or neighboring facilities.

INPUTS & ASSSUMPTIONS

- Power flow analysis performed with ETAP v16.0.0C power system simulation software.
- Medium voltage AC collector electrical layout is per the Westwood Professional Services Electrical Drawings, MVAC Collection One-Line Diagrams E.200 & E.210.
- ETAP model parameters for equipment such as turbines (WTG), step-up transformers (GSU) and main power transformer (MPT) based on manufacturer data when available or typical ETAP values when information is not available.
- The harmonic profile for the existing utility system without the Northwest Ohio wind plant connected was unavailable at the time of this report. Wind turbine harmonic profile data provided by GE.
- ETAP model parameters for MV cables based on thermal analysis using CYME Cymcap Underground Cable Thermal Analysis software.
- ETAP model parameters for overhead transmission line data based on ETAP library of standard overhead conductors.
- ETAP model parameters for utility equivalent impedance information provided by AEP.
- Appendix C shows the various ETAP inputs used.
- The 2.5 MW GE wind turbines are capable of delivering a maximum leading or lagging power factor of 0.9
- The grounded wye connection of the main power transformer secondary is connected to ground reactor of 0.6 ohms.
- The MPT has a load tap changer (LTC) on the high side windings which maintains a voltage of 1.0 pu on the low-side transformer bus.

METHODOLOGY

- This calculation utilizes the ETAP Harmonic Load Flow Analysis module, which employs the Newton-Raphson method for power flow iterative solution. See Appendix A for the ETAP Load Flow and Losses output reports.
- A frequency scan is performed for several different operating configurations to ensure parallel or series resonance does not occur at any of the more problematic harmonic frequencies (i.e. 3rd, 5th, 7th, 11th, 13th).
- Series resonant frequencies can create problems if there are high levels of harmonic voltage distortion already existing in the utility system, however this is not a common occurrence.
- Parallel resonant frequencies can create problems if there are other harmonic sources near the wind farm with similar resonant frequencies. Parallel resonance can result in large voltages at capacitor bank terminals during switching which can lead to premature equipment failure.
- An analysis of the total harmonic distortion (current and voltage) at the POI was performed to determine if the PV plant interconnection results in any harmonic distortion exceeding the limits defined in IEEE Standard 519-2014. The harmonic voltage distortion limits are shown in Table 1 harmonic current distortion limits from IEEE-519-2014 (Table 3) are shown below.

Table 1—Voltage distortion limits

Bus voltage V at PCC	Individual harmonic (%)	Total harmonic distortion THD (%)
$V \leq 1.0$ kV	5.0	8.0
1 kV $< V \leq 69$ kV	3.0	5.0
69 kV $< V \leq 161$ kV	1.5	2.5
161 kV $< V$	1.0	1.5[a]

[a]High-voltage systems can have up to 2.0% THD where the cause is an HVDC terminal whose effects will have attenuated at points in the network where future users may be connected.

Table 3—Current distortion limits for systems rated above 69 kV through 161 kV

Maximum harmonic current distortion in percent of I_L						
Individual harmonic order (odd harmonics)[a, b]						
I_{sc}/I_L	$3 \leq h < 11$	$11 \leq h < 17$	$17 \leq h < 23$	$23 \leq h < 35$	$35 \leq h \leq 50$	TDD
< 20[c]	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

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

[b]Current distortions that result in a dc offset, e.g., half-wave converters, are not allowed.

[c]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

I_L = maximum demand load current (fundamental frequency component) at the PCC under normal load operating conditions

CONCLUSION

- The first configurations analyzed were with all collection feeders online. The utility equivalent impedance was modeled for the current intact transmission system as well as an equivalent impedance for an N-1 contingency configuration and an estimated future (2022) utility equivalent impedance.
- 14 additional scans were performed for various combinations of feeders in-service with the current intact system utility equivalent information.
- Frequency scans were also run at the MV buses of the closest and farthest wind turbines on the collection system.
- Additionally, all scenarios were run with the 4 Mvar substation cap bank in and out of service.
- Appendix C shows the frequency scan plots for all study cases, spikes in the plot represent the parallel resonant frequencies, dips or troughs in the plot represent series resonant frequencies.
- The following table shows a summary of the parallel resonant frequencies for the different configurations and indicates parallel resonant frequencies at the 11th harmonic with the capacitor bank online. This could create issues during capacitor bank switching if nearby harmonic sources also have similar parallel resonance.

Table 1: Resonant Frequency Summary

Study Case	Resonant Frequency w/out Cap	Resonant Frequency with Cap
Current System Intact	12	11
Timber Switch Contingency	12	11
Future (2022) System	13	11
Feeder 1 Only	21	14
Feeder 2 Only	22	14
Feeder 3 Only	19	13
Feeder 4 Only	15	12
Feeders 1 & 2	17	13
Feeders 1 & 3	16	12
Feeders 1 & 4	14	11
Feeders 2 & 3	16	12
Feeders 2 & 4	14	12
Feeders 3 & 4	13	11
Feeders 1, 2 & 3	15	12
Feeders 1, 2 & 4	13	11
Feeders 1, 3 & 4	13	11
Feeders 2, 3 & 4	13	11
T-25 (Closest)	13	11
T-48 (Farthest)	13	11
WindFree (0kW 400kvar)	12	11

- Series resonant frequencies typically fall on even numbered harmonics which would indicate these should not pose any detrimental impacts to the wind farm or other nearby interconnected customers.

- Total Harmonic Current Distortion (THD) at the POI is summarized in the following table and plot. It can be seen that the THID levels at the POI are well within the limits established by IEEE 519-2014.

Table 2: Current Harmonic Distortion Summary

Maximum Demand Load Current I_L: 458.54 A

Harmonic Order	% of I_L	IEEE Limit	Harmonic Order	% of Fund Amps	IEEE Limit	Harmonic Order	% of Fund Amps	IEEE Limit	Harmonic Order	% of Fund Amps	IEEE Limit
THD	0.39	2.5	14	0.02	0.25	27	0	0.3	40	0	0.0375
2	0.03	0.5	15	0	1	28	0	0.075	41	0	0.15
3	0	2	16	0	0.1875	29	0	0.3	42	0	0.0375
4	0.01	0.5	17	0.01	0.75	30	0	0.075	43	0	0.15
5	0.08	2	18	0	0.1875	31	0	0.3	44	0	0.0375
6	0	0.5	19	0	0.75	32	0.01	0.075	45	0	0.15
7	0.12	2	20	0	0.1875	33	0	0.3	46	0	0.0375
8	0.01	0.5	21	0	0.75	34	0	0.0375	47	0	0.15
9	0	2	22	0	0.075	35	0	0.15	48	0	0.0375
10	0.01	0.25	23	0	0.3	36	0	0.0375	49	0	0.15
11	0.03	1	24	0	0.075	37	0	0.15	50	0	0.0375
12	0	0.25	25	0	0.3	38	0	0.0375			
13	0.36	1	26	0	0.075	39	0	0.15			

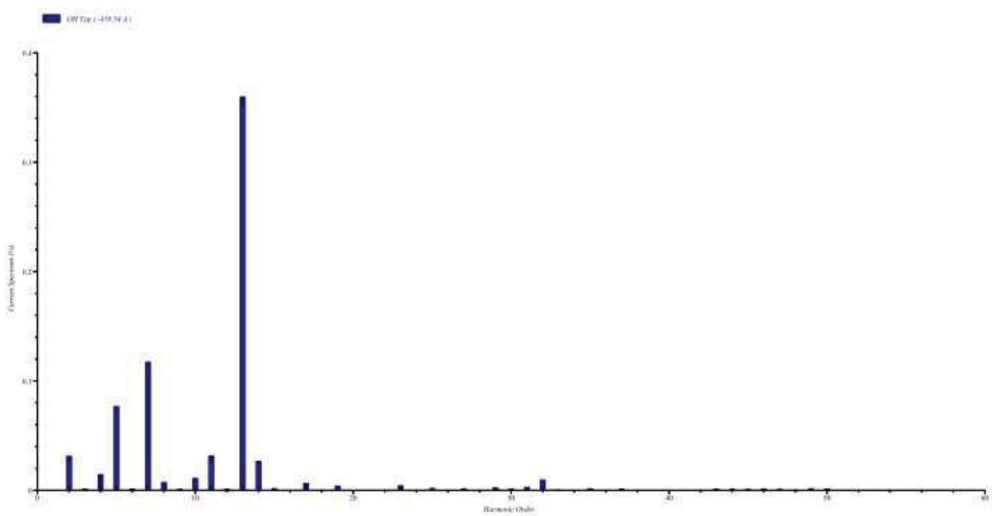


Figure 1: Current Harmonic Distortion Plot

- A Total Harmonic Voltage Distortion (THD) summary at the POI is also shown below in Table 3. It can be seen that the THID levels at the POI are well within the limits established by IEEE 519-2014.

Table 3: Voltage Harmonic Distortion Summary

Fundamental Voltage V_F: 131.1 kV

Harmonic Order	% of V_F	IEEE Limit	Harmonic Order	% of V_F	IEEE Limit	Harmonic Order	% of V_F	IEEE Limit	Harmonic Order	% of V_F	IEEE Limit
THD	0.39	2.5	14	0.02	1.5	27	0	1.5	40	0	1.5
2	0	1.5	15	0	1.5	28	0	1.5	41	0	1.5
3	0	1.5	16	0	1.5	29	0	1.5	42	0	1.5
4	0	1.5	17	0.01	1.5	30	0	1.5	43	0	1.5
5	0.03	1.5	18	0	1.5	31	0.01	1.5	44	0	1.5
6	0	1.5	19	0	1.5	32	0.02	1.5	45	0	1.5
7	0.05	1.5	20	0	1.5	33	0	1.5	46	0	1.5
8	0	1.5	21	0	1.5	34	0	1.5	47	0	1.5
9	0	1.5	22	0	1.5	35	0	1.5	48	0	1.5
10	0.01	1.5	23	0.01	1.5	36	0	1.5	49	0.01	1.5
11	0.02	1.5	24	0	1.5	37	0	1.5	50	0	1.5
12	0	1.5	25	0	1.5	38	0	1.5			
13	0.31	1.5	26	0	1.5	39	0	1.5			

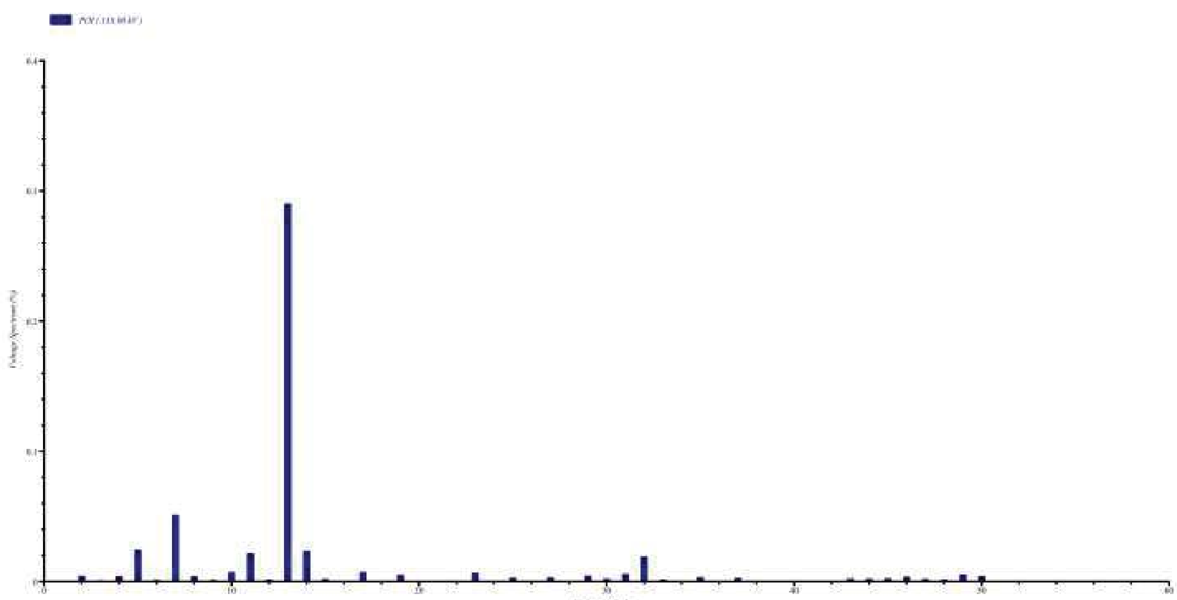


Figure 2: Voltage Harmonic Distortion Plot

- Given the relatively low level of voltage harmonic distortion and the presence of series resonance at even harmonics, the likelihood of the Trishe Wind installation experiencing negative effects from harmonics is low.

- The presence of parallel resonant frequencies at the 11th and 13th harmonics indicates a potential issue if there are other harmonic sources with similar resonant frequencies. This would not warrant any immediate action as far as harmonic filters or other mitigation. However, if problems are suspected, RMS data logger metering can be installed to monitor and record the harmonic performance of the wind farm and utility system interconnected to determine problem harmonics and remedy them accordingly.

Westwood

APPENDIX A: ETAP MODEL INPUTS

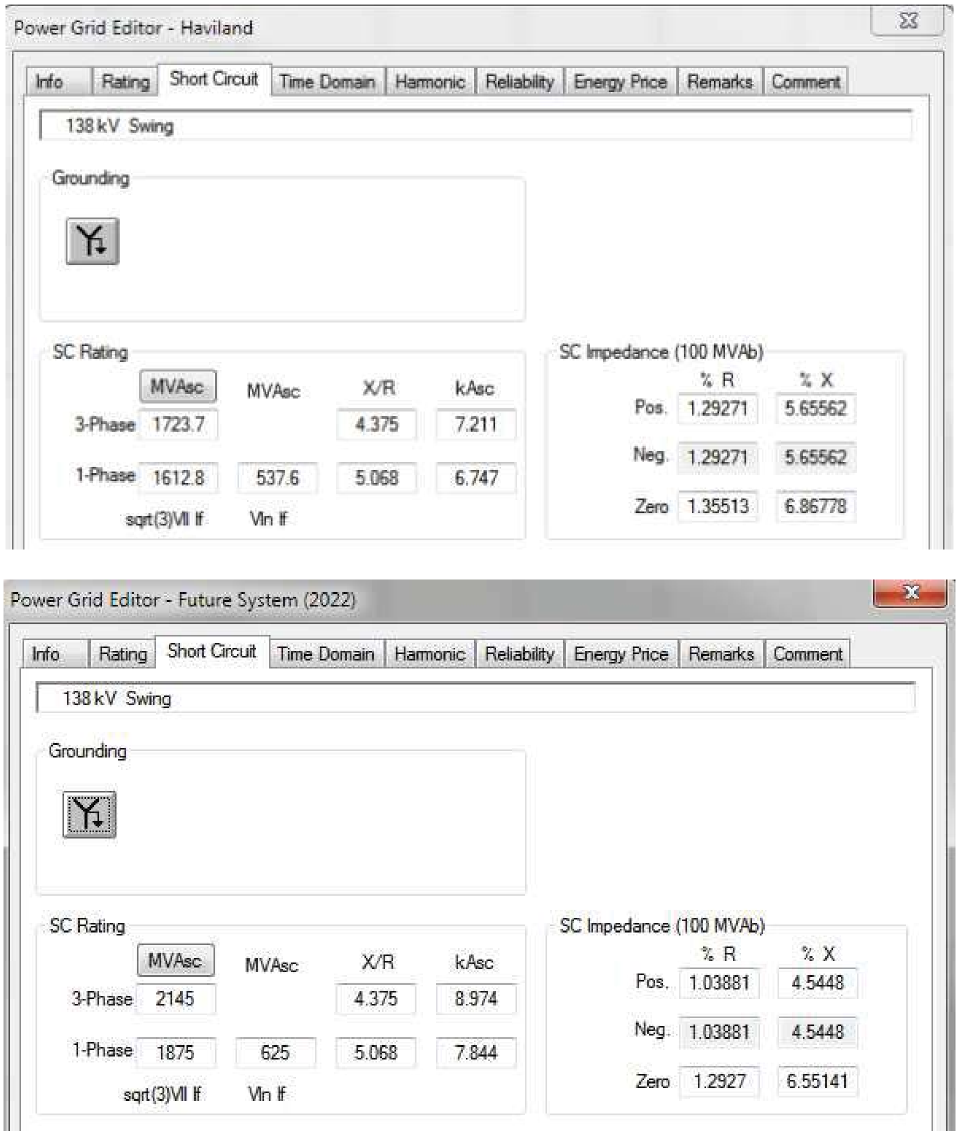


Figure 3: Utility Equivalent Data

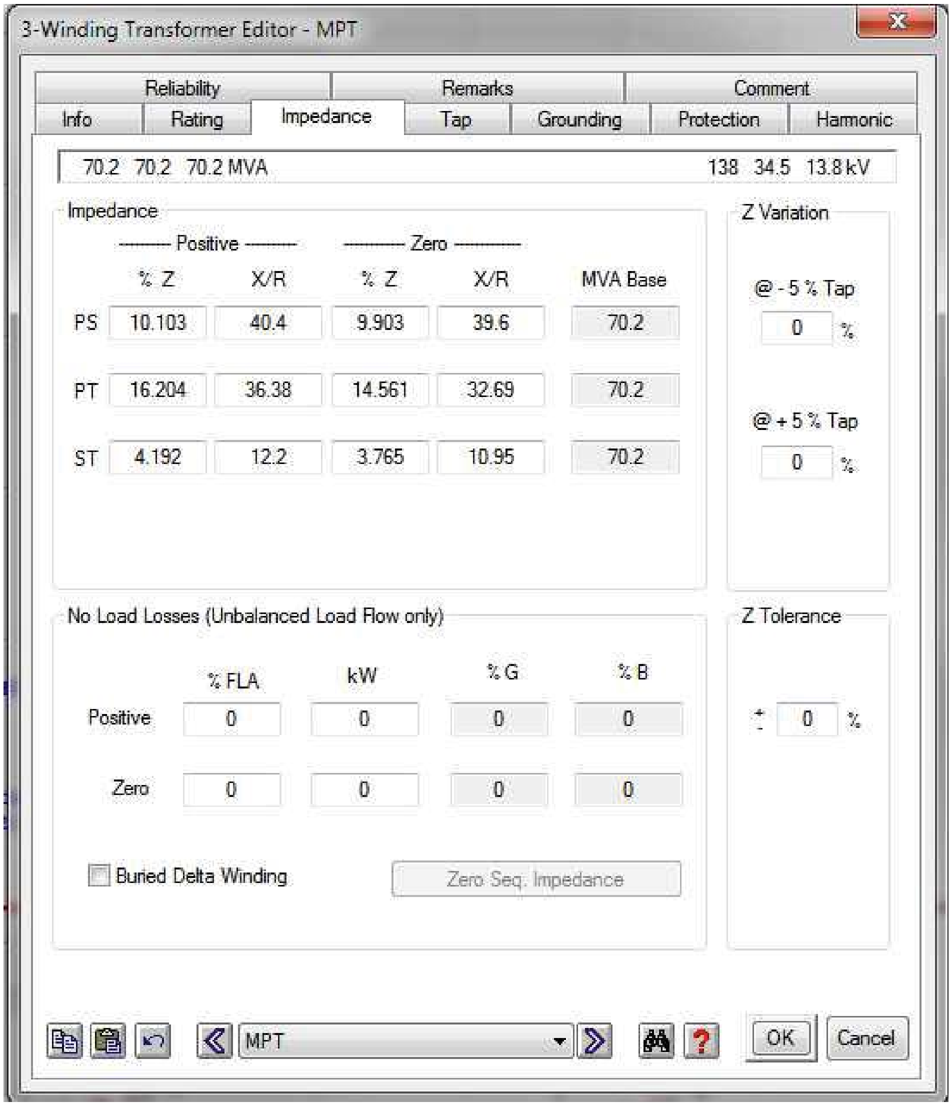


Figure 4: Main Power Transformer Impedance

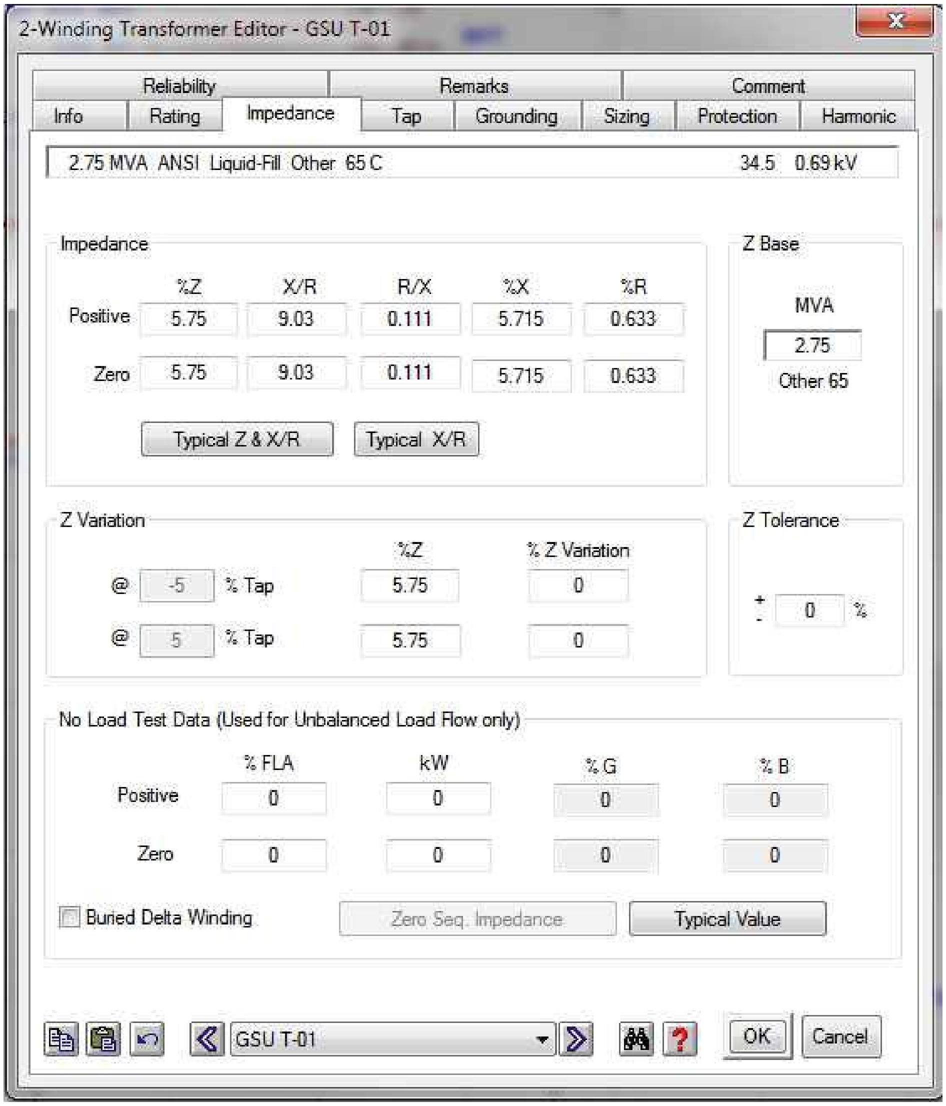


Figure 5: Step-Up Transformer Impedance Data

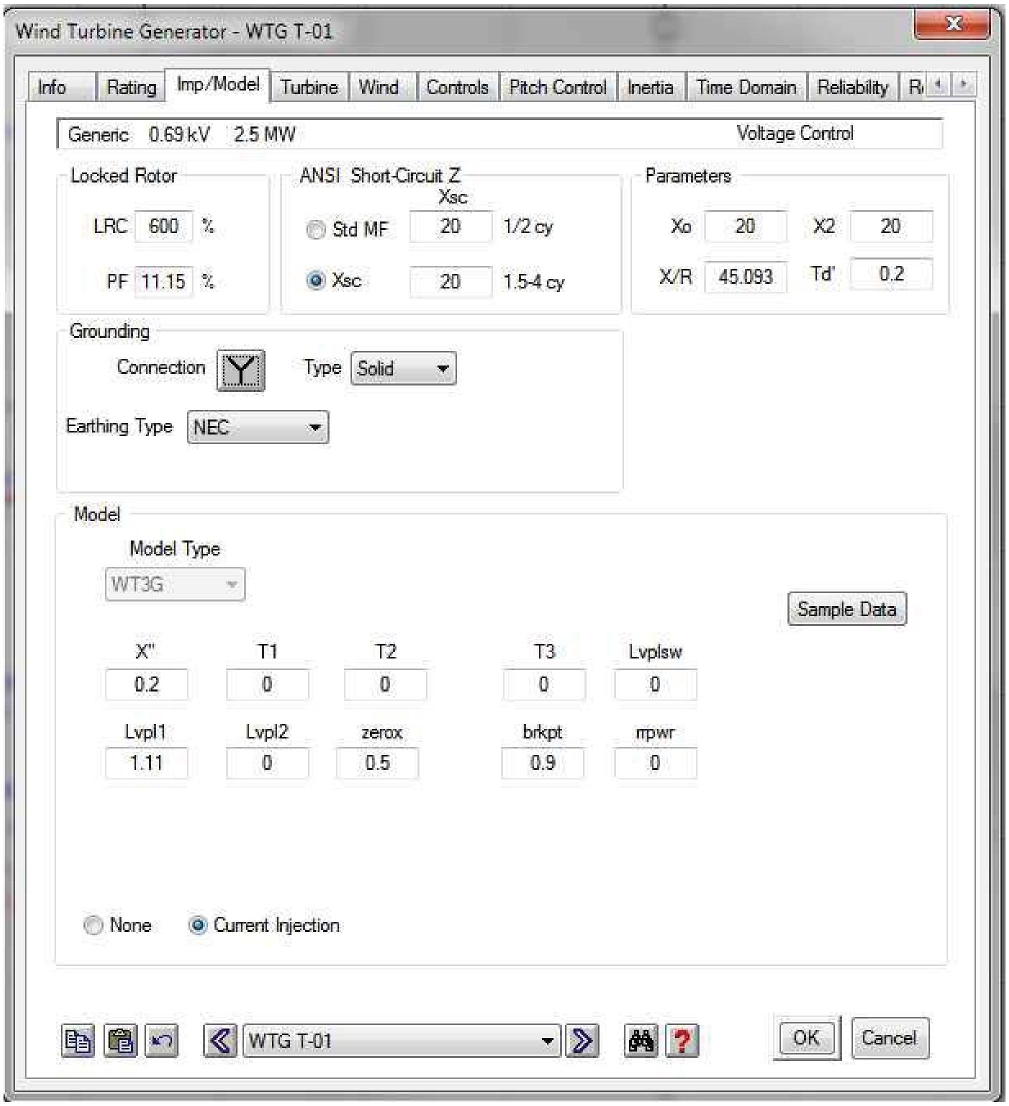


Figure 6: Turbine Impedance/Short Circuit Data

NW_OH 1/C AL XLPE 35 kV 100 % Non-Mag. 60 Hz Ohms/1000ft RHO 200°C.cm/W

Ampacity | Impedance | Physical | Cable Pulling

	Phase			Ground/Neutral		R	X	L	Y	Ro	Xo	Lo	Yo	Rdc
	Avail.	Code	Size	#	Size	90°C	60 Hz	60 Hz	60 Hz	90°C	60 Hz	60 Hz	60 Hz	25°C
1	Yes	1/0 - 2/3 CN	1/0	18	16	0.24087	0.05182	0.00014	1.77E-05	0.35886	0.05482	0.00015	1.77E-05	0.18596
2	Yes	4/0 - 1/2 CN	4/0	17	14	0.11303	0.04679	0.00012	2.2E-05	0.28416	0.07373	0.0002	2.2E-05	0.08673
3	Yes	500 - 1/3 CN	500	16	12	0.4939	0.04115	0.00011	3.05E-05	0.16756	0.04488	0.00012	3.05E-05	0.0361
4	Yes	750 - 1/6 CN	750	19	14	0.0343	0.03865	0.0001	3.56E-05	0.18978	0.05914	0.00016	3.56E-05	0.0248
5	Yes	1000 - 1/6 CN	1000	25	14	0.02568	0.03703	0.0001	3.98E-05	0.20941	0.07373	0.0002	3.98E-05	0.01814
6	Yes	1250 - 1/6 CN	1250	20	12	0.02048	0.03537	9E-05	4.36E-05	0.23977	0.09952	0.00026	4.36E-05	0.01422

Figure 7: Cable Impedance Data

Westwood

Harmonic Current content tranformed from 2500kVA base to 2750kVA						
Frequency	Order	ZWTGN1	IWTGN1	Z'TRF	IWTGN2 p.u.	IWTGN2 %
120	2	1.4934	0.0007	-0.52%	0.000702446	0.07024%
180	3	0.9742	0.0003	-0.52%	0.000301610	0.03016%
240	4	0.7365	0.0003	-0.52%	0.000302133	0.03021%
300	5	0.7566	0.0015	-0.52%	0.001510381	0.15104%
360	6	0.9617	0.0002	-0.52%	0.000201087	0.02011%
420	7	1.1793	0.0019	-0.52%	0.001908415	0.19084%
480	8	1.4439	0.0001	-0.52%	0.000100361	0.01004%
540	9	1.7393	0.0001	-0.52%	0.000100300	0.01003%
600	10	2.0955	0.0001	-0.52%	0.000100249	0.01002%
660	11	2.5326	0.0002	-0.52%	0.000200411	0.02004%
720	12	3.1029	0.0001	-0.52%	0.000100168	0.01002%
780	13	3.9474	0.0003	-0.52%	0.000300396	0.03004%
840	14	5.3926	0.0001	-0.52%	0.000100097	0.01001%
900	15	8.3778	0.0001	-0.52%	0.000100062	0.01001%
960	16	16.9707	0	-0.52%	0.000000000	0.00000%
1020	17	13.525	0.0001	-0.52%	0.000100038	0.01000%
1080	18	5.8805	0	-0.52%	0.000000000	0.00000%
1140	19	3.2628	0.0001	-0.52%	0.000100160	0.01002%
1200	20	2.0024	0	-0.52%	0.000000000	0.00000%
1260	21	1.2792	0	-0.52%	0.000000000	0.00000%
1320	22	0.8236	0	-0.52%	0.000000000	0.00000%
1380	23	0.5726	0.0002	-0.52%	0.000201833	0.02018%
1440	24	0.5534	0	-0.52%	0.000000000	0.00000%
1500	25	0.6856	0.0001	-0.52%	0.000100764	0.01008%
1560	26	0.8592	0	-0.52%	0.000000000	0.00000%
1620	27	1.0333	0.0002	-0.52%	0.000201012	0.02010%
1680	28	1.2015	0	-0.52%	0.000000000	0.00000%
1740	29	1.3641	0.0002	-0.52%	0.000200765	0.02008%
1800	30	1.5197	0.0002	-0.52%	0.000200687	0.02007%
1860	31	1.6686	0.0002	-0.52%	0.000200625	0.02006%
1920	32	1.8121	0.0003	-0.52%	0.000300863	0.03009%
1980	33	1.95	0.0001	-0.52%	0.000100267	0.01003%
2040	34	2.0832	0	-0.52%	0.000000000	0.00000%
2100	35	2.2126	0.0001	-0.52%	0.000100236	0.01002%
2160	36	2.3385	0	-0.52%	0.000000000	0.00000%
2220	37	2.4618	0.0001	-0.52%	0.000100212	0.01002%
2280	38	2.5829	0	-0.52%	0.000000000	0.00000%
2340	39	2.7018	0	-0.52%	0.000000000	0.00000%
2400	40	2.8184	0	-0.52%	0.000000000	0.00000%
2460	41	2.9328	0	-0.52%	0.000000000	0.00000%
2520	42	3.0454	0	-0.52%	0.000000000	0.00000%
2580	43	3.1568	0.0001	-0.52%	0.000100165	0.01002%
2640	44	3.2672	0.0001	-0.52%	0.000100159	0.01002%
2700	45	3.3764	0.0003	-0.52%	0.000300463	0.03005%
2760	46	3.4847	0.0002	-0.52%	0.000200299	0.02003%
2820	47	3.592	0.0001	-0.52%	0.000100145	0.01001%
2880	48	3.6984	0.0001	-0.52%	0.000100141	0.01001%
2940	49	3.804	0.0003	-0.52%	0.000300411	0.03004%
3000	50	3.9089	0.0002	-0.52%	0.000200266	0.02003%

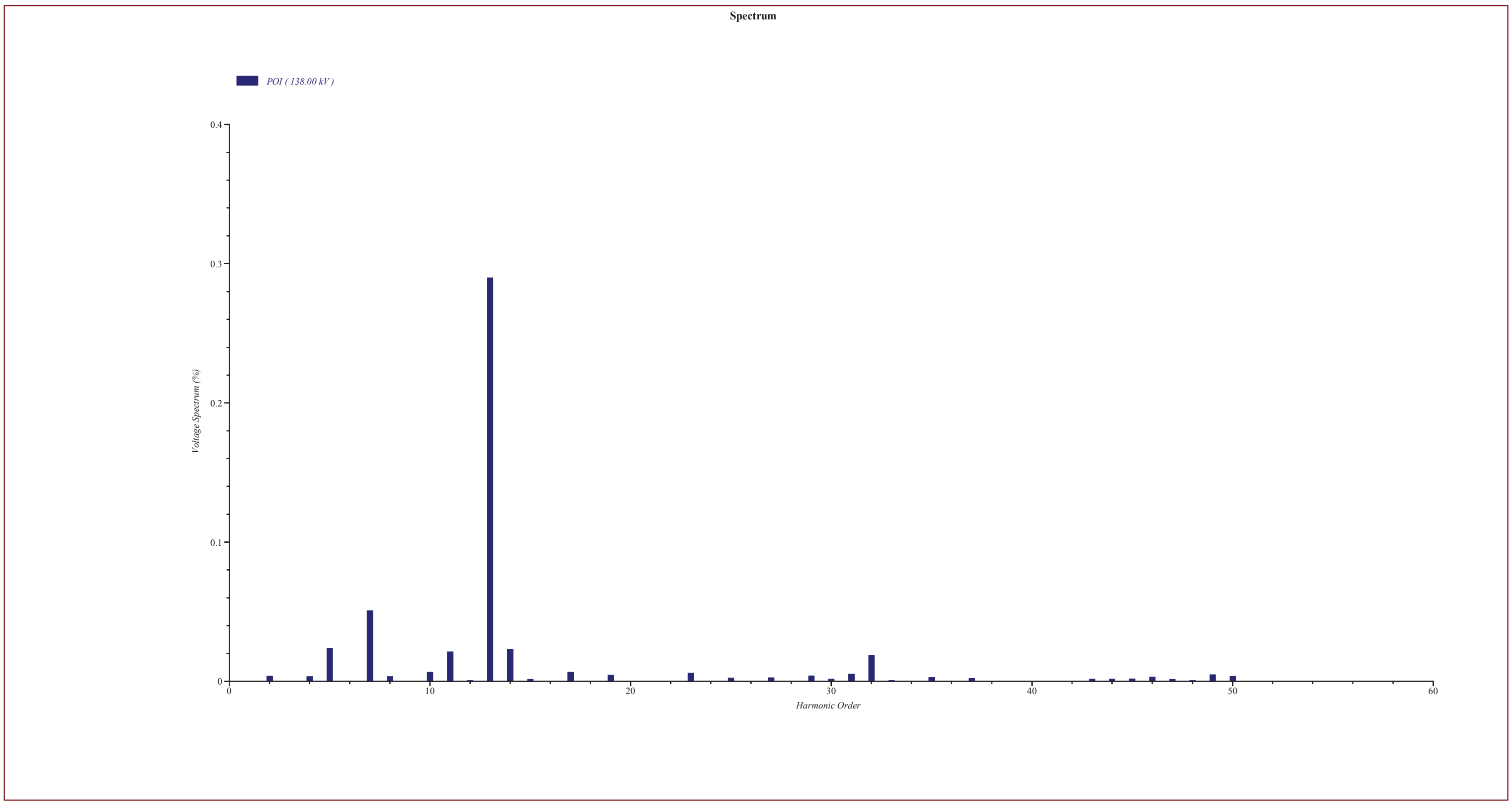
Figure 8: Wind Turbine Harmonic Profile

Westwood

APPENDIX B: HARMONIC SPECTRUM PLOTS

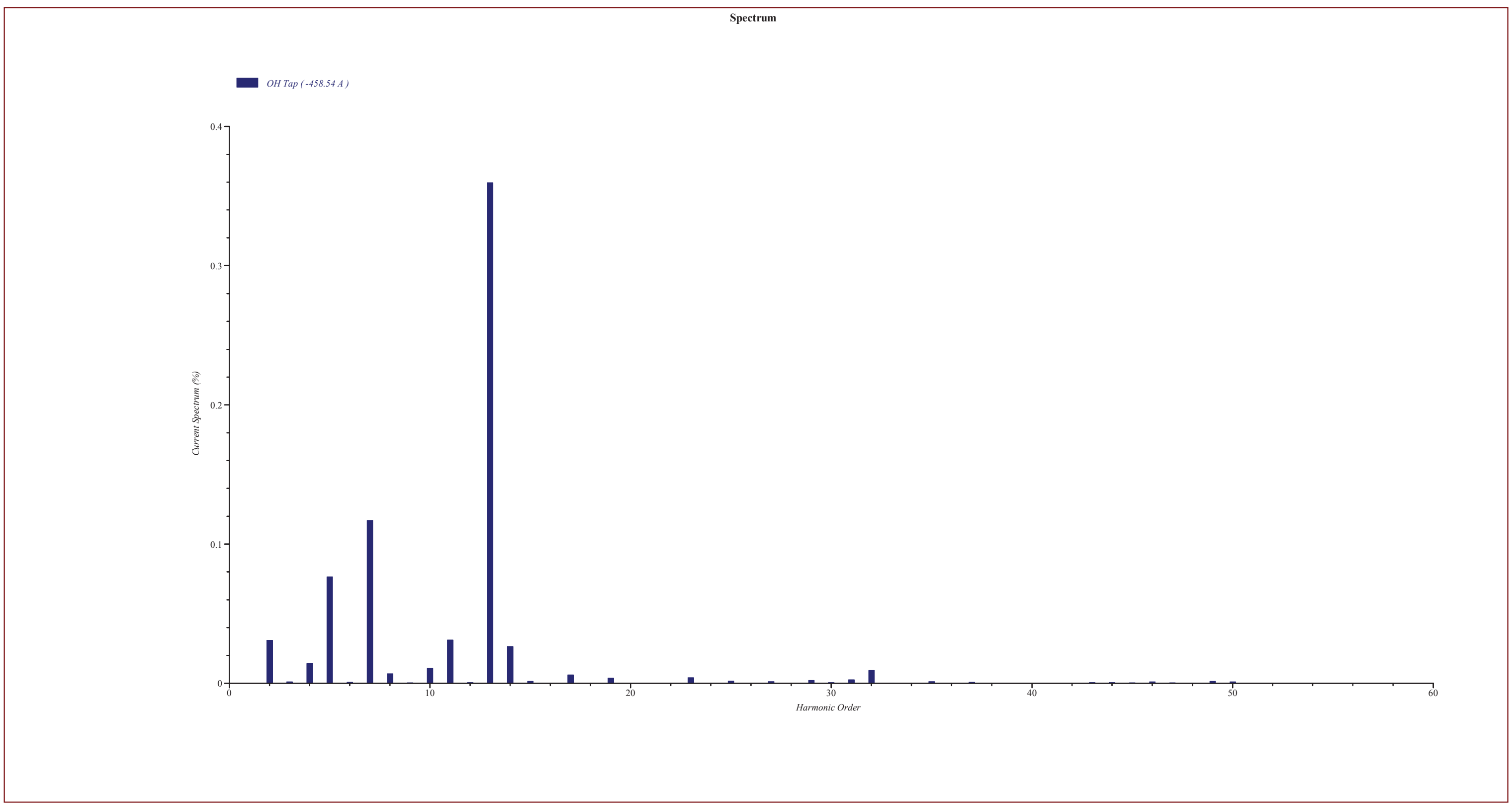
Project File: C:\Users\JVenden\Documents\WESTWOOD\PROJECTS\0007186 NW OH\ETAP\NW_OH
Output Report: 95PU 95LEAD

HARMONIC LOAD FLOW ANALYSIS



Project File: C:\Users\JVenden\Documents\WESTWOOD\PROJECTS\0007186 NW OH\ETAP\NW_OH
Output Report: 95PU 95LEAD

HARMONIC LOAD FLOW ANALYSIS

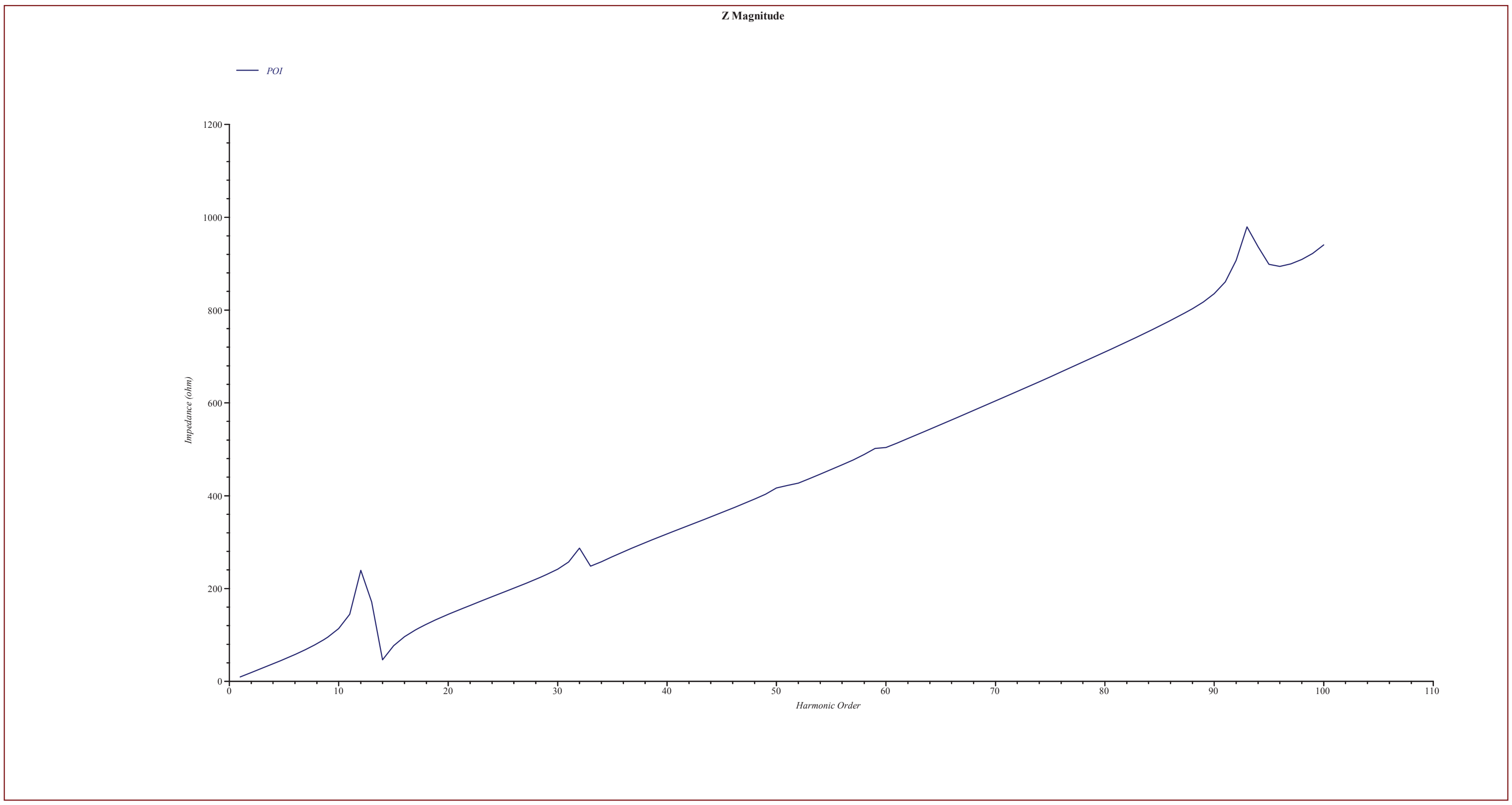


APPENDIX C: FREQUENCY SCAN SUMMARY REPORTS

Project File: C:\Users\JVenden\Documents\WESTWOOD\PROJECTS\0007186 NW OH\ETAP\NW_OH
Output Report: Current System Intact

Cap Bank OFF

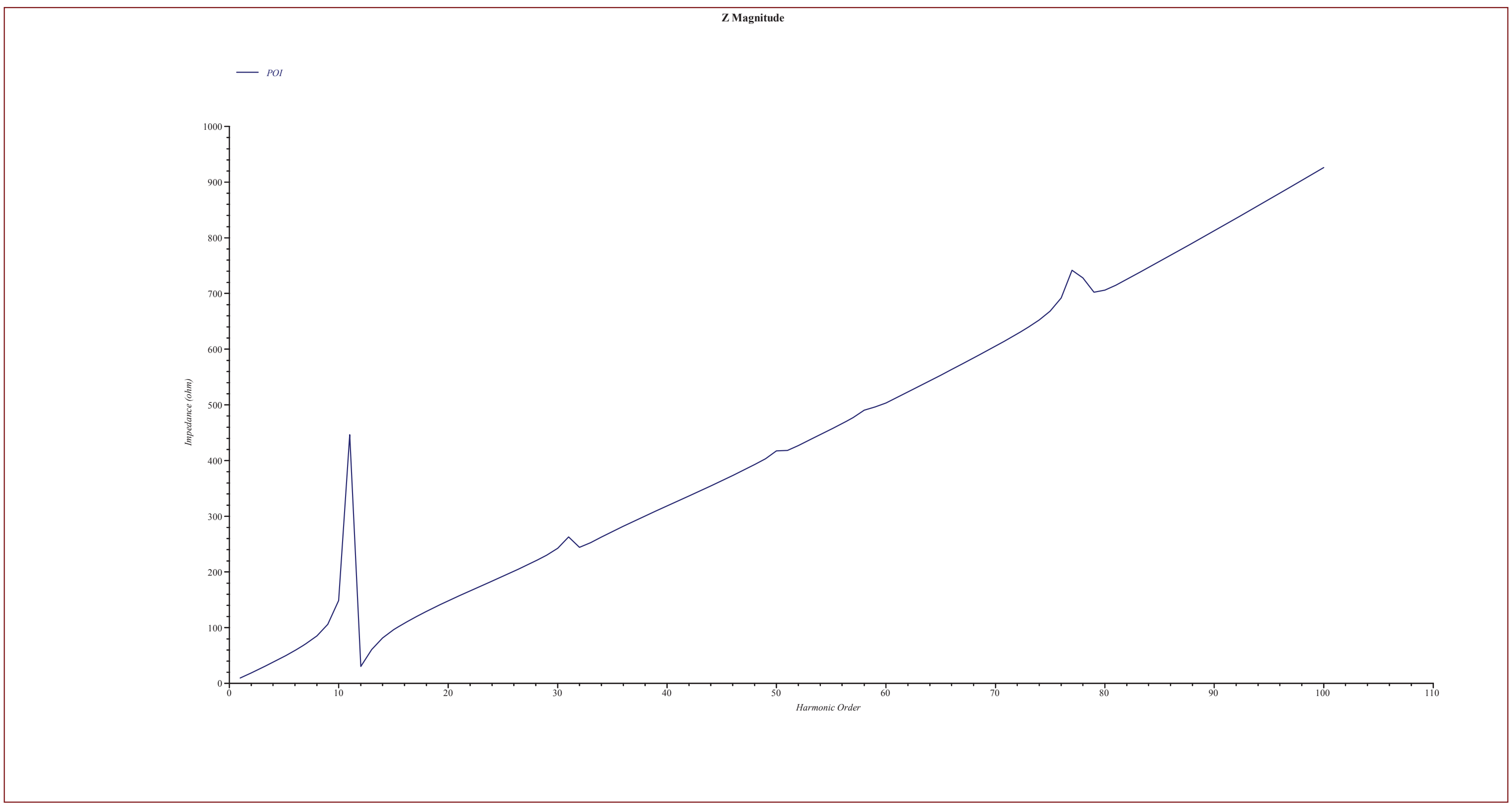
FREQUENCY SCAN ANALYSIS



Project File: C:\Users\JVenden\Documents\WESTWOOD\PROJECTS\0007186 NW OH\ETAP\NW_OH
Output Report: Current System Intact

Cap Bank ON

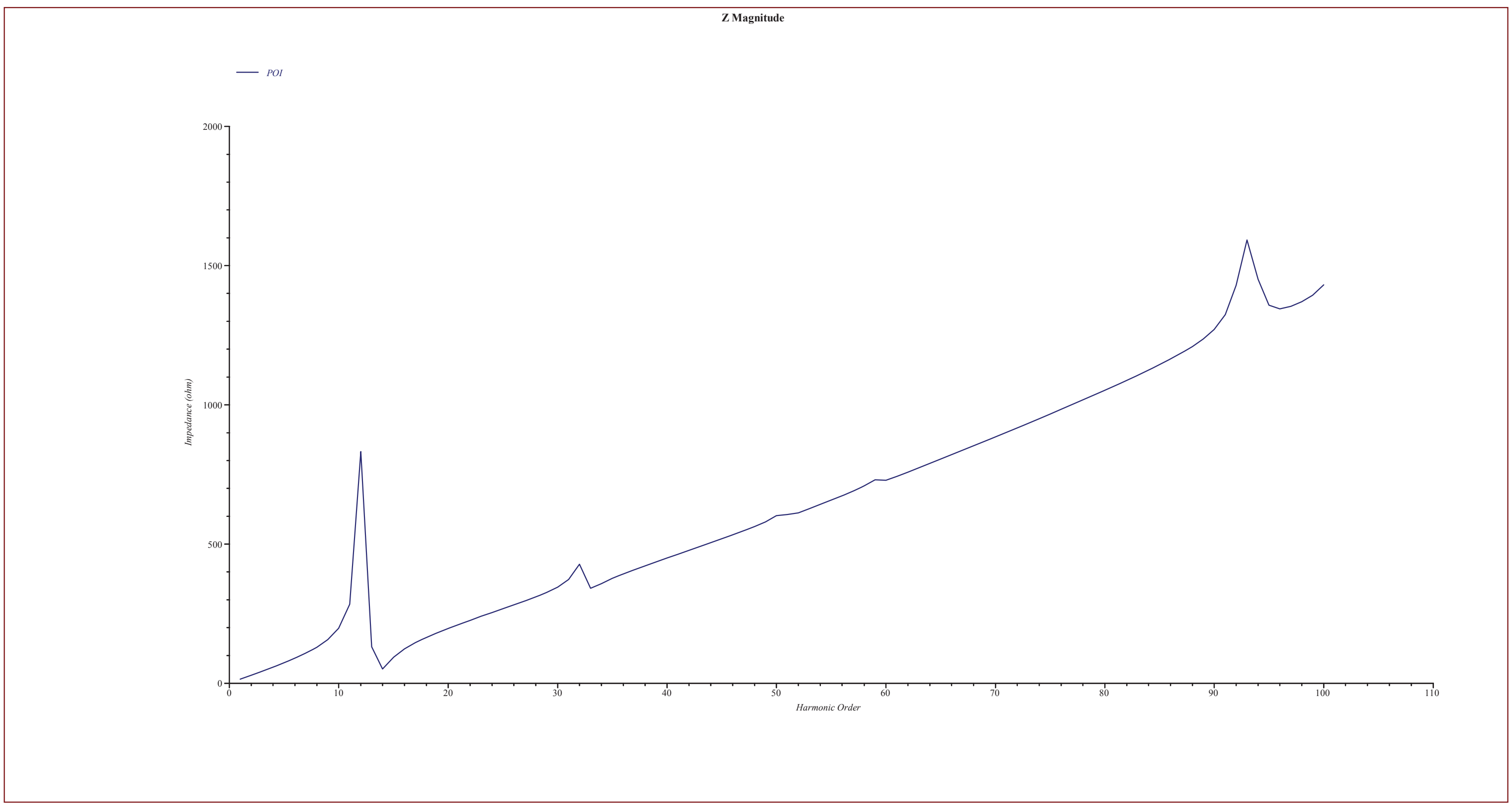
FREQUENCY SCAN ANALYSIS



Project File: C:\Users\JVenden\Documents\WESTWOOD\PROJECTS\0007186 NW OH\ETAP\NW_OH
Output Report: Contingency

Cap Bank OFF

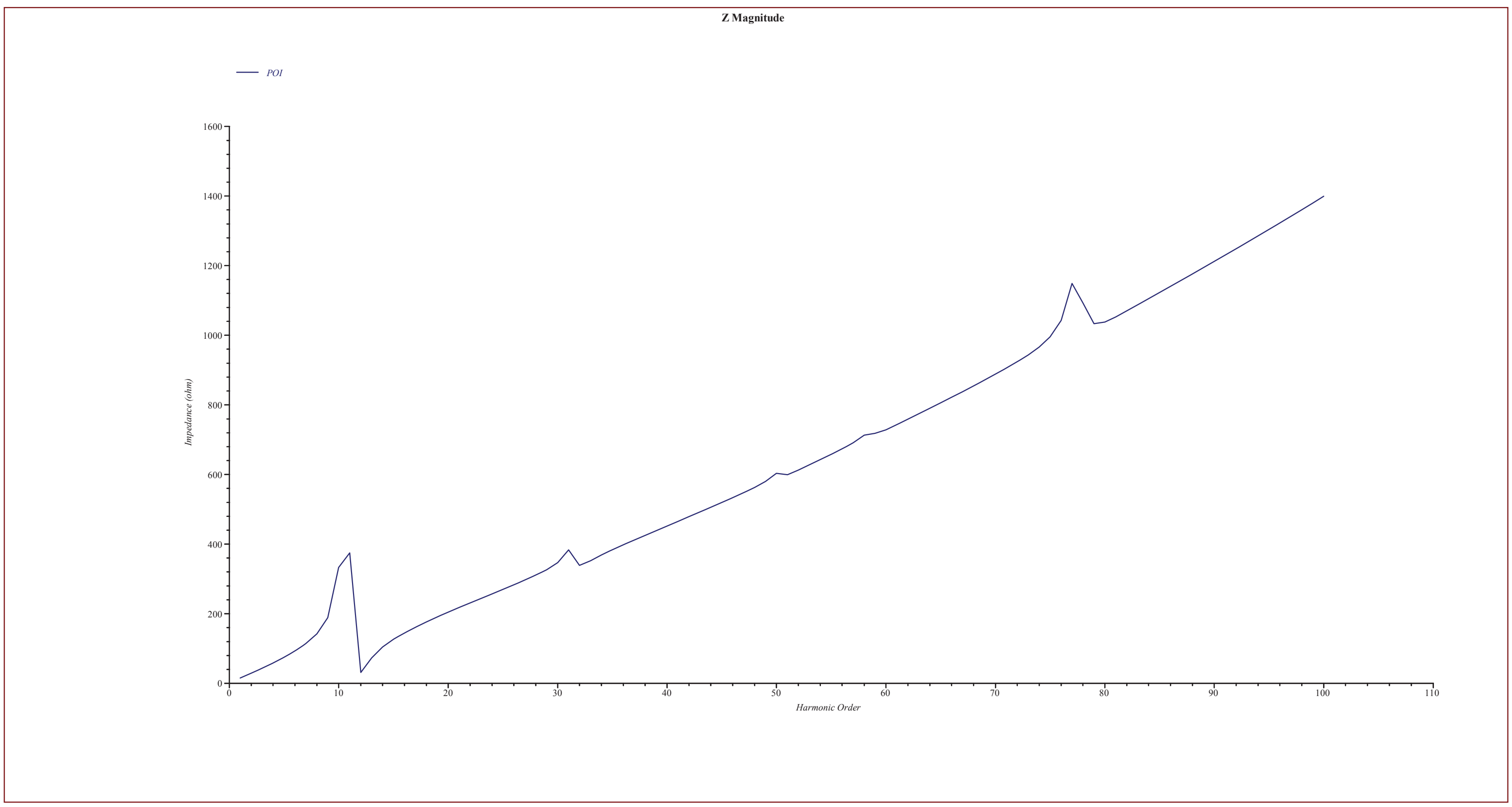
FREQUENCY SCAN ANALYSIS



Project File: C:\Users\JVenden\Documents\WESTWOOD\PROJECTS\0007186 NW OH\ETAP\NW_OH
Output Report: Contingency

