Load Monitoring & FIDVR

Dominion Efforts

October 2014
Houston, TX

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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.”
  

- 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
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.
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
Distribution-level monitoring can help us understand the dynamic behavior of the load as an aggregate.
Technology Gap – Monitoring Resolution

- Generation
- Transmission
- T/D
- Distribution
- Customer

- DFRs, Relays, SERs, PMUs
- PQ Network, Portable DFRs
- PQubes, PMUs

- SCADA
- AMI Meters

- μs
- ms
- sec
- min
- hr
- day
- months
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
Example 1 – July 4, 2006 15:56:19 EST

Voltage [kV L-N]

- Rated Voltage: 12.5kV_{LL}
- Fault Voltage: ~ 0.5 pu
- Over-voltage: ~ 1.2 pu

Time [s]

10 s
Example 1 – July 4, 2006 15:56:19 EST
Example 2 – August 1, 2006 18:02:49 EST

Voltage [kV L-N] Rated Voltage
34.5kV_{LL} 

Fault Voltage ~ 0.5 pu

Over-voltage ~ 1.1 pu

Rated Voltage 34.5kV_{LL}

Fault Voltage ~ 0.5 pu

[Diagram showing voltage over time with markers for rated voltage, over-voltage, and fault voltage]
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
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
Future Planned PMU Installations to be incorporated into system developed under this grant.

Thank You!

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