PROTECTION CONSIDERATIONS FOR AN IMPROPERLY INSTALLED ON-LOAD TAP CHANGER

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OBJECTIVES

- Introduction
- On-Load Tap Changer (OLTC) theory
- Power system description
- OLTC installation issues
- Relay event data collection and analysis
- Relay settings recommendations
- OLTC installation testing procedure
- Aftermath
- Conclusion

INTRODUCTION

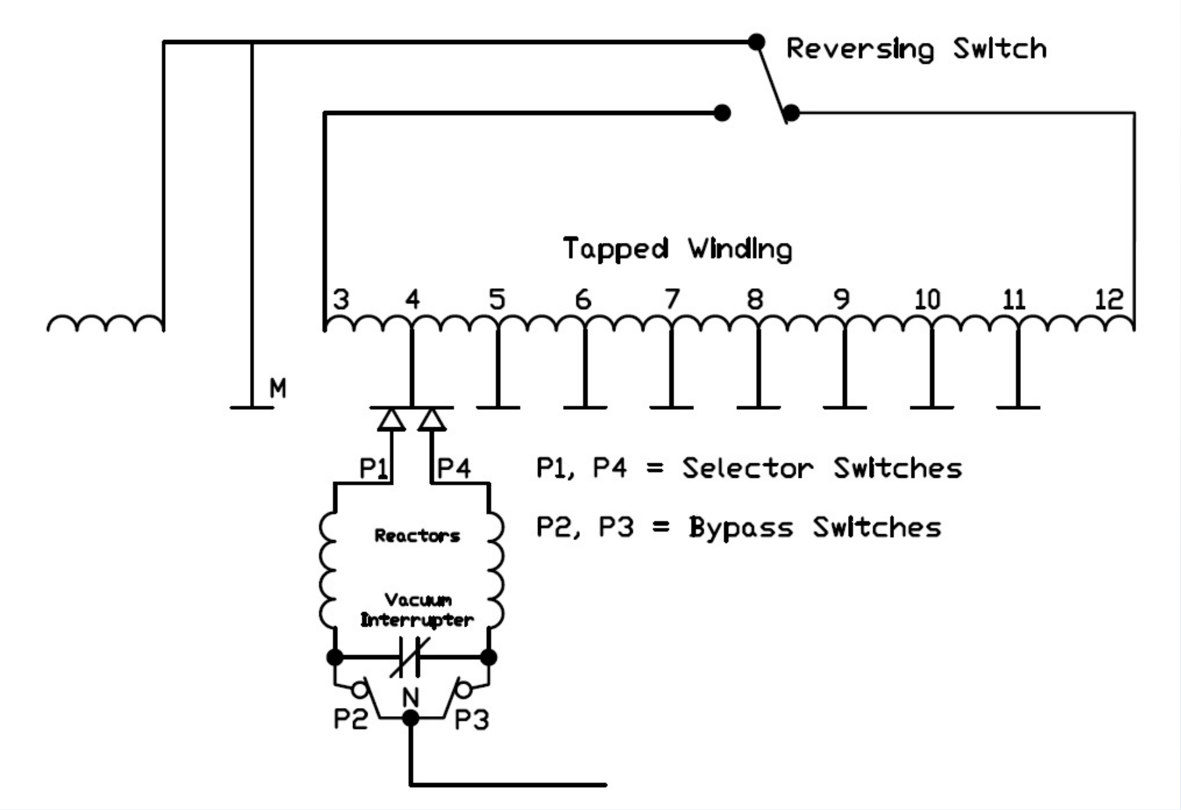
- Power transformers are widely used: Interconnect solar farms to utility grid
- Tap changers used to control voltage variation due to grid voltage fluctuation
- On-Load Tap Changers (OLTCs) are used to match grid’s voltage ***automatically***

OLTC THEORY

- Add or remove turns to the windings on either side of the transformer
- A No-Load Tap Changer (NLTC) requires the system to be de-energized
- An OLTC allows a tap change while the system is energized using a “make-before-break” concept using resistors/reactors, bypass switches, selector switches, and a vacuum interrupter (VI).