Cap Bank ON

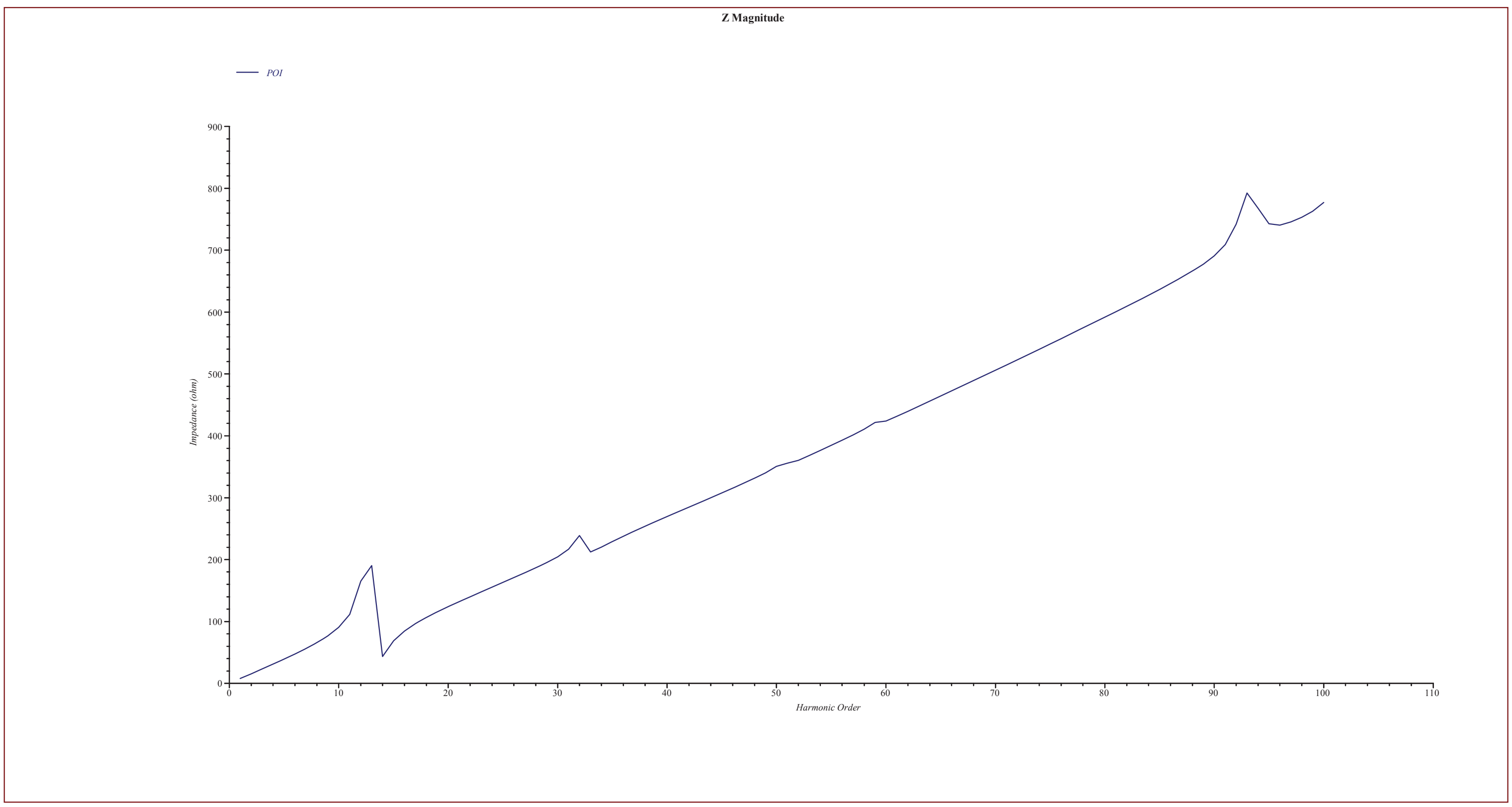
FREQUENCY SCAN ANALYSIS



Project File: C:\Users\JVenden\Documents\WESTWOOD\PROJECTS\0007186 NW OH\ETAP\NW_OH
Output Report: Future System

Cap Bank OFF

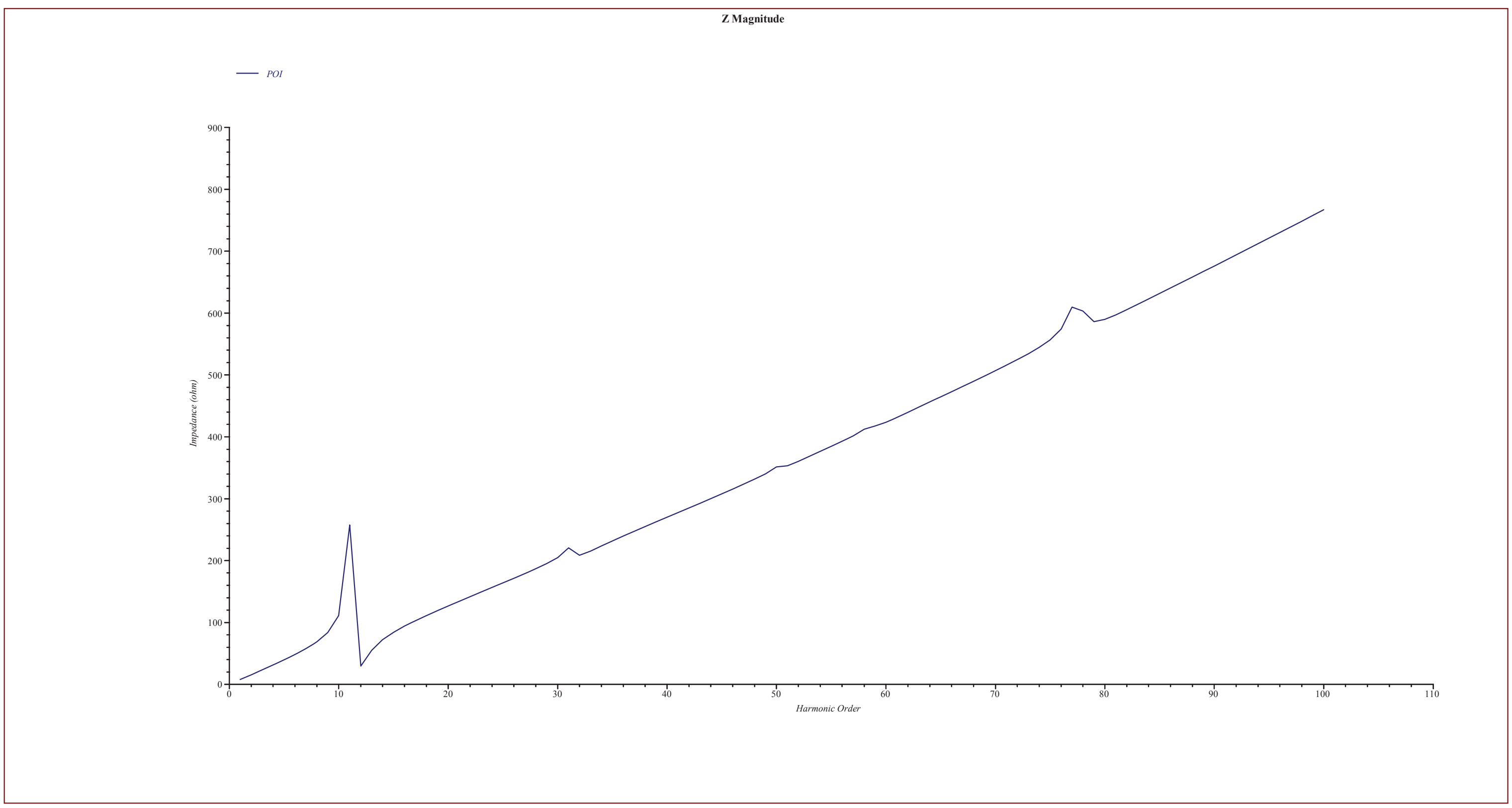
FREQUENCY SCAN ANALYSIS



Project File: C:\Users\JVenden\Documents\WESTWOOD\PROJECTS\0007186 NW OH\ETAP\NW_OH
Output Report: Future System

Cap Bank ON

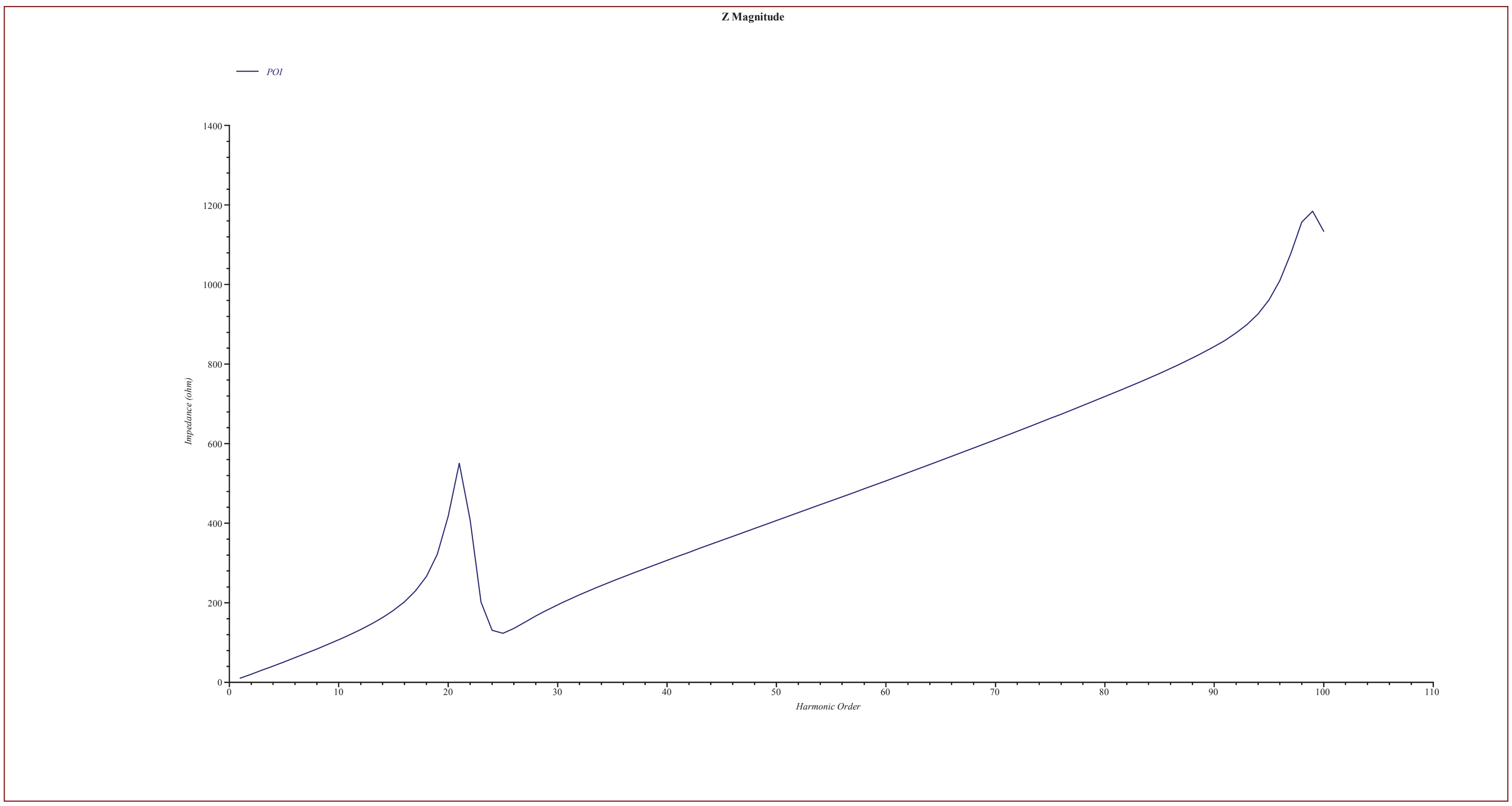
FREQUENCY SCAN ANALYSIS



Project File: C:\Users\JVenden\Documents\WESTWOOD\PROJECTS\0007186 NW OH\ETAP\NW_OH
Output Report: Feeder1

Cap Bank OFF

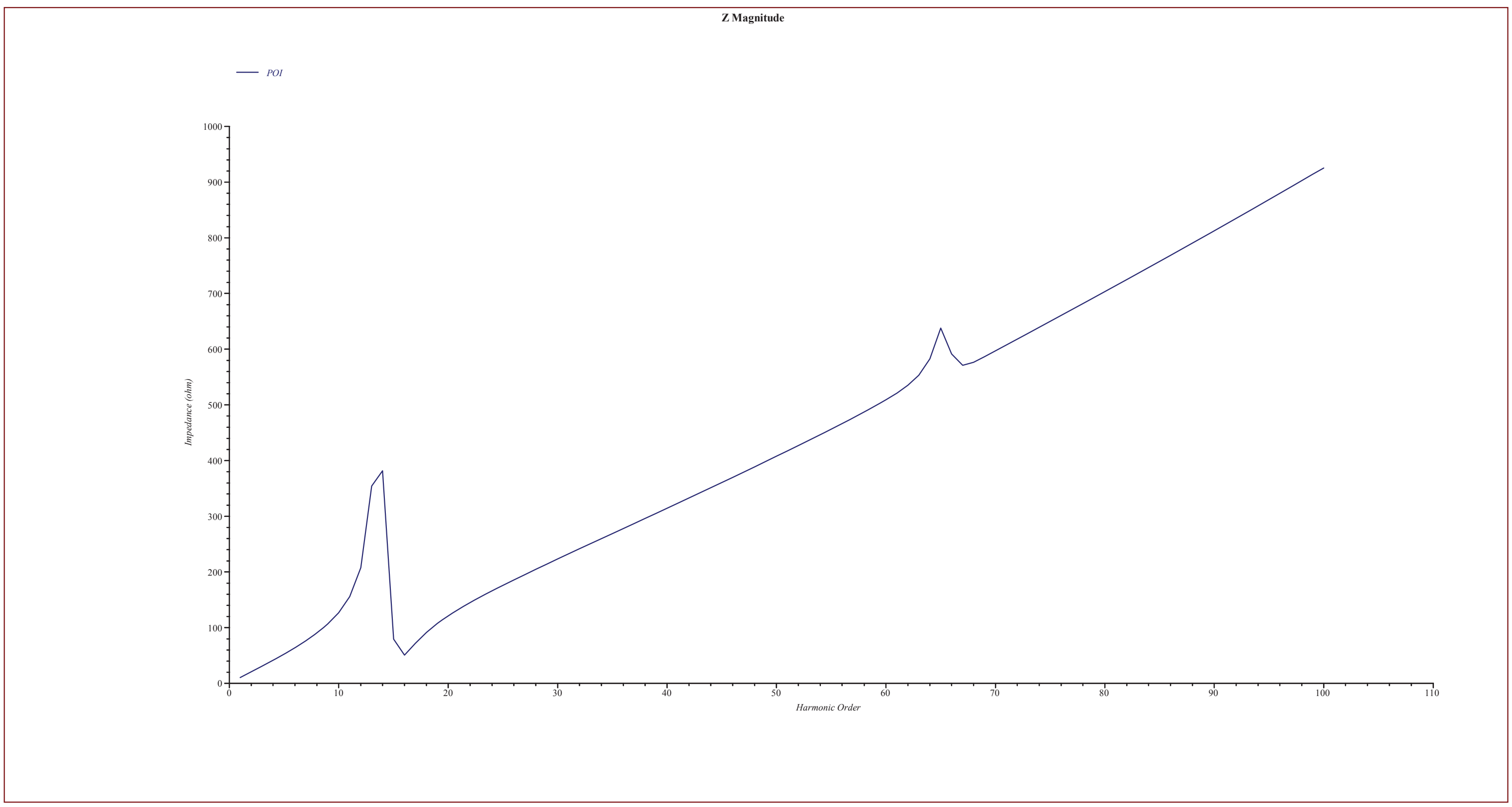
FREQUENCY SCAN ANALYSIS



Project File: C:\Users\JVenden\Documents\WESTWOOD\PROJECTS\0007186 NW OH\ETAP\NW_OH
Output Report: Feeder1

Cap Bank ON

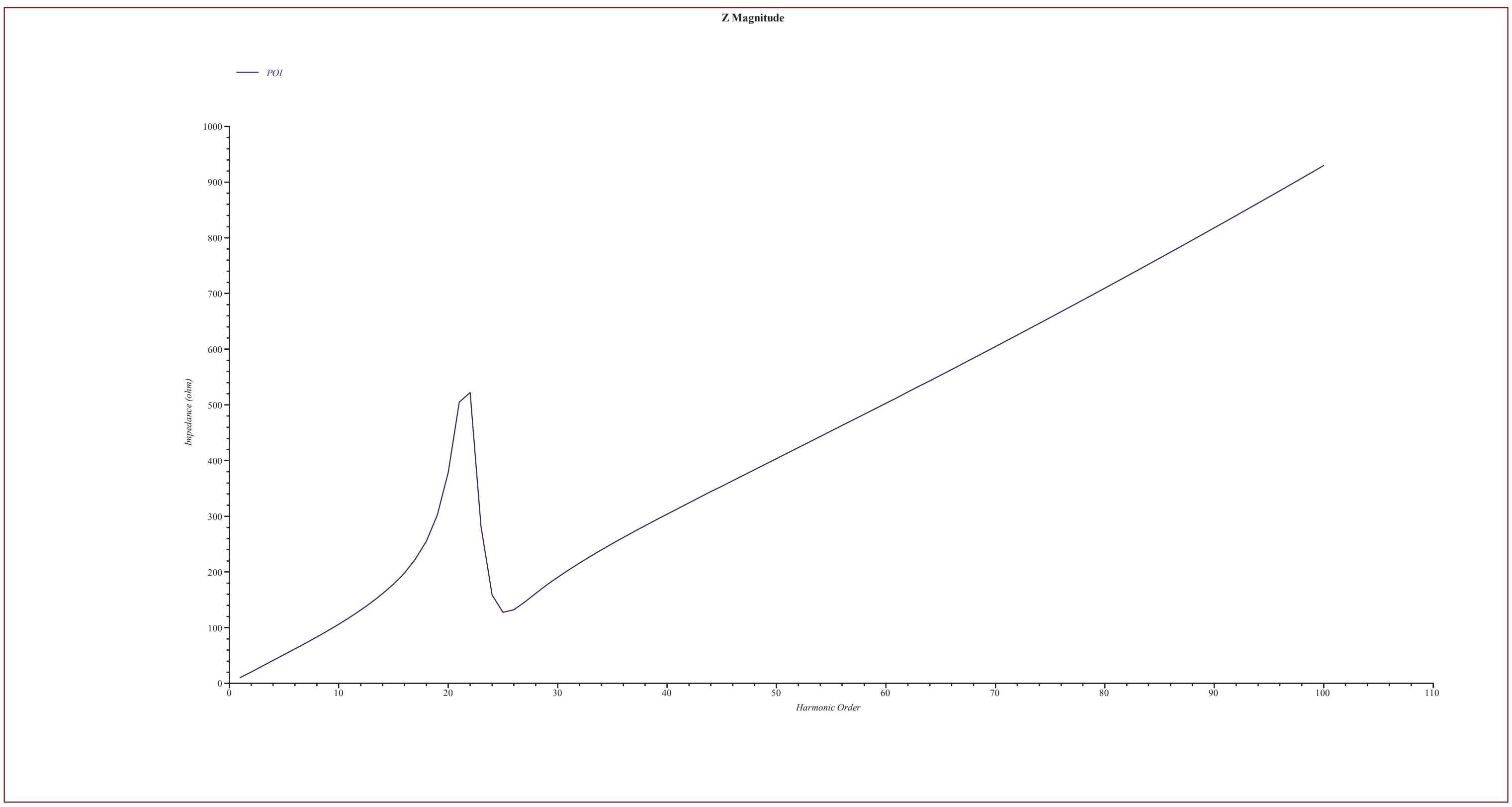
FREQUENCY SCAN ANALYSIS



Project File: C:\Users\JVenden\Documents\WESTWOOD\PROJECTS\0007186 NW OH\ETAP\NW_OH
Output Report: Feeder2

Cap Bank OFF

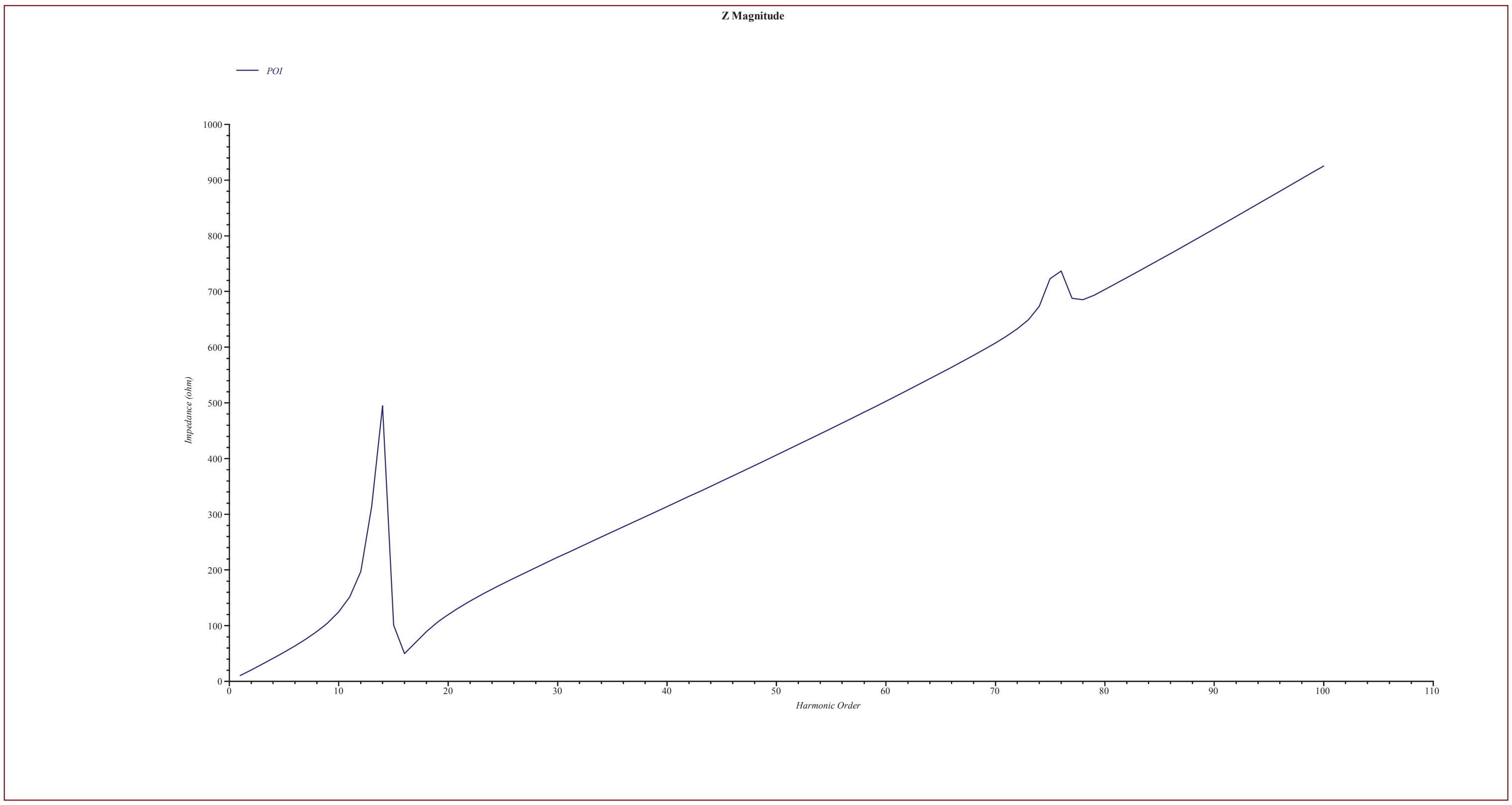
FREQUENCY SCAN ANALYSIS



Project File: C:\Users\JVenden\Documents\WESTWOOD\PROJECTS\0007186 NW OH\ETAP\NW_OH
Output Report: Feeder2

Cap Bank ON

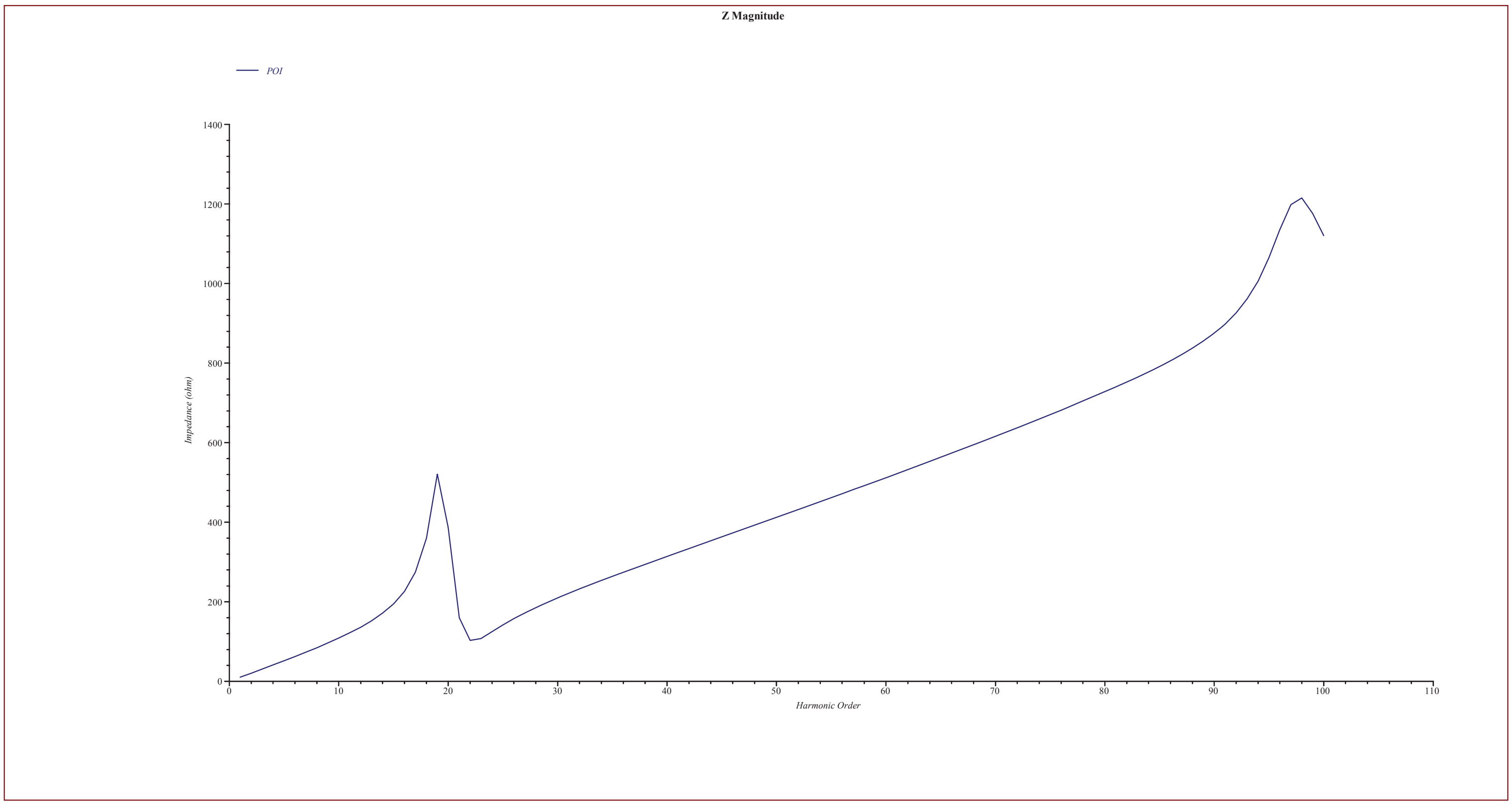
FREQUENCY SCAN ANALYSIS



Project File: C:\Users\JVenden\Documents\WESTWOOD\PROJECTS\0007186 NW OH\ETAP\NW_OH
Output Report: Feeder3

Cap Bank OFF

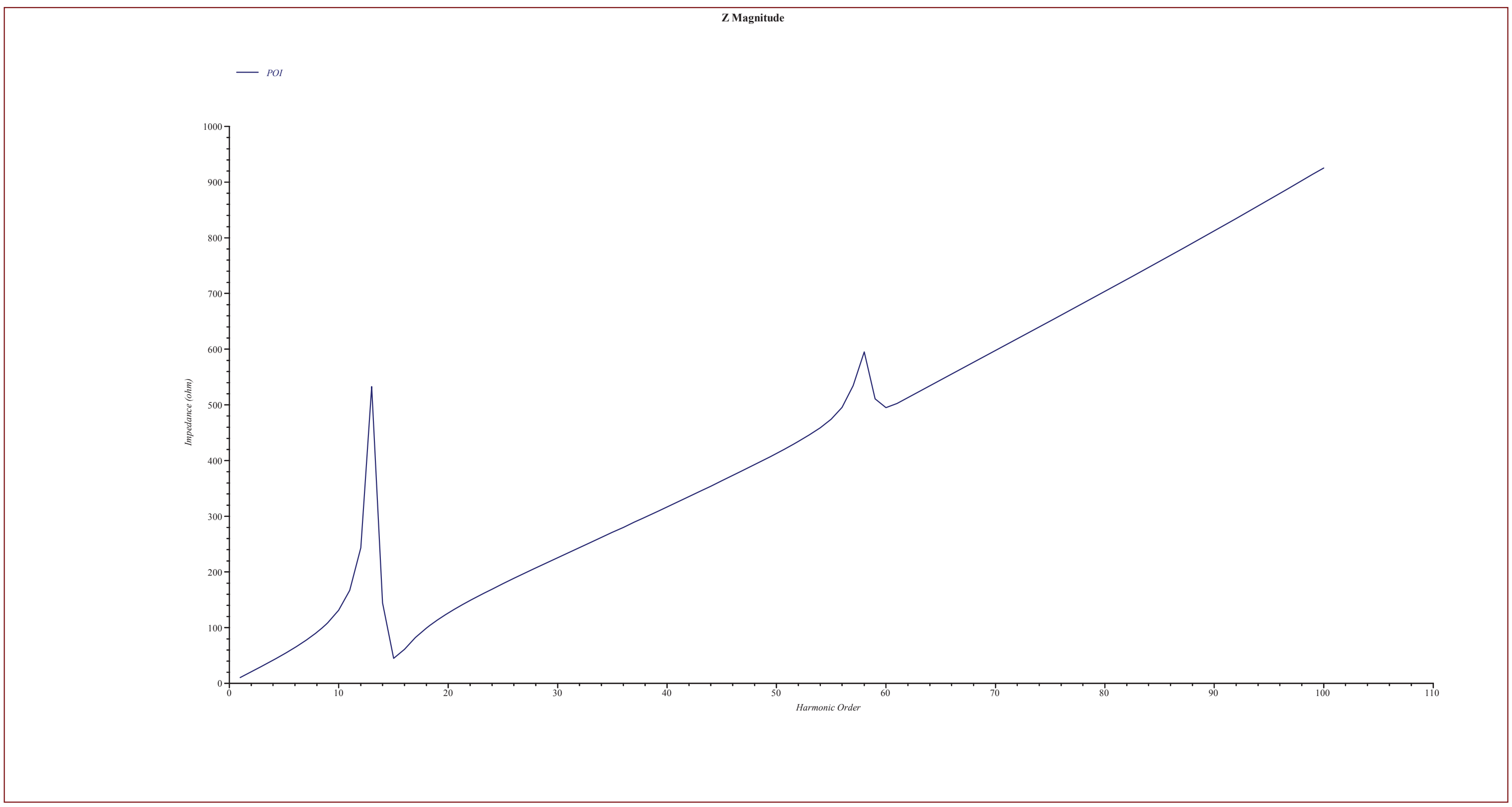
FREQUENCY SCAN ANALYSIS



Project File: C:\Users\JVenden\Documents\WESTWOOD\PROJECTS\0007186 NW OH\ETAP\NW_OH
Output Report: Feeder3

Cap Bank ON

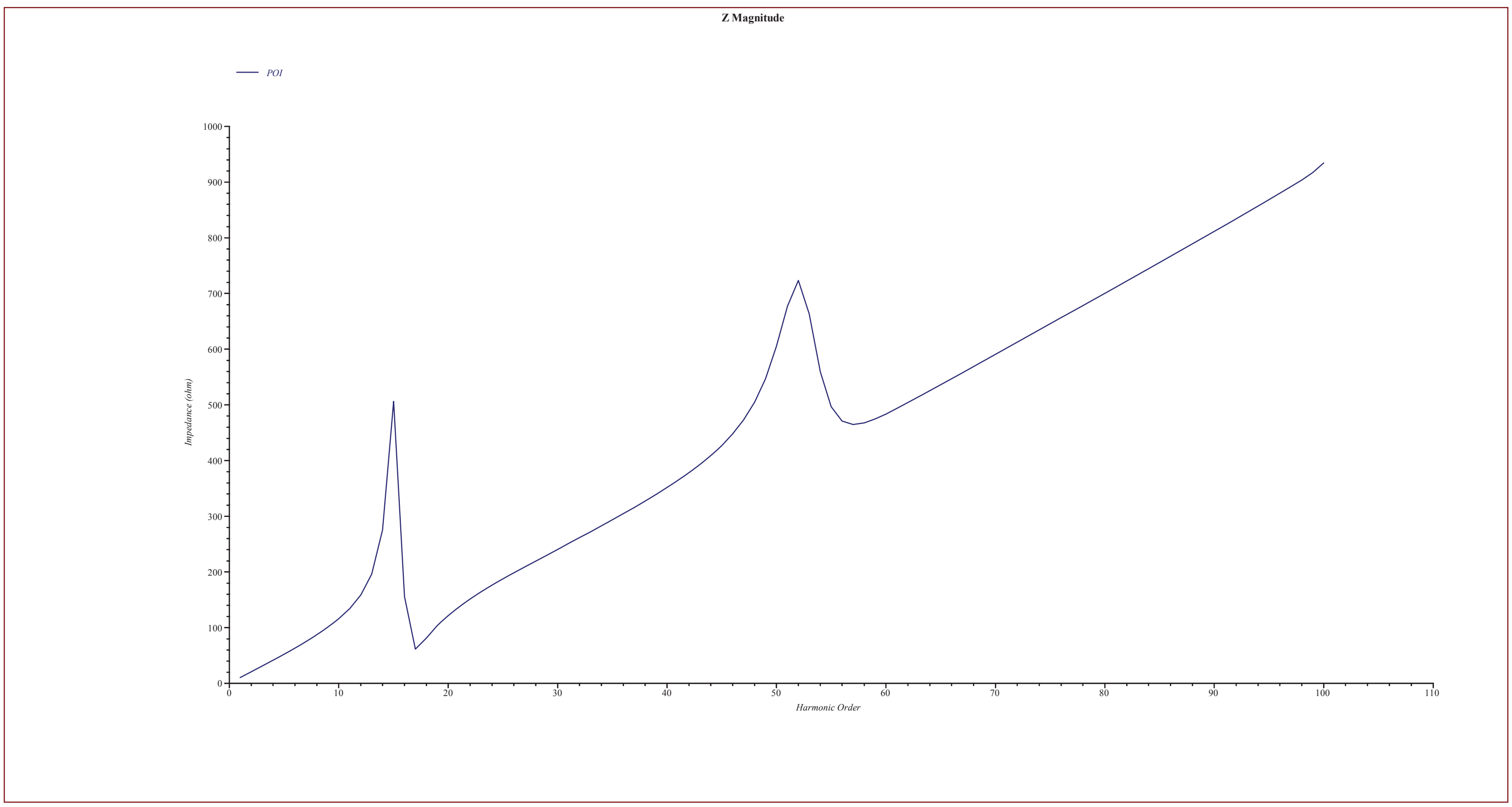
FREQUENCY SCAN ANALYSIS



Project File: C:\Users\JVenden\Documents\WESTWOOD\PROJECTS\0007186 NW OH\ETAP\NW_OH
Output Report: Feeder4

Cap Bank OFF

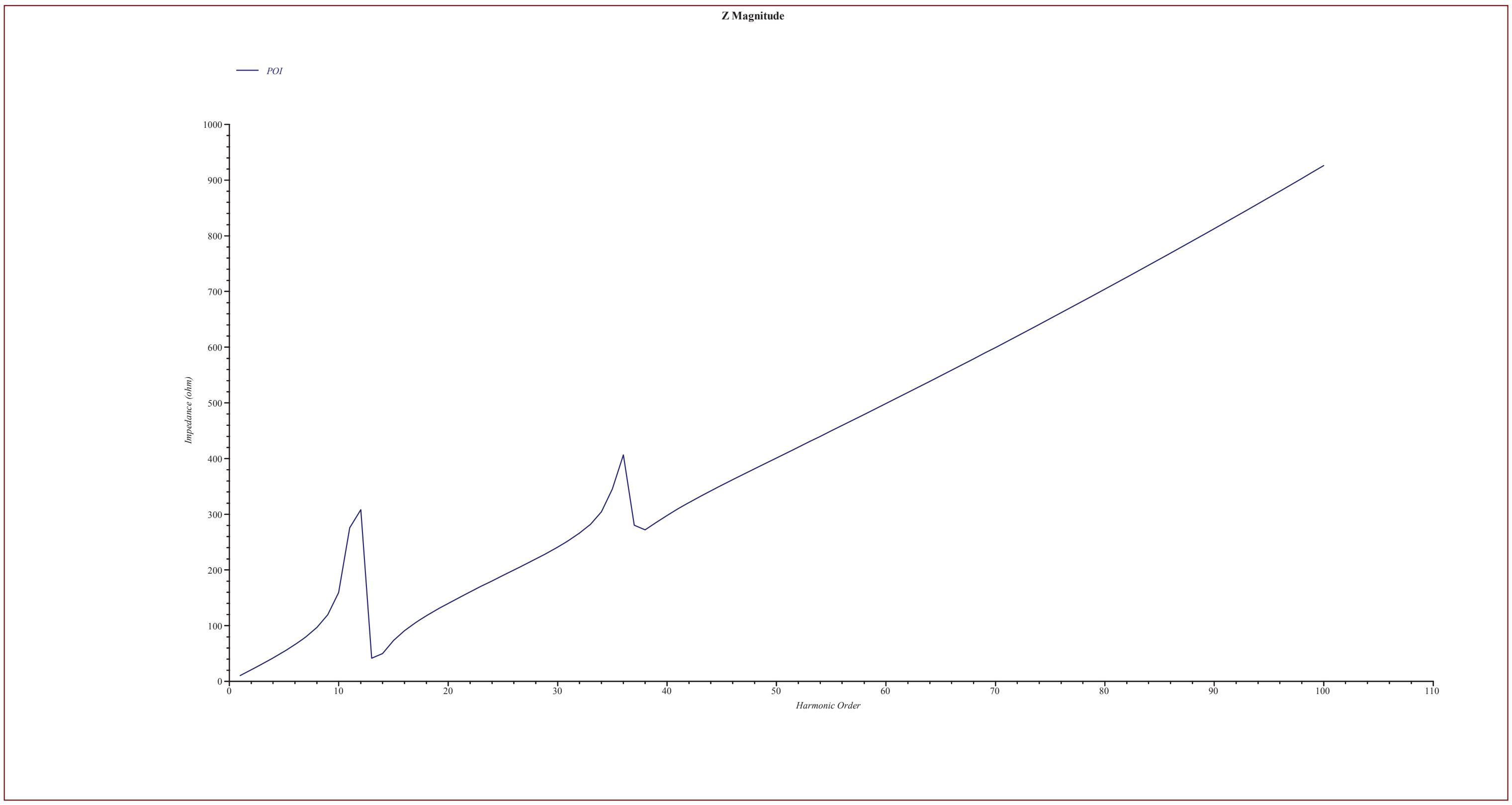
FREQUENCY SCAN ANALYSIS



Project File: C:\Users\JVenden\Documents\WESTWOOD\PROJECTS\0007186 NW OH\ETAP\NW_OH
Output Report: Feeder4

Cap Bank ON

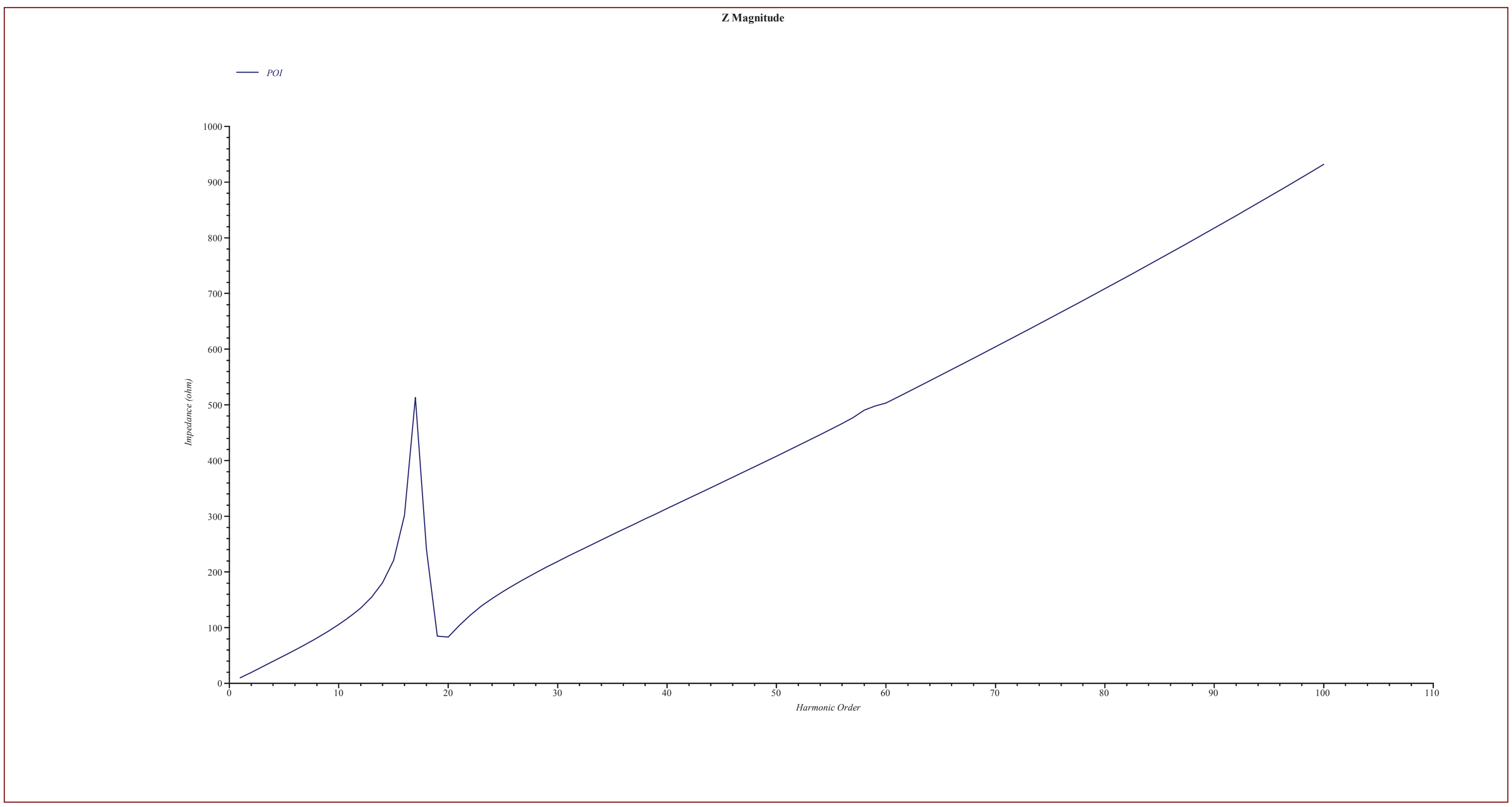
FREQUENCY SCAN ANALYSIS



Project File: C:\Users\JVenden\Documents\WESTWOOD\PROJECTS\0007186 NW OH\ETAP\NW_OH
Output Report: Feeder1&2

Cap Bank OFF

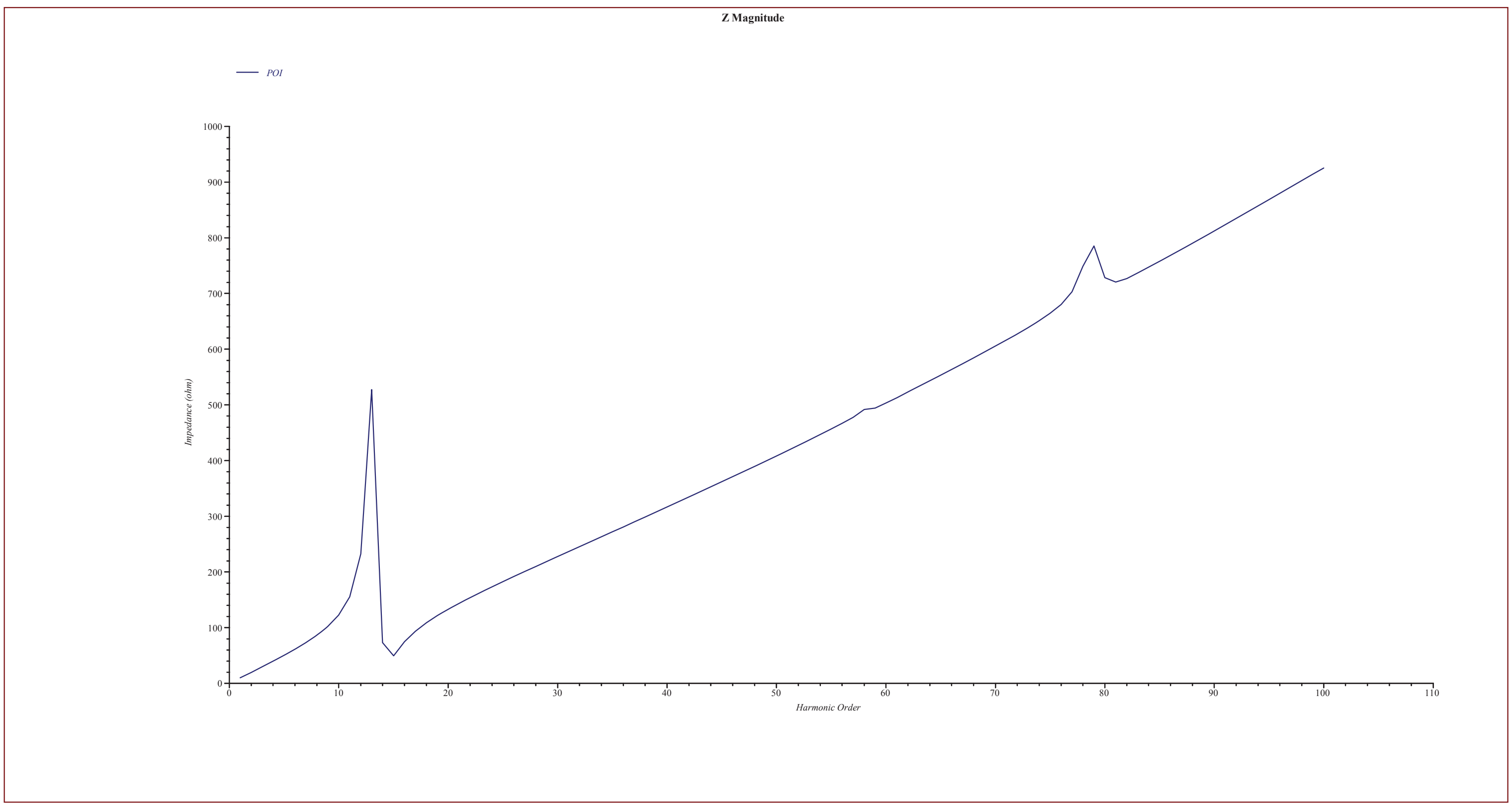
FREQUENCY SCAN ANALYSIS



Project File: C:\Users\JVenden\Documents\WESTWOOD\PROJECTS\0007186 NW OH\ETAP\NW_OH
Output Report: Feeder1&2

Cap Bank ON

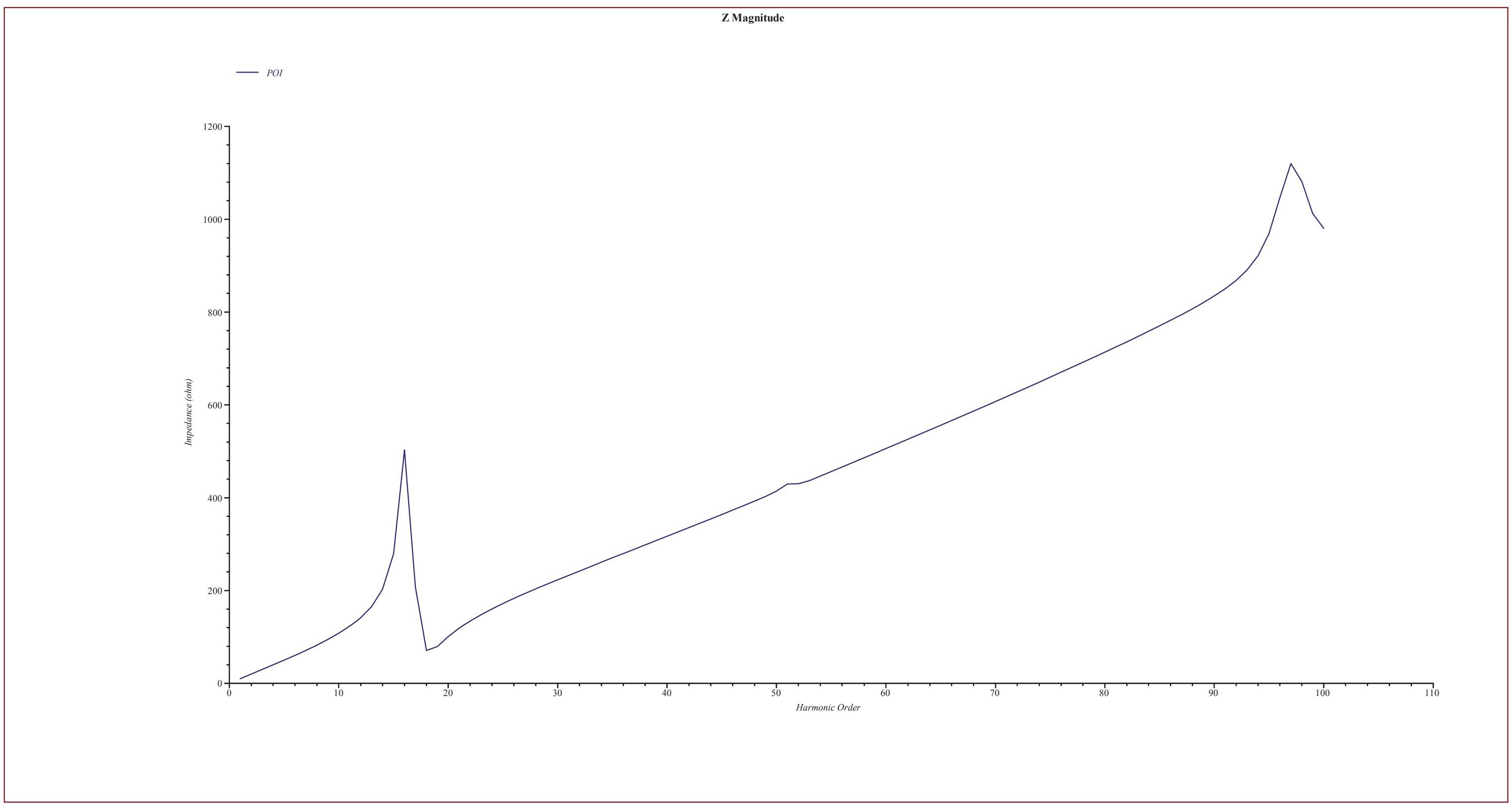
FREQUENCY SCAN ANALYSIS



Project File: C:\Users\JVenden\Documents\WESTWOOD\PROJECTS\0007186 NW OH\ETAP\NW_OH
Output Report: Feeder1&3

Cap Bank OFF

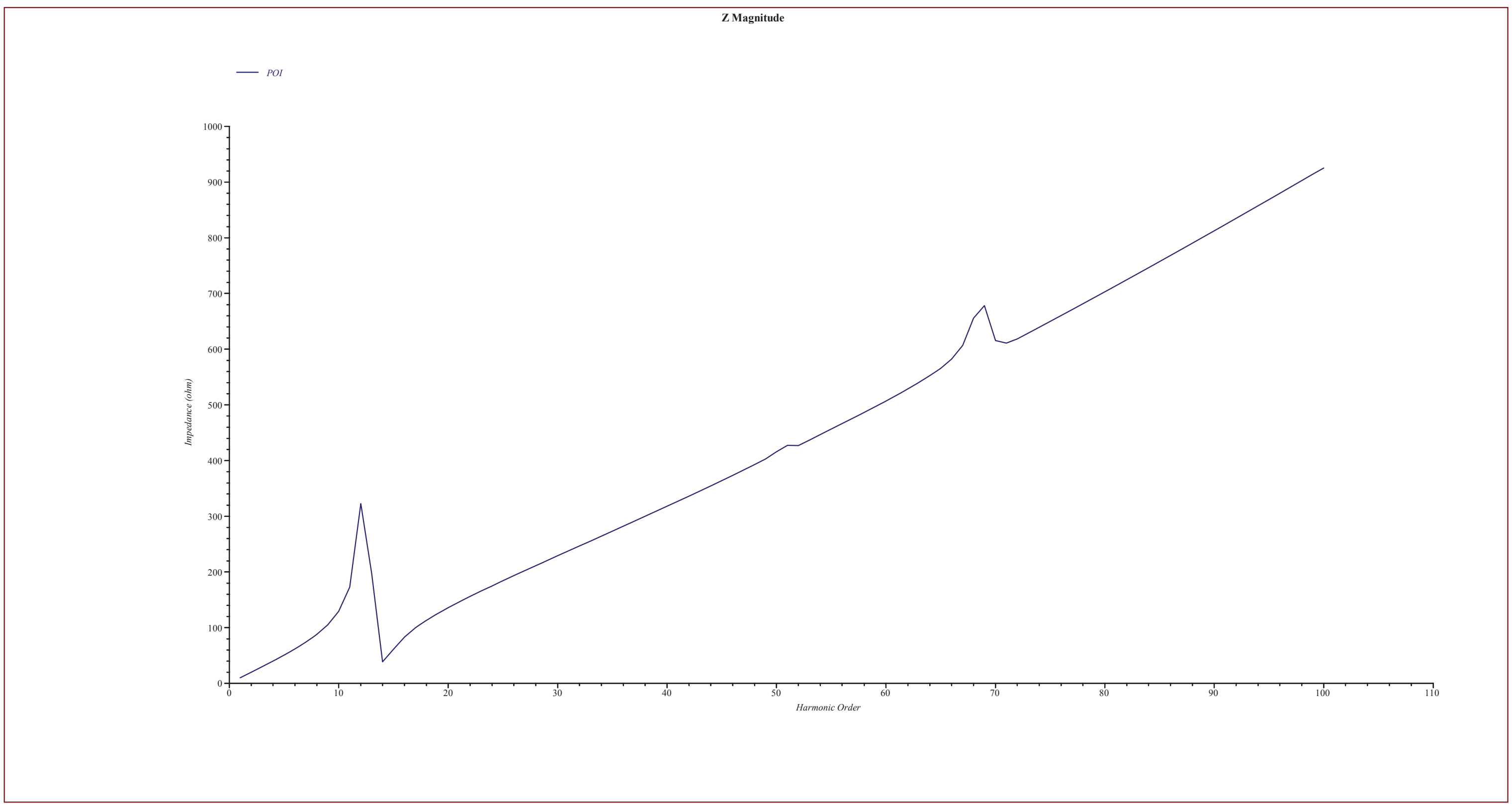
FREQUENCY SCAN ANALYSIS



Project File: C:\Users\JVenden\Documents\WESTWOOD\PROJECTS\0007186 NW OH\ETAP\NW_OH
Output Report: Feeder1&3

Cap Bank ON

FREQUENCY SCAN ANALYSIS



Project: NW OH WIND
Location: Paulding, OH
Contract:
Engineer: Josh Venden

ETAP
16.0.0C

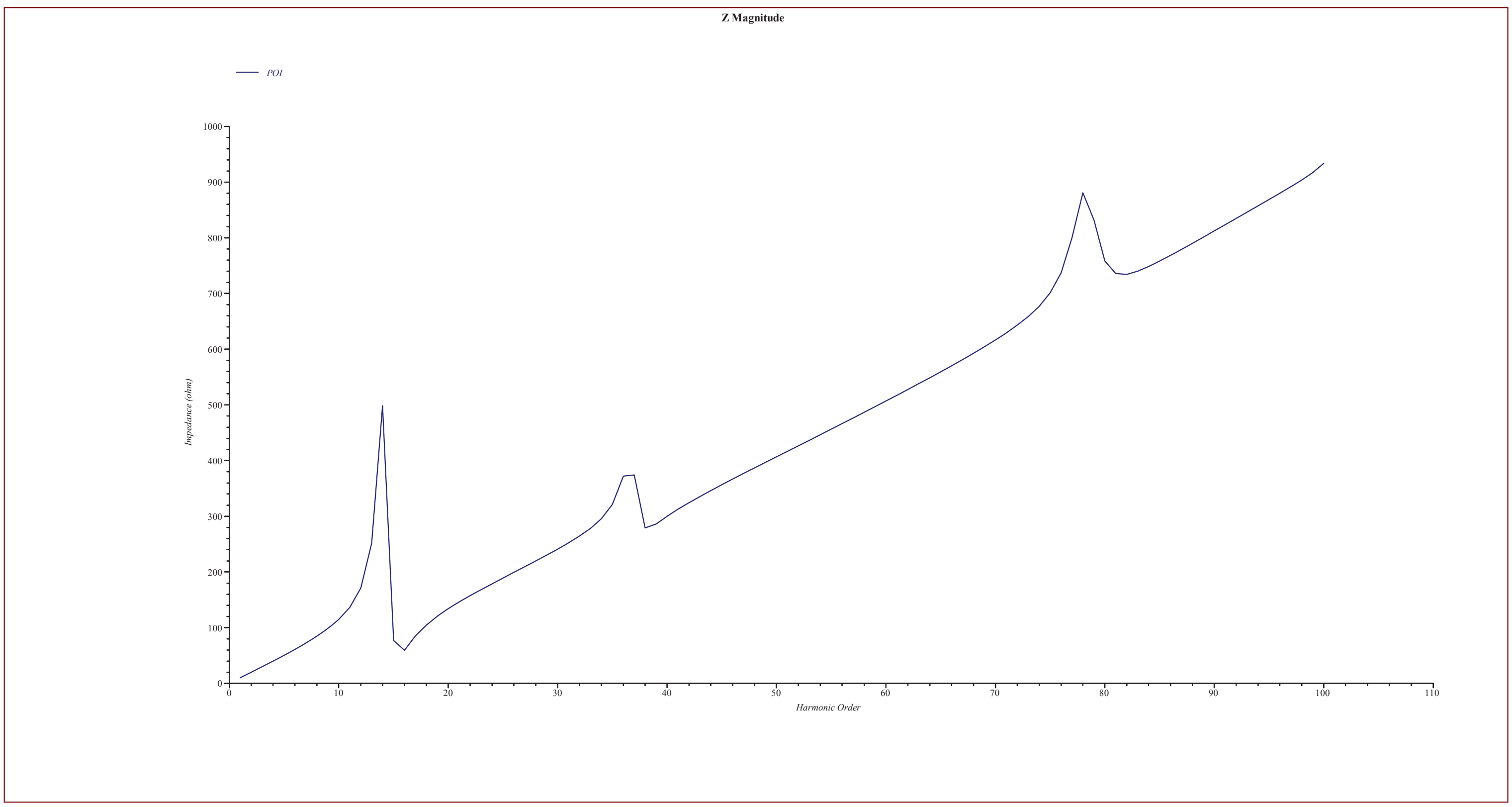
Study Case: Freq Scan

Date: 10-13-2017
SN: WESTWOOD3
Revision: 100% GEN
Config.: HarmonicGen

Project File: C:\Users\JVenden\Documents\WESTWOOD\PROJECTS\0007186 NW OH\ETAP\NW_OH
Output Report: Feeder1&4

