



PPL Electric Utilities

We Deliver.

Driving Forward with Condition Based Maintenance

Brandon Gustafson – System Maintenance Senior Engineer
PPL Electric Utilities

Transformer #2 Oil Results



– DGA

Hydrogen (H2)	7.2	µL/L (ppm)
Oxygen (O2)	440.0	µL/L (ppm)
Nitrogen (N2)	75000.0	µL/L (ppm)
Methane (CH4)	8.26	µL/L (ppm)
Carbon Monoxide (CO)	34.9	µL/L (ppm)
Carbon Dioxide (CO2)	1053.0	µL/L (ppm)
Ethylene (C2H4)	4.5	µL/L (ppm)
Ethane (C2H6)	4.2	µL/L (ppm)
Acetylene (C2H2)	4.1	µL/L (ppm)
Propane (C3H8)		µL/L (ppm)
Propylene (C3H6)		µL/L (ppm)
Total gas	76556.0	%
TCG (headspace or relay)		%

– DGA

Hydrogen (H2)	158.1	µL/L (ppm)
Oxygen (O2)	782.0	µL/L (ppm)
Nitrogen (N2)	55700.0	µL/L (ppm)
Methane (CH4)	50.0	µL/L (ppm)
Carbon Monoxide (CO)	27.3	µL/L (ppm)
Carbon Dioxide (CO2)	914.0	µL/L (ppm)
Ethylene (C2H4)	77.3	µL/L (ppm)
Ethane (C2H6)	9.3	µL/L (ppm)
Acetylene (C2H2)	190.1	µL/L (ppm)
Propane (C3H8)		µL/L (ppm)
Propylene (C3H6)		µL/L (ppm)
Total gas	57908.0	%
TCG (headspace or relay)		%

Transformer Inspection Findings



- Electrical Testing was completed
 - Concerns with the results of the core ground test as well as DC winding resistance test
- Internal inspection of the transformer performed
 - Deteriorated core ground



The Ask: Continue to drive down operating cost without risking failure or reliability

- Time-based maintenance plan cost exceeding yearly budget
- How can we reduce cost without increasing risk?
 - Focus in on the need to have maintenance
 - Ensure correct maintenance is being completed
 - Do not just rely on past practices
 - Utilizing all available data to drive priority



Past Maintenance Practice

- Completely time-based maintenance schedule
- Only condition based completed was as result of time-based maintenance