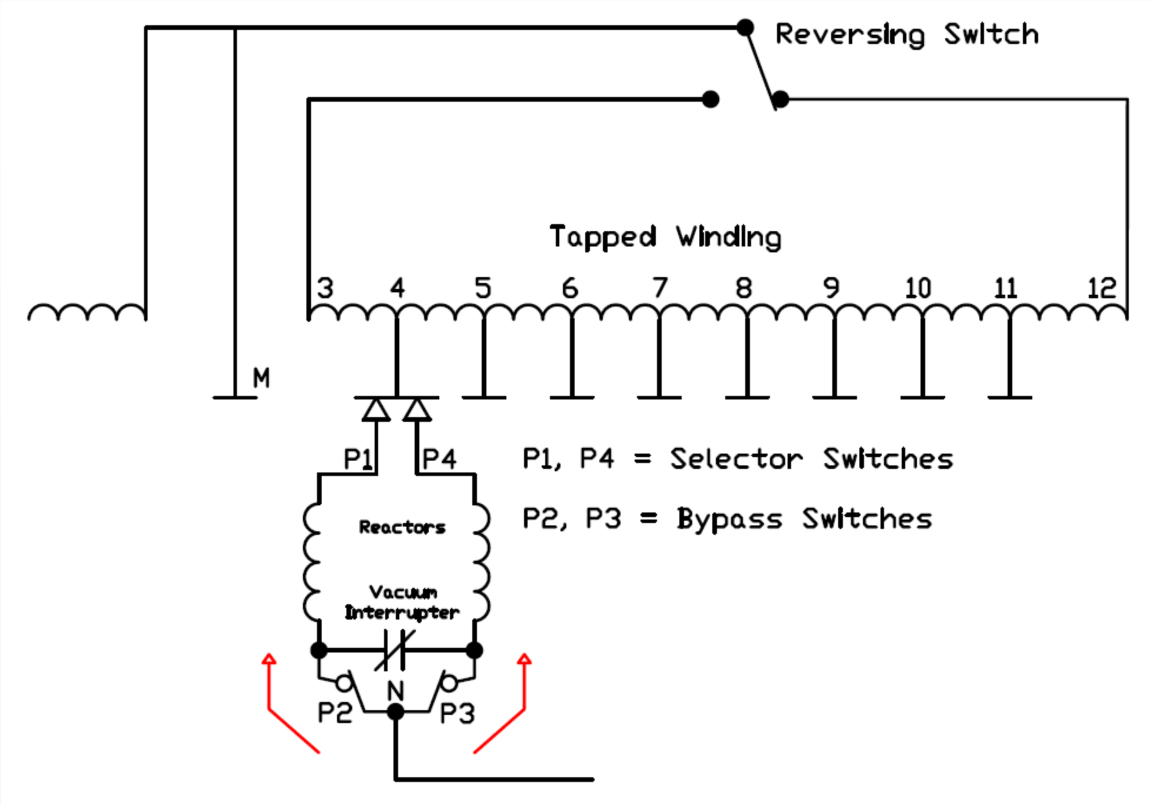
OLTC THEORY – SYSTEM OF INTEREST

- 32-step, 26.4 kV rated
- ***Simplified*** schematic shown
- OLTC components:
  - P1 & P4: Selector (mobile) switches
  - P2 & P3: Bypass switches
  - Vacuum Interrupter: Breaks current
  - Reversing switch: Doubles the number of taps (irrelevant to this presentation).



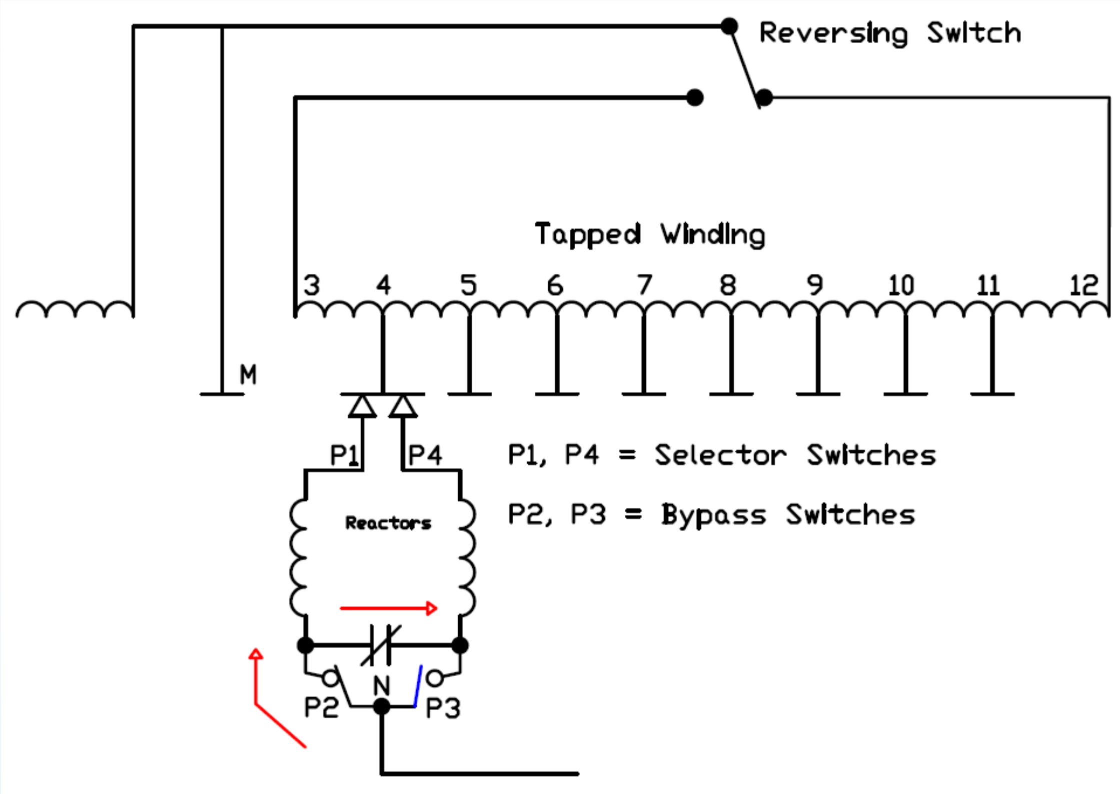
OLTC THEORY – MODE OF OPERATION

- Initially, current flows in parallel from the bypass switches to the selector switches (P2 – P1 and P3 – P4).



OLTC THEORY – MODE OF OPERATION

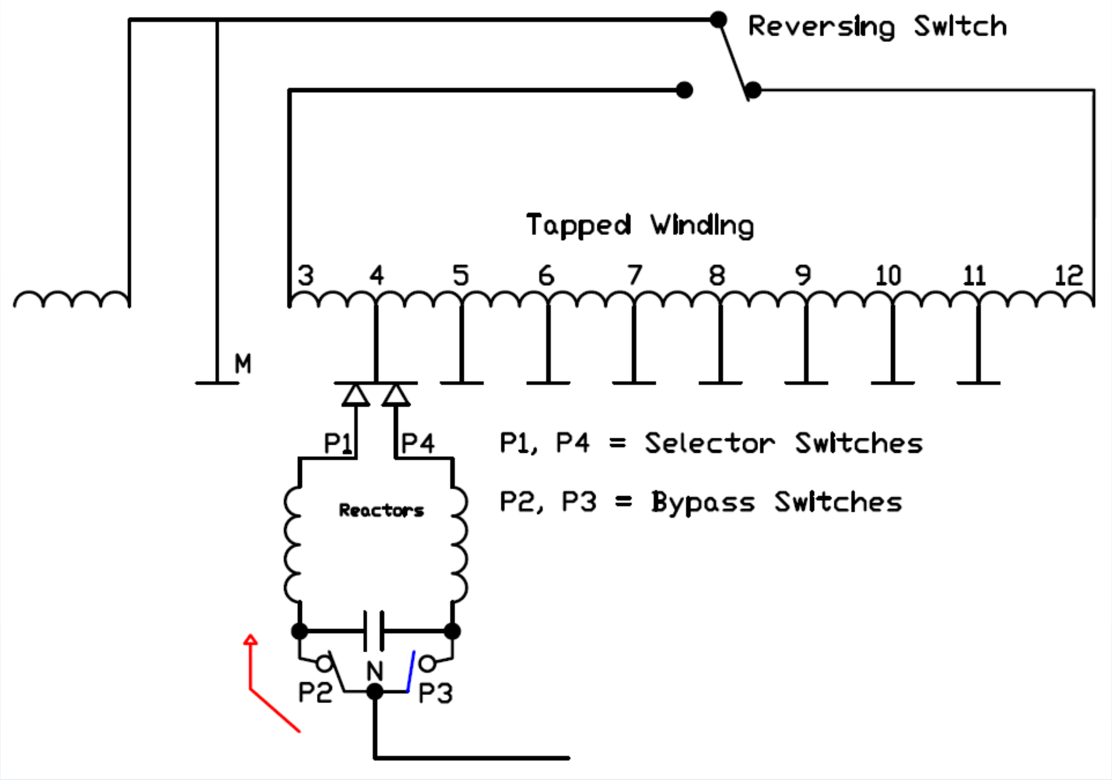
- Bypass switch P3 opens and that forces current to flow through the vacuum interrupter.