Cap Bank OFF

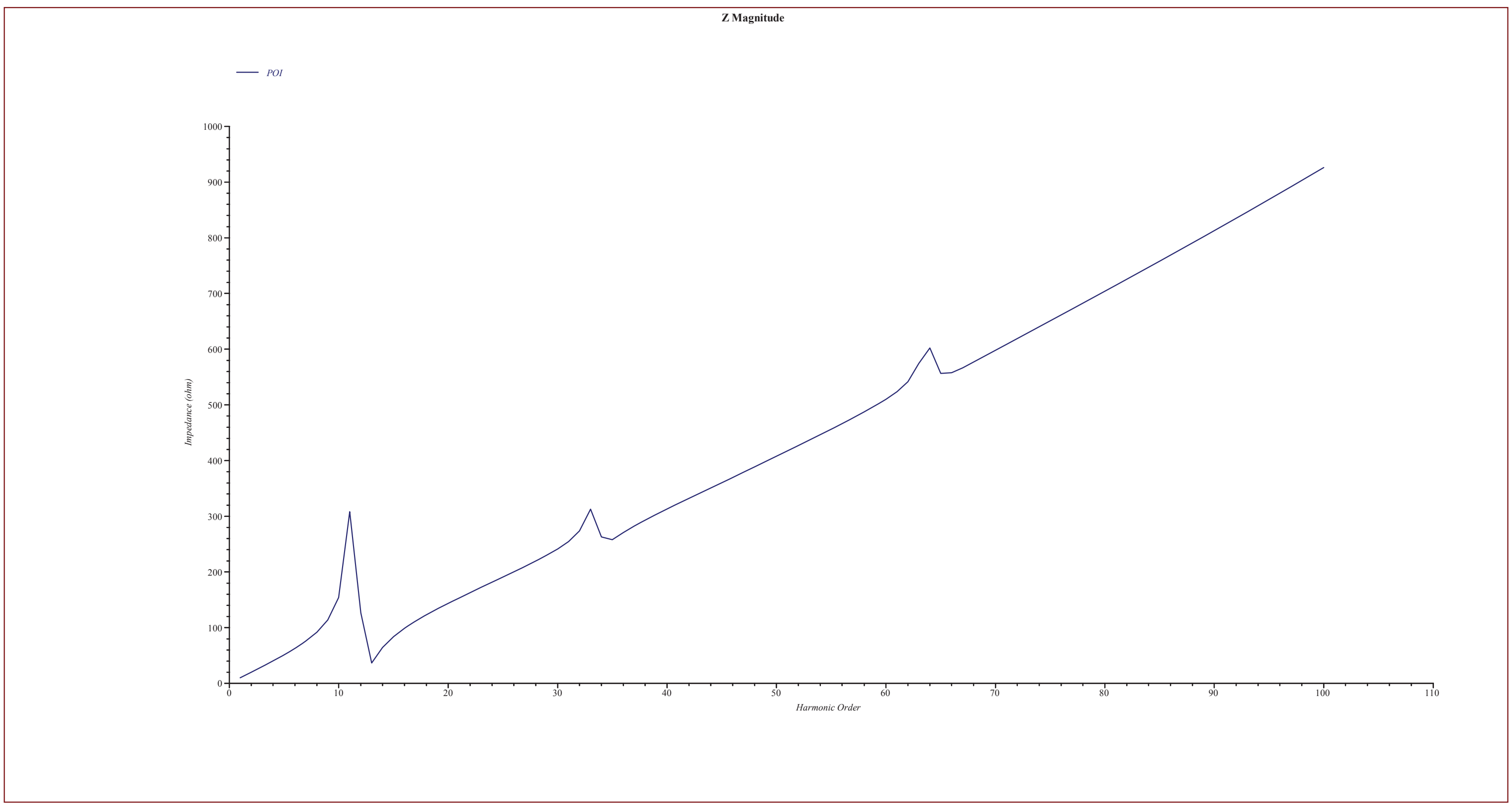
FREQUENCY SCAN ANALYSIS



Project File: C:\Users\JVenden\Documents\WESTWOOD\PROJECTS\0007186 NW OH\ETAP\NW_OH
Output Report: Feeder1&4

Cap Bank ON

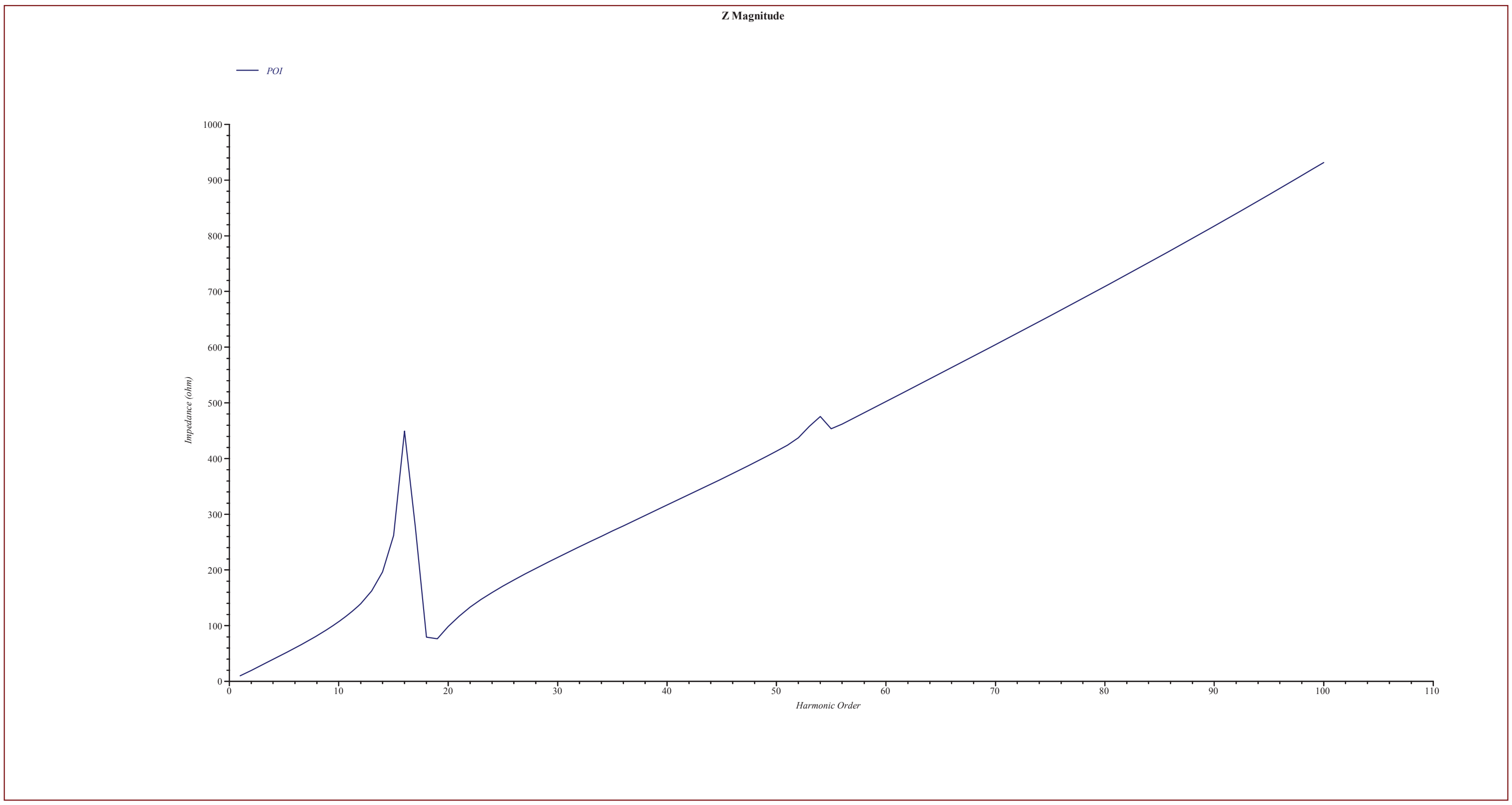
FREQUENCY SCAN ANALYSIS



Project File: C:\Users\JVenden\Documents\WESTWOOD\PROJECTS\0007186 NW OH\ETAP\NW_OH
Output Report: Feeder2&3

Cap Bank OFF

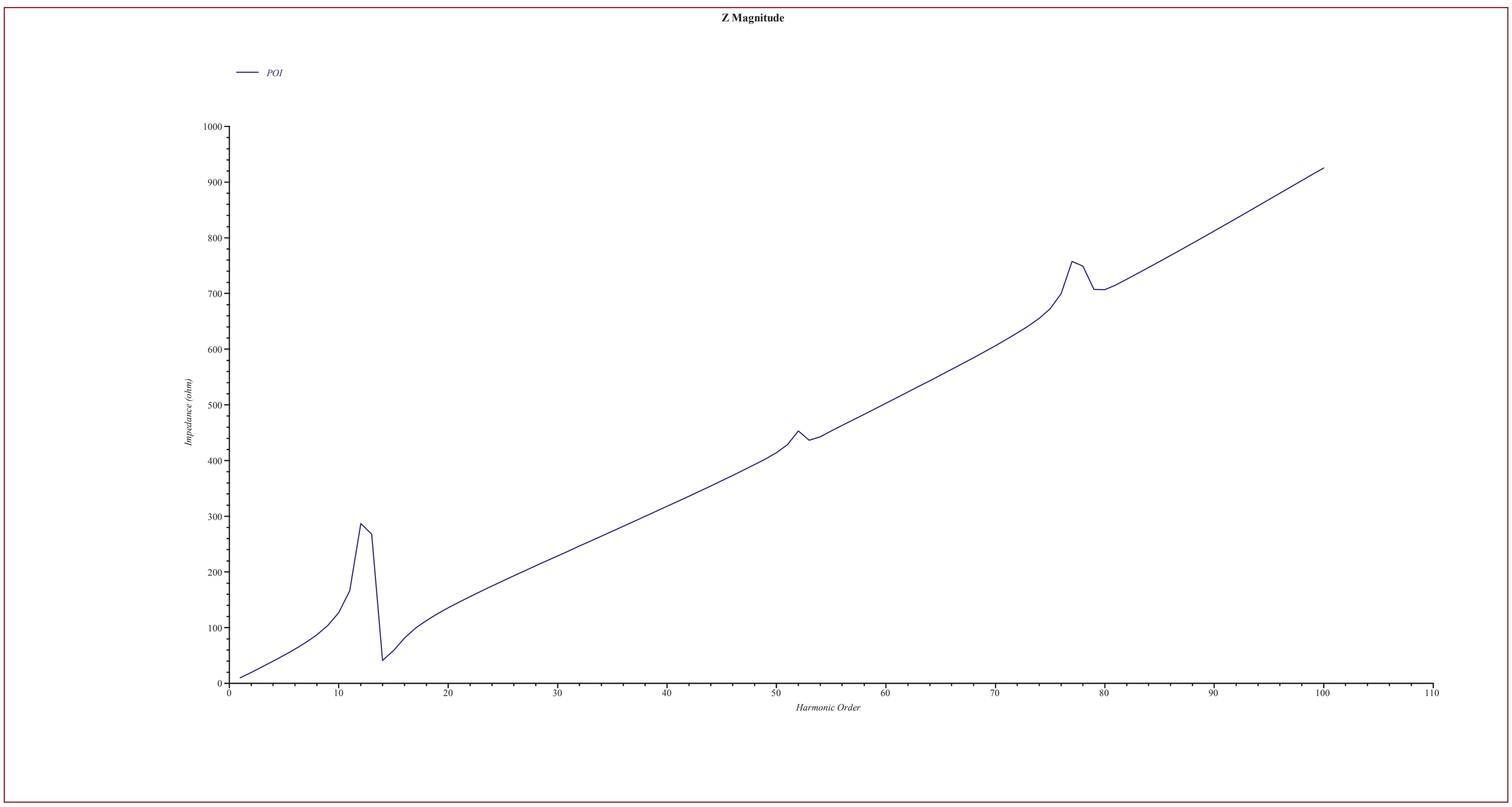
FREQUENCY SCAN ANALYSIS



Project File: C:\Users\JVenden\Documents\WESTWOOD\PROJECTS\0007186 NW OH\ETAP\NW_OH
Output Report: Feeder2&3

Cap Bank ON

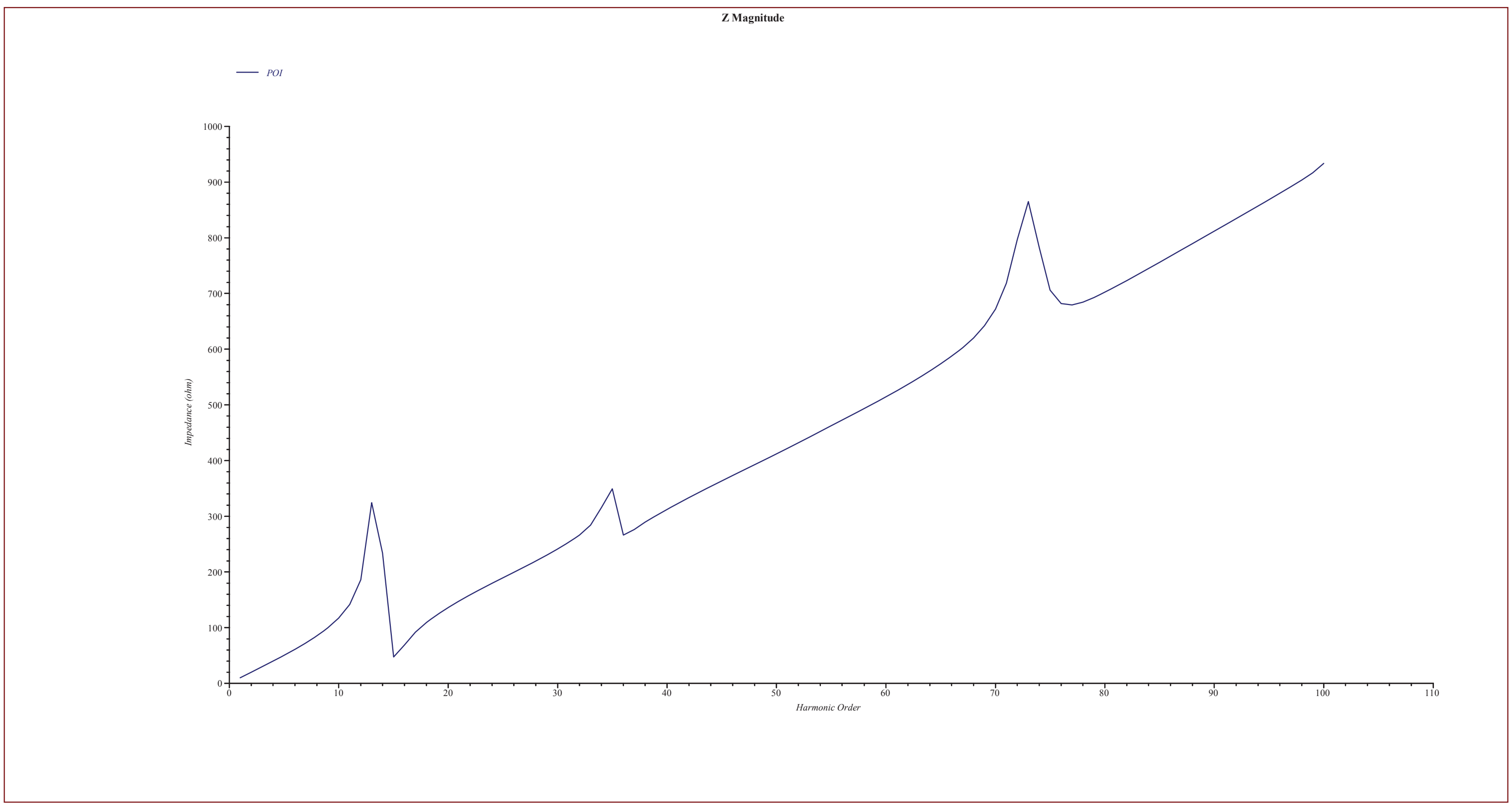
FREQUENCY SCAN ANALYSIS



Project File: C:\Users\JVenden\Documents\WESTWOOD\PROJECTS\0007186 NW OH\ETAP\NW_OH
Output Report: Feeder3&4

Cap Bank OFF

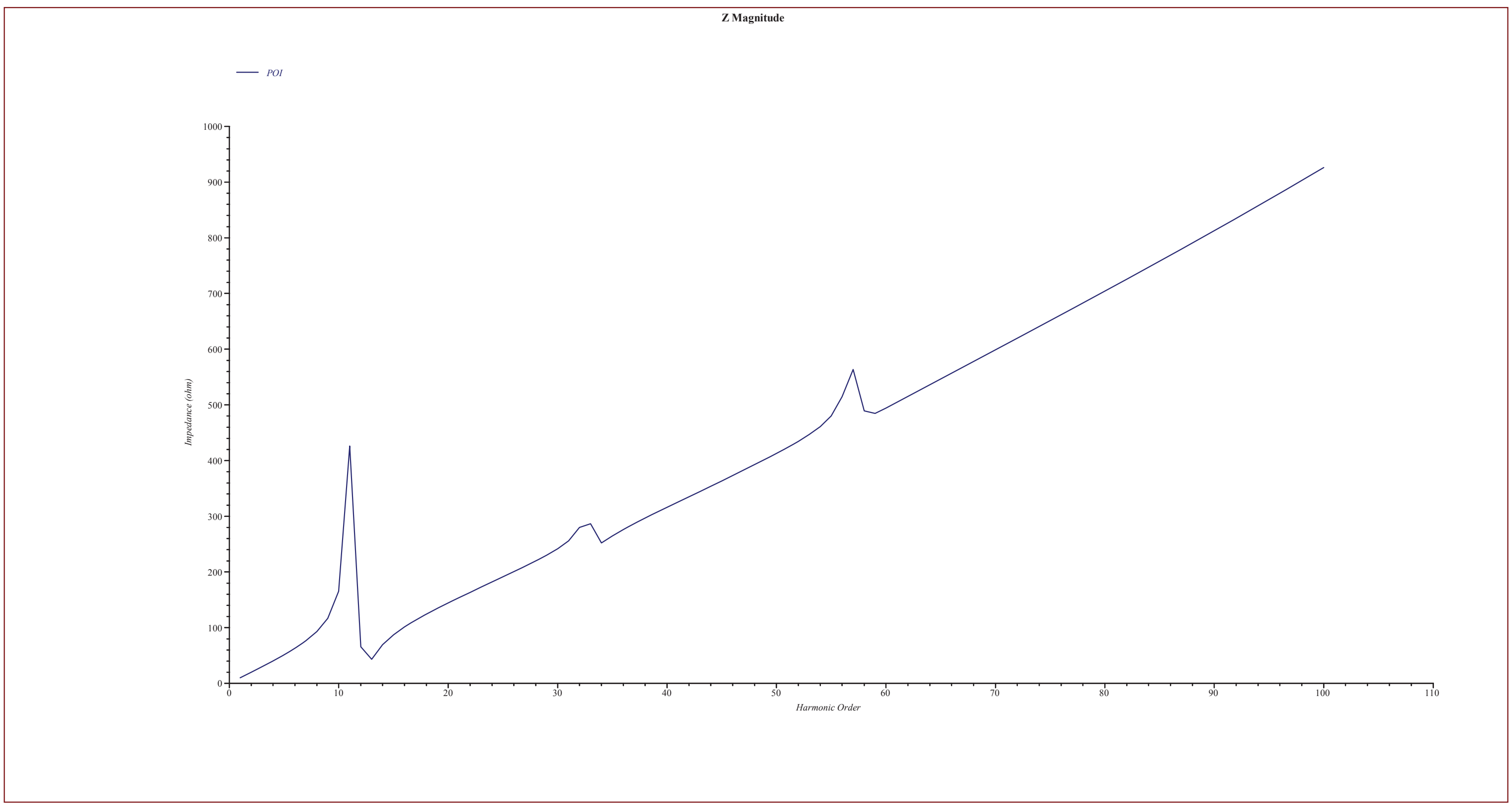
FREQUENCY SCAN ANALYSIS



Project File: C:\Users\JVenden\Documents\WESTWOOD\PROJECTS\0007186 NW OH\ETAP\NW_OH
Output Report: Feeder3&4

Cap Bank ON

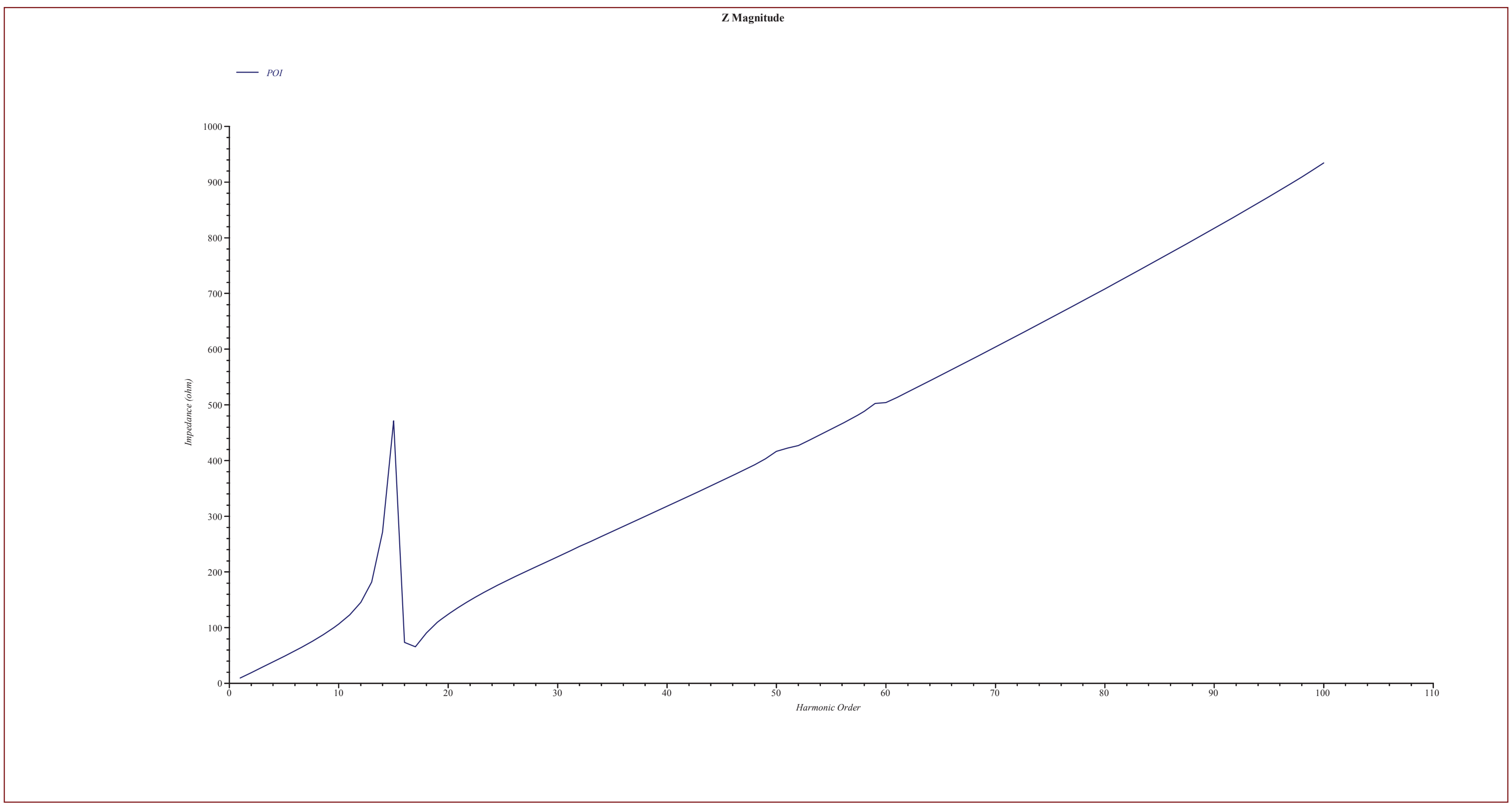
FREQUENCY SCAN ANALYSIS



Project File: C:\Users\JVenden\Documents\WESTWOOD\PROJECTS\0007186 NW OH\ETAP\NW_OH
Output Report: Feeder1 2 3

Cap Bank OFF

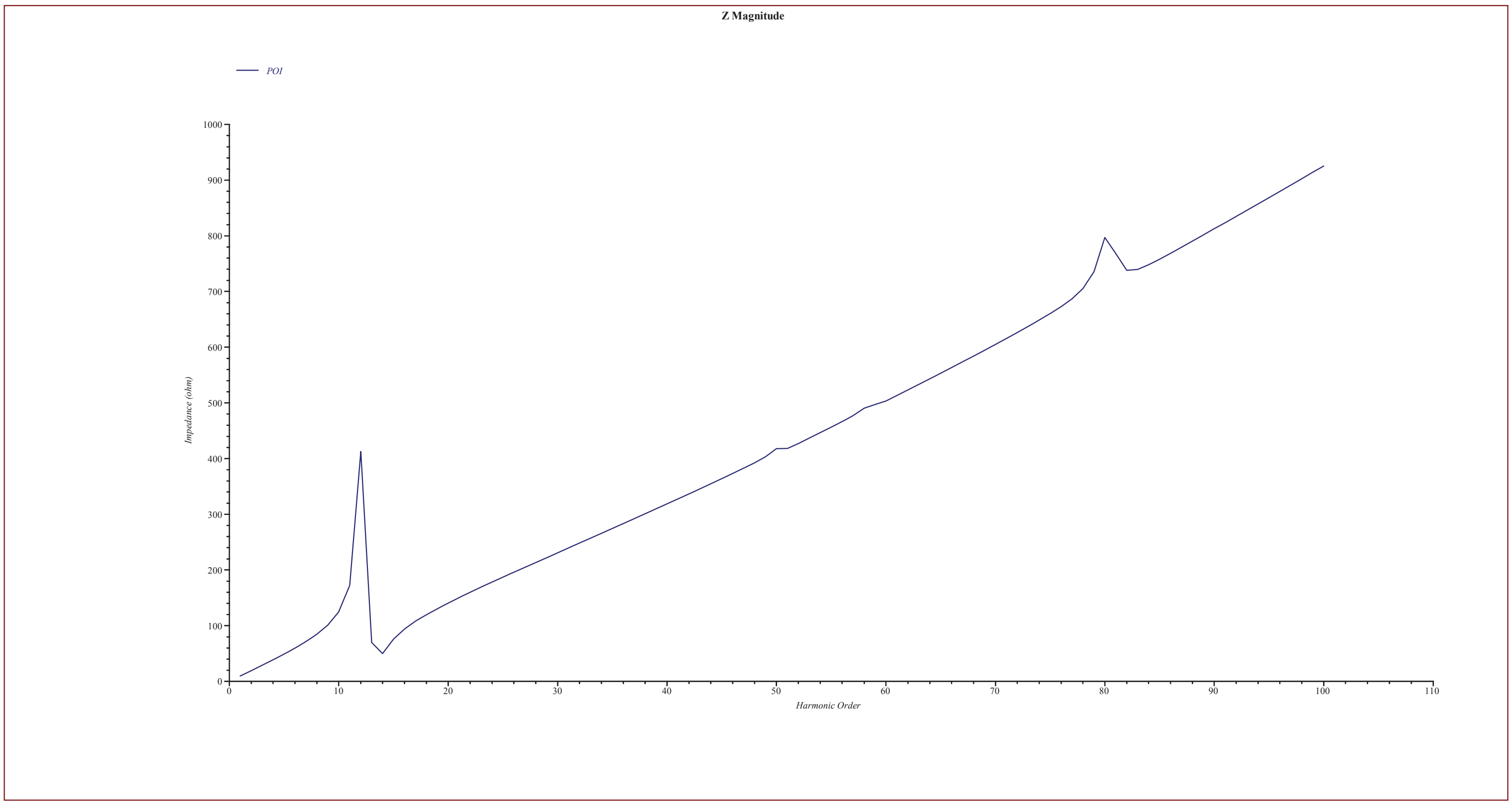
FREQUENCY SCAN ANALYSIS



Project File: C:\Users\JVenden\Documents\WESTWOOD\PROJECTS\0007186 NW OH\ETAP\NW_OH
Output Report: Feeder1 2 3

Cap Bank ON

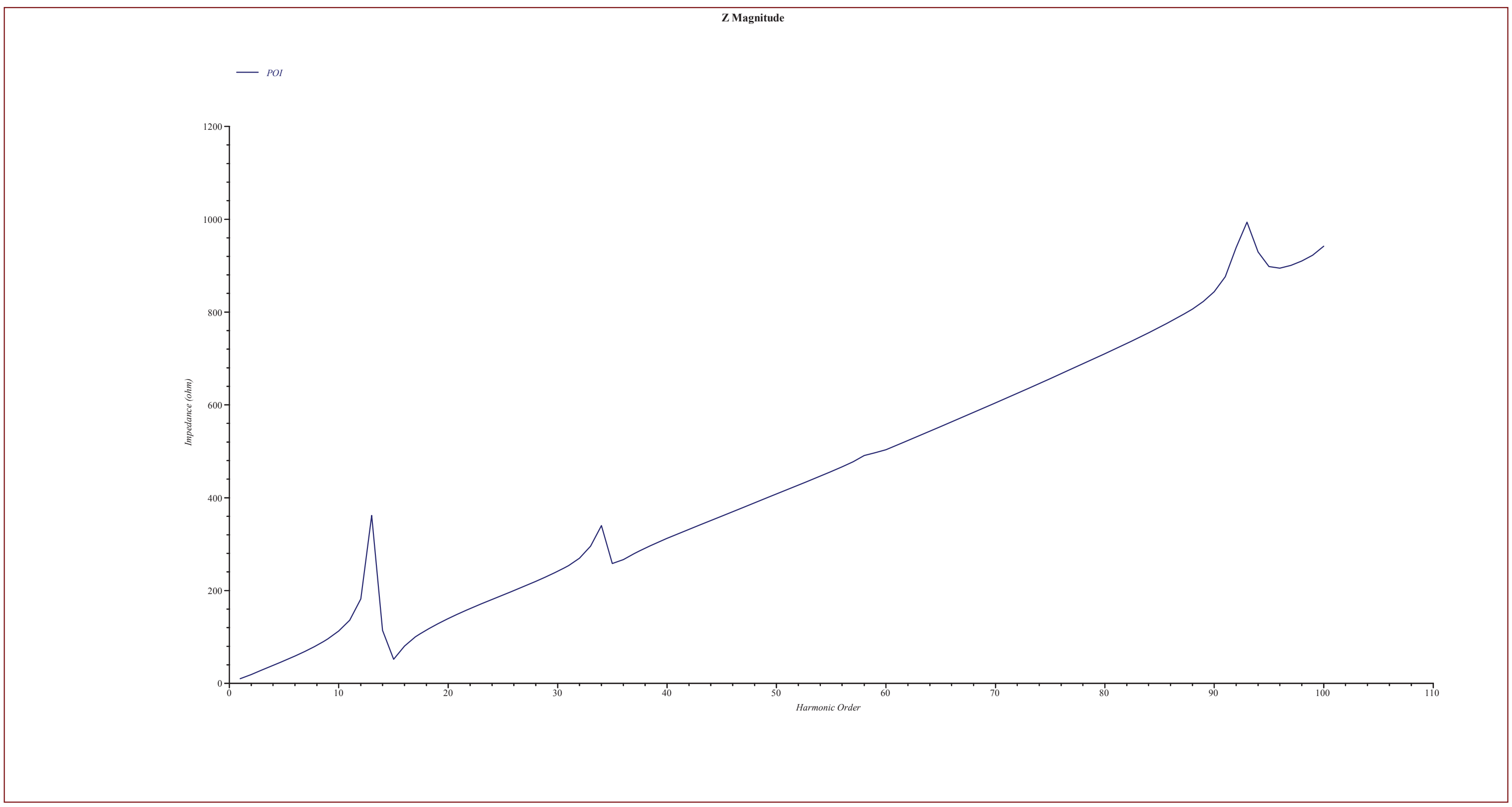
FREQUENCY SCAN ANALYSIS



Project File: C:\Users\JVenden\Documents\WESTWOOD\PROJECTS\0007186 NW OH\ETAP\NW_OH
Output Report: Feeder 1 2 4

Cap Bank OFF

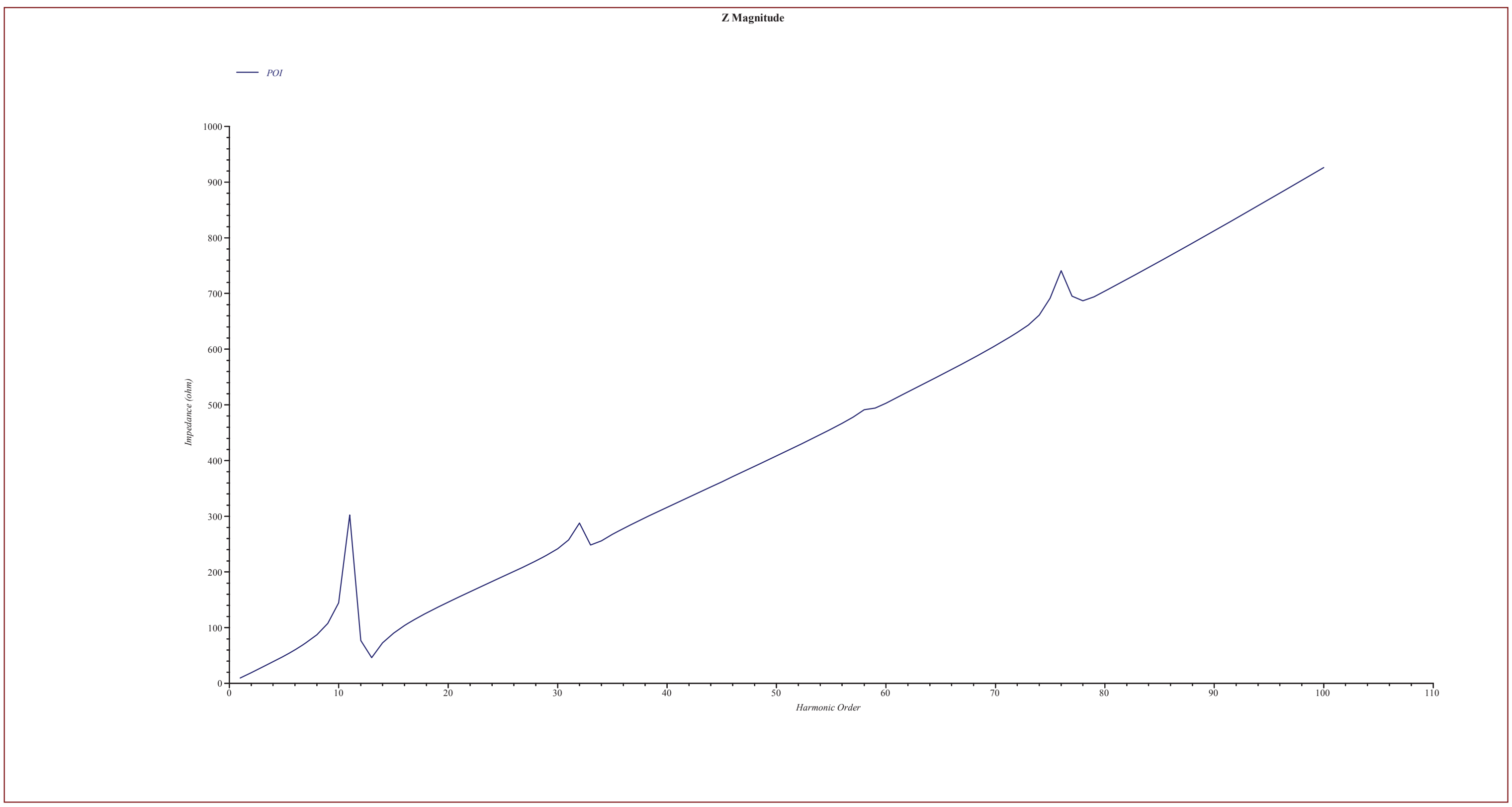
FREQUENCY SCAN ANALYSIS



Project File: C:\Users\JVenden\Documents\WESTWOOD\PROJECTS\0007186 NW OH\ETAP\NW_OH
Output Report: Feeder 1 2 4

Cap Bank ON

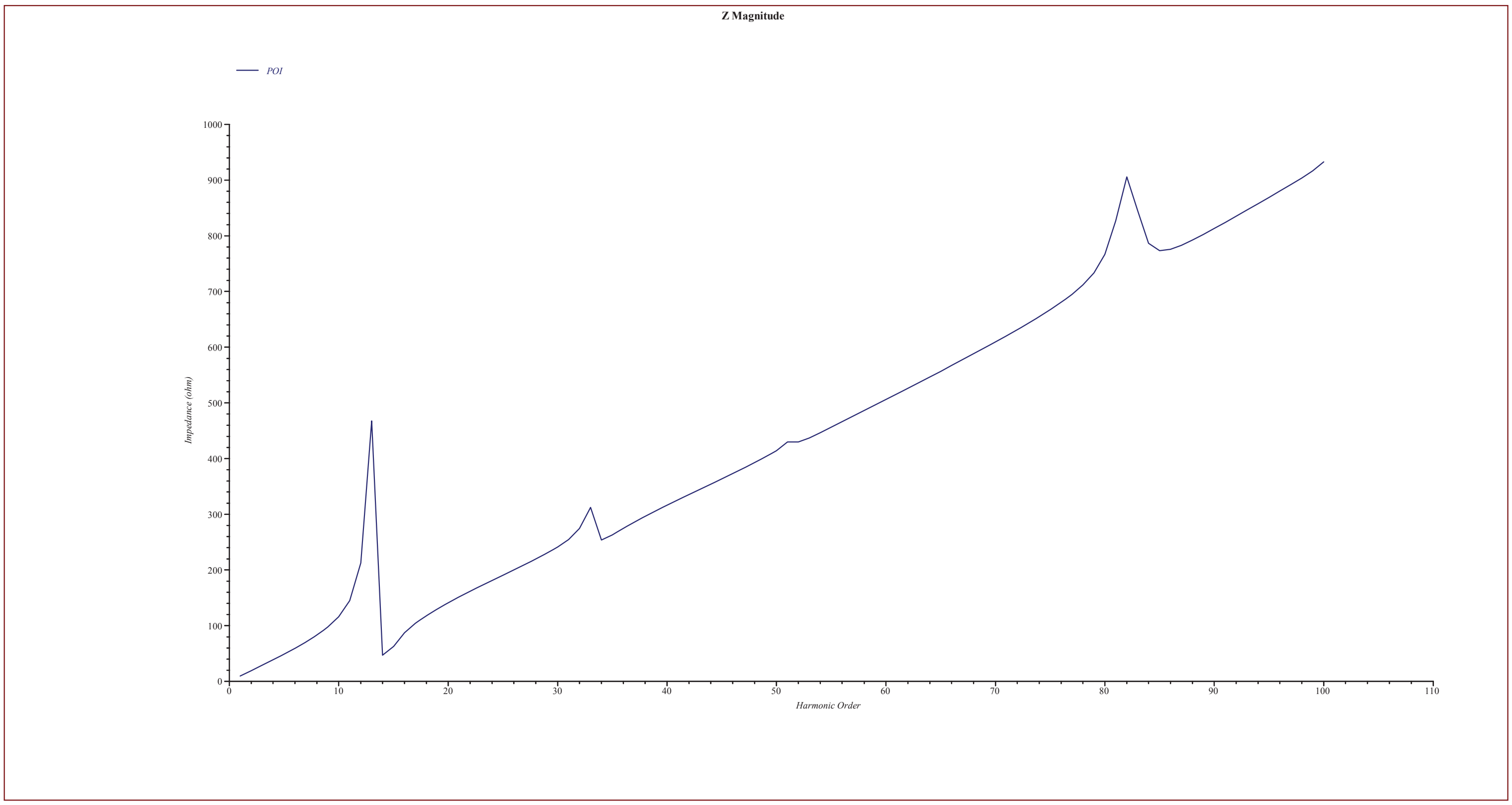
FREQUENCY SCAN ANALYSIS



Project File: C:\Users\JVenden\Documents\WESTWOOD\PROJECTS\0007186 NW OH\ETAP\NW_OH
Output Report: Feeder 1 3 4

Cap Bank OFF

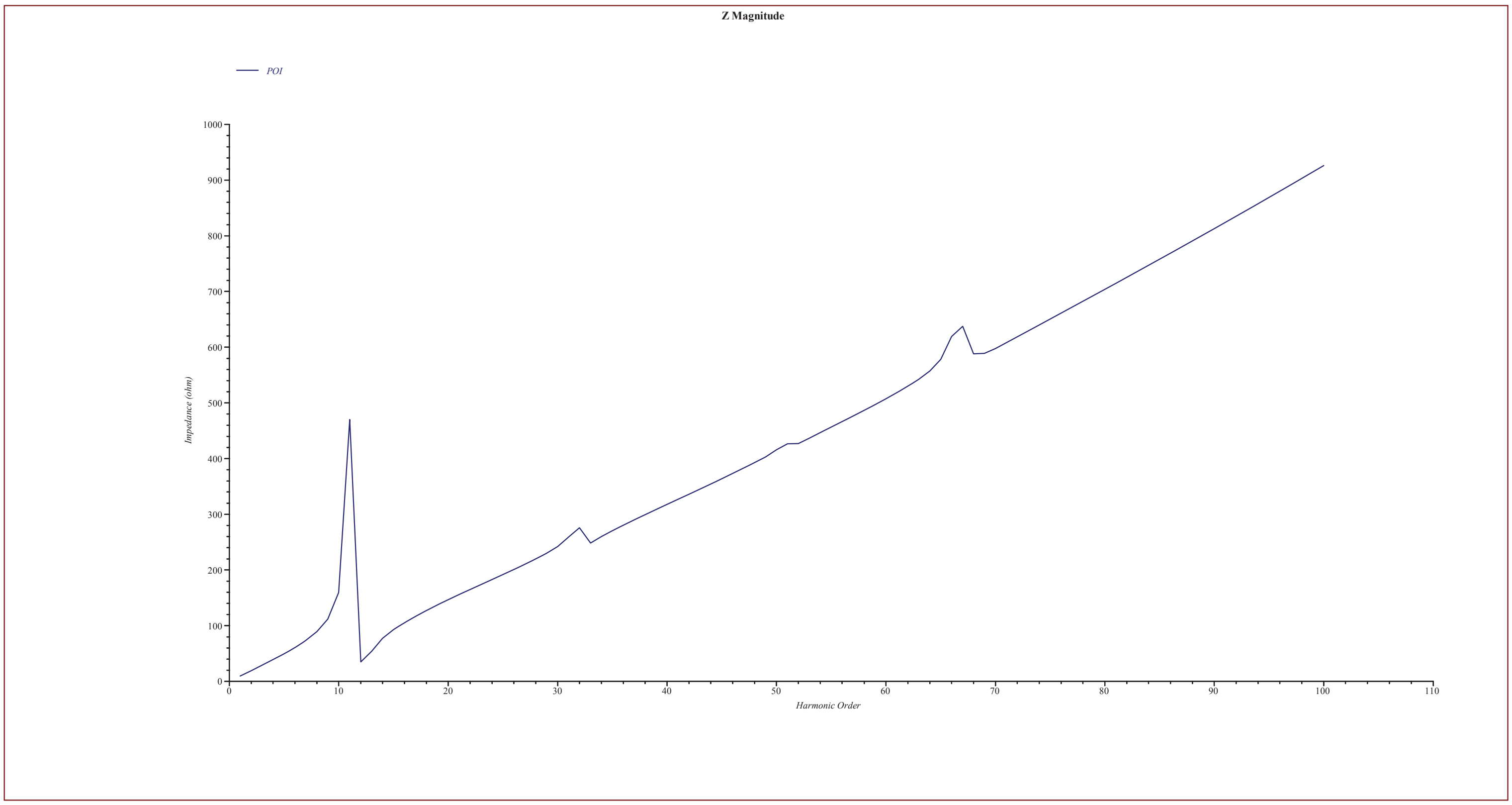
FREQUENCY SCAN ANALYSIS



Project File: C:\Users\JVenden\Documents\WESTWOOD\PROJECTS\0007186 NW OH\ETAP\NW_OH
Output Report: Feeder 1 3 4

Cap Bank ON

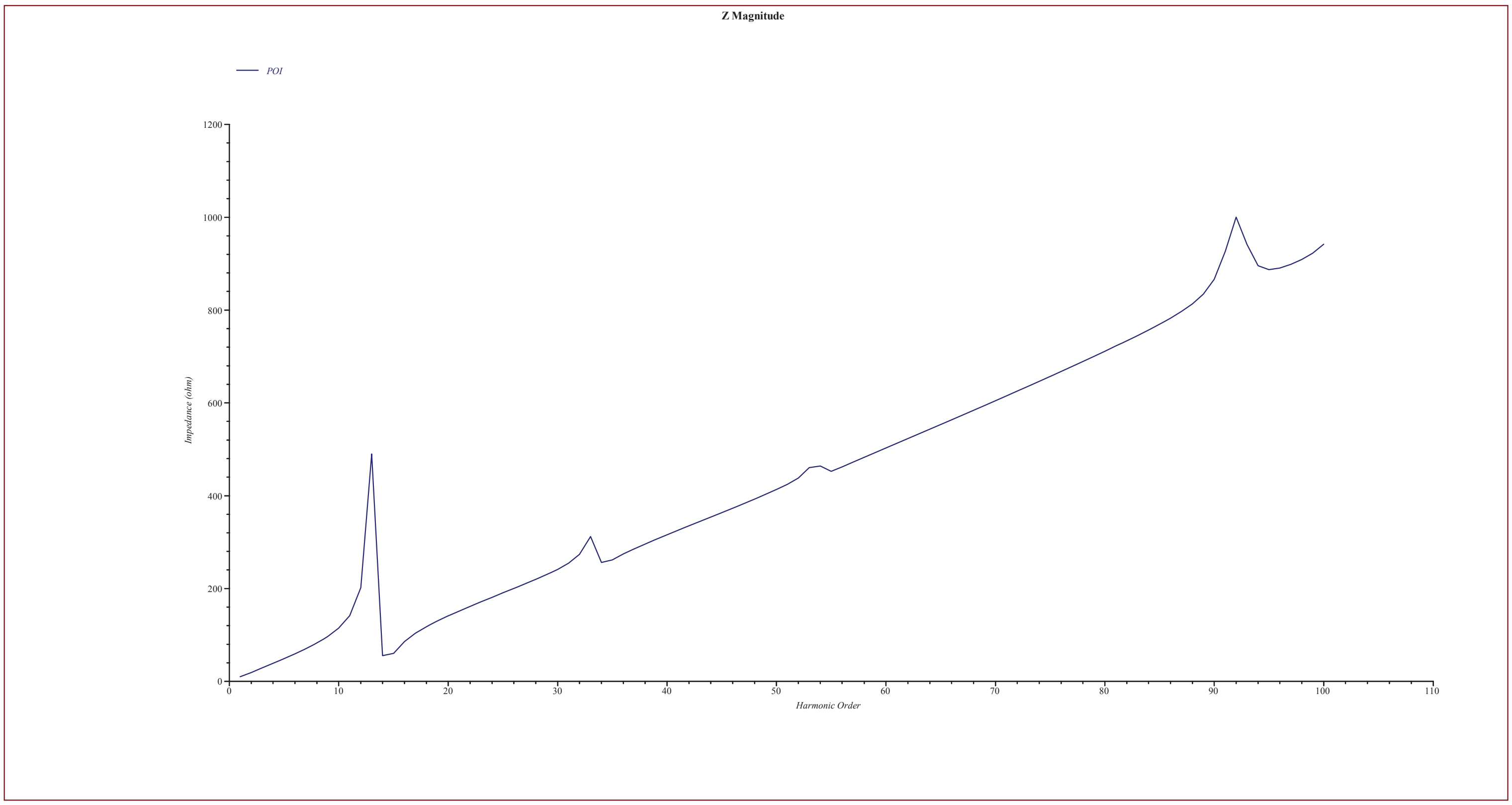
FREQUENCY SCAN ANALYSIS



Project File: C:\Users\JVenden\Documents\WESTWOOD\PROJECTS\0007186 NW OH\ETAP\NW_OH
Output Report: Feeder 2 3 4

Cap Bank OFF

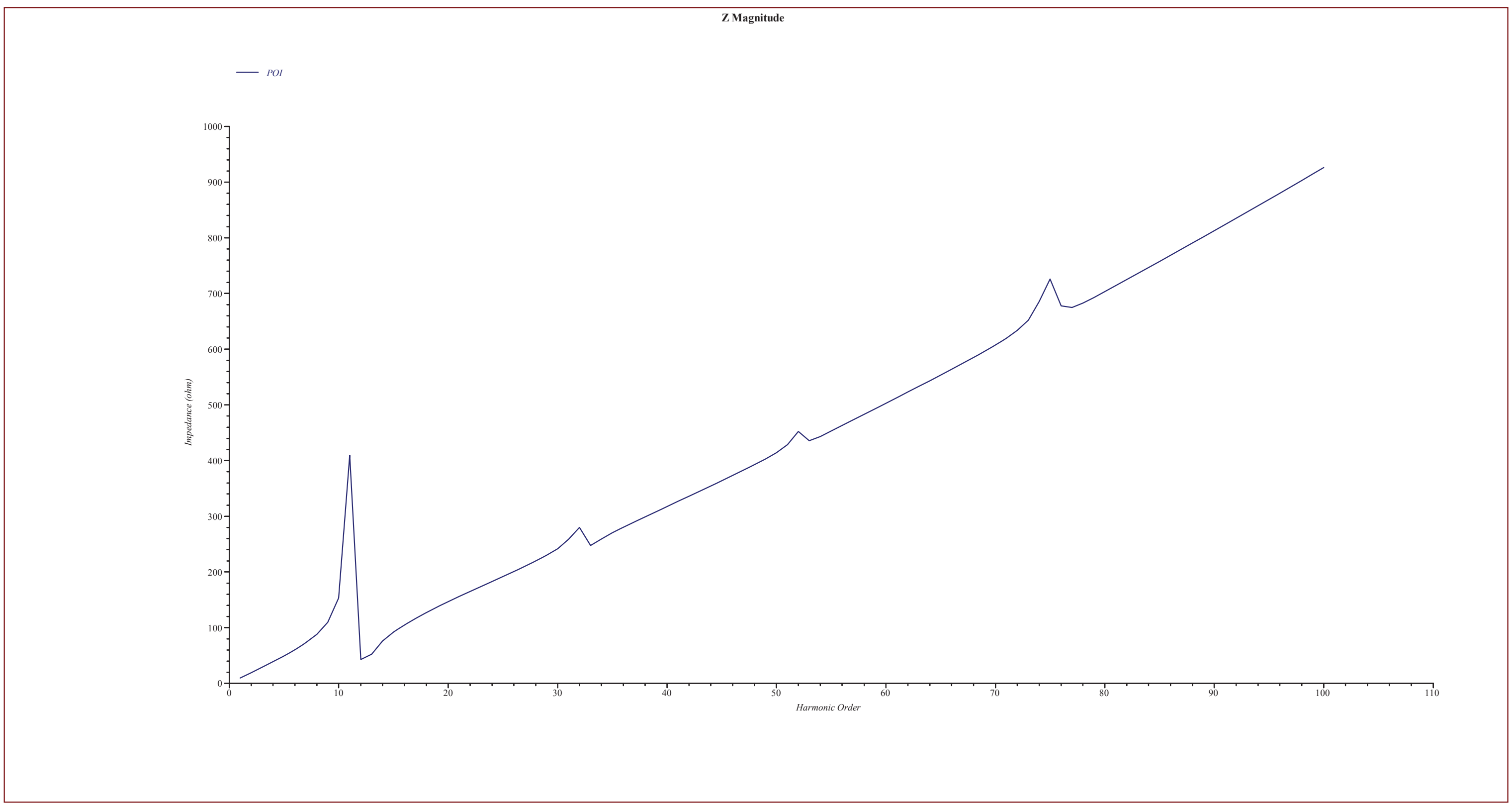
FREQUENCY SCAN ANALYSIS



Project File: C:\Users\JVenden\Documents\WESTWOOD\PROJECTS\0007186 NW OH\ETAP\NW_OH
Output Report: Feeder 2 3 4

Cap Bank ON

FREQUENCY SCAN ANALYSIS



ETAP
16.0.0C

Project: NW OH WIND
Location: Paulding, OH
Contract:
Engineer: Josh Venden

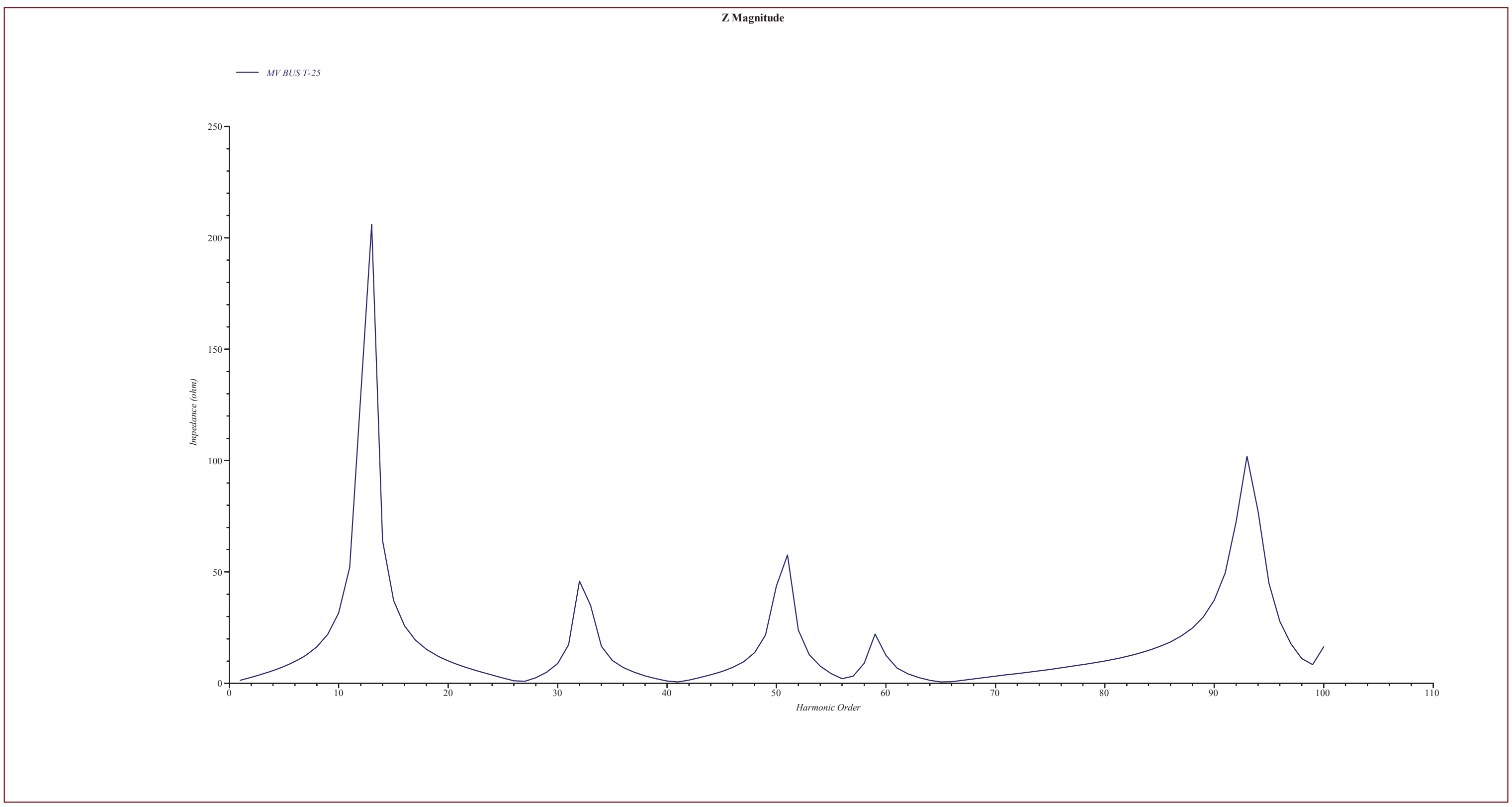
Study Case: Freq Scan

Date: 10-13-2017
SN: WESTWOOD3
Revision: 100% GEN
Config.: HarmonicGen

Project File: C:\Users\JVenden\Documents\WESTWOOD\PROJECTS\0007186 NW OH\ETAP\NW_OH
Output Report: T-25

