

NERC Lessons Learned

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Transient Induced Misoperation:
Approach I



Control Circuit Transient
Misoperation of Microprocessor
Relay



February 25, 2021

- 2019:
 - Voltage transients from 230 kV bus fault initiated protective relay inputs to a hydroelectric dam
 - Created multiple powerhouse line misoperations and tripping 221 MW generation
 - 47 k Ω resistor was added on all line relays to dampen fault
 - 15 kHz continuous recorder was installed to monitor relay input
- 2020:
 - Single phase fault on 500 kV line
 - Misoperation of same 2 powerhouse lines tripped 315 MW

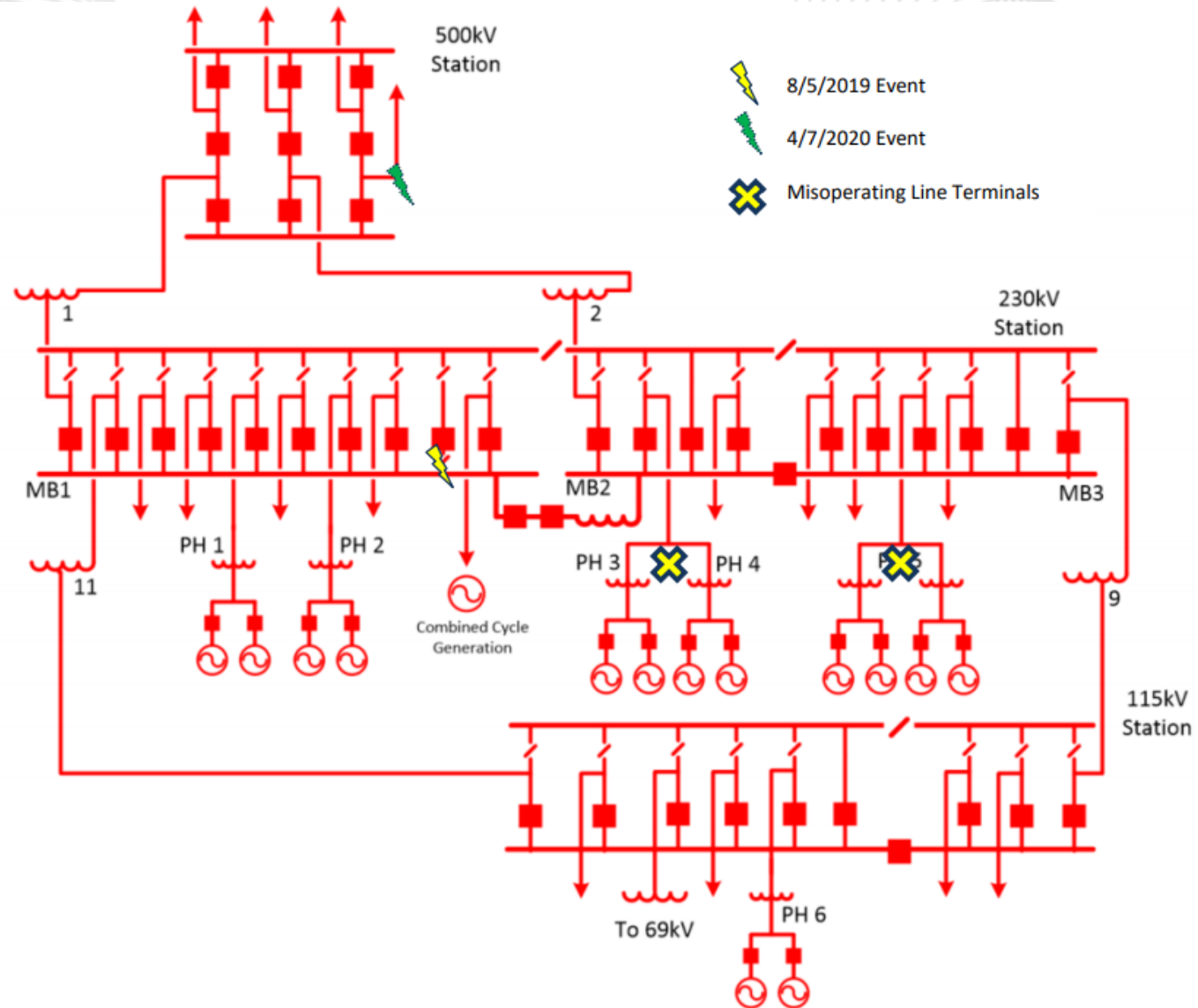


Figure 1: One line diagram of the impacted station.
 Line relay misoperations occurred on powerhouse lines 3/4 and 5 [1]