OLTC THEORY – MODE OF OPERATION

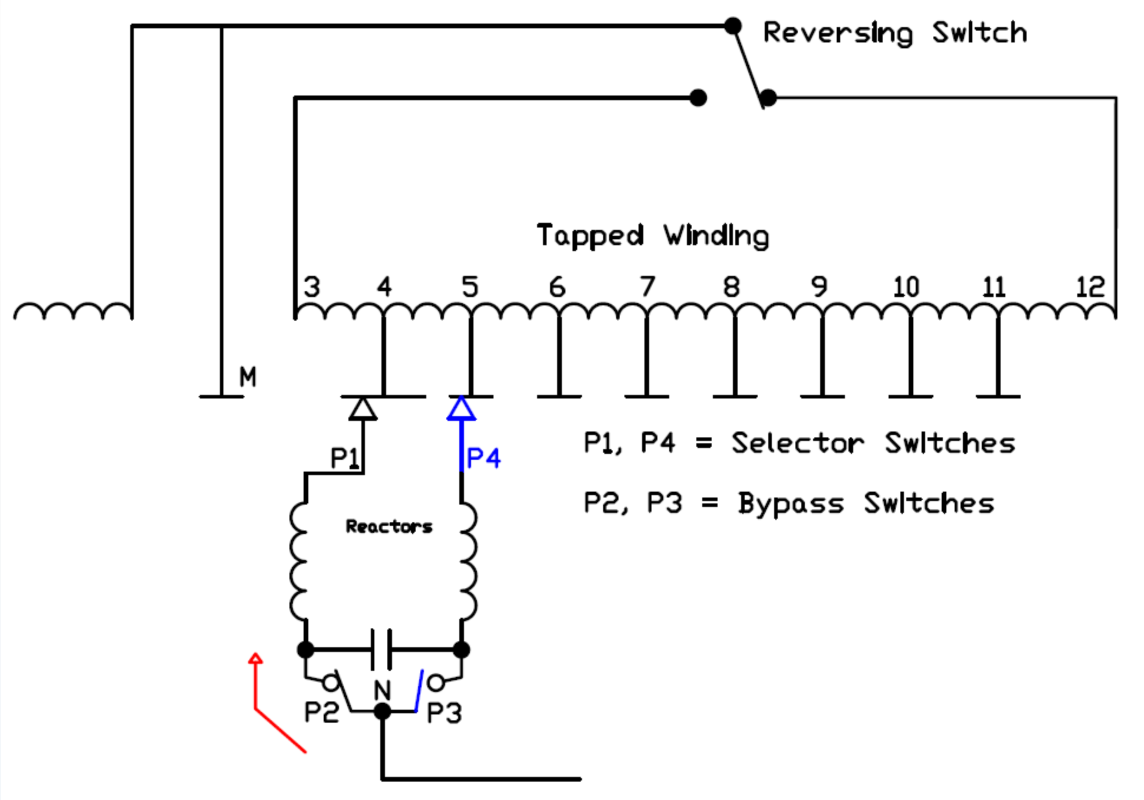
- The vacuum interrupter opens and breakers the current.

- Note: Because the break operation happens in the vacuum interrupter, the oil is not affected by the arc produced during the operation.



