Load Monitoring & FIDVR

Dominion Efforts

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NASPI North American SynchroPhasor Initiative

What is FIDVR?

- **FIDVR – Fault-Induced Delayed Voltage Recovery**
  - "phenomenon whereby system voltage remains at significantly reduced levels for several seconds after a … fault has been cleared."

    - NERC, "A Technical Reference Paper Fault-Induced Delayed Voltage Recovery," June 2009

  - Low voltage condition (typically < 0.5-0.6 pu)
  - Induction motor stalling, resulting in large reactive power draw
  - Delayed voltage response (typically > 2 seconds)
  - Load drop due to device protection (relays, contactors, thermal)
  - Possible over-voltage conditions due to load loss

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Motivation – NERC Standards

- **NERC TPL-001-4**
  - **Requirement R5:** "…For transient voltage response, the criteria shall at a minimum, specify ***a low voltage level*** and a ***maximum length of time*** that transient voltages may remain below that level."
  - **Requirement R2.4.1**: "…shall include a Load model which represents the ***expected dynamic behavior of Loads*** … considering the behavior of ***induction motor Loads***.

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Beginning Stages

- **Model vs. Actual:** Modeled dynamic load should match actual, yet expected model parameters do not match actual
  - Need to improve monitoring to understand
- **Risk of Delayed Recovery:** Is delayed recovery a reliability risk? Should there be mandatory standards specifying a recovery criteria?
  - Need detailed studies of interaction with generators, protection, etc.
- **Overvoltage:** Delayed recovery and FIDVR results in motor load tripping, which can cause severe overvoltages; yet this is rarely mentioned and not focus of reliability standards.

Understanding the FIDVR for DVP

- **Observations:**
  - Simulations using composite load model with expected load composition parameters show widespread FIDVR
  - Transmission level monitoring shows little to no widespread FIDVR
  - Distribution level monitoring shows prominent local FIDVR events
  - Anecdotal evidence of distribution circuit sympathetic tripping - due to overcurrent (*motor stalling*)

- **Goal:**
  - Improve distribution level monitoring capability
  - Use captured data to understand phenomena & model parameters
  - Use improved model parameters to perform better informed studies