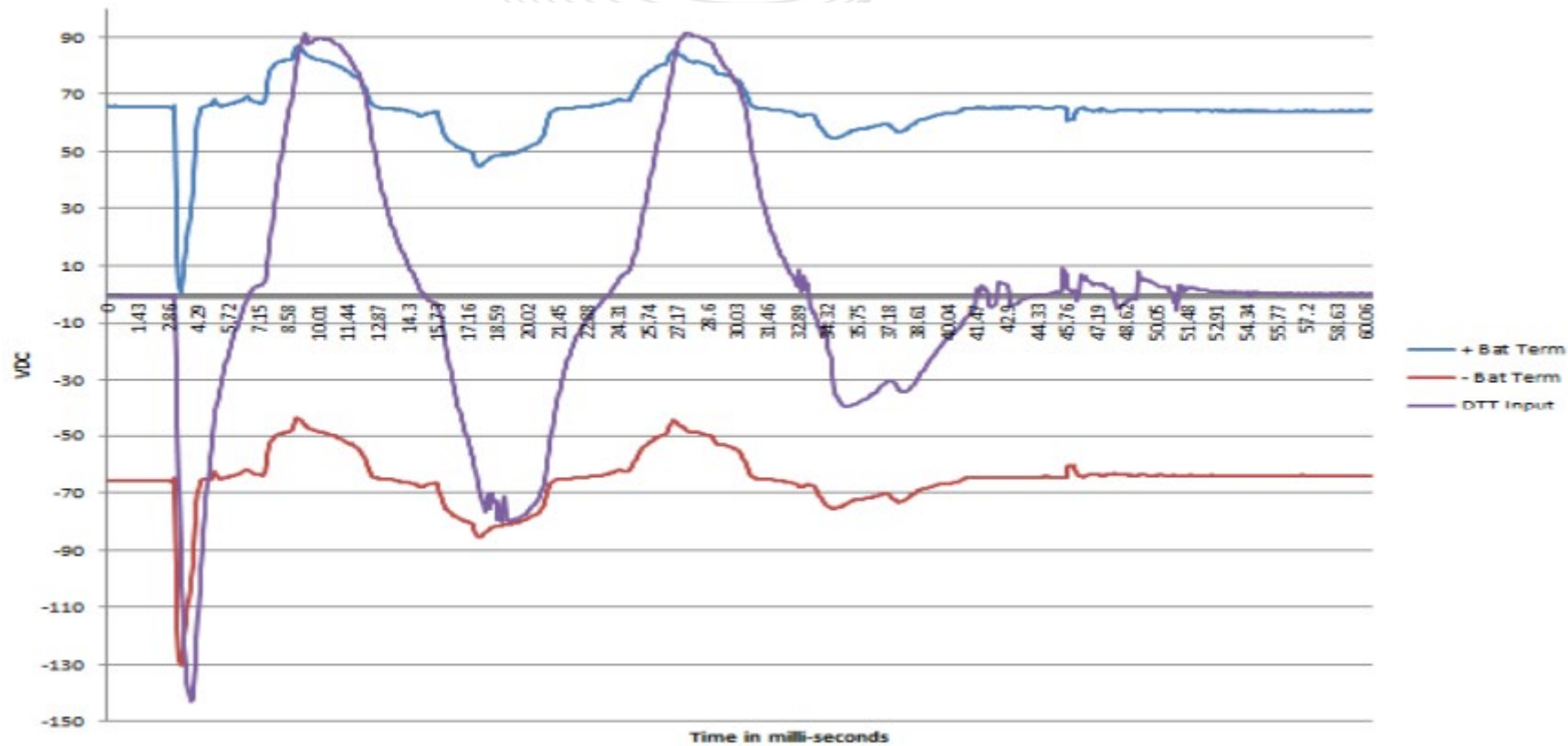


Figure 2: 15 kHz continuous recorder data measuring relay supply voltage (Blue and Red) and the DTT input voltage across the installed resistor (Purple) [1]