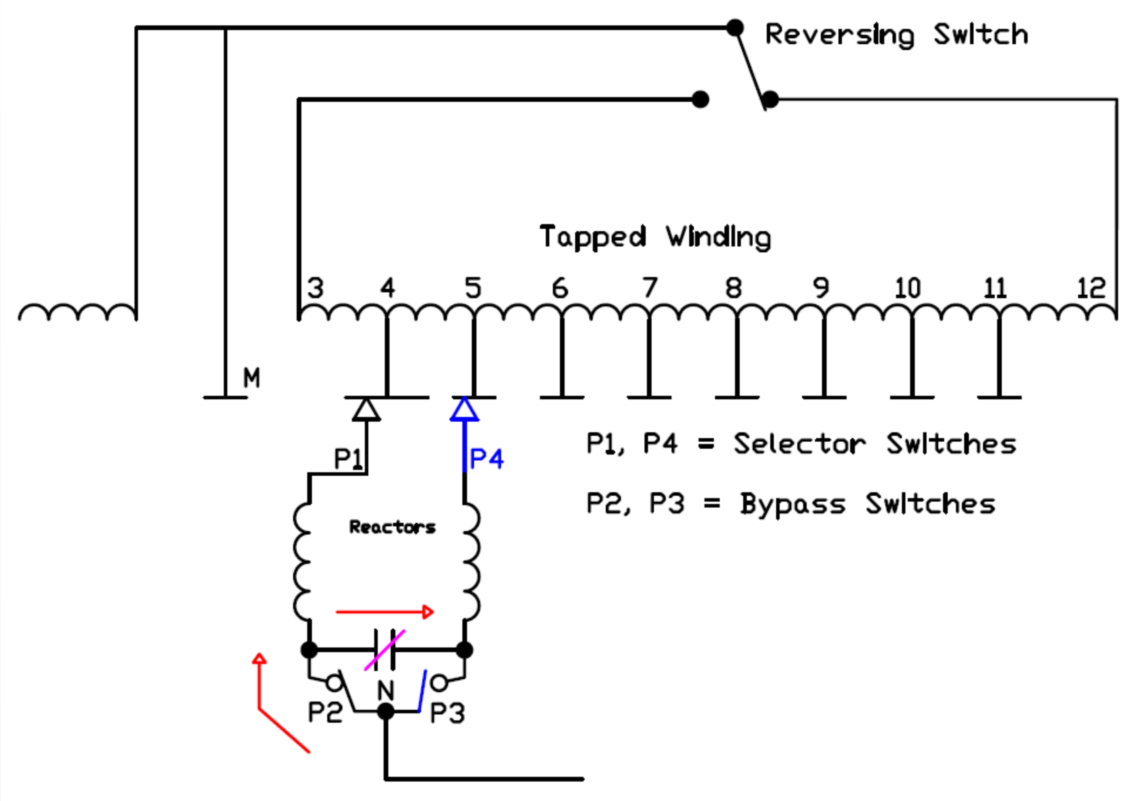
OLTC THEORY – MODE OF OPERATION

- Selector switch P4 advances to the next tap



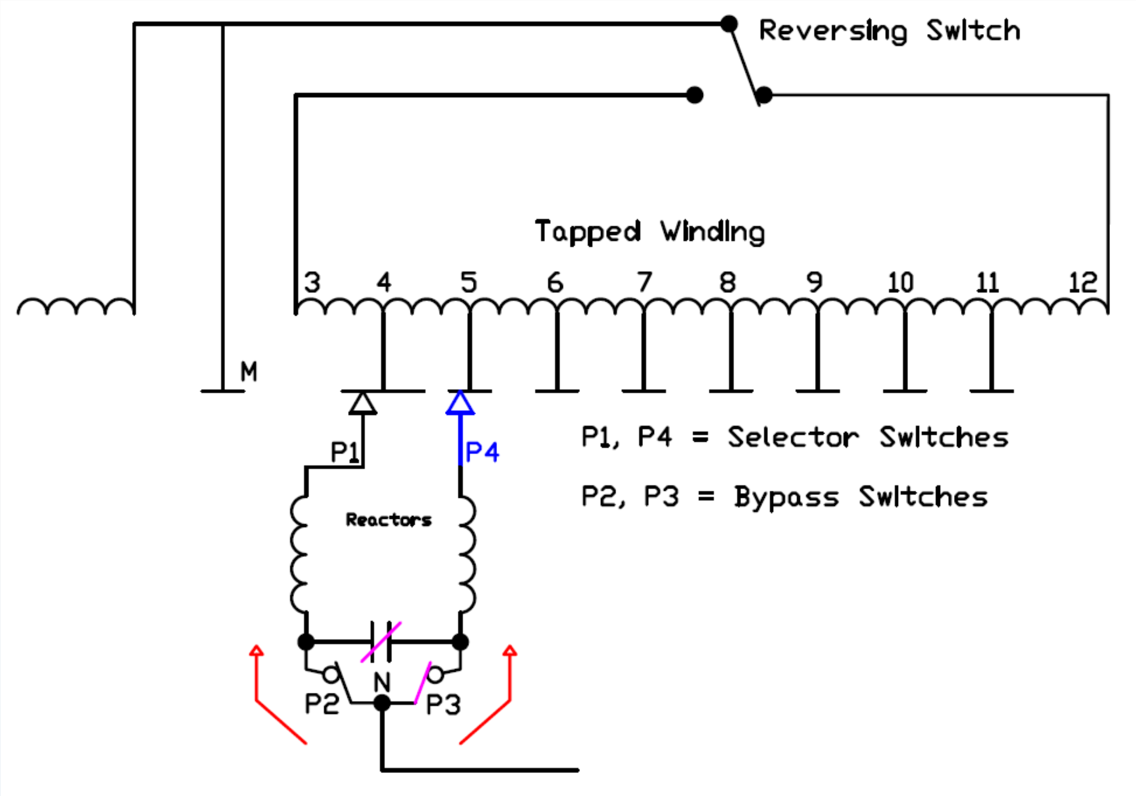
OLTC THEORY – MODE OF OPERATION

- The vacuum interrupter recloses to allow current flow.

