Smart Grid Integration with DERs and EVs

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2013 i-PCGRID Workshop
San Francisco, California
February 26-28, 2013

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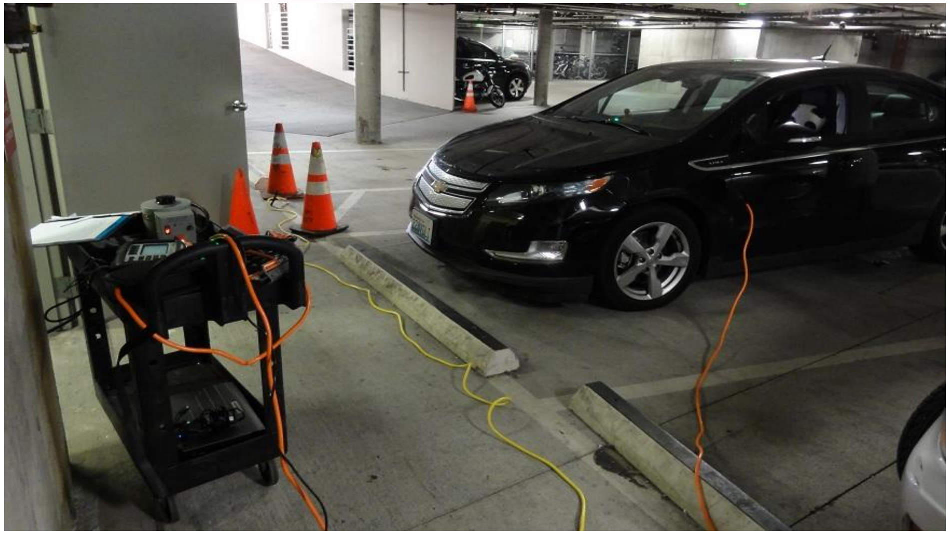
Outline

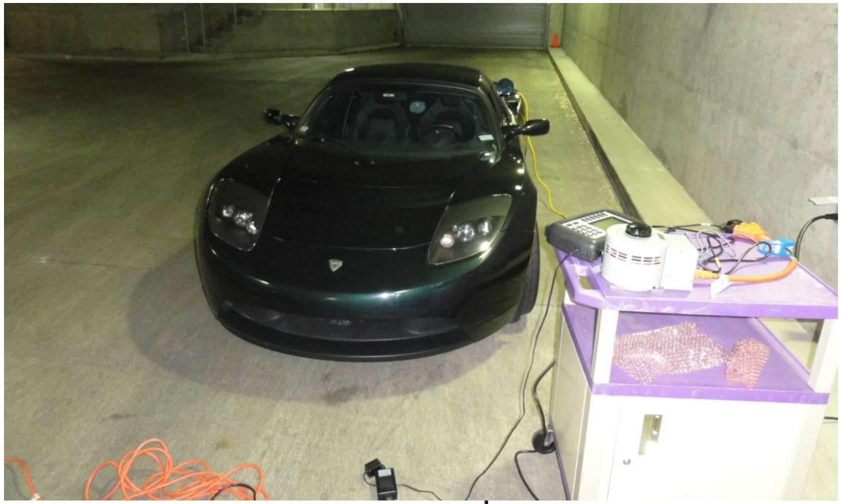
- Introduction
- EV Modeling and Management
- Solar PV Modeling and Management
- Advanced and Adaptive Protection
- Summary

DER Modeling: Charging EVs

- Modeled several EVs while charging at various voltage levels to make voltage dependent models of
  - Nissan LEAF
  - Tesla Roadster
  - Tesla Model S
  - Chevy Volt
- Due to data sensitivity issues each EV is randomly assigned a number from 1 to 4
- Measured the active and reactive power while charging at Level 1 AC (120V):
  - Voltage
  - Real power
  - Reactive power