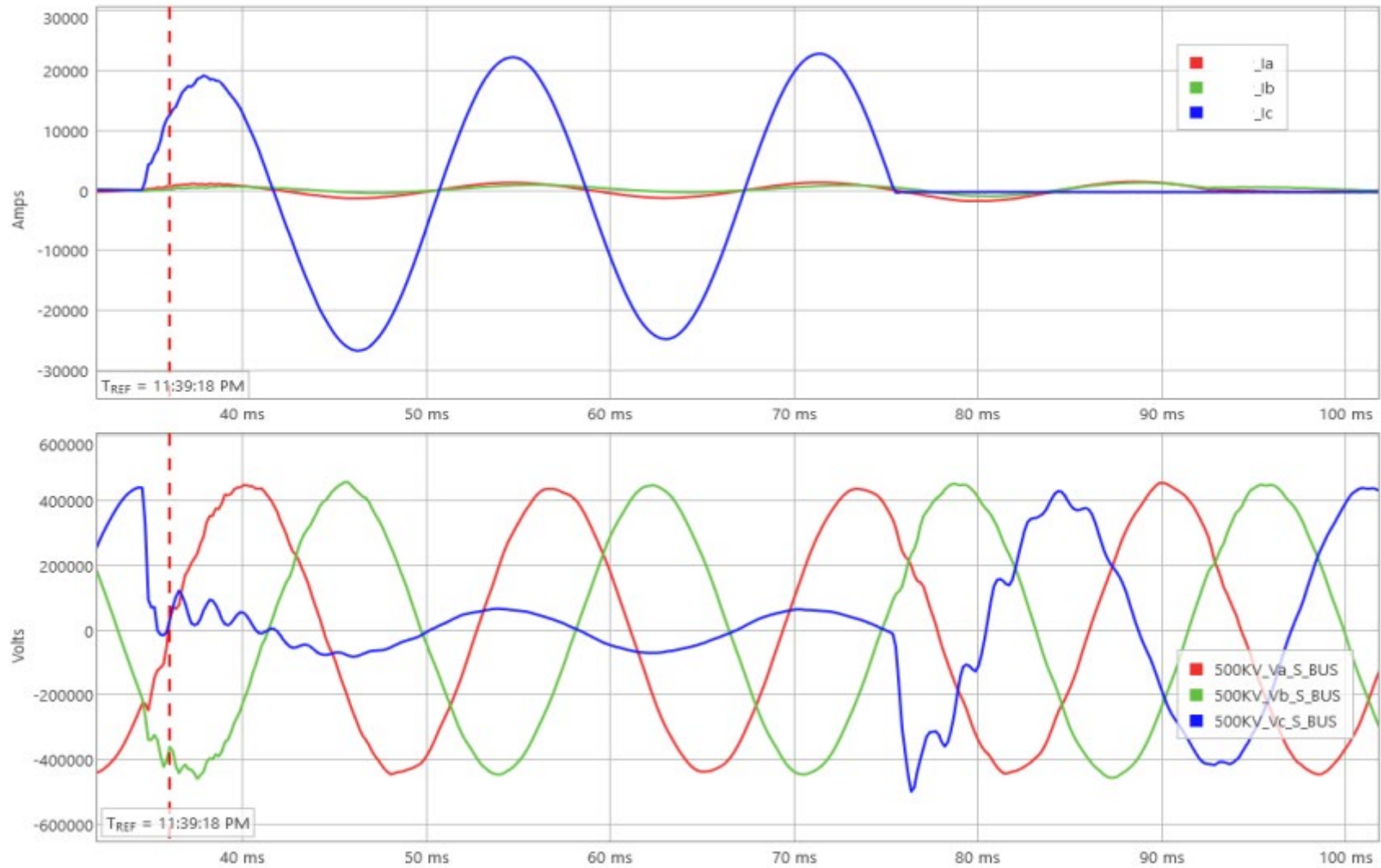


Figure 3: Event from digital fault recorder, located at the substation adjacent to the powerhouse, showing line current (top) and bus voltage (bottom) during the 2020 500 kV line fault [1]

