

Engineering Computations for Generator Maintenance Engineering

(PART II) – 2021 IRIS Rotating Machines Conference



Introduction



- Recently joined BC Hydro
- 18 Years at Manitoba Hydro
- Engineering and management
- Background in hydro generator P&C
- Career focus on generator maintenance

If you didn't see it, you didn't know you could do it.



PART II ?

Where is PART I ?



IEEE PES MEETING – JAN 2013
Practical Engineering Methods
for Generator Maintenance & Repair

Eric See-Toh, B.Sc. EE, P.Eng



“Take what you want, eat what you take”

in terms of data management & resources,

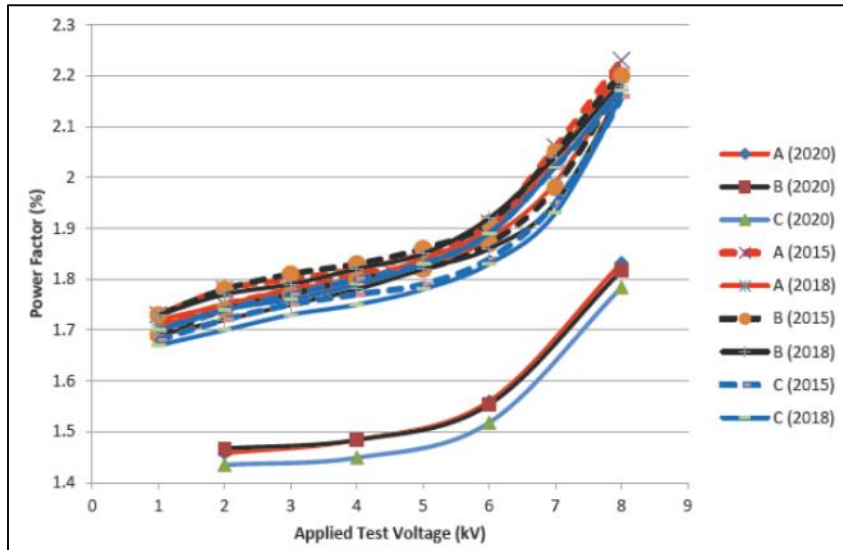
“if you don't know what to do with the data, don't waste everyone's time doing the test”



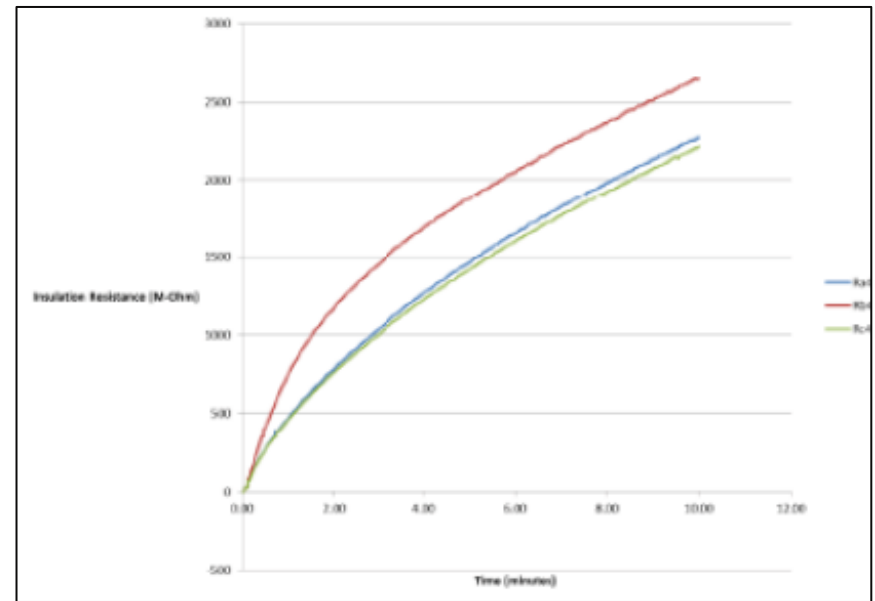
Typical Applications

PLOTTING BASIC TEST DATA, START WITH THIS.

Power Factor Tip Up Trends




PI Charge Curve



Spreadsheets: Stator Coil Bypass Phase Angle Calculation

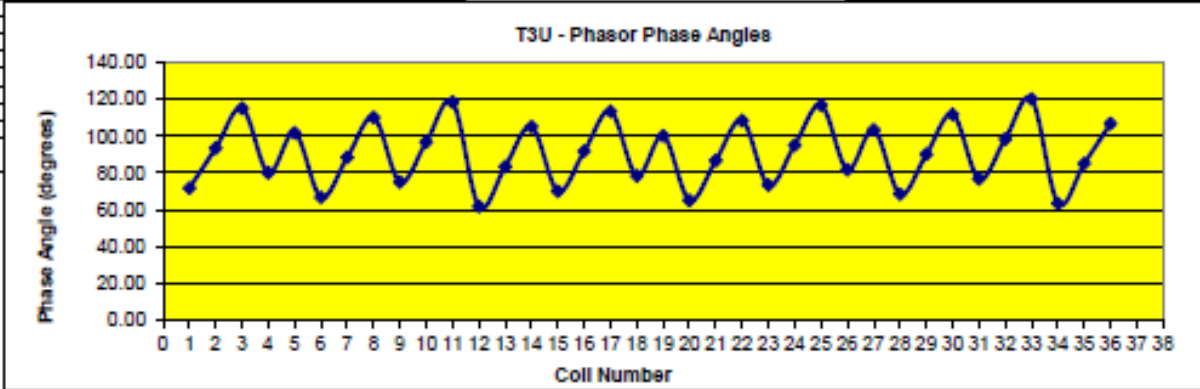
BASIC SPREADSHEETS TO LAYOUT A COMPLEX SOLUTION

Procedure	Performed By	Date
Identify and prepare jumper 70F-61B for isolation. Cover and tape all neighbouring jumpers and end-arms.		
		
Isolate pole jumper 70F-61B.		
The coil jumper is suspected to be soldered with low-temperature materials. Remove and clean the joint section, swear the soldered strand connections.		
Ensure a non-impacting cutting tool is used. Sawzall and reciprocating equipment is prohibited. High speed cutters with small diameter end-mills are preferred.		

T3 Downstream									
Pole Group	Slot #	Slot #	Angle	Slot #	Slot #	Angle	Slot #	Slot #	Angle
1	305b	304	59	334b	330b	36	303b	307b	15
2	303b	348b	68	351b	345b	45	300b	344b	23
3	300b	363b	53	307b	361b	31			
4	305b	372b	61	364b	371b	40	302b	377b	18
5	402b	398b	70	401b	395b	48	400b	394b	26
6	412b	413b	58	417b	411b	35	418b	415b	13
7	1b	408b	65	1b	420b	43	1b	421b	21
8	15b	13b	51	18b	15b	30			
9	34b	34b	66	35b	29b	34	34b	21b	16
10	53b	47b	68	52b	48b	46	51b	45b	25
11	65b	63b	55	68b	65b	33	67b	64b	11
12	80b	80b	63	85b	79b	41	84b	78b	20
13	102b	94b	50	101b	95b	28			
Total Coils	36								

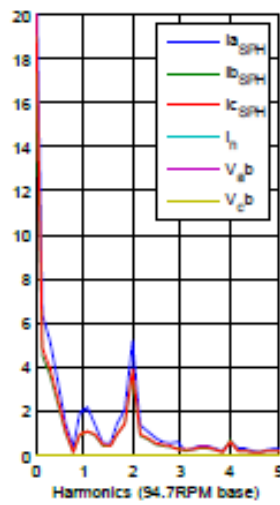
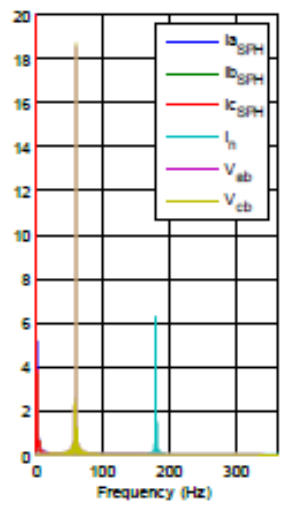
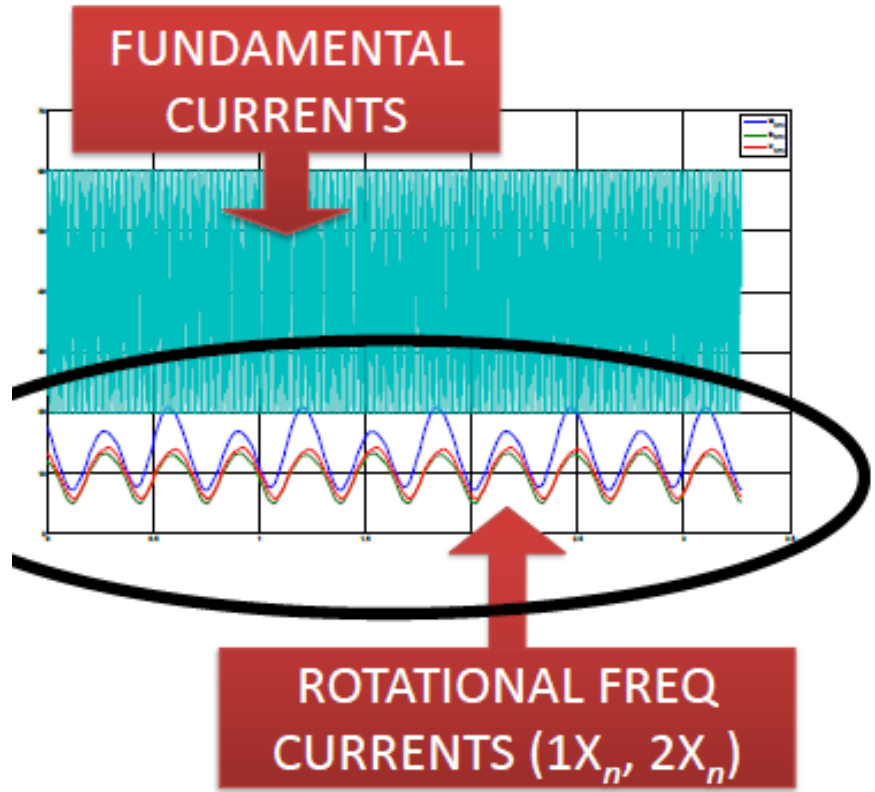
T3 Upstream										
Pole Group	Slot #	Slot #	Angle	Slot #	Slot #	Angle	Slot #	Slot #	Angle	
1	310b	304	238	306	303b	215	308b	302b	193	
2	394b	388b	248	393b	387b	221	392b	386b	208	
3	277b	271b	241	278b	270b	220	275b	269b	198	
4	260b	254b	233	259b	253b	211				
							227	242b	236b	200
							218	225b	219b	187
							208			
							221	192b	186b	200
							213	175b	169b	191
							226	158b	152b	202
							218	143b	137b	198
							210			
							223	126b	120b	201