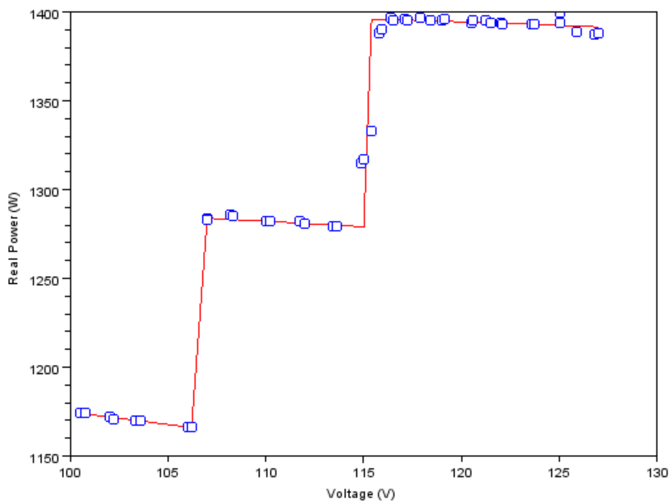
DER Modeling: Nissan Leaf Charging



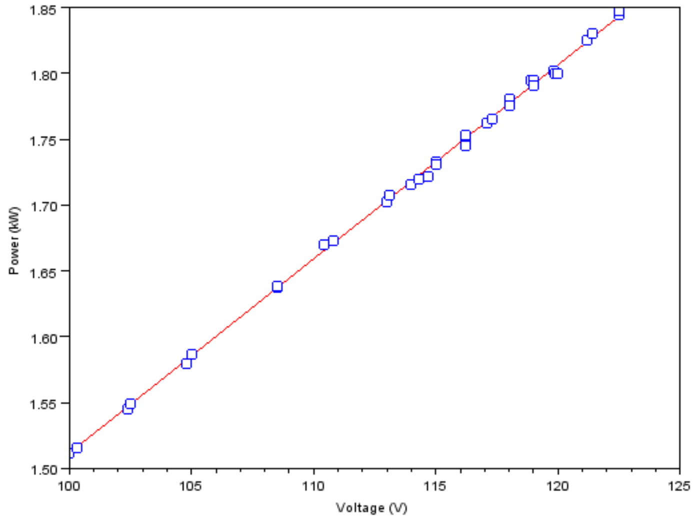


DER Modeling: Real Power Measurements and Fit Curve

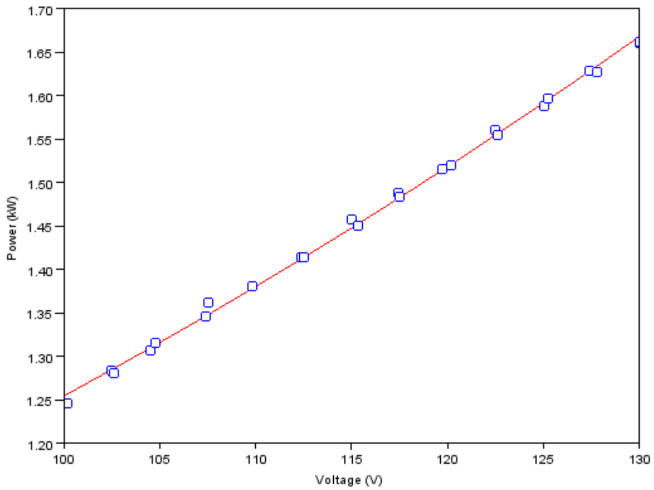
EV 1



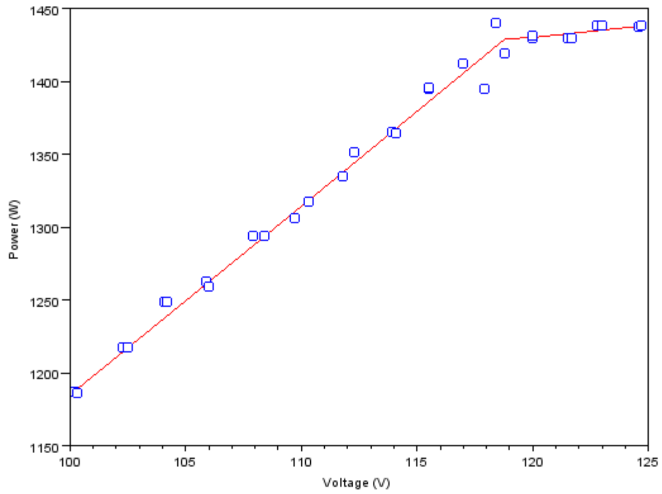
EV 2



EV 3

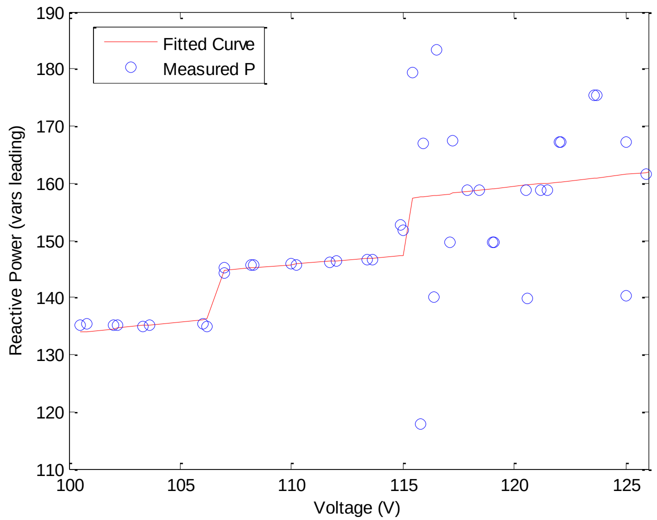


EV 4

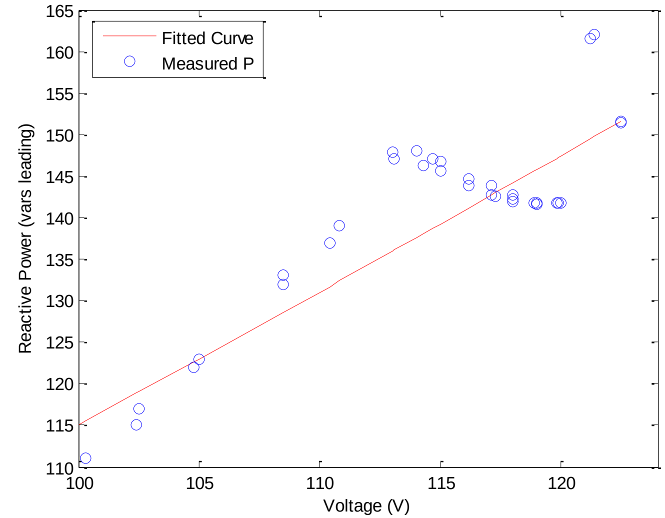


DER Modeling: Reactive Power Measurements and Fit Curve

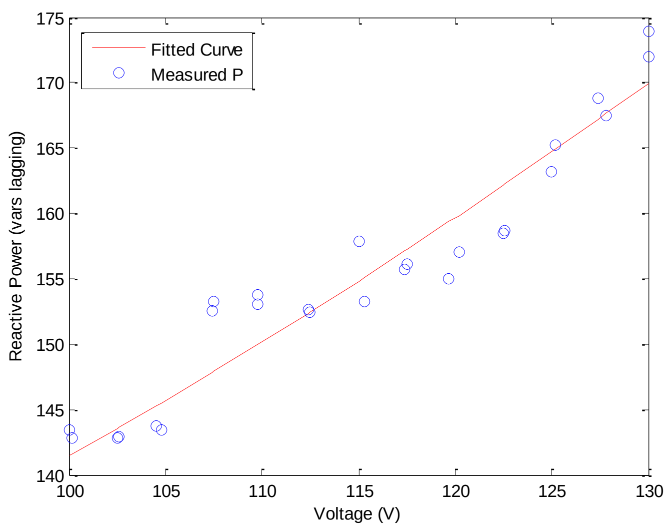
EV 1



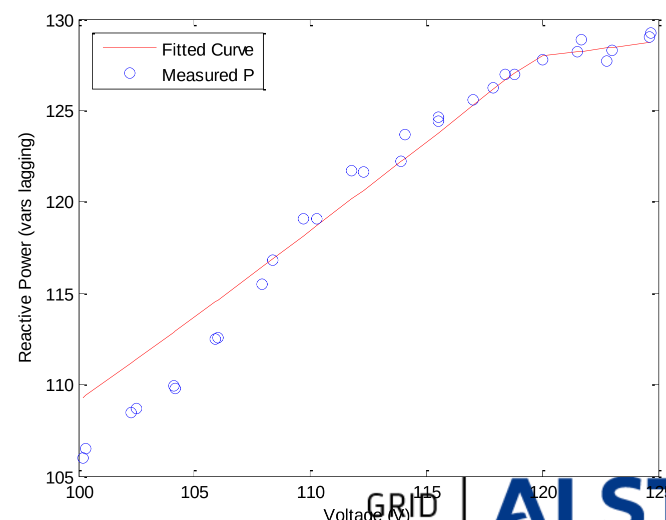
EV 2



EV 3



EV 4



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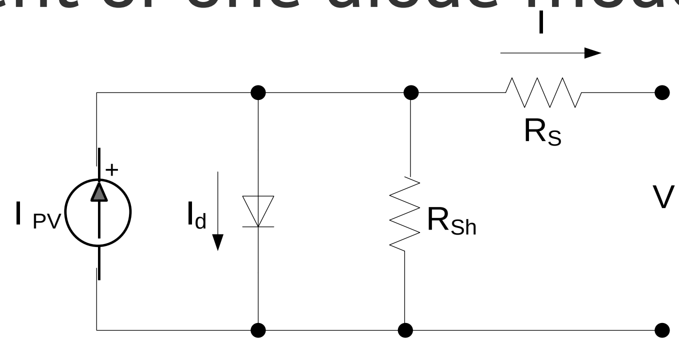
