Software Tools For Optimized AC Power Flow and Ranking

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Soorya Kuloor
Richard Hammond
GRIDiant Corporation
Agenda

- Introduction to distribution modeling
- Introduction to GRIDfast
- GRIDfast ranking and uses
- Specific case study and results
- Conclusions
Distribution Modeling

- Asset intensive
  - 900 substations, 1500 feeders, 50K fuses
  - 1M distribution transformers
  - 4.5M line sections
  - >5M power poles

- Lower voltage (<33 kV)

- Substation -> feeders -> Primary line -> Laterals -> Secondary lines -> Customer

- Radially operated

- Reconfigurable topology for load balancing and/or partial restoration, but always radial

- Geo-spatially modeled

- 3-phase unbalanced modeling
Distribution Electrical Model (DEM)

- **Distribution assets**
  - Substations, feeders
  - Overhead lines, underground cables (primary & secondary)
  - Substation and distribution transformers
  - Circuit breakers, re-closers, sectionalizers
  - Tculs, voltage regulators, capacitors
  - DER units

- **Asset connectivity**
- **Phase information**
- **Automation schemes**
- **System state**
  - Loading
  - Switch states

- **Geo-spatial information**
GRIDfast Optimization

- Multi-objective non-linear optimization & analysis algorithm, with resource, load, and asset ranking
- 10+ years in development, testing, validation
- 3-phase balanced & unbalanced power flow & power flow optimization
- Fast optimization & analysis of large integrated T&D networks or any section/area of T, D
  - Minimize system losses (P, Q)
  - Minimize cost
  - Optimize voltages
  - Optimally integrate renewables, DG (P, Q), DR, storage/EVs
  - Optimize fault restoration
  - Minimize branch power/current flow
  - Minimize asset overloading
- Detailed, bus/node-specific ranking of resources, loads, assets
GRIDfast Ranking

- Assigns LMP-like indexes (Resource Sensitivity Index, RSI) to every node/bus in the network
- Derived from the dual variables of optimization
- RSIs are available for both active and reactive power resources and loads
- RSIs indicate marginal sensitivity of the objective towards any resource/load change at the node/bus
- Multiple uses:
  - Optimal location and sizing selection for capacitors
  - Optimal location and size/type selection for distributed energy resources (DER), and mitigation / support
  - Optimal dispatch of capacitors
  - Optimal dispatch of DER
Loss-Based RSIs Visualized

Company Confidential
DER Dispatch Based on RSIs
Asset Loading RSIs
Case Study

CEC PIER-funded R&D 2005-2010; CEC Report Dec 2010

- NPT: Developed advanced T&D model of SCE host network
- Developed an optimal DER portfolio for SCE’s distribution subsystem
- Multiple SCE system load scenarios, run by PSLF & GRIDfast engine
- Field verification of results

To maximize reliability & economics, GRIDfast determined:

- Optimal portfolio of VAr sources and re-controls, DR, DG, D storage
- Optimal topological changes for improved reliability
- Impact of EVs; EV infrastructure planning under non-optimized and optimized conditions
- Cost/benefit of optimized DER portfolio; ranking of asset maintenance and new asset investment measures.

SCE “Hobby” Subsystem

- 1,300 MW peak load
- 280,000 customers
- 1,000 square-mile service area
- 58 transmission, sub-transmission & distribution substations
- 241 radial distribution feeders or circuits, 2.4kV to 33kV
- 102 voltage regulators & transformer taps
- 839 capacitor banks
- 30 embedded generation P&Q resources
- 4,684 individually addressable DR resources
- 46,000 customer service distribution transformers
- 100,000 SCE nodes connected to 15,000 buses in transmission model from WECC
Case Study (SCE): Ranked Network P Loss Impacts of Specific Capacitor Additions
Case Study (SCE): Ranked Network Voltage Impacts (Vmin), Specific Capacitor Additions
Case Study (SCE): Ranked Network Voltage Impacts of Specific Demand Response Additions
Case Study (SCE): Ranked Network Voltage Impacts of Specific DG Additions

Voltage Impact of Distributed Generation Additions in Rank Order
Conclusions

- Distribution network modeling is complex but increasingly feasible and accurate.
- There is a small % of new and existing resources, loads, assets, and topological changes that provide a disproportionately high level of network benefits (the 80-20 rule).
- The challenge is to identify this small % of resources, loads, assets, and topology changes, and locations, and manage them effectively.
- GRIDfast has been able to model, identify, rank, and manage these resources, loads, changes, and locations reasonably efficiently.
Contact

Technical:
Dr. Soorya Kuloor, CTO
GRIDiant Corporation
soorya.kuloor@gridiantcorp.com
919-757-6225 (m)

Richard Hammond, SVP
GRIDiant Corporation
+1.415-846-2688
richard.hammond@gridiantcorp.com
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