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Electric Energy Systems Group

Electrical & Computer ENGINEERING

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

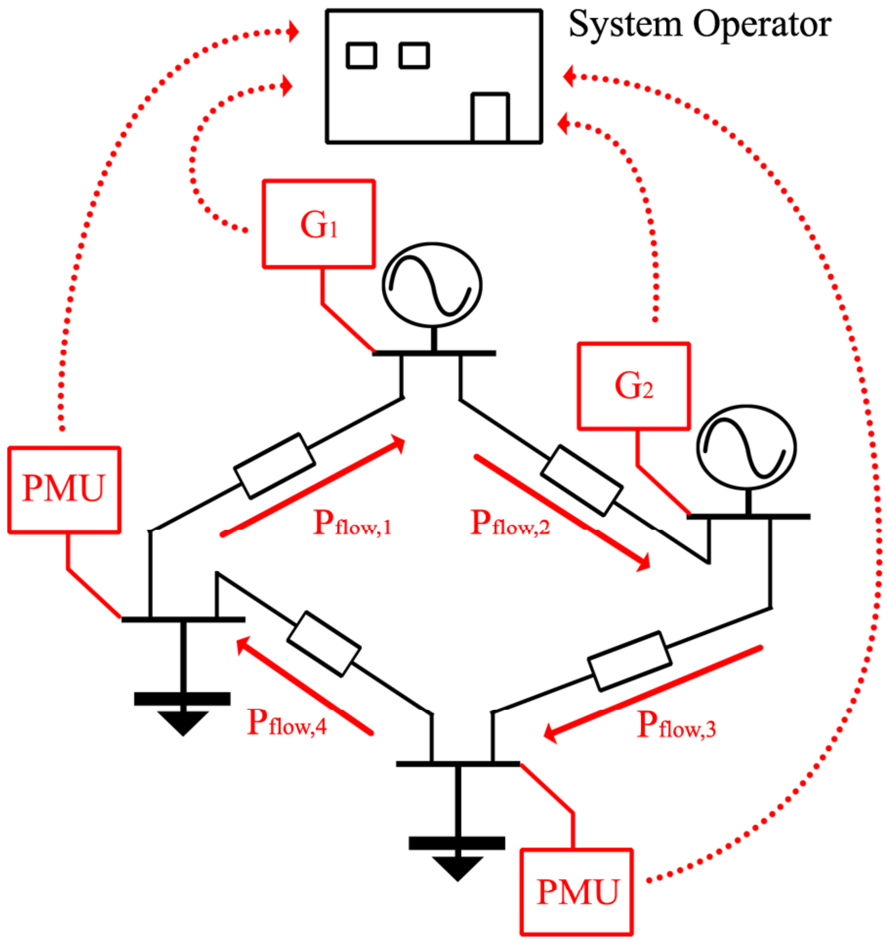
- Uses for power flow calculation
  - Congestion monitoring