DER Modeling: Observations on EV Modeling

- EV 1 Model
  - Constant power load with three distinct operating states
  - 0.99 leading power factor
- EV 2 Model
  - Constant current load with only 1 operating state
  - 0.99 leading power factor
- EV 3 Model
  - Constant current load with only 1 operating state
  - 0.99 lagging power factor
- EV 4 Model
  - Constant current load when less than 120 V
  - Constant power load when greater than 120 V
  - 0.99 lagging power factor

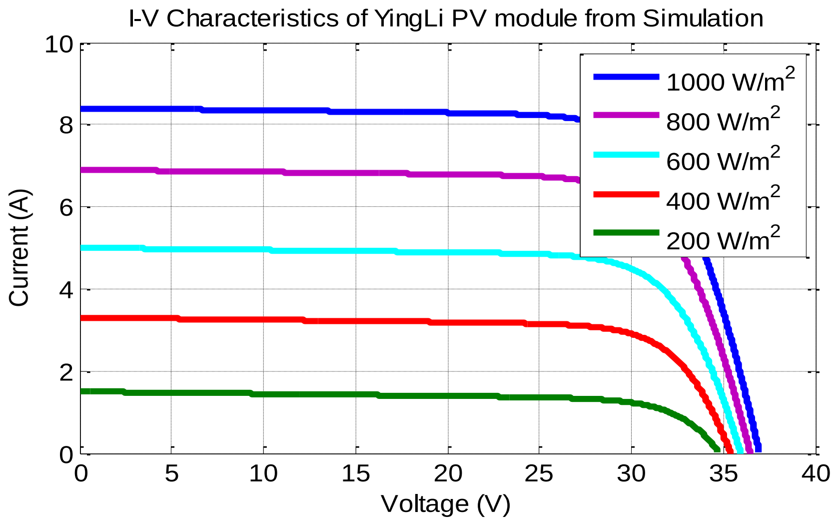
Solar PV Dynamic Modeling and Validation

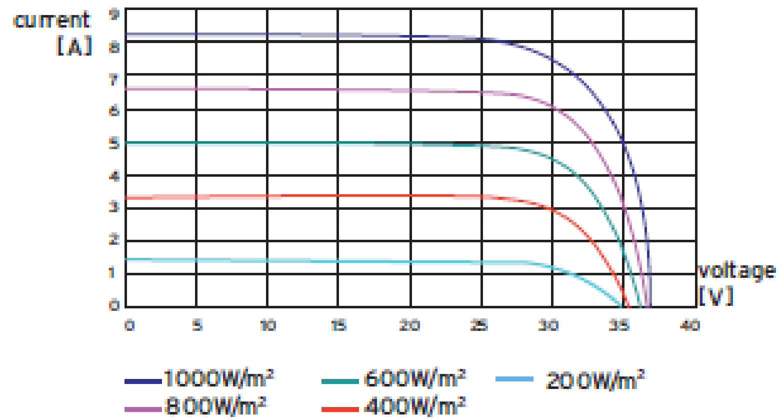
- Development of one diode model of PV panel