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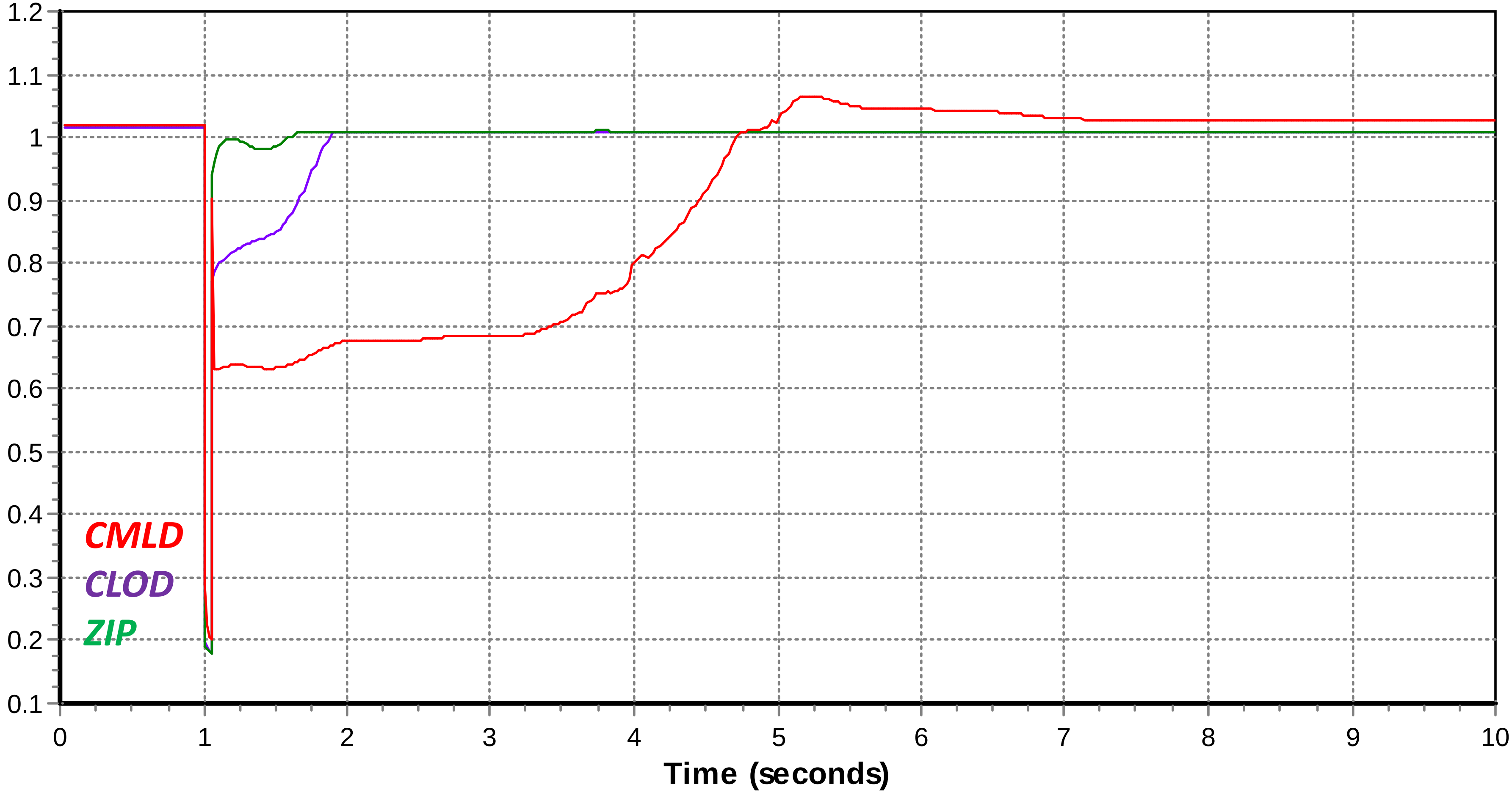
