MODERNIZING FUTURE ELECTRIC POWER DISTRIBUTION GRIDS

Modeling, Analysis, and Implementations under New Challenges

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Electric Power Distribution Grid 101

- Components in power distribution grids

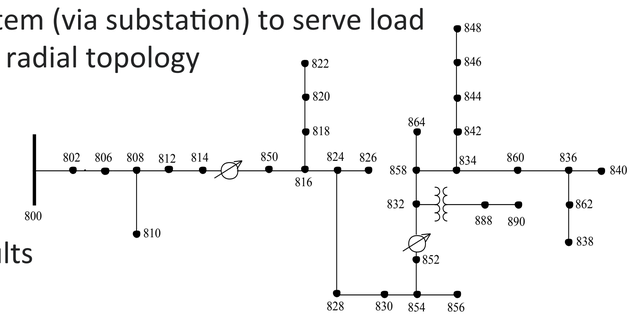

Substation


Voltage regulator


Transformer


Pole & Capacitor bank

- Current distribution system operation principles
  - Power flows from transmission system (via substation) to serve load
  - Design in loop topology, operate in radial topology
  - One-way power flow
  - Kirchhoff voltage and current laws
- Distribution utilities' objectives
  - Maintain voltage within range
  - Protect distribution assets from faults
  - Ensure reliability of service
  - Minimize electrical losses



Example: IEEE 34-node test feeder

New Challenges from Grid Modernization

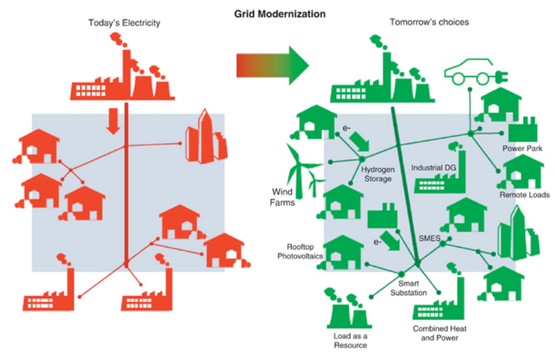
- Changes from passive to a more active and complex distribution grid
  - Growing penetration of distributed energy resources (DER): two-way power flow


Distributed Renewables | Distributed Generators | Distributed Storage | Controllable Loads

  - Growing customer expectation for service reliability and power quality
  - Better operating efficiency with existing grid assets
  - Impact of new type of loads


Electric Vehicles

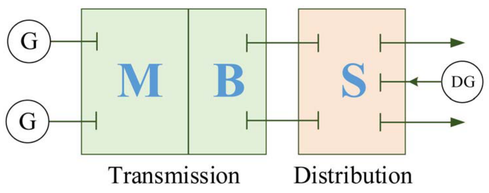
- Challenges to distribution utilities
  - Distribution automation
  - More monitor & control with smart grid
  - Advanced technologies integrated



Grid modernization (source: IEEE)

Coupled Transmission and Distribution (T&D) Modeling

- Transmission and distribution are operated by different entities
- Increasing penetration of DER, increasing deployment of automation devices needs coupled T&D modeling
- Proposed global power flow model by master-slave-splitting method



M: Master System

B: Boundary System

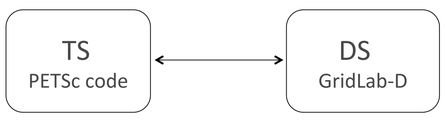
S: Slave System

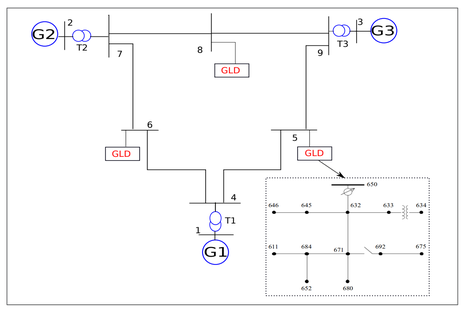
$$\begin{cases} G_T(x_T, x_B) = 0 \\ G_B(x_T, x_B) = y_B \end{cases} \qquad G_D(x_B, x_D) = 0$$

x: State variables
y: Injections from DPS to TPS
G: Power flow equations

T: TPS (Transmission Power System)
D: DPS (Distribution Power System)
B: Set of boundary buses that connect DPS feeders