- Issues at powerhouse began after the addition of a second 1,300 MVA 500/230/34.5 kV autotransformer in 2016
- Root Cause: result of high ground current present at the powerhouse during high magnitude ground faults
- Change to a more effective 23 k Ω resistor
- Current Transformer grounds were checked and tested to rule out coupling between CT and DTT control circuit during faults
- Install relay-to-relay communication from GSU protection to alternate powerhouse line relay
- Powerhouse relay protection replaced with microprocessor relays

- Resistors have been added and monitoring equipment has been installed
- Situations like this happens when various generations of equipment and designs are combined together at a single site
- Reduce cabling connected to single input
- Increase burden of microprocessor relay input
- Evaluate system before installing relays or equipment



Transient Induced Misoperation:
Approach II



Loss of Protection during
Severe Lighting Event



February 25, 2021

- Lightning strike induced fault of 345 kV transmission line
- System 1 and 2 protection groups shut down
- Neither system cleared the fault
- Terminated 345/115/13.8 kV substation
- Fault continued over 1.5 seconds
- Protection at remote terminal tripped

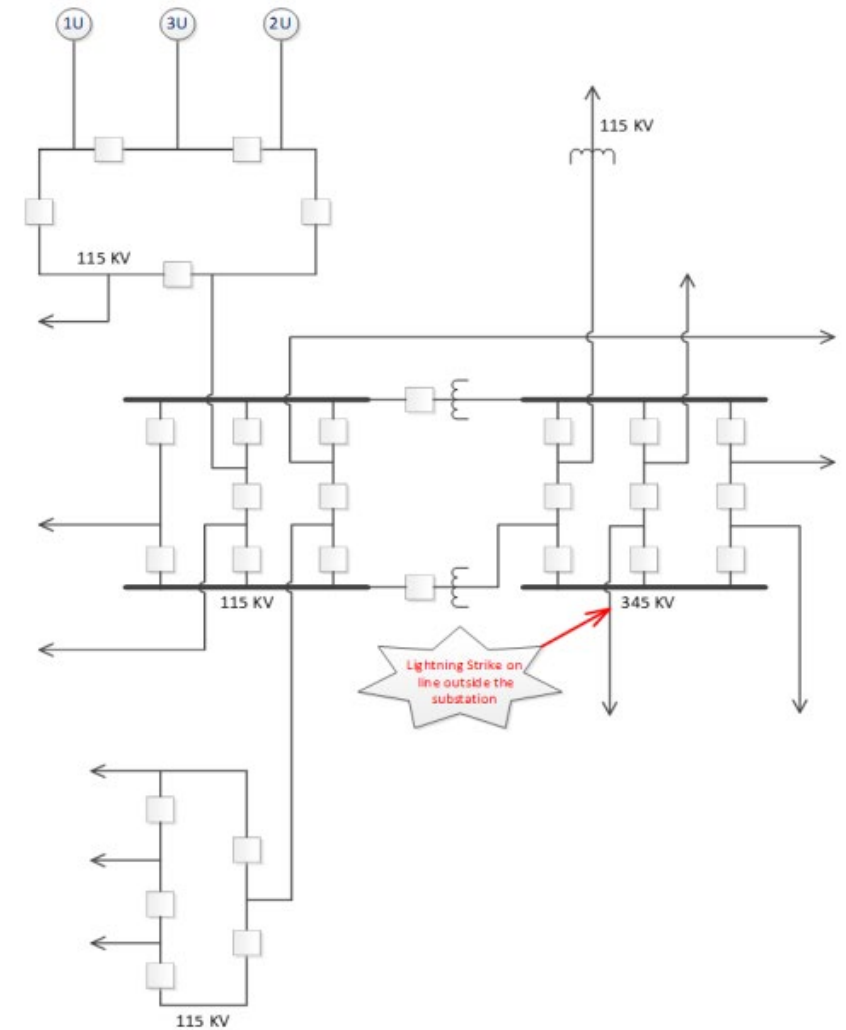
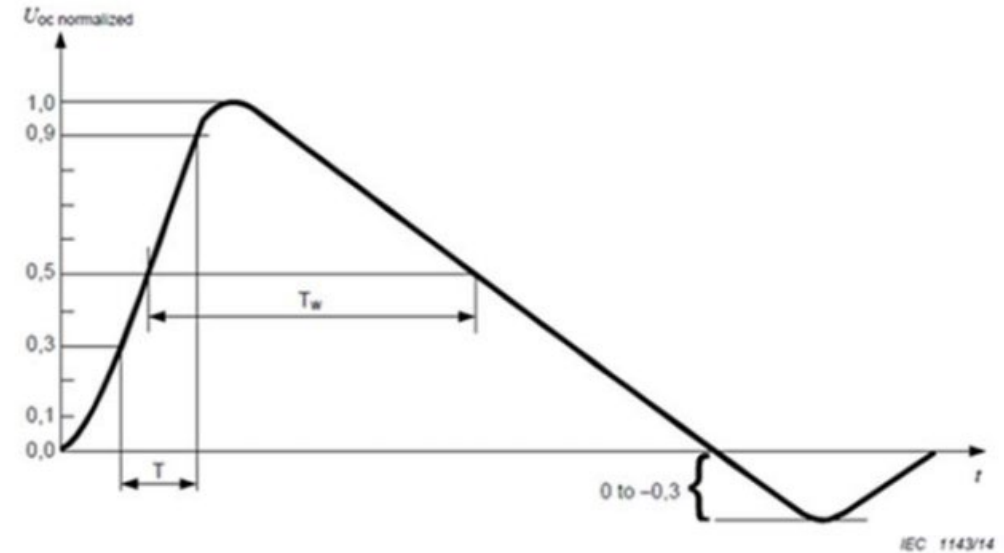