• First Steps into Data Driven Condition Based Maintenance

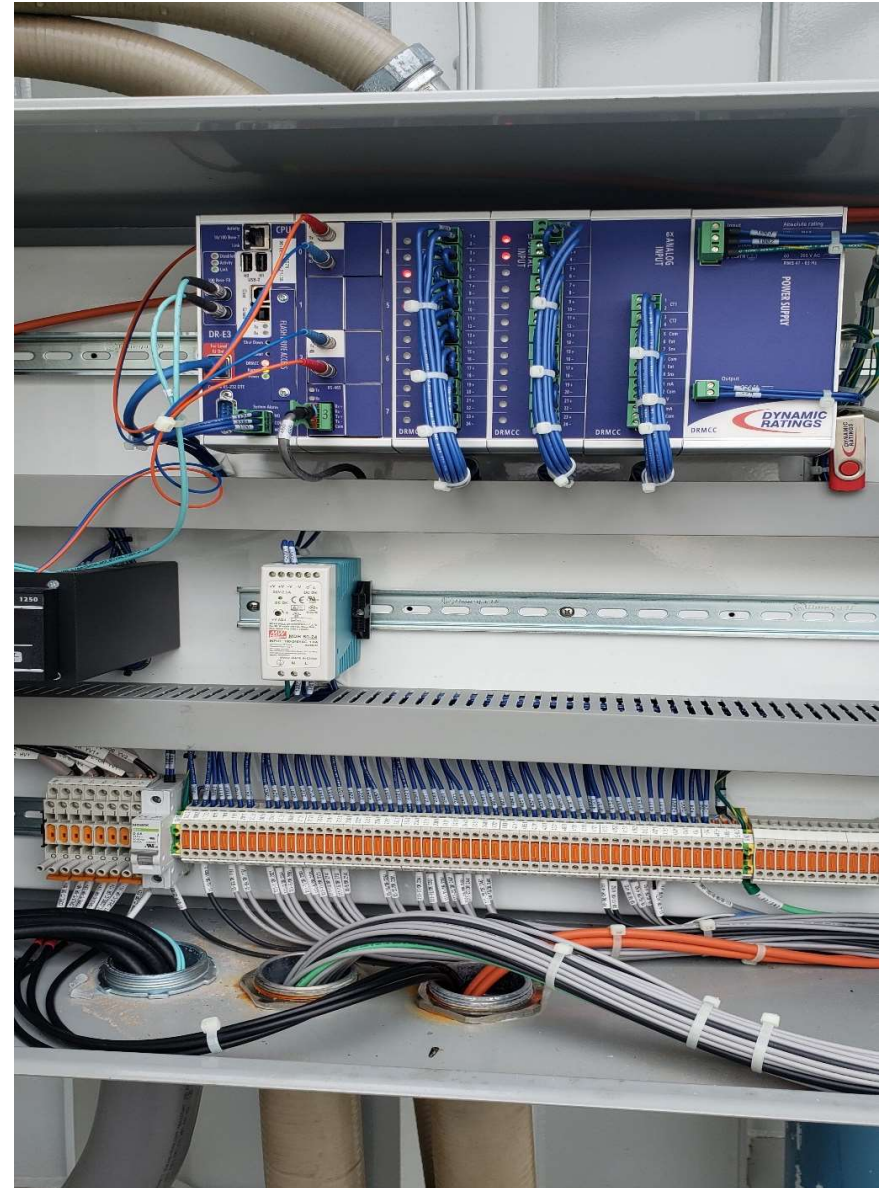


- Review completed of all breaker models and maintenance triggers created based on manufacture suggested operation counts
- TCUL maintenance triggers also developed based on operation count
- Hesitation of these approaches led us to keep a time component as part of the trigger



Where we are going

- Monitoring installed on all major equipment types
 - Dashboard for real time health index to drive future maintenance and replacements
 - Alarming and Alerts in place to have round the clock oversight
- Fully condition based maintenance program



Battery Monitor Display



Battery Data: LAUS_230.BATT.A Location: BATT_BLDG

120V CONTROL BATTERY SYS A 230KV CONTROL HOUSE



Ambient Temperature 72.96 °F
String Voltage 133.55 VDC
Float Current 463 mA
Ripple Current 0.00 A

Ground Fault Resistance
Positive 11.10 MOhm
Negative 11.57 MOhm
Charger Cable Resistance
Positive 18,889 µΩ
Negative 18,210 µΩ



Turn on lights

Operating Mode ★ Normal LVL

Log in to Monitor Webpage

admin / alber

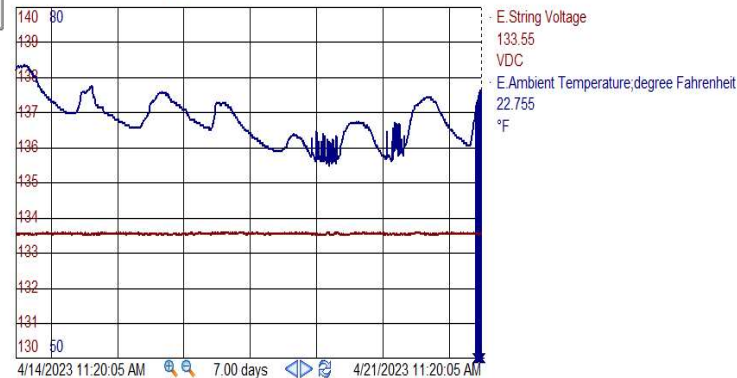
Alarms/Status

Hardware Failure ★ NORM
Major Alarm ★ NORM

Minor Alarm ★ NORM

ELSi Alarm ★ NORM

Discharge Status ★ False



Cell Voltages

Cell Resistances

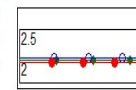
Inter-cell

ELS

Module Status

Cell Voltages

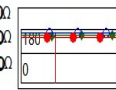
Max 2.234 VDC
Average 2.214 VDC
Min 2.191 VDC