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

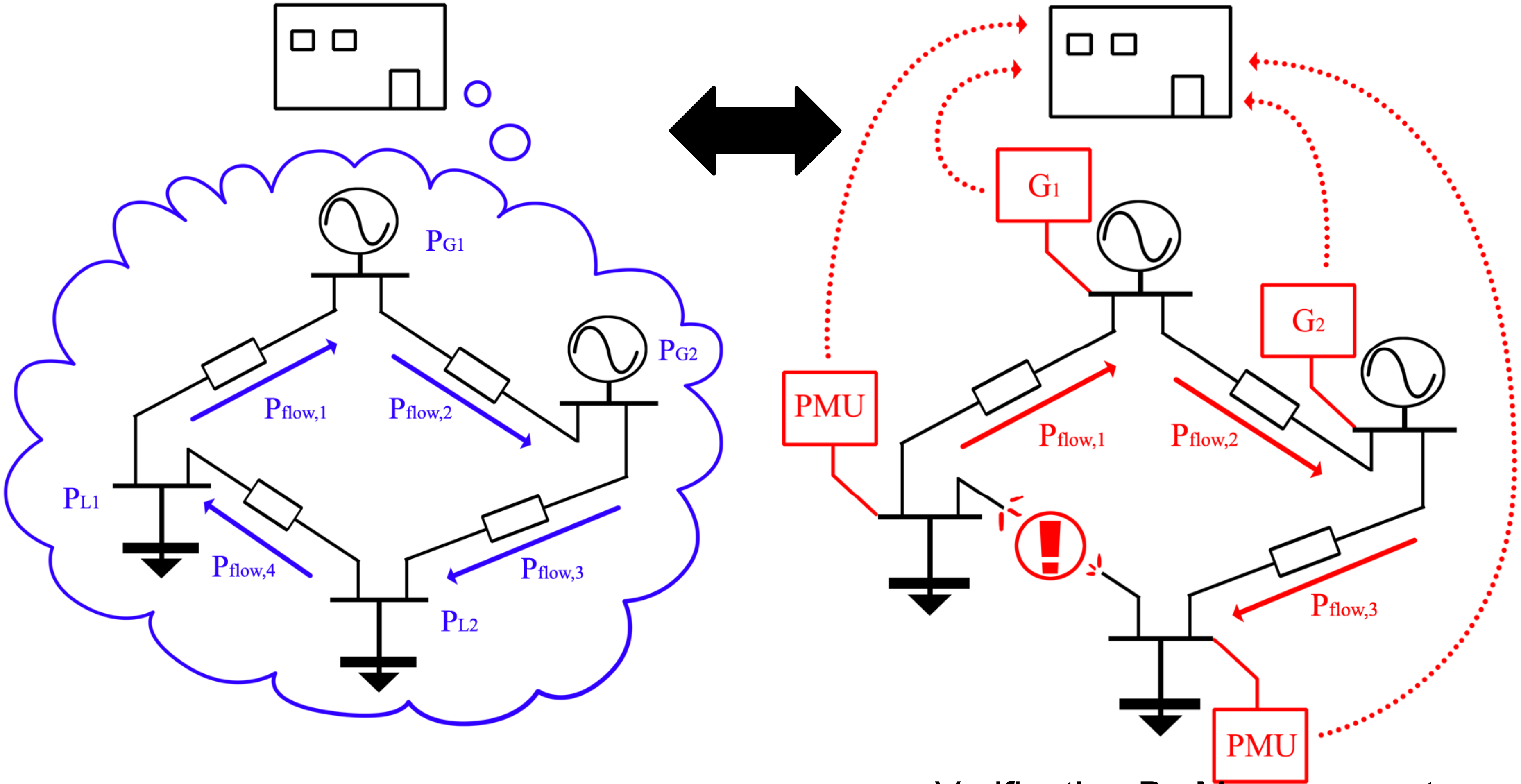
- Mathematical method inspired by distributed optimization method for transportation networks
  - We extend this to electric energy power flow