Cap Bank OFF

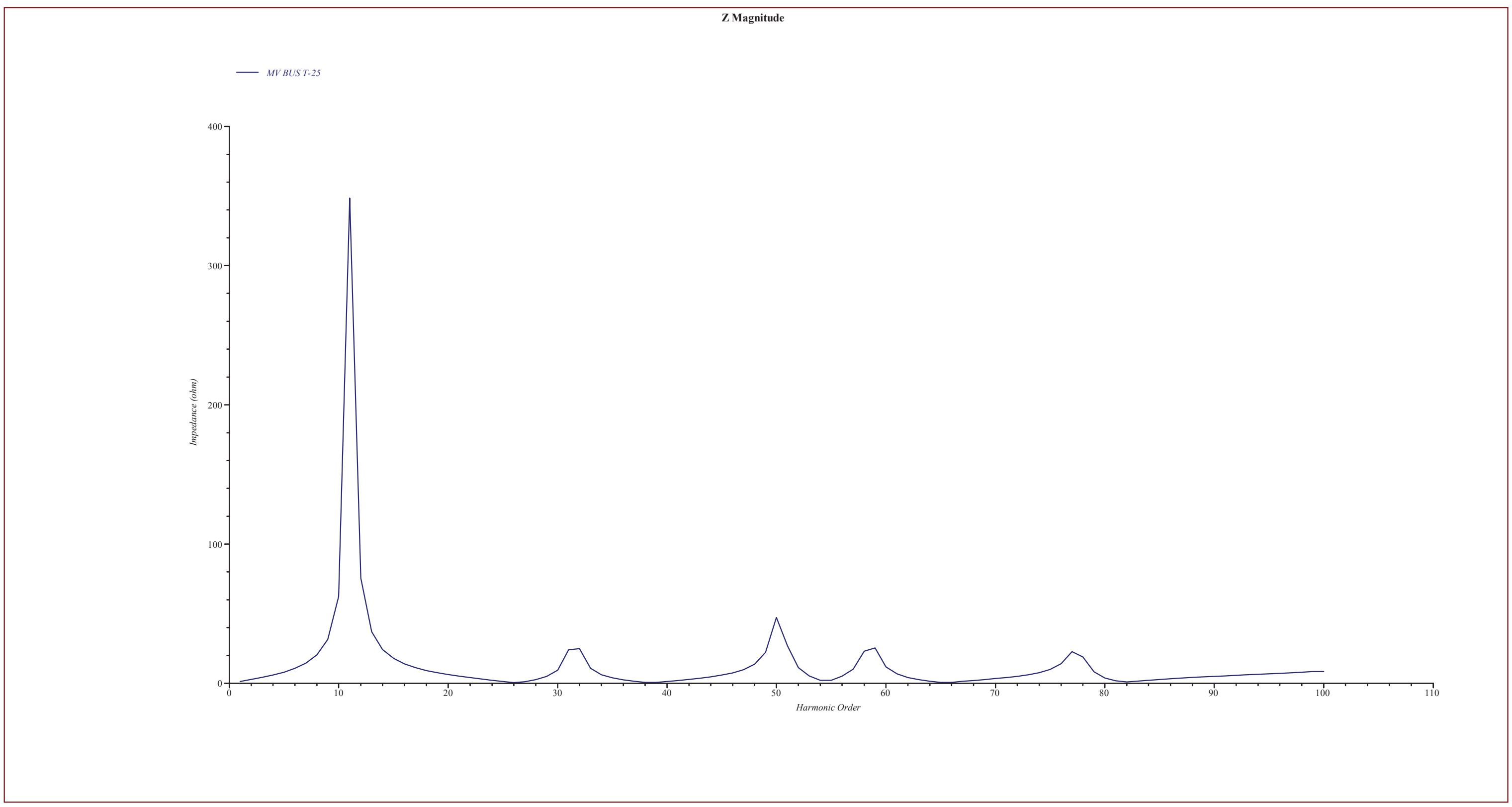
FREQUENCY SCAN ANALYSIS



Project File: C:\Users\JVenden\Documents\WESTWOOD\PROJECTS\0007186 NW OH\ETAP\NW_OH
Output Report: T-25

Cap Bank ON

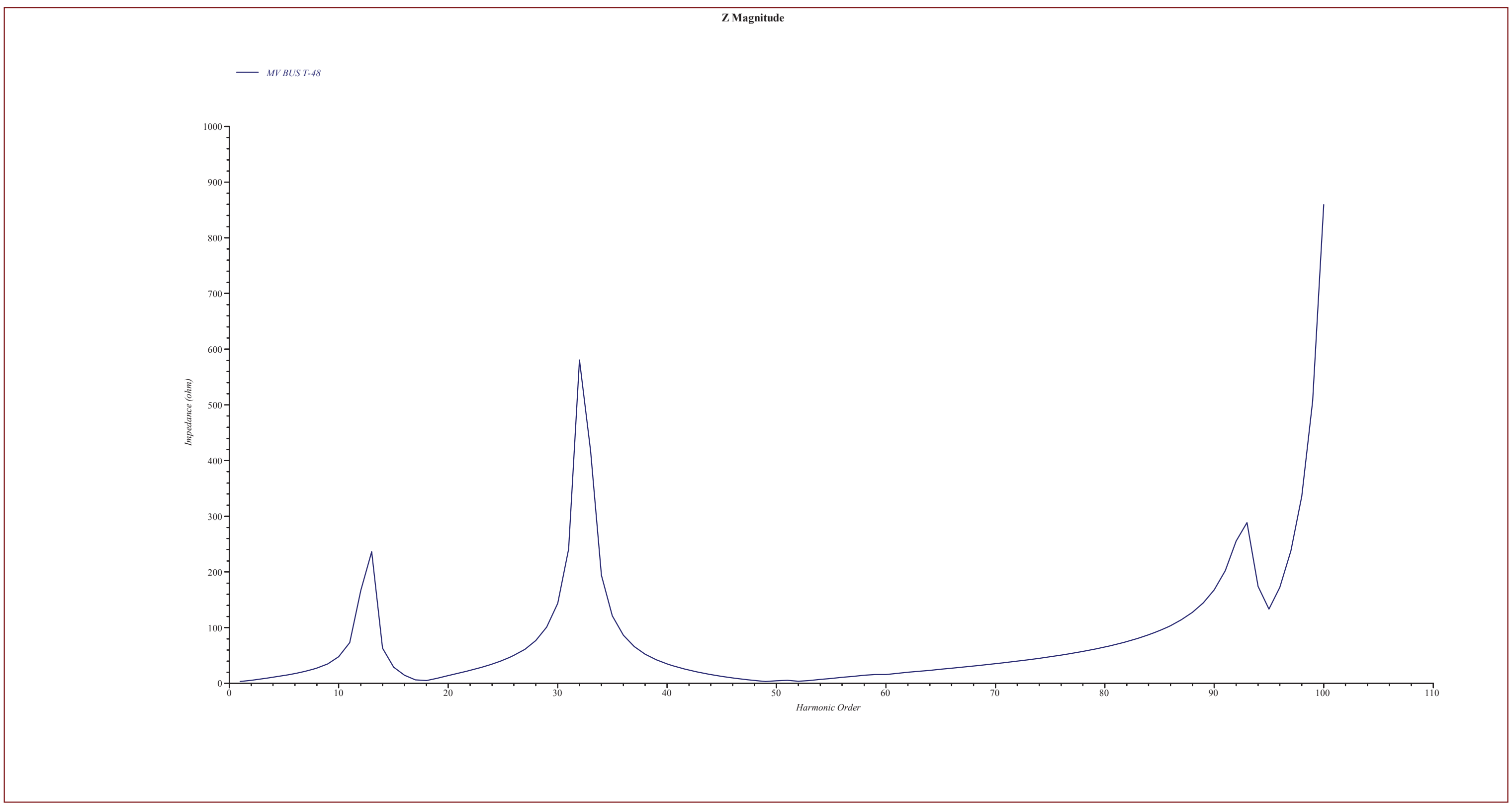
FREQUENCY SCAN ANALYSIS



Project File: C:\Users\JVenden\Documents\WESTWOOD\PROJECTS\0007186 NW OH\ETAP\NW_OH
Output Report: T-48

Cap Bank OFF

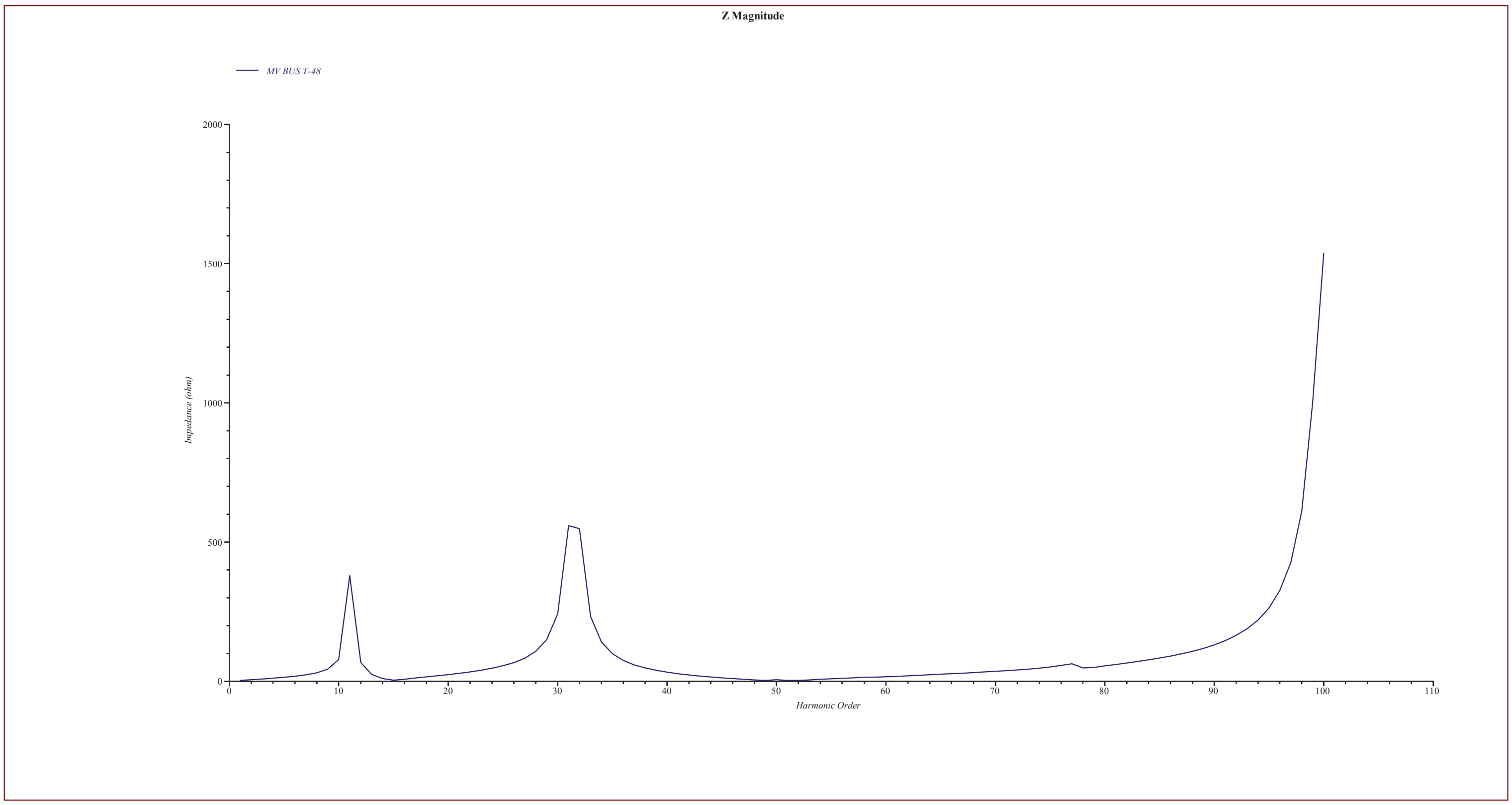
FREQUENCY SCAN ANALYSIS



Project File: C:\Users\JVenden\Documents\WESTWOOD\PROJECTS\0007186 NW OH\ETAP\NW_OH
Output Report: T-48

Cap Bank ON

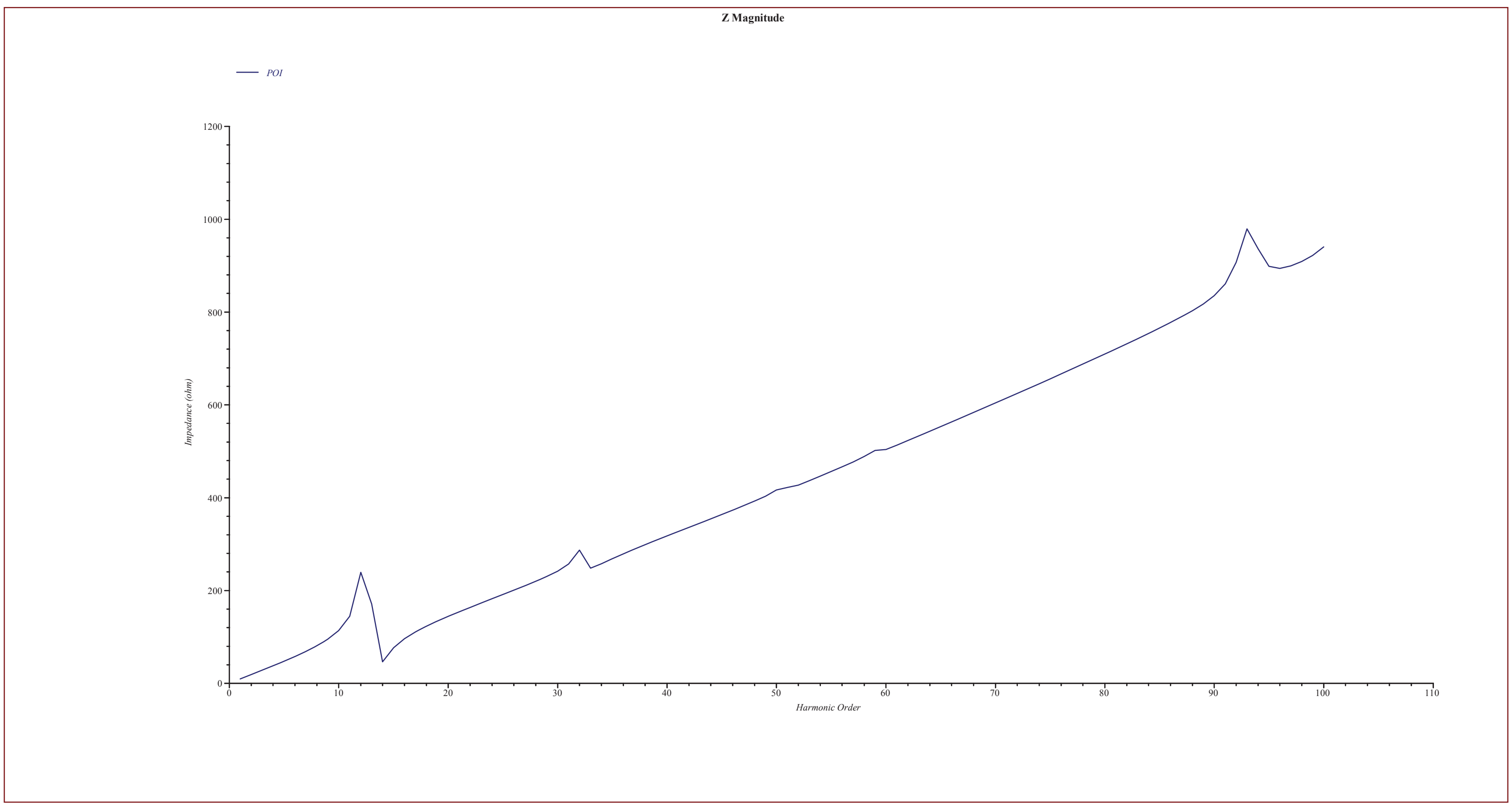
FREQUENCY SCAN ANALYSIS



Project File: C:\Users\JVenden\Documents\WESTWOOD\PROJECTS\0007186 NW OH\ETAP\NW_OH
Output Report: WindFree400

Cap Bank OFF

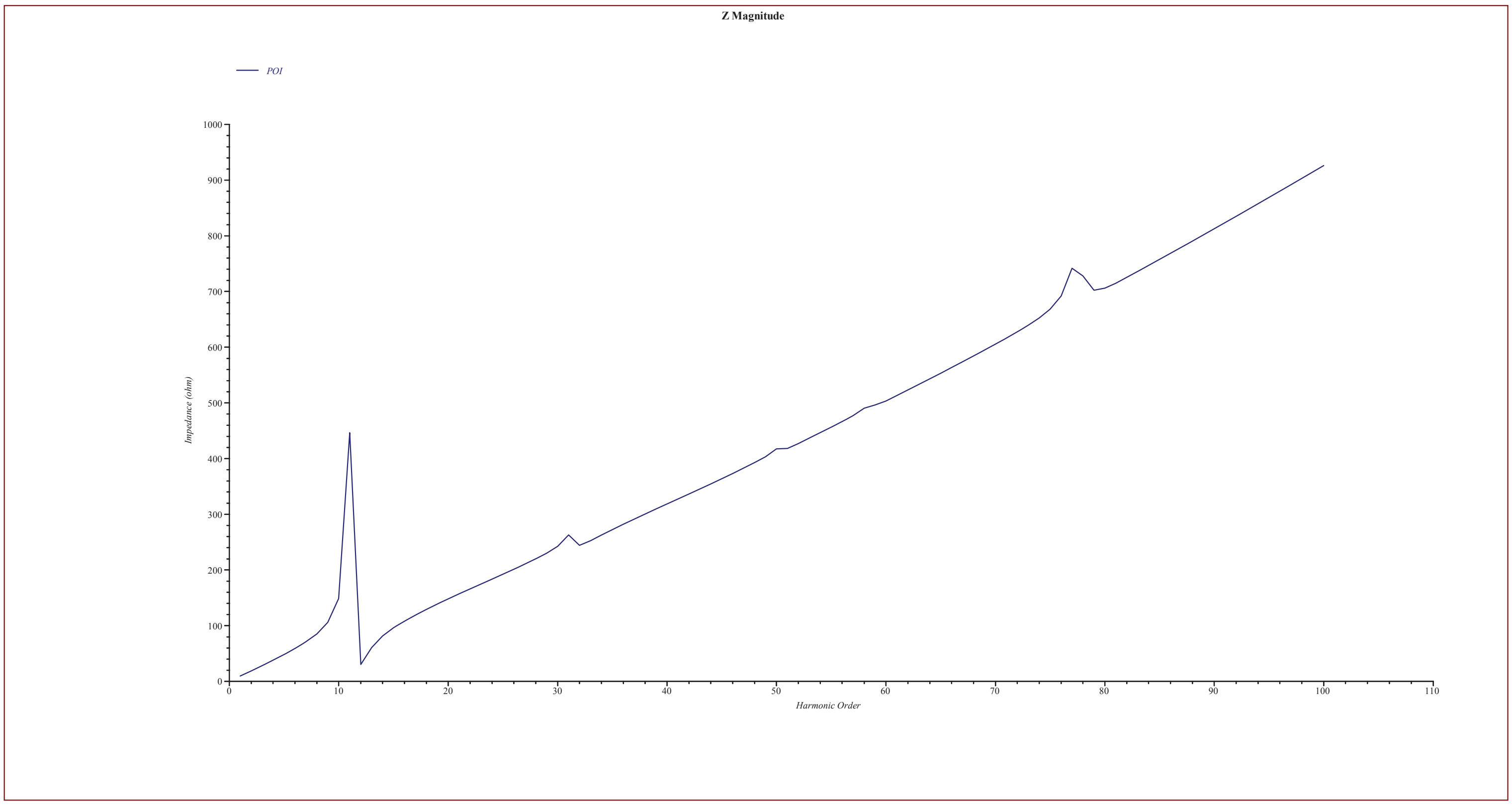
FREQUENCY SCAN ANALYSIS



Project File: C:\Users\JVenden\Documents\WESTWOOD\PROJECTS\0007186 NW OH\ETAP\NW_OH
Output Report: WindFree400

Cap Bank ON

FREQUENCY SCAN ANALYSIS



AC CABLE SIZING STUDY

Northwest Ohio Wind Project

Paulding, Ohio
October 27, 2017

Prepared for:

WHITE
an IEA company

Prepared by:

Westwood

Westwood

Project Name: NW OH Wind Project	
Title	**J.O. or W.O. Number**
AC Cable Sizing Study	0007186.00

Approvals		**Revision Number**	**Date**	**Description**
Preparer(s) Name	**Reviewer(s) Name**			
Josh Venden	Drew Szabo	0	09/27/2017	Original Release
Josh Venden	Drew Szabo	1	10/06/2017	Added options for homerun trenches
Josh Venden	Drew Szabo	2	10/27/2017	Added boring details

Westwood

TABLE OF CONTENTS

INTRODUCTION

NW OH Wind Project is a 100 MW wind generation installation in Paulding, OH consisting 42 of GE 2.5 MW wind turbines. The turbines are grouped into four medium voltage (MV) feeders with 10 turbines on Feeders 1 and 4 and 11 turbines on Feeders 2 and 3. The feeders are connected to a main power transformer that steps the voltage up to 138kV where it interconnects with the AEP transmission system via a short overhead line segment.

OBJECTIVE

The objective of this report is to provide the design basis for determining the ampacity ratings of the medium and low voltage AC cables between the turbines, transformers, and junction boxes.

INPUTS & ASSSUMPTIONS

- The native soil thermal resistivity is 150°C-cm/W as per the assessment of Westwood Professional Services based on the Geotechnical Engineering Report for Northwest Ohio Wind Project; completed by BARR, December 2014.
- Thermal resistivity of the disturbed soil in the cable trench is based on considerations of residual moisture, such that it indicates a worst case rho value of 190°C-cm/W at the specified 85% compaction.
- Thermal resistivity of the concrete ductbank is assumed to be 55 C-cm/W per NEC.
- Appendix D, has the excerpts for the dry out curves of the soil at various test points.
- Soil ambient temperature at various depths is shown in the following table.

Depth [ft]	Depth [m]	T_{max} [C]
3	0.91	22
4	1.22	21
5	1.52	20
6	1.83	19
7	2.13	18
8	2.44	18
9	2.74	17
10	3.05	17

- Cables are analyzed at their maximum allowable continuous operating temperature of 90° C.
- Load factor assumed conservatively at 100% for determining the cable ampacities.
- Direct buried medium voltage AC Cables are evaluated with minimum 48” soil cover.
- Medium voltage AC collector electrical layout is per the Westwood Professional Services Electrical Drawings, MVAC Collection One-Line Diagrams E.200 & E.210 and Trench Details E.600.
- The standard installation is based on a trefoil arrangement of cables, aluminum conductors with copper concentric neutral wires bonded at both ends.
- The nameplate rating of the turbines is 2.5MW with reactive power capability of 0.9 lead/lag. Maximum cable amp loadings are based on maximum total turbine MVA output; approximately 49A at 34.5 kV.

METHODOLOGY

- Thermal analysis of underground cables is conducted with CYME Cymcap software, which uses the Neher-McGrath methodology to determine reduced cable ratings based on project specific thermal constraints.
- CYMCAP analysis is conducted for single and multiple circuit trenches for all of the MV cable sizes and configurations used in the underground collection design.
- CYMCAP analysis is also performed to verify the ampacity of the low voltage cables passing through the turbine foundation.

THERMAL ANALYSIS RESULTS AND CONCLUSION

SINGLE CIRCUIT AMPACITY

- Table 1 shows a summary of the single circuit cable ampacities and maximum number of turbines that can be connected to each cable size without violating its respective ampacity rating.

Cable	Material	Maximum 3PH Fault Current	Min. Required Area	Phase Conductor Area	Ampacity & Configuration	
1/0	Al	10412	83315	105600	143	Trefoil
4/0	Al	13136	105113	211600	214	Trefoil
500	Al	10166	81347	500000	337	Trefoil
750	Al	11365	90941	750000	411	Trefoil
1000	Al	10185	81499	1000000	481	Trefoil
1250	Al	12570	100583	1250000	545	Trefoil
1250*	Al	12570	100583	1250000	570	Trefoil

** Increased ampacity based on 90% soil compaction in trenches with 11 turbines on the ckt*

Table 1: Cable Ampacity Summary

- As the final two rows of the above table indicate, for 1250 kCMIL cable with an ampacity rating large enough to accommodate 11 turbines, a soil compaction of at least 90% must be achieved in the trenches, which reduces the soil thermal resistivity closer to the native soil value of 150°C-cm/W. Feeders 2 and 3 require this compaction level for the MV cable trenches from the substation to the first wind turbine on each feeder.

MULTIPLE CIRCUIT TRENCHES

- In several locations, multiple MV circuits will run parallel to one another in the same right of way (ROW). Further thermal analysis was performed on these areas to determine the minimum spacing between circuits required to maintain acceptable operating temperatures.
- The following table summarizes the locations where multiple circuits will occupy the same parallel trench paths. The table indicates the number of turbines and corresponding loading on each cable segment and the minimum spacing required for double, triple and quad circuit ROW.

Westwood

TRENCH SEGMENT FROM	TO	FEEDERS IN TRENCH FDR	TURBINES	AMPS	Cable Sizes	Trench Detail Dwg
SUB	HWY 114	1	10	489.32	1250	4 ckts; 12" trenches 15' min spacing center-center
		2	11	538.25	1250	
		3	11	538.25	1250	
		4	10	489.32	1250	
HWY 114	T-25	1	10	489.32	1250	4 ckts; 12" trenches 15' min spacing center-center
		2	11	538.25	1250	
		3	11	538.25	1250	
		4	10	489.32	1250	
T-25	T-24	1	1	48.93	4/0	4 ckts; 12" trenches 15' min spacing center-center
		2	11	538.25	1250	
		3	11	538.25	1250	
		4	10	489.32	1250	
T-24	JB-2/1	2	11	538.25	1250	3 ckts; 12" trenches 11' min spacing center-center
		3	11	538.25	1250	
		4	10	489.32	1250	
JB-2/1	T-22	2	4	195.73	4/0	3 ckts; 12" trenches 11' min spacing center-center
		3	11	538.25	1250	
		4	10	489.32	1250	
T-22	T-23	2	1	48.93	1/0	3 ckts; 12" trenches 11' min spacing center-center
		3	11	538.25	1250	
		4	11	538.25	1250	
T-23	T-28	3	10	489.32	1250	2 ckts; 12" trenches; 5' min spacing center-center
		4	10	489.32	1250	
T-28	T-33	3	7	342.52	750	2 ckts; 12" trenches; 5' min spacing center-center
		4	10	489.32	1250	
T-33	T-34	3	4	195.73	4/0	2 ckts; 12" trenches; 5' min spacing center-center
		4	10	489.32	1250	
T-34	T-39	3	1	48.93	1/0	2 ckts; 12" trenches; 5' min spacing center-center
		4	10	489.32	1250	

Table 2: Multiple Circuit Trench Summary

CONSTRAINED EASEMENT

- The worst case from a thermal standpoint occurs in the ROW from Turbine 25 to the Substation where all four fully loaded feeders run parallel to one another. The cable ROW that runs along the south side of Hwy 114 is currently limited to less than 20 feet. At the eastern end of this easement the cables would run on land designated for the O&M building and substation where the ROW could again be expanded to the spacing indicated in Table 2 above. Several options for this ROW are discussed below.
    - Copper Conductors

      This option looks at using copper conductors for the approximately 1,450 feet in the ditch along the south of Hwy 114. Junction boxes would have to be installed on each end of the constrained easement to convert the cables from Al to Cu. This is approximately 4,350 feet of 1250 kCMIL copper cable for each feeder. The feeder spacing is shown in the following table.

TRENCH SEGMENT FROM TO	FEEDERS IN TRENCH FDR	TURBINES	AMPS	Cable Sizes	Ckt Spacing (center-to-center)
CONSTRAINED EASEMENT	1	10	489.32	1250 CU	four 12" trenches; 13' ROW
	2	11	538.25	1250 CU	3' FDR1-FDR2;
	3	11	538.25	1250 CU	4' FDR2-FDR3;
	4	10	489.32	1250 CU	3' FDR3-FDR4

- Duct Bank

  This option looks at the installation of a 4 circuit duct bank for the approximately 1,450 feet in the ditch along the south of Highway 114. The duct bank would be a minimum of 10' wide and 18" high with approximately 18" of cover over the duct bank. The following table summarizes the duct spacing for the four circuits.

TRENCH SEGMENT FROM TO	FEEDERS IN TRENCH FDR	TURBINES	AMPS	Cable Sizes	Ckt Spacing (center-to-center)
CONSTRAINED EASEMENT	1	10	489.32	1250	limited ROW < 20'
	2	11	538.25	1250	1.5' x 10' duct bank
	3	11	538.25	1250	rho <= 0.55 C-m/W
	4	10	489.32	1250	2.5' duct spacing

- 3 Turbine Tap

  For this option, the total number of turbines per homerun are reduced by installing a separate "tap" circuit to collect turbines 23, 24 and 29. The reconfiguration reduces the total turbines on circuits 2 and 3 to ten. Additionally, turbine 24 would be connected to this feeder to eliminate the tap connection from turbine 25 to 24. This option also impacts several of the trench segments as the number of circuits and loading on each circuit has changed. The following table summarizes the new trench configurations. This would result in an additional 40,725 feet of 4/0 cable.

TRENCH SEGMENT FROM	TO	FEEDERS IN TRENCH FDR	TURBINES	AMPS	Cable Sizes	Ckt Spacing (center-to-center)
		1	9	440.39	1250	
SUB	HWY 114	2	10	489.32	1250	85% compaction all trenches
		3	10	489.32	1250	10' center-center
HWY 114	T-25	4	10	489.32	1250	45' ROW
		TAP	3	146.80	4/0	
		1	9	440.39	1250	limited ROW < 20'
CONSTRAINED		2	10	489.32	1250	1.5' x 13' duct bank
EASEMENT		3	10	489.32	1250	rho <= 0.55 C-m/W
		4	10	489.32	1250	2.75' duct spacing
		TAP	3	146.80	4/0	
		2	10	489.32	1250	85% compaction all trenches
T-25	T-24	3	10	489.32	1250	8' FDR2-TAP; 10.5' TAP-FDR3;
		4	10	489.32	1250	10.5' FDR3-FDR4
		TAP	3	146.80	4/0	35' ROW
		2	10	489.32	1250	85% compaction all trenches
T-24	JB-2/1	3	10	489.32	1250	4' FDR2-TAP; 8.5' TAP-FDR3;
		4	10	489.32	1250	11.5' FDR3-FDR4
		TAP	2	97.86	4/0	25' ROW
		2	3	146.80	4/0	85% compaction all trenches
JB-2/1	T-22	3	10	489.32	1250	8' FDR2-FDR3; 7' FDR3-TAP;
		4	10	489.32	1250	6' TAP-FDR4
		TAP	2	97.86	4/0	25' ROW
		3	10	489.32	1250	85% compaction all trenches
T-22	T-23	4	10	489.32	1250	5.5' center-center
		TAP	2	97.86	4/0	15' ROW

A summary of the additional materials required for each option is shown in the table below.

OPTION	DESCRIPTION	BOM CHANGES	QTY
1	Copper Conductor Cable	Junction boxes	8
		Remove 1250 kCMIL Aluminum	17,400'
		Add 1250 kCMIL Copper	17,400'
2	Slurry Backfill and Duct Bank	Add flowable fill (trench feet 4 ckts)	1,928 cu yd 19,280'
		Add 10x1.5' duct bank	1,450'
3	Additional Circuit and Duct Bank	Add 4/0 AWG AL 1/2CN	40,725'
		Add 7#8 trench ground	13,575'
		Add 13x1.5' duct bank	1,450'
		Additional trenching	8,040'

Westwood

WETLANDS, ROAD AND PIPELINE CROSSINGS

- There are several designated wetland areas, road and gas pipeline crossings throughout the site that require directional drill boring installation. The following table summarizes the location of each boring with the assumed depth. For boring locations, a soil temperature of 17 °C and a thermal resistivity of 100 °C-cm/W are assumed due to native soil compaction and moisture assumptions at greater depths.

Table 3: Boring Summary, Feeders 1 & 2

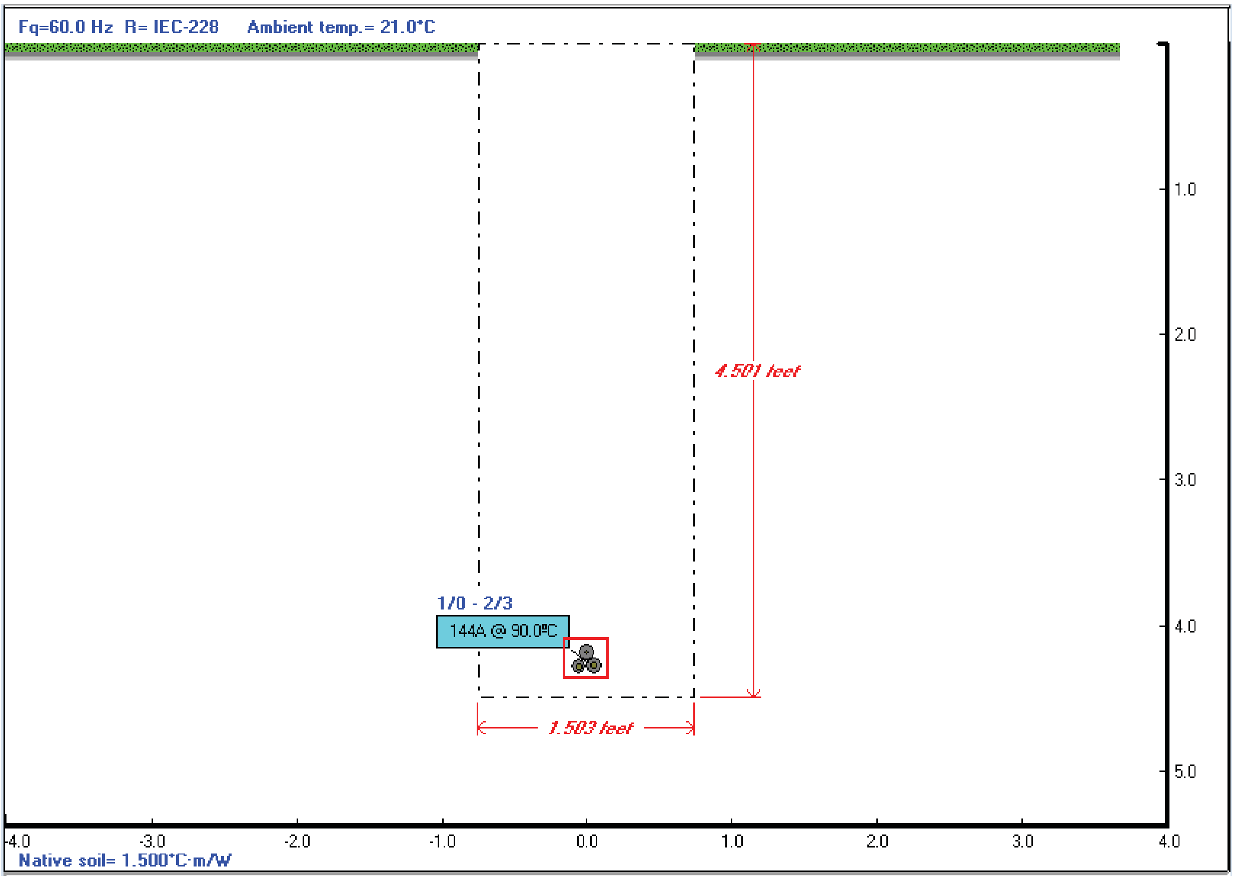
Bore ID	Bore Type	Cable Size	Lowest Depth Of Ditch, Pipe, or Wetland (ft)	Depth Of Cable Duct (ft)	Multi-Circuit Separation	Notes
MV1.T02-T01.1	COUNTY RD	1/0 AWG	5.0	9.0	N/A	Assume 4' below lowest point in ditch
MV1.T03-T02.1	WETLAND	1/0 AWG	5.0	9.0	N/A	Assume 4' below lowest point of wetland
MV1.T05-T04.1	COUNTY RD	4/0 AWG	4.5	8.5	N/A	Assume 4' below lowest point in ditch
MV1.T08-T05.1	COUNTY RD	500 MCM	1.0	5.0	N/A	Assume 4' below lowest point in ditch
MV1.T09-T08.1	GAS PIPELINE	500 MCM	3.5	13.5	N/A	Assume 10' separation with gas pipeline
MV1.T09-T08.2	WETLAND	500 MCM	6.5	10.5	N/A	Assume 4' below lowest point of wetland
MV1.T09-T08.3	COUNTY RD	500 MCM	1.0	5.0	N/A	Assume 4' below lowest point in ditch
MV1.T25-T10.1	COUNTY RD	1000 MCM	2.0	6.0	N/A	Assume 4' below lowest point in ditch
MV1.T25-T10.2	WETLAND	1000 MCM	10.0	14.0	N/A	Assume 4' below lowest point of wetland
MV1.T25-T10.3	COUNTY RD	1000 MCM	5.5	9.5	N/A	Assume 4' below lowest point in ditch
MV1.SUB-T25.1	GAS PIPELINE	1250 MCM	3.5	13.5	23' (76' ROW)	Assume 10' separation with gas pipeline
MV1.SUB-T25.2	STATE HWY	1250 MCM	2.0	6.0	23' (76' ROW)	Assume 4' below lowest point in ditch
MV1.SUB-T25.3	GAS PIPELINE	1250 MCM	3.0	13.0	N/A	Assume 10' separation with gas pipeline
MV2.T15-T14.1	COUNTY RD	1/0 AWG	6.0	10.0	N/A	Assume 4' below lowest point in ditch
MV2.T15-T07.1	COUNTY RD	4/0 AWG	6.0	10.0	3' (10' ROW)	Assume 4' below lowest point in ditch
MV2.T07-T16.1	WETLAND	1/0 AWG	8.0	12.0	N/A	Assume 4' below lowest point of wetland
MV2.T07-T16.2	COUNTY RD	1/0 AWG	7.0	11.0	3' (10' ROW)	Assume 4' below lowest point in ditch
MV2.T17-T15.1	WETLAND	500 MCM	6.5	10.5	N/A	Assume 4' below lowest point of wetland
MV2.T17-T15.2	COUNTY RD	500 MCM	1.0	5.0	N/A	Assume 4' below lowest point in ditch
MV2.T17-T15.3	WETLAND	500 MCM	2.0	6.0	N/A	Assume 4' below lowest point of wetland
MV2.T17-T15.4	WETLAND	500 MCM	1.5	5.5	N/A	Assume 4' below lowest point of wetland
MV2.JB2/1-T17.1	COUNTY RD	750 MCM	8.0	12.0	N/A	Assume 4' below lowest point in ditch
MV2.JB2/1-T22.1	WETLAND	4/0 AWG	5.0	9.0	12' (28' ROW)	Assume 4' below lowest point of wetland
MV2.JB2/1-T22.2	COUNTY RD	4/0 AWG	6.0	10.0	18' (40' ROW)	Assume 4' below lowest point in ditch
MV2.T22-T29.1	COUNTY RD	1/0 AWG	1.5	5.5	N/A	Assume 4' below lowest point in ditch
MV2.T22-T29.2	COUNTY RD	1/0 AWG	6.0	10.0	N/A	Assume 4' below lowest point in ditch
MV2.T21-T20.1	COUNTY RD	1/0 AWG	1.0	5.0	N/A	Assume 4' below lowest point in ditch
MV2.T21-T20.2	WETLAND	1/0 AWG	1.0	5.0	N/A	Assume 4' below lowest point of wetland
MV2.T21-T20.3	WETLAND	1/0 AWG	13.5	17.5	N/A	Assume 4' below lowest point of wetland
MV2.SUB-JB2/1.1	GAS PIPELINE	1250 MCM	3.5	13.5	23' (76' ROW)	Assume 10' separation with gas pipeline
MV2.SUB-JB2/1.2	GAS PIPELINE	1250 MCM	3.5	13.5	23' (76' ROW)	Assume 10' separation with gas pipeline

Westwood

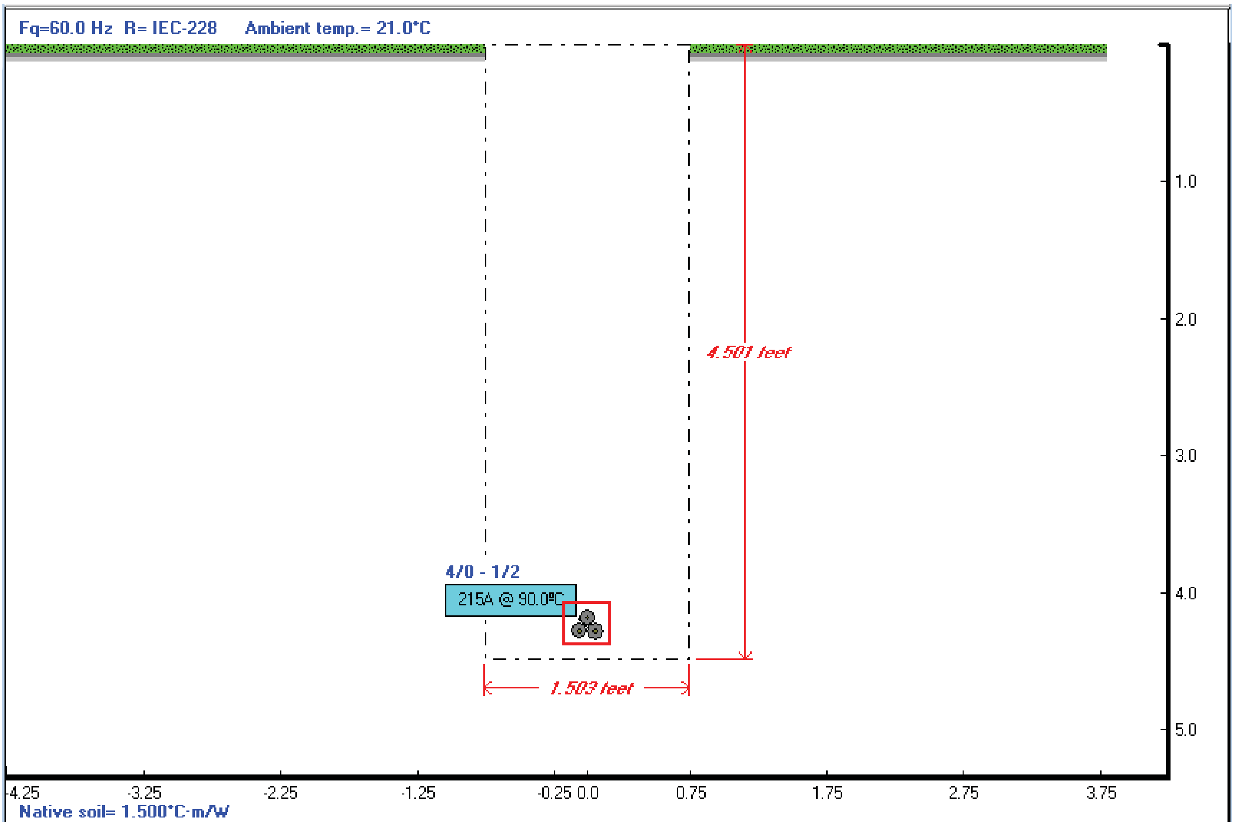
Table 3: Boring Summary, Feeders 3 & 4

Bore ID	Bore Type	Cable Size	Lowest Depth Of Ditch, Pipe, or Wetland (ft)	Depth Of Cable Duct (ft)		Notes
MV3.T32-T31.1	WETLAND	1/0 AWG	3.5	7.5	N/A	Assume 4' below lowest point of wetland
MV3.T32-T31.2	COUNTY RD	1/0 AWG	5.5	9.5	N/A	Assume 4' below lowest point in ditch
MV3.T34-T36.1	COUNTY RD	1/0 AWG	2.0	6.0	N/A	Assume 4' below lowest point in ditch
MV3.T34-T39.1	WETLAND	1/0 AWG	9.0	13.0	3' (10' ROW)	Assume 4' below lowest point of wetland
MV3.T34-T39.2	COUNTY RD	1/0 AWG	5.5	9.5	3' (10' ROW)	Assume 4' below lowest point in ditch
MV3.T34-T39.3	COUNTY RD	1/0 AWG	2.0	6.0	3' (10' ROW)	Assume 4' below lowest point in ditch
MV3.T28-T33.1	STATE HWY, GAS PIPE	750 MCM	7.0	11.0	3' (10' ROW)	Assume 4' below lowest point in ditch - VERIFY REQS
MV3.T28-T33.2	WETLAND	750 MCM	4.0	8.0	3' (10' ROW)	Assume 4' below lowest point of wetland
MV3.T23-T28.1	COUNTY RD	1250 MCM	5.5	9.5	3' (10' ROW)	Assume 4' below lowest point of wetland
MV3.T23-T28.2	MVAC FDR2	1250 MCM	4.0	7.0	15' (20' ROW)	Assume boring 7' beneath circuit 2
MV3.SUB-T23.1	WETLAND	1250 MCM	5.5	9.5	12' (28' ROW)	Assume 4' below lowest point of wetland
MV3.SUB-T23.2	COUNTY RD	1250 MCM	1.5	5.5	18' (40' ROW)	Assume 4' below lowest point in ditch
MV3.SUB-T23.3	GAS PIPELINE	1250 MCM	3.5	13.5	23' (76' ROW)	Assume 10' separation with gas pipeline
MV3.SUB-T23.4	STATE HWY	1250 MCM	2.0	6.0	23' (76' ROW)	Assume 4' below lowest point in ditch
MV3.SUB-T23.5	GAS PIPELINE	1250 MCM	3.0	13.0	N/A	Assume 10' separation with gas pipeline
MV4.T49-T50.1	WETLAND	1/0 AWG	2.0	6.0	N/A	Assume 4' below lowest point of wetland
MV4.T49-T50.2	WETLAND	1/0 AWG	1.0	5.0	N/A	Assume 4' below lowest point of wetland
MV4.T49-T48.2	WETLAND	1/0 AWG	2.0	6.0	N/A	Assume 4' below lowest point of wetland
MV4.T42-T49.1	COUNTY RD	4/0 AWG	3.0	7.0	N/A	Assume 4' below lowest point in ditch
MV4.T42-T49.2	COUNTY RD	4/0 AWG	4.0	8.0	N/A	Assume 4' below lowest point in ditch
MV4.T44-JB4/1.1	COUNTY RD	500 MCM	3.0	7.0	N/A	Assume 4' below lowest point in ditch
MV4.T46-T45.1	COUNTY RD	1000 MCM	2.0	6.0	N/A	Assume 4' below lowest point in ditch
MV4.T45-T44.1	WETLAND	750 MCM	7.5	11.5	N/A	Assume 4' below lowest point of wetland
MV4.T45-T44.2	COUNTY RD	750 MCM	0.5	4.5	N/A	Assume 4' below lowest point in ditch
MV4.T40-T46.1	COUNTY RD	1000 MCM	1.5	5.5	N/A	Assume 4' below lowest point in ditch
MV4.SUB-T40.1	WETLAND	1250 MCM	9.5	13.5	3' (10' ROW)	Assume 4' below lowest point of wetland
MV4.SUB-T40.2	COUNTY RD	1250 MCM	5.5	9.5	3' (10' ROW)	Assume 4' below lowest point in ditch
MV4.SUB-T40.3	COUNTY RD	1250 MCM	1.5	5.5	3' (10' ROW)	Assume 4' below lowest point in ditch
MV4.SUB-T40.4	STATE HWY	1250 MCM	7.5	11.5	3' (10' ROW)	Assume 4' below lowest point in ditch
MV4.SUB-T40.5	WETLAND	1250 MCM	3.5	7.5	3' (10' ROW)	Assume 4' below lowest point of wetland
MV4.SUB-T40.6	COUNTY RD	1250 MCM	5.5	9.5	3' (10' ROW)	Assume 4' below lowest point in ditch
MV4.SUB-T40.7	MVAC FDR2	1250 MCM	4.0	7.0	15' (20' ROW)	Assume boring 7' beneath circuit 2
MV4.SUB-T40.8	WETLAND	1250 MCM	5.5	9.5	12' (28' ROW)	Assume 4' below lowest point of wetland
MV4.SUB-T40.9	COUNTY RD	1250 MCM	1.0	5.0	18' (40' ROW)	Assume 4' below lowest point in ditch
MV4.SUB-T40.10	GAS PIPELINE	1250 MCM	3.5	13.5	23' (76' ROW)	Assume 10' separation with gas pipeline
MV4.SUB-T40.11	GAS PIPELINE	1250 MCM	3.5	13.5	23' (76' ROW)	Assume 10' separation with gas pipeline

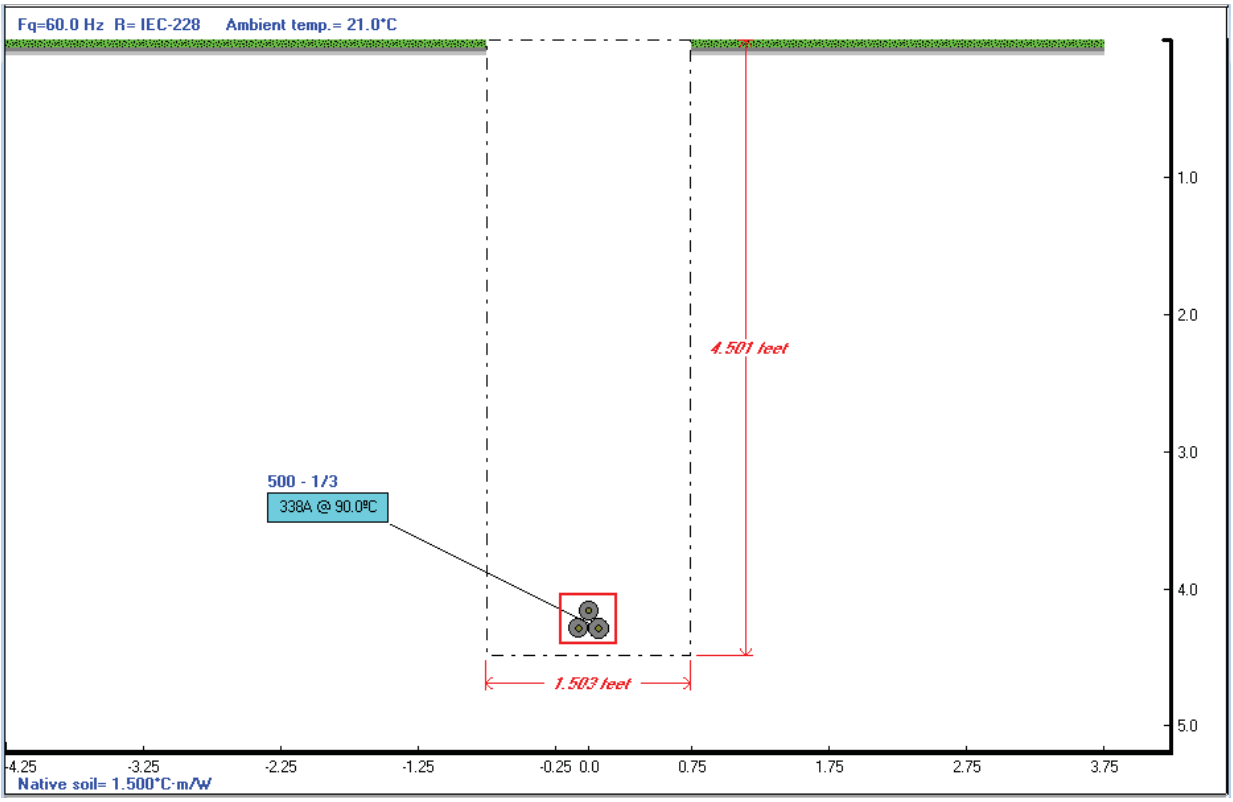
APPENDIX A: **TRENCHED CIRCUITS CYMCAP OUTPUT**



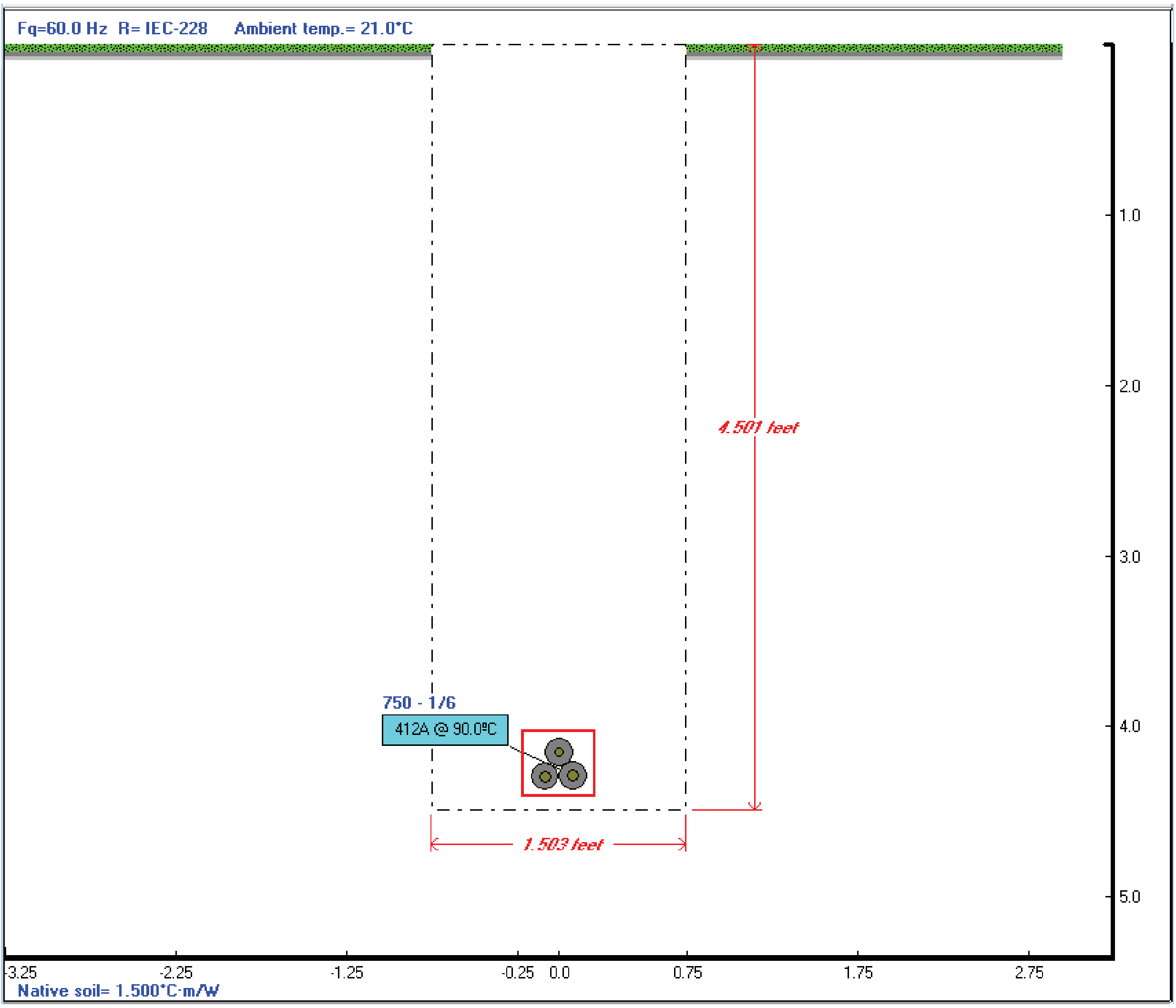
Westwood



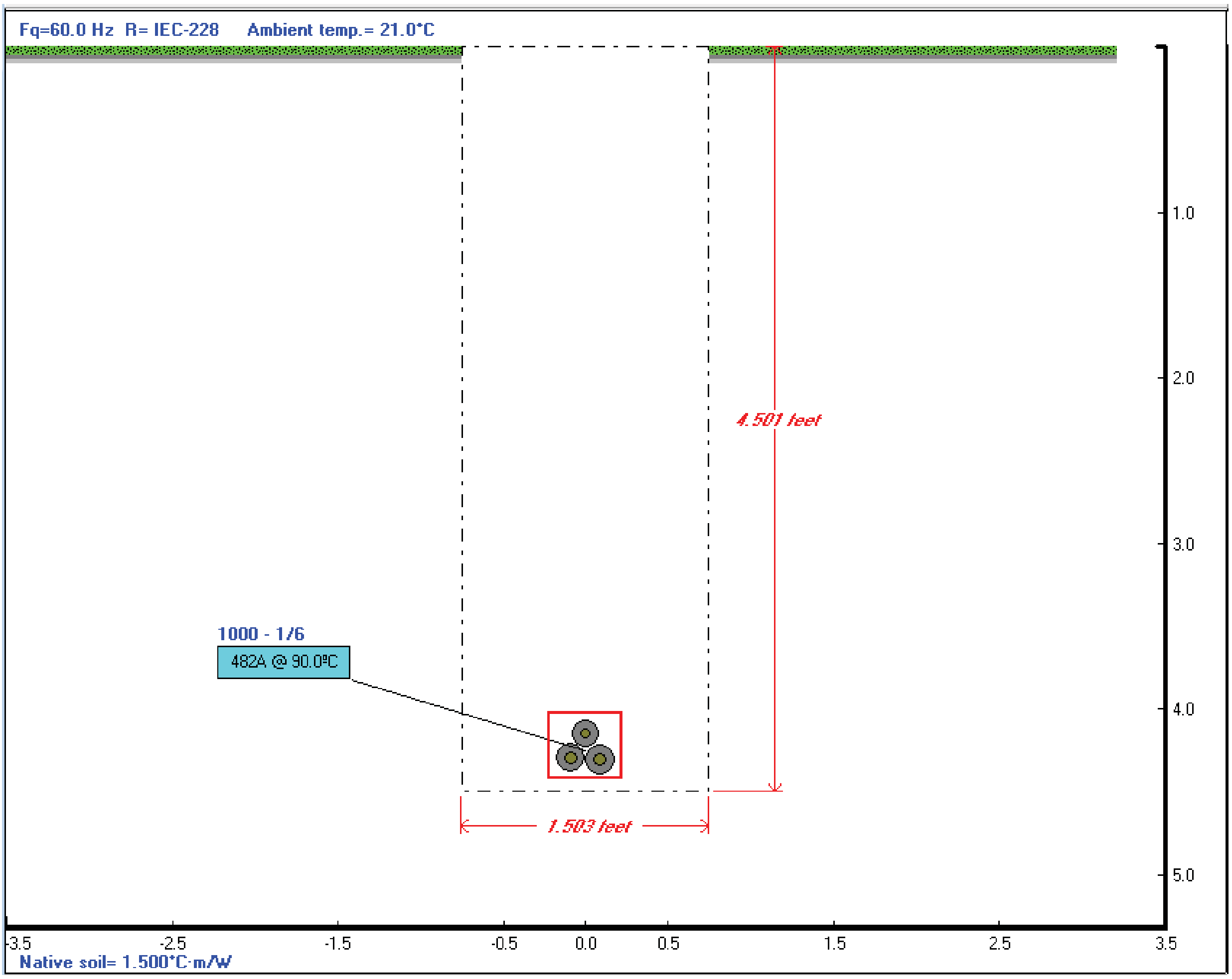
Fq=60.0 Hz R= IEC-228 Ambient temp.= 21.0°C
4.501 feet
4/0 - 1/2
215A @ 90.0ºC
1.503 feet
1.0
2.0
3.0
4.0
5.0
-4.25
-3.25
-2.25
-1.25
-0.25 0.0
0.75
1.75
2.75
3.75
Native soil= 1.500°C·m/W