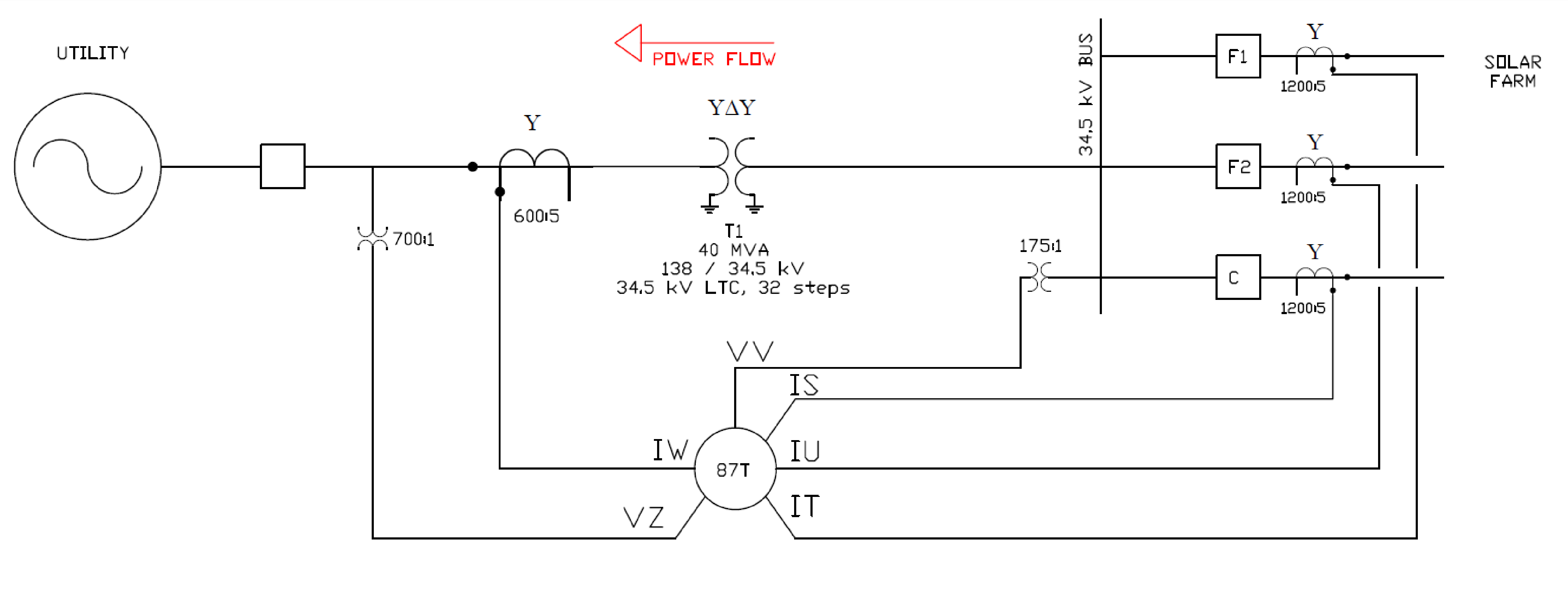


OLTC THEORY – MODE OF OPERATION

- The bypass switch P3 closes and that completes the tap operation



POWER SYSTEM DESCRIPTION



OLTC INSTALLATION ISSUES

- Prior OLTC to be replaced due to leaks
- New OLTC was installed and the transformer was energized
- Solar inverters began to “trip offline randomly”
- Same behavior observed for a few days

OLTC INSTALLATION ISSUES

- Due to concern, oil samples were obtained…

- Comments from the sample company: “LTC Emergency Condition. Immediate remedial action needed”.

Sample Date	06/07/2019	04/29/2019
Top Oil Temp °C		22
Hydrogen (H2)	9000	0
Oxygen (O2)	8760	2070
Nitrogen (N2)	50100	13100
Methane (CH4)	2990	0.8
Carbon Monox. (CO)	69	15
Ethane (C2H6)	206	0
Carbon Dioxide (CO2)	297	248
Ethylene (C2H4)	6240	0
Acetylene (C2H2)	23800	0
Total Gas	101462	15434
COMB GAS	42305	16
EST TCG %	26.12	0.08
C2H4/ C2H2	0.26	0.00
Comb Gas Rate ppm/day	1,084.33	-1.30

RELAY EVENT DATA COLLECTION AND ANALYSIS

- To facilitate the investigation, the 87T relay was programmed to capture relevant data.

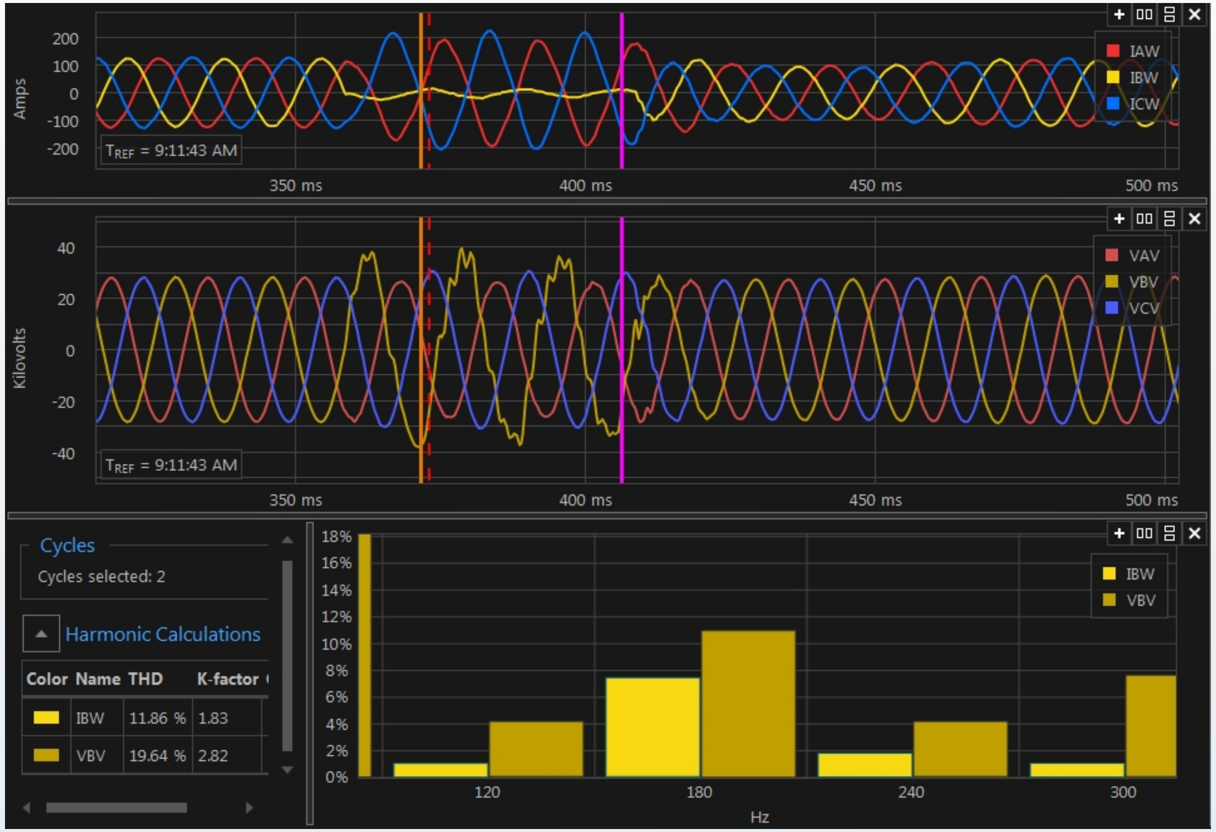
- Several events were triggered daily

RELAY EVENT DATA COLLECTION AND ANALYSIS

- B-phase current drops to mostly zero; A- and C-phase currents at 180 degrees.