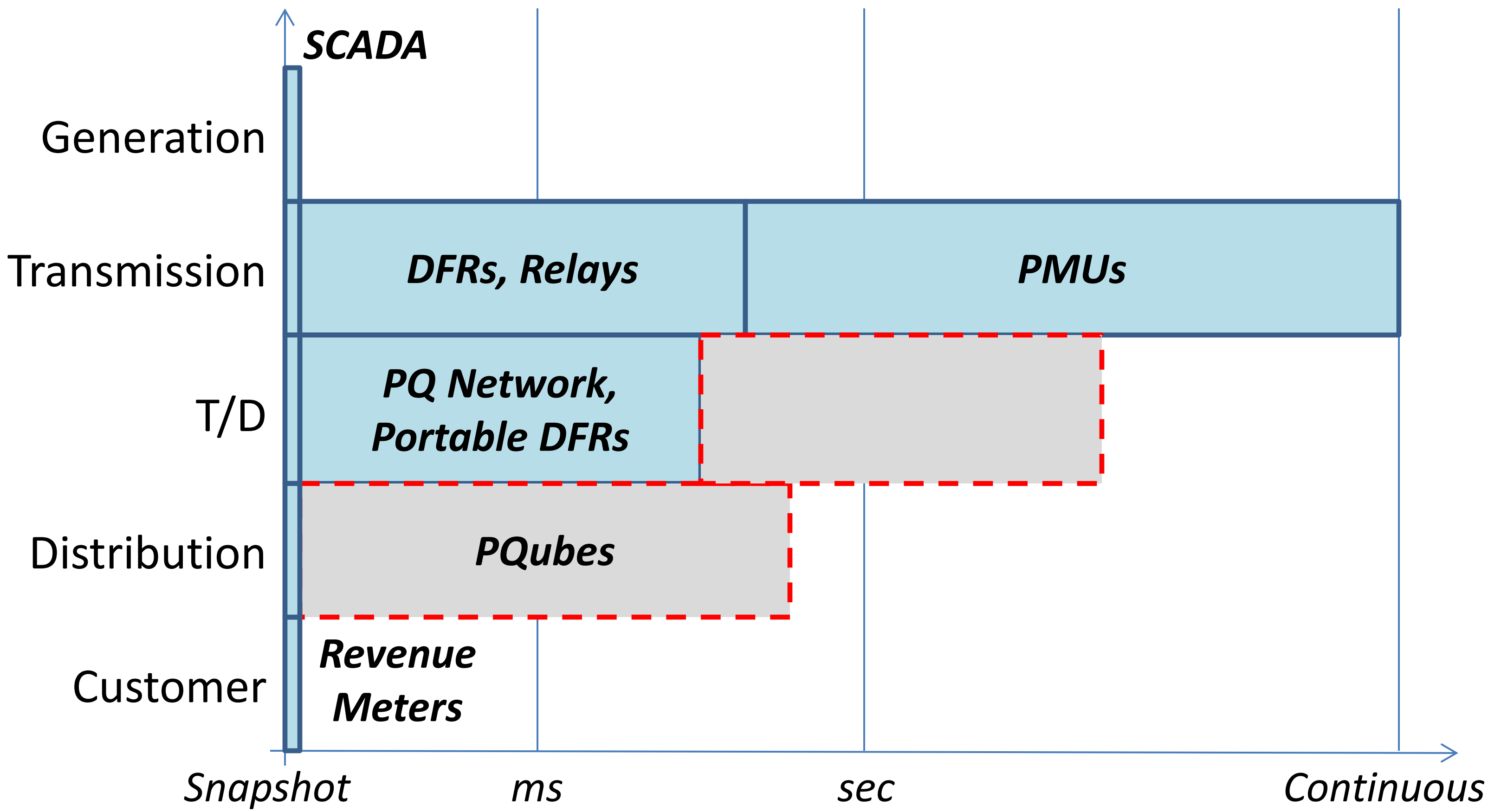
Same System, Different Model