Cell #	VDC
#1	2.212
#2	2.217
#3	2.225
#4	2.217
#5	2.212
#6	2.215
#7	2.217
#8	2.212
#9	2.223
#10	2.234
#11	2.213
#12	2.206
#13	2.191
#14	2.202
#15	2.222
#16	2.215
#17	2.207
#18	2.207
#19	2.208
#20	2.211
#21	2.224
#22	2.215
#23	2.207
#24	2.206
#25	2.199
#26	2.224
#27	2.219
#28	2.228
#29	2.228
#30	2.220
#31	2.209
#32	2.206
#33	2.215
#34	2.218

Cell Resistances

Max 170 µΩ
Average 161 µΩ
Min 153 µΩ



Cell #	µΩ
#1	161
#2	159
#3	153
#4	157
#5	159
#6	161
#7	159
#8	157
#9	162
#10	168
#11	164
#12	161
#13	159
#14	159
#15	162
#16	162
#17	161
#18	162
#19	164
#20	164
#21	162
#22	162
#23	158
#24	160
#25	162
#26	160
#27	162
#28	164
#29	165
#30	165
#31	163
#32	159
#33	163
#34	161

Inter-cell Resistances

Cell #	µΩ
#1	16
#2	18
#3	15
#4	18
#5	15
#6	19
#7	15
#8	19
#9	15
#10	23
#11	15
#12	18
#13	15
#14	18
#15	315
#16	16
#17	15
#18	16
#19	16
#20	20
#21	15
#22	17
#23	15
#24	17
#25	15
#26	17
#27	15
#28	49
#29	15
#30	743
#31	16
#32	17
#33	15
#34	17

ELS Module Status

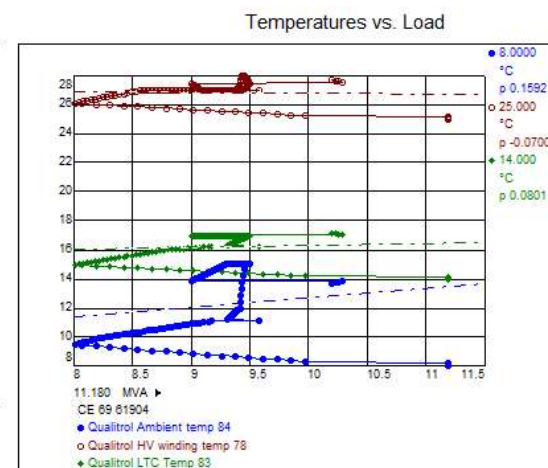
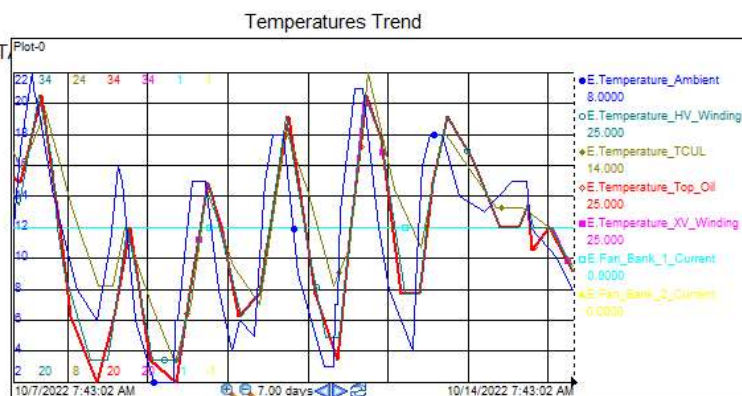
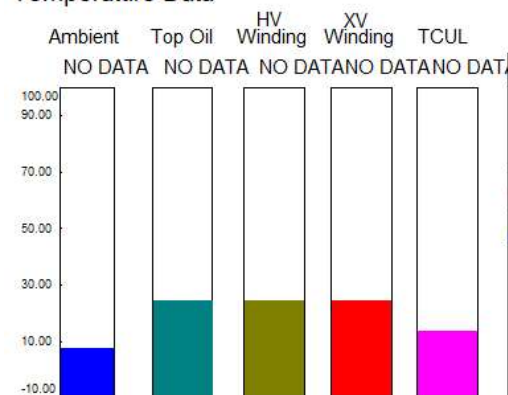
★ Normal