Fq=60.0 Hz R= IEC-228 Ambient temp.= 21.0°C
4.501 feet
500 - 1/3
338A @ 90.0ºC
1.503 feet
1.0
2.0
3.0
4.0
5.0
-4.25
-3.25
-2.25
-1.25
-0.25 0.0
0.75
1.75
2.75
3.75
Native soil= 1.500°C·m/W

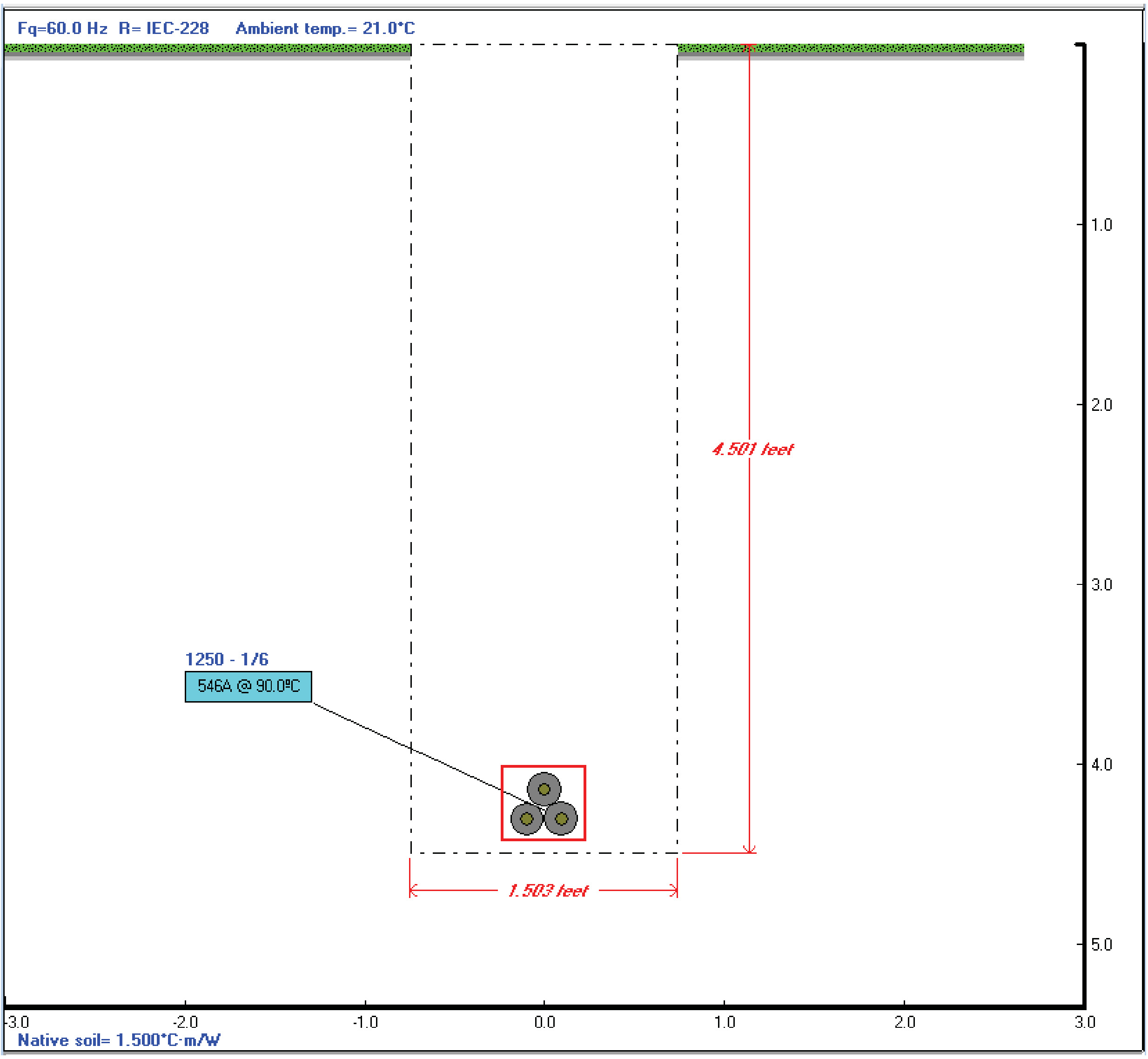
Westwood


Fq=60.0 Hz R= IEC-228 Ambient temp.= 21.0°C
4.501 feet
750 - 1/6
412A @ 90.0ºC
1.503 feet
1.0
2.0
3.0
4.0
5.0
-3.25
-2.25
-1.25
-0.25
0.0
0.75
1.75
2.75
Native soil= 1.500°C·m/W

Westwood

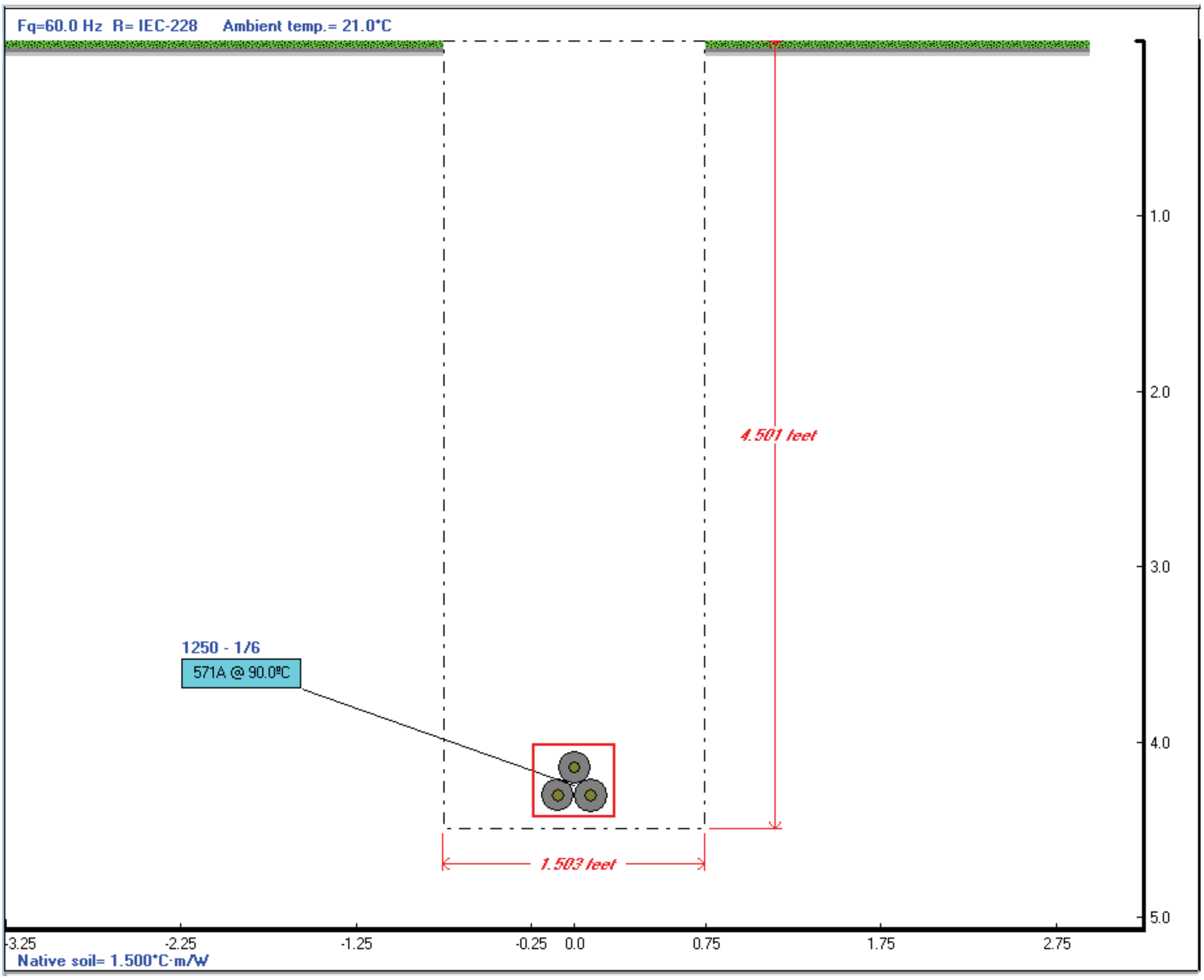

Fq=60.0 Hz R= IEC-228 Ambient temp.= 21.0°C
4.501 feet
1000 - 1/6
482A @ 90.0ºC
1.503 feet
1.0
2.0
3.0
4.0
5.0
-3.5
-2.5
-1.5
-0.5
0.0
0.5
1.5
2.5
3.5
Native soil= 1.500°C·m/W

Westwood



Fq=60.0 Hz R= IEC-228 Ambient temp.= 21.0°C
4.501 feet
1250 - 1/6
546A @ 90.0ºC
1.503 feet
1.0
2.0
3.0
4.0
5.0
-3.0
-2.0
-1.0
0.0
1.0
2.0
3.0
Native soil= 1.500°C-m/W

Westwood

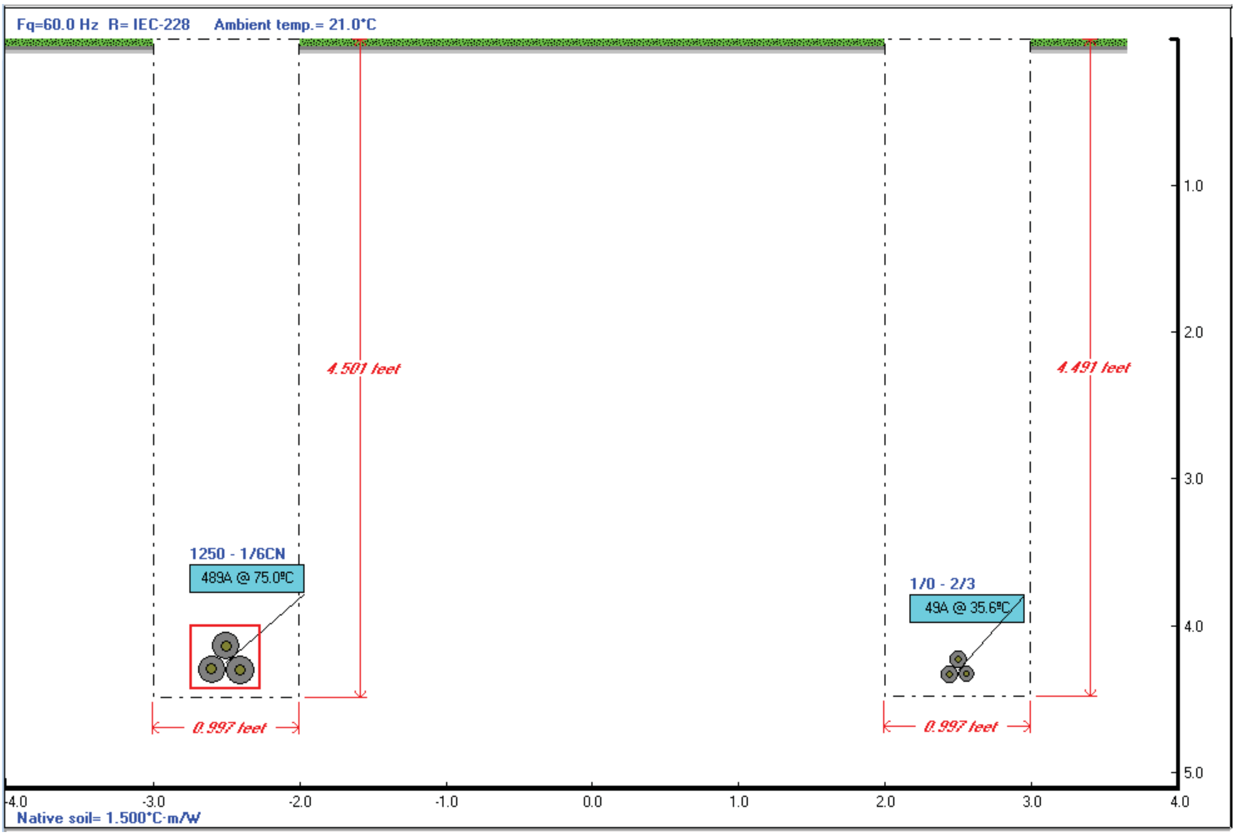


Fq=60.0 Hz R= IEC-228 Ambient temp.= 21.0°C
4.501 feet
1250 - 1/6
571A @ 90.0ºC
1.503 feet
1.0
2.0
3.0
4.0
5.0
-3.25
-2.25
-1.25
-0.25
0.0
0.75
1.75
2.75
Native soil= 1.500°C·m/W

Westwood

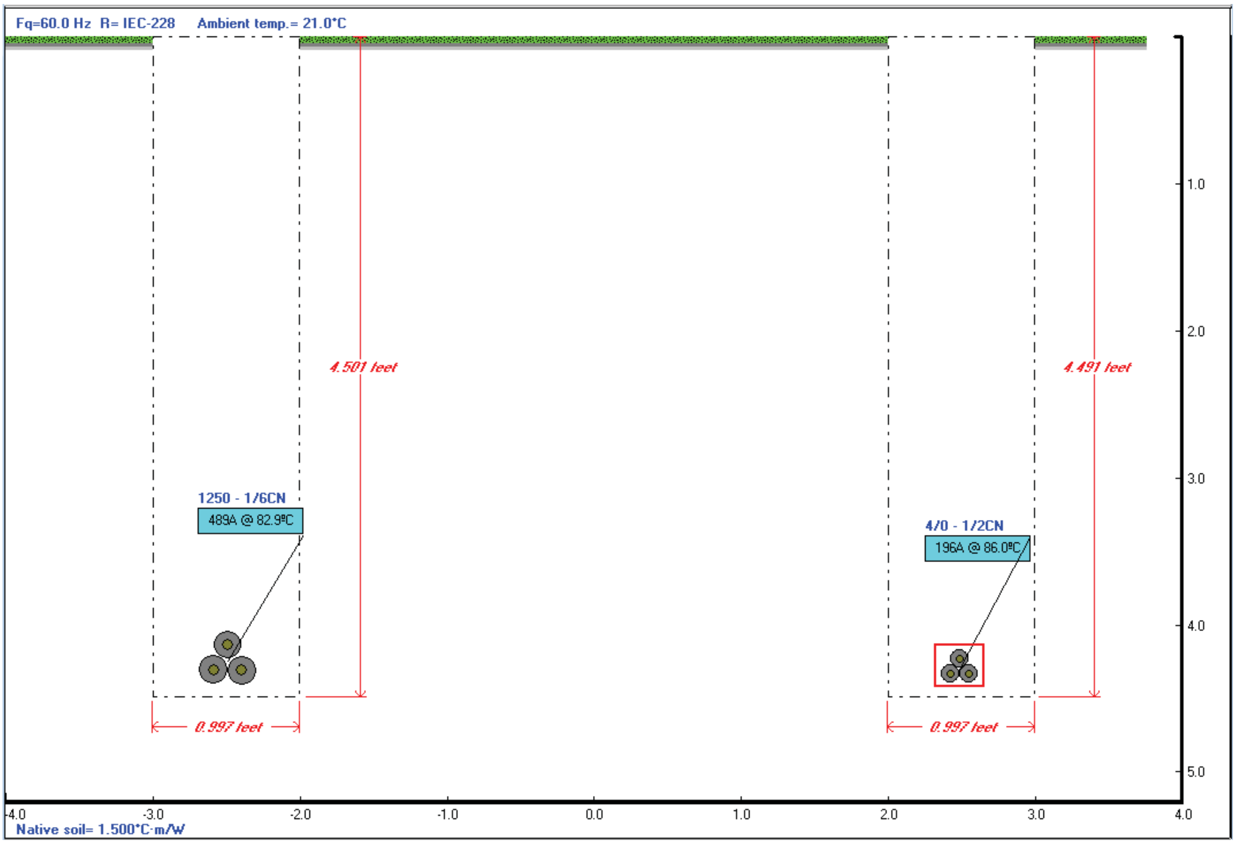
MULTI-CIRCUIT TRENCHES

ROW: T-34 to T39



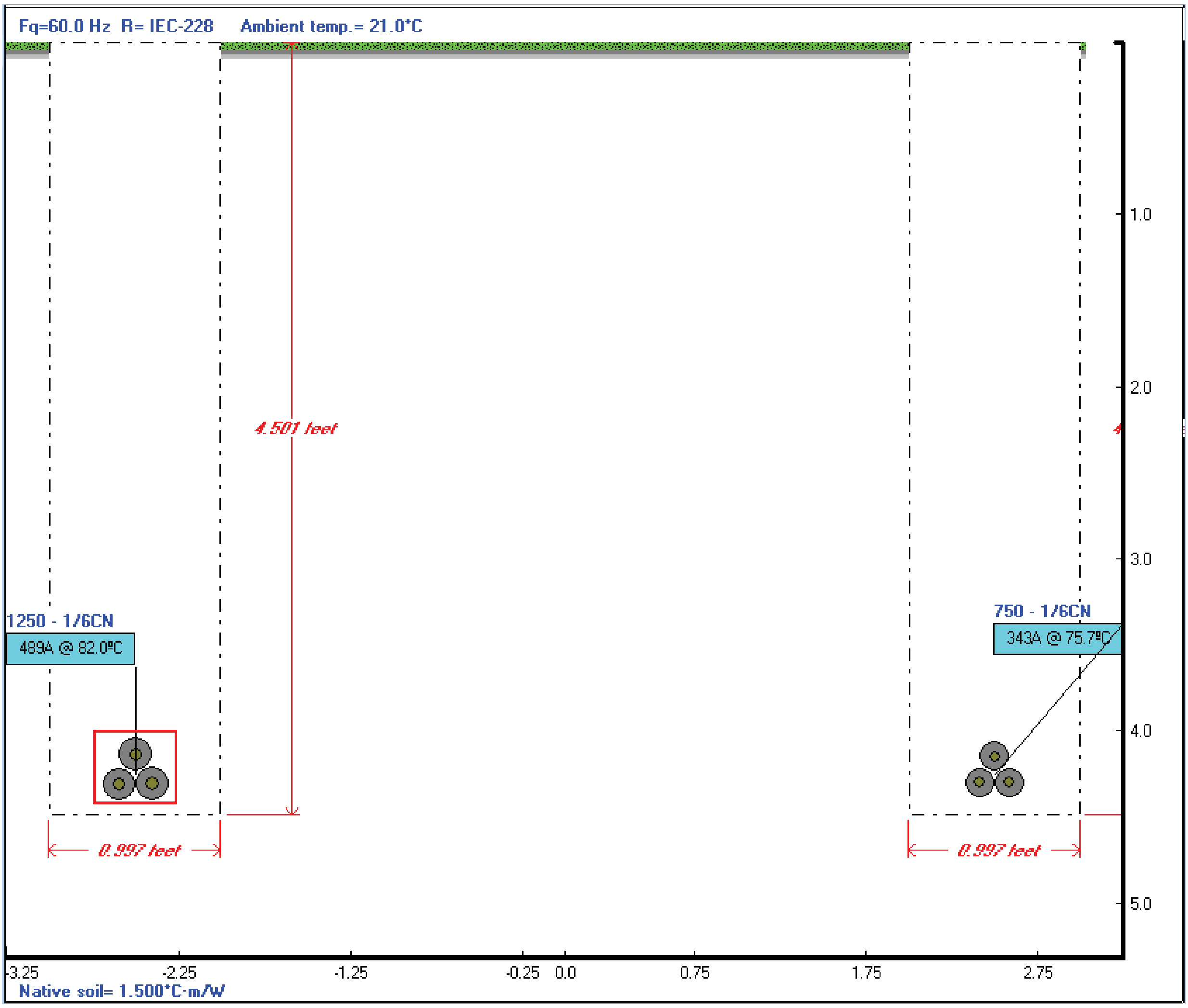
Westwood

ROW: T-33 to T-34

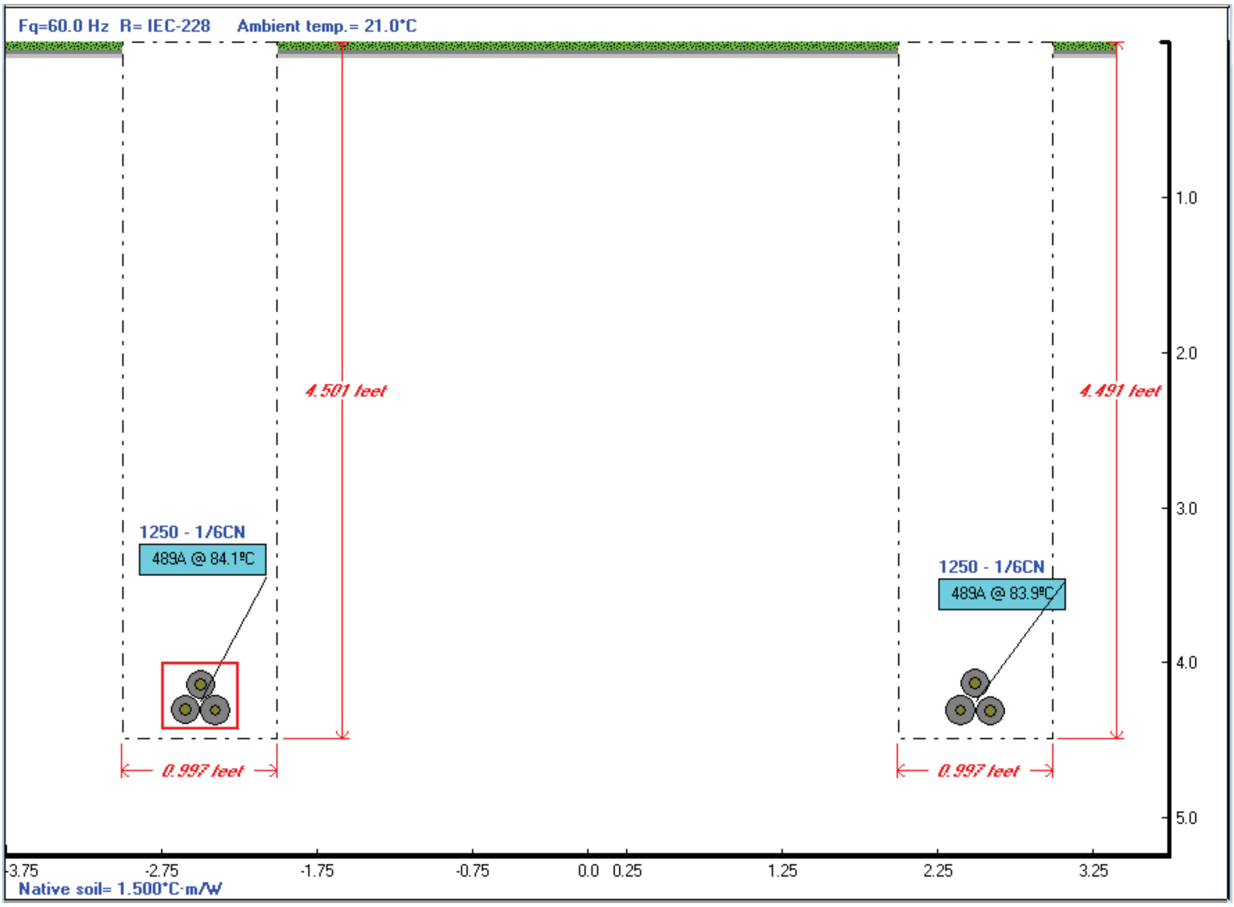


Westwood

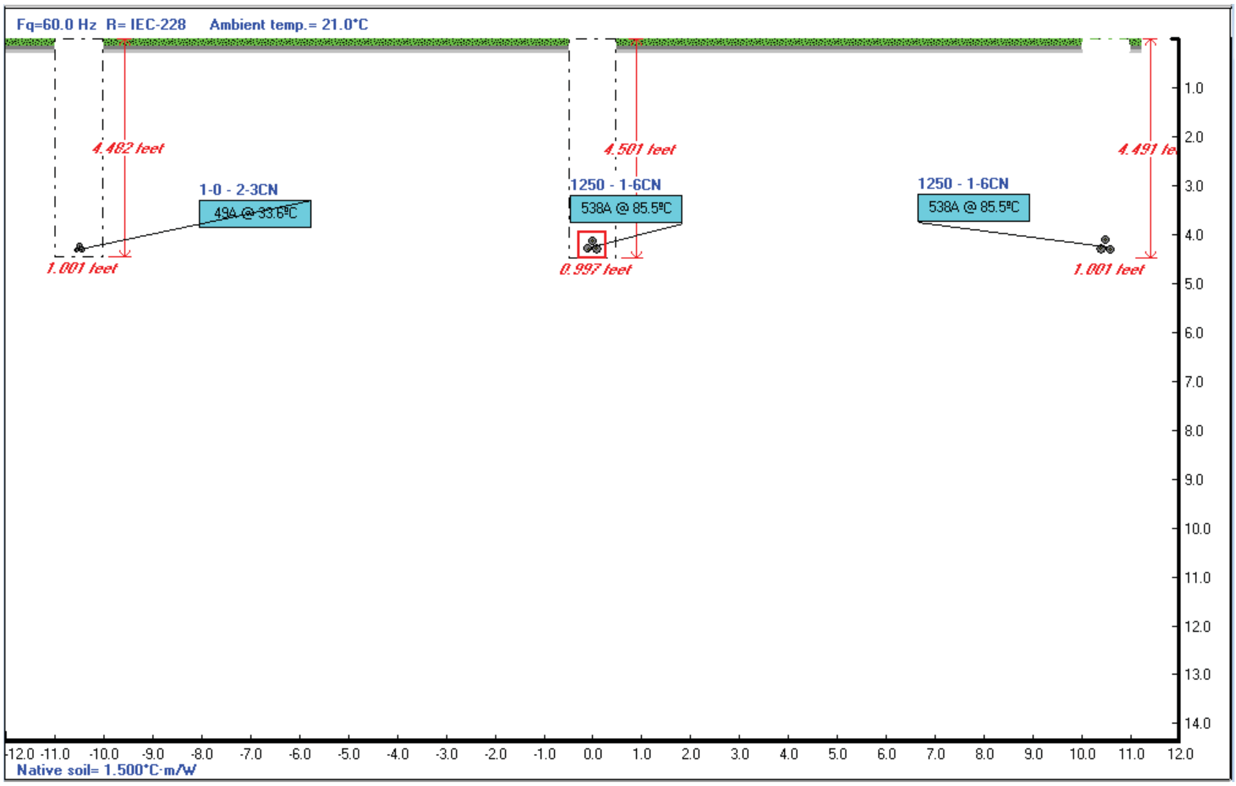
ROW: T-28 to T-33



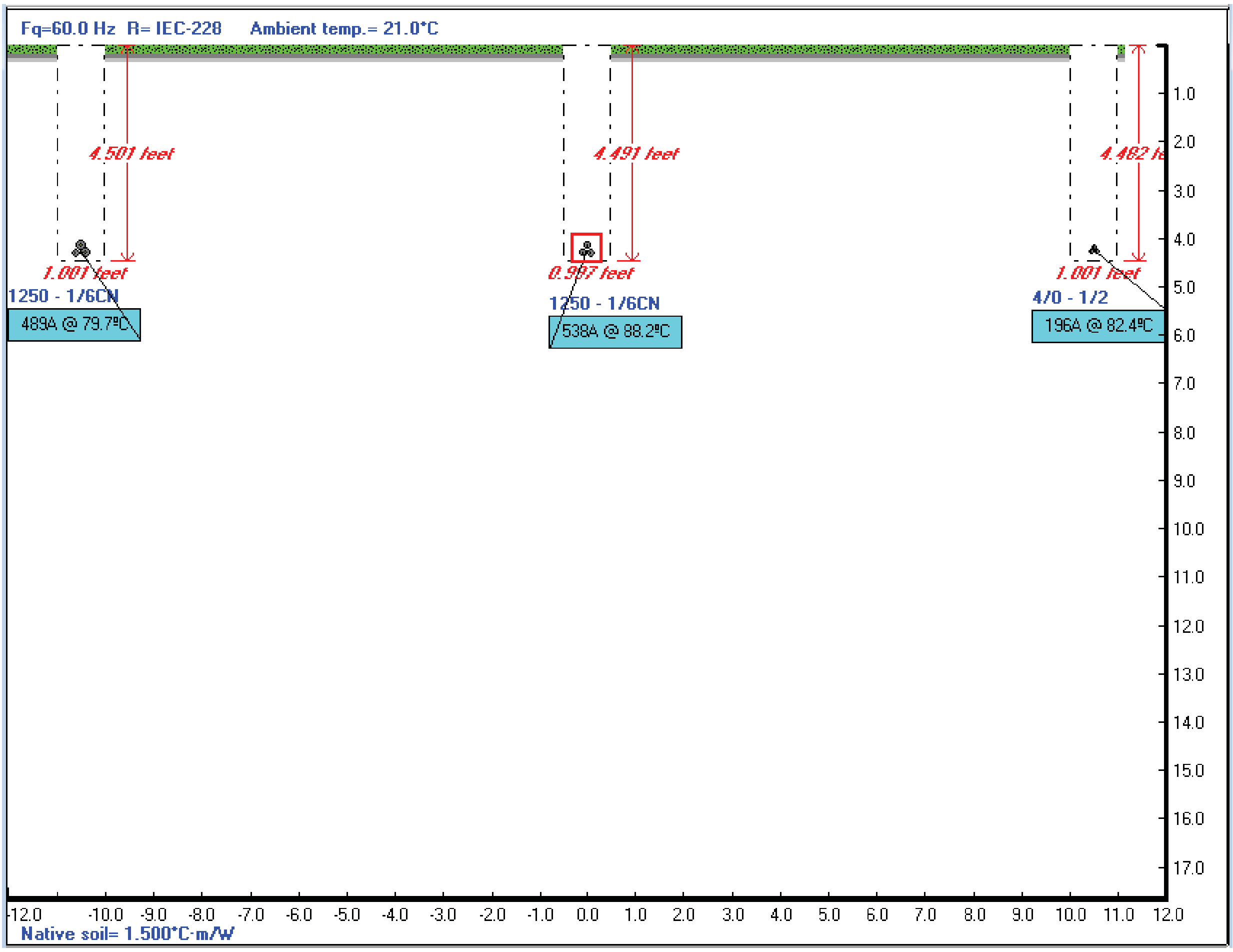
ROW: T-23 to T-28



ROW: T-22 to T-23

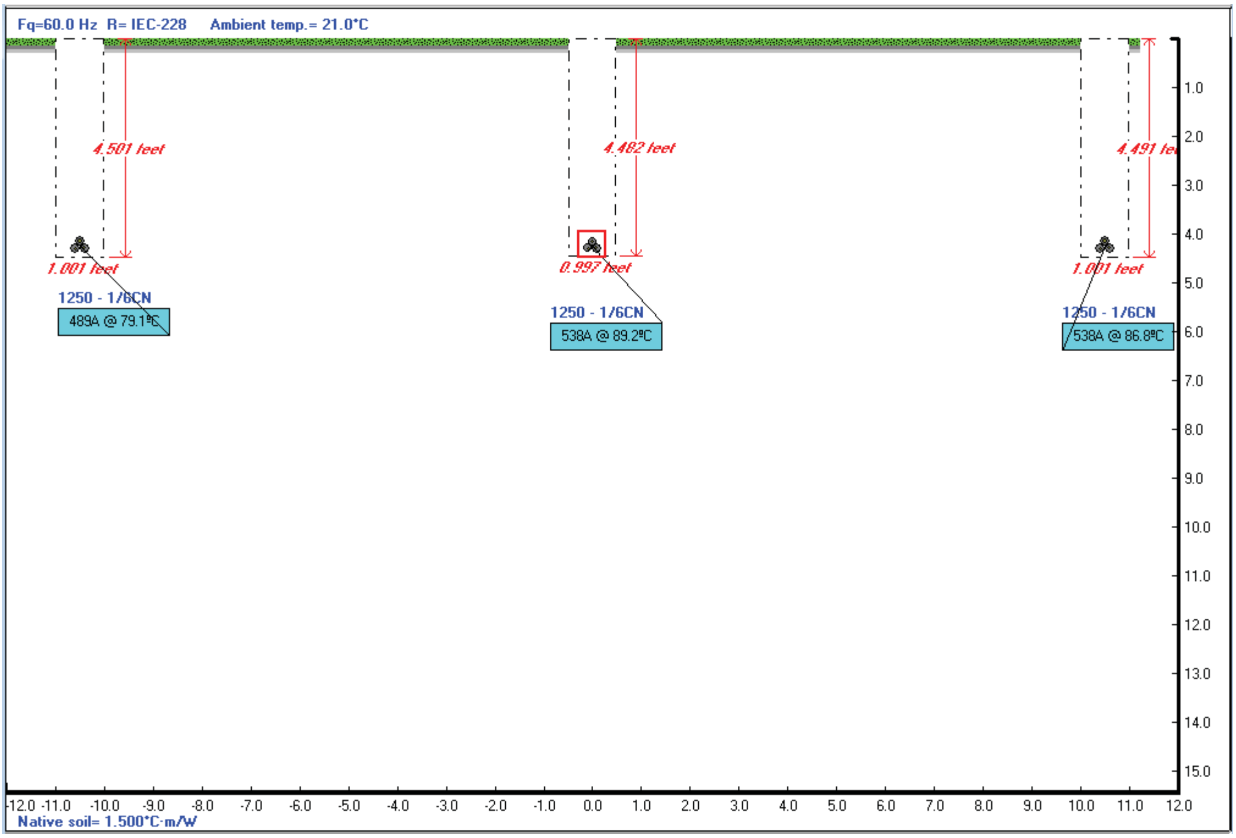


ROW: JB-2/1 – T-22



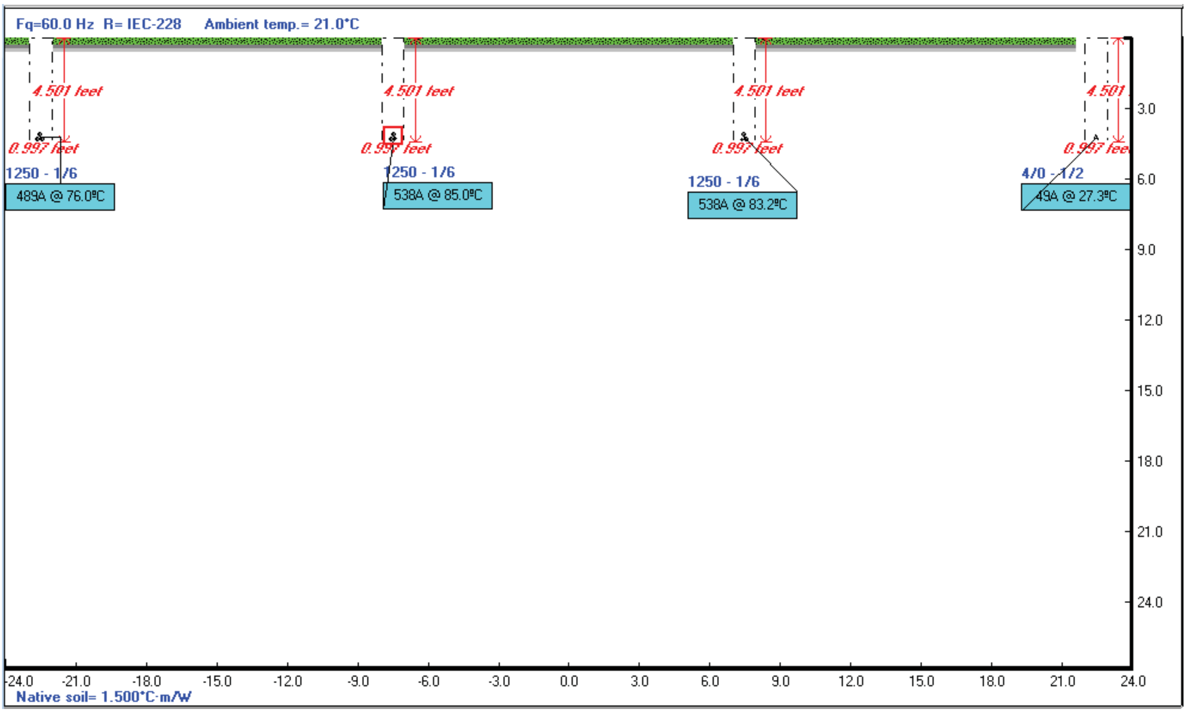
Fq=60.0 Hz R= IEC-228 Ambient temp.= 21.0°C
4.501 feet
4.491 feet
1.001 feet
0.997 feet
1.001 feet
1250 - 1/6CN
489A @ 79.7ºC
1250 - 1/6CN
538A @ 88.2ºC
4/0 - 1/2
196A @ 82.4ºC
Native soil= 1.500°C·m/W

ROW: T-24 to JB-2/1

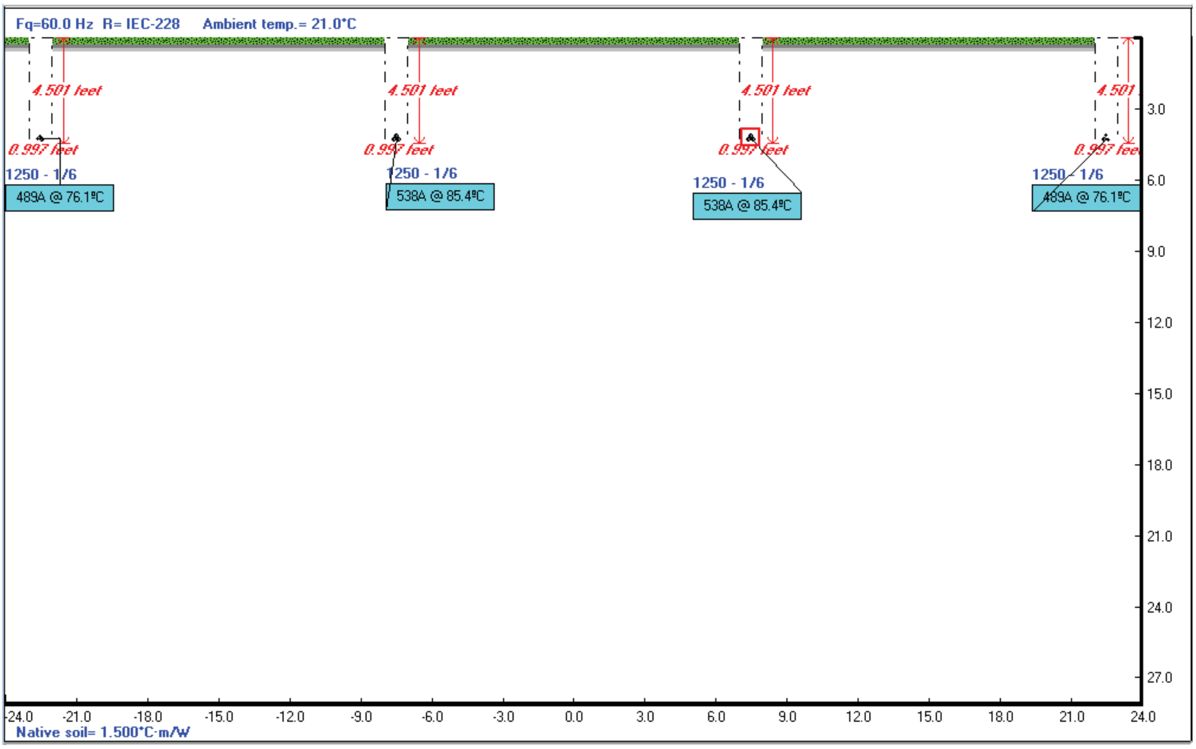


Westwood

ROW: T-24 to T-25



ROW: T-25 to SUB (unconstrained ROW)