Distribution-level monitoring can help us understand the dynamic behavior of the load as an aggregate.

Technology Gap – Capture Duration



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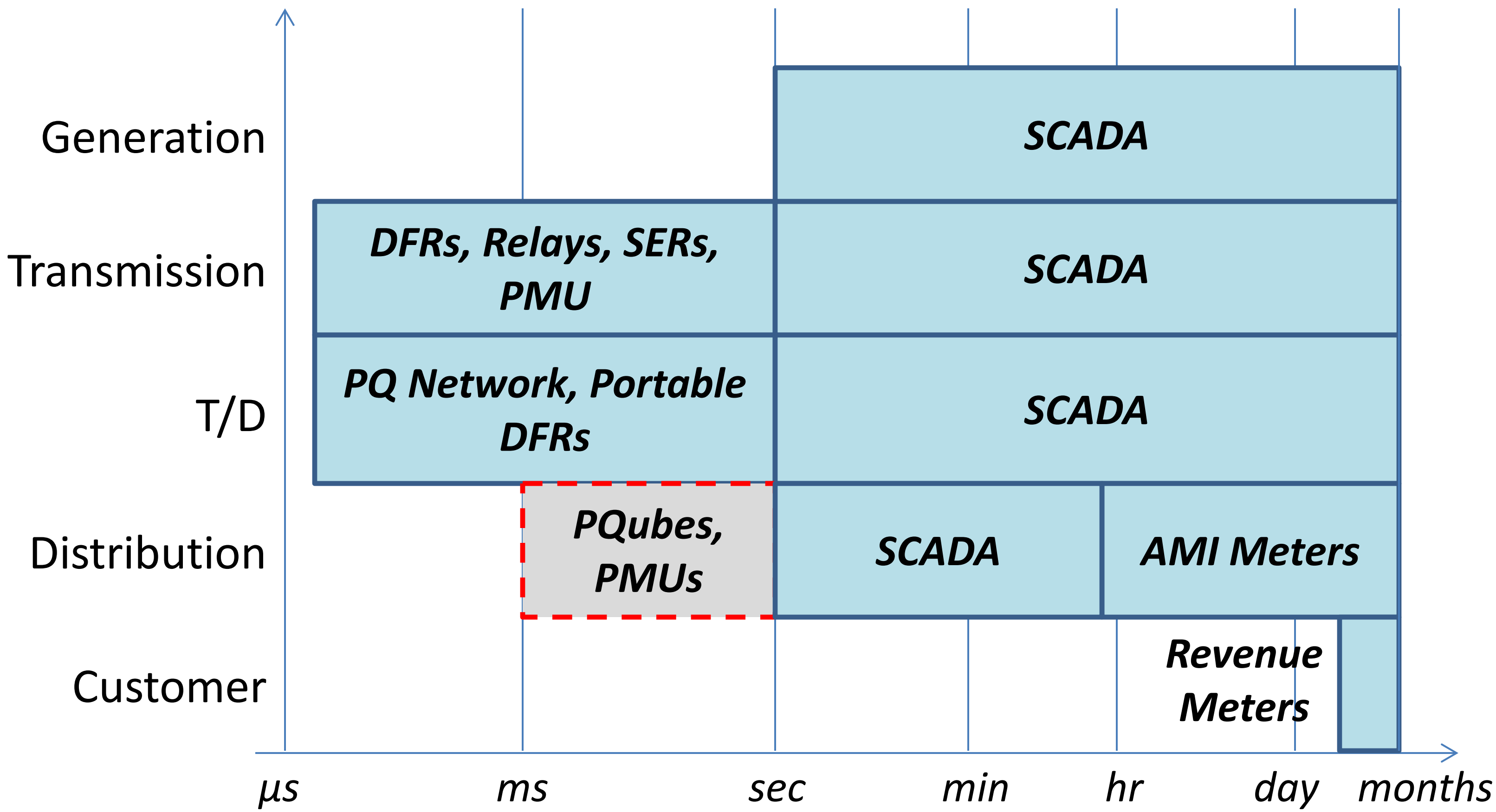
Technology Gap – Monitoring Resolution



PQ Meter Settings

- **Past:** Magnitude trigger with duration setting
  - Can capture longer term dynamics following faults
- **Current:** Trigger on V < 0.9 pu, stop capture upon recovery back to 0.9 pu
  - Very useful for fault analysis, but not for longer dynamics such as A/C motor stalling

- We haven't seen many "FIDVR" events on the PQ meter network since the 2008-2009 timeframe.
  - "We've solved the problem?"
  - No, the meters are likely just not capturing the phenomenon