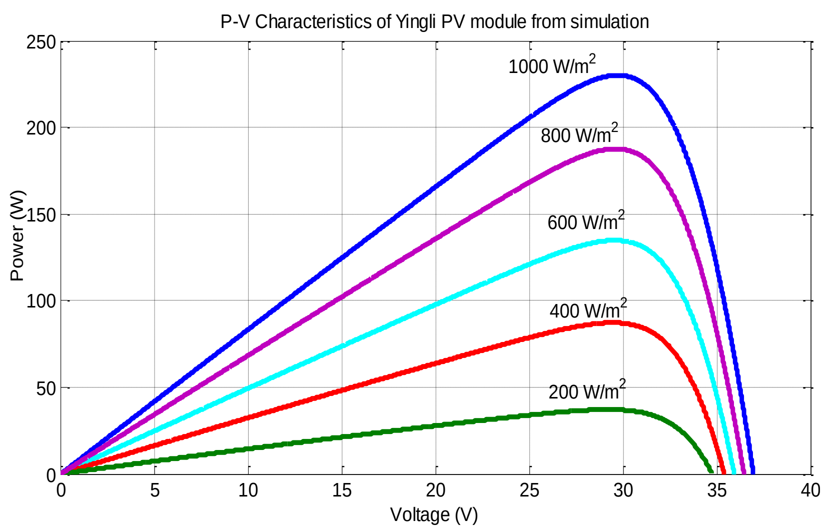
- Calculation of equivalent series and shunt resistances of the equivalent model
- Validation of the developed model with the panel datasheet I-V Characteristics and parameters

Solar PV Modeling and Validation





I-V Curve from datasheet



Make	YINGLI
Model	YL230P-258
Max Power Point Current (I_{MPP})	7.8A
Max Power Point Voltage (V_{MPP})	29.5V
Open Circuit Voltage (V_{OC})	37.0V
Short Circuit Current (I_{SC})	8.4A
Maximum Power (P_{Max})	230W
V_{DC}Temp Coeff	-0.0037/K

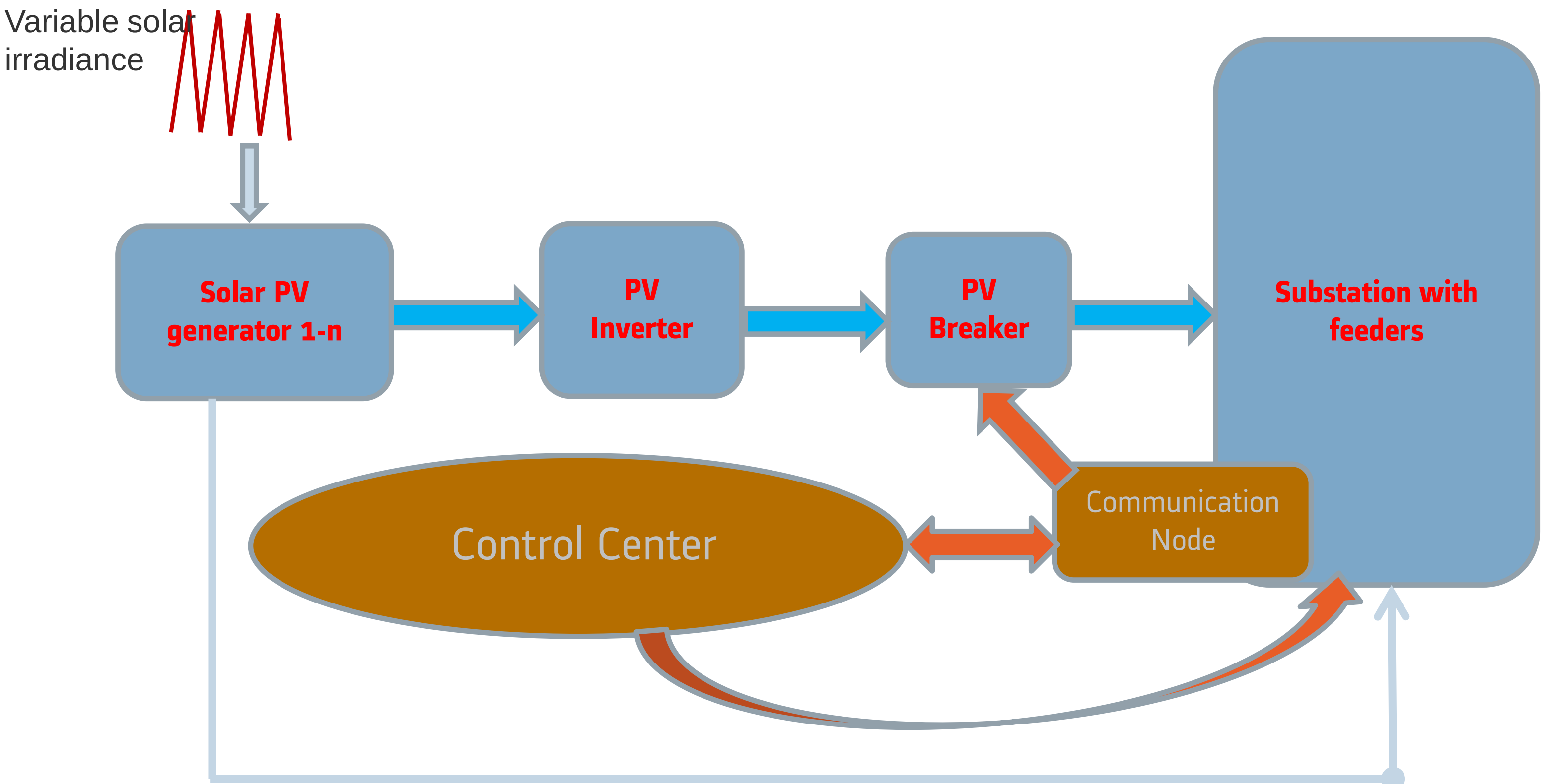
Solar Swing Management

- The intermittency and variability of Solar irradiance is a big challenge to the successful deployment of PV generators in distribution systems
  - Change of irradiance throughout the day
  - Change of irradiance due to passing clouds (More vulnerable causing solar swings)
- The impact of PV power output is observed in feeder voltage profiles in distribution systems