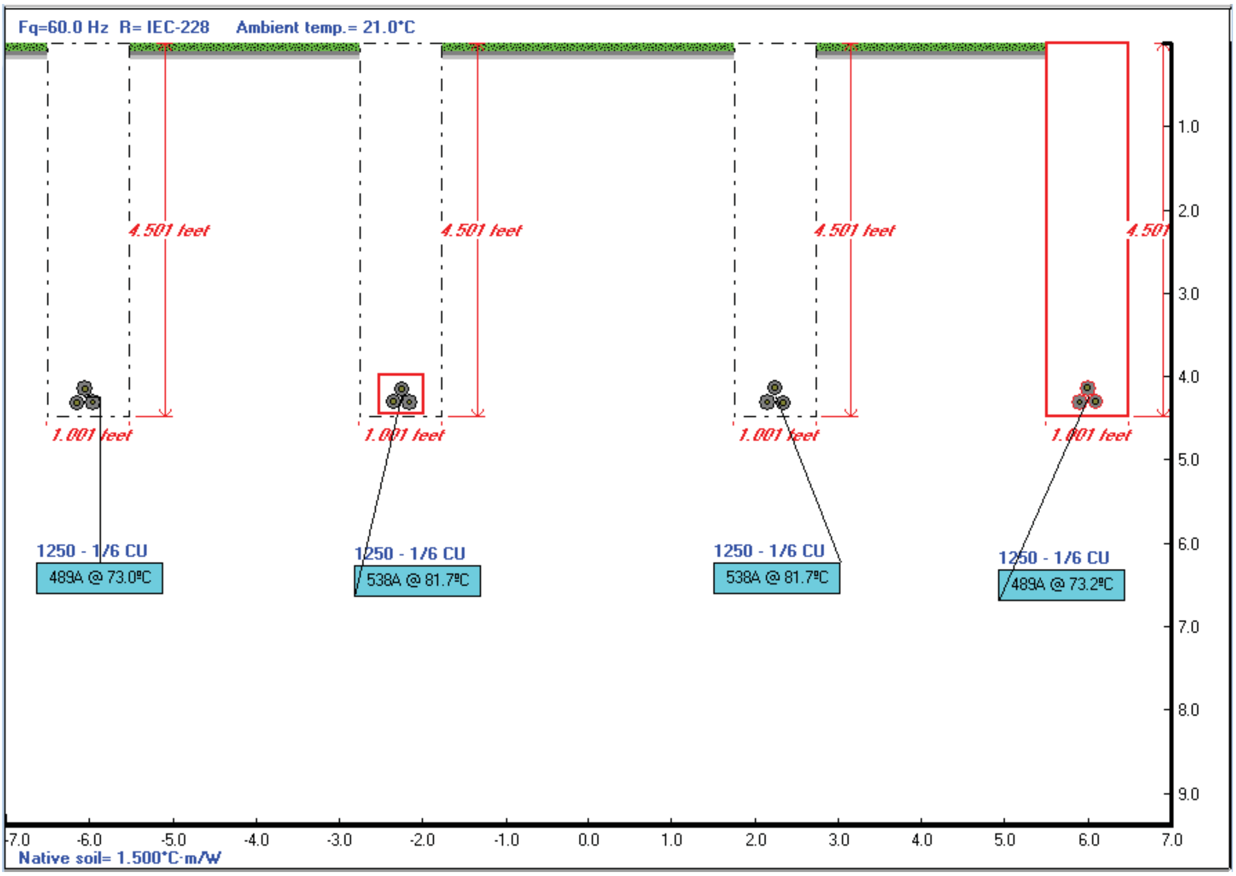


APPENDIX B: CONSTRAINED RIGHT OF WAY OPTIONS

ROW: T-25 to SUB   OPTIONS

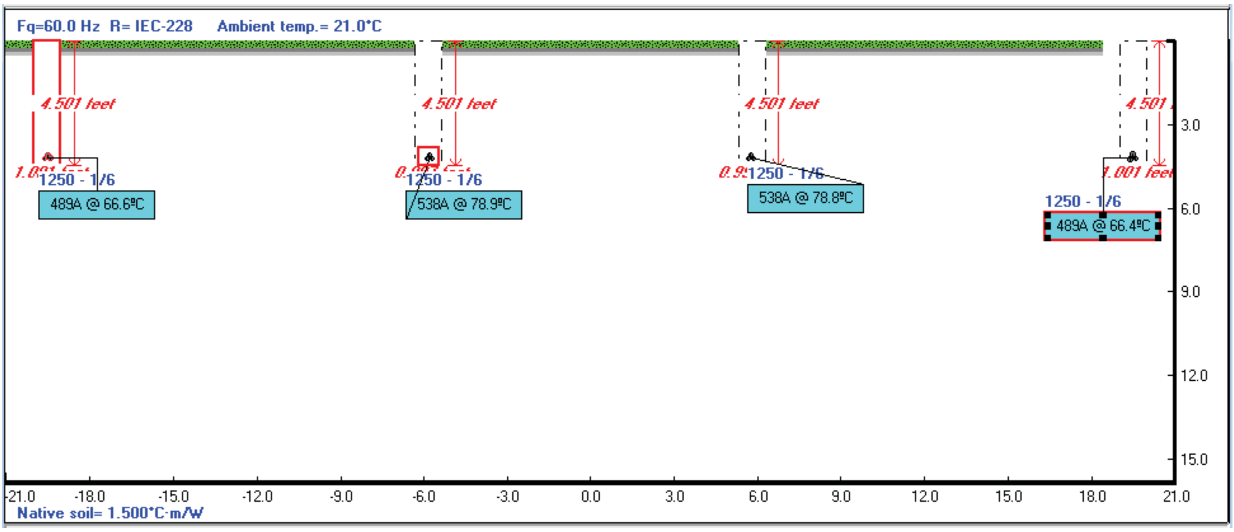
COPPER CABLES

ROW :: T-25 to SUB

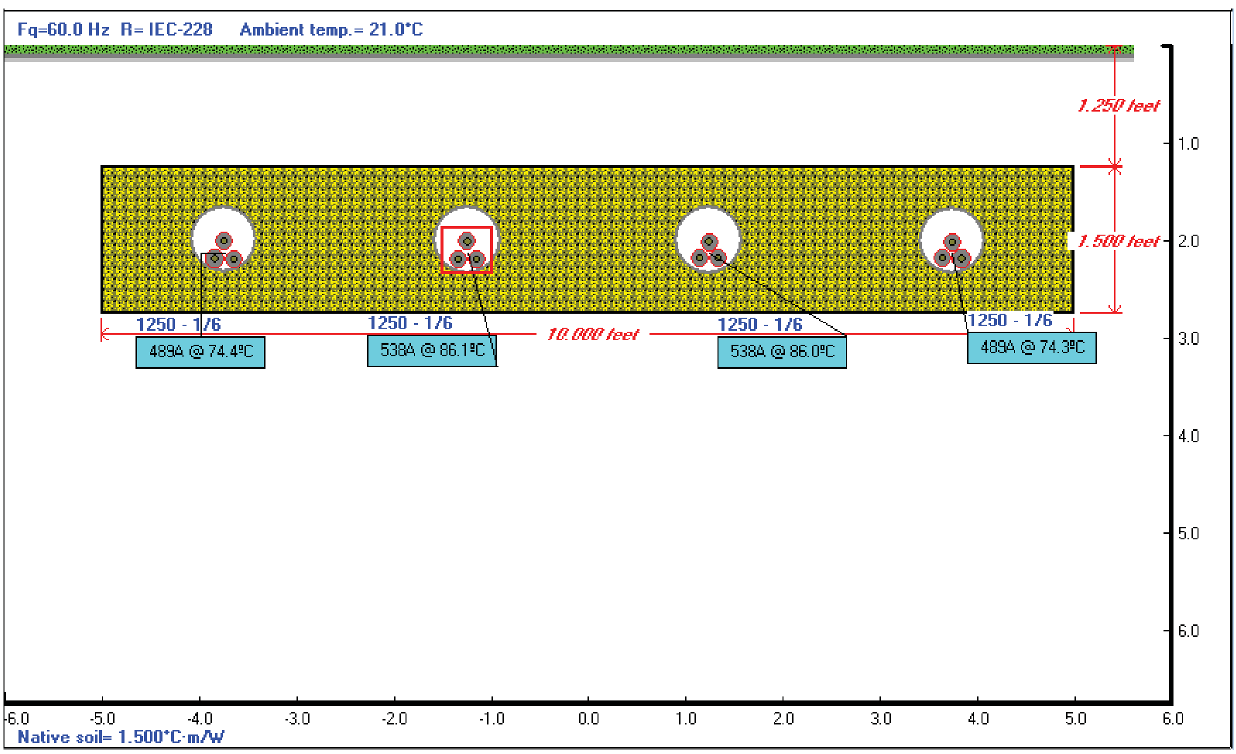


SLURRY & DUCT BANK

ROW :: T-25 to SUB



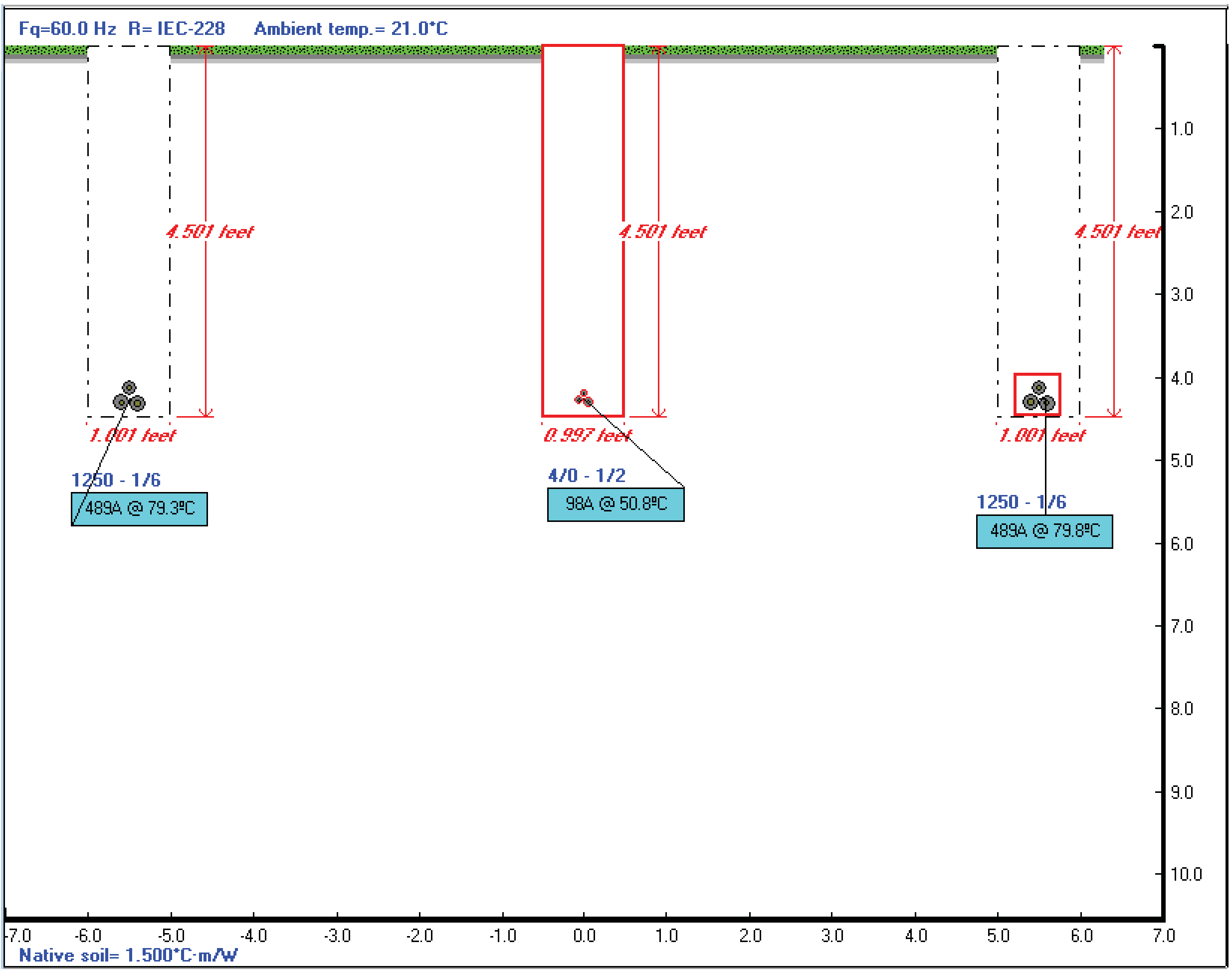
CONSTRAINED EASEMENT



Westwood

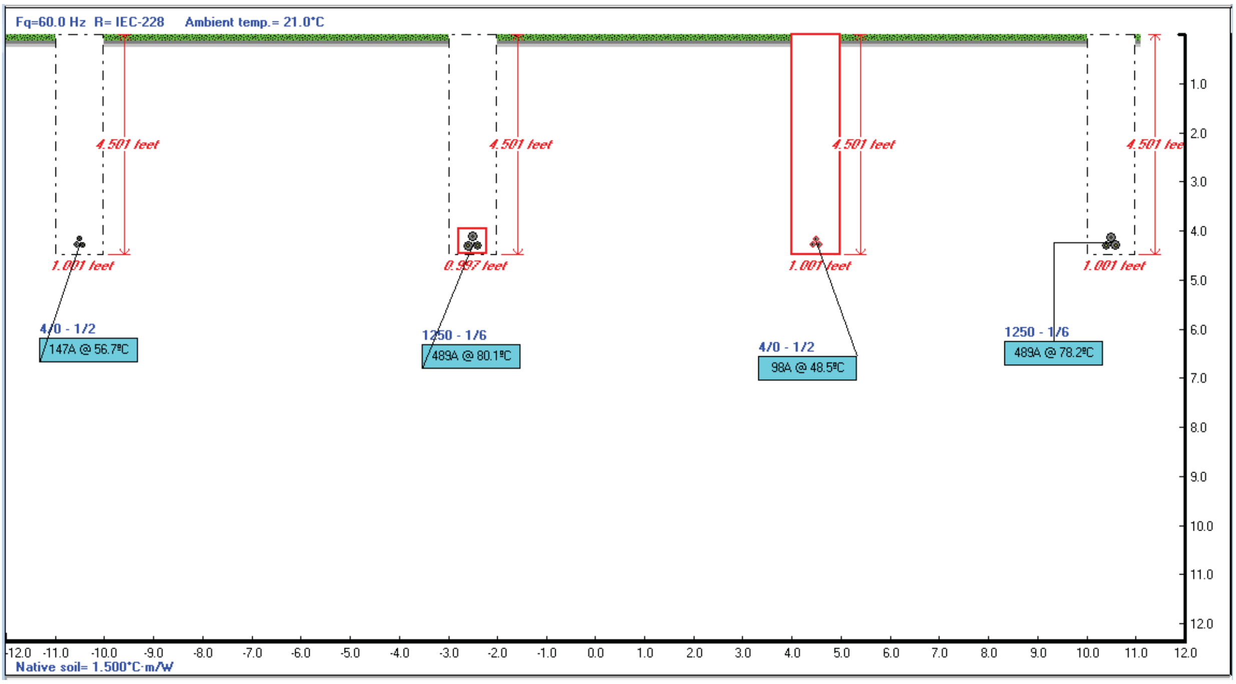
EXTRA TAP & DUCT BANK

ROW :: T-23 to T-22



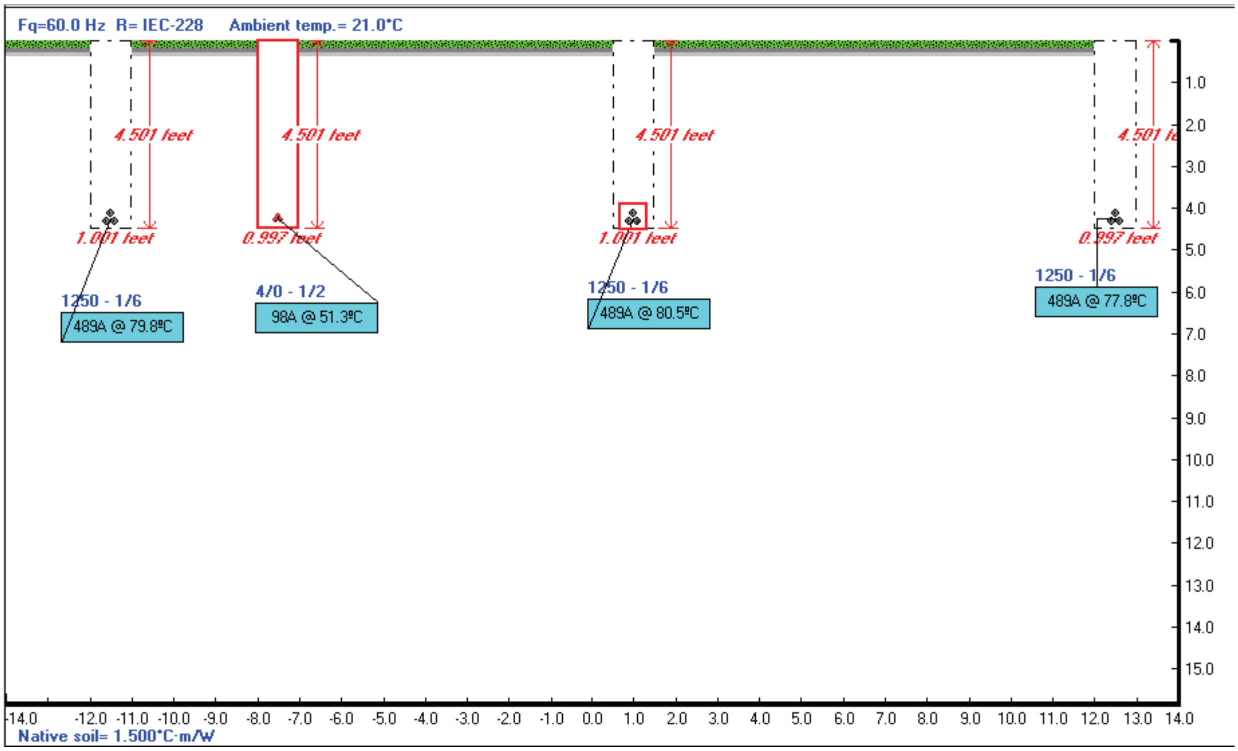
Westwood

ROW :: T-22 to JB-2/1

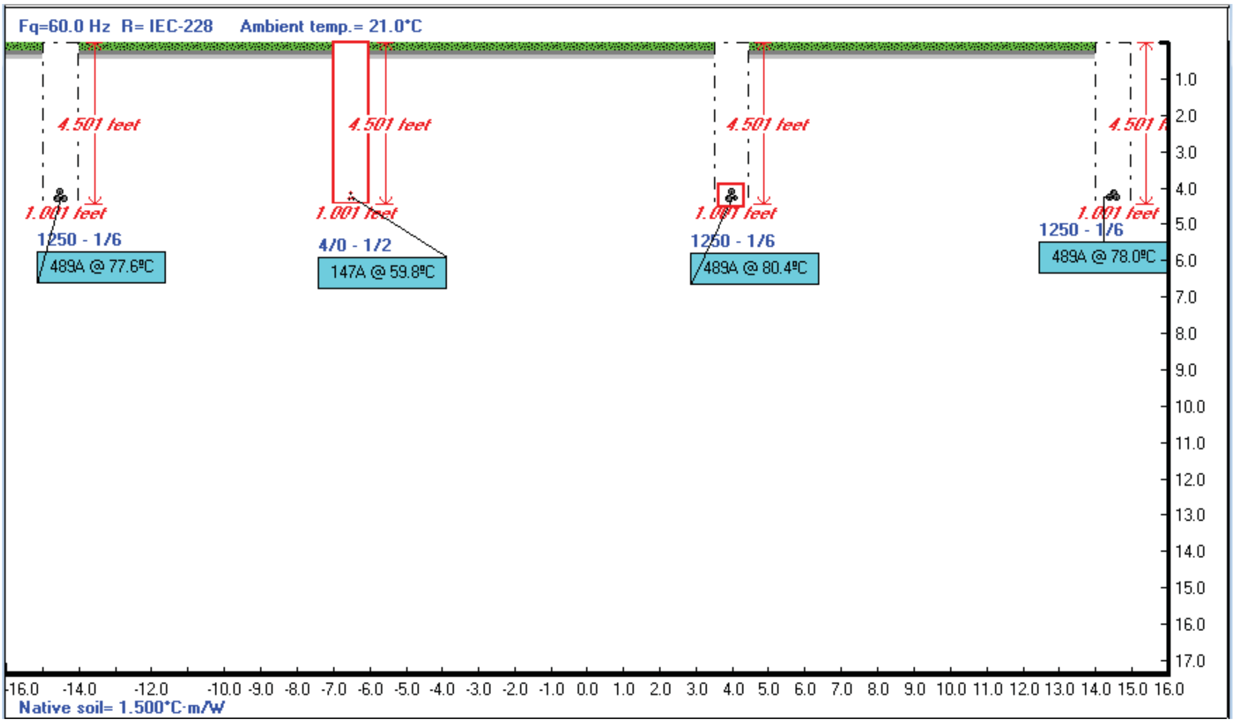


Westwood

ROW :: JB-2/1 to T-24

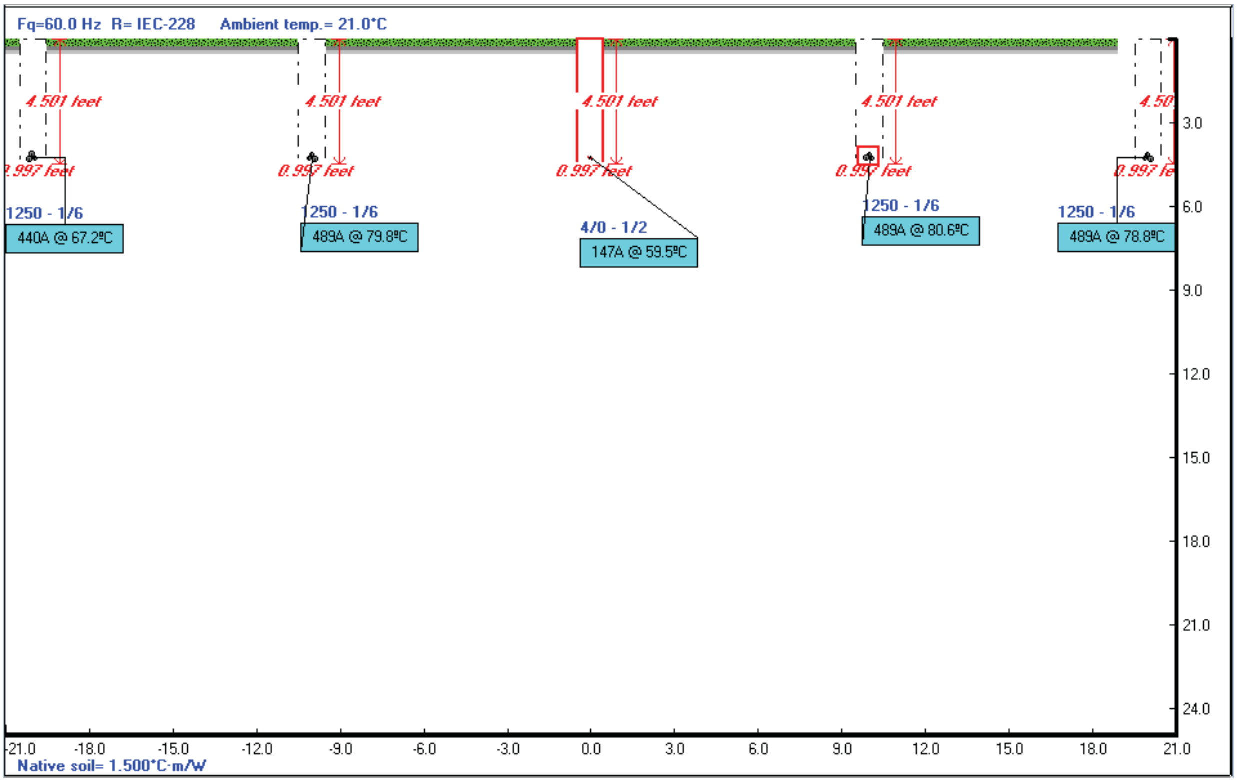


ROW :: T-24 to T-25



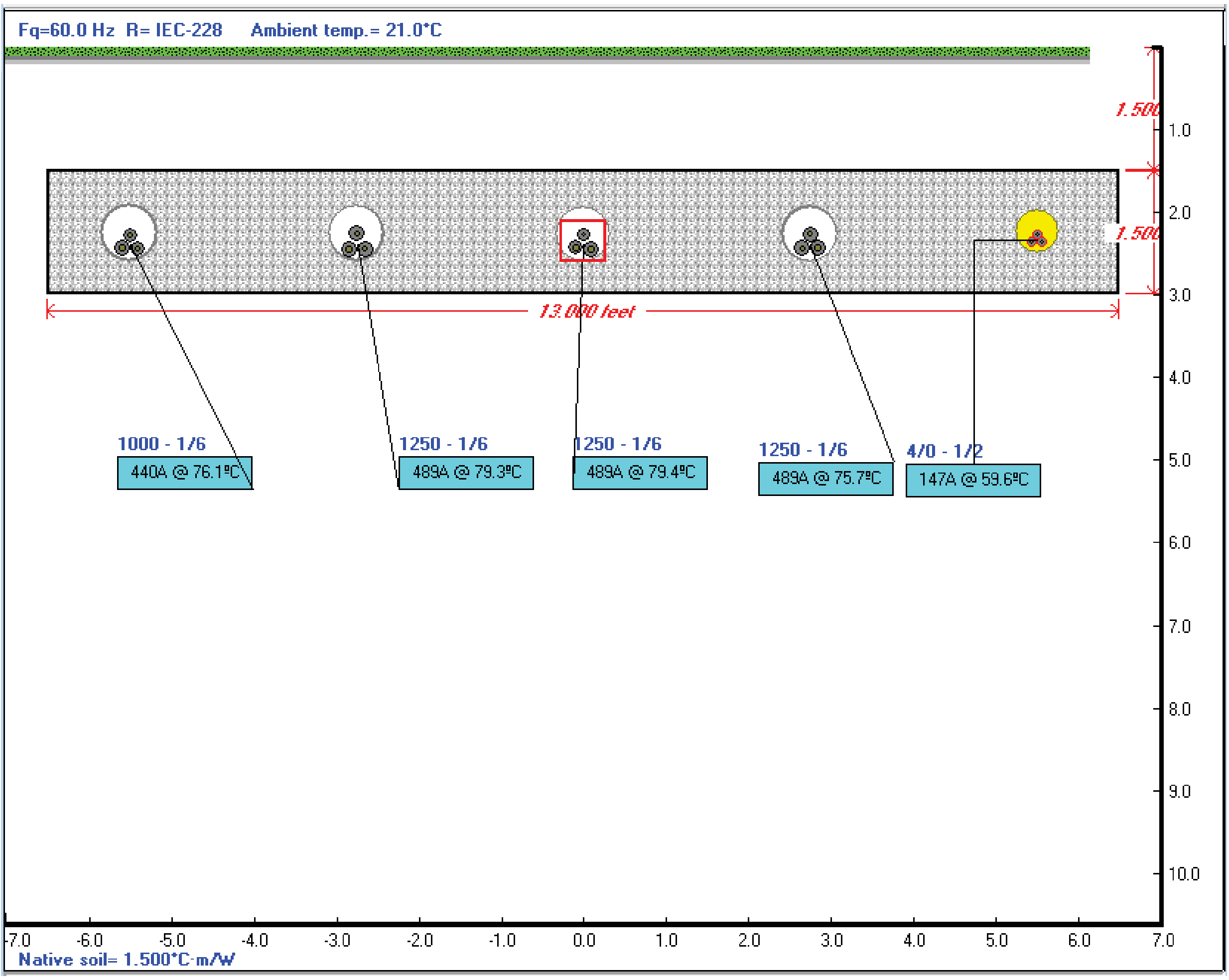
Westwood

ROW :: T-25 to SUB



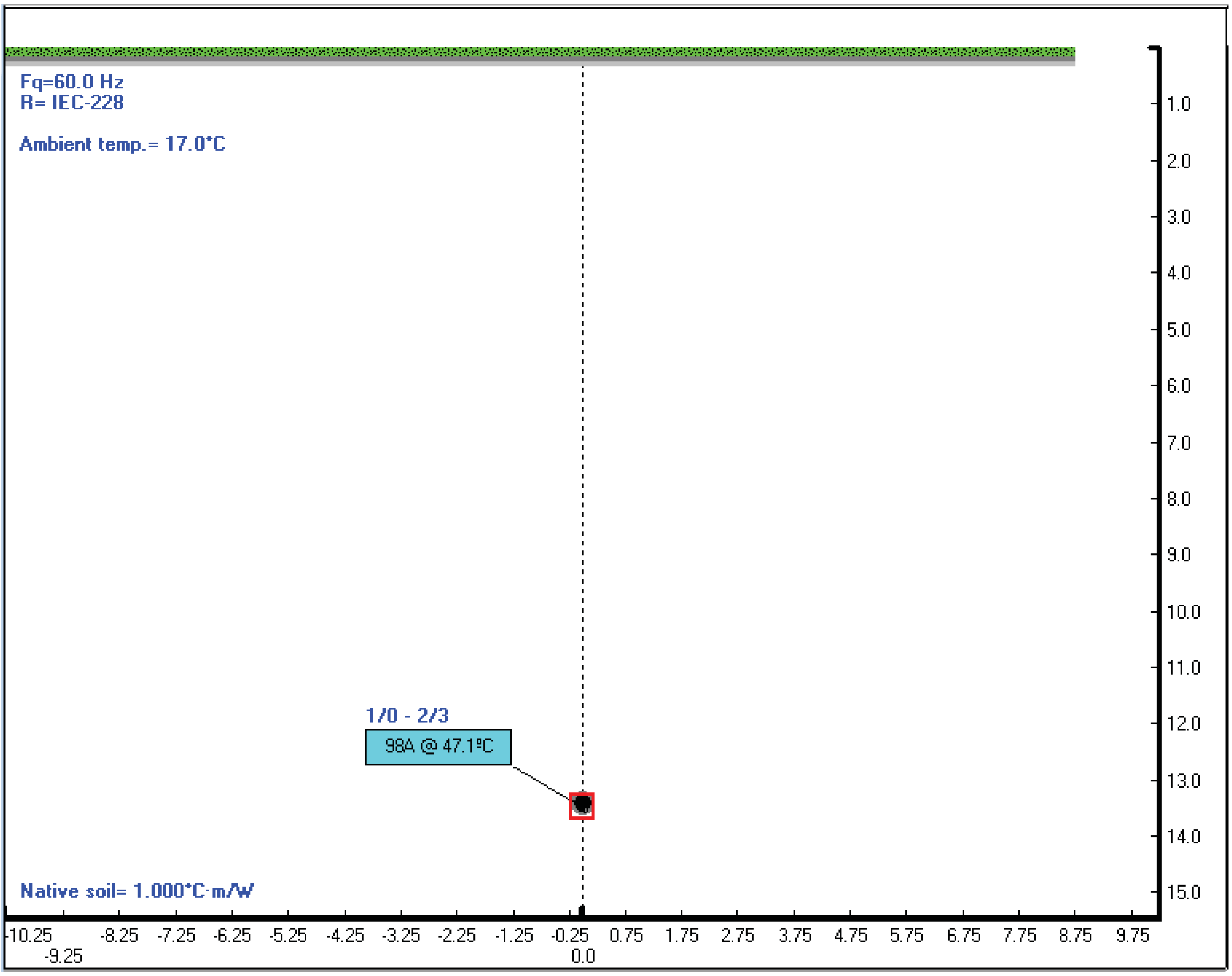
Westwood

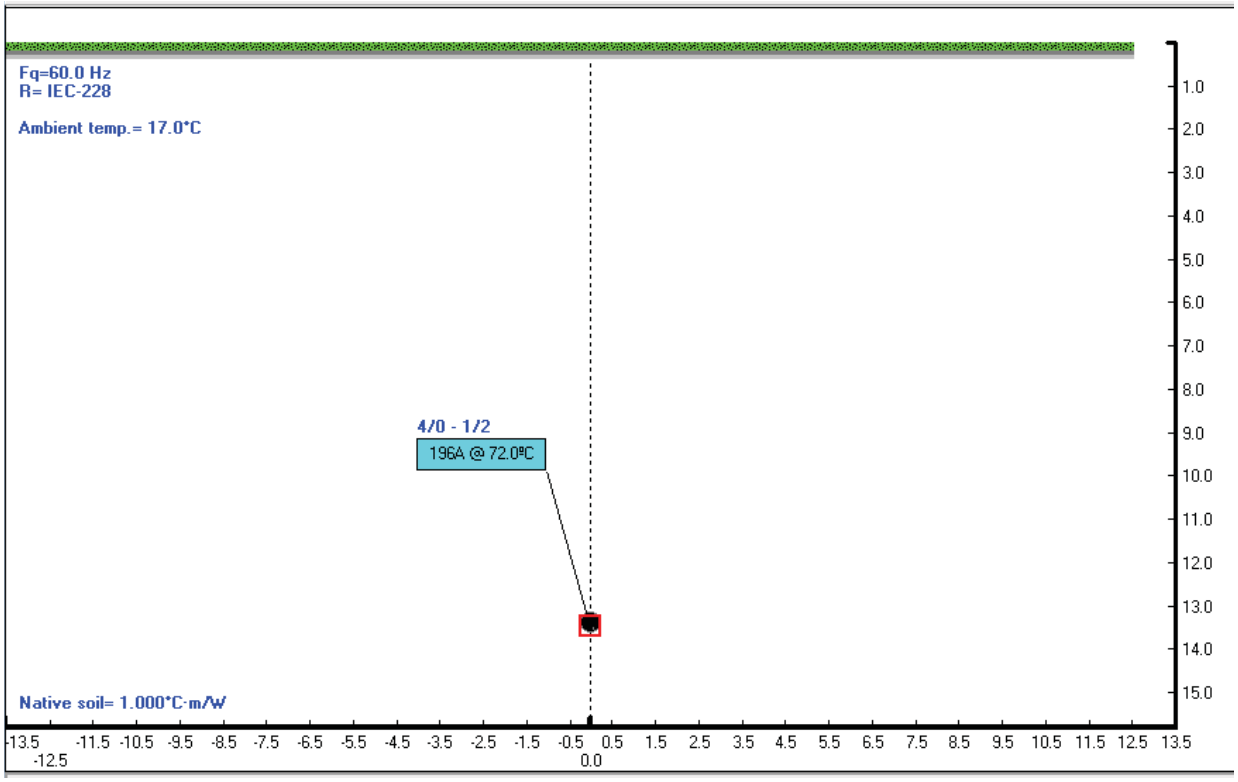
CONSTRAINED ROW

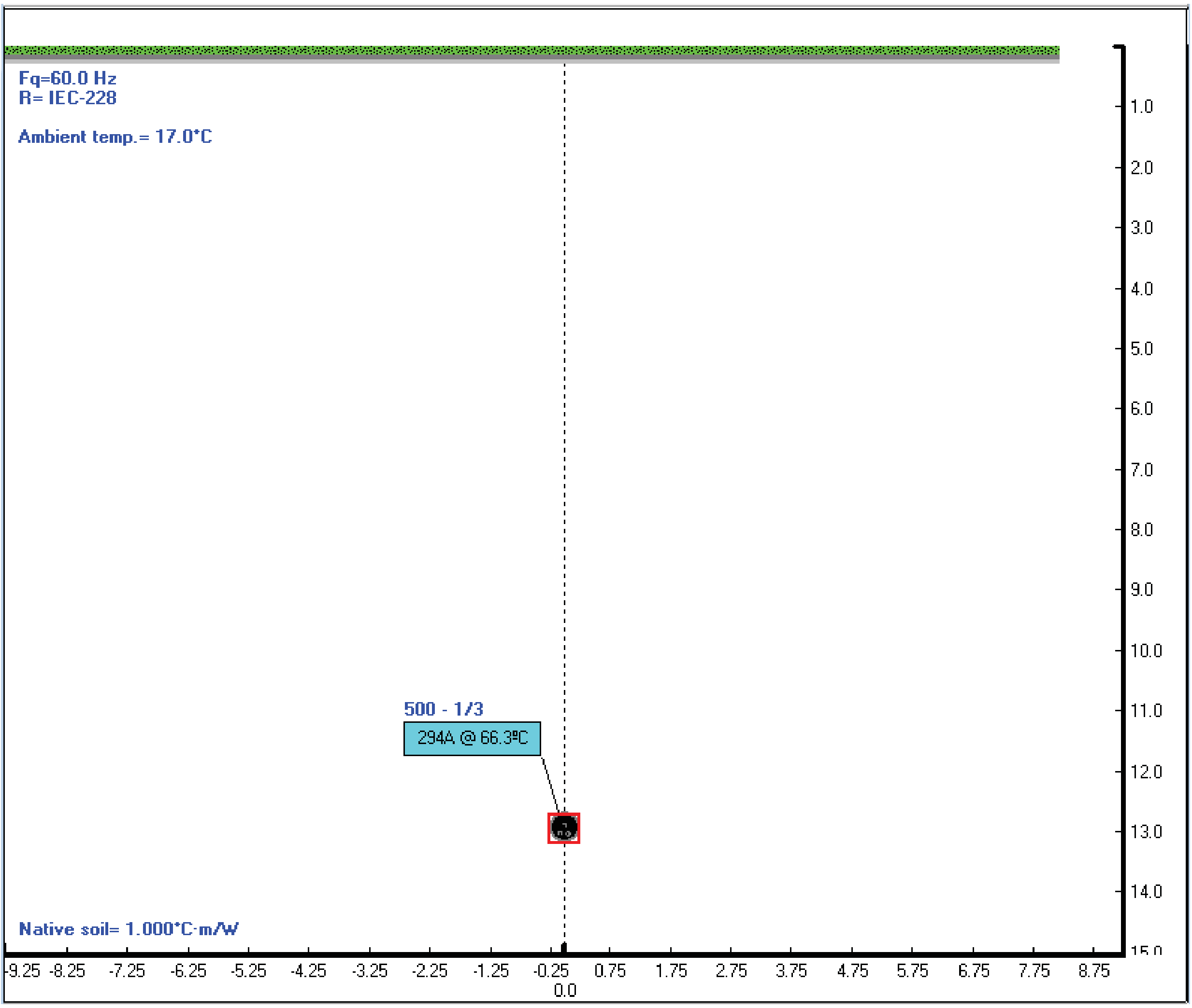


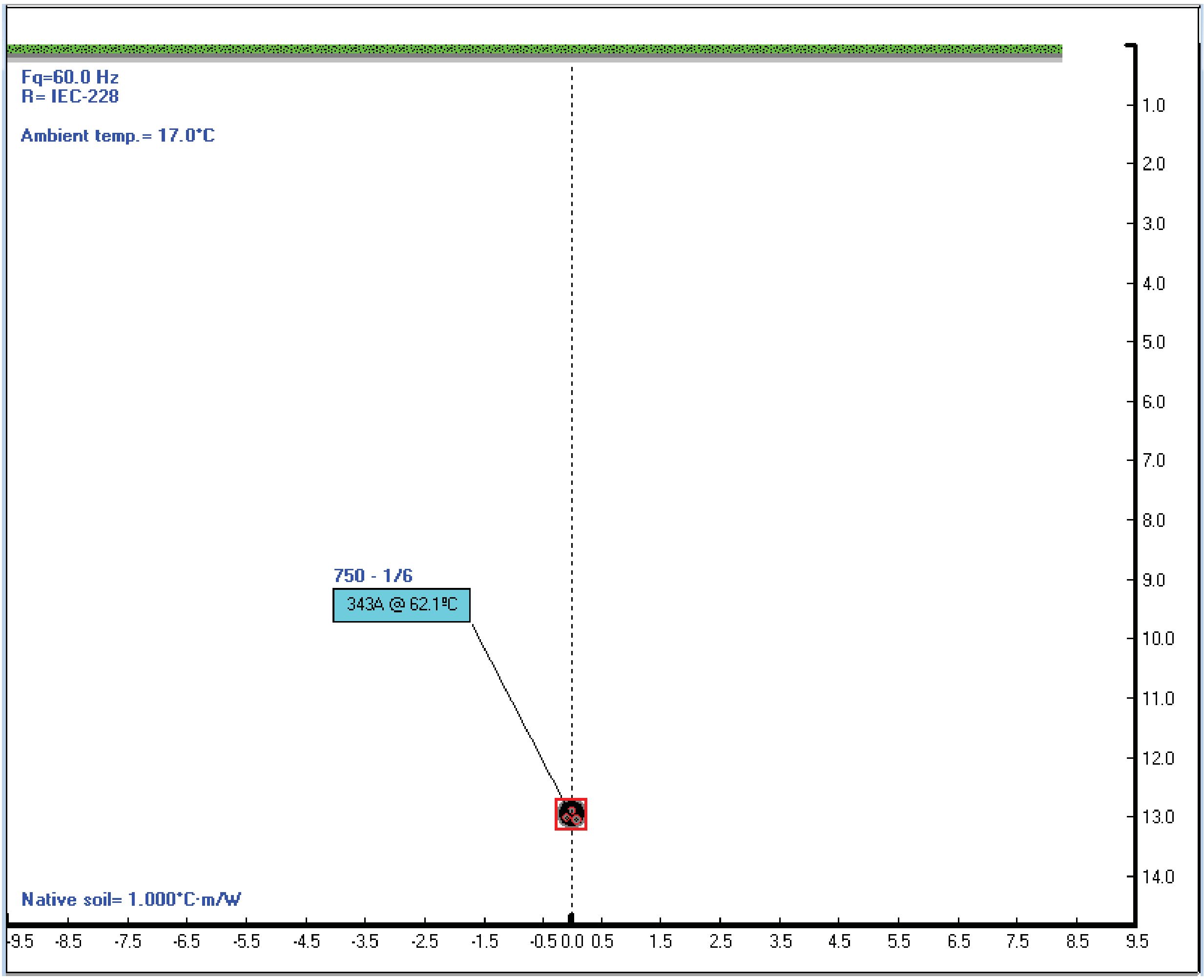
Westwood

APPENDIX C: DIRECTIONAL BORING CYCMAP OUTPUT



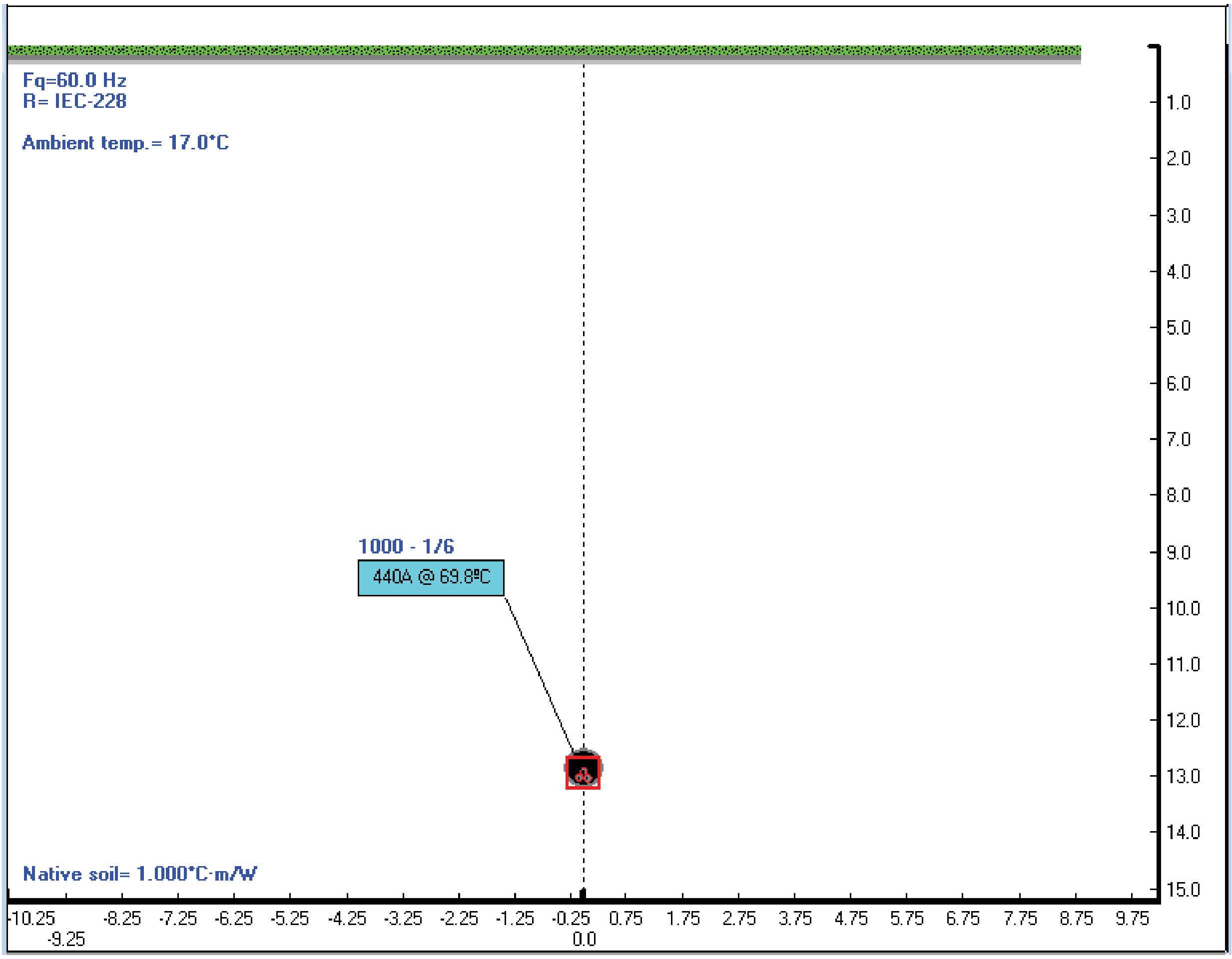

Fq=60.0 Hz
R= IEC-228
Ambient temp.= 17.0°C
4/0 - 1/2
196A @ 72.0ºC
Native soil= 1.000°C·m/W


Fq=60.0 Hz
R= IEC-228
Ambient temp.= 17.0°C
500 - 1/3
294A @ 66.3ºC
Native soil= 1.000°C·m/W
1.0
2.0
3.0
4.0
5.0
6.0
7.0
8.0
9.0
10.0
11.0
12.0
13.0
14.0
-9.25 -8.25 -7.25 -6.25 -5.25 -4.25 -3.25 -2.25 -1.25 -0.25 0.75 1.75 2.75 3.75 4.75 5.75 6.75 7.75 8.75
0.0



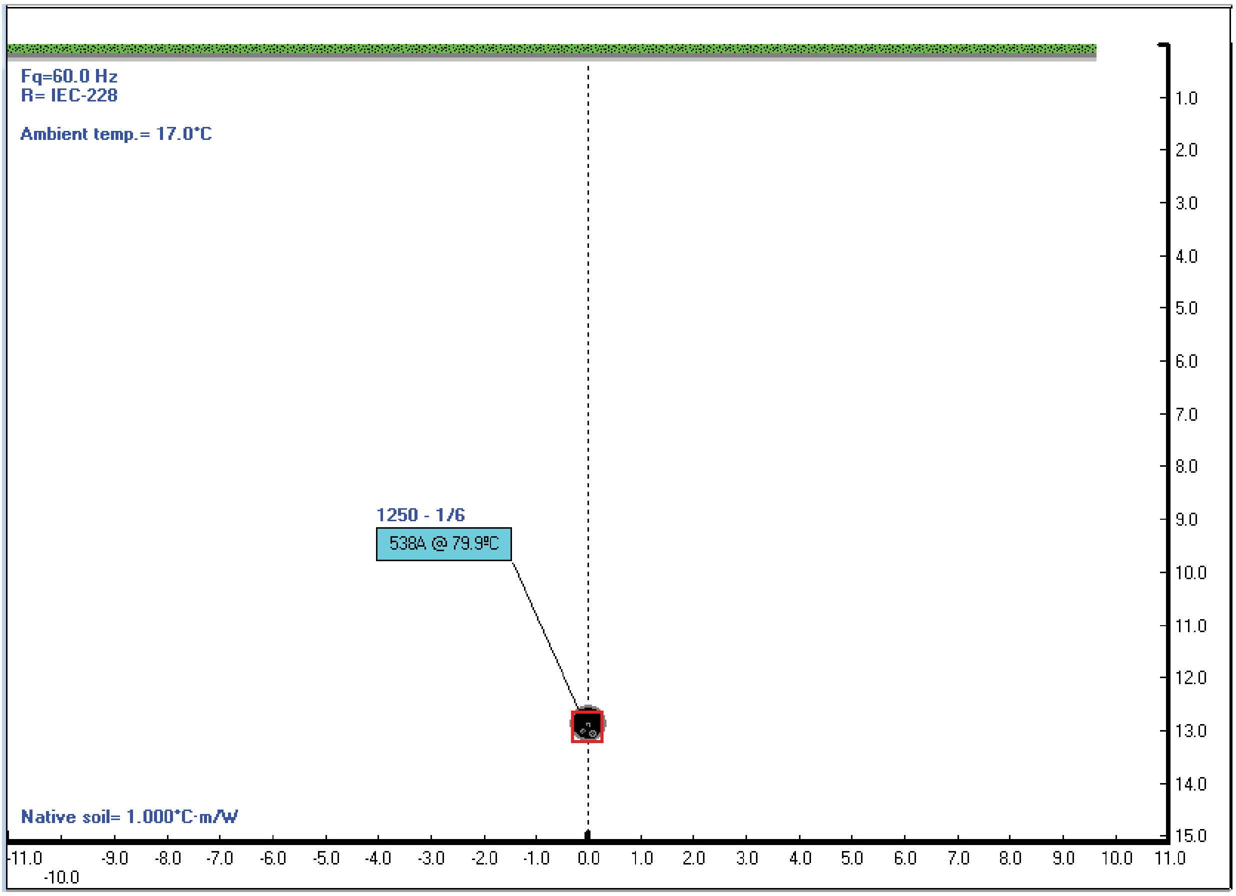
Fq=60.0 Hz
R= IEC-228
Ambient temp.= 17.0°C
750 - 1/6
343A @ 62.1ºC
Native soil= 1.000°C·m/W
1.0
2.0
3.0
4.0
5.0
6.0
7.0
8.0
9.0
10.0
11.0
12.0
13.0
14.0
-9.5 -8.5 -7.5 -6.5 -5.5 -4.5 -3.5 -2.5 -1.5 -0.5 0.0 0.5 1.5 2.5 3.5 4.5 5.5 6.5 7.5 8.5 9.5

Westwood

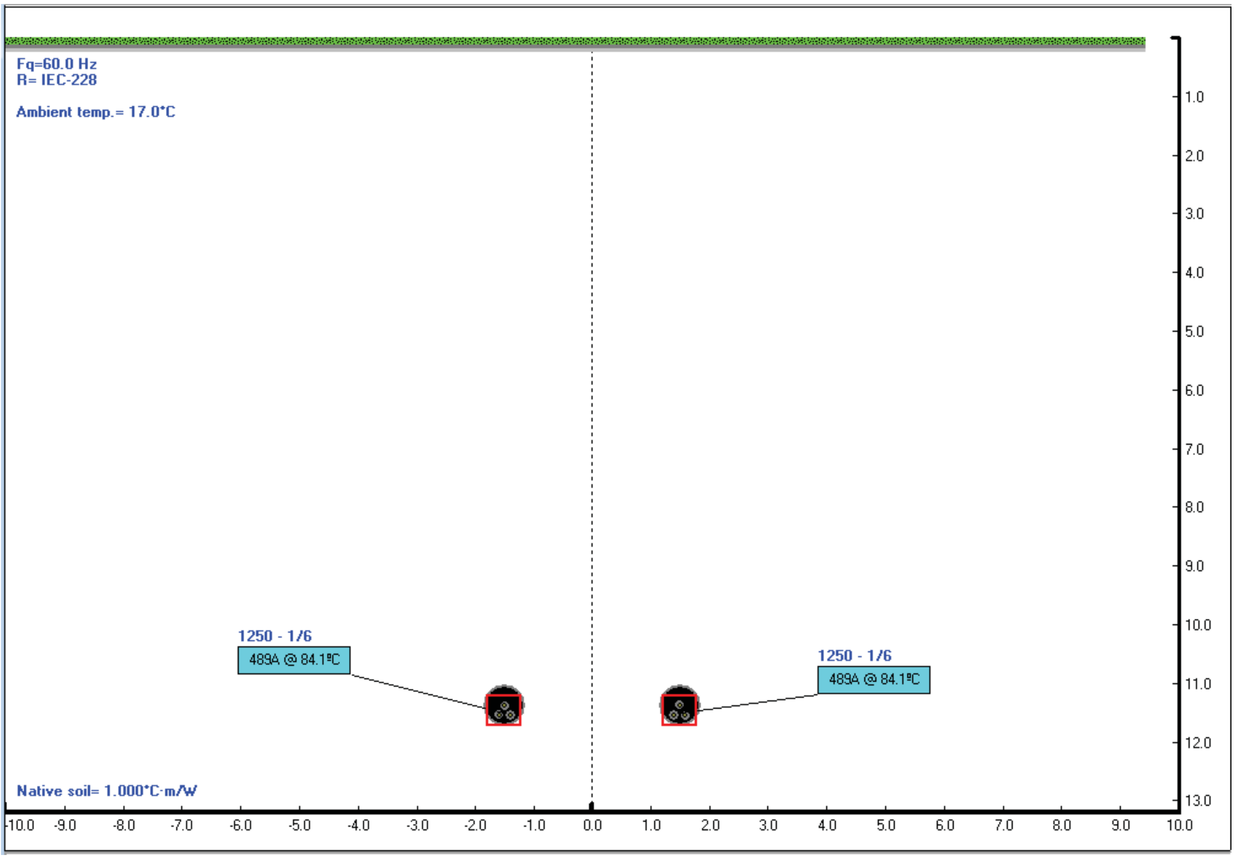


Fq=60.0 Hz
R= IEC-228
Ambient temp.= 17.0°C
1000 - 1/6
440A @ 69.8ºC
Native soil= 1.000°C·m/W
1.0
2.0
3.0
4.0
5.0
6.0
7.0
8.0
9.0
10.0
11.0
12.0
13.0
14.0
15.0
-10.25
-9.25
-8.25
-7.25
-6.25
-5.25
-4.25
-3.25
-2.25
-1.25
-0.25
0.0
0.75
1.75
2.75
3.75
4.75
5.75
6.75
7.75
8.75
9.75

Westwood

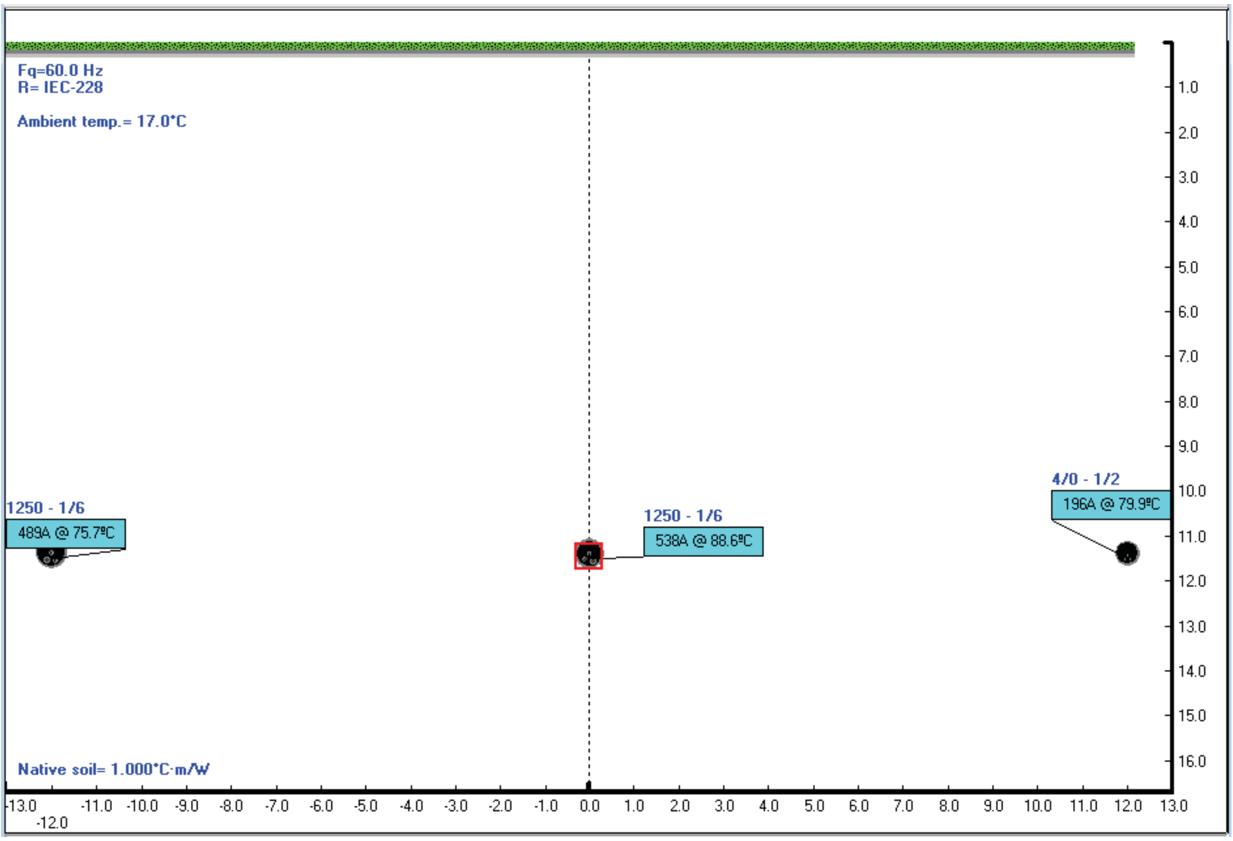


Fq=60.0 Hz
R= IEC-228
Ambient temp.= 17.0°C
1250 - 1/6
538A @ 79.9ºC
Native soil= 1.000°C·m/W

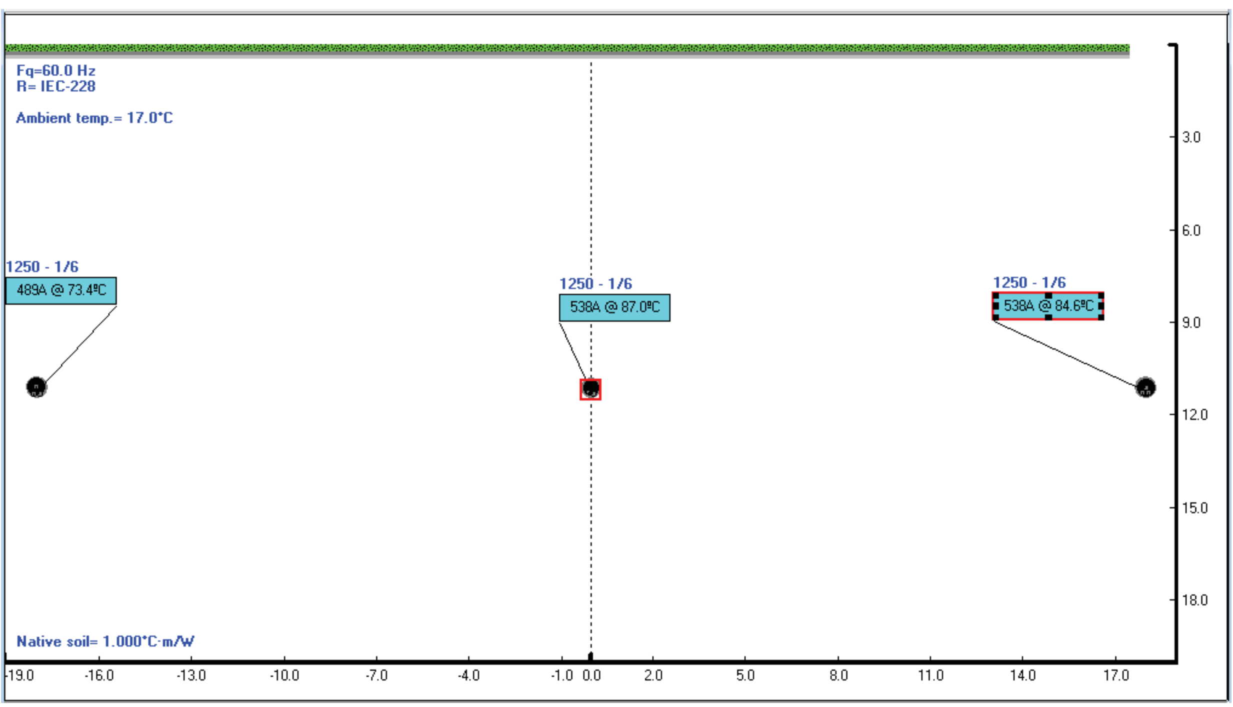


Fq=60.0 Hz
R= IEC-228
Ambient temp.= 17.0°C
1250 - 1/6
489A @ 84.1ºC
1250 - 1/6
489A @ 84.1ºC
Native soil= 1.000°C·m/W
-10.0 -9.0 -8.0 -7.0 -6.0 -5.0 -4.0 -3.0 -2.0 -1.0 0.0 1.0 2.0 3.0 4.0 5.0 6.0 7.0 8.0 9.0 10.0
1.0 2.0 3.0 4.0 5.0 6.0 7.0 8.0 9.0 10.0 11.0 12.0 13.0

Westwood

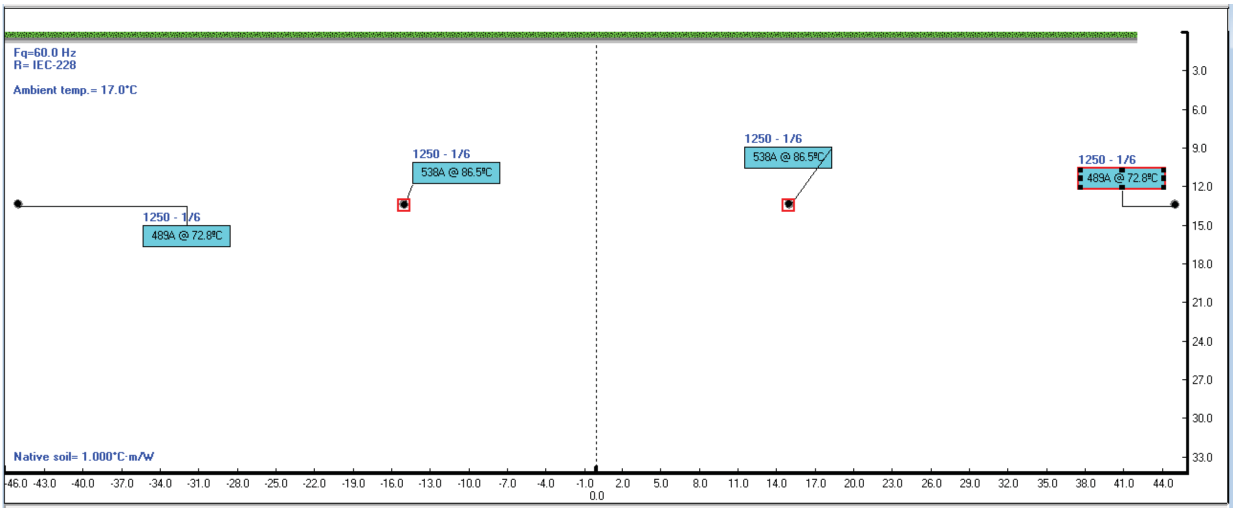


Fq=60.0 Hz
R= IEC-228
Ambient temp.= 17.0°C
1250 - 1/6
489A @ 75.7ºC
1250 - 1/6
538A @ 88.6ºC
4/0 - 1/2
196A @ 79.9ºC
Native soil= 1.000°C·m/W



Fq=60.0 Hz
R= IEC-228
Ambient temp.= 17.0°C
1250 - 1/6
489A @ 73.4ºC
1250 - 1/6
538A @ 87.0ºC
1250 - 1/6
538A @ 84.6ºC
Native soil= 1.000°C·m/W

Westwood



Fq=60.0 Hz
R= IEC-228
Ambient temp.= 17.0°C
1250 - 1/6
538A @ 86.5ºC
1250 - 1/6
538A @ 86.5ºC
1250 - 1/6
489A @ 72.8ºC
1250 - 1/6
489A @ 72.8ºC
Native soil= 1.000°C·m/W
3.0
6.0
9.0
12.0
15.0
18.0
21.0
24.0
27.0
30.0
33.0
-46.0 -43.0 -40.0 -37.0 -34.0 -31.0 -28.0 -25.0 -22.0 -19.0 -16.0 -13.0 -10.0 -7.0 -4.0 -1.0 0.0 2.0 5.0 8.0 11.0 14.0 17.0 20.0 23.0 26.0 29.0 32.0 35.0 38.0 41.0 44.0

GROUNDING STUDY

Northwest Ohio Wind Project

Paulding County, Ohio

October 30 2017
Revision 0

Prepared For:

WHITE
an IEA company

Prepared By:

Westwood

Project Name: NW OH Wind Project	
Title	**J.O. or W.O. Number**
Grounding Study	0007186.00

Approvals		**Revision Number**	**Date**	**Description**
Preparer(s) Name	**Reviewer(s) Name**			
Joseph Gorman	Drew Szabo	0	10/30/2017	Original Release

CONTENTS

Background

The Northwest Ohio Wind project in Paulding, Ohio is a new wind power generation installation with an overall capacity of 100 MW, consisting of 42 GE 2.5MW Wind Turbines. The turbines are grouped into four medium voltage (MV) feeders with 10 turbines on feeders 1 and 4, and 11 turbines on feeders 2 and 3. The feeders are connected to a main power transformer that steps the voltage up to 138kV where it interconnects with the AEP transmission system via a short overhead line segment.

Objective

This study assesses the facility grounding design for touch and step potential hazards which may arise due to ground faults on the high voltage electrical system. The design is assessed using the methods of IEEE Std. 80, "IEEE Guide for Safety in AC Substation Grounding" The grounding system was modeled using WinIGS (Integrated Grounding System Analysis and Design) software, which combines both tools for modeling electrical properties of soil and grounding systems, and electrical network analysis tools which give the flexibility to model interface with the electrical transmission or distribution system in many ways, depending on the amount of detail desired.

Summary of Results

The study finds that the wind turbine ground grid as indicated in the 90% electrical collection drawings meet the IEEE Std 80 requirements for touch and step potential hazard. These main findings are summarized below.

Parameter	Calculated Result
Individual Turbine Ground Grid Resistance	2.098 ohms (< 10 ohms)
Maximum Ground Potential Rise at a wind turbine	1,223 volts at WTG 31 (Circuit 3)
Maximum Touch Potential at a wind turbine	122 volts (168.5 volts permitted by IEEE Std. 80 for 0.5 seconds)
Maximum Step Potential at a wind turbine	27.6 volts (182.9 volts permitted by IEEE Std. 80 for 0.5 seconds)

Soil Resistivity Data and Two-Layer Soil Model

The electrical soil resistivity for the site was measured and recorded in the document "Geotechnical Engineering Report" by BARR Engineering dated December 2014. The soil resistivity at the site was measured at 4 turbine locations within the site area using the Wenner Four-Pin method, running in both a North-South and East-West directions using probe spacing ranging between 5 and 60 feet. The soil resistivity was also measured at the substation location using probe spacing ranging between 5 and 300 feet. Figures 1 and 2 below show the data collected from the site at WTG 37, which yielded the worst case ground grid resistance of 2.098 Ohms. The resulting tower ground grid resistance from WinIGS is shown in Figure 4.

Figure 1: Wenner Method Field Data – Worst Case Site

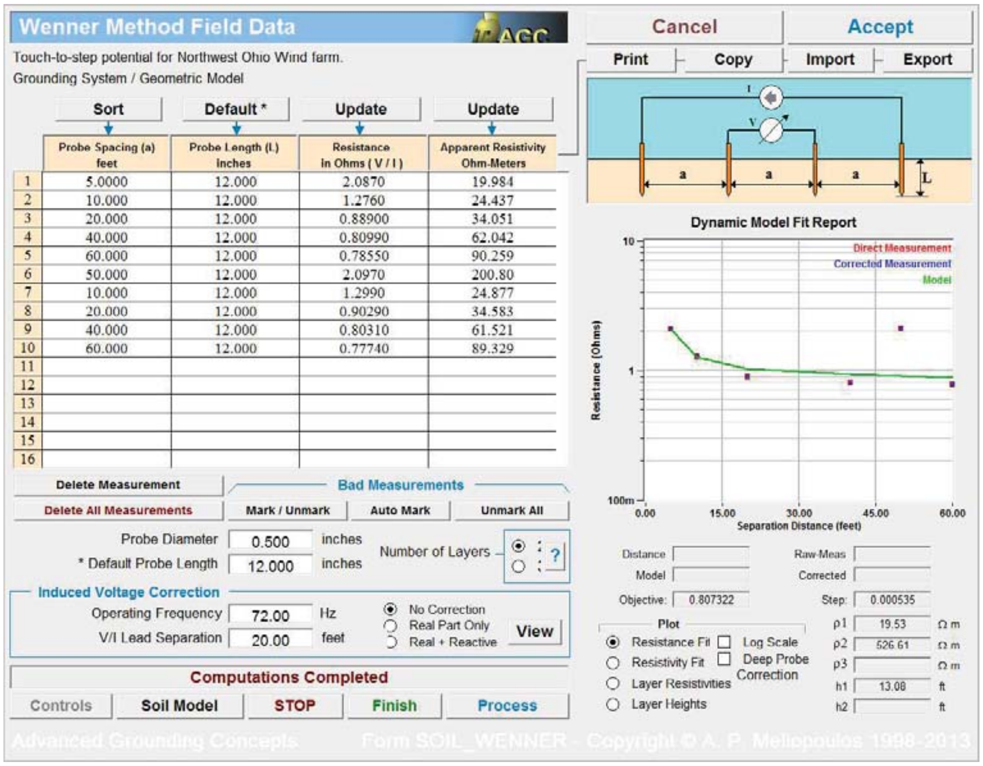
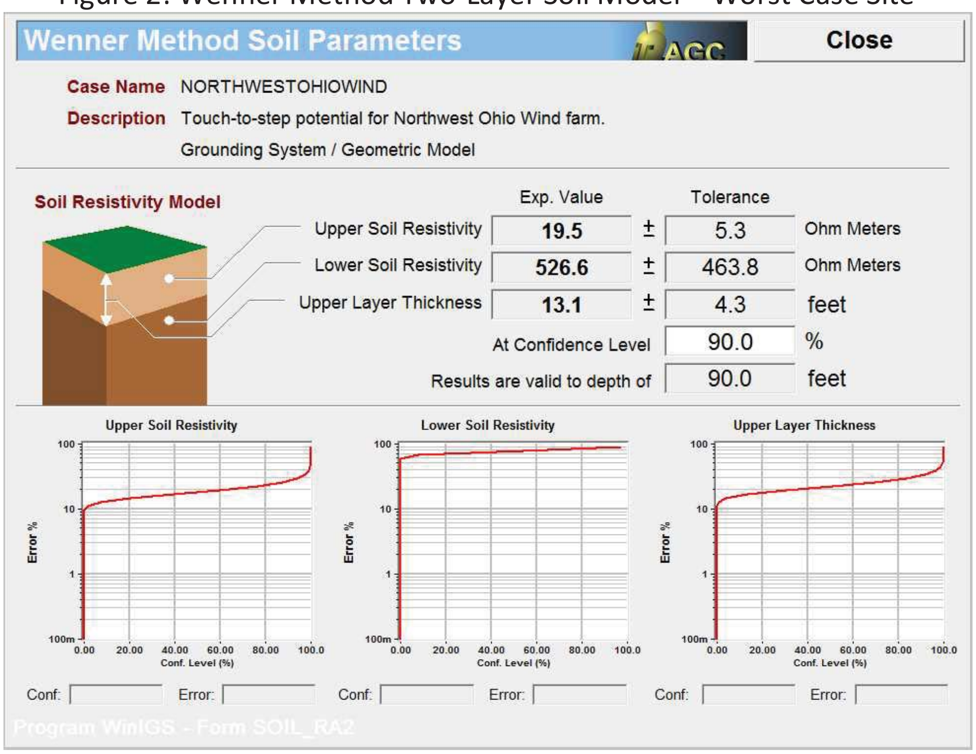


Figure 2: Wenner Method Two-Layer Soil Model – Worst Case Site

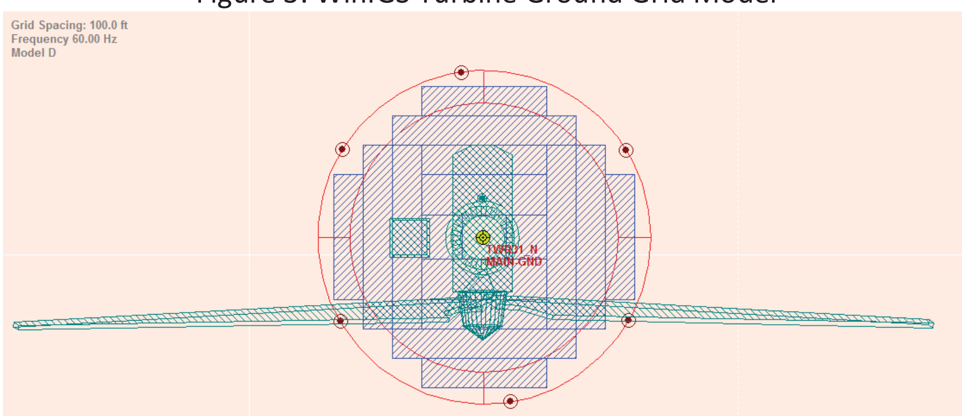


Westwood

Ground Grid Model

A ground grid model was developed for all wind turbine locations based on the ground grid design. The ground grid for each GE wind turbine consists of two buried 4/0 AWG bare copper rings that are bonded to each other and electrically bonded to six driven 5/8" x 8' copper clad steel ground rods, equally spaced. The innermost of the two buried copper rings is encased in the concrete foundation and mechanically connected to the foundation rebar as well as the turbine tower flange. The outer bare copper ring is buried in soil and is bonded, using compression connectors, to the six 8-foot vertical ground rods, as well as the inner copper ring. The turbine grounding arrangement can be found on detail drawing E.411. Figure 3 shows the turbine ground grid model, encompassing the outer ring and the concrete encased electrode of the foundation and the inner ring.

Figure 3: WinIGS Turbine Ground Grid Model



Based on the physical and soil resistivity model, WinIGS calculates the resistance of the ground grid to be 2.098 Ohms. This meets the requirement of 10 Ohms or less specified by GE. The results from WinIGS are shown on Figure 4.

Figure 4: Result of Resistance Calculation for Individual Turbine Ground Grid

Ground System Resistance Report Close

Study Case Title: Touch-to-step potential for Northwest Ohio Wind farm.
Grounding System: Grounding System / Geometric Model
Frequency: 60.00 Hz

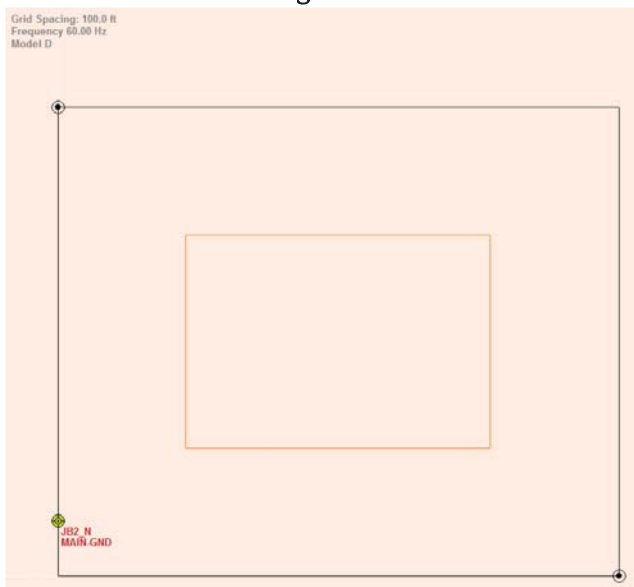
Group Name	Node Name	Resistance (Ohms)	Reactance (Ohms)	Voltage (Volts)	Current (Amperes)
MAIN-GND	TWR31_N	2.0978	0.0136	1223.10	583.02
		Rp = 2.0978	Xp = 0.0136	Earth Current:	583.02
				Fault Current:	3940.03
				Split Factor:	14.80 %

* Resistance Definition: ◉ Driving Point ○ Equivalent Circuit Shunt Branch

View Full Matrix
View Equivalent Ckt

The junction box ground grid consists of two 10-foot 3/4 CCS rods driven into the soil on two of the corners of a 4/0 copper ground ring which exists 3 feet beyond the perimeter of the junction box, and 1.5 feet below ground level. The WinIGS rendering of the junction box ground grid is shown on Figure 5.