- Coupled T&D system dynamics simulator
  - PETSc + Socket communication + GridLab-D

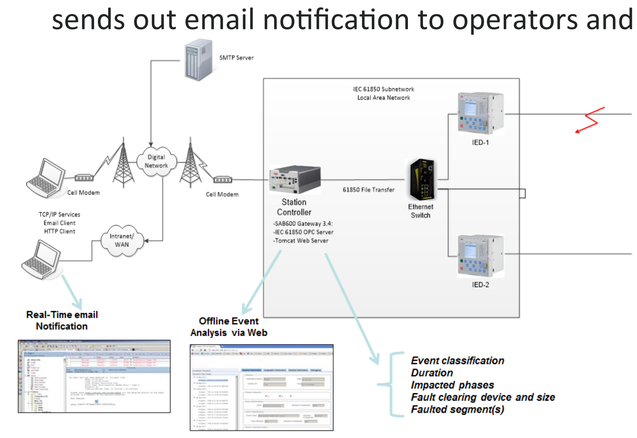


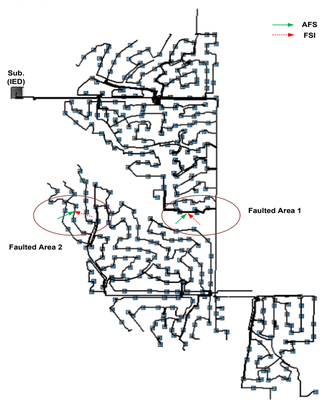


Structure of coupled T&D dynamics simulator (above)
An example of coupled T&D simulation (right)

Distribution System Faulted Segment Identification

- Motivation
  - Most distribution circuit faults are cleared by non-communicating fuses
  - Once the fuse blows, hundreds of customers lose electricity
  - Usually takes the crew hours to identify the faulted segment to restore service
- Our Solution
  - An automated solution that determines the faulted segment in real time
  - Feeder head relay triggers upon a fault and starts recording fault data
  - Substation computer receives fault data, calculates the faulted segment, and sends out email notification to operators and repair crew



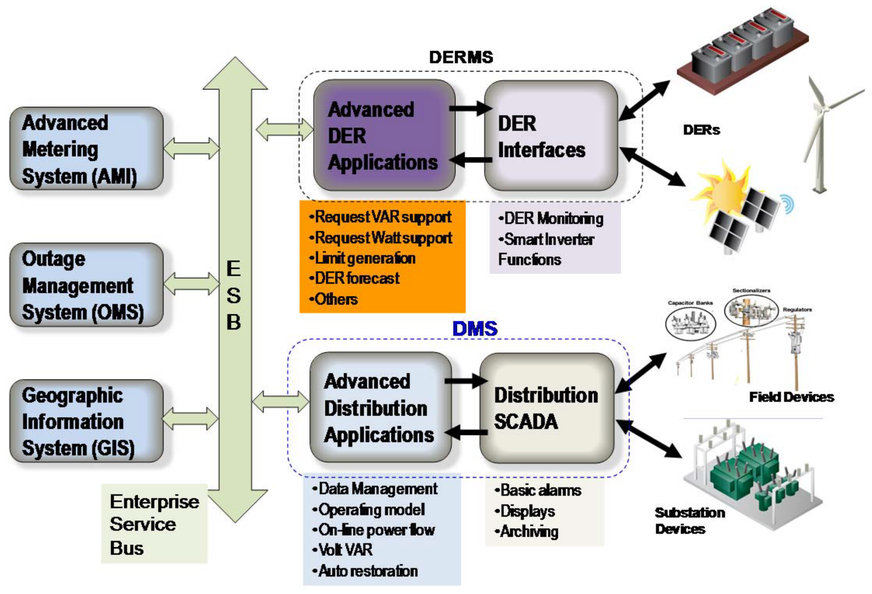


Advanced Distribution Management Systems (ADMS)

- Integration of DER to DMS via DER management system (DERMS)
- Integration with OMS, advanced metering infrastructure (AMI), GIS
- Provide advanced distribution applications – expansion from distribution SCADA system

Typical applications

- Topology processor
- Intelligent alarm processing
- On-line power flow
- Short-circuit analysis
- State estimation
- Fault location, isolation, and service restoration
- Volt/VAR optimization
- Optimal network reconfiguration
- Switch order management
- Emergency load shedding
- Short-term load forecasting



ADMS integration structure

Projects

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