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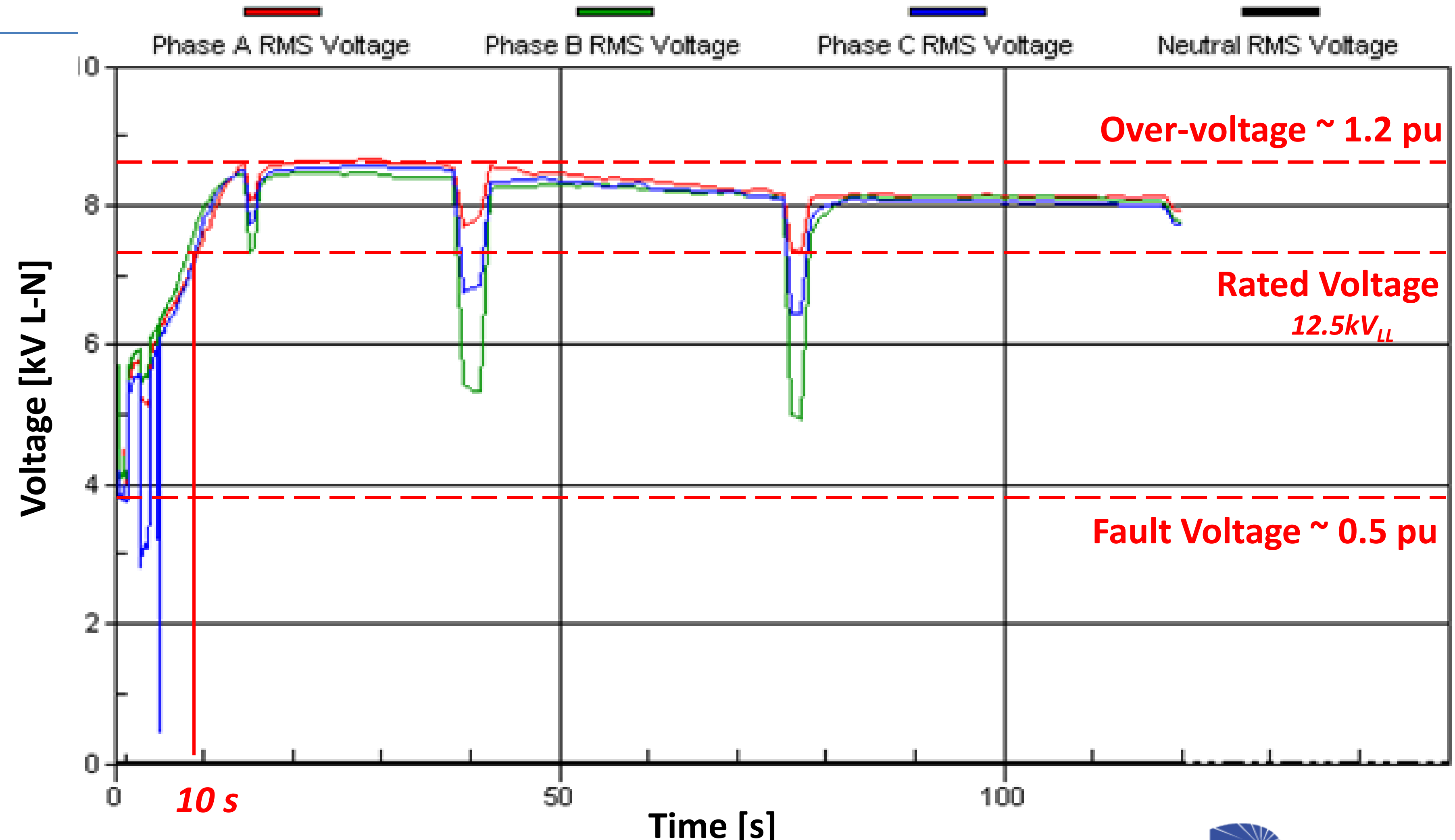
Example 1 – July 4, 2006 15:56:19 EST