Solar Swing Management (Immediate Solution)

- Switch the PV inverter off whenever there is a harmful swing affecting the system voltage profile
- Switch the PV inverter back on after the swing problem is over
- Requirements:
  - Communication node to communicate with the PV breaker/switchable devices
  - Algorithm to identify the harmful swing and to come up with the strategy to disconnect/re-connect the PV generator to the system

Solar Swing Management
(Direct Immediate Solution)



1. SOLAR SWING IMPACT STUDY/ PROBLEM IDENTIFICATION
2. CORRECTIVE SWITCHING ON/OFF STRATEGY OF PV UNITS

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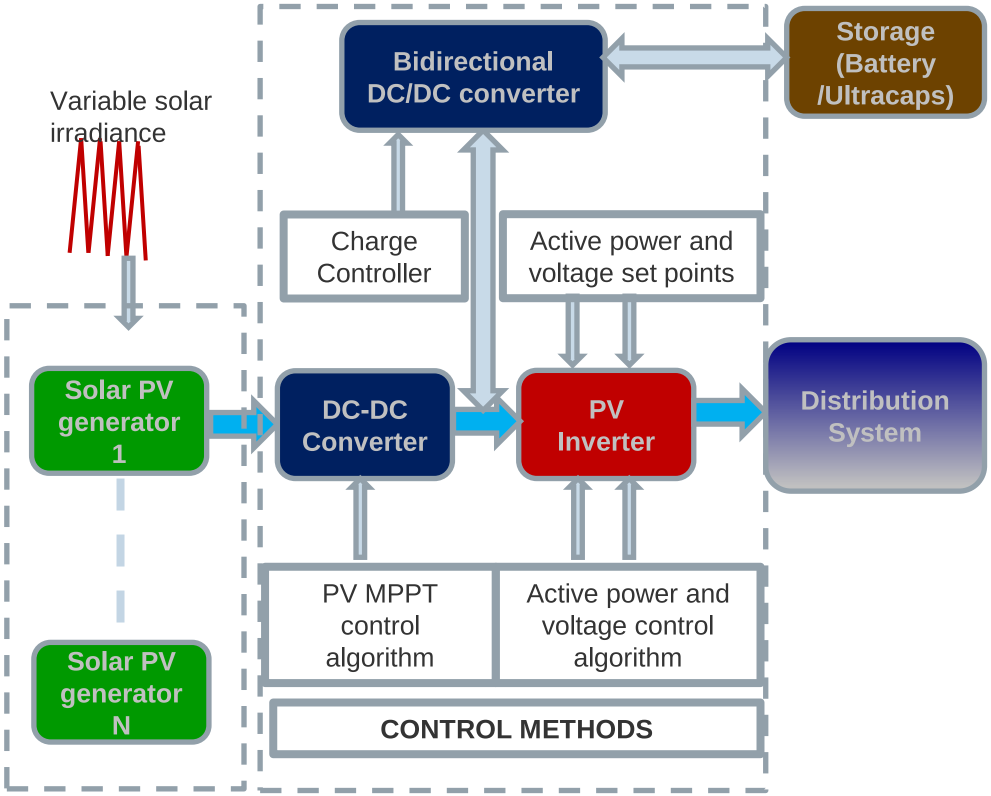
Solar Swing Management (Probable Solution With Storage)

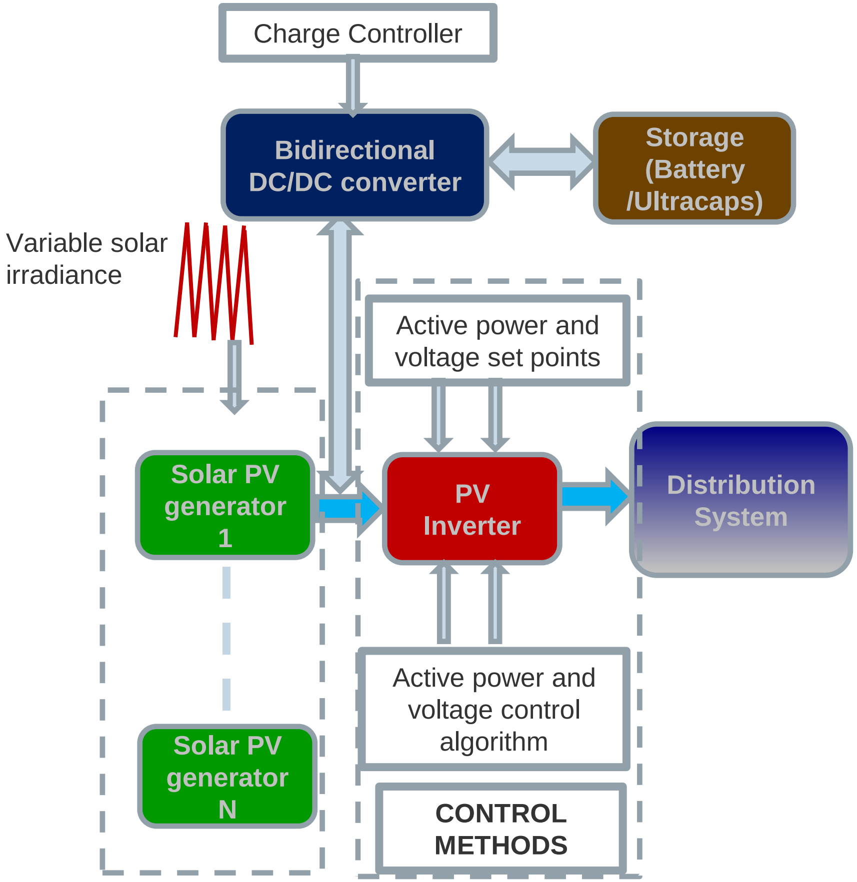
- In a two stage configuration:
  - Control PV side converter for MPPT(Maximum Power Point Tracking)
  - Control the bidirectional converter connected to the storage to absorb or inject surplus or deficit active power
  - Control the PV inverter for active power and voltage control at PCC
- In a single stage configuration:
  - Control PV inverter for MPPT and voltage control
  - Control the bidirectional converter connected to the storage to absorb or inject surplus or deficit active power

