Noise in the Wind

A Practical Approach to Mitigating Power Influence Related Noise Problems in Copper Telephone Cable Created by Wind Farm Collector Systems and the Affects of Stand Alone Wind Turbines on the Local Power Distribution System

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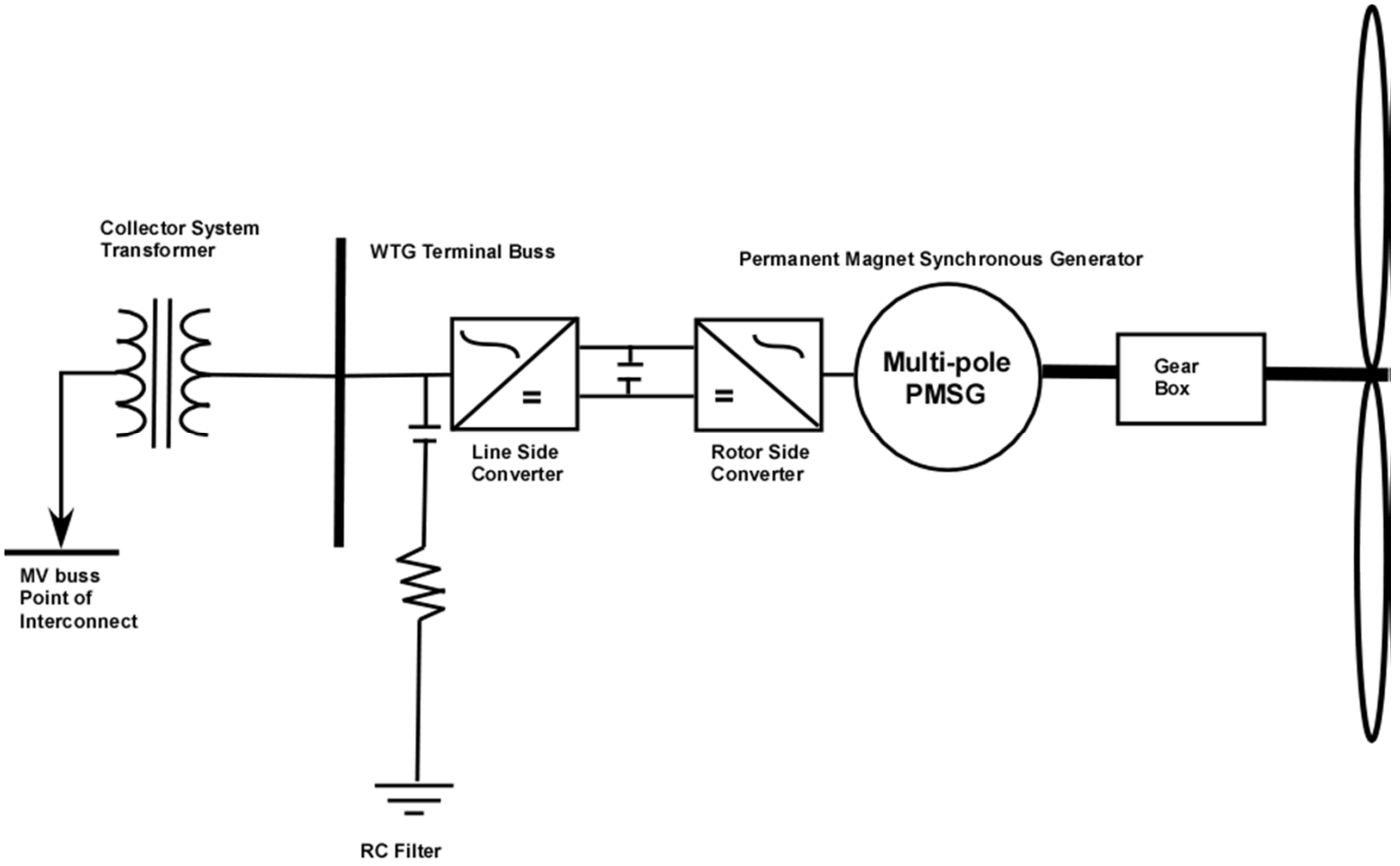
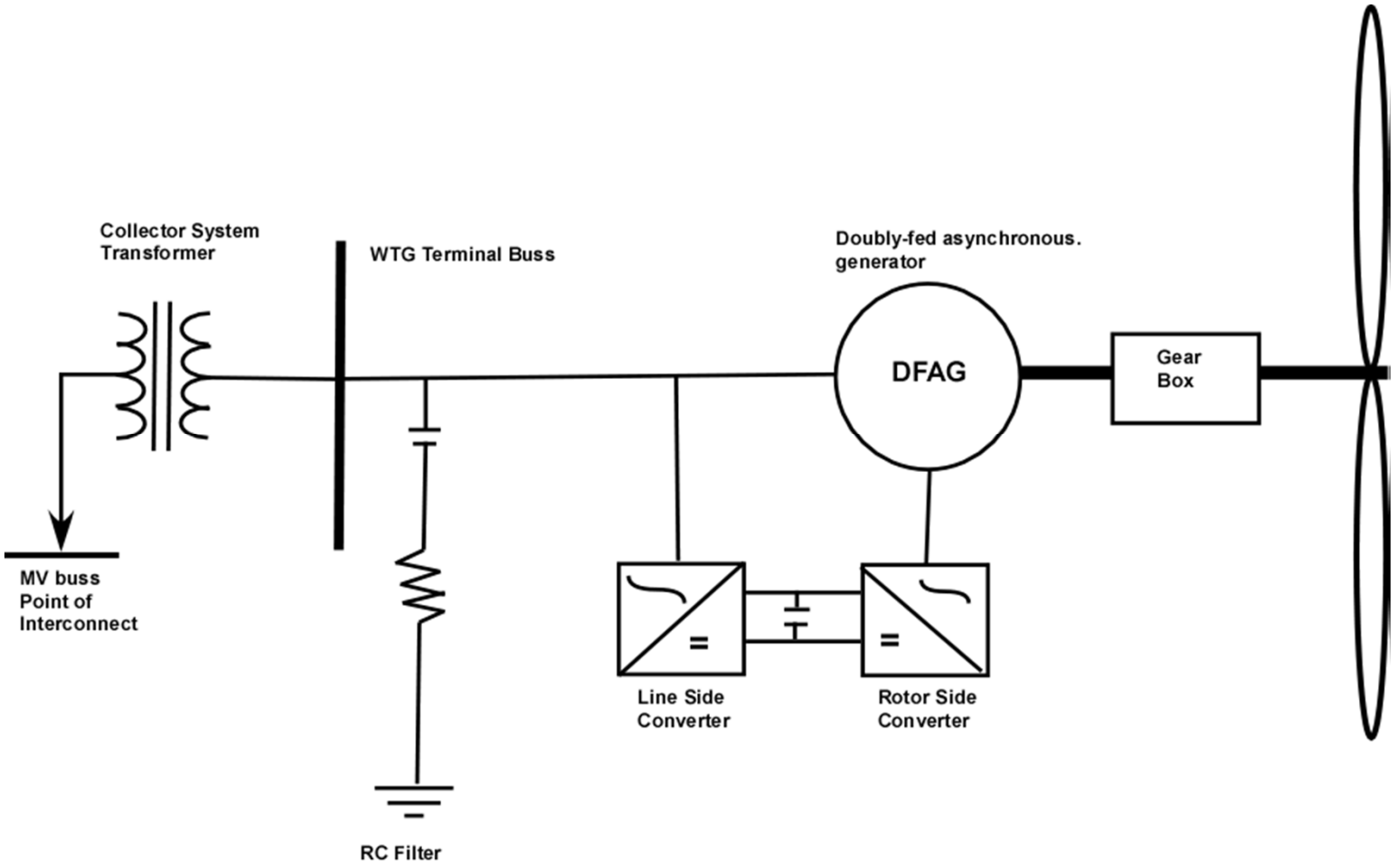
- Case 1- Induced Harmonics From Wind Farm Collector System
- Case 2- Induced Harmonics From a Wind Farm 420 Megawatt Transmission System Between the Wind Farm and Point of Interconnect.
- Case 3- The Affects of Stand Alone Wind Turbine Generators on the Local Power Distribution System That Appears to Cause System Resonance.