- B-phase voltage swell.

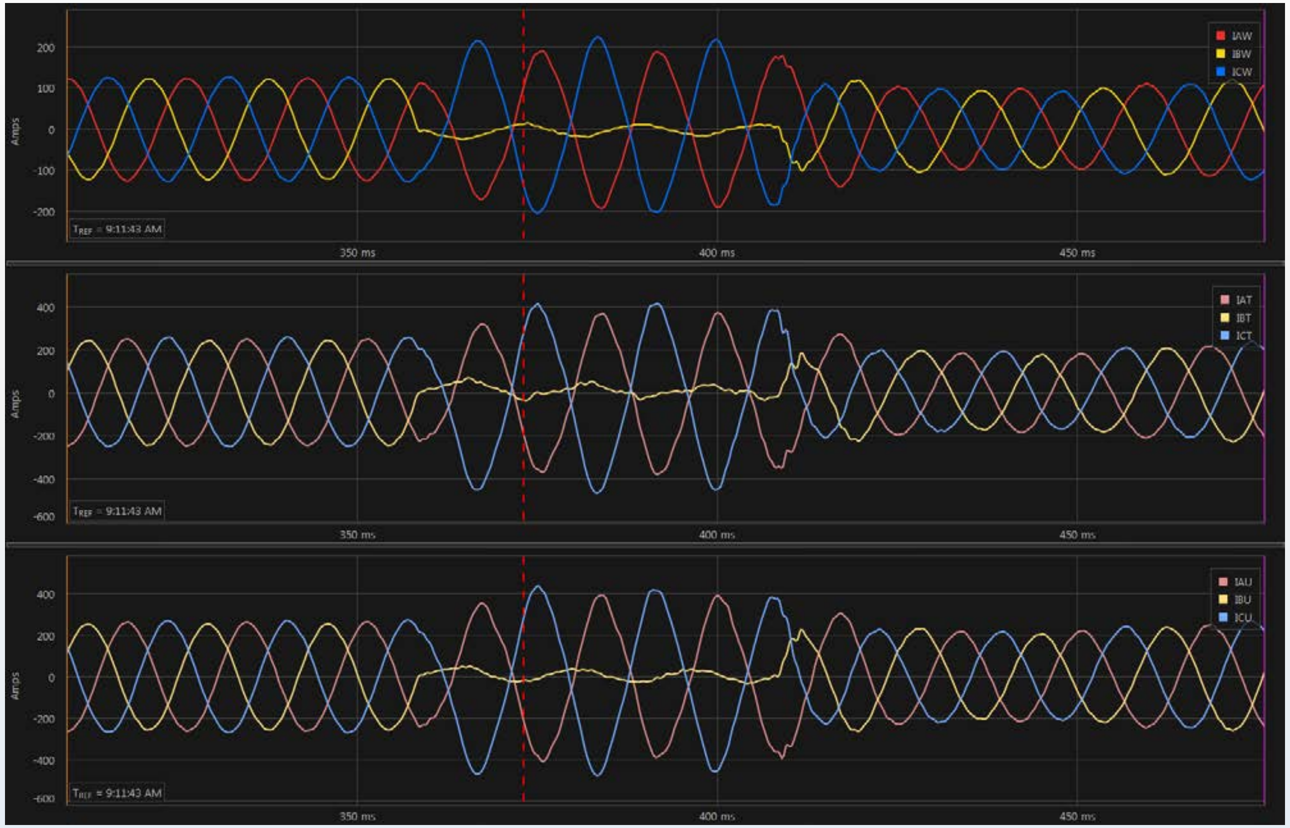
- Larger harmonic content at B-phase.