Solar Swing (Probable Solution With Storage)

Schematic



2-Stage Configuration



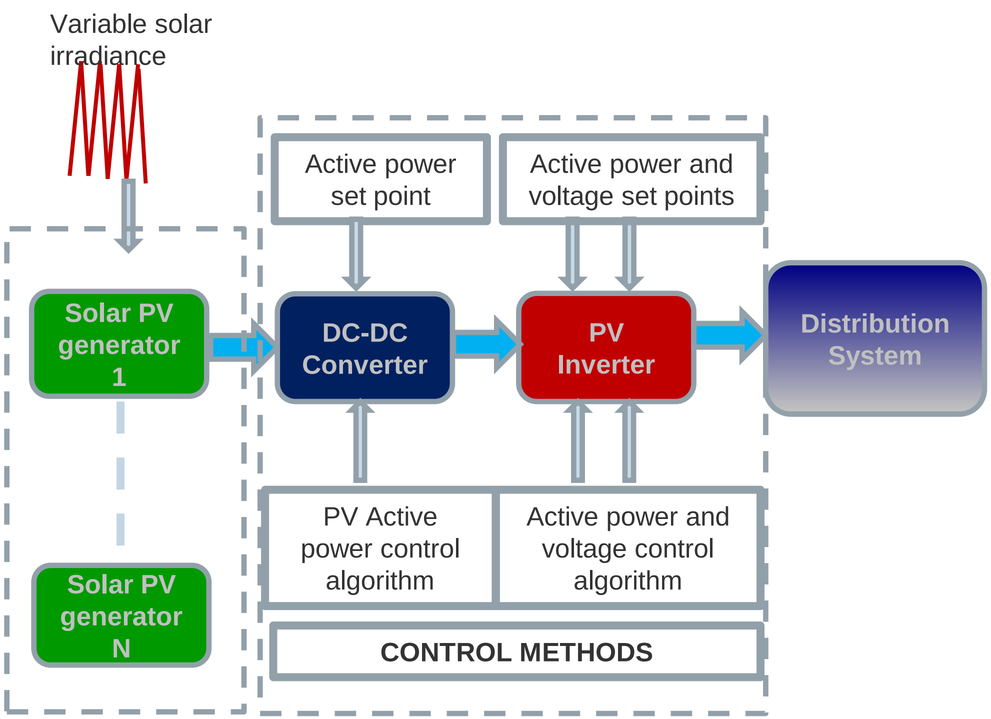
1-Stage Configuration

Solar Swing Management (Probable Solution Without Storage)

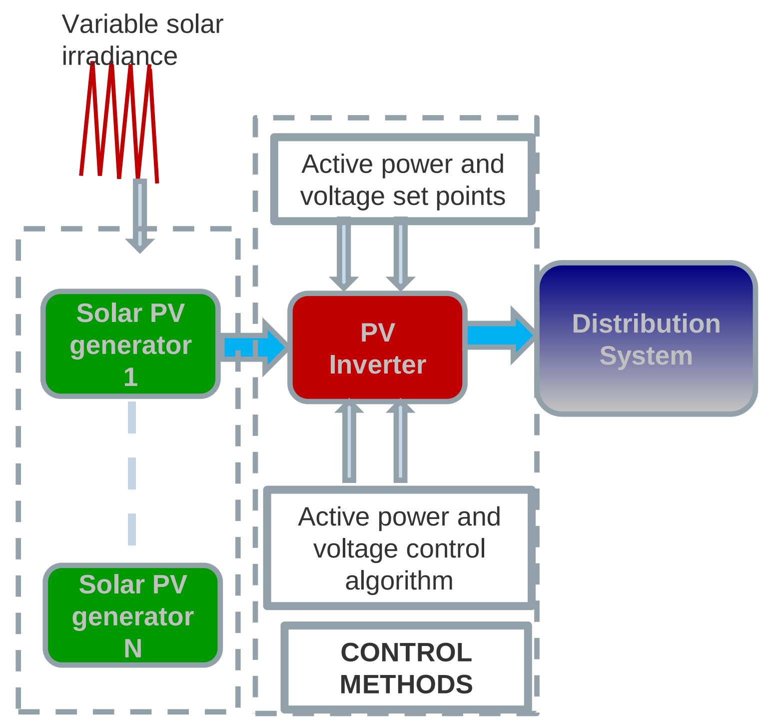
- In a two stage configuration
  - Control PV side converter for constant active power
  - Control the PV inverter for active power and voltage control at PCC
- In a single stage configuration
  - Control the PV inverter for active power and voltage control at PCC
- These solutions would however sacrifice MPP of the PV array, hence reduce efficiency of the system

Solar Swing Mangement (Probable Solution Without Storage)