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

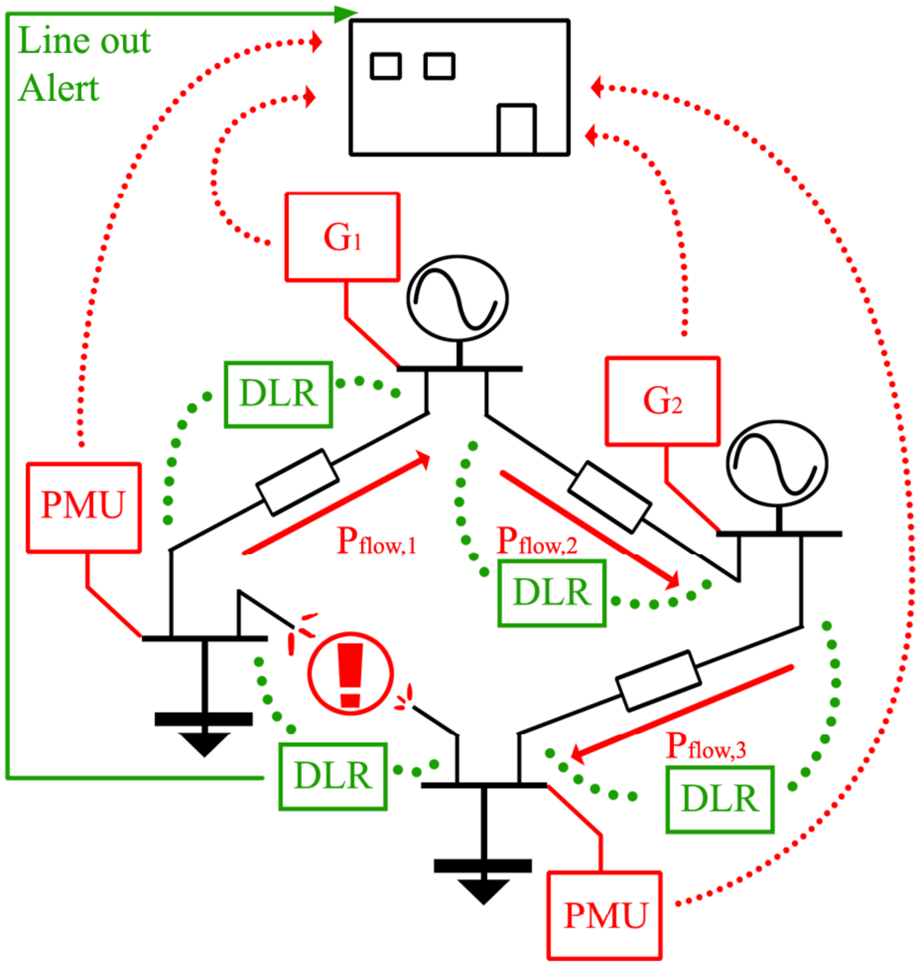


Power Flow

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



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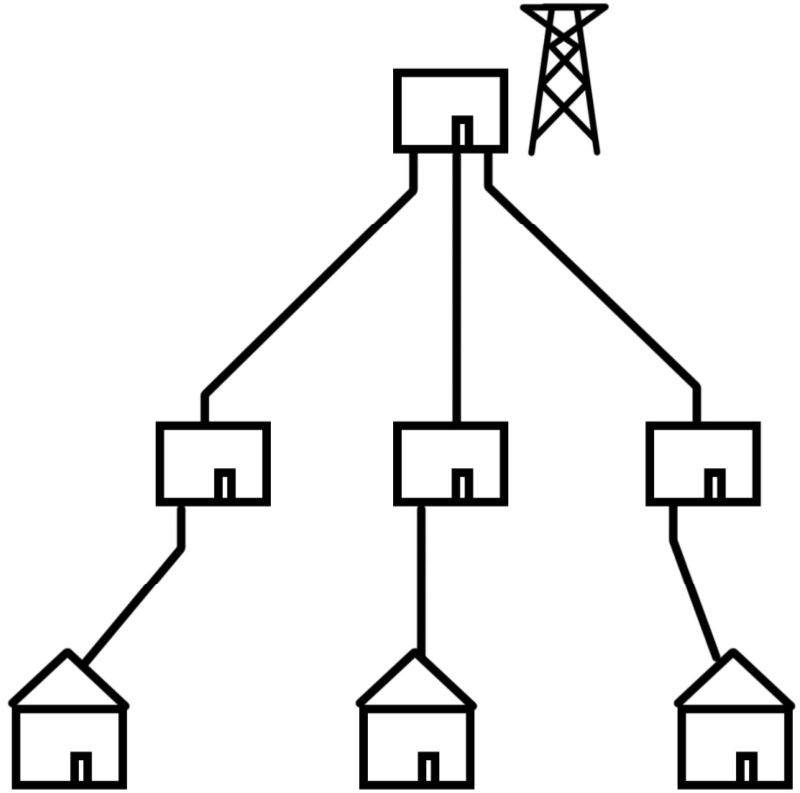
