SAND2018-8852C

Sandia National Laboratories

NM STATE UNIVERSITY

# Protection - How can we detect faults in a 100% inverter-based system

Matthew J. Reno

Sandia National Laboratories

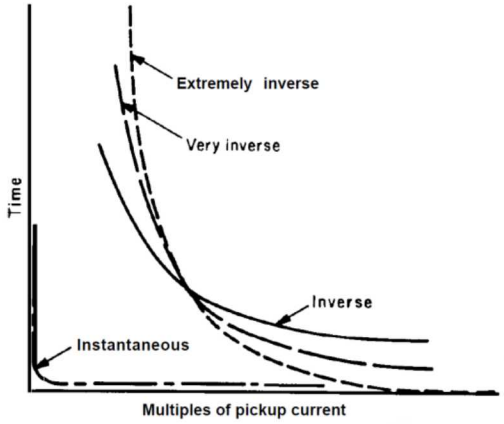
IEEE PES Power & Energy Society®

Sandia National Laboratories is a multimission laboratory managed and operated by National Technology & Engineering Solutions of Sandia, LLC, a wholly owned subsidiary of Honeywell International Inc., for the U.S. Department of Energy's National Nuclear Security Administration under contract DE-NA0003525.

IEEE

# Power System Protection

- The protection systems and equipment is designed to maintain safe operation of the grid and reliable service
  - Must rapidly and automatically disconnect the faulty sections of the power network
  - Minimize the disconnection of customers
- Conventional power system protection design will not work for 100% renewables
- Traditional protection systems are designed for large fault currents from synchronous and induction machines
  - Short-circuit modeling and protection of traditional systems is well established
  - *Increasing penetration of inverter-interfaced resources underscore the need of inverter models for short circuit studies*

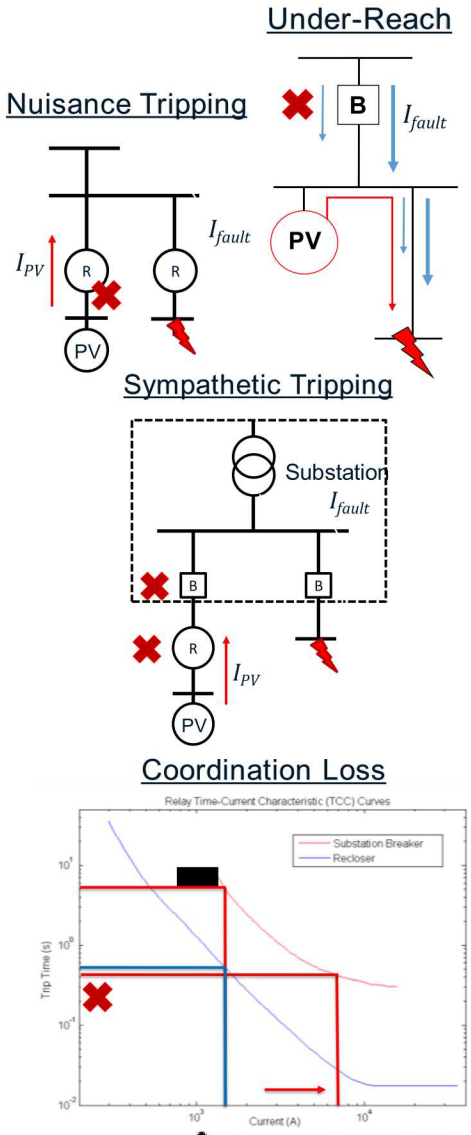


# Inverter-Based DG Impacts on Protection

- The legacy protection was not designed for the presence of inverter-based DG

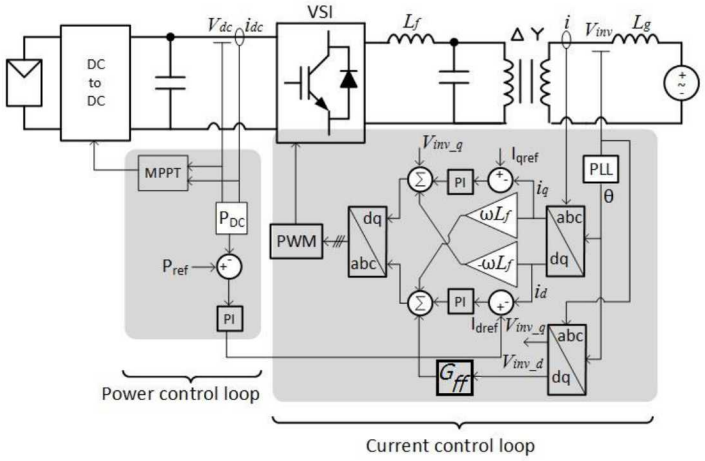
Common Protection Issues and Impacts:

- ✓ Reverse power flow and multiple injection points of fault current
- ✓ Loss in coordination between protection devices
- ✓ Relay desensitization
- ✓ Transfer trip strategies
- ✓ Anti-islanding detection
- ✓ Open-phase detection
- ✓ Interconnection transformer winding configuration and grounding
- ✓ Load rejection transient over-voltage



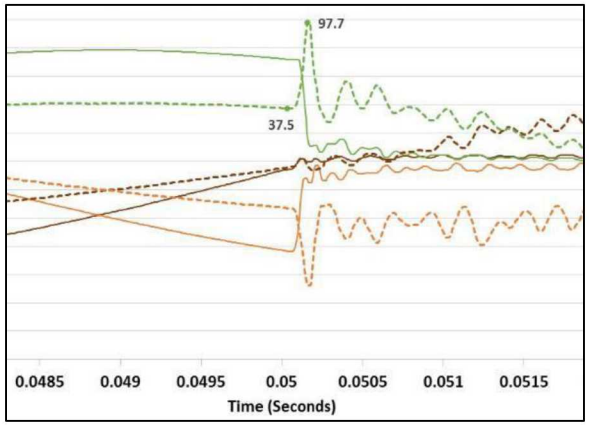
# 100% Inverter-Based System Protection Challenges

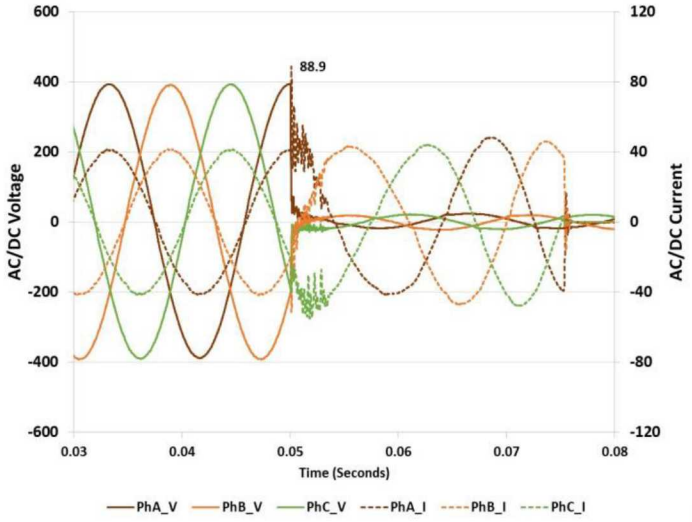
- 100% inverter-based systems present a new set of challenges for protection
- Inverters do not provide significant current during faults
  - Overcurrent protection schemes might not detect the fault
  - Fault currents can look similar to motor starts or inrush
  - With low fault currents, the fault currents are more sensitive to generation dispatch, complicating coordination



# Inverter Short-Circuit Models

- It is important to have accurate models of inverters for dynamic studies and protection coordination
  - Initial spike (~0.1ms) depends on filter cap, system impedance, and prefault condition
  - Transients during control actions, lasting 2-8ms
  - Steady-state fault current based on the current limiter
- Models are challenging to develop because there are stark differences between manufacturers, single vs. three-phase inverters, PV vs. energy storage vs. grid forming inverters.



# 100% Inverter-Based System Protection Challenges

Other Protection Challenges Include:

1. Inverters do not provide zero sequence or negative sequence fault currents (depending on the controls)
2. Inverters have no inherent inertia, so power swing characteristics may be different and impact Power Swing Blocking and Out-of-step Tripping functions
3. Inverter fault current response depends on the prefault conditions (e.g. power output level, power factor, etc.), so they have to be included in the models and analysis

# Inverter-Based System Protection

- For 100% inverter-based system protection:
  - Accurate short-circuit current models are needed
  - New protection schemes are required to detect faults

- Protection solutions have been developed for inverter-based microgrids:
  - Using novel fault indicators or features with analytic approaches
  - Using fast communication and time-synchronized measurements from multiple sensors for communication-based protection or wide-area protection schemes

# QUESTIONS?

Sandia National Laboratories
Matthew J. Reno
mjreno@sandia.gov
505-844-3087