Basics of Wind Turbine Generators



Basics of Wind Turbine Generators



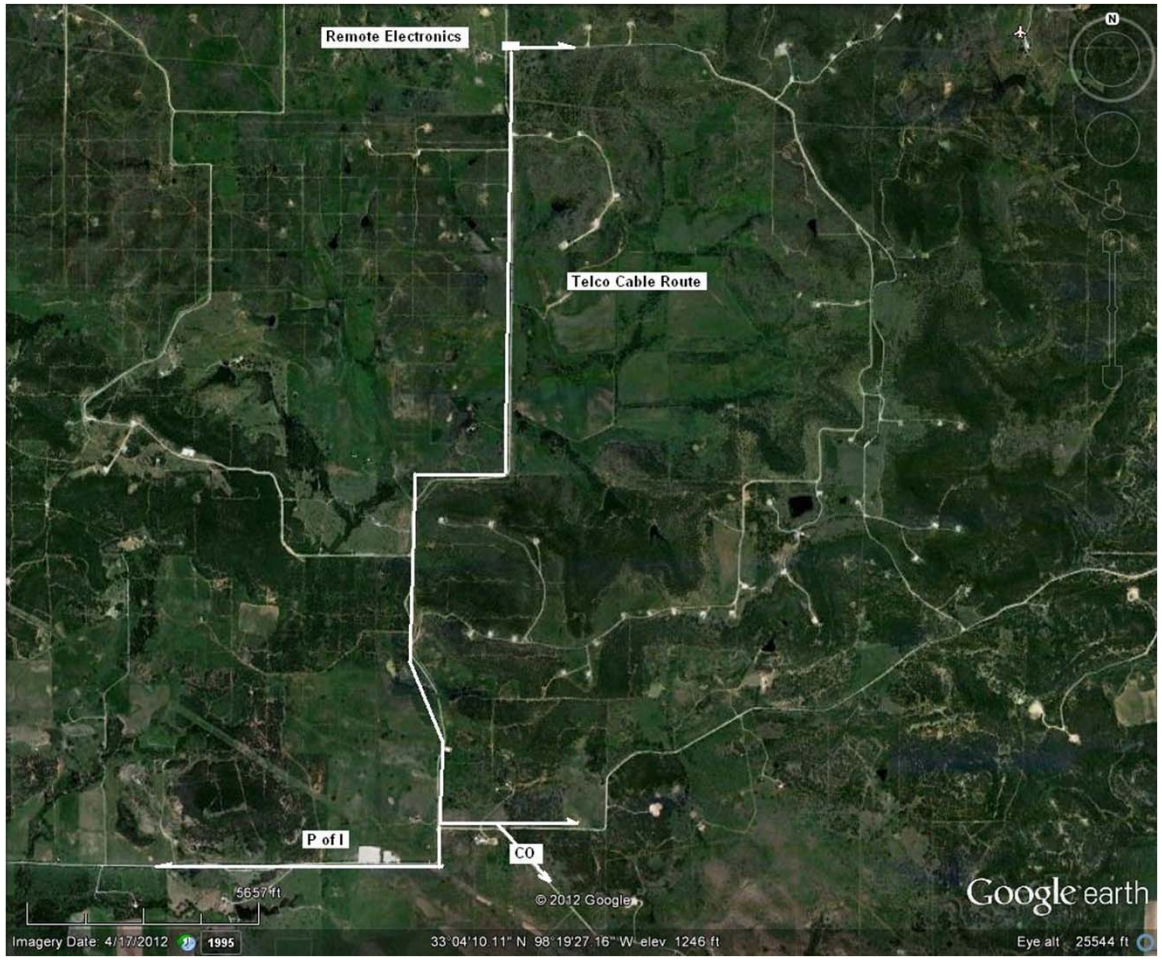
Basics of Wind Turbine Generators

Generator Manufacturers model harmonic distortion created by the WTG's and build filters to mitigate these harmonics.

Frequency	Harmonic Order	Magnitude, ZWTGN	Angle, ZWTGN
Hz	h	pu on 1.6MVA	Deg.
180	3	0.44	14.5
240	4	0.44	31.3
300	5	0.47	49.3
360	6	0.59	62.7
420	7	0.73	69.5
480	8	0.91	74.4
540	9	1.12	77.8
600	10	1.38	80.1
660	11	1.70	81.3
720	12	2.19	82.2
780	13	2.96	81.9
840	14	4.69	79.1
900	15	9.61	63.5
960	16	13.68	-23.2
1020	17	5.24	-62.2
1080	18	2.76	-68.9
1140	19	1.68	-68.7
1200	20	1.10	-65.2
1260	21	0.73	-58.2
1320	22	0.48	-45.8
1380	23	0.32	-22.6
1440	24	0.28	12.5
1500	25	0.34	40.2
1560	26	0.43	55.2
1620	27	0.53	63.8
1680	28	0.63	69.1
1740	29	0.72	72.6
1800	30	0.81	75.1
1860	31	0.90	76.9
1920	32	0.98	78.4
1980	33	1.07	79.5
2040	34	1.15	80.5
2100	35	1.22	81.2
2160	36	1.30	81.9
2220	37	1.37	82.4
2280	38	1.44	82.9
2340	39	1.51	83.3
2400	40	1.58	83.6
2460	41	1.65	84.0
2520	42	1.72	84.2
2580	43	1.79	84.5
2640	44	1.85	84.7
2700	45	1.92	84.9
2760	46	1.98	85.1
2820	47	2.04	85.2
2880	48	2.11	85.4
2940	49	2.17	85.5
3000	50	2.23	85.7