Pole Group	Slot #	Slot #	Angle	Slot #	Slot #	Angle	Slot #	Slot #	Angle
1	110b	113	50	118b	115	34	117b	111b	15
2	130b	130	68	132b	129	45	134b	128b	23
3	152b	148	53	151b	145b	31			
4	168b	163	61	168b	163b	40	167b	161b	18
5	184b	182	70	182b	179b	48	184b	178b	26
6									
7									
8									
9									
10									
11									
12									
13									
Total Coils	36								



FFT: Split Phase Current – Identification of Oblong Rotor

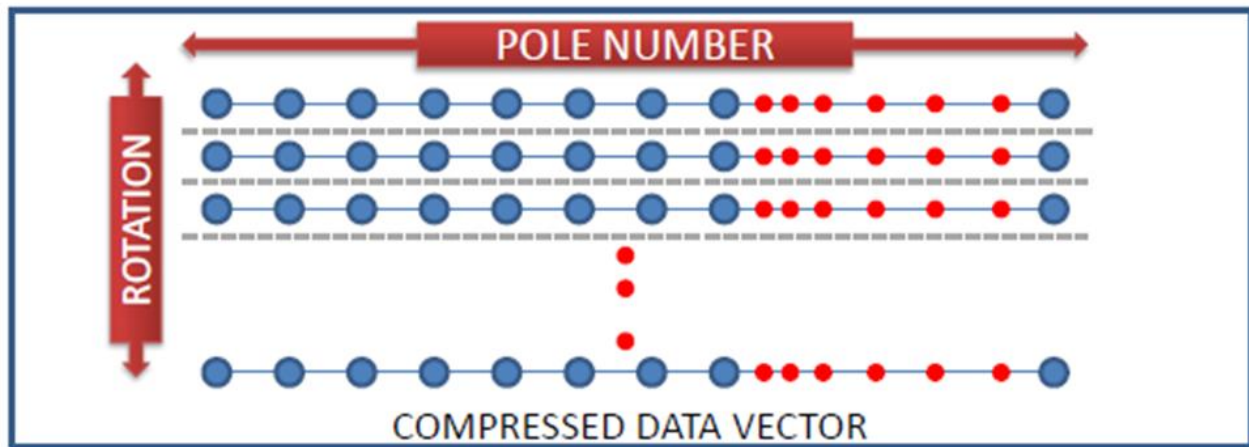
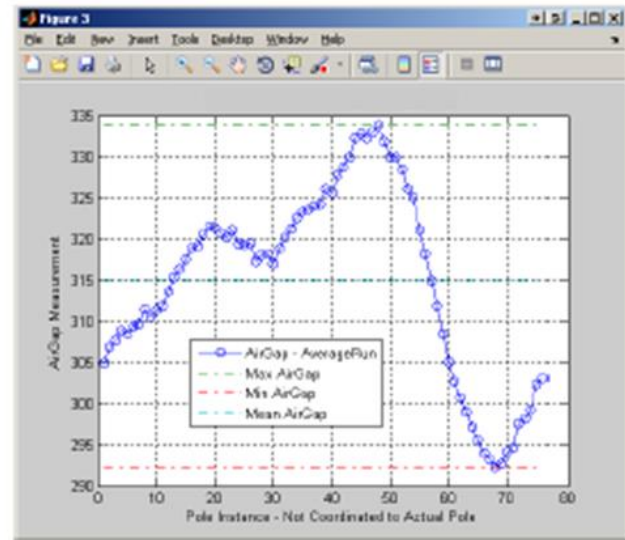
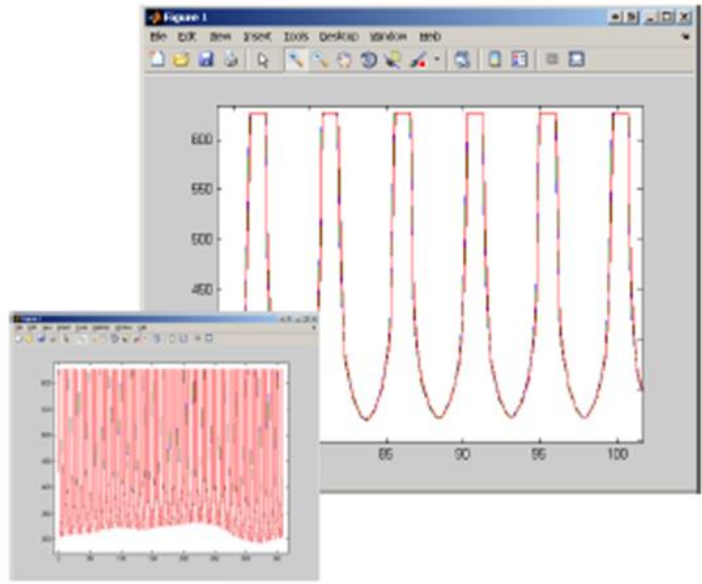
USE PROTECTION KNOWLEDGE TO IDENTIFY MECHANICAL PROBLEMS



FFT SPECTRUM

Data Compression: Air Gap Analysis Algorithm

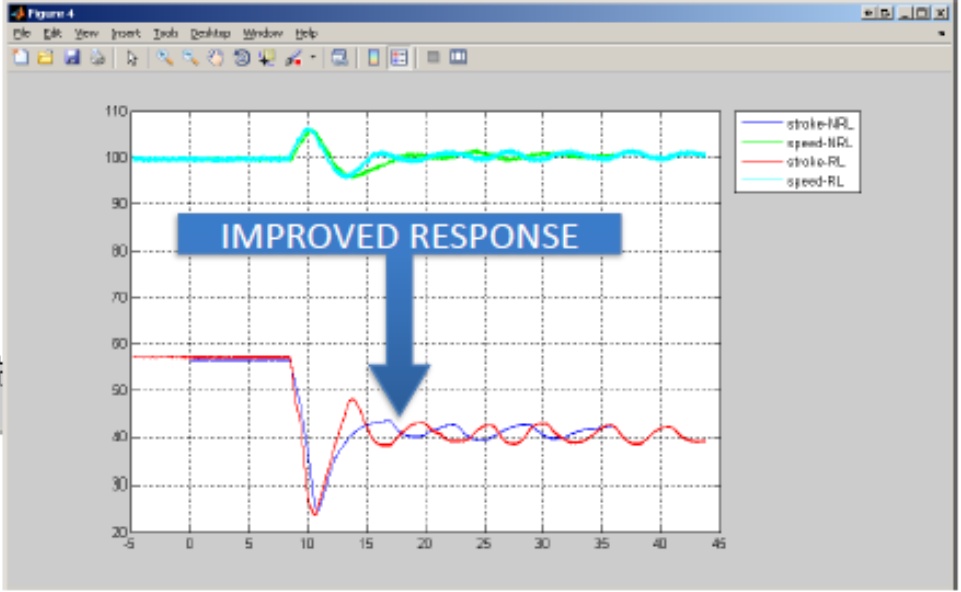
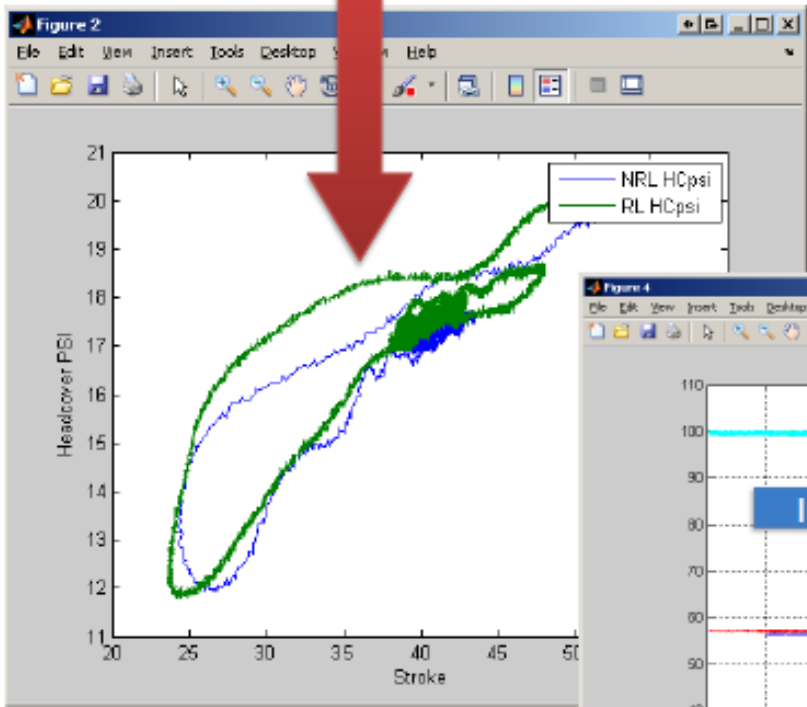
1GB RAW DATA SIGNAL PROCESSED TO KB