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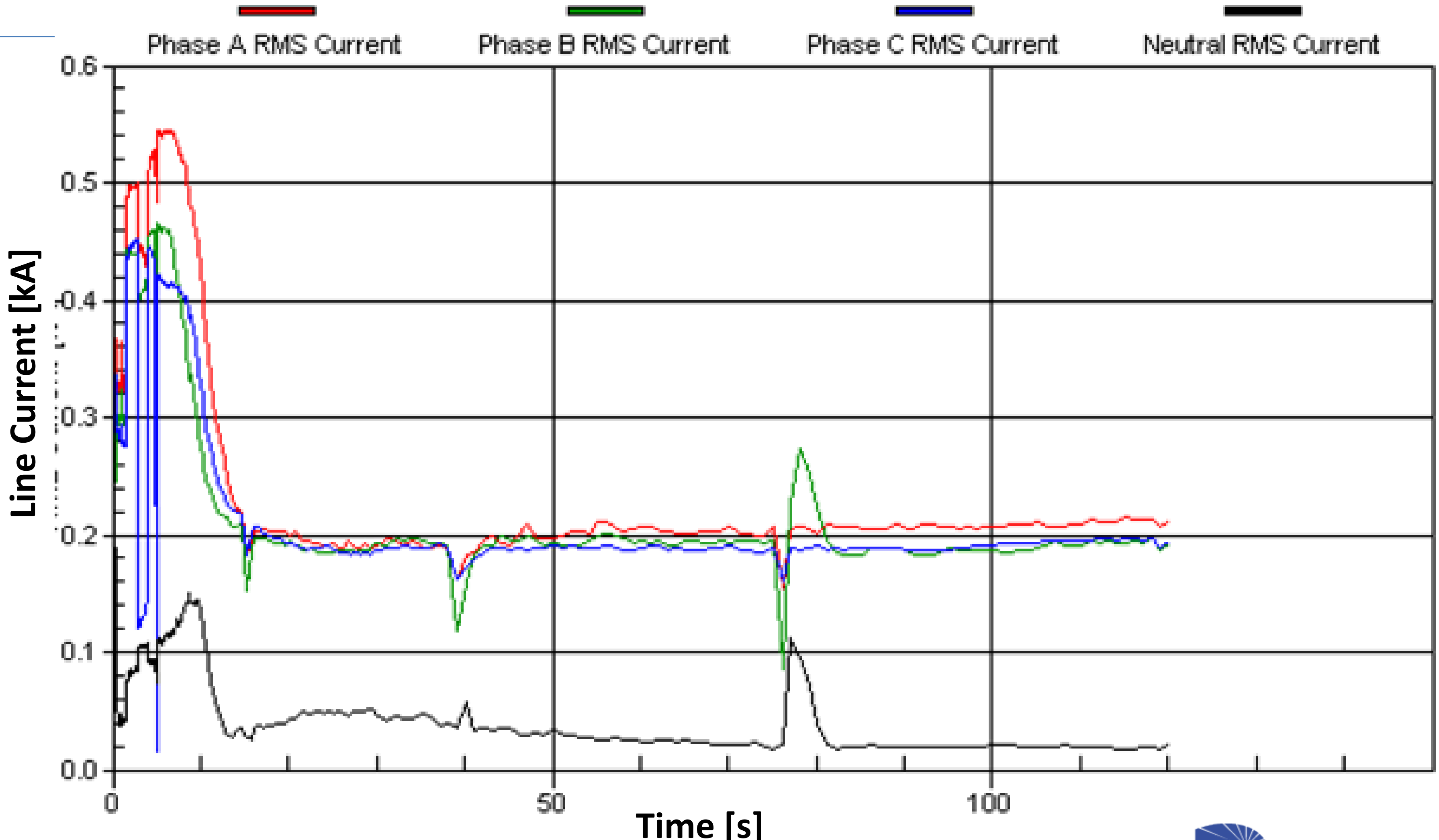