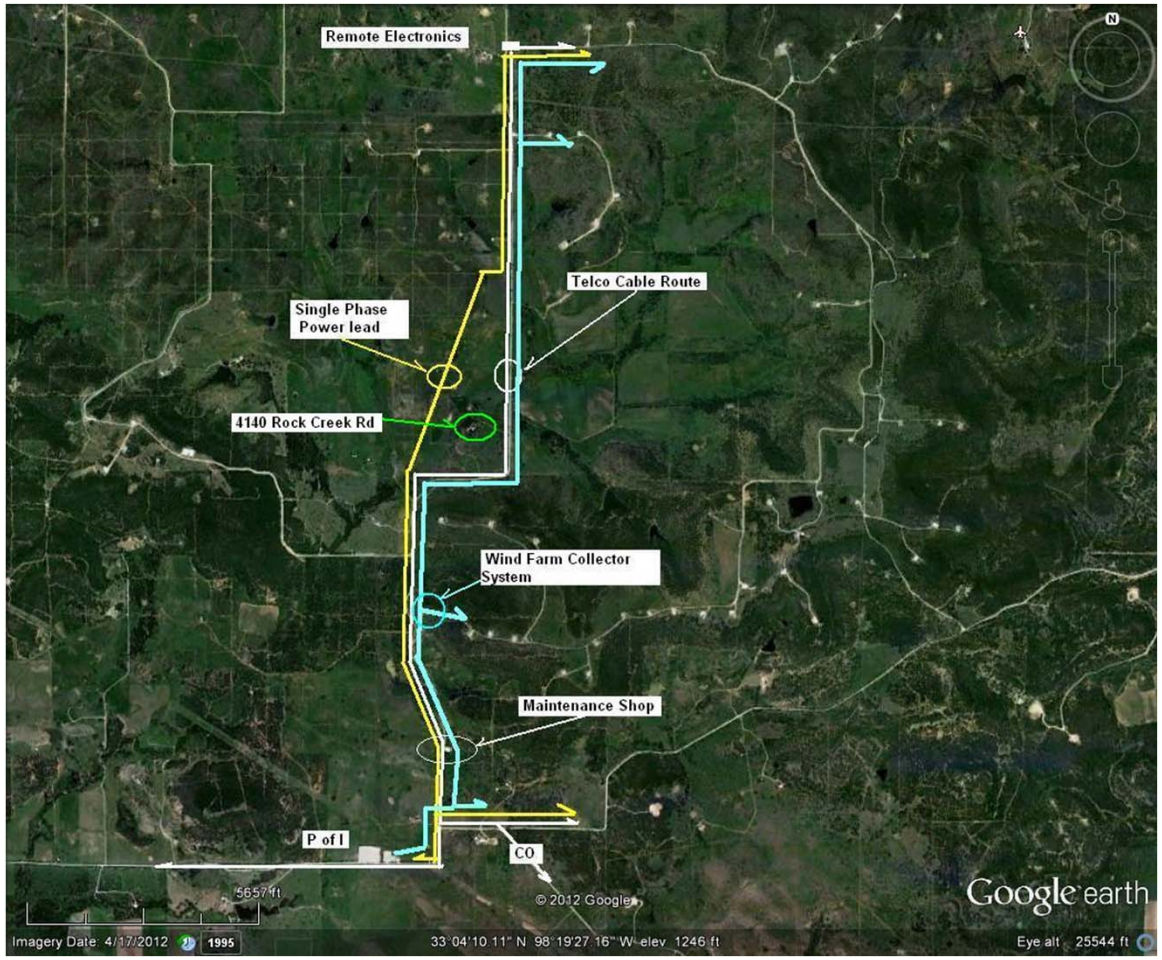
CASE 1- GRAFORD, TX WINDFARM

Area of exposure = paralleling four miles of 3 phase collector system



CASE 1- GRAFORD, TX WINDFARM

Exposure to “local” single phase power and three phase “delta” collector system



CASE 1- GRAFORD, TX WINDFARM

Initial test results- high Power Influence and Metallic Noise with no shield current present. (location one)

NOISE MITIGATION WORK SHEET

	HSR Test Preparation	Date:	10/4/2011 10/5/2011
X	Noise Analyzation	Central Office:	Graford, TX
	Trouble Shooting	City:	Graford TX
	Technicians:	Dan/ Mark	

	965 DSP or Equivalent							Spectrum Analyzer/ Mitigater			Fluke ***
								PI / Noise to ground		Metallic Noise	Sheath current
Location	VDC	VAC	Ma	Loss	Noise	PI	Long. Bal	Flat	CMSG	CMSG	Amps
	45.1	3.9		-5	37	>100		103.4	102.3	36.8	0
PUC complaint @ 4140 Rock Creek Rd											

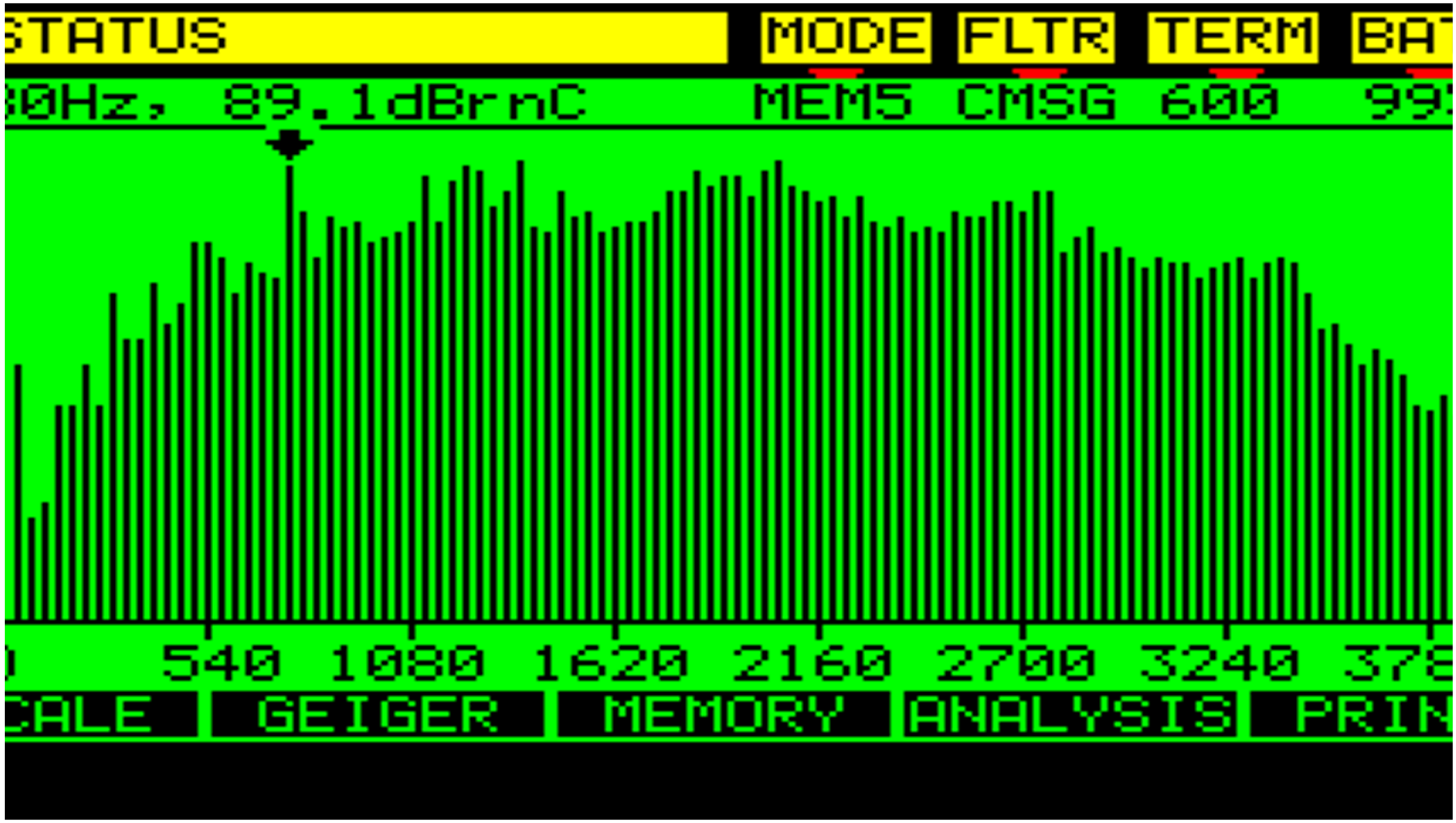
CASE 1- GRAFORD, TX WINDFARM

Initial test results for location two.

NOISE MITIGATION WORK SHEET

	HSR Test Preparation		Date:	10/4/2011	10/5/2011
X	Noise Analyzation		Central Office:	Graford, TX	
	Trouble Shooting		City:	Graford TX	
	Technicians:	Dan/ Mark			

	965 DSP or Equivalent							Spectrum Analyzer/ Mitigater			Fluke ***
								PI / Noise to ground		Metallic Noise	Sheath current
Location	VDC	VAC	Ma	Loss	Noise	PI	Long. Bal	Flat	CMSG	CMSG	Amps
	45.1			6.4	>50	>100					0
					38	>100					
Maint shop					45	>100					
@ 6005											
Rock Creek											
Rd											



CASE 1- GRAFORD, TX WINDFARM

Predominant harmonic is the 13th, (780 Hz) but there are also high 19th and 23rd harmonics. This has some, but not all, of the characteristics of a 12 pulse rectifier.

