A Proposed Framework For A Simple Information Exchange Standard Protocol For Distributed State Estimation

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Outline

- Current SCADA: state estimation and power flow to verify topology

- Uses for power flow calculation
  - Congestion monitoring

- Towards plug-and-play smart grids framework
  - Dealing with many small and varying participants

- Mathematical method inspired by distributed optimization method for transportation networks
  - We extend this to electric energy power flow
Current SCADA

- State estimation using system measurements
  - Measurements taken from system by sensors and communicated back to control center
  - Compared with power flow calculation to verify topology of system (starts with known topology)
  - High volume of data and redundant measurements
Power Flow To Verify Topology

Power Flow

Verification By Measurement
Power Flow Calculators For Contingency Screening

- Power flow calculators may help identify line congestion in conjunction with other “smart” components, such as dynamic line rating units (DLR’s)
- Contingency check can be done without central operator
- Central operator can be sent an alert upon contingency, thus complementing existing systems
Plug-And-Play For Distribution Networks

- Addition of many new and unconventional types of resources
- Local system operator may wish to use power flow information (aggregation useful for power flow on higher level system)
Plug-And-Play For Distribution Networks

- A standardized information exchange protocol would let new components know what is necessary to participate in distributed network calculations (only communicate with neighbors)
- Helps deal with many small and varying participants without the system operator needing all information
Plug-And-Play For Distribution Networks

• A standardized information exchange protocol would let new components know what is necessary to participate in distributed network calculations (only communicate with neighbors)
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Adding Detail To System
Distributed Power Flow Framework

- Data exchange between neighboring components, e.g. line connected to bus\(^1\)[\(^2\)]
  - Power flow calculators for each line
  - Power injection sensor/data for each bus
- Newton method based iterative method determines which variables to exchange per iteration
  - Flow variable (line to bus)
  - Lagrange multipliers (bus to line)

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Information Exchange

- Newton method based iterative method determines which variables to exchange per iteration
  - Flow variable (line to bus)
  - Lagrange multipliers (bus to line)
Decoupled Real Power Simulations

- IEEE 14 bus simulation done for real power decoupled power flow example[2][3]
- Solution checked using simultaneous equation solver in Matlab


14 Bus System

14 bus example

14 bus example graphical representation
14 bus – Results

Convergence of distributed method on the 14 bus system took 23 iterations, and 11 iterations using Matlab’s fsolve (centralized).

Convergence tolerance: 0.001 p.u.  Max. Deviation: 0.0184 p.u./3%
Conclusions and Future Work

❖ Proof of concept example for distributed power flow shown
❖ Explore information exchange framework and uses in complementing existing system
❖ Future work will take into account uncertainty in data and/or measurements
❖ Proof of convergence, range of initial conditions, and other numerical considerations to be examined
Questions?
References