Figure 4: One Line Diagram [2]

- Fault was not cleared by System 1 or 2 as they were rebooting simultaneously, 14 remote terminals cleared the fault
- System 1
 - Directional Comparison Blocking via power line carrier
 - Line operated via DBC communication assisted elements in 4.5 cycles
- System 2
 - Line Current Differential via optical ground wire
 - Did not operate due to the loss of communication with powered off relay

- No SOL violations or security issues occurred
- Event added stressed conditions that could have resulted to IROL violation
- Microscopic damage to circuit board in System 1
- No damage in System 2 relay
- Equipment in the station incurred damage
- Both systems relays were sent in for testing

- System 2 testing subjected 4.0 kV surge
- Ground potential difference exceeded the surge withstanding capability of the relay, resulting in a reboot
- System 1 did not withstand surge, no reboot



Front time: $T_f = 1,67 \times T = 1,2 \mu s \pm 30 \%$
 Duration: $T_d = T_w = 50 \mu s \pm 20 \%$

NOTE The value 1,67 is the reciprocal of the difference between the 0,9 and 0,3 thresholds.

Figure 5: IEEE Surge Withstand [2]

- Protection system owner must consider the surge withstand rating of the equipment being installed
- Protective relay systems, when exposed to surges beyond their specified criteria, may not operate as intended or fail as expected
- As substations are modified, cabling should be upgraded to comply with latest design

[1] Transient Induced Misoperation: Approach I (Control Circuit Transient Misoperation of Microprocessor Relay)

https://www.nerc.com/pa/rrm/ea/Lessons_Learned_Document_Library/LL20210203_Transient_Induced_Misoperation_Approach_I.pdf

[2] Transient Induced Misoperation: Approach II (Loss of Protection during Severe Lightning Event)

https://www.nerc.com/pa/rrm/ea/Lessons_Learned_Document_Library/LL20210204_Transient_Induced_Misoperation_Approach_II.pdf

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