No.	FREQ	Volts
1	60	0.00327
3*	180	0.00231
5	300	0.04662
7	420	0.09302
9*	540	0.12855
11	660	0.03420
13	**780**	**0.86911**
15*	900	0.15616
17	1020	0.08493
19	**1140**	**0.77460**
21*	1260	0.19660
23	**1380**	**0.59371**
25	1500	0.33005
27*	1620	0.13617
29	**1740**	**0.63691**
31	1860	0.37938
33*	1980	0.29112
35	**2100**	**0.69755**
37	2220	0.17725
39*	2340	0.10692
41	2460	0.19457
43	2580	0.14591

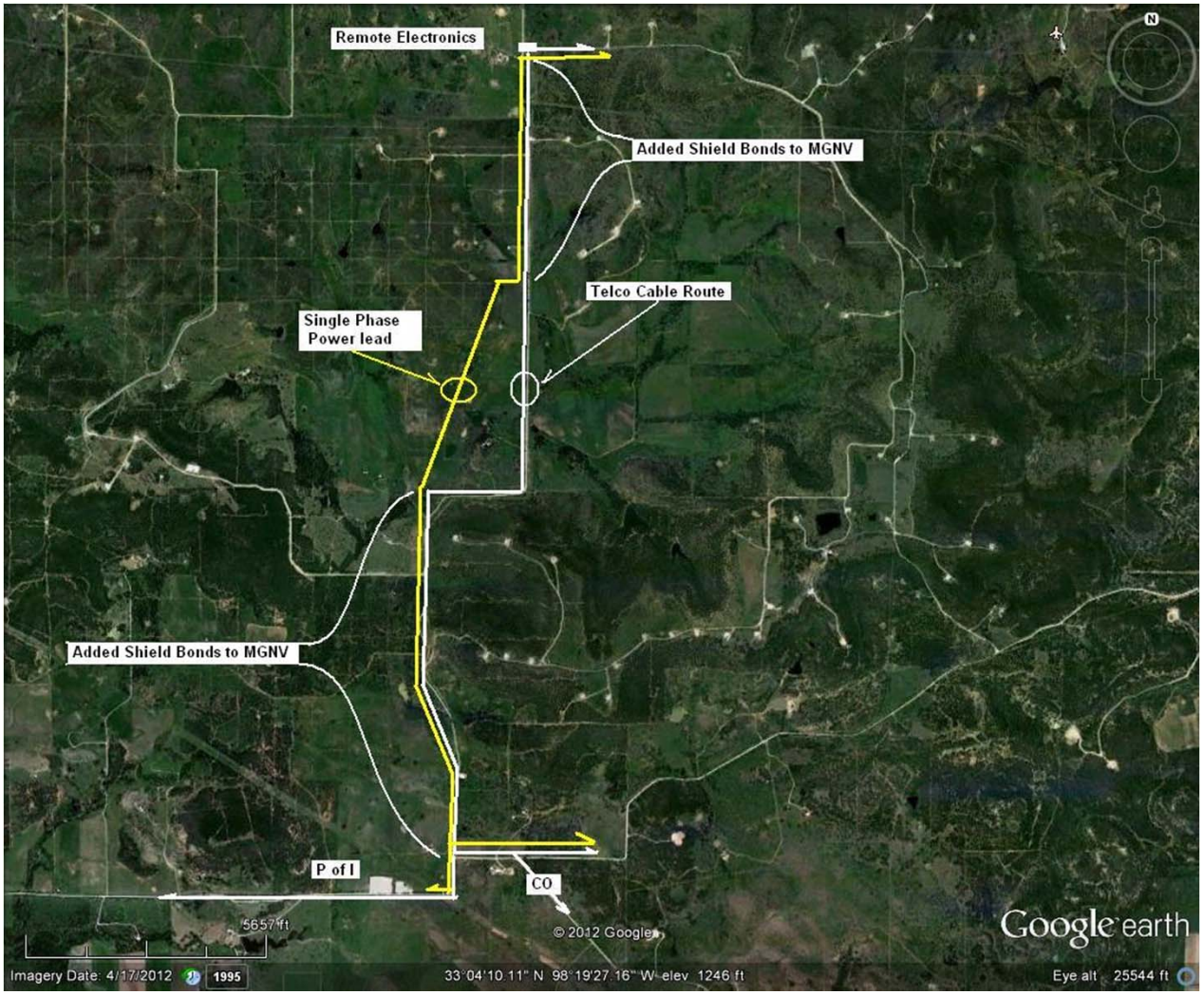
*Odd Tipple

CASE 1- GRAFORD, TX WINDFARM

Harmonic voltage readings. Highest voltages at the 13th and 19th harmonic. This , again, has similarities to a 12 pulse rectifier. In wind farm collector systems, I have found the 13th harmonic consistently to be the primary offending harmonic.

CASE 1- GRAFORD, TX WINDFARM

Start with the basics- Bonding the cable shield to the Multi-Grounded Neutral Verticals (MGNV) to provide a low impedance path for shield current.



CASE 1- GRAFORD, TX WINDFARM

What NOT to bond to! Collector system is a three phase delta power system with an intersystem bonding/ static wire which is bonded to a ground electrode at every pole.

CASE 1- GRAFORD, TX WINDFARM

Test results, location 1, with ½ amp of shield current within the first mile of cable.

NOISE MITIGATION WORK SHEET

	HSR Test Preparation	Date:	10/4/2011 10/5/2011
X	Noise Analyzation	Central Office:	Graford, TX
	Trouble Shooting	City:	Graford TX
	Technicians:	Dan/ Mark	

	965 DSP or Equivalent							Spectrum Analyzer/ Mitigater			Fluke ***
								PI / Noise to ground		Metallic Noise	Sheath current
Location	VDC	VAC	Ma	Loss	Noise	PI	Long. Bal	Flat	CMSG	CMSG	Amps
	45.1	3.9		-5	37	>100		103.4	102.3	36.8	0
PUC complaint @ 4140 Rock Creek Rd											
					17	85					0.5
4140 Rock creek Rd w/ sheild current											

CASE 1- GRAFORD, TX WINDFARM

Test results, location 2, with ½ amp of shield current within the first mile of cable

NOISE MITIGATION WORK SHEET

	HSR Test Preparation		Date:	10/4/2011	10/5/2011
X	Noise Analyzation		Central Office:	Graford, TX	
	Trouble Shooting		City:	Graford TX	
	Technicians:	Dan/ Mark			

	965 DSP or Equivalent							Spectrum Analyzer/ Mitigater			Fluke ***
								PI / Noise to ground		Metallic Noise	Sheath current
Location	VDC	VAC	Ma	Loss	Noise	PI	Long. Bal	Flat	CMSG	CMSG	Amps
	45.1			6.4	>50	>100					0
					38	>100					
Maint shop					45	>100					
@ 6005											
Rock Creek											
Rd											
					40	90					0.5
					28	90					
6005 Rock					30	90					
Creek Rd											
W/ sheild											
current											

CASE 1- GRAFORD, TX WINDFARM

- Case 1 Conclusion-
  - Harmonics induced from a balanced 3-phase delta collector system can be effectively cancelled if shield current is applied to the telephone cable through bonding to a low impedance path such as the MGNV's.

Case 2- Manly IA

Parallel exposure to 420 megawatt transmission line between the Crystal lake Iowa Wind Farm and the Point of Interconnect. Verified with spectrum analyzer -13th harmonic predominant.

Case 2- Manly IA

Looking east on 340th Street, transmission line on right, buried phone cable on left
No “local” power distribution system to provide MGN bonding.

Case 2- Manly IA

"State of the Art" telephone cable terminal

Case 2- Manly IA

Initial test results

Approximately 9 Volts AC induced in 8/10 of a mile of exposure. High Power Influence and Metallic Noise readings on customer lines at the east end of exposure.

	HSR Test Preparation					Date:	3/29/2012			
X	Noise Analyzation					Central Office:	Manly, IA			
	Trouble Shooting					City:	Manly, IA			
	Technicians: Dan, Brad, Curt									
	965 DSP or Equivalent						Spectrum Analyzer/ Mitigater			Fluke ***
							PI / Noise to ground		Metallic Noise	Sheath current
Location	VDC	VAC	Ma	Loss	Noise	PI	Bal	Flat	CMSG	CMSG	Amps
Corner Nettle Rd and 340th St/ start of exposure											
		2.1			16	79	63				0
14737 340th Street/ no shield current											
	terminal	11.4			34	95	61				0
	214-30	11.2			25	95	70				0
		11.3			24	95	71				0