Performance = f_x(Machine Health)

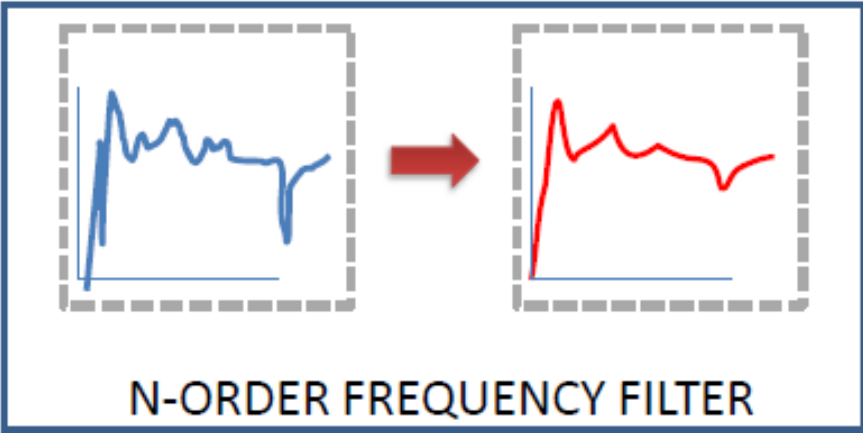
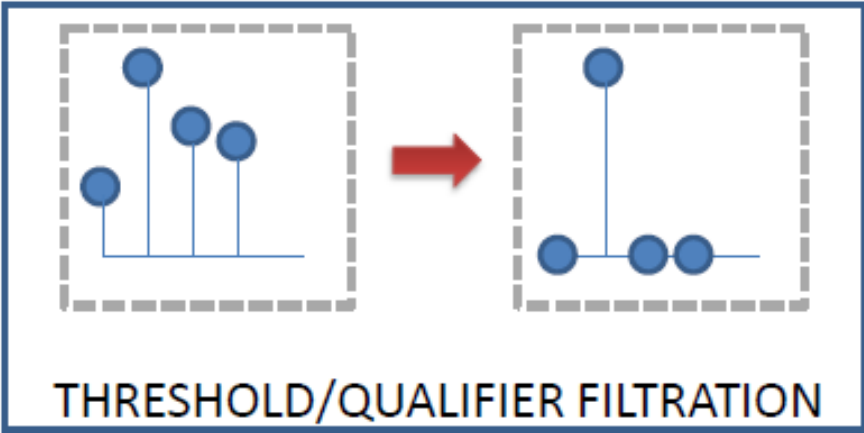
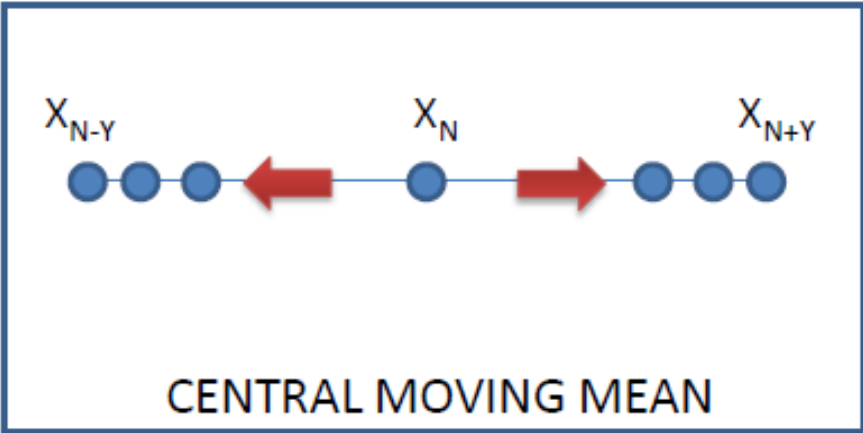
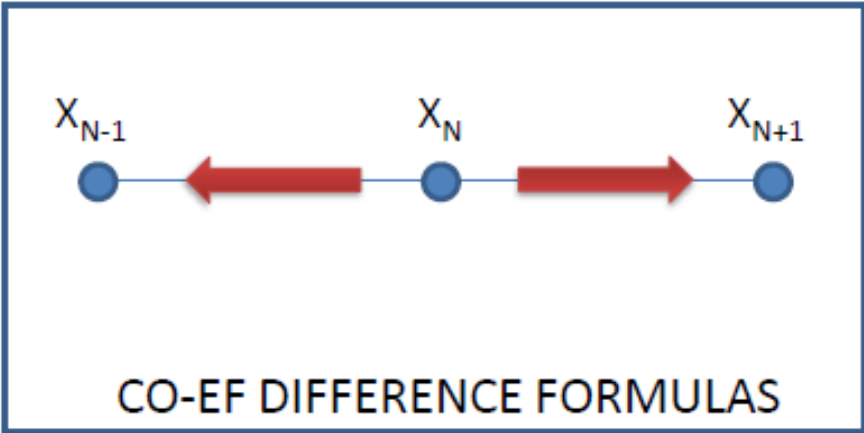
DETUNING A GOVERNOR TO DECREASE HEADCOVER PRESSURE