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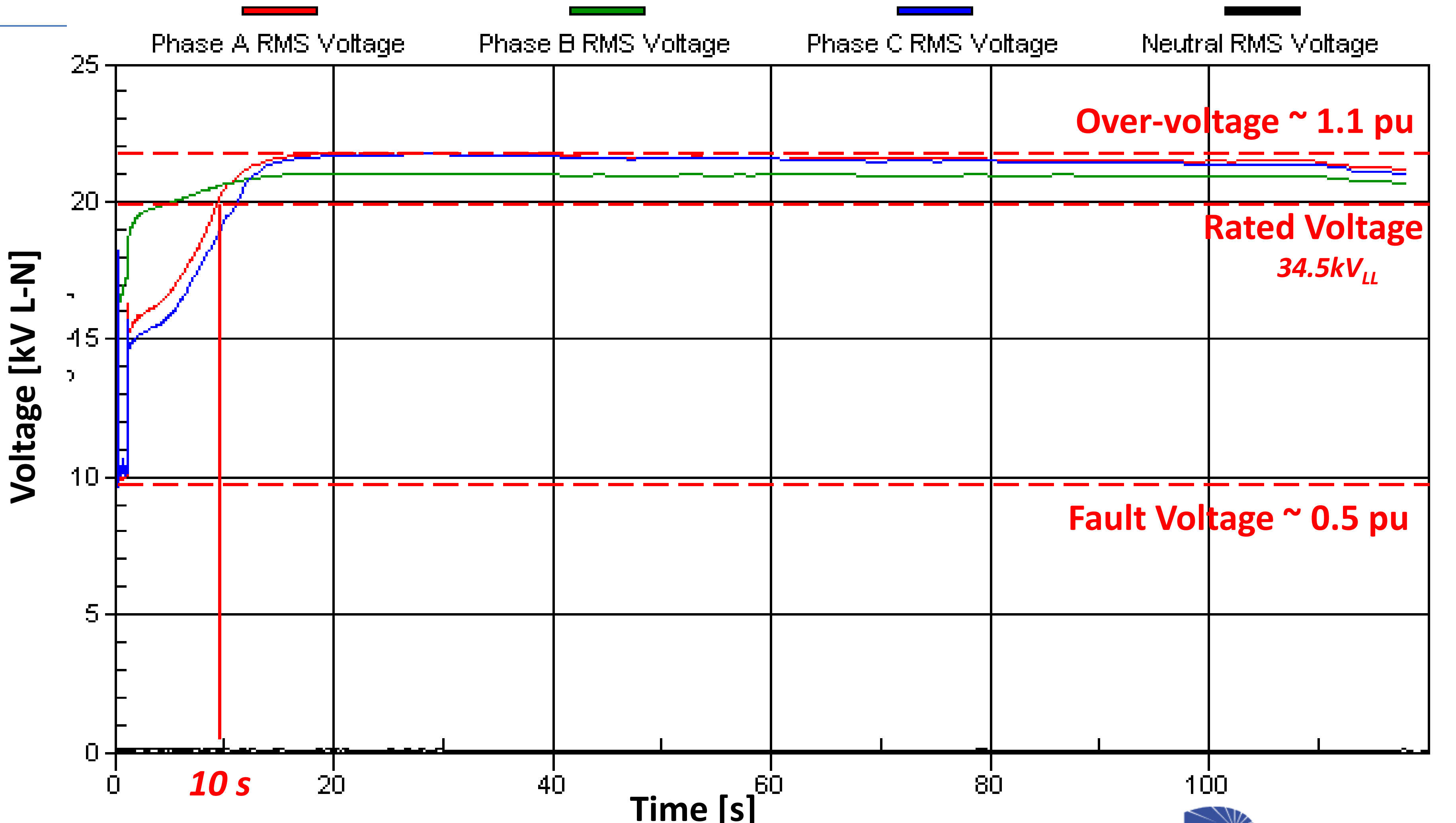
Example 2 – August 1, 2006 18:02:49 EST