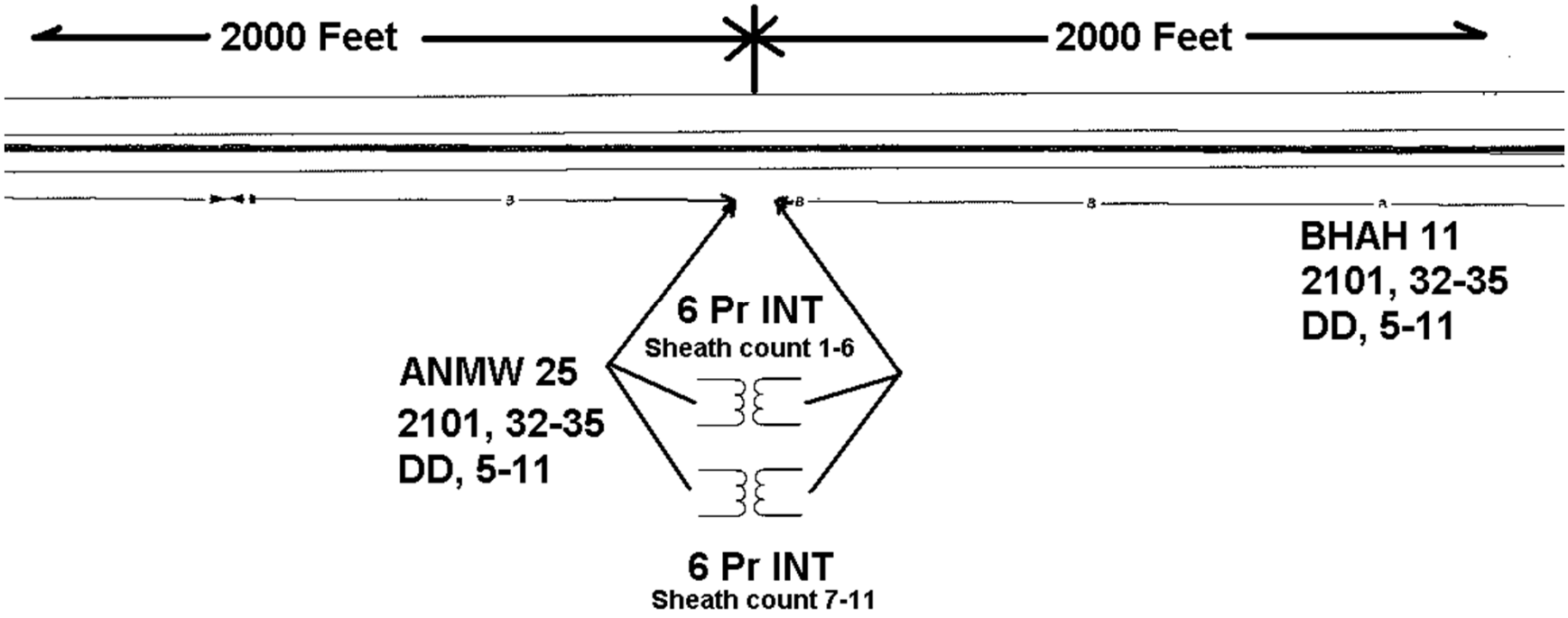
Case 2- Manly IA

Test results after Induction Neutralizing Transformer applied to cable pairs. Only 3 pairs where treated and the INT was applied at the “dead end” terminal, not in the electrical center of exposure.

	HSR Test Preparation						Date:		3/29/2012		
X	Noise Analyzation					Central Office:			Manly, IA		
	Trouble Shooting						City:		Manly, IA		
		Technicians: Dan, Brad, Curt									
	965 DSP or Equivalent							Spectrum Analyzer/ Mitigater			Fluke ***
								PI / Noise to ground		Metallic Noise	Sheath current
Location	VDC	VAC	Ma	Loss	Noise	PI	Bal	Flat	CMSG	CMSG	Amps
Corner Nettle Rd and 340th St/ start of exposure		2.1			16	79	63				0
14737 340th Street/ no shield current	terminal	11.4			34	95	61				0
	214-30	11.2			25	95	70				0
		11.3			24	95	71				0
14737 340th Street/ with INT	terminal	8.2			20	86	66				0
	214-30	8.1			19	86	67				0
		8.2			24	86	62				0

Case 2- Manly IA

Recommendation to place 2- 6 pair INT's included cable map drawing example. When treating a cable for high induced AC, the entire cable must be treated for best results.



Case 2- Manly IA

Recommendation to place 2- 6 pair INT's including exciter pair detail

- Splicing detail included remark
  - "Sheath count Pairs 6 and 11 must be grounded at both ends of this exposure and tagged {**DO NOT DISCONNECT, I.N.T. EXCITER PAIR**.}"

Case 3- Stand Alone Wind Turbine Generator- Northwood IA

"When ever that wind turbine is turning, there is a loud buzz on my phone line"
(Quoted from the customers letter of complaint to the Iowa Utility Board)

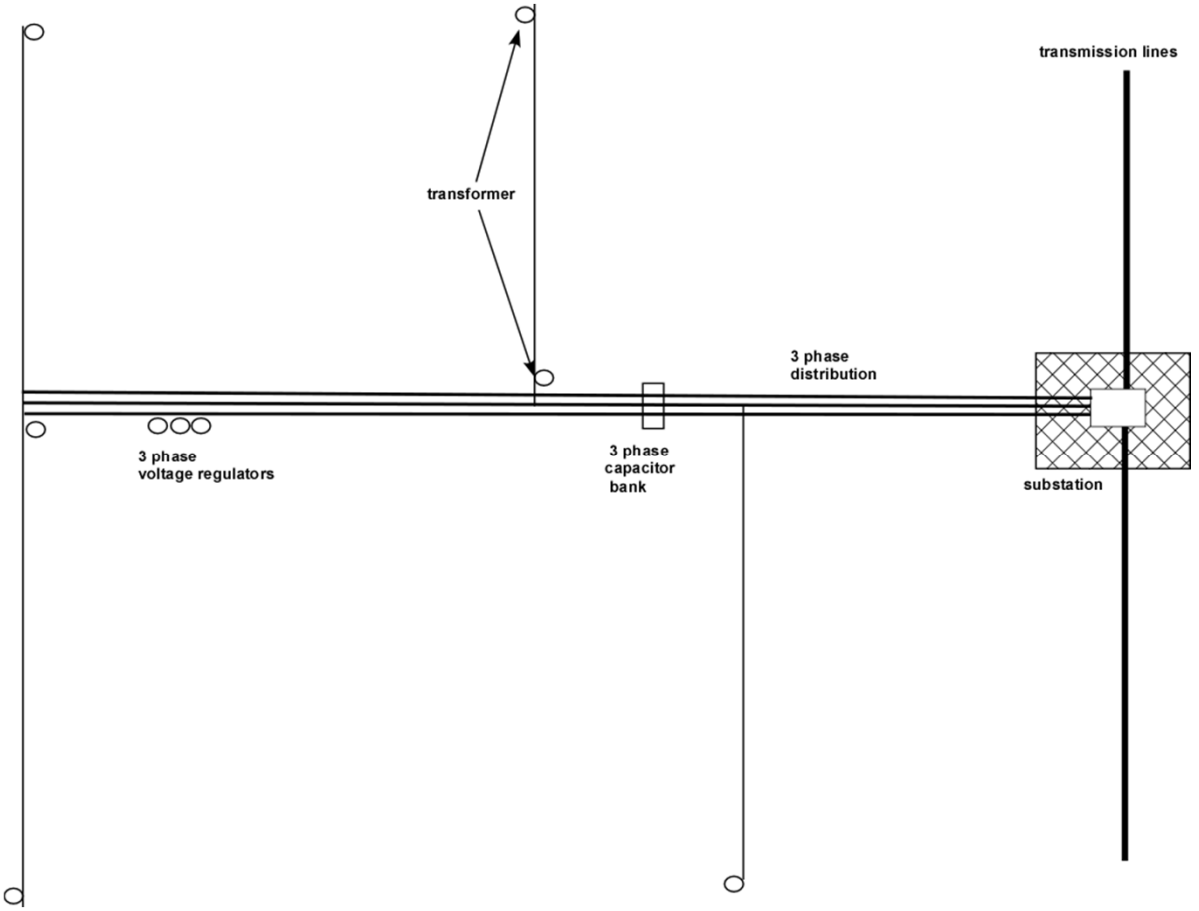
Case 3- SAWTG- Northwood IA

Customers relationship to SAWTG

Case 3- SAWTG- Northwood IA

Very basic power distribution system .