REDUCTION OF HEAD COVER PRESSURE



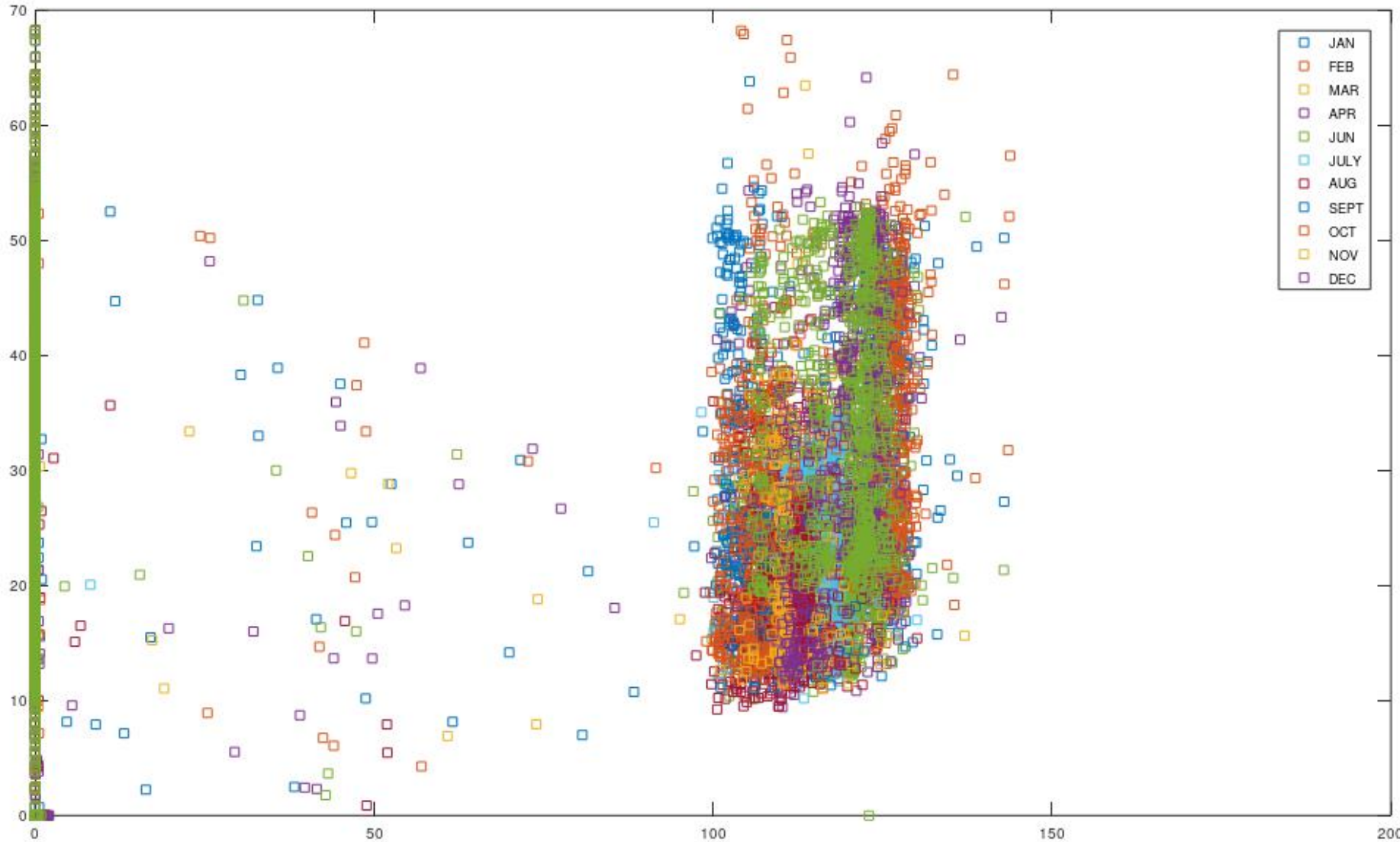
Filters & Mathematics

POST PROCESSING DATA TO GENERATE A RESULT



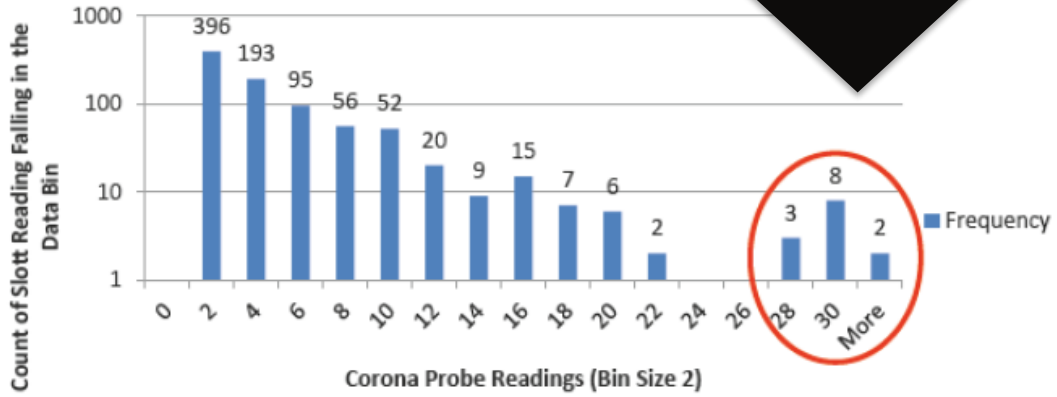
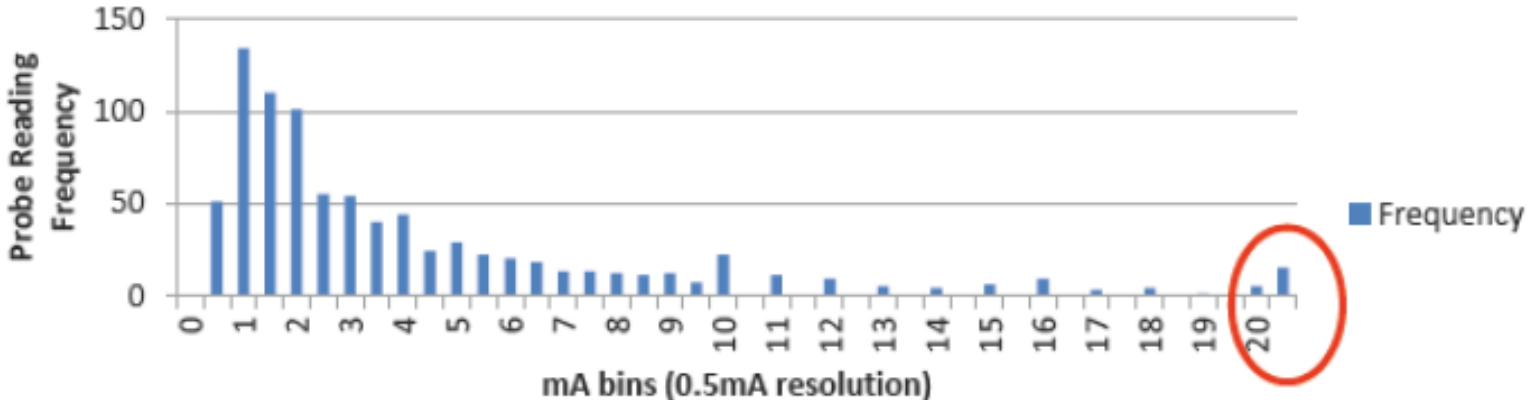
Logical Operator Filtration: Which Month? (Split Phase vs MVA)

USING MATRIX SCRIPTING PARSE YOUR DATA WITH LOGIAL OPERATORS



Histograms: TVA Corona Probe

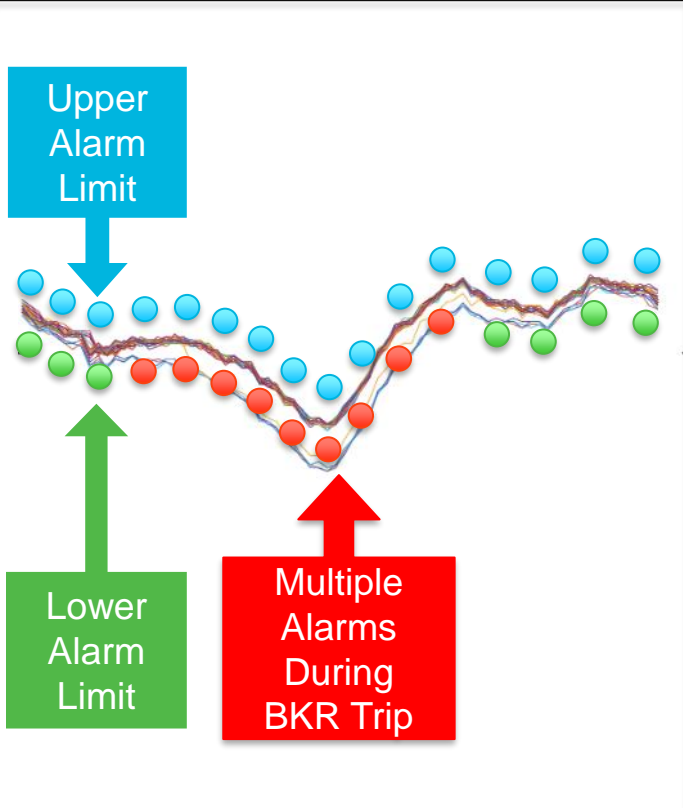
HOW TO FIND A NEEDLE IN A HAYSTACK?



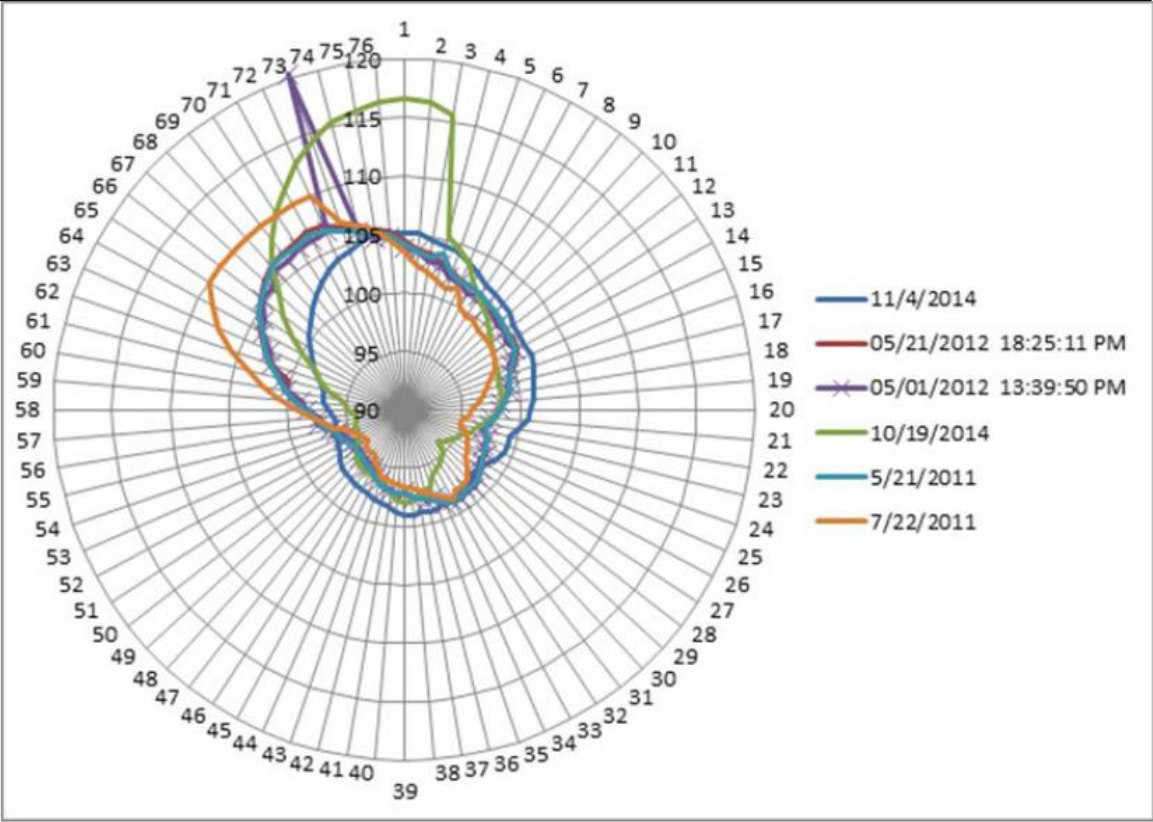
Flux Probe – Changing Rotor Rim Shape

USING A WINDOWED ALARM TO CAPTURE SHAPE CHANGE

Field Breaker Trip



Radar Plot of Flux Data vs Time (Hoola Hoop)