Figure 5: WinIGS rendering of Junction Box Ground Grid



Based on the physical and soil resistivity model, WinIGS calculates the resistance for the collector junction box to be 3.9 Ohms. The results from resistance report from WinIGS are shown below, on figure 6.

Figure 6: Result of Resistance Calculation for Collector Junction Box

Ground System Resistance Report AGC **Close**

Study Case Title: Touch-to-step potential for Northwest Ohio Wind farm.
Grounding System: Grounding System / Geometric Model
Frequency: 60.00 Hz

Group Name	Node Name	Resistance (Ohms)	Reactance (Ohms)	Voltage (Volts)	Current (Amperes)
MAIN-GND	JB2_N	3.8994	0.0006	359.30	92.14
		Rp = 3.8994	Xp = 0.0006	Earth Current:	92.14
				Fault Current:	7430.06
				Split Factor:	1.24 %

* Resistance Definition: (•) Driving Point ( ) Equivalent Circuit Shunt Branch

View Full Matrix | View Equivalent Ckt

Network Model

To accurately simulate touch and step potential at the various locations in the collector system during a ground fault, it is necessary to construct a network model that includes the transmission source, substation main transformer, collector system cabling, padmount transformers, generators, and grounding electrodes. Figure 7 shows the WinIGS depiction of a single turbine generator site, with incoming concentric neutral collector cable, ground grid, delta/wye padmount transformer, and generator. The network model is based on the collector one-line drawings (E.200 and E.201). Also shown below in Figure 8 is the full network model.

Figure 7: WinIGS schematic rendering of single turbine location

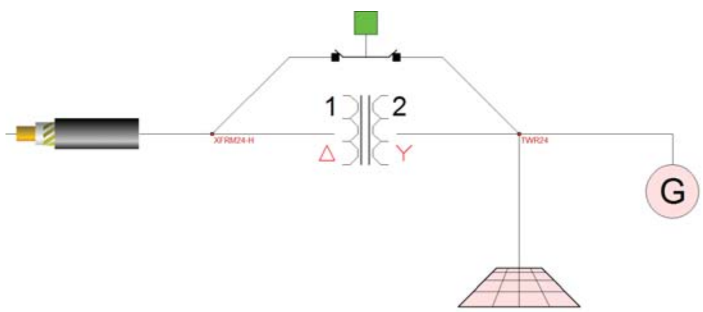


Figure 8: WinIGS schematic rendering of full network

GPR and Touch and Step Potential Results

<u>Turbine Ground Grid</u>

Ground potential rise was examined for faults at select locations on the 34.5kV collector system. The highest ground potential rise at a turbine for a ground fault was found at WTG-31 on Circuit 3. The instances where the higher ground potential rises exist were at turbines relatively close to the substation. High ground potential rise at the turbines which are short distances from the substation are due to the higher fault current present near the substation. The high ground potential rise occurrences at turbines that are further away from the substation occur due to increased neutral path impedance on the longer collector lines, resulting in larger portions of fault current returning through the ground. Figure 9 shows the resulting ground current. Figures 10 and 11 show the touch and step potential plots, which can be seen to be below the permissible values for the entire surface within the outer ground ring for an assumed ground fault of 0.5 second, based on IEEE Std. 80.

Figure 9: Ground Current for Single Line to Ground Fault at Turbine 31 (34.5kV)

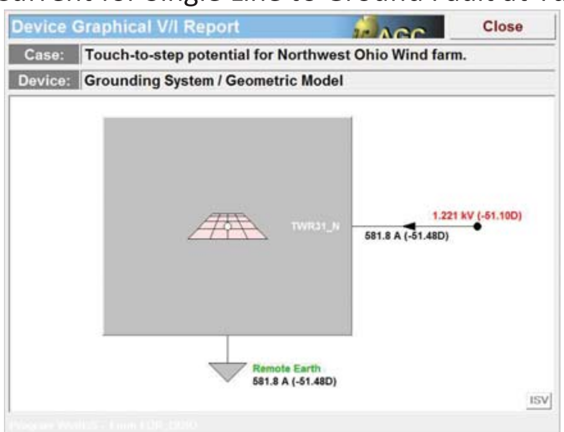
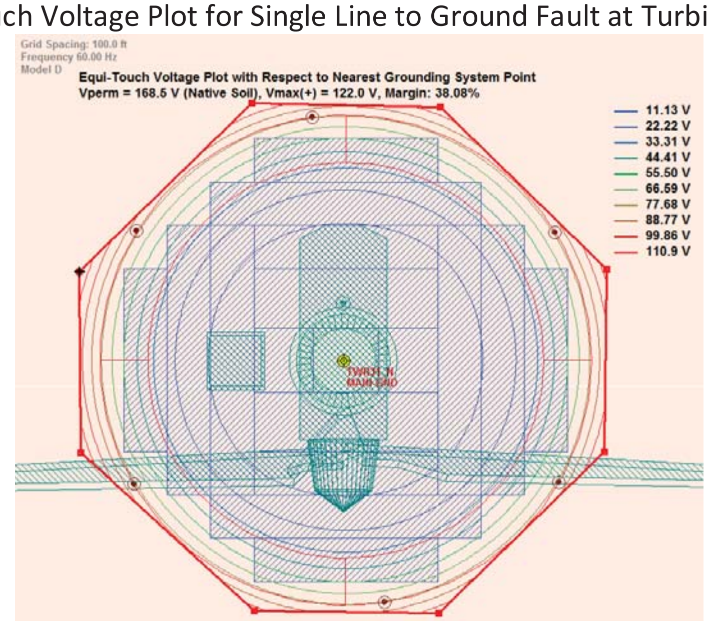
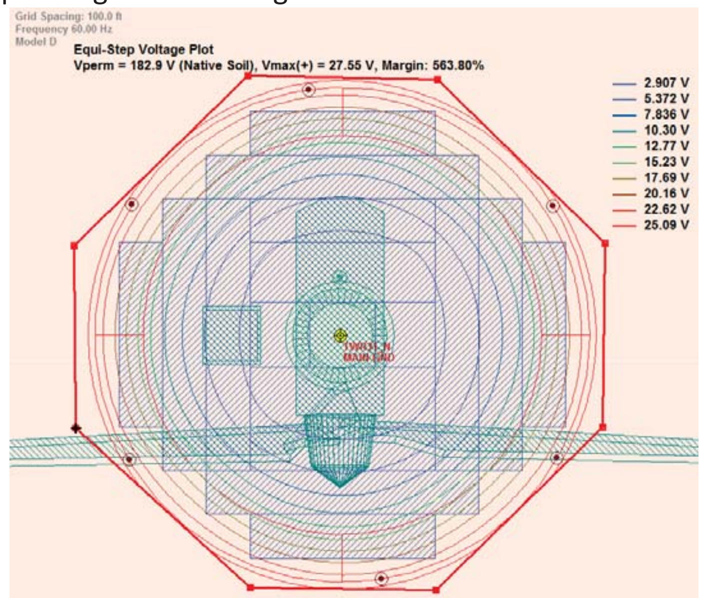


Figure 10: Touch Voltage Plot for Single Line to Ground Fault at Turbine 31 (34.5kV)



Westwood

Figure 11: Step Voltage Plot for Single Line to Ground Fault at Turbine 31 (34.5kV)



Junction Boxes

The highest ground potential rise at a junction box for a ground fault was found at JB2 on circuit 2. The touch and step potential plots for JB2 are shown on figures 12 and 13 below. As shown on the plots, touch and step potentials are below the permissible values for a .5 seconds fault, based on IEEE Std. 80.

Figure 12: Touch Voltage Plot for Single Line to Ground Fault at Turbine 31 (34.5kV)

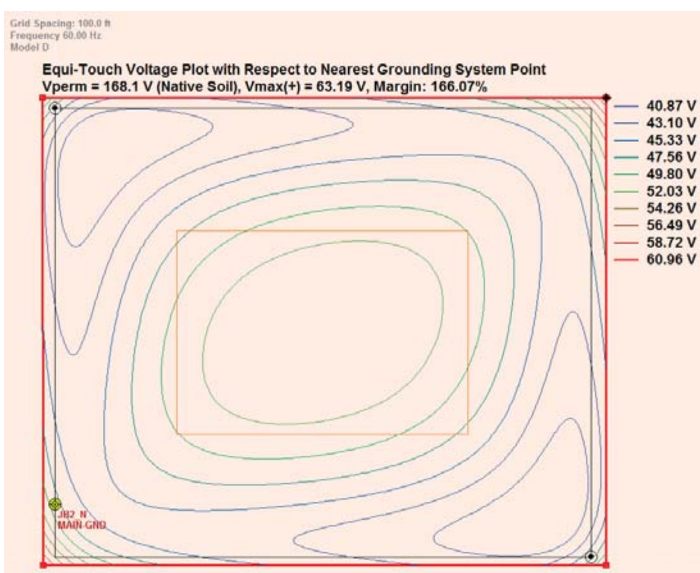


Figure 13: Step Voltage Plot for Single Line to Ground Fault at Turbine 31 (34.5kV)

Conclusion

The preceding analysis has modeled the electrical network and grounding systems of the Northwest Ohio Wind Farm. The analysis shows an expected worst case individual wind turbine ground resistance of 2.098 ohms. Additionally, simulations of line to ground faults show that the design meets IEEE Std. 80 safety criteria for touch and step potential.

Westwood

1800 Deming Way, Suite 102
Middleton, WI 53562

Main (608) 821-6600

westwoodps.com

NORTHWEST OHIO WIND INSULATION COORDINATION REPORT

October 30, 2017

INTRODUCTION:

The following presents Westwood Professional Services' insulation coordination analysis for Northwest Ohio Wind Project. The purpose of the report is to confirm that surge arrestors are rated properly to coordinate with insulation level and provide protective margins consistent with the requirements of IEEE standard C62.22 "IEEE Guide for the Application of Metal-Oxide Surge Arresters for Alternating-Current Systems"

Equipment: Medium voltage equipment on the site consists of shielded cable, padmount transformers and junction boxes (sectionalizing cabinets). The 2750 kVA step-up transformers are 34.5 kV(delta)/690 V(wye-g), with 200 kV BIL for the windings. All major medium voltage equipment is rated with a BIL level of 150kV, which is standard for a system energized at 34.5 kV. Since 150 kV is the lowest level, protective margins are calculated with respect to 150 kV.

A preliminary selection of 24.4 kV MCOV was made and is evaluated here. It is noted that the 24.4 kV MCOV rating is sufficient to operate continuously on the 34.5 kV system even if the system should operate at greater than 10% over the nominal voltage.

CALCULATION:

IEEE Std. C62.22 recommends the calculation of two different margins of protection, as identified below, the first with respect to the chopped wave (CWW) withstand level of the equipment, and the second with respect to the basic impulse insulation level (BIL).

$$PM_{L1} = [\mathrm{CWW}/(\mathrm{FOW} + \mathrm{L}di/dt) - 1]100\%$$

$$PM_{L1} = [(\mathrm{BIL}/\mathrm{LPL}) - 1]100(\%)$$

where

PM_{L1}	is FOW Protective Margin (in percent)
PM_{L2}	is Full Wave Protective Margin (in percent)
CWW	is Chopped Wave Withstand of protected equipment (in kilovolts)
FOW	is Front-of-Wave protective level of arrester (in kilovolts)
BIL	is Basic Impulse Insulation Level of protected equipment (in kilovolts)
LPL	is Lightning Protective Level (in kilovolts)
Ldi/dt	is connecting lead wire voltage drop (in kilovolts)—see 6.7.1

The configuration studied assumes a 24.4 kV MCOV station class arrester at the substation, with direct connect, 24.4 kV MCOV elbow-type arrestors at the end of each medium voltage feeder. Calculations are as follows:

Equipment BIL = 150 kV
CWW = 1.0 x BIL for solid insulation cable = 150 kV (Since CWW for liquid insulation is 110% of BIL, this represents a worst case.

di/dt = 8kV/foot of lead length (assumed based on .4 microHenry/ft and 20 kA/microsec)

L = 3 feet (assumed lead length of arrestor in substation)
LPL – For the case with an arrester in the substation and end point arresters at the remote end of the circuit, the 20 kA protection level is assume for the substation arrester and the 1.5 kA protection level for the end point arrester. A reflected magnitude of ½ the end point arresters protection level is assumed to add to the voltage at the riser corresponding to the reflection that occurs before the endpoint arrester starts full conduction.

FOW protective level for 24.4 kV MCOV substation arrestor = 85.8 kV (Hubbell Power Systems assumed)
Maximum discharge voltage at 20 kA for 8/20 current wave is 75.0 kV.

Collection arrester is assumed as Tyco ELB-35-600-30, 24.4 kV MCOV. FOW protective level (10 kA) is 93.1 kV. Maximum discharge voltage at 1.5 kA for 8/20 current wave is 72.6 kV.

Based on these inputs and assumptions, the results are as follows:

PML1 = [CWW/(FOW+Ldi/dt)-1] x 100 (%) = [150/(93.1+3x8)-1] x 100 (%) = 28%.
This exceeds the minimum recommended by IEEE C62.22 of 20%

PML2 = [BIL/LPL-1] x 100 (%) = [150/(75+0.5*72.6)-1] x 100 (%) = 35%
This exceeds the minimum recommended by IEEE C62.22 of 20%

<u>CONCLUSION</u>
Based on the analysis presented, referencing the IEEE standards 62.22 and typical arrester datasheets, it is verified that the proposed arresters satisfy the minimum protective margin recommendations and are suitable to be applied on this 34.5 kV system.

APPENDIX – Arrester Data Sheets

Collection Arresters – TE Connectivity

Product Selection Information

Catalog Number	Duty Cycle Rating (kV/ rms)	MCOV (kVrms)	Maximum Discharge Voltage (kV crest) 8 x 20 microsecond current wave			
			1.5kA	5kA	10kA	20kA
ELB-35-600 ARSTR-27	27	22.0	65.6	72.3	78.2	85.7
ELB-35-600 ARSTR-30	30	24.4	72.6	79.9	86.5	94.8
ELB-35-600 ARSTR-33	33	26.8	80.1	88.2	95.4	104.5
ELB-35-600 ARSTR-36	36	29.0	87.1	95.9	103.8	113.8

PROTECTIVE CHARACTERISTICS

	Duty Cycle Rating (kVrms)	MCOV (kVrms)	8/20us Discharge Voltage Lightning Impulse Classifying Current LPL (10kA)	30/60us Switching Impulse Protective Level SPL (500A)	1us Front of Wave Protective Level FOW (10kA)
ELB-35-600-ARSTR-27	27	22.0	78.2	61.2	84.1
ELB-35-600-ARSTR-30	30	24.4	86.5	67.7	93.1
ELB-35-600-ARSTR-33	33	26.8	95.4	74.7	102.6
ELB-35-600-ARSTR-36	36	29.0	103.8	81.3	111.7

Substation Riser arresters - Hubbell Power Systems

Polymer Station [18kV - 444kV Rated]

Protective Characteristics

Standard Arrester Catalog Number	Duty Cycle Rating kV rms	Maximum Continuous Operating Voltage (MCOV) kV rms	Maximum 0.5μs Discharge Voltage kV (1)	Maximum Switching Surge Protective Level (kV) (2)	TOV Capability (3)		Maximum Discharge Voltage using an 8/20 Current Wave-kV					
					1 sec kV rms	10 sec kV rms	1.5kA	3kA	5kA	10kA	20kA	40kA
SVN018GA015AA	18	15.3	48.5	34.1	17.8	17.1	38.9	40.5	41.9	44.0	46.7	52.0
SVN021GA017AA	21	17	53.9	37.9	19.8	19.0	43.3	45.0	46.5	48.9	52.5	57.5
SVN024GA019AA	24	19.5	61.8	43.5	22.7	21.8	49.6	52.0	53.5	56.5	60.0	66.0
SVN027GA022AA	27	22	69.8	49.1	25.7	24.6	56.0	58.5	60.5	63.5	67.5	74.5
SVN030GA024AA	30	24.4	79.3	55.8	28.5	27.3	62.5	64.5	67.0	70.5	75.0	82.5
SVN036GA029AA	36	29	92.0	64.7	33.8	32.4	74.0	77.0	79.5	83.5	89.0	98.0
SVN039GA031AA	39	31.5	101	71.4	36.7	35.2	80.5	83.5	86.5	90.5	97.0	107
SVN045GA036AA	45	36.5	116	81.4	42.6	40.8	93.0	96.5	100	105	112	124
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

TOV STUDY

Northwest Ohio Wind Project

Paulding, Ohio
October 30, 2017

Prepared for:

WHITE
an IEA company

Prepared by:

Westwood

Westwood

Project Name: NW OH Wind Project	
Title	**J.O. or W.O. Number**
TOV Study	0007186.00

Approvals		Revision Number	Date	Description
Preparer(s) Name	**Reviewer(s) Name**			
Josh Venden	Drew Szabo	0	10/30/2017	Original Release

Westwood

TABLE OF CONTENTS

INTRODUCTION

The NW OH Wind Project is a 100 MW wind generation installation in Paulding, OH consisting 42 of GE 2.5 MW wind turbines. The turbines are grouped into four medium voltage (MV) feeders with 10 turbines on Feeders 1 and 4 and 11 turbines on Feeders 2 and 3. The feeders are connected to a main power transformer that steps the voltage up to 138kV where it interconnects with the AEP transmission system via a short overhead line segment.

A temporary transient overvoltage (TOV) study was performed on the medium voltage collection system to determine if any system changes or additions are required in order to limit the transient overvoltage on the collection system. This wind plant substation consists of EMA circuit breakers, which use a three-phase integral grounding switch to effectively ground the feeders once the feeder breaker has opened. This type of circuit breaker has been shown to limit exposure of temporary transient overvoltage on wind farm collection circuits when an unbalanced ground fault occurs. Additionally, surge arresters are installed at the end of each feeder string.

OBJECTIVE

This transient study assesses temporary overvoltage (TOV), and will analyze system responses to switching and during fault interrupting events. The TOV results for a single line to ground fault on the collector system are used to assess impact on surge arrestor MCOV ratings. Typically the TOV can be significant with weak systems which are interconnected to wind plants, since these plant have a larger than normal capacitive reactance due to the electrical collector system and capacitor banks. The wind plant substation integrates collector feeder circuit breakers which include an integral grounding switch and will typically not require any additional effective grounding techniques such as neutral derived grounding transformers due to the speed of this three phase grounding mechanism. The EMTP-RV and ATP software programs are used to perform this analysis. The model parameters are located in Appendix C.

Another purpose of the TOV study is to determine the maximum energy that will be absorbed by each medium voltage arrester installed on the collection system circuits. Energy is an integral function and therefore increases over time, so the total energy absorption is determined and then compared to the energy rating of the installed surge arresters. The comparison is used to determine that the arresters are appropriately sized to withstand the amount of energy present during a single line-to-ground fault.

METHODOLOGY

Several switching times were studied, including the peak of all three phase sinusoidal waves, the zero crossings of all three phases, and various other points on the waveform. The preliminary analysis showed that the transient overvoltage values seen were similar at each switching time. For the transient overvoltage analysis results provided in this report, the single line-to-ground fault was applied at 33.12 ms to correspond with the positive voltage peak for the faulted phase. Fault locations on the feeder were analyzed for locations close (near) to the substation, the farthest location on the collector circuit (far), and points in the middle of the feeder. It was determined from results that the temporary overvoltage levels seen at the individual arrestor locations were slightly higher for the far end fault.

INPUTS & ASSSUMPTIONS

For a single line-to-ground fault occurring on the collection system circuits it is assumed, per the substation engineer, that the corresponding circuit breaker will trip in a total of 58.33 ms, or 3.5 cycles after the fault The EMA circuit breaker grounding switch operates in 1 cycle (16.67 ms) after the circuit breaker opens.

The energy is recorded at 1108.12 ms; which accounts for application of the fault at 1.98 cycles (33.12 ms), plus the total time for the breaker to open of 3.5 cycles (58.33 ms), and 1 cycle (16.67 ms) for the grounding switch to close. The GE wind turbines will stop contributing current to a fault at 60 cycles (1000 ms) after the circuit breaker opens. The total simulation time will yield results for the maximum possible absorbed energy; 33.12 ms + 58.33 ms + 16.67 ms + 1000 ms = 1108.12 ms.

STUDY RESULTS

The simulation results provide the transient overvoltage waveform for each of the un-faulted phases after the single line-to-ground fault is applied, the feeder circuit breaker opens and the grounding switch closes. The waveforms are analyzed to obtain the TOV magnitude values, which are compared to per unit transient voltage levels provided in IEEE Standard C62.92, which are characteristic of an effectively grounded system. The maximum pre-fault peak voltage (normal operation) is 28.17 kV which is equal to the peak line-to-ground voltage of the 34.5 kV system. The line-to-ground voltage of 34.5 kV_{L-L} is 34.5 / √3 = 19.92 kV_{L-N}, the peak voltage is 19.92 * √2 = 28.17 kV.

The voltage waveforms in Figure 1 and Figure 2 are for Feeder 4 (Figure 1: fault at substation (near); Figure 2: fault at far end of circuit). In each figure, the upper curve is for the substation 34.5 kV bus, while the lower curve depicts voltages at the far end of the circuit. The waveforms show a fault being applied at 33.12 ms, the feeder circuit breaker opening 58.33 ms later at 91.45 ms, and the EMA breaker three-phase grounding switch closing 1 cycle later at 108.12 ms. The fault is applied at the peak of the voltage waveform (at 33.12 ms), which yields the most conservative transient overvoltage. Other pre-fault peaks prior to 33.12 ms could have been used, but this one was chosen in order to show a small time period of steady-state voltage prior to the fault being applied for reference purposes in the study results.

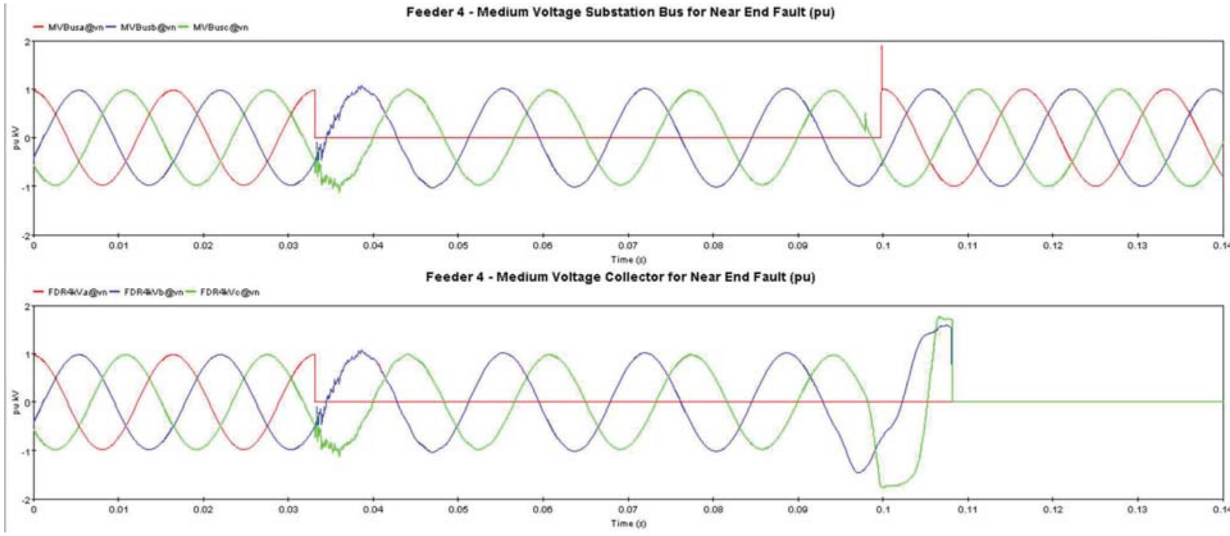


Figure 1: Feeder 4 (Near) 34.5 kV circuit (Top=Substation Bus, Bottom=Feeder 4)

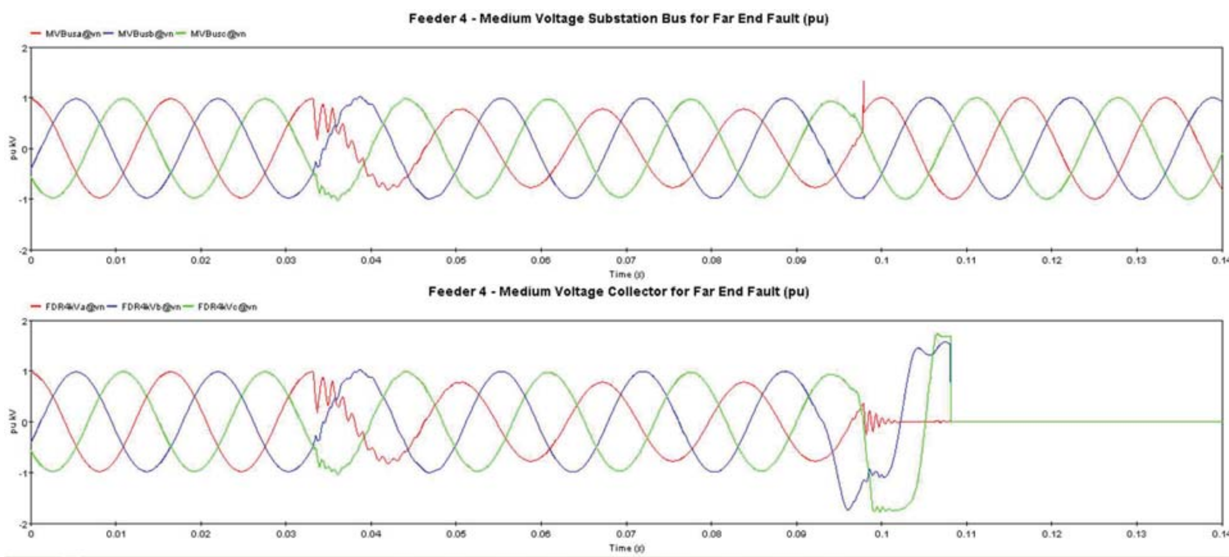


Figure 2: Feeder 4 (Far) 34.5 kV Circuit (Top=Substation Bus, Bottom=Feeder 4)

The waveforms in Figure 2 show the applied fault at 33.12 ms, the circuit breaker opening at 91.45 ms, and a quickly damped transient voltage once the grounding switch closes at 108.12 ms. The peak voltage varies based on the feeder properties such as number of turbines and total feeder impedance and capacitance.

Table 1 shows the maximum transient voltages at each time for near and far locations of the feeder. In all cases the transient voltage after the grounding switch operates is significantly damped within 30 ms.

						Maximum Transient L-G Voltage				
Collector Circuit	Overvoltage Arrestor Location	Single Line to Ground Fault Location on the Collector Circuit	Peak Line to Ground Rated Voltage (kV)	Single Line to Ground Fault @ 33.12ms Line to Ground Voltage (kVrms)	EMA Circuit Breaker Opening @ 91.45ms Line to Ground Voltage (kVrms)	EMA Circuit Breaker Three-Phase Ground Switch Closes @ 108.12ms Line to Ground Voltage (kVrms)	Steady-State Voltage after EMA Circuit Breaker Grounding Three-Phase Grounding Switch Closes Line to Ground Voltage (kVrms)	24.4kV MCOV Arrestor Location Maximum Voltage in per-unit of rated MCOV [typical max @ 108.12 ms] (pu)	24.4kV MCOV Arrestor Energy Absorbed at 1108.12ms (kJ/kVMCOV)	
1	WTG-1	Near	28.17	19.56	10.75	33.05	0.51	1.37	0.4474	
1	WTG-24	Near	28.17	19.48	10.62	33.02	0.104	1.36	0.4517	
1	WTG-1	Far	28.17	19.56	15.43	33.29	0.55	1.41	0.5096	
1	WTG-24	Far	28.17	19.48	11.07	33.22	0.122	1.4	0.4734	
2	WTG-16	Near	28.17	19.31	10.84	31.1	0.354	1.32	0.2262	
2	WTG-6	Near	28.17	19.52	10.47	31.14	0.344	1.31	0.2266	
2	WTG-13	Near	28.17	19.53	10.67	31.03	0.359	1.32	0.2269	
2	WTG-20	Near	28.17	19.52	10.55	31.14	0.269	1.31	0.2271	
2	WTG-29	Near	28.17	19.51	10.53	31.14	0.254	1.31	0.227	
2	WTG-16	Far	28.17	19.52	14.86	31.21	0.305	1.42	0.2604	
2	WTG-6	Far	28.17	19.52	14.37	31.2	0.298	1.41	0.2548	
2	WTG-13	Far	28.17	19.37	13.66	30.75	0.314	1.41	0.2493	
2	WTG-20	Far	28.17	19.51	12.43	31.15	0.241	1.38	0.2413	
2	WTG-29	Far	28.17	19.51	12.55	31.17	0.228	1.38	0.2411	
3	WTG-39	Near	28.17	19.53	10.49	31.37	0.4058	1.35	0.2915	
3	WTG-37	Near	28.17	19.54	10.51	31.37	0.4196	1.35	0.2925	
3	WTG-31	Near	28.17	19.53	10.49	31.36	0.4286	1.35	0.2918	
3	WTG-26	Near	28.17	19.51	10.42	31.22	0.3108	1.35	0.2946	
3	WTG-39	Far	28.17	19.53	15.89	31.74	0.4347	1.43	0.3414	
3	WTG-37	Far	28.17	19.54	15.41	31.73	0.4562	1.42	0.3317	
3	WTG-31	Far	28.17	19.53	14.58	31.71	0.4304	1.42	0.3265	
3	WTG-26	Far	28.17	19.51	14.05	31.69	0.3323	1.41	0.3195	
4	WTG-41	Near	28.17	19.54	10.95	33.84	0.8101	1.39	0.4428	
4	WTG-43	Near	28.17	19.46	10.96	33.84	0.8714	1.39	0.4428	
4	WTG-50	Near	28.17	19.57	10.96	33.81	0.9301	1.39	0.4368	
4	WTG-48	Near	28.17	19.56	10.89	33.81	0.9303	1.39	0.4367	
4	WTG-41	Far	28.17	19.54	18.77	33.41	0.7321	1.53	0.6569	
4	WTG-43	Far	28.17	19.54	18.56	33.16	0.7325	1.53	0.6477	
4	WTG-50	Far	28.17	19.57	18.71	33.33	0.8101	1.55	0.6435	**Worst Case**
4	WTG-48	Far	28.17	19.57	18.7	33.51	0.8076	1.55	0.6434	

Table 1: Transient and temporary healthy phase voltages.

IEEE Std C62.92.1-2000 indicates that a characteristic of an effectively grounded system is that the transient line-to-ground voltage is less than or equal to 2 pu. Based on this, an effectively grounded system would have transient voltages that remain below (34.5 kV / √3) * √2 * 2 = 56.34 kV on the medium voltage equipment.

Table 1 shows that for the one cycle between when the feeder breaker opens and the grounding switch operates, the transient voltages are the highest. This is because, for this short period of time, the system is not grounded through the substation transformer, so during this period the system is not effectively grounded. Once the grounding switch operates at 108.12 ms and effectively grounds the isolated feeder, the overvoltage is reduced to less than the 2 pu which is characteristic of an effectively grounded system.

The EMA grounding breaker also significantly decreases the steady-state voltage after the grounding switch operates, as Figure 1 and Figure 2 show by the decreased steady-state line-to- ground voltage after 108.12 ms. The steady-state voltages are recorded in Table 1, at least 30 ms after the grounding switch operates to allow time for damping. These steady-state voltages are related to the steady-state effectively grounded requirements in IEEE Std C62.92.1-2000.

The analysis also verifies the maximum energy required to be absorbed by the arresters does not exceed the energy the arrester is able to absorb. This is accomplished by measuring the energy through each surge arrester after the single line-to-ground fault is applied. Figure 3 shows the energy waveform at the worst case wind turbine WTG-50 surge arresters on Feeder 4. This waveform is typical of all medium voltage surge arresters in this wind power plant. Below, Figure 3 shows that the arrester stops absorbing significant amounts of energy once the grounding switch in the EMA grounding breaker closes at 108.12 ms. The greatest period of energy absorption is in the 1 cycle between when the circuit breaker opens and the grounding switch closes. If the grounding switch is not there, the arrester would continue to absorb more energy after the circuit breaker opens.

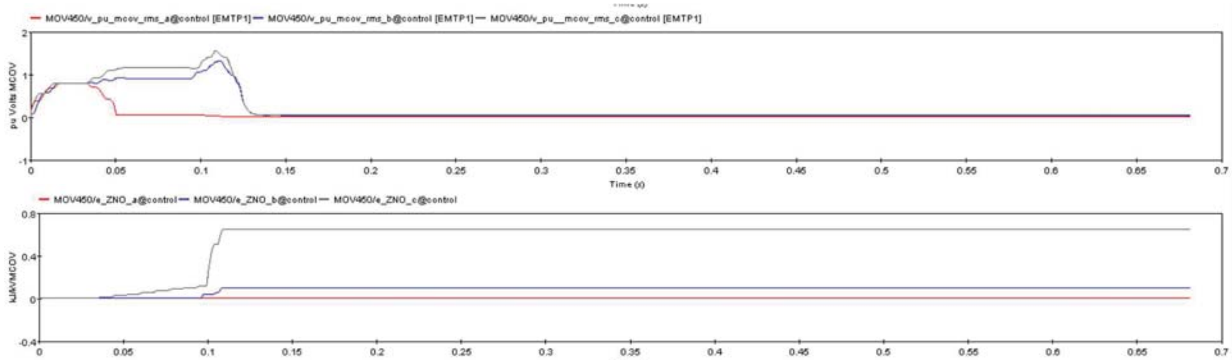


Figure 3: kV MCOV pu and Arrestor Energy at WTG-50 (Top=kV MCOV pu, Bottom=kJ/kVMCOV)

The GE wind turbines shut off 1000 ms after being disconnected from the grid when the feeder breaker opens due to a single line-to-ground fault, so the maximum energy absorbed by each arrester will occur at approximately 1108.12 ms. The maximum energy is calculated in Joules at 1108.12 ms on the time scale for each of the collector system surge arresters. In reality after the turbines stop contributing fault current at 1108.12 ms, the energy absorbed by the surge arrester would dampen. That is not shown in this simulation. The maximum absorbed energy on each feeder for a single line-to-ground fault on the feeder are also shown in Table 1 in kJ/kVMCOV. The maximum energy absorption rate for the 24.4 kV MCOV arrester is rated at 5.1 kJ/kVMCOV. The maximum energy the WTG-50 arrester is required to absorb is 27.28 kJ for a medium voltage single line-to-ground fault, which gives a normalized energy of 0.6435kJ/kVMCOV, which is less than the 5.1 kJ/kVMCOV allowable. The results show that the medium voltage collector system arresters are adequately sized to absorb the required energy for a single line-to-ground fault on any of the collection system feeders.

Westwood

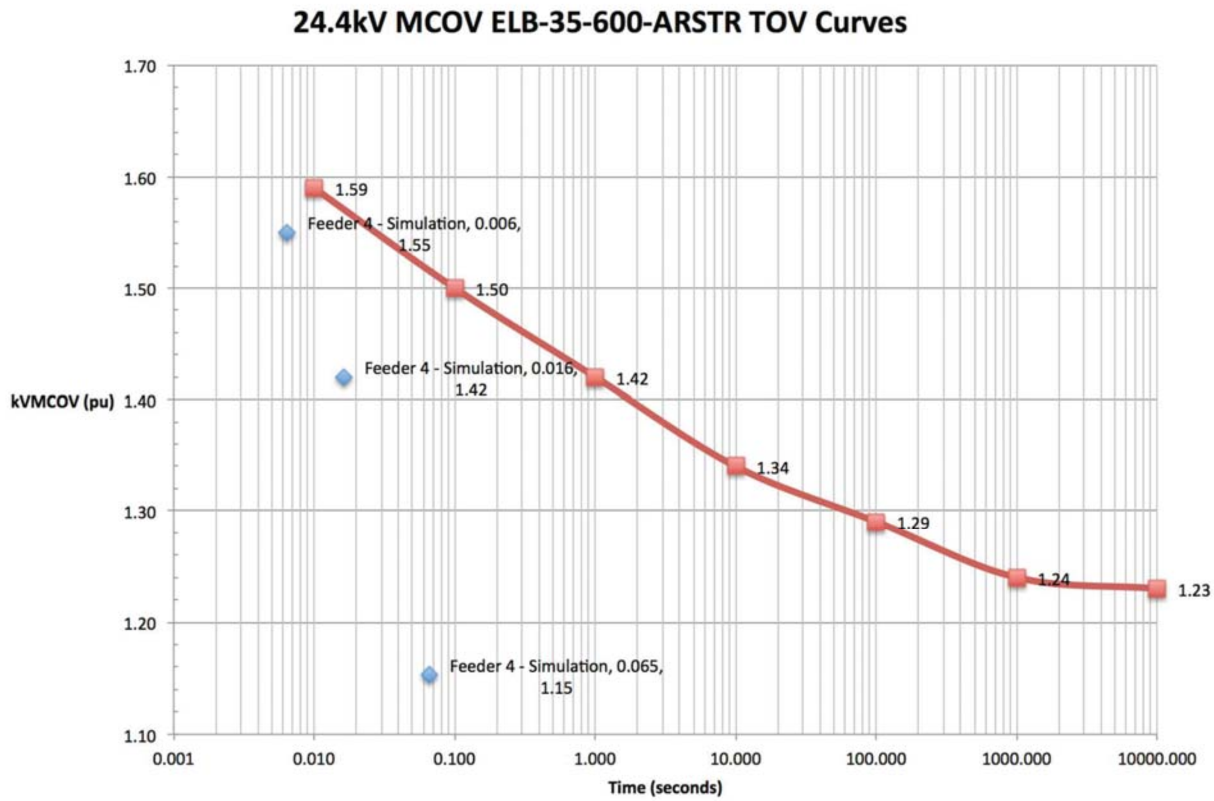


Figure 4: Maximum TOV in kV MCOV pu correlate with the 24.4kVMCOV arrestor TOV Curve.

The maximum TOV is on Feeder 4 at the arrestor located closest to WTG-50, the TOV magnitudes during the single line to ground fault, after the circuit breaker trips, and after the three-phase grounding switch closes. The results show that the maximum overvoltage is less than the 24.4kV MCOV arrestor TOV characteristic.

CONCLUSION

The maximum TOV is on Feeder 4, as shown in Table 1 and Figure 5, located at the arrestor closest to WTG-50, the TOV magnitudes during the single line to ground fault, after the circuit breaker trips, and after the three-phase grounding switch closes. The results show that the maximum overvoltage is less than the 24.4kV MCOV arrestor TOV characteristic.

The maximum transient overvoltage results on all medium voltage feeder equipment are less than 2 per-unit after the EMA circuit breaker integral three-phase grounding switch closes. IEEE Std C62.92.1-2000 states that a characteristic of an effectively grounded system is when the maximum transient overvoltage is less than or equal to 2 per-unit of the crest of the pre-fault line-to-ground operating voltage.

The results also show the maximum required energy to be absorbed by the 24.4 kV MVOC TE Connectivity (TE) collector system arresters. The energy through each surge arrester was simulated for condition both before and after the single phase to ground fault is applied within the collection system. As shown in the results, these arresters are adequately sized to absorb the required energy in the case of a phase to ground fault on any of the four collection system circuits. No equipment changes or modifications are recommended.

The study results show the un-faulted phase voltage waveforms for the collection system feeders due to a single phase to ground fault and then for circuit breaker isolation from the substation ground. The waveforms show the transient voltage peak after the single line-to-ground fault before the feeder circuit breaker opens, after the feeder circuit breaker receives the signal to trip due to the fault, and after the grounding switch in the EMA grounding breaker operates. The maximum overvoltage on all medium voltage collectors are shown to be less than the 24.4kVMCOV arrestor characteristics, and is less than 2 pu after the grounding switch of the EMA breakers close, and the energy absorbed by the arresters are also within acceptable limits. No equipment modifications are recommended.

Westwood

APPENDIX A: EMA VDH/GMSI Grounding Breaker Data Sheets

Grounding Switch

Combined 34.5 kV Vacuum Circuit Breaker & High Speed Grounding Switch VDH/GSMI™

VDH/GSMI

Deutscher Akkreditierungs Rat
DAR
TGA-ZM-28-96-00

TÜV CERT
DIN EN ISO 9001:2000
Certificado: 01 100 78186

EMA ELECTRO MECANICA

VDH/GSMI™

Combined 34.5 kV Vacuum Circuit Breaker & High Speed Mechanically Interlocked Grounding Switch

- VDH/GSMI™ model is especially designed for application with **wind farm collection circuits**. This model combines a circuit breaker with a high speed, mechanically-interlocked grounding switch within the same outdoor enclosure, and **totally replaces traditional use of grounding transformers in wind generation installations**.

- Circuit breaker connects wind turbine collection circuits to the substation bus, while the associated grounding switch automatically switches the collection circuits to ground immediately after the circuit breaker opens. The primary characteristic of the overall system is that the complete switching operation (time duration for opening circuit breaker through closing grounding switch) is mechanically accomplished **in less than 1 cycle** (between 12 to 16 milliseconds), with a maximum electrical switching of **12 milliseconds**.

- When a conventional wind farm collection system circuit breaker opens and the wind turbines are still in operation the voltage will typically rise on the 34.5 kV collection system cables between the turbines and the substation. If the voltage is allowed to rise excessively then surge arresters at the substation and at the ends of the 34.5 kV cable runs may be subject to overvoltage failure. The turbine controllers may also be subject to overvoltage failure. It's essential to keep the voltage down to the withstand limits of the surge arresters and the turbine controllers.

- Wind generation installations have typically used grounding transformers in order to limit that voltage rising. Now VDH/GSMI™ model provides a very fast switching time to ground which holds transient voltage excursion to very low levels, thereby **eliminating the need for grounding transformers**, with very important advantanges as follows:

  **Appreciably less expensive compared to a grounding transformer + conventional substation circuit breaker, plus lower installation labor costs & lower installation materials costs, which amounts to a very large first cost savings.*

  **Eliminates grounding transformers core losses, which amounts to a very large savings over project life.*

- Enclosure is metal enclosed, self-supporting and free standing construction, with weatherproof design suitable for installation in an unprotected environment, equipped inside with the following main components:

  **Three-pole vacuum circuit breaker combined with a high speed, mechanically-interlocked three-pole vacuum grounding switch.*

  **Switching & operating mechanism, spring stored energy type.*

  **Epoxy resin bushings including 4-hole flat pad stud connectors.*

  **Epoxy insulated ring-core current transformers installed around the bushings (up to two current transformers per bushing).*

  **Frontal control panel & rear auxiliary compartment.*

- All exterior parts fabricated from steel sheet with an electro-chemical process as anticorrosive protection which provides longlasting perfomance in corrosive or contaminated environments. Roof assembly especially fabricated in aluminium to prevent eddy currents around bushings.

- Manufactured and tested to meet ANSI C37 and IEC 62271-100 standards, this series provides easy installation and accessibility, minimal maintenance and long service life.

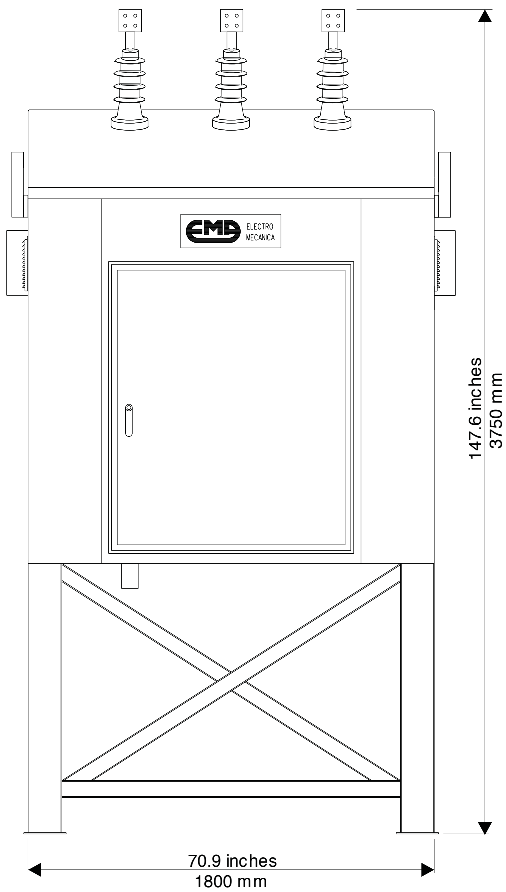
EMA VDH/GSMI™

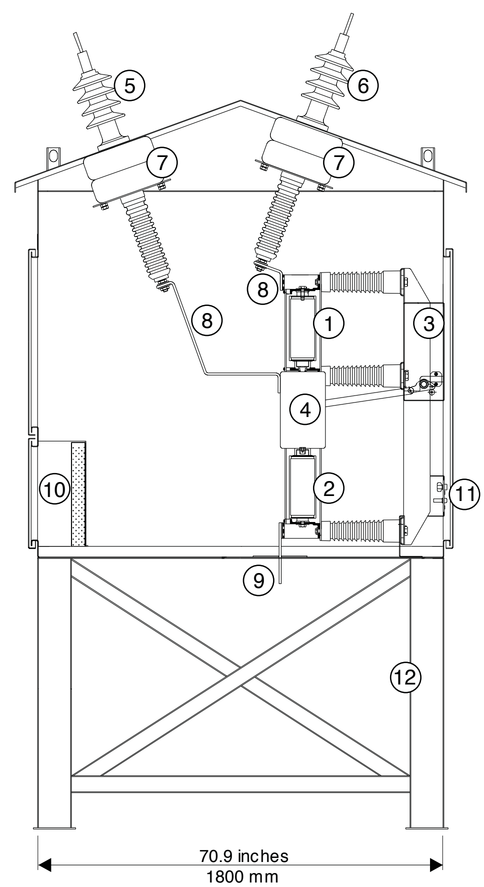
Electrical Ratings

	Rated Voltage	Rated Maximum Voltage	Rated Continuous Current	Symmetrical Interrupting Capability	Short Time Withstand Current	Making Capability (peak)	Dielectric Strength Withstand 60 Hz 1 min	Dielectric Strength Impulse Full Wave (BIL)	Rated Frecuency	Rated Closing Time	Rated Opening Time	Rated Arcing Time	Rated Mechanical Switching Time	Maximum Electrical Switching Time
	kV	kV	A	kA	kA (3 sec)	kA	kV	kV	Hz	msec	msec	msec	msec	msec
circuit breaker	34.5	38	1200 2000	25 31.5 40	25 31.5 40	68 85 106	80	200	60	40	30	4 to 11	12 to 16	12
grounding switch			–	–	12.5	34				–	–	–		

EMA VDH/GSMI™

Dimensions and Weight





Approximate Weight: 4070 pounds / 1850 kg

1. VACUUM CIRCUIT BREAKER
2. VACUUM GROUNDING SWITCH
3. OPERATING & COMMUTATION MECHANISM
4. MECHANICAL INTERLOCK
5. BUSHINGS (WIND FARM SIDE)
6. BUSHINGS (TRANSFORMER SIDE)
7. CURRENT TRANSFORMERS
8. MAIN BUSBARS
9. GROUNDING BAR
10. AUXILIARY & TERMINAL BLOCKS COMPARTMENT
11. CONTROL PUSH-BUTTONS & INDICATING LAMPS
12. SUPPORTING FRAME

VDH/GSMI™
The Circuit Breaker & Grounding Switch Unit

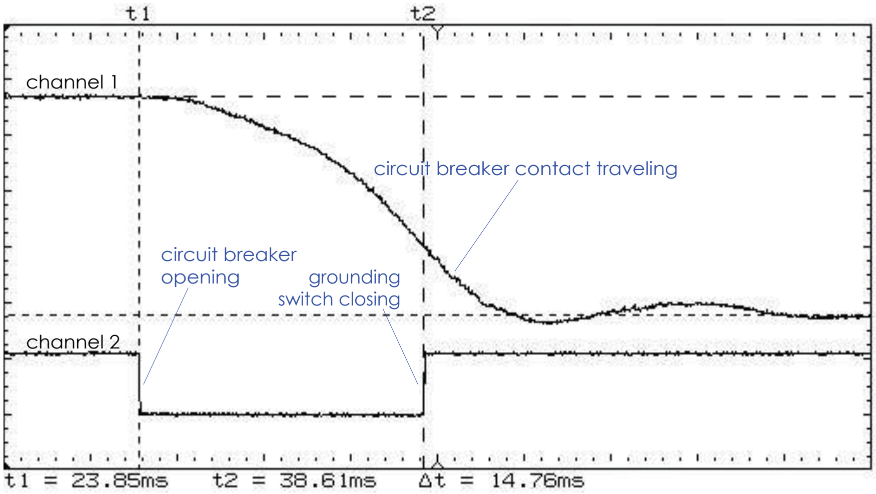
FRONTAL VIEW

SIDE VIEW

REAR VIEW

Circuit breaker (upper vacuum interrupters) connects wind turbine collection circuits to the substation bus, while the associated high speed, mechanically-interlocked grounding switch (lower vacuum interrupters) connects collection circuits automatically to ground. Complete switching sequence is mechanically accomplished in less than 1 cycle (between 12 to 16 milliseconds), with a maximum electrical switching of 12 milliseconds, thus the transient voltage doesn't rise enough to be above the withstand of the arresters or the allowable rise at the wind turbine controllers.

VDH/GSMI™
Switching Oscillogram



In this oscillogram, channel 1 is the analog representation of the circuit breaker contact traveling, while channel 2 is the representation of the contact mechanical positions of both circuit breaker and grounding switch, connected in a parallel circuit.

This shows that complete switching sequence (time duration for opening circuit breaker through closing grounding switch) was accomplished in 14.76 msec, and the circuit breaker contact traveled more than 75% of its total stroke when the grounding switch closed.

REPRESENTATIVE

1012E 11/2008 DV

Due to the continuous development of standars as well as materials, the characteristics and dimensions indicated in this brochure should be considered as binding only on confirmation from Ema Electromecanica S.A.
© Ema Electromecanica S.A. 2008 - All rights reserved.