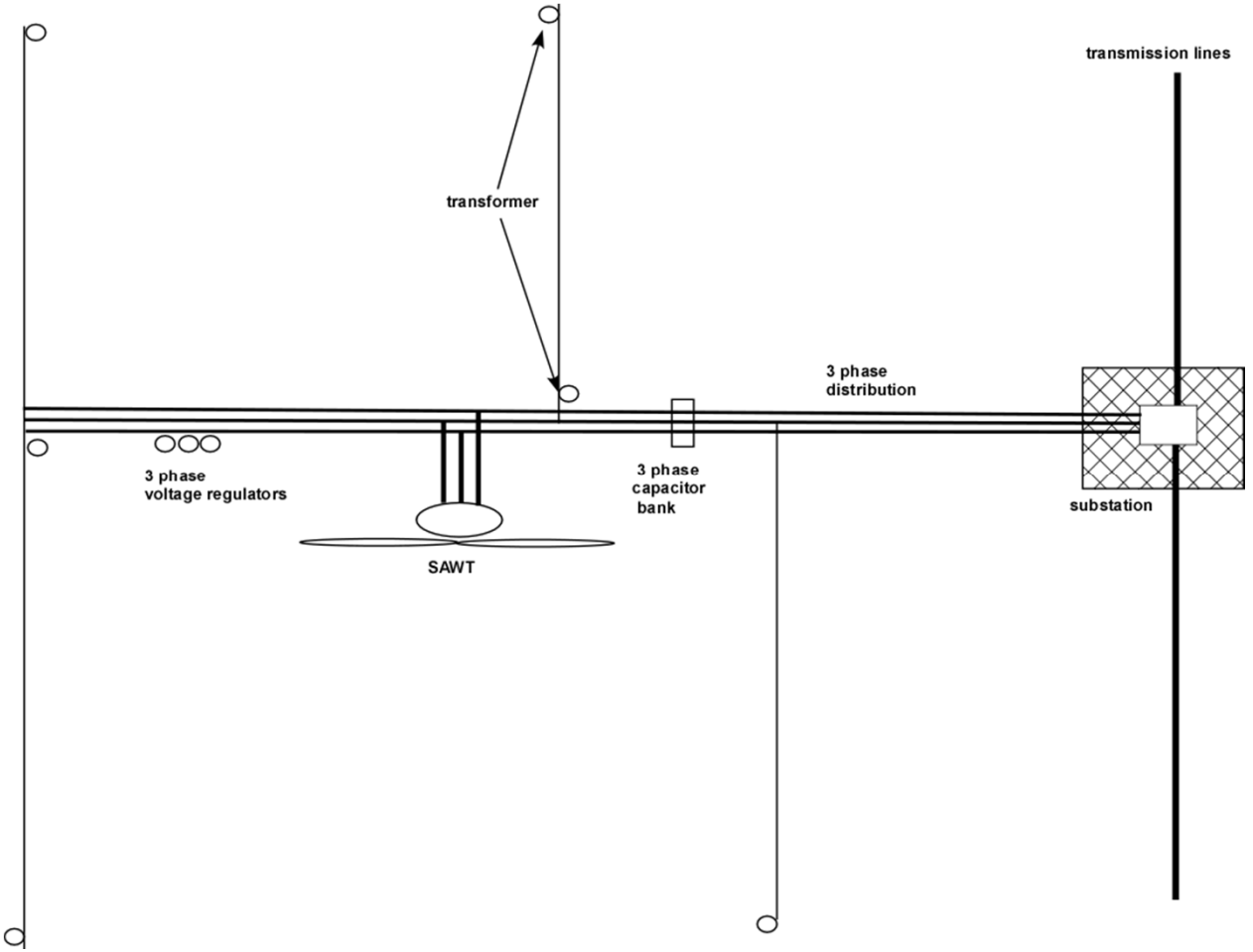
By design, the substation is the “power source” .



Case 3- SAWTG- Northwood IA

Very basic power distribution system .

When a secondary “power source” (SAWTG) is added, it alters the relationship of power system components to each other and the substation which seems to create system resonance. In these cases the 9th Harmonic (540 Hz) is predominant.



Case 3- SAWTG- Northwood IA

Three voltage regulators at the Point of Interconnect.

Case 3- SAWTG- Northwood IA

Test results taken in November 2011 made by field technician.

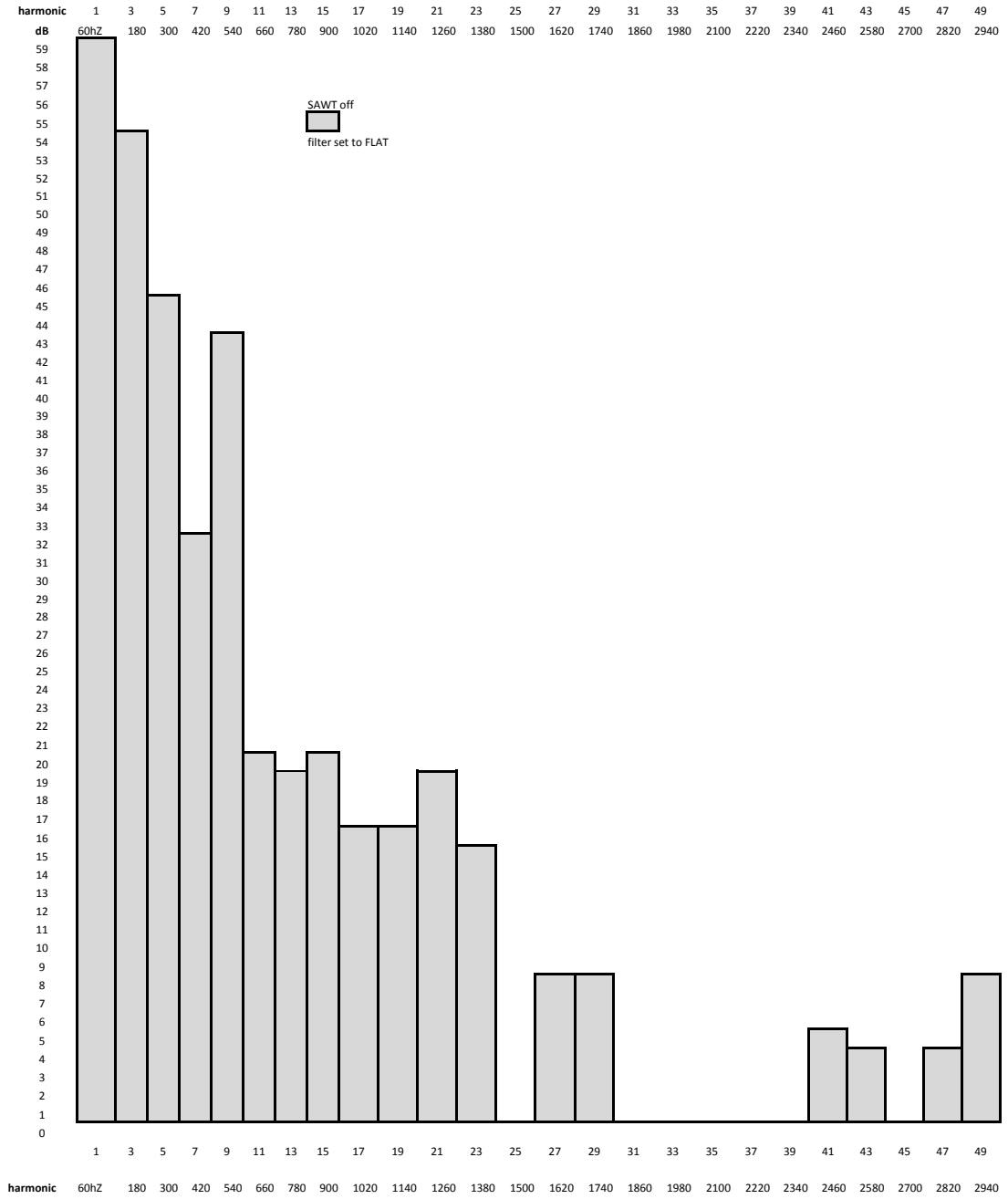
NOISE MITIGATION WORK SHEET

	HSR Test Preparation	Date:	Nov-11
X	Noise Analyzation	Central Office:	Manly, IA
	Trouble Shooting	City:	Manly, IA
	Technicians:	Tim Hoheisel field tech/ Dan Ashton tech support	