Data Overload

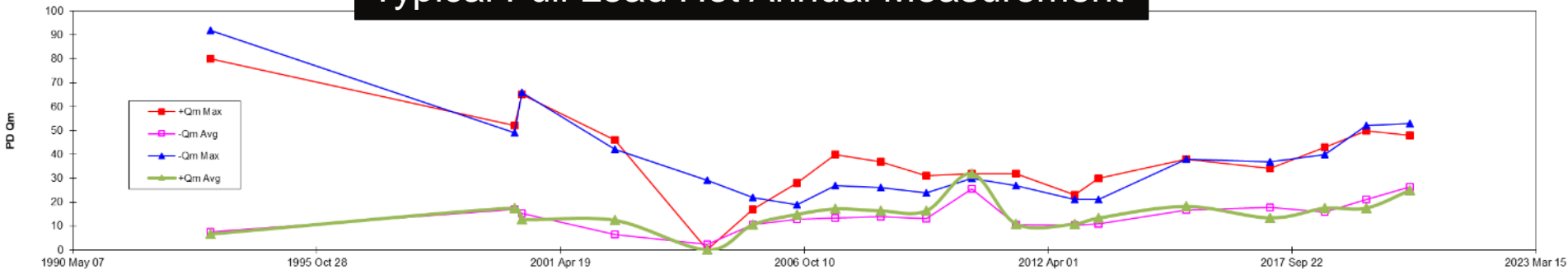
MAINTAINING YOUR MACHINE OR THE INSTRUMENT SYSTEM?



Data Overload: PD Monitor - 7 Years of Online Data

USING THE POWER OF ONLINE MONITORING AND A PI HISTORIAN

Typical Full Load Hot Annual Measurement



Qm Intensity vs MW by Stator WDG Temp

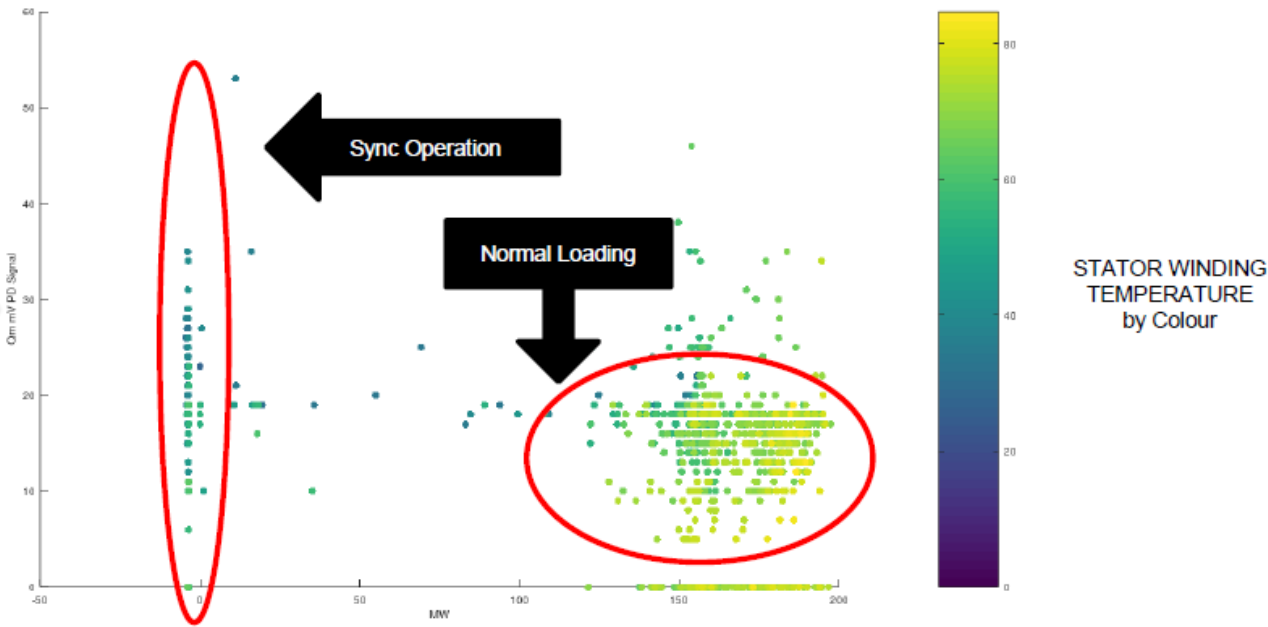


Figure 38: OI DATA - Q_m Data vs MW by Stator Winding Temperature

PARTIAL DISCHARGE EXAMPLE

MULTI-VARIABLE DATA



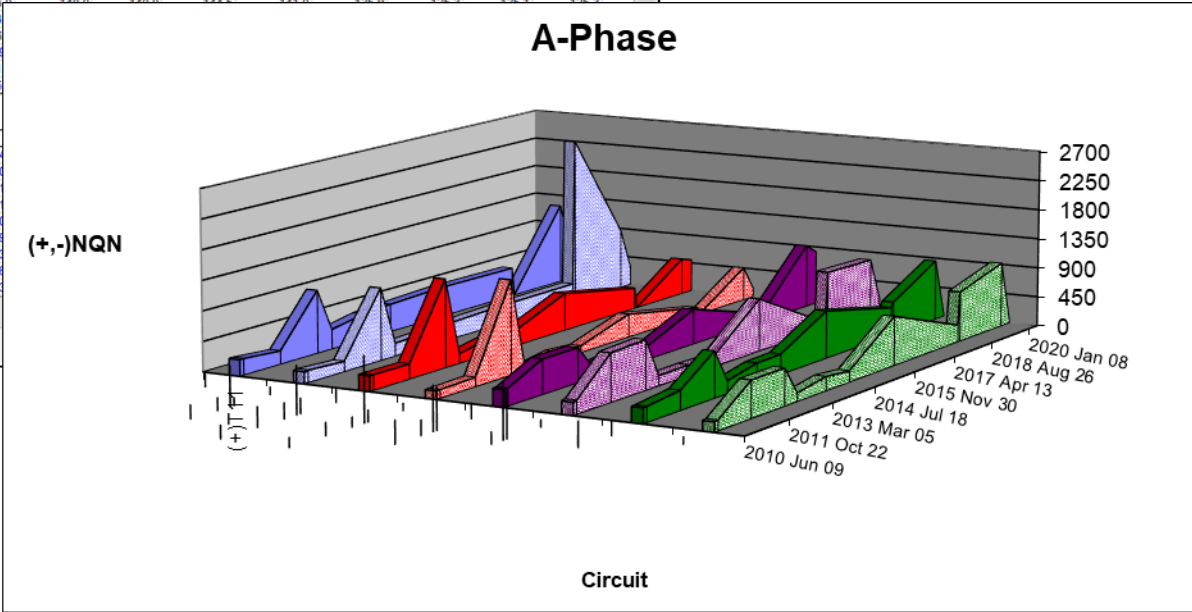
Existing Data?: Add a plotting engine & automate

POWERING HISTORICAL EXCEL SHEETS WITH A PLOTTING ENGINE

Excel interface showing a spreadsheet with the following data:

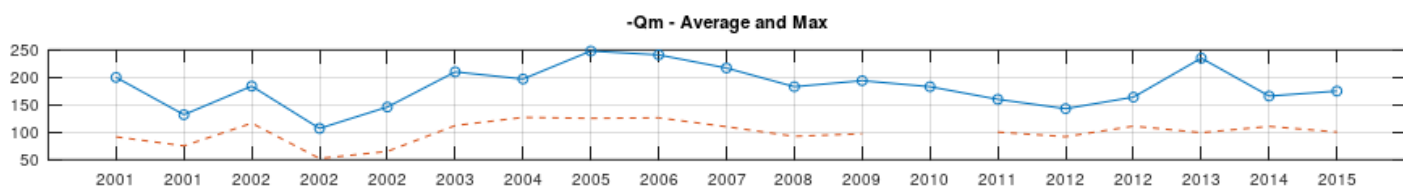
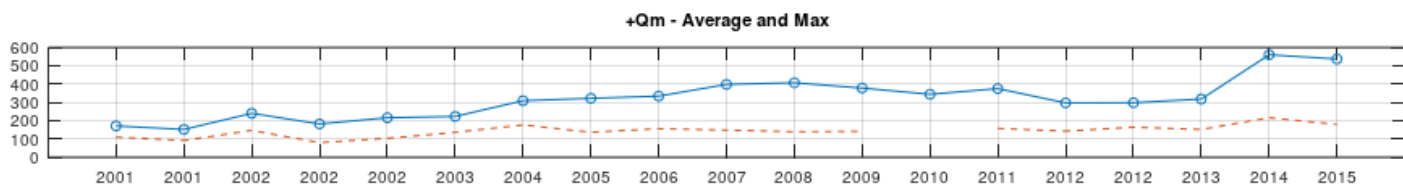
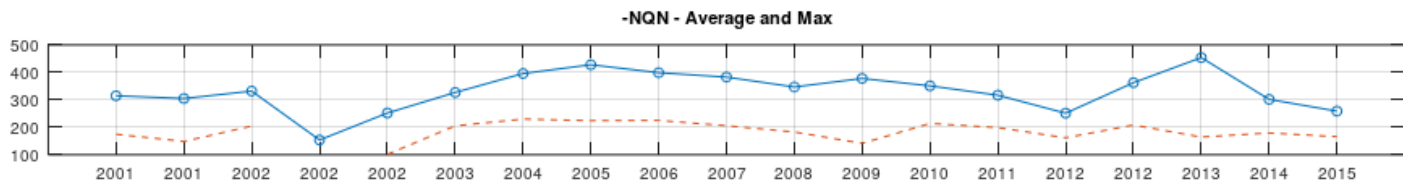
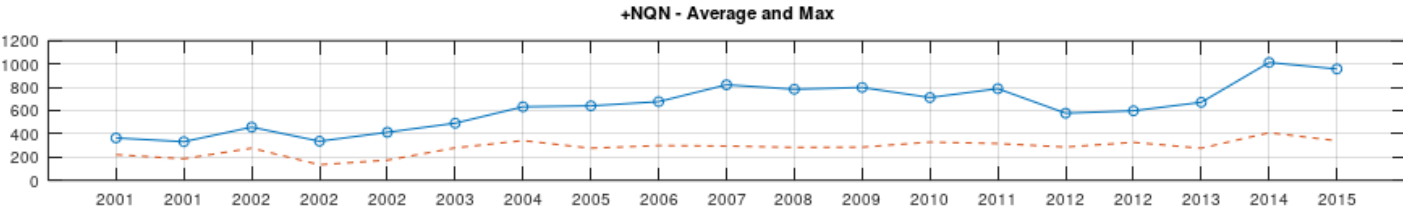
Stator Winding Partial Discharge NQN Summary															
NQN Test Conditions															
Test Type	1993 Jun 09	1996 Jul 06	2001 May 22	2002 Sep 04	2003 Jul 28	2004 Aug 04	2005 Aug 11	2006 Jul 18	2007 Jun 22	2008 Feb 27	2008 Jun 24	2008 Jun 25	2008 Jul 30	2008 Jul 31	2009
MW	132	126	123	145	146	146	140	140	144	140	125	123	125	125	
MVar	-7	-20	-8	-17	1	1	0	2	12	-17	-15	24	-4	-8	
MVA	132.2	127.6	123.3	146.0	146.0	146.0	140.0	140.0	144.0	140.0	125.0	123.0	125.0	125.0	
kV	13.8	13.7	14	13.8	13.9	14									
KA	5.5	5.4	5.1	6.1	6.1	6									
Winding °C	86	62	74	86	96	9									
%RH		59	40	47	42	61									
Ambient °C			22.1	22.4	27	25									

+NQN			
Circuit	Pair	Phase	
(+)T11	A-C1	A	283
(+)T12	A-C2	A	107
(+)T13	A2-C1	A	318
(+)T14	A2-C2	A	17
(+)T21	B-C1	B	307
(+)T22	B-C2	B	55
(+)T23	B2-C1	B	319
(+)T24	B2-C2	B	19
(+)T31	C-C1	C	82