Cell #	Level	Temp °F
#1	Normal	71.6
#2	Normal	71.6
#3	Normal	70.7
#4	Normal	71.6
#5	Normal	70.7
#6	Normal	70.7
#7	Normal	70.7
#8	Normal	71.6
#9	Normal	71.6
#10	Normal	70.7
#11	Normal	71.6
#12	Normal	71.6
#13	Normal	71.6
#14	Normal	71.6
#15	Normal	71.6
#16	Normal	72.5
#17	Normal	72.5
#18	Normal	73.4
#19	Normal	72.5
#20	Normal	72.5
#21	Normal	72.5
#22	Normal	72.5
#23	Normal	72.5
#24	Normal	72.5
#25	Normal	72.5
#26	Normal	71.6
#27	Normal	72.5
#28	Normal	71.6
#29	Normal	72.5
#30	Normal	72.5
#31	Normal	72.5
#32	Normal	71.6
#33	Normal	71.6
#34	Normal	71.6

Transformer Monitoring Display



Temperature Data



Fan Bank Data

Fan Bank 1 Status: 0 A

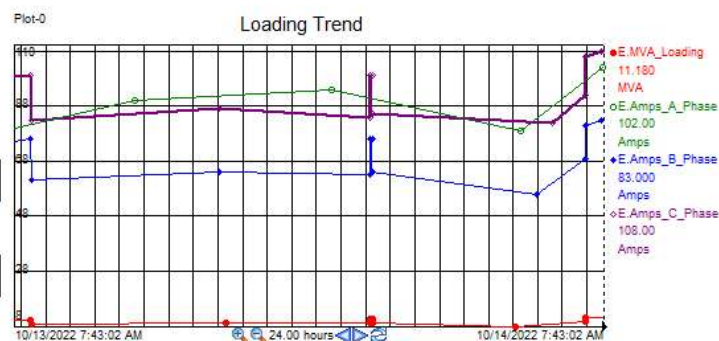
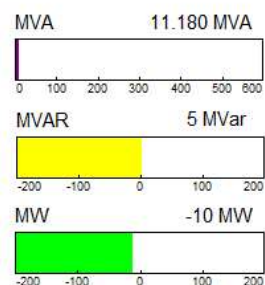
Fan Bank 2 Status: 0 A