	965 DSP or Equivalent							Spectrum Analyzer/ Mitigater			Fluke ***
								PI / Noise to ground		Metallic Noise	Sheath current
Location	VDC	VAC	Ma	Loss	Noise	PI	Balance	Flat	CMSG	CMSG	Amps
Northwood SAWT taken from customer house											
	SAWT on	3.8	24	6.9	40	90	51				
	SAWT off			5.4	22	78	56				

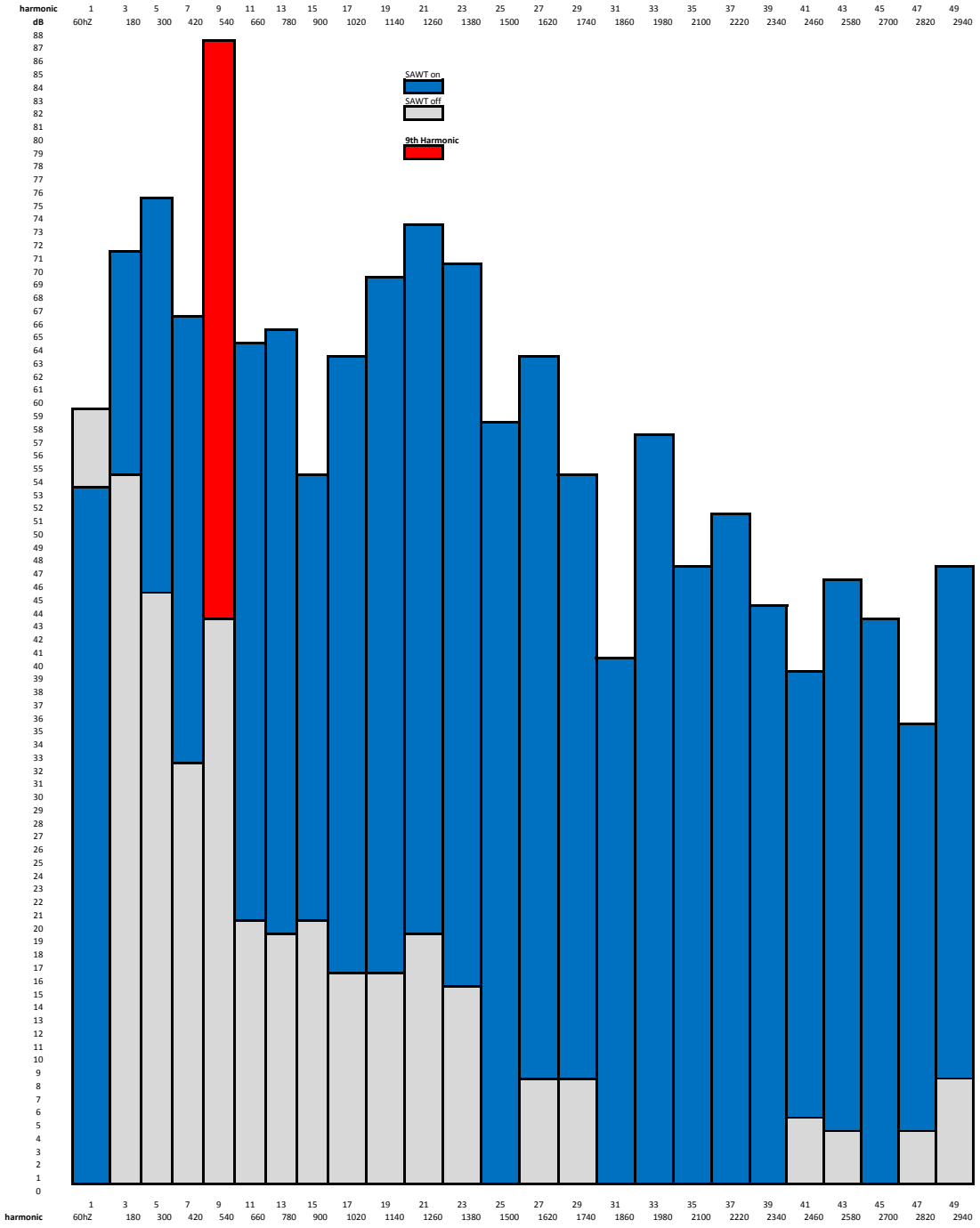
Case 3- SAWTG- Northwood IA

Harmonic graph with cable pair data taken with a spectrum analyzer and FLAT filtered from customers serving terminal. Stand alone wind turbine generator is <u>OFF</u> line.



Case 3- SAWTG- Northwood IA

Harmonic graph with cable pair data taken with a spectrum analyzer and FLAT filtered from customers serving terminal. Stand alone wind turbine generator is ON line.



Case 3- SAWTG- Northwood IA

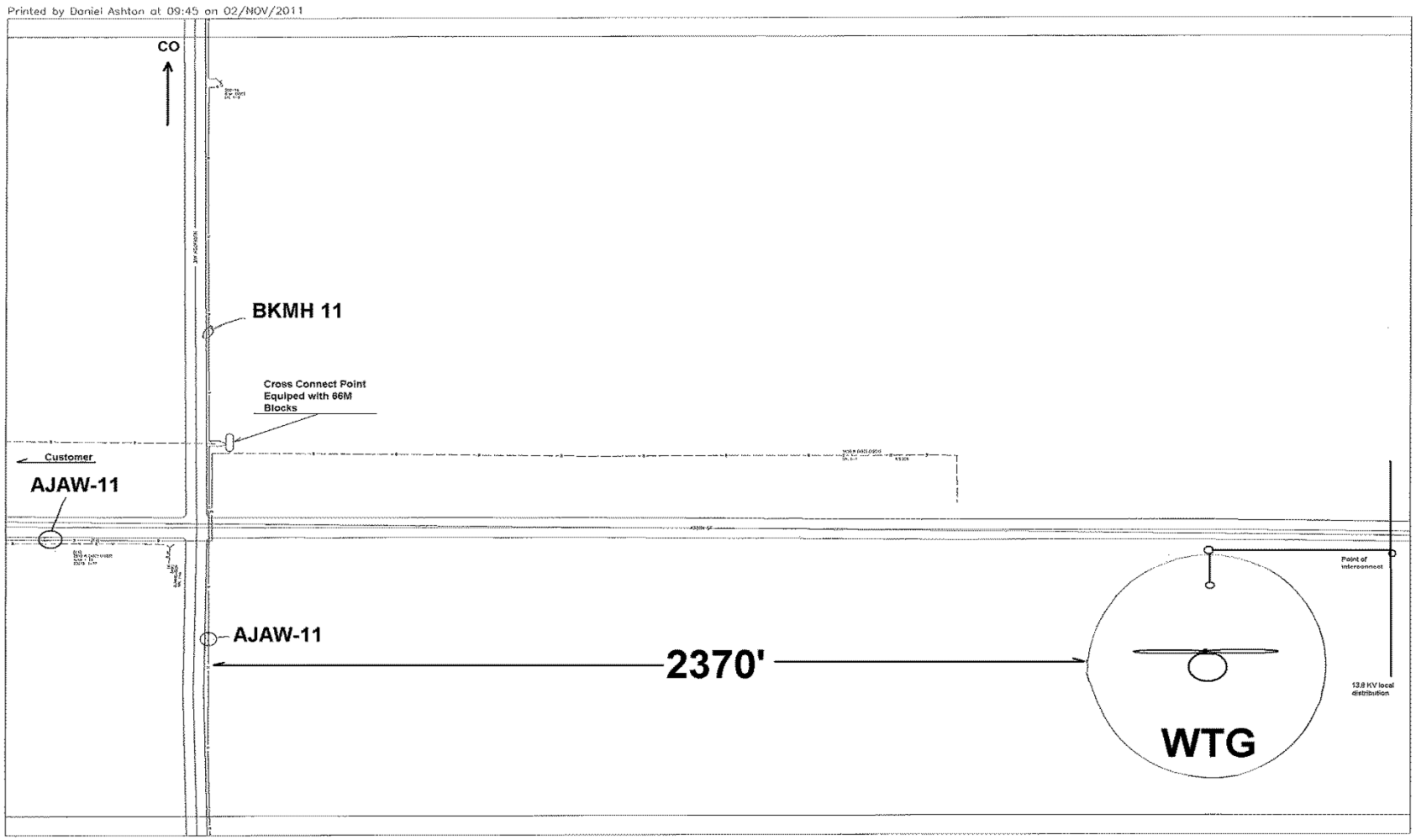
Additional data from “Contel” chart

Top 5 possible sources of harmonics

- 83% Probability- Defective Step Down Transformer
- 80% Probability- Grounded transformer aggravated by grounded capacitors
- 77% Probability- Open Cable Shield
- 72% Probability- AC Side of 12 pulse/ multiphase Rectifier
- 70% Probability- defective or over excited transformers

Case 3- SAWTG- Northwood IA

Mean while, back on 430th Street- cable records at 1st intersection ¾ of a mile east of customer with I U B Complaint.