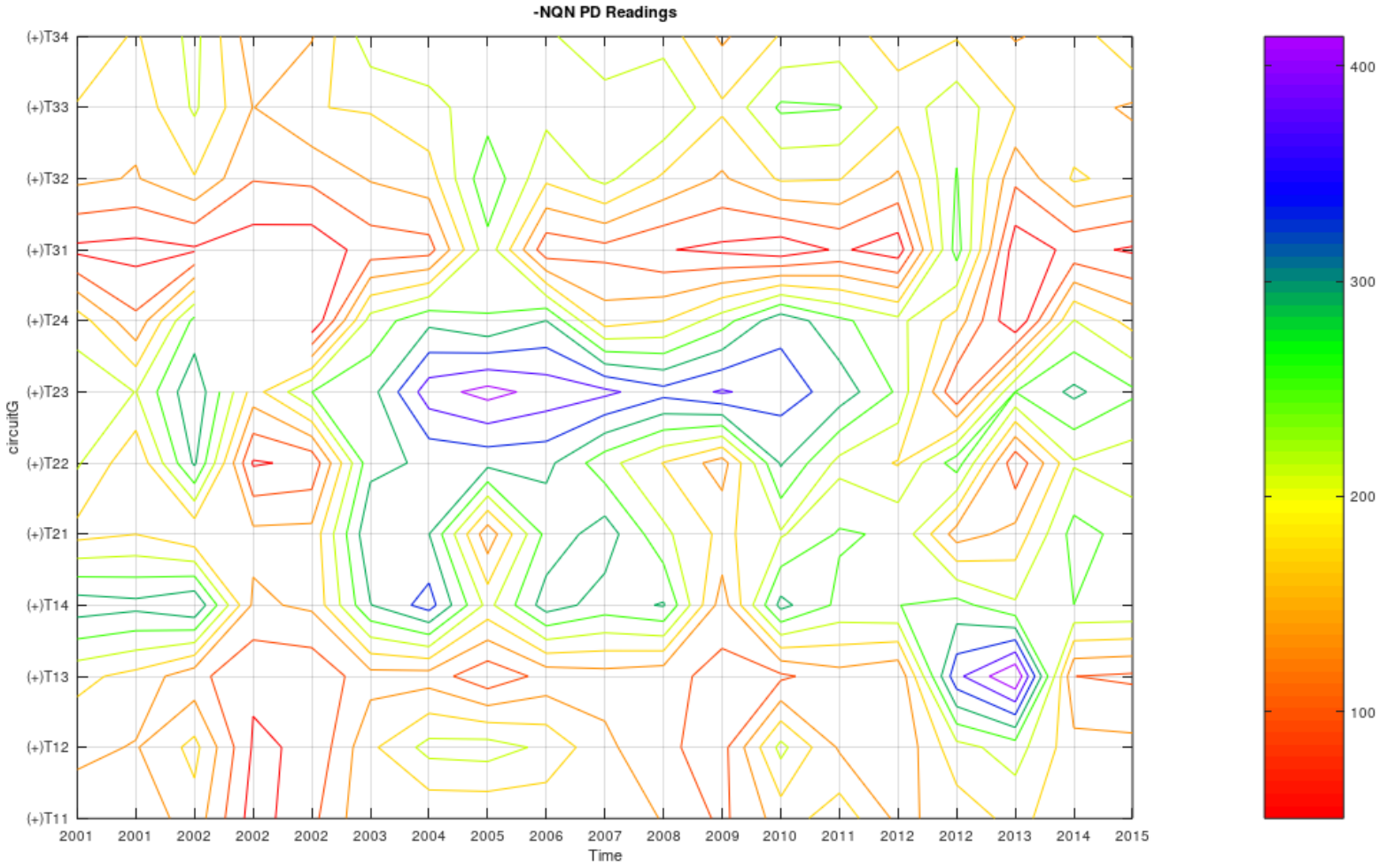
Existing Data?: Add a plotting engine

PROCESSING OF ALL PARALLEL CIRCUIT COUPLERS FOR MAX AND AVERAGES



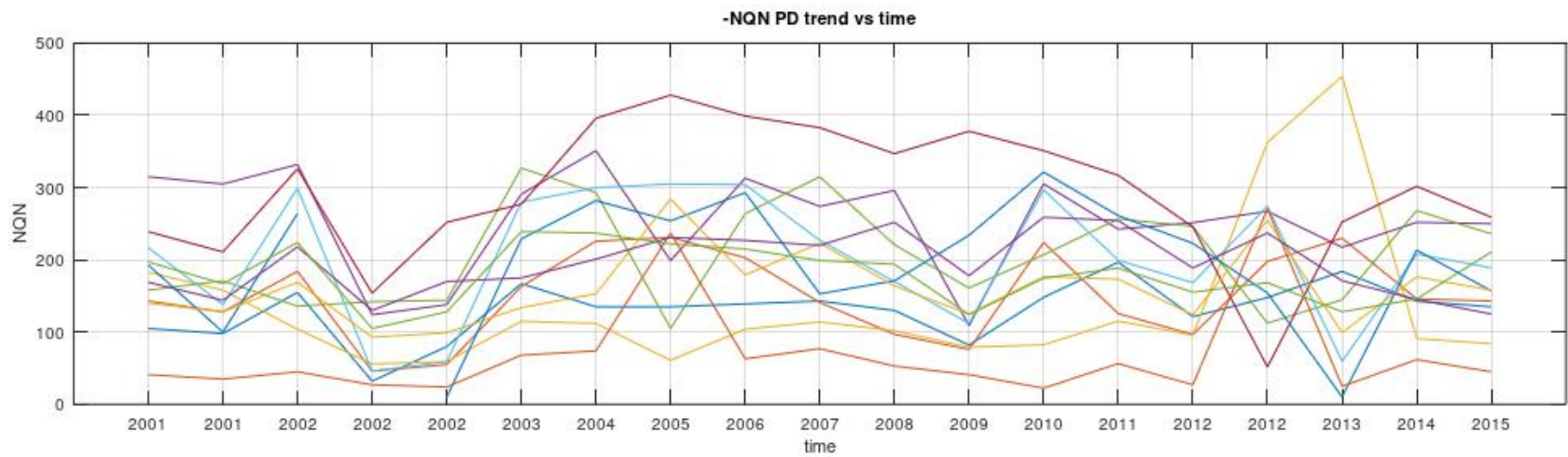
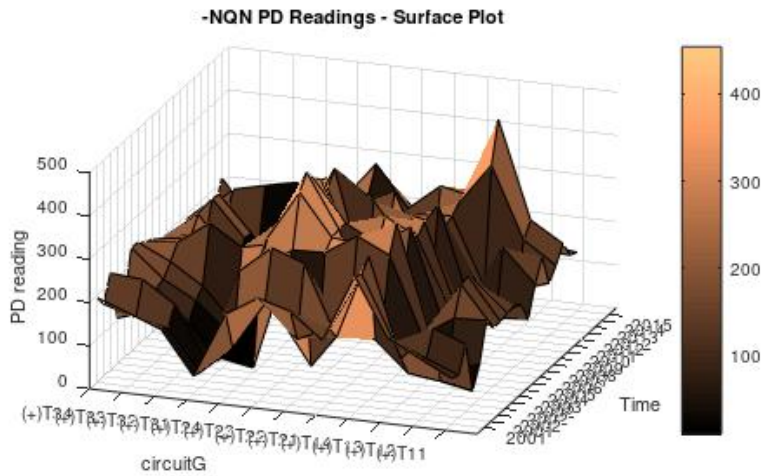
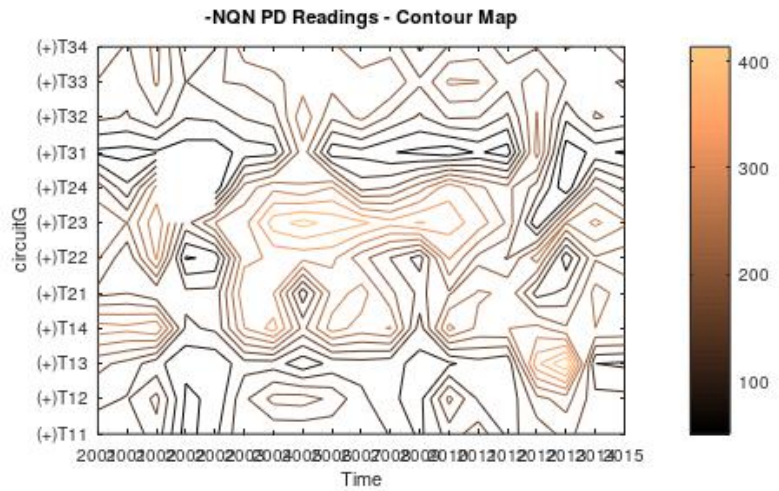
Existing Data?: Add a plotting engine

CONTOUR PLOT BY CIRCUIT, TIME AND MAGNITUDE



Existing Data?: Add a plotting engine

COMBINED INTERACTIVE PLOTS





Do More with Less

KEEP IT SIMPLE

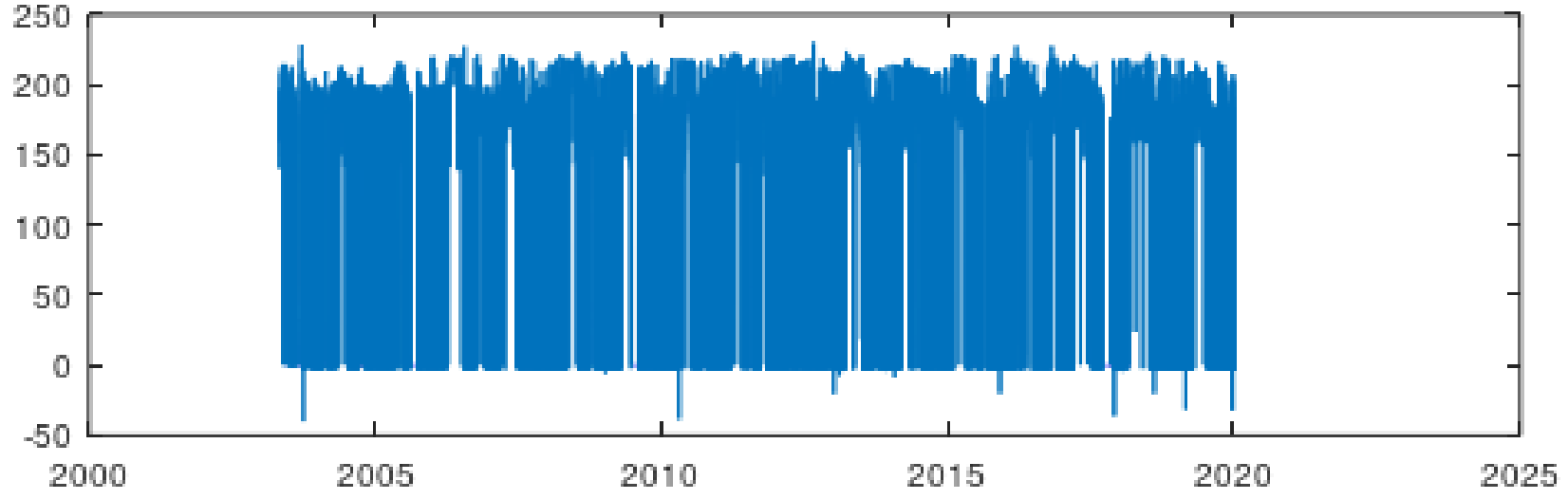


Do More with Less – 4 Signal Example

WHAT CAN YOU DO WITH A FEW BASIC SIGNALS? (t, Vt, MW, MQ, SWDG_temp)

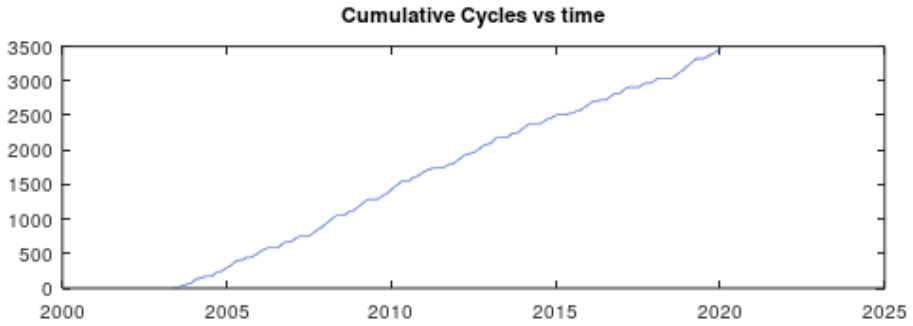
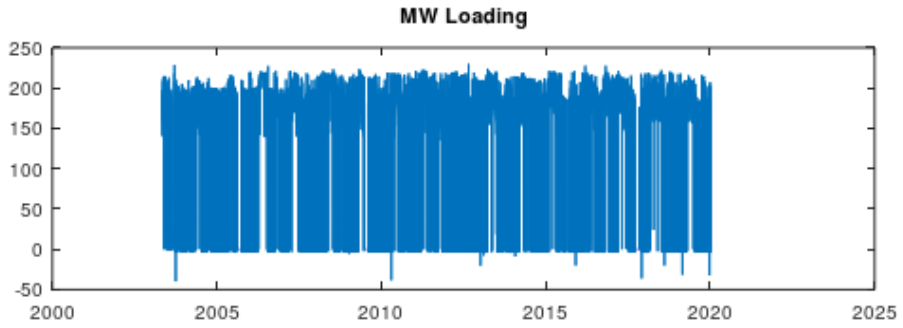
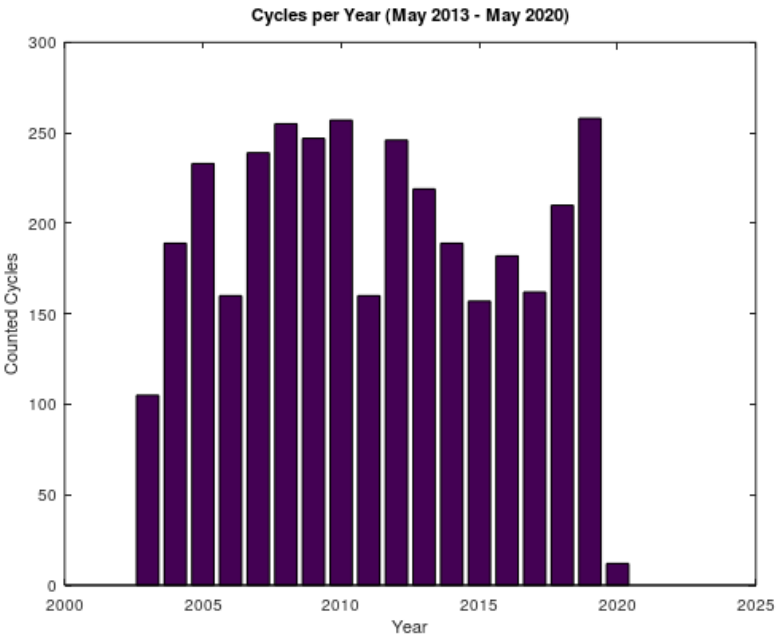
Timeframe: 7 years
Vt
MW + jMQ
Stator Winding Temp