Schematic



2-Stage Configuration



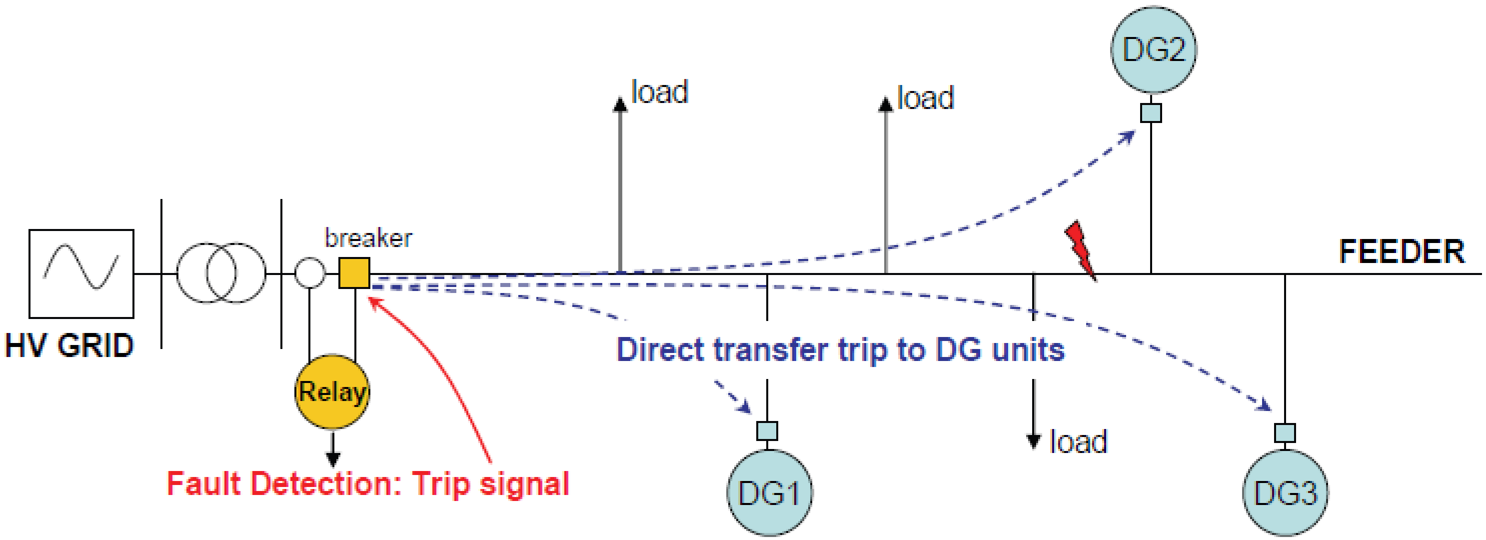
1-Stage Configuration

Protection Issues for Emerging Grids

- U. S. Network vs. Europe Network
- Primary (MV) and Secondary (LV) systems
- Protection architecture with integration of DGs
  - Low fault currents from inverter supplied sources make traditional protection schemes inadequate
- Adoption of new protective devices and sensors
  - Digital relays (i.e. overcurrent and differential)
  - Intelligent reclosers
  - PMUs, line sensors and smart meters

Impact of DGs on Protection

- Unsynchronized Reclosing
  - A transfer trip scheme to avoid unsynchronized Reclosing:
    - Relay trips feeder circuit breaker
    - Disconnect DGs by transfer trip
    - Recloser reconnects feeder automatically
    - Reconnect DGs after normal power is established



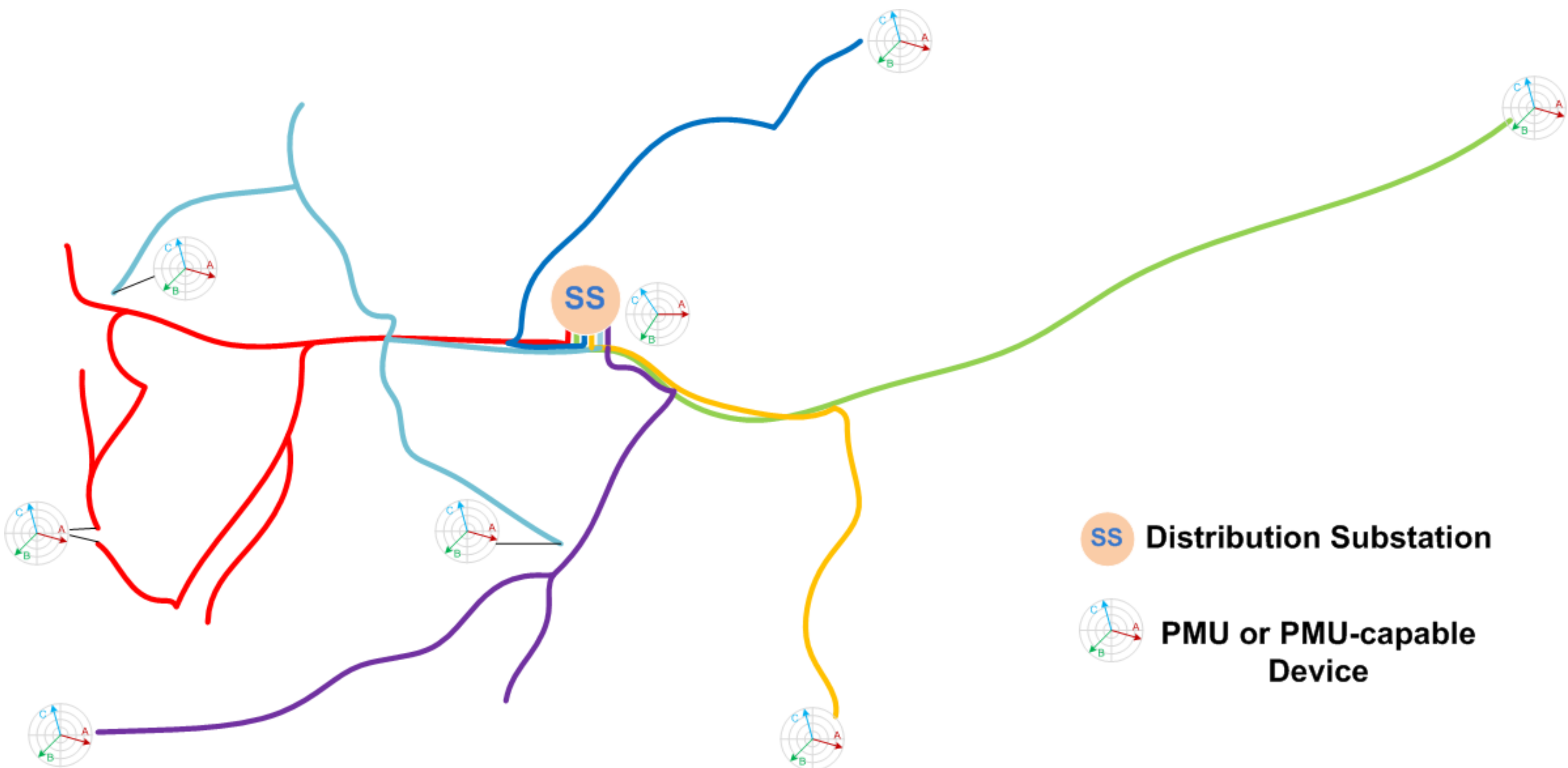
Source: http://www.intechopen.com/books/distributed-generation