RELAY EVENT DATA COLLECTION AND ANALYSIS

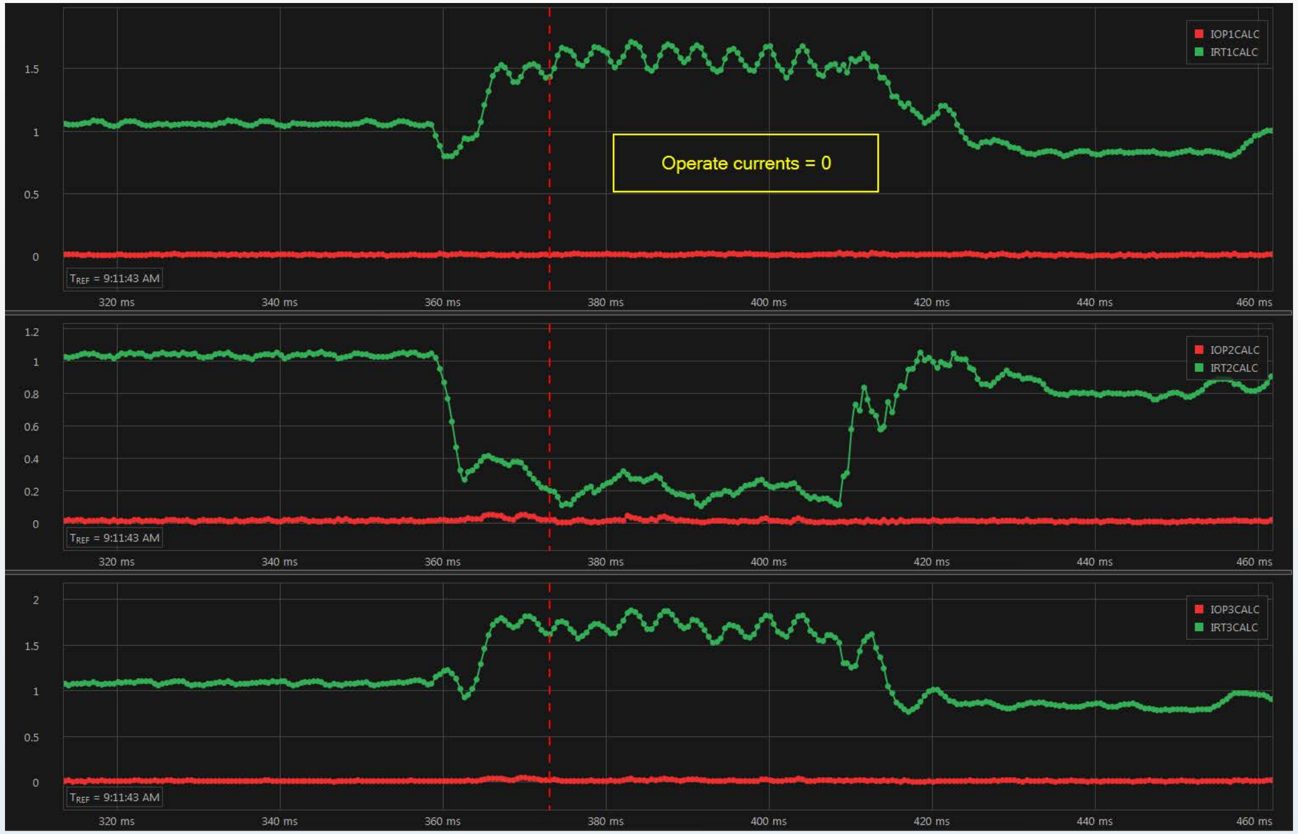
- Same behavior in primary and secondary currents.

- Seen as a through fault?



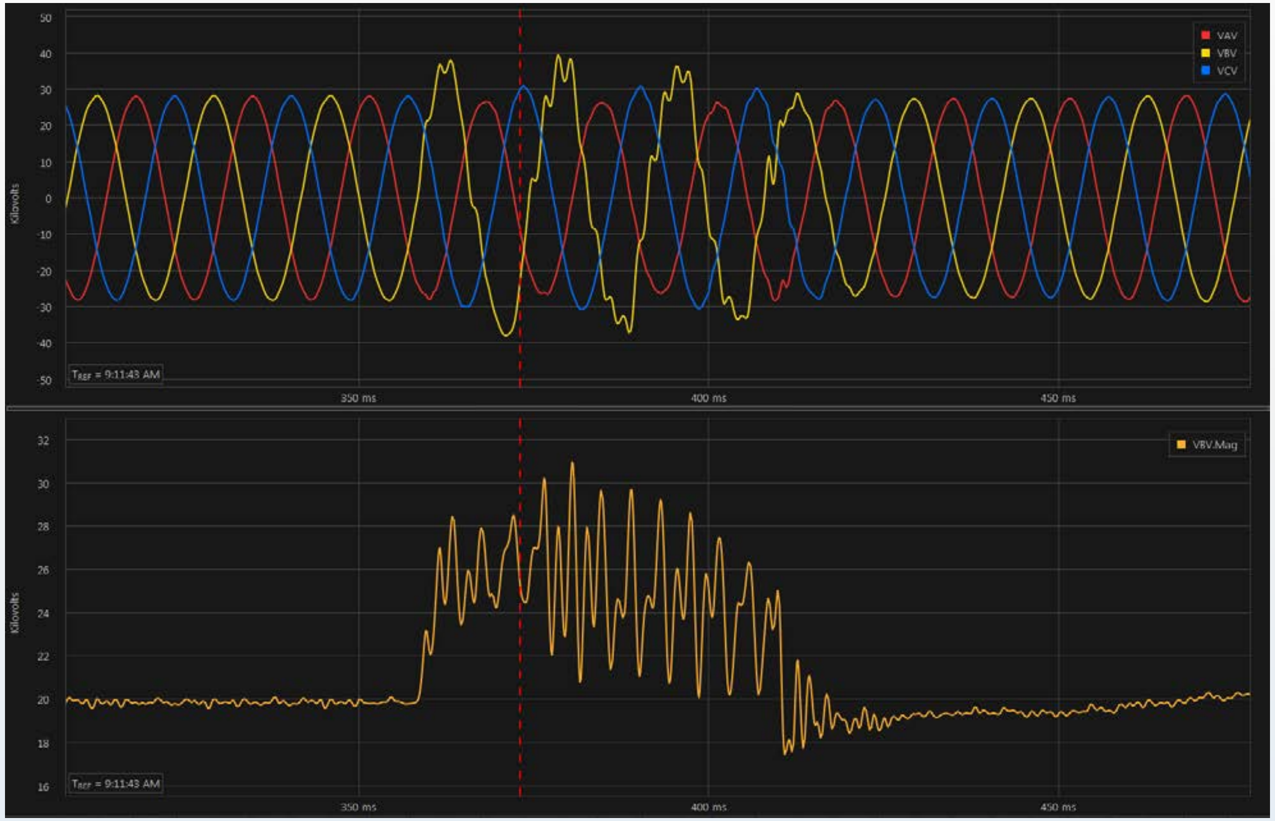
RELAY EVENT DATA COLLECTION AND ANALYSIS

- Operate current remains at nearly zero (external fault)
- Relay restrains for this type of disturbance