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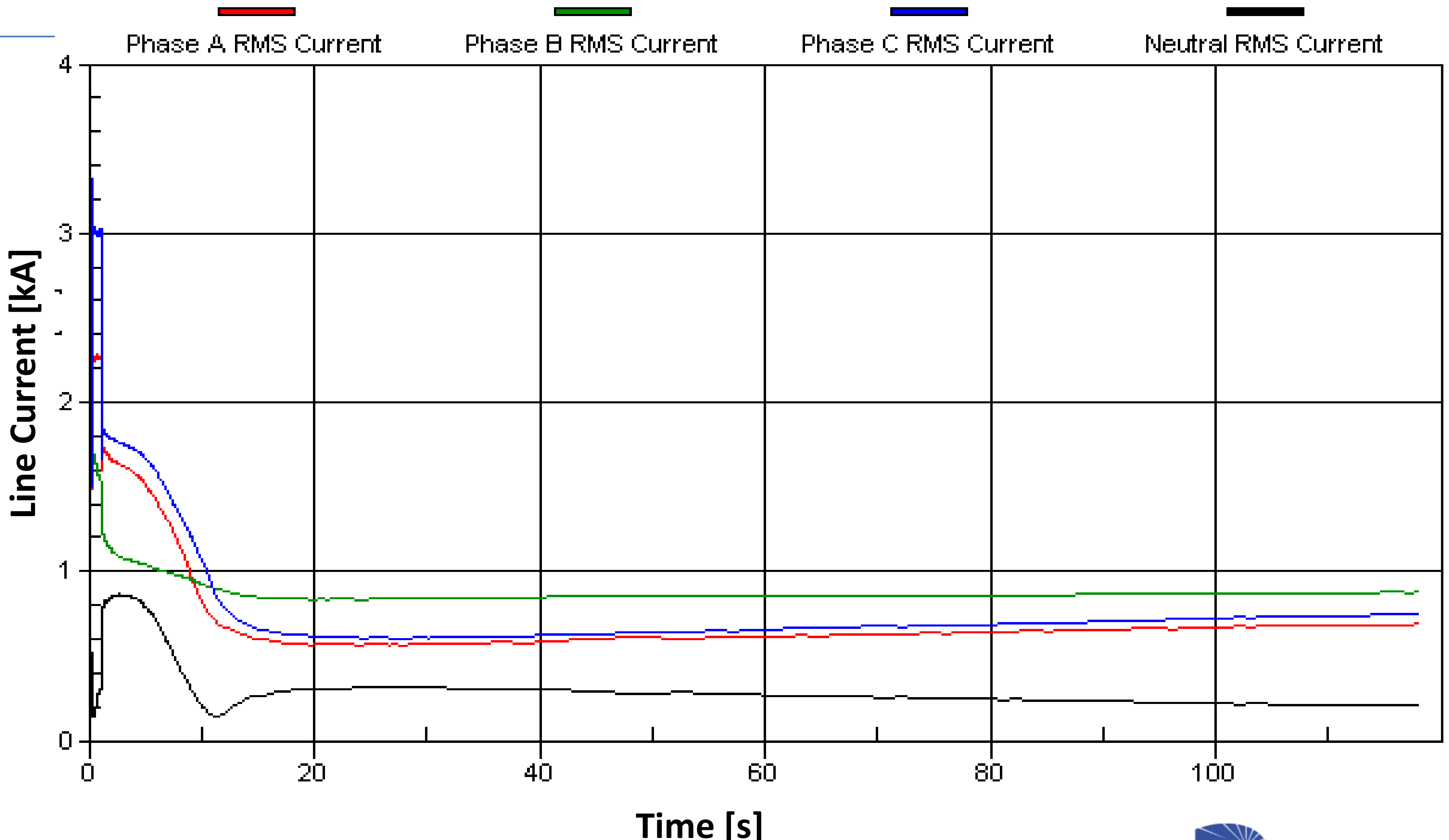
Example 2 – August 1, 2006 18:02:49 EST



Standardization = Proliferation

- % of synchrophasors for Capital Expenditure = < 0.1%
  - $1M/yr expected on PDC infrastructure & architecture

- **Transmission**– 500/230/115kV
  - 27 control houses (21 substations) with PDCs streaming
  - 43 control houses (38 substations) added but not yet networked
  - Proliferation very fast – **"300 substation by 2020"**

- **Distribution** Level – Hurdles
  - Use 300-series SEL relays (387/351) w/o PMU capability
  - Use Power Quality meters (SEL 734/735) w/o PMU capability
  - Adding PMU functionality to these devices will proliferate PMU technology into Distribution

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Moving Forward

- **Technology Need:** PMU capability in distribution or T/D protective and monitoring equipment
- **PMU Proliferation:** PMU coverage will expand drastically on Transmission network thanks to standardization
- **Distribution Feeder Coverage:** Install PQube or PMU-type meters in distribution system to capture down-the-feeder response to system faults
- **Leverage Existing Equipment:** Reconfigure existing recording capabilities to ensure longer term dynamics are captured
- **Streamline Event Detection:** Develop automation for analyzing real-time and/or database of data

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Thank You!

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