PMU Application – Fault Location

- Difficulties of Fault Location in Distribution Systems
  - A large number of branches
  - High resistive fault
  - Bidirectional current flow conditions in emerging grids
  - Traditional methods are either time consuming and/or less accurate
- Benefits of Synchrophasors from PMU
  - Accurate: less than 1% TVE in steady state and 3% TVE in dynamic state conditions (IEEE C37.118.1-2012)
  - Time synchronized
  - Voltage and current phasors for pre-fault and post-fault states

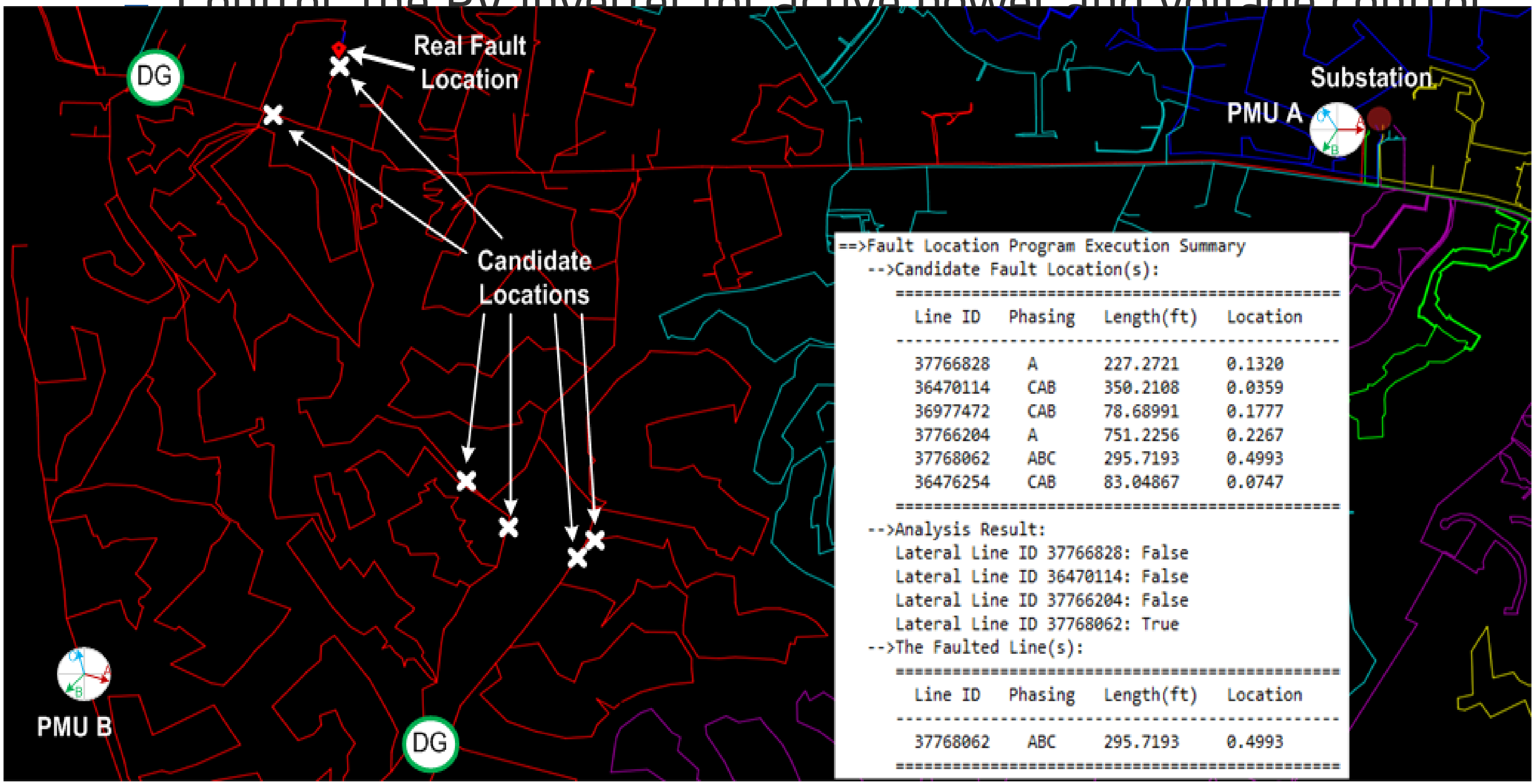
PMU Application – Fault Location

- PMUs are located at substation and feeders' end
- Voltage and current phasors are used to locate a circuit fault
- The method is demonstrated in a 25 kV/120 MVA six-feeder system



PMU Application – Fault Location

- A single phase to ground fault with resistance of 100 ohm
  - Control the PV inverter for active power and voltage control



Thank you!
Questions?

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