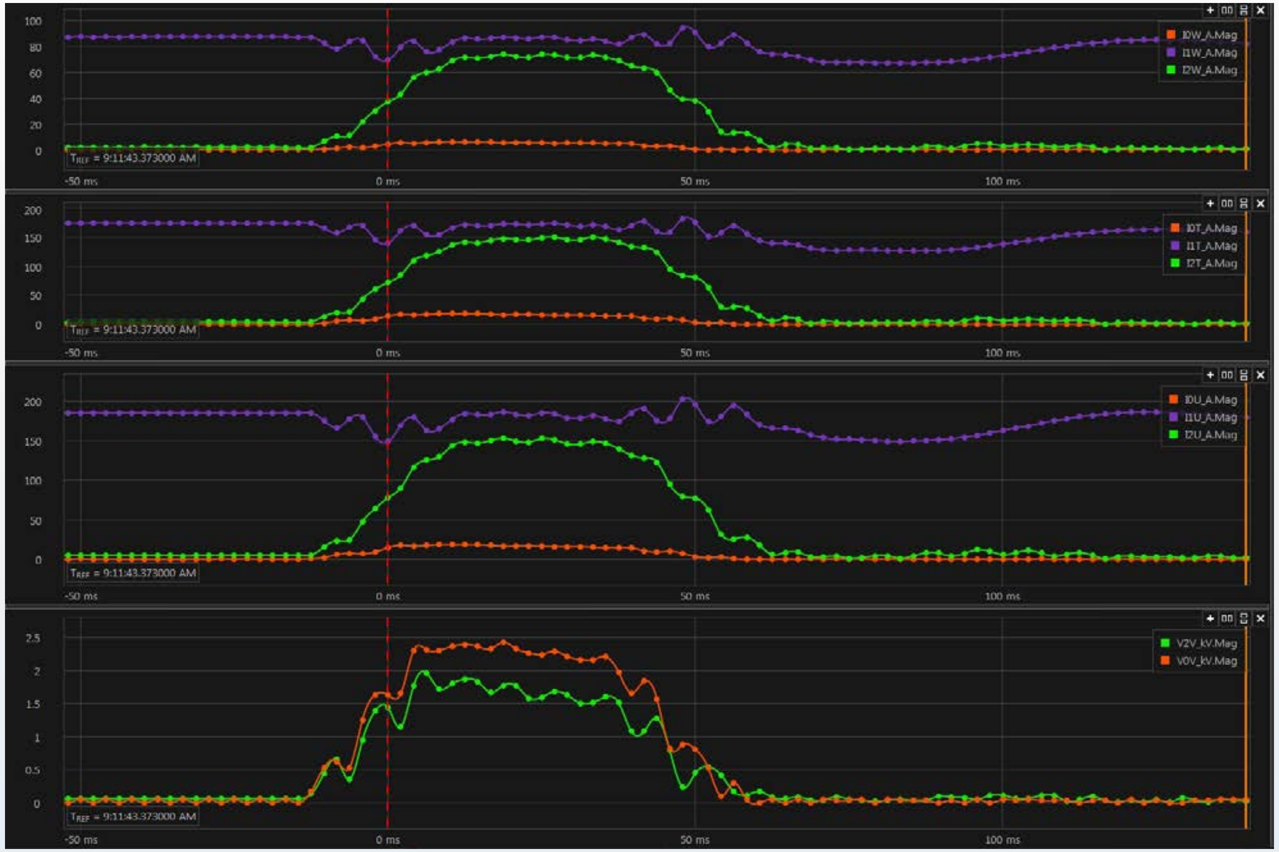
RELAY EVENT DATA COLLECTION AND ANALYSIS

- B-phase voltage swell >30%



RELAY EVENT DATA COLLECTION AND ANALYSIS

- Sequence components shown during the disturbance



RELAY EVENT DATA COLLECTION AND ANALYSIS

Date	6/5/2019	6/5/2019	6/6/2019	6/6/2019	6/6/2019	6/7/2019	6/7/2019	6/7/2019
Time	9:40 PM	9:40 PM	9:11 AM	9:11 AM	9:08 PM	1:21 AM	3:34 AM	9:27 AM
VB RMS (kV)	21.8	21.9	26.1	25.8	21.95	22	21.47	26.5
%VNOM	109.5	110.1	131.2	129.6	110.3	110.6	107.9	133.2
V2 RMS (kV)	0.7	0.7	1.7	1.86	0.7	0.7	0.7	2.1
%VNOM	3.5	3.5	8.5	9.3	3.5	3.5	3.5	10.6
I2W (A)	0.87	0.89	73	55	0.73	0.9	1.3	60.4
I1W (A)	3.9	3.92	87	70	3.53	3.78	3.47	80.7
W - %I2/I1	22.3	22.7	83.9	78.6	20.7	23.8	37.5	74.8
I2T (A)	1.64	1.7	147	109	1.34	1.87	1.7	116.9
I1T (A)	8.11	8.65	172	138	8.32	8.13	8.65	162.8
T - %I2/I1	20.2	19.7	85.5	79	16.1	23	19.7	71.8
I2U (A)	1.89	1.6	153	116	1.84	2.1	1.76	123.79
I1U (A)	4.93	5.21	186	158	5.04	5.2	5.26	173.51
U - %I2/I1	38.3	30.7	82.3	73.4	36.5	40.4	33.5	71.3
3rd harmonic	2.37	2.19	11.28	6.07	3.75	3.95	2.85	10

RELAY SETTINGS RECOMMENDATIONS

- Overvoltage (59) trip on the LV side:
  - Level 1: 20%, no delay
  - Level 2: 10%, small time delay
- Alarm based on values from the previous table
- Note: 59 trip is used to detect site disturbances, not utility variation

OLTC INSTALLATION TESTING PROCEDURE

Raise:

- Operate the OLTC in the raise direction from neutral to open P3 and P4
- Use a continuity tester to verify that P3 - P4 are a closed circuit
- Use a continuity tester to verify that P3-P2, P3-P1, P4-P2, & P4-P1 are an open circuit

Lower:

- Operate the OLTC in the lower direction from neutral to open P1 and P2
- Use a continuity tester to verify that P1 – P2 are a closed circuit
- Use a continuity tester to verify that P3-P2, P3-P1, P4-P2 & P4-P1 are an open circuit

AFTERMATH

CONCLUSION

- OLTCs are essential for automated voltage regulation
- Testing is required when replacing OLTCs to ensure leads have been connected properly
- Alarming recommended to identify issues
- Overvoltage protection recommended to prevent further damage

QUESTIONS?