MW Loading



Do More with Less – Cycling Calculation

WHAT CAN YOU DO WITH A FEW BASIC SIGNALS? (t, Vt, MW, MQ, SWDG_temp)

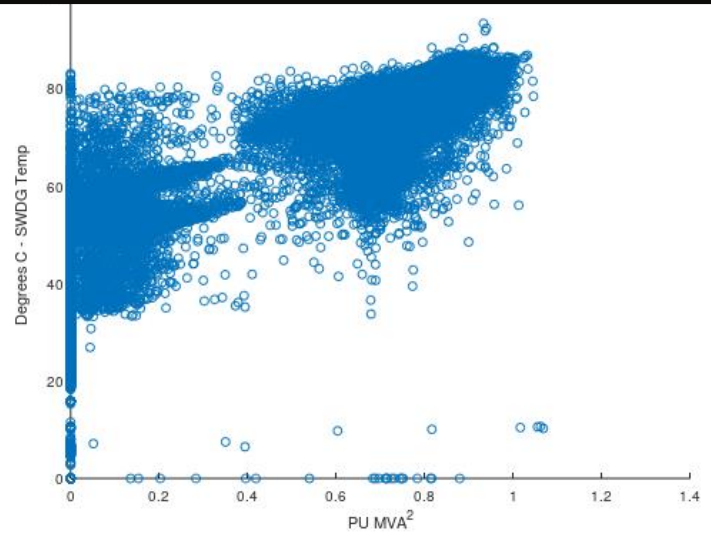


Do More with Less – Operating Information

WHAT CAN YOU DO WITH A FEW BASIC SIGNALS? (t, Vt, MW, MQ, SWDG_temp)



Stator WDG Temp vs MVA²



Calculated Parameter	Data
On Time	132668 hours
Off Time	13588 hours
Gen Mode Time	109784 hours
Sync Mode Time	22944 hours
Gen AVG Temp	75.6 deg C
Sync AVG Temp	54.7 deg C
Gen-Sync Diff Temp	20.9 deg C

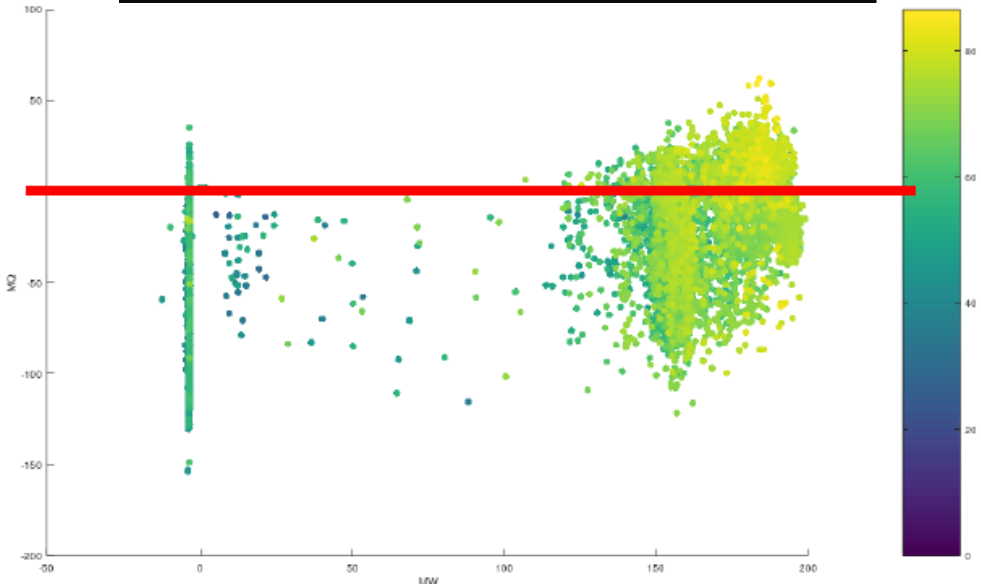
Do More with Less – Where and How Did I Run?

WHAT CAN YOU DO WITH A FEW BASIC SIGNALS? (t, Vt, MW, MQ, SWDG_temp)

7 YR Data from
PI Historian



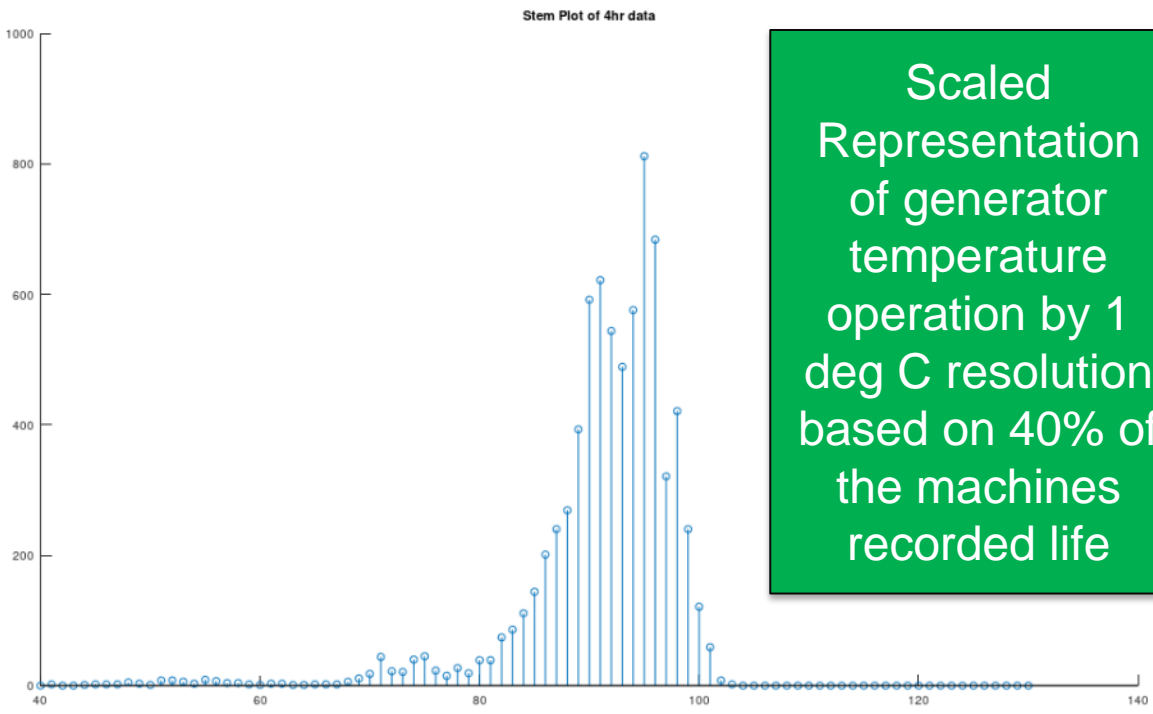
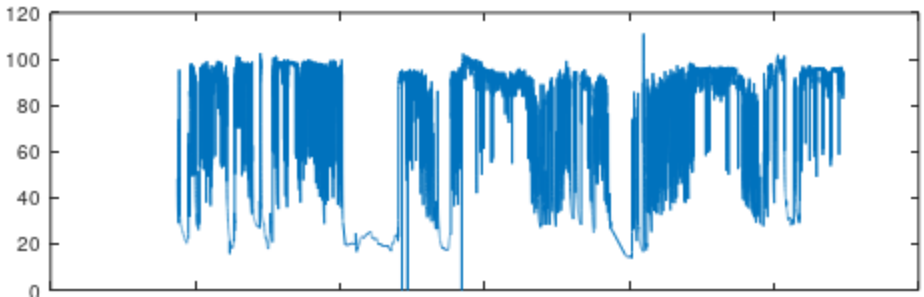
D-Curve Operation
by
Stator WDG Temp



Do More with Less – Temperature Histogram

WHAT CAN YOU DO WITH A FEW BASIC SIGNALS? (t, Vt, MW, MQ, SWDG_temp)

53820 Recorded Hours of Temperature Data



Scaled Representation of generator temperature operation by 1 deg C resolution based on 40% of the machines recorded life

Temp (degC)	Hours @ Temperature	Scaled Life Hours
84	444	1097
85	576	1423
86	804	1987
87	960	2372
88	1076	2659
89	1572	3885
90	2368	5852
91	2488	6148
92	2176	5377
93	1956	4834
94	2304	5694
95	3248	8026
96	2736	6761
97	1284	3173
98	1684	4162
99	960	2372
100	484	1196
101	236	583
102	32	79



The end, any questions?