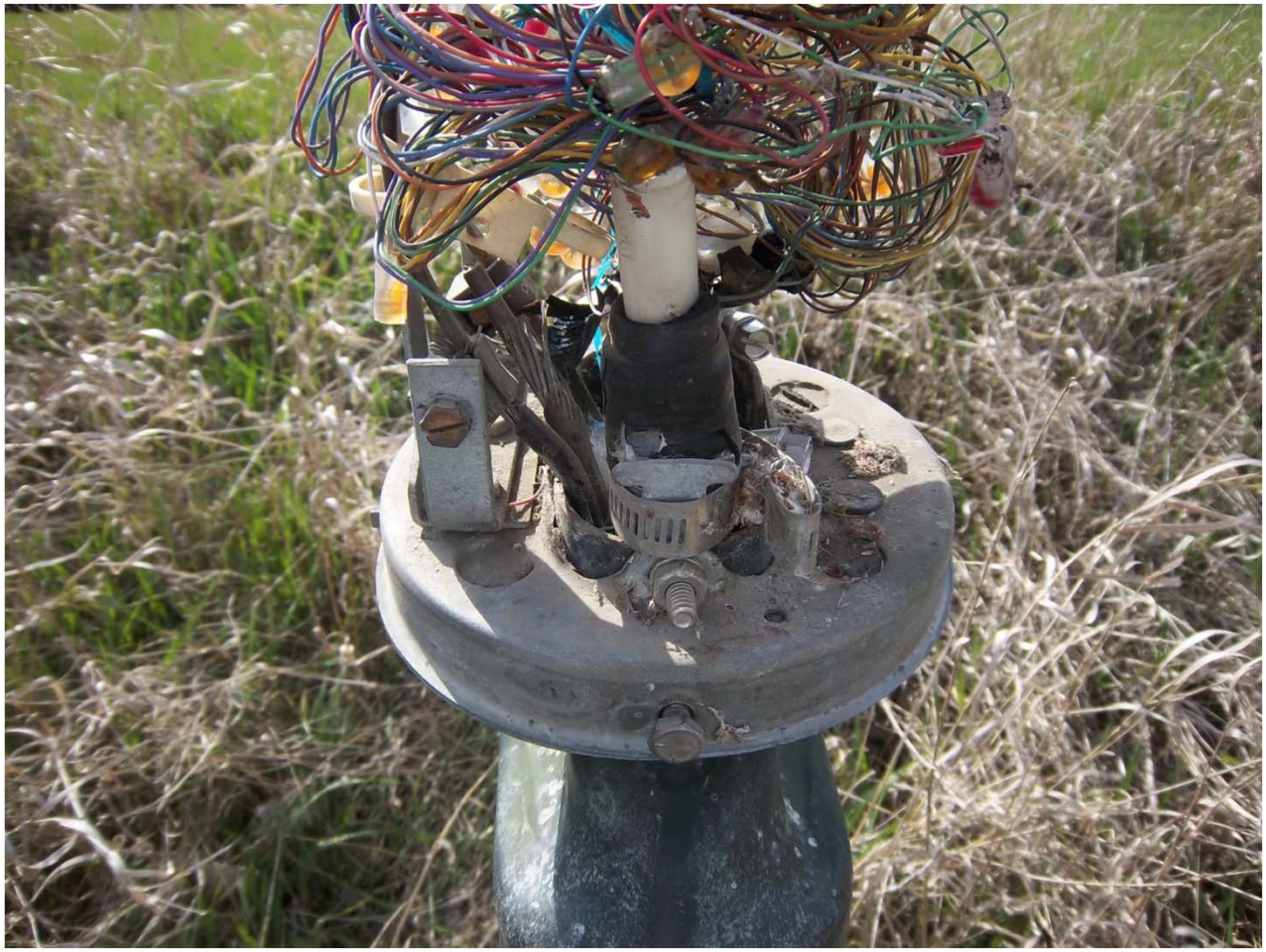
Case 3- SAWTG- Northwood IA

Mean while, back on 430th Street- a portion of the report to the IUB

- "We proceeded to the telephone serving terminal for the customer to take noise and power influence measurements. (During all of the testing process the SAWTG was operational) Power Influence measured **92 dBrnc**; Metallic Noise measured **41 dBrnc** which gave a **balance of 51**. This was an indicator that the customer's noise problems were caused by a defective Centurylink cable facility and not by harmonics from the SAWTG."
- "We moved 3/4 mile east to the Centurylink access point (200.15) at the corner of 430th St. and Nuthatch Ave. Measurements there were; PI **92**, Noise- **28**, Balance **64** *with the customer's cable pair disconnected toward the customer*. We tested other pairs in the cable towards the customer's home and found 2 to 10 volts DC battery on every cable pair. These readings provide evidence of a wet buried splice in "jelly" filled cable."

Case 3- SAWTG- Northwood IA

“I’m sure we’ve bonded the cable at every pedestal !!” No shield current here.



Case 3- SAWTG- Northwood IA

Location on 430th Street where 100 feet of cable was replace due to the damage of the existing cable and two wet cable splices.

Case 3- SAWTG- Northwood IA

Mean while, back on 430th Street- a portion of the conclusion in my report to the IUB

- "After testing the spare cable pairs in the cable that runs south on Nuthatch Ave, 1 pair was found with no physical trouble and good longitudinal balance to use for the customers service. By cutting to this pair, we reduced the noise at the customer's house from 42 to 30 dBrnc. The local Centurylink cable repairman found several points of damage in the cable on 430th street along with two wet splices. After all cable repairs were made and *(temporary*)*bonding and grounding work completed, we where able to measure ½ to ¾ amps of shield current and the final test results at the customers house were- Power Influence = **82dB**, Metallic Noise = **20 dB**, balance = **62**."

  * AT locations where the MGNV's where across the road from Centurylink cable facilities, 6 pair aerial service wires where used to cross the road for bonding purposes until solid #6 AWG copper wire could be trenched across the roads as a permanent bonding conductor.

Case 3- SAWTG- Northwood IA

- Case 3 Conclusions
  - Copper cable pair issues not withstanding, by applying shield current to the copper cable feeding this customer, we where able to decrease Power Influence and Metallic Noise by 8 dBrnc.
  - Additional cable shield and MGNV bonding work should have decreased these numbers even more.
  - The evidence shows that there is a significant increase in harmonics, especially the 9^{th} harmonic, which suggests a power system resonance caused by a reaction of the power distribution system and the additional power from the stand alone wind turbine generators.
  - Further studies will be necessary to better understand the over all affects of SAWTG's on the local power distribution systems and the subsequent affects on copper telecommunication cable.

Noise in the Wind

FINAL THOUGHTS

- Alternate forms of power generation are frequently being added to the national and local power grids.
- Each site may create challenges specific to the telephone cable facilities in and around these power generation facilities.
- Focused attention to the time tested basics of noise mitigation should always be used before any focus on harmonics.
- The majority of the noise and power influence problems caused by these sites can be resolved using these basic techniques.
- Additional testing and analysis must continue to better understand the full extent of the cause and affect of these alternate forms of power generation on the power system and copper telephone facilities.

Questions ??