Alarms

DR System

Cooler Fail

Loading Data



A Phase Amps 102 Amps

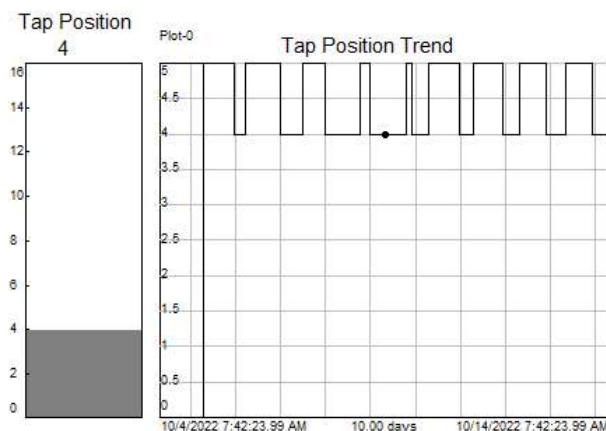
B Phase Amps 83 Amps

C Phase Amps 108 Amps

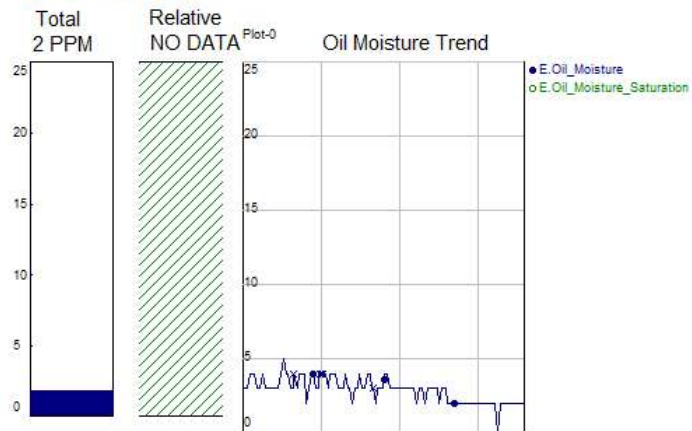
Transformer Monitoring Display



TCUL Data

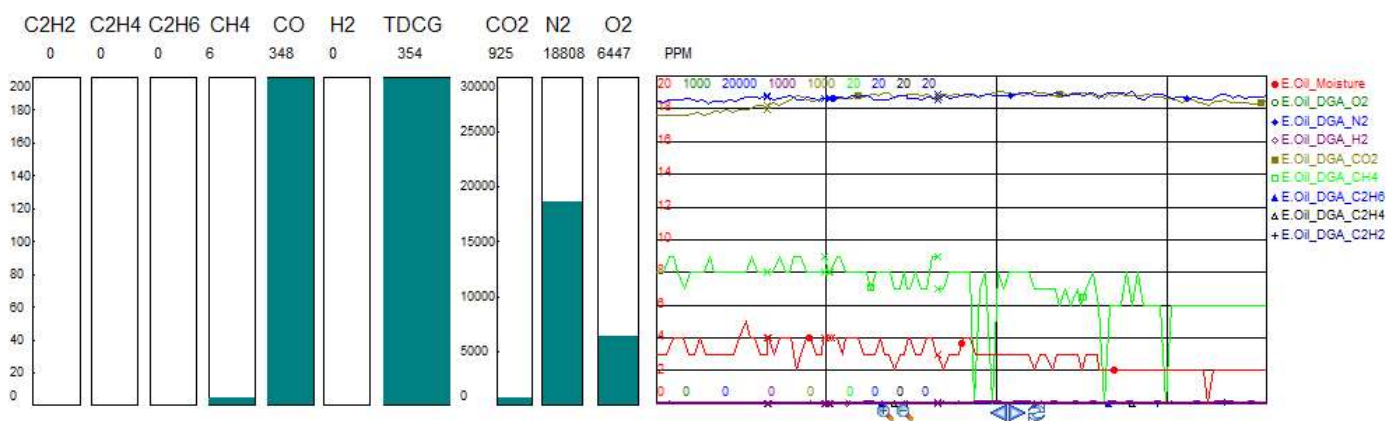


Oil Moisture Data



Oil Gas Data

Last Oil Test Temperature = NO DATA



CB Monitoring Display



SFLD.CB.BUXM_2 SF6 CB Monitor

Log in to Monitor Webpage

<https://10.85.0.26>

Alarms

Alarm Relay
Close Time Alarm
Close Travel Time Alarm
Open Time Alarm
Open Travel Time Alarm
A-B Logic Alarm



SF6 Data

SF6 Sensor Status
SF6 Low Gas
SF6 Gas Trend
SF6 Gas Forecast



Pressure 65.92 PSIG
Pressure Trend -0.01 PSIG/Day
Trend Confidence 98 %
Density 2.23 lb/ft³
Density Trend 0.00 lb/ft³/day
Mass Loss -0.01 lbs
Low Gas Forecast 1000 Days