Ema Electromecanica S.A. - Av. San Martín 4970 (B1604CDX) Florida - Buenos Aires - Argentina - Phone: (54 11) 4760-0051 - Fax: (54 11) 4761-0646
E-mail: gcom@ema-sa.com.ar - Website: www.ema-sa.com.ar

APPENDIX B: 34.5kV Collection Cable Electrical Parameters

NW_OH 1/C AL XLPE 35 kV 100 % Non-Mag. 60 Hz Ohms/1000ft RHO 200°C.cm/W

Ampacity | Impedance | Physical | Cable Pulling

		Phase		Ground/Neutral		R	X	L	Y	Ro	Xo	Lo	Yo	Rdc
	Avail.	Code	Size	#	Size	90°C	60 Hz	60 Hz	60 Hz	90°C	60 Hz	60 Hz	60 Hz	25°C
1	Yes	1/0 - 2/3 CN	1/0	18	16	0.24087	0.05182	0.00014	1.77E-05	0.35886	0.05482	0.00015	1.77E-05	0.18596
2	Yes	4/0 - 1/2 CN	4/0	17	14	0.11303	0.04679	0.00012	2.2E-05	0.28416	0.07373	0.0002	2.2E-05	0.08673
3	Yes	500 - 1/3 CN	500	16	12	0.4939	0.04115	0.00011	3.05E-05	0.16756	0.04488	0.00012	3.05E-05	0.0361
4	Yes	750 - 1/6 CN	750	19	14	0.0343	0.03865	0.0001	3.56E-05	0.18978	0.05914	0.00016	3.56E-05	0.0248
5	Yes	1000 - 1/6 CN	1000	25	14	0.02568	0.03703	0.0001	3.98E-05	0.20941	0.07373	0.0002	3.98E-05	0.01814
6	Yes	1250 - 1/6 CN	1250	20	12	0.02048	0.03537	9E-05	4.36E-05	0.23977	0.09952	0.00026	4.36E-05	0.01422

Figure 5: Cable Impedance Data

Feeder 1

From	To	Cable Type	Voltage Rating [kV]	Length [Feet]	Length [Miles]	R1 [Ohms]	L1 [mH]	C1 [uF]	R0 [Ohms]	L0 [mH]	C0 [uF]
101	102	1/0 AWG AL	34.5	1400	0.265151515	0.2976316	0.229143236	0.0418376	0.5512892	0.103692838	0.03974572
102	JB1B	1/0 AWG AL	34.5	1500	0.284090909	0.318891	0.24551061	0.044826	0.590667	0.111099469	0.0425847
103	104	1/0 AWG AL	34.5	1400	0.265151515	0.2976316	0.229143236	0.0418376	0.5512892	0.103692838	0.03974572
104	JB1B	1/0 AWG AL	34.5	2000	0.378787879	0.425188	0.32734748	0.059768	0.787556	0.148132626	0.0567796
JB1B	105	1/0 AWG AL	34.5	900	0.170454545	0.1913346	0.147306366	0.0268956	0.3544002	0.066659682	0.02555082
105	106	4/0 AWG AL	34.5	2400	0.454545455	0.2590152	0.427709284	0.0884664	0.4878744	0.444407427	0.08404308
106	107	4/0 AWG AL	34.5	1800	0.340909091	0.1942614	0.320781963	0.0663498	0.3659058	0.33330557	0.06303231
107	108	500 MCM AL	34.5	3400	0.643939394	0.1590826	0.657228117	0.1579504	0.561833	0.605145889	0.15005288
108	109	500 MCM AL	34.5	1400	0.265151515	0.0655046	0.270623342	0.0650384	0.231343	0.249177719	0.06178648
109	110	500 MCM AL	34.5	1900	0.359848485	0.0888991	0.367274536	0.0882664	0.3139655	0.338169761	0.08385308
110	111	500 MCM AL	34.5	3900	0.738636364	0.1824771	0.75387931	0.1811784	0.6444555	0.694137931	0.17211948
111	JB1A	500 MCM AL	34.5	4700	0.890151515	0.2199083	0.90852122	0.2183432	0.7766515	0.836525199	0.20742604
112	113	1/0 AWG AL	34.5	3500	0.662878788	0.744079	0.57285809	0.104594	1.378223	0.259232095	0.0993643
113	JB1A	1/0 AWG AL	34.5	5800	1.098484848	1.2330452	0.949307692	0.1733272	2.2839124	0.429584615	0.16466084
JB1A	114	1000kCMILS AL	34.5	800	0.151515152	0.0196568	0.16324244	0.045212	0.1142264	0.149415385	0.0429514
114	115	1000kCMILS AL	34.5	4400	0.833333333	0.1081124	0.897833422	0.248666	0.6282452	0.821784615	0.2362327
115	FDR1	1000kCMILS AL	34.5	6600	1.25	0.1621686	1.346750133	0.372999	0.9423678	1.232676923	0.35434905

Feeder 2

From	To	Cable Type	Voltage Rating [kV]	Length [Feet]	Length [Miles]	R1 [Ohms]	L1 [mH]	C1 [uF]	R0 [Ohms]	L0 [mH]	C0 [uF]
201	202	1/0 AWG AL	34.5	1300	0.246212121	0.2763722	0.212775862	0.0388492	0.5119114	0.096286207	0.03690674
202	203	1/0 AWG AL	34.5	1300	0.246212121	0.2763722	0.212775862	0.0388492	0.5119114	0.096286207	0.03690674
203	204	1/0 AWG AL	34.5	1400	0.265151515	0.2976316	0.229143236	0.0418376	0.5512892	0.103692838	0.03974572
204	205	4/0 AWG AL	34.5	1200	0.227272727	0.1295076	0.213854642	0.0442332	0.2439372	0.222203714	0.04202154
205	JB2A	4/0 AWG AL	34.5	1500	0.284090909	0.1618845	0.267318302	0.0552915	0.3049215	0.277754642	0.052526925
206	207	1/0 AWG AL	34.5	2000	0.378787879	0.425188	0.32734748	0.059768	0.787556	0.148132626	0.0567796
207	JB2A	1/0 AWG AL	34.5	1600	0.303030303	0.3401504	0.261877984	0.0478144	0.6300448	0.118506101	0.04542368
JB2A	208	4/0 AWG AL	34.5	1800	0.340909091	0.1942614	0.320781963	0.0663498	0.3659058	0.33330557	0.06303231
208	209	500 MCM AL	34.5	1300	0.246212121	0.0608257	0.251293103	0.0603928	0.2148185	0.23137931	0.05737316
209	210	500 MCM AL	34.5	1900	0.359848485	0.0888991	0.367274536	0.0882664	0.3139655	0.338169761	0.08385308
210	211	500 MCM AL	34.5	2100	0.397727273	0.0982569	0.405935013	0.0975576	0.3470145	0.373766578	0.09267972
211	212	500 MCM AL	34.5	2000	0.378787879	0.093578	0.386604775	0.092912	0.33049	0.35596817	0.0882664
212	213	1000kCMILS AL	34.5	1500	0.284090909	0.0368565	0.306079576	0.0847725	0.2141745	0.280153846	0.080533875
213	214	1000kCMILS AL	34.5	4500	0.852272727	0.1105695	0.918238727	0.2543175	0.6425235	0.840461538	0.241601625
214	215	1000kCMILS AL	34.5	2500	0.473484848	0.0614275	0.510132626	0.1412875	0.3569575	0.466923077	0.134223125
215	FDR2	1000kCMILS AL	34.5	12600	2.386363636	0.3095946	2.571068435	0.712089	1.7990658	2.353292308	0.67648455

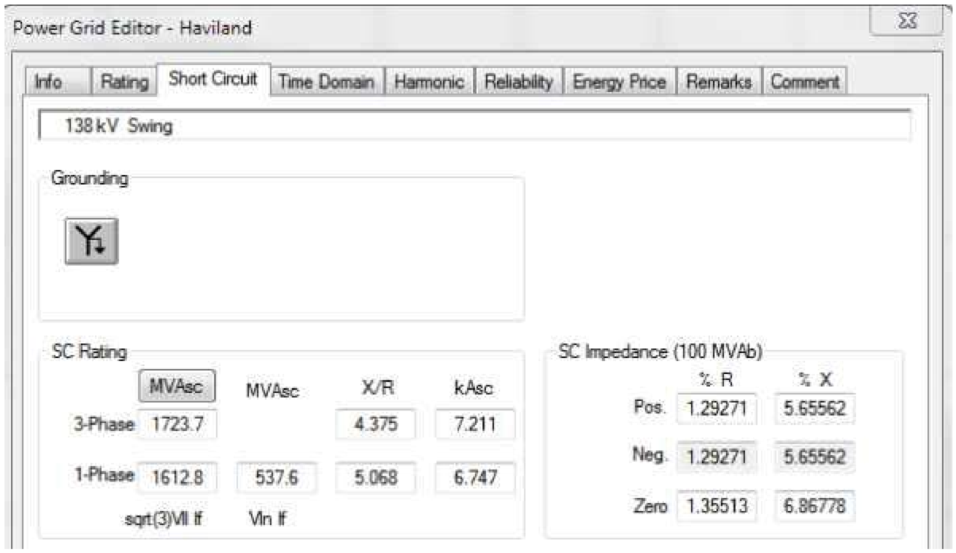
Feeder 3

From	To	Cable Type	Voltage Rating [kV]	Length [Feet]	Length [Miles]	R1 [Ohms]	L1 [mH]	C1 [uF]	R0 [Ohms]	L0 [mH]	C0 [uF]
301	302	1/0 AWG AL	34.5	1200	0.227272727	0.2551128	0.196408488	0.0358608	0.4725336	0.088879576	0.03406776
302	303	1/0 AWG AL	34.5	1400	0.265151515	0.2976316	0.229143236	0.0418376	0.5512892	0.103692838	0.03974572
303	304	1/0 AWG AL	34.5	1300	0.246212121	0.2763722	0.212775862	0.0388492	0.5119114	0.096286207	0.03690674
304	305	1/0 AWG AL	34.5	1200	0.227272727	0.2551128	0.196408488	0.0358608	0.4725336	0.088879576	0.03406776
305	306	4/0 AWG AL	34.5	1600	0.303030303	0.1726768	0.285139523	0.0589776	0.3252496	0.296271618	0.05602872
306	307	4/0 AWG AL	34.5	1700	0.321969697	0.1834691	0.302960743	0.0626637	0.3455777	0.314788594	0.059530515
307	JB3A	350kCMILS AL	34.5	1300	0.246212121	0.070267727	0.152140176	0.123556629	0.151567	0.162941379	0.117378797
308	309	1/0 AWG AL	34.5	1500	0.284090909	0.318891	0.24551061	0.044826	0.590667	0.111099469	0.0425847
309	JB3A	1/0 AWG AL	34.5	1500	0.284090909	0.318891	0.24551061	0.044826	0.590667	0.111099469	0.0425847
JB3A	310	350kCMILS AL	34.5	1200	0.227272727	0.064862517	0.140437086	0.114052273	0.139908	0.150407427	0.108349659
310	311	350kCMILS AL	34.5	1300	0.246212121	0.070267727	0.152140176	0.123556629	0.151567	0.162941379	0.117378797
311	312	350kCMILS AL	34.5	2100	0.397727273	0.113509405	0.2457649	0.199591477	0.244839	0.263212997	0.189611903
312	313	1000kCMILS AL	34.5	1500	0.284090909	0.0368565	0.306079576	0.0847725	0.2141745	0.280153846	0.080533875
313	314	1000kCMILS AL	34.5	2300	0.435606061	0.0565133	0.469322016	0.1299845	0.3284009	0.429569231	0.123485275
314	315	1000kCMILS AL	34.5	1900	0.359848485	0.0466849	0.387700796	0.1073785	0.2712877	0.354861538	0.102009575
315	FDR3	1000kCMILS AL	34.5	17800	3.371212121	0.4373638	3.632144297	1.005967	2.5415374	3.324492308	0.95566865

Feeder 4

From	To	Cable Type	Voltage Rating [kV]	Length [Feet]	Length [Miles]	R1 [Ohms]	L1 [mH]	C1 [uF]	R0 [Ohms]	L0 [mH]	C0 [uF]
401	402	1/0 AWG AL	34.5	1300	0.246212121	0.2763722	0.212775862	0.0388492	0.5119114	0.096286207	0.03690674
402	403	1/0 AWG AL	34.5	1200	0.227272727	0.2551128	0.196408488	0.0358608	0.4725336	0.088879576	0.03406776
403	404	1/0 AWG AL	34.5	1300	0.246212121	0.2763722	0.212775862	0.0388492	0.5119114	0.096286207	0.03690674
404	405	1/0 AWG AL	34.5	1400	0.265151515	0.2976316	0.229143236	0.0418376	0.5512892	0.103692838	0.03974572
405	406	4/0 AWG AL	34.5	2000	0.378787879	0.215846	0.356424403	0.073722	0.406562	0.370339523	0.0700359
406	407	4/0 AWG AL	34.5	1900	0.359848485	0.2050537	0.338603183	0.0700359	0.3862339	0.351822546	0.066534105
407	408	4/0 AWG AL	34.5	1200	0.227272727	0.1295076	0.213854642	0.0442332	0.2439372	0.222203714	0.04202154
408	409	500 MCM AL	34.5	1300	0.246212121	0.0608257	0.251293103	0.0603928	0.2148185	0.23137931	0.05737316
409	410	500 MCM AL	34.5	1200	0.227272727	0.0561468	0.231962865	0.0557472	0.198294	0.213580902	0.05295984
410	411	500 MCM AL	34.5	1900	0.359848485	0.0888991	0.367274536	0.0882664	0.3139655	0.338169761	0.08385308
411	412	500 MCM AL	34.5	2100	0.397727273	0.0982569	0.405935013	0.0975576	0.3470145	0.373766578	0.09267972
412	413	1000kCMILS AL	34.5	2300	0.435606061	0.0565133	0.469322016	0.1299845	0.3284009	0.429569231	0.123485275
413	414	1000kCMILS AL	34.5	1400	0.265151515	0.0343994	0.285674271	0.079121	0.1998962	0.261476923	0.07516495
414	415	1000kCMILS AL	34.5	2500	0.473484848	0.0614275	0.510132626	0.1412875	0.3569575	0.466923077	0.134223125
415	FDR4	1000kCMILS AL	34.5	25200	4.772727273	0.6191892	5.14213687	1.424178	3.5981316	4.706584615	1.3529691

APPENDIX C: MODEL INPUTS



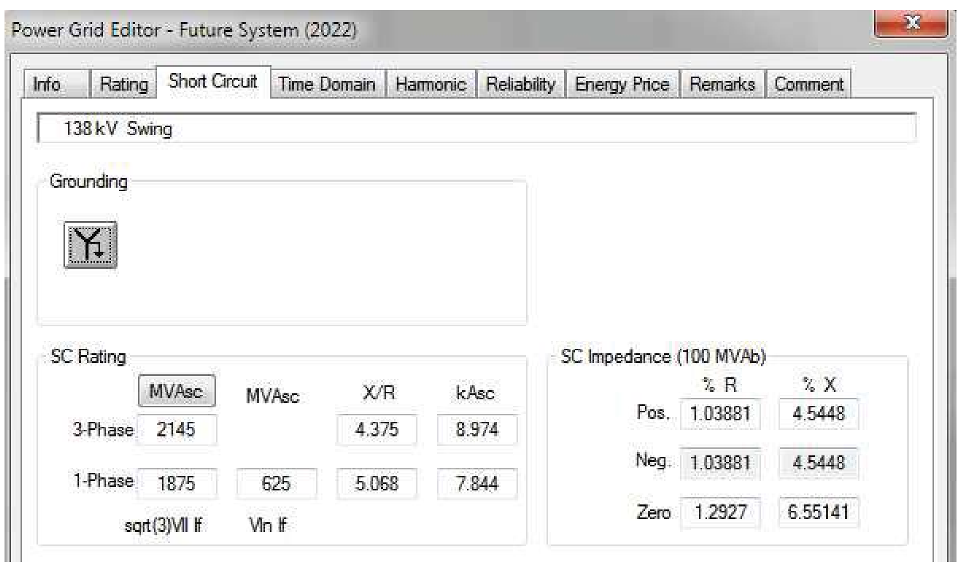


Figure 6: Utility Equivalent Data

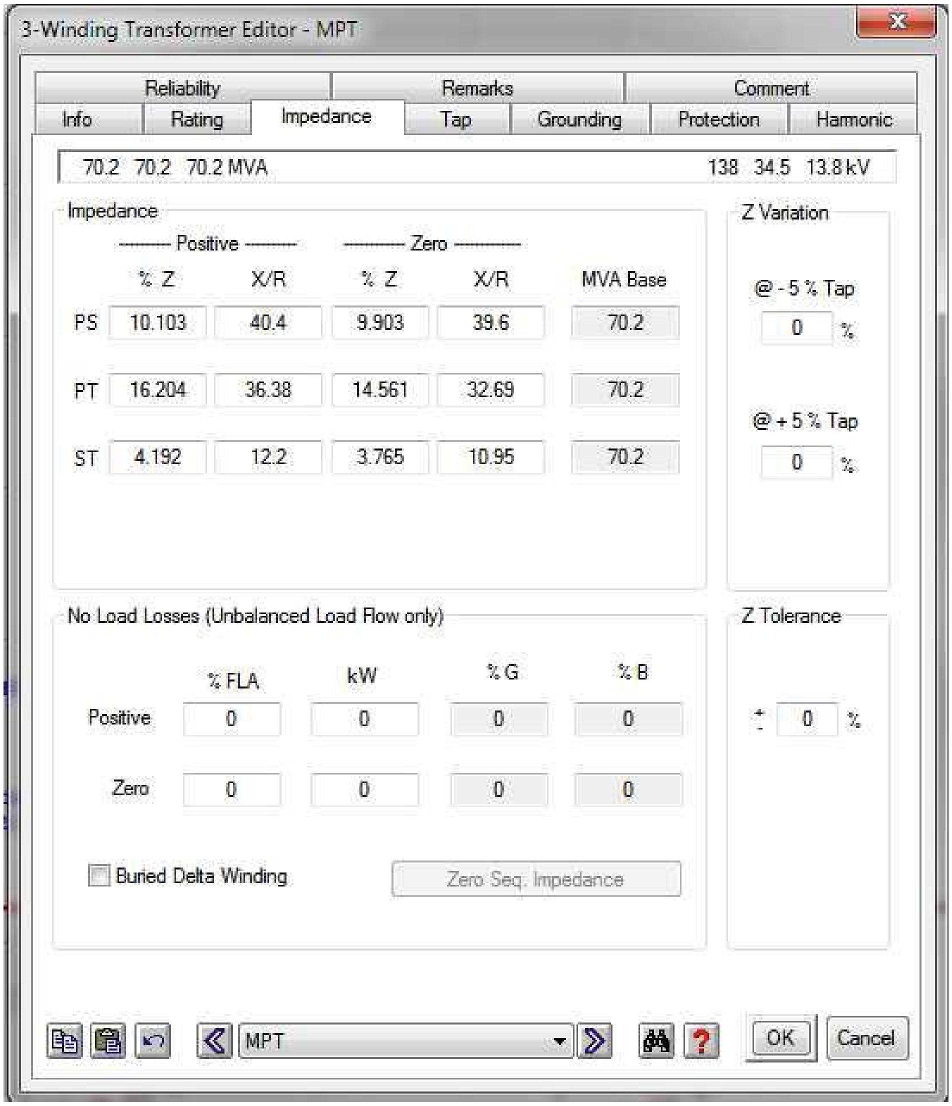


Figure 7: Main Power Transformer Impedance

Westwood

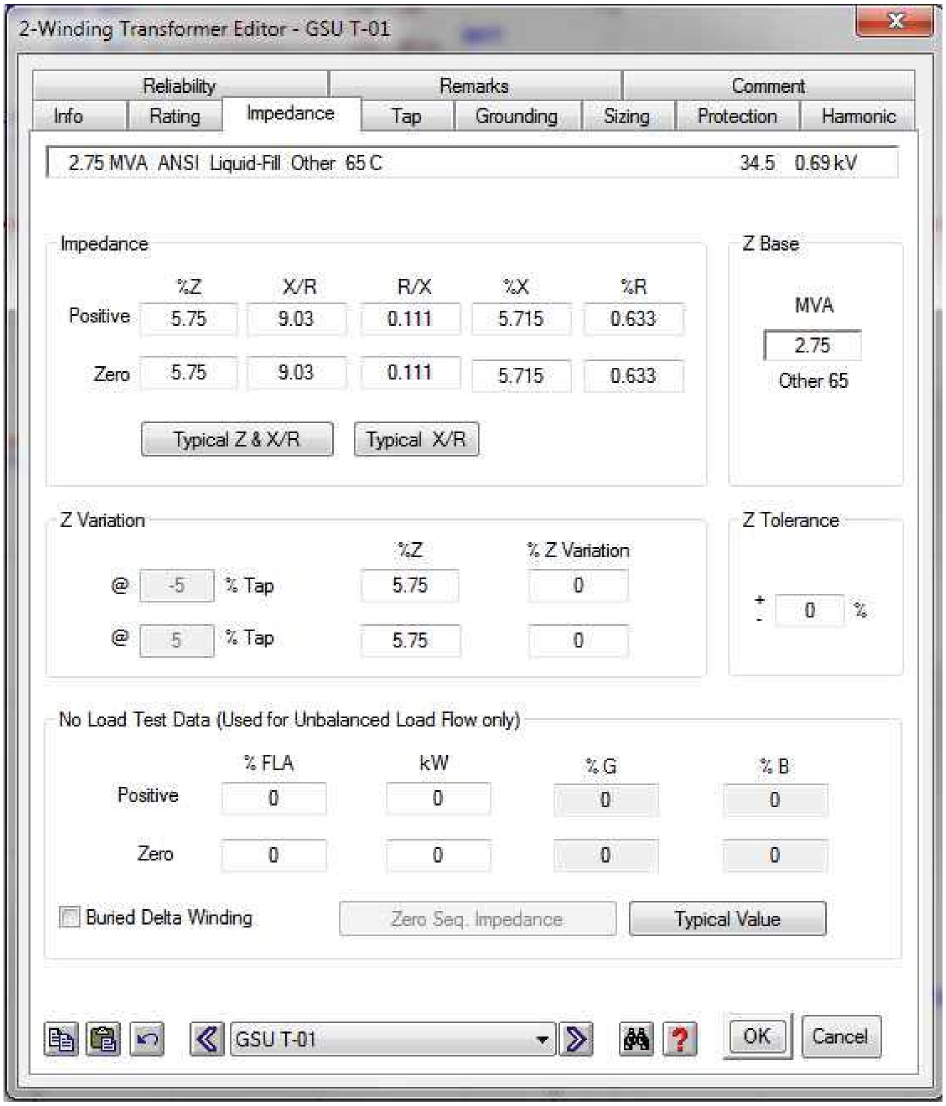


Figure 8: Step-Up Transformer Impedance Data

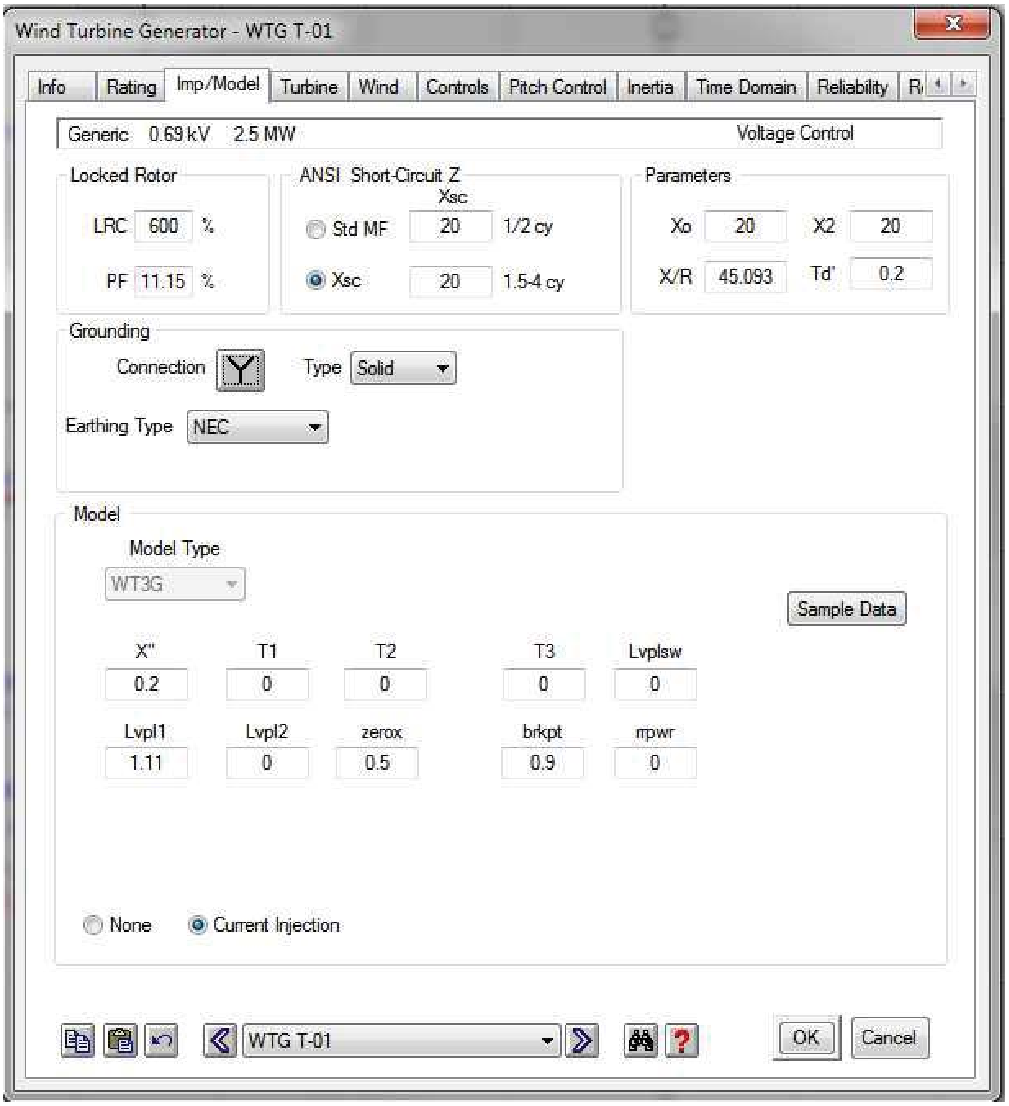
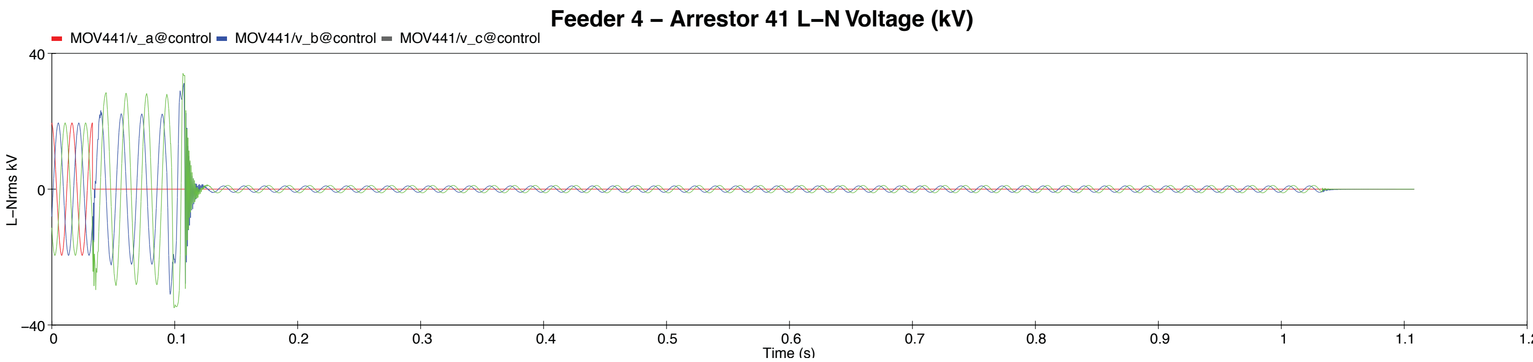
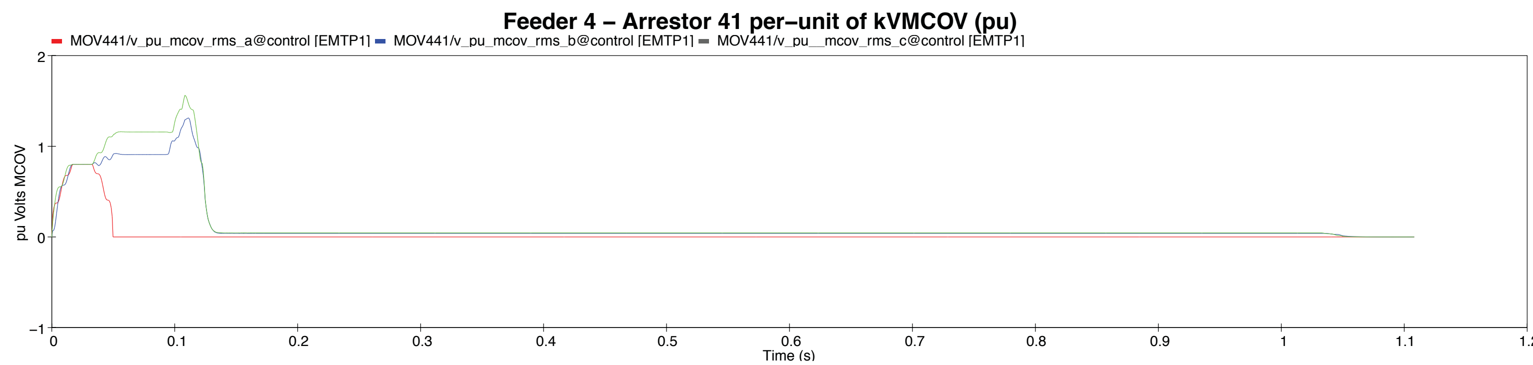


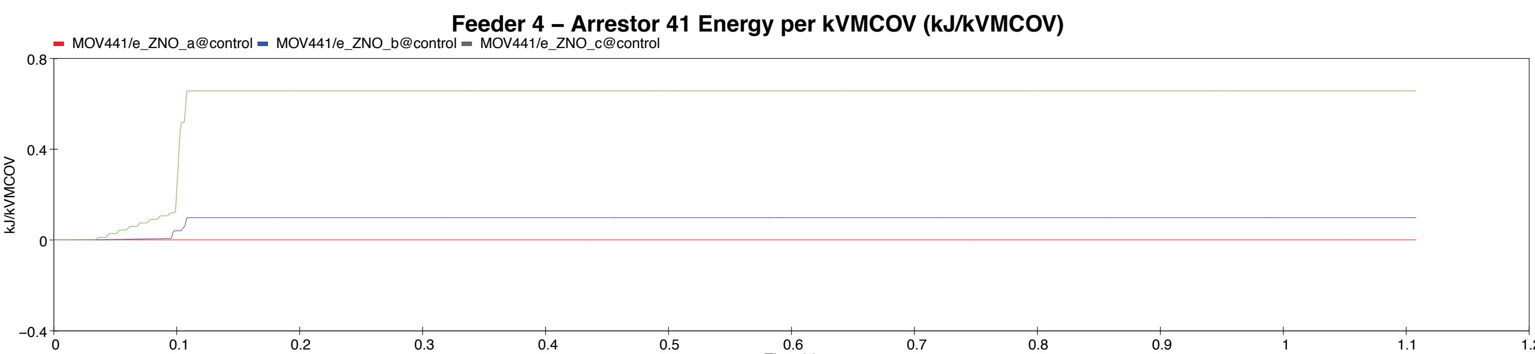
Figure 9: Turbine Impedance/Short Circuit Data

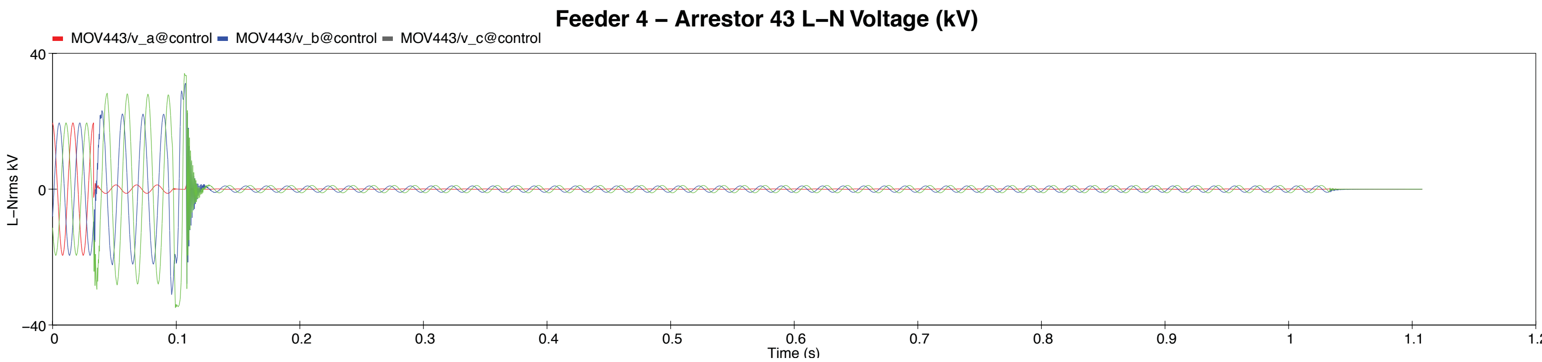
Westwood

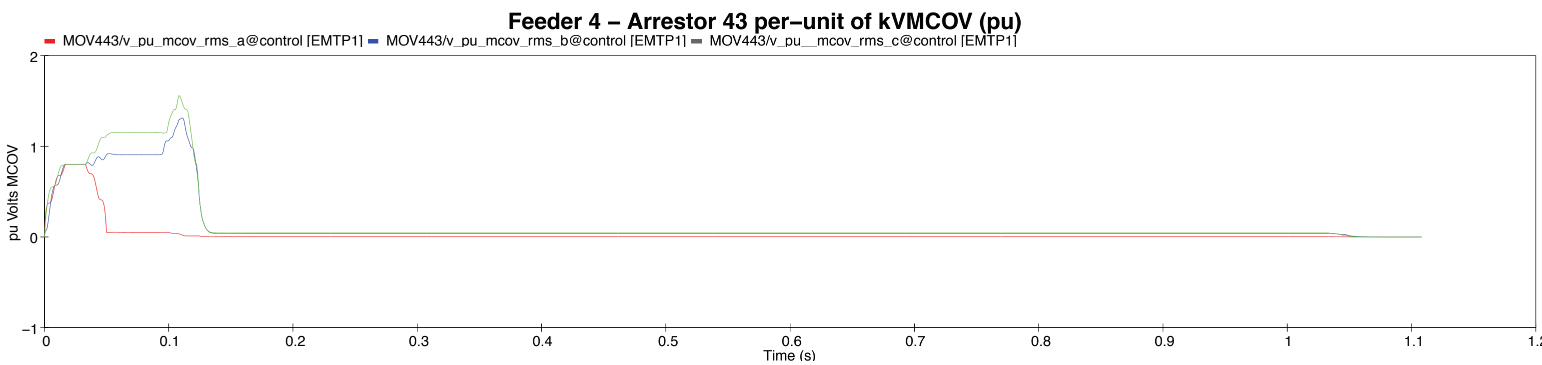
APPENDIX D: Feeder 4 TOV Waveforms for a Far End Fault

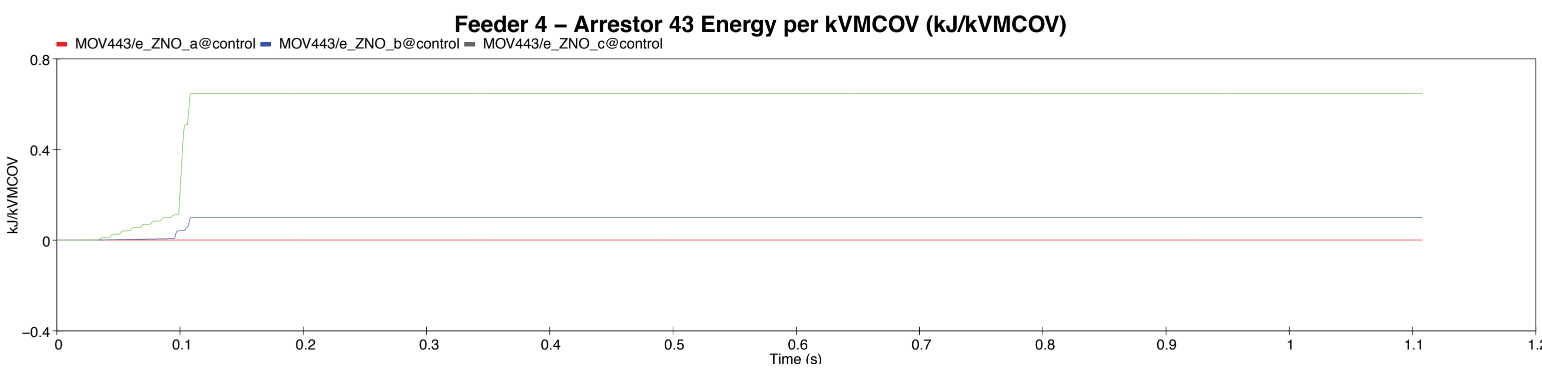

Feeder 4 – Arrestor 41 L–N Voltage (kV)
MOV441/v_a@control MOV441/v_b@control MOV441/v_c@control
L–Nrms kV
40
0
–40
0 0.1 0.2 0.3 0.4 0.5 0.6 0.7 0.8 0.9 1 1.1 1.2
Time (s)

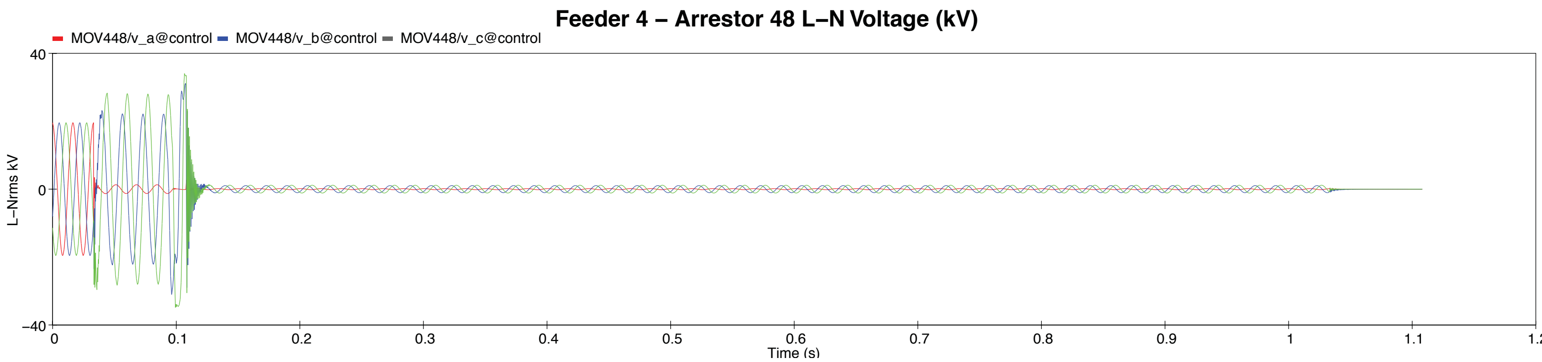

Feeder 4 – Arrestor 41 per–unit of kVMCOV (pu)
MOV441/v_pu_mcov_rms_a@control [EMTP1] MOV441/v_pu_mcov_rms_b@control [EMTP1] MOV441/v_pu__mcov_rms_c@control [EMTP1]
pu Volts MCOV
2
1
0
–1
0 0.1 0.2 0.3 0.4 0.5 0.6 0.7 0.8 0.9 1 1.1 1.2
Time (s)

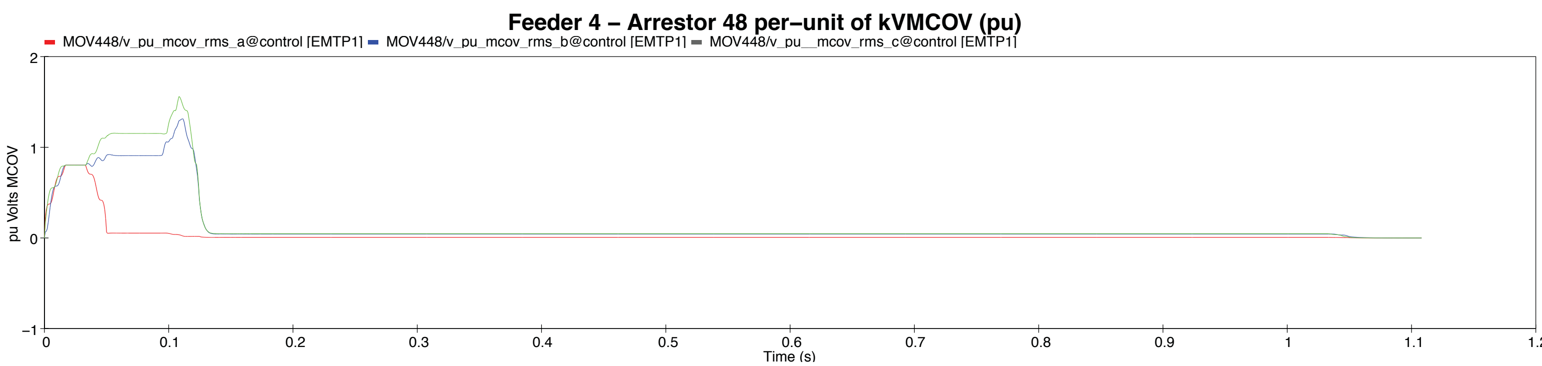

Feeder 4 – Arrestor 41 Energy per kVMCOV (kJ/kVMCOV)
MOV441/e_ZNO_a@control MOV441/e_ZNO_b@control MOV441/e_ZNO_c@control
kJ/kVMCOV
0.8
0.4
0
–0.4
0 0.1 0.2 0.3 0.4 0.5 0.6 0.7 0.8 0.9 1 1.1 1.2
Time (s)

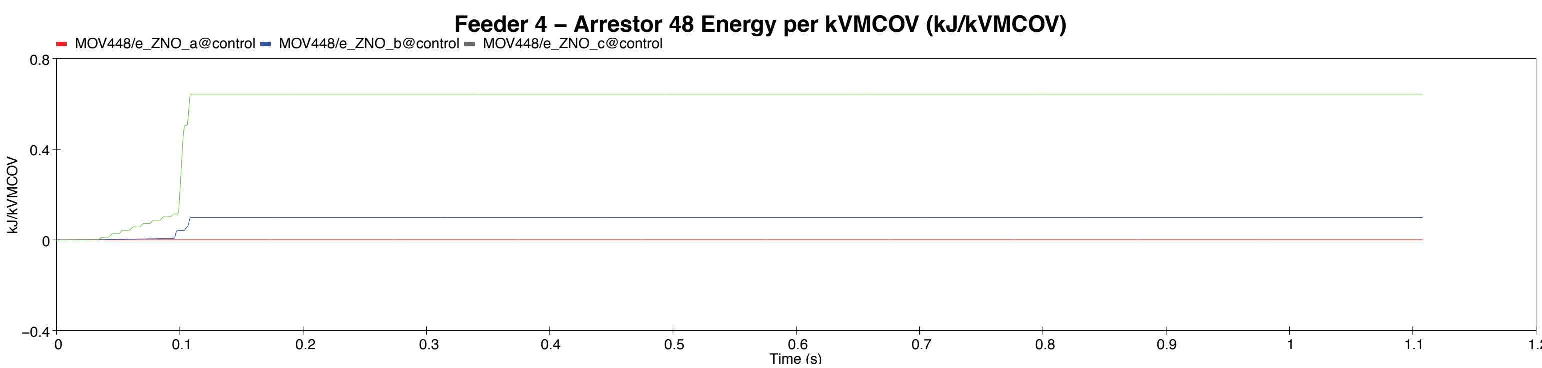

Feeder 4 – Arrestor 43 L–N Voltage (kV)
MOV443/v_a@control
MOV443/v_b@control
MOV443/v_c@control
L–Nrms kV
Time (s)

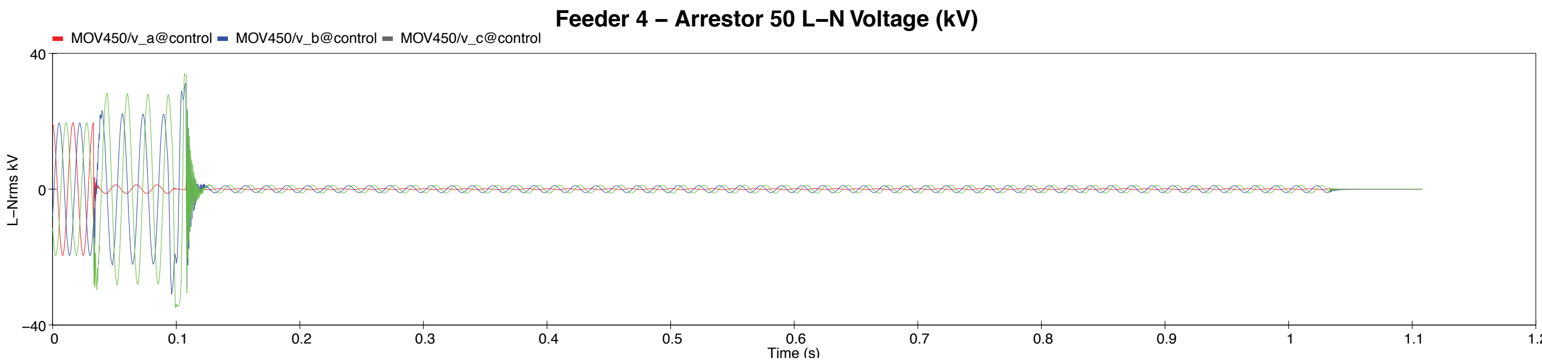

Feeder 4 – Arrestor 43 per–unit of kVMCOV (pu)
MOV443/v_pu_mcov_rms_a@control [EMTP1]
MOV443/v_pu_mcov_rms_b@control [EMTP1]
MOV443/v_pu__mcov_rms_c@control [EMTP1]
pu Volts MCOV
Time (s)

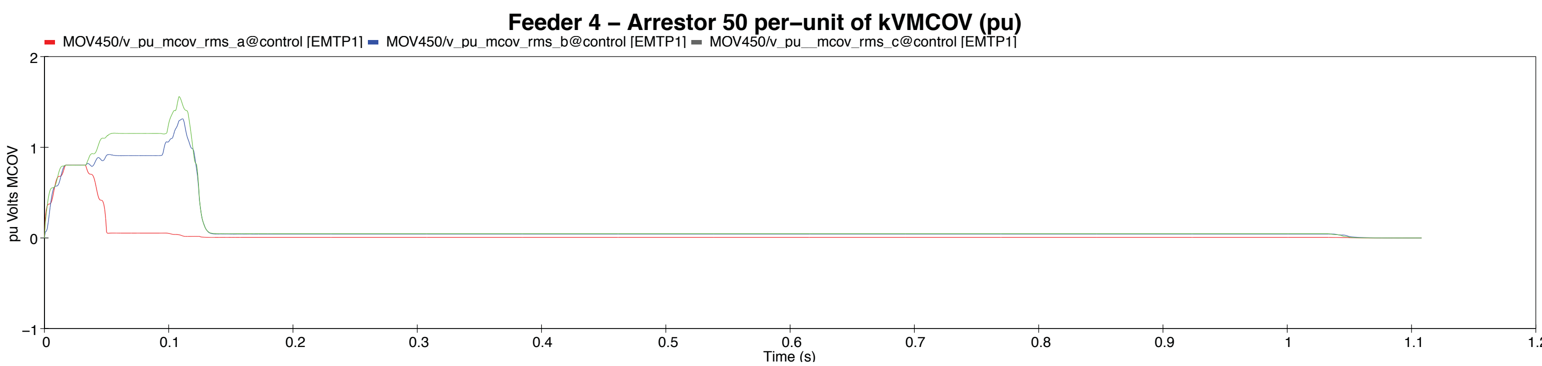

Feeder 4 – Arrestor 43 Energy per kVMCOV (kJ/kVMCOV)
MOV443/e_ZNO_a@control
MOV443/e_ZNO_b@control
MOV443/e_ZNO_c@control
kJ/kVMCOV
Time (s)

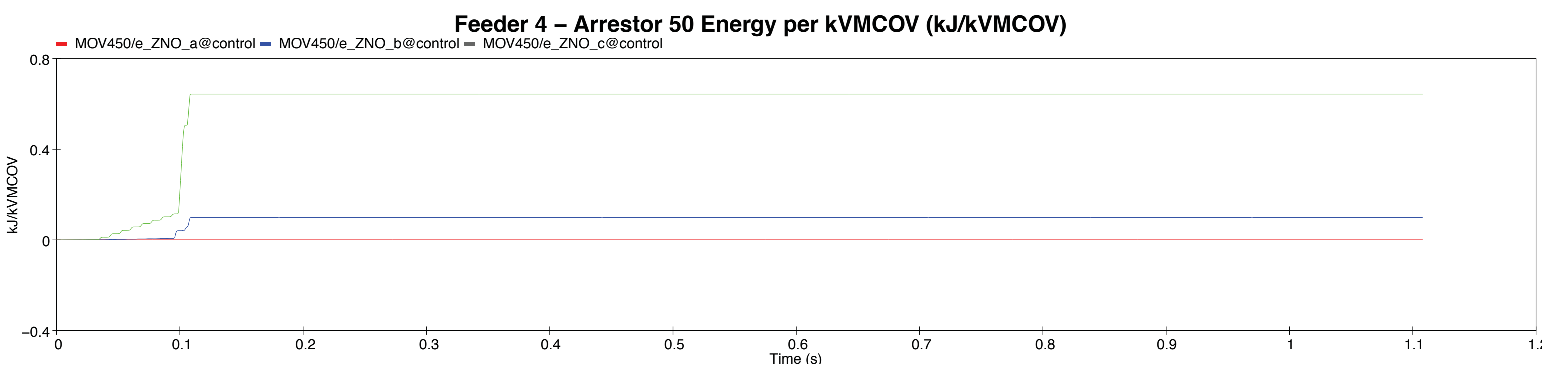

Feeder 4 – Arrestor 48 L–N Voltage (kV)
MOV448/v_a@control MOV448/v_b@control MOV448/v_c@control
L–Nrms kV
Time (s)


Feeder 4 – Arrestor 48 per–unit of kVMCOV (pu)
MOV448/v_pu_mcov_rms_a@control [EMTP1] MOV448/v_pu_mcov_rms_b@control [EMTP1] MOV448/v_pu__mcov_rms_c@control [EMTP1]
pu Volts MCOV
Time (s)

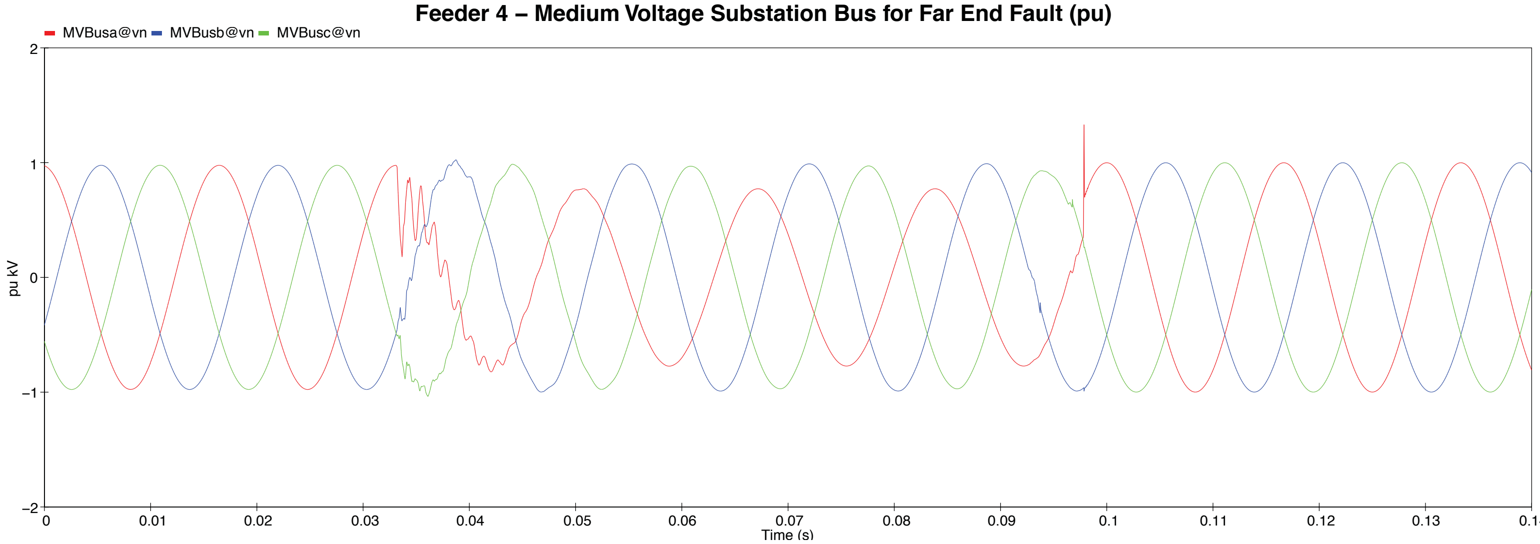

Feeder 4 – Arrestor 48 Energy per kVMCOV (kJ/kVMCOV)
MOV448/e_ZNO_a@control MOV448/e_ZNO_b@control MOV448/e_ZNO_c@control
kJ/kVMCOV
Time (s)


Feeder 4 – Arrestor 50 L–N Voltage (kV)
MOV450/v_a@control
MOV450/v_b@control
MOV450/v_c@control
L–Nrms kV
Time (s)

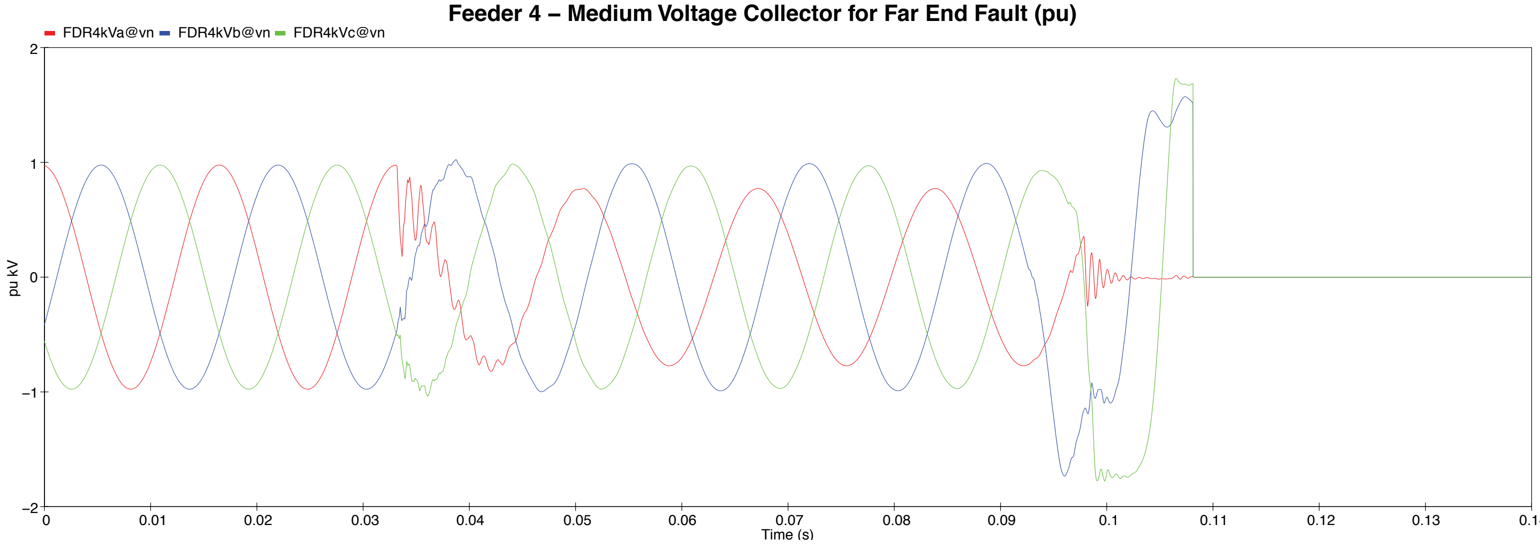

Feeder 4 – Arrestor 50 per–unit of kVMCOV (pu)
MOV450/v_pu_mcov_rms_a@control [EMTP1]
MOV450/v_pu_mcov_rms_b@control [EMTP1]
MOV450/v_pu__mcov_rms_c@control [EMTP1]
pu Volts MCOV
Time (s)


Feeder 4 – Arrestor 50 Energy per kVMCOV (kJ/kVMCOV)
MOV450/e_ZNO_a@control
MOV450/e_ZNO_b@control
MOV450/e_ZNO_c@control
kJ/kVMCOV
Time (s)

Feeder 4 – Medium Voltage Substation Bus for Far End Fault (pu)

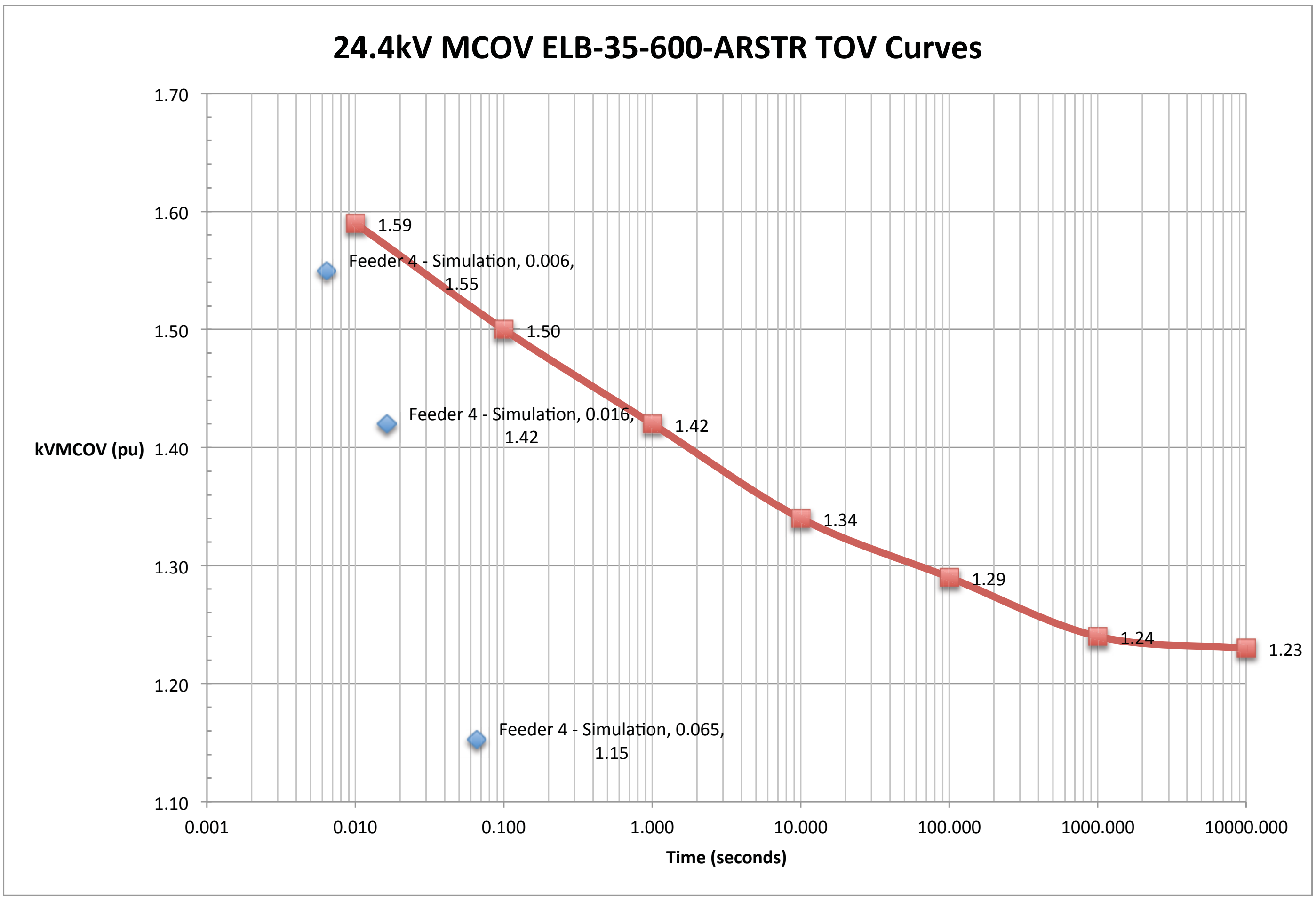


Feeder 4 – Medium Voltage Collector for Far End Fault (pu)



Maximum Transient L-G Voltage

Collector Circuit	Overvoltage Arrestor Location	Single Line to Ground Fault Location on the Collector Circuit	Peak Line to Ground Rated Voltage (kV)	Single Line to Ground Fault @ 33.12ms Line to Ground Voltage (kVrms)	EMA Circuit Breaker Opening @ 91.45ms Line to Ground Voltage (kVrms)	EMA Circuit Breaker Three-Phase Ground Switch Closes @ 108.12ms Line to Ground Voltage (kVrms)	Steady-State Voltage after EMA Circuit Breaker Grounding Three-Phase Grounding Switch Closes Line to Ground Voltage (kVrms)	24.4kV MCOV Arrestor Location Maximum Voltage in per-unit of rated MCOV [typical max @ 108.12 ms] (pu)	24.4kV MCOV Arrestor Energy Absorbed at 1108.12ms (kJ/kVMCOV)	
1	WTG-1	Near	28.17	19.56	10.75	33.05	0.51	1.37	0.4474	
1	WTG-24	Near	28.17	19.48	10.62	33.02	0.104	1.36	0.4517	
1	WTG-1	Far	28.17	19.56	15.43	33.29	0.55	1.41	0.5096	
1	WTG-24	Far	28.17	19.48	11.07	33.22	0.122	1.4	0.4734	
2	WTG-16	Near	28.17	19.31	10.84	31.1	0.354	1.32	0.2262	
2	WTG-6	Near	28.17	19.52	10.47	31.14	0.344	1.31	0.2266	
2	WTG-13	Near	28.17	19.53	10.67	31.03	0.359	1.32	0.2269	
2	WTG-20	Near	28.17	19.52	10.55	31.14	0.269	1.31	0.2271	
2	WTG-29	Near	28.17	19.51	10.53	31.14	0.254	1.31	0.227	
2	WTG-16	Far	28.17	19.52	14.86	31.21	0.305	1.42	0.2604	
2	WTG-6	Far	28.17	19.52	14.37	31.2	0.298	1.41	0.2548	
2	WTG-13	Far	28.17	19.37	13.66	30.75	0.314	1.41	0.2493	
2	WTG-20	Far	28.17	19.51	12.43	31.15	0.241	1.38	0.2413	
2	WTG-29	Far	28.17	19.51	12.55	31.17	0.228	1.38	0.2411	
3	WTG-39	Near	28.17	19.53	10.49	31.37	0.4058	1.35	0.2915	
3	WTG-37	Near	28.17	19.54	10.51	31.37	0.4196	1.35	0.2925	
3	WTG-31	Near	28.17	19.53	10.49	31.36	0.4286	1.35	0.2918	
3	WTG-26	Near	28.17	19.51	10.42	31.22	0.3108	1.35	0.2946	
3	WTG-39	Far	28.17	19.53	15.89	31.74	0.4347	1.43	0.3414	
3	WTG-37	Far	28.17	19.54	15.41	31.73	0.4562	1.42	0.3317	
3	WTG-31	Far	28.17	19.53	14.58	31.71	0.4304	1.42	0.3265	
3	WTG-26	Far	28.17	19.51	14.05	31.69	0.3323	1.41	0.3195	
4	WTG-41	Near	28.17	19.54	10.95	33.84	0.8101	1.39	0.4428	
4	WTG-43	Near	28.17	19.46	10.96	33.84	0.8714	1.39	0.4428	
4	WTG-50	Near	28.17	19.57	10.96	33.81	0.9301	1.39	0.4368	
4	WTG-48	Near	28.17	19.56	10.89	33.81	0.9303	1.39	0.4367	
4	WTG-41	Far	28.17	19.54	18.77	33.41	0.7321	1.53	0.6569	
4	WTG-43	Far	28.17	19.54	18.56	33.16	0.7325	1.53	0.6477	
4	WTG-50	Far	28.17	19.57	18.71	33.33	0.8101	1.55	0.6435	**Worst Case**
4	WTG-48	Far	28.17	19.57	18.7	33.51	0.8076	1.55	0.6434	



24.4kV MCOV ELB-35-600-ARSTR TOV Curves
1.70
1.60
1.50
1.40
1.30
1.20
1.10
kVMCOV (pu)
1.59
Feeder 4 - Simulation, 0.006, 1.55
1.50
Feeder 4 - Simulation, 0.016, 1.42
1.42
1.34
1.29
1.24
1.23
Feeder 4 - Simulation, 0.065, 1.15
0.001
0.010
0.100
1.000
10.000
100.000
1000.000
10000.000
Time (seconds)

This foregoing document was electronically filed with the Public Utilities

Commission of Ohio Docketing Information System on

11/1/2017 4:00:13 PM

in

Case No(s). 13-0197-EL-BGN, 16-1687-EL-BGA, 17-1099-EL-BGA

Summary: Notice of Update to September 1, 2017 Filing Regarding Compliance with Condition 6 – Drawings for Final Design Plan (Part 2 of 2) electronically filed by Mr. William V Vorys on behalf of Trishe Wind Ohio, LLC