Load Current
Last Arc Time
Last Interrupt Time
Contact Life
Contact Wear I2T

212 Amps
0 mS
0 mS
90 %
13,436,905 A2Sec

199 Amps
0 mS
0 mS
90 %
12,800,000 A2Sec

213 Amps
0 mS
0 mS
90 %
12,800,000 A2Sec

Op Metrics

Non-Fault Interrupt Count 19
Fault Interrupt Count 2
Since Last Op 373 Days

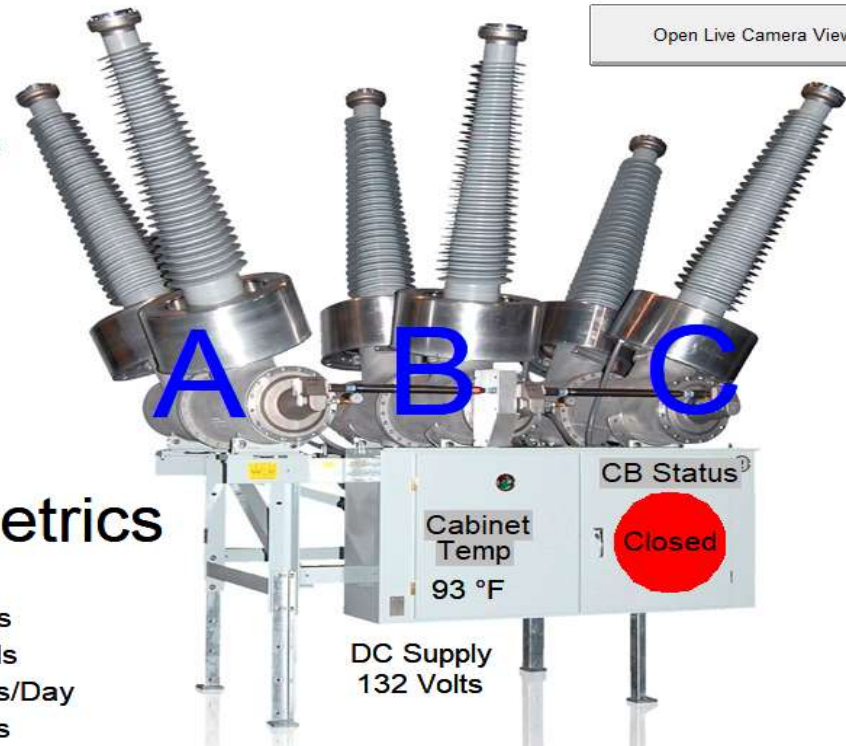
Last Operation Metrics:

Operation Number 211
Op was a Fault False
Op was an Interrupt False
Close Time 34 mS
Close Travel Time 14 mS
Open Time 0 mS
Open Travel Time 0 mS

Charge Motor Metrics

Charge Motor Current 0 Amps
Avg Time Between Run 202 Hours
Avg Run Time 6 Seconds
Avg Run Frequency 0.00 Runs/Day
Total Run Time 0.04 Runs

Open Live Camera View



Additional Monitoring



- PT and CCVT Monitoring
 - Predictive algorithms created to flag voltage abnormalities coming back through PI
- Air Break and Disconnect
 - Exercise and maintain stagnant disconnects



Monitoring Challenges



- Proper setup to ensure that data being collected is accurate and desirable
- Understanding the data being brought back
- Alert and Alarm setup
 - Critique to fit companies needs
- Upkeep of additional components now on the system



Other Sources of Data



- Due to the advancing age of most utilities' infrastructure, it is crucial that maintenance and replacement decisions are based off the best available data
- Other data sources:
 - Sub configuration
 - Stranded load
 - Customer count
 - Unit age
 - Inspection data
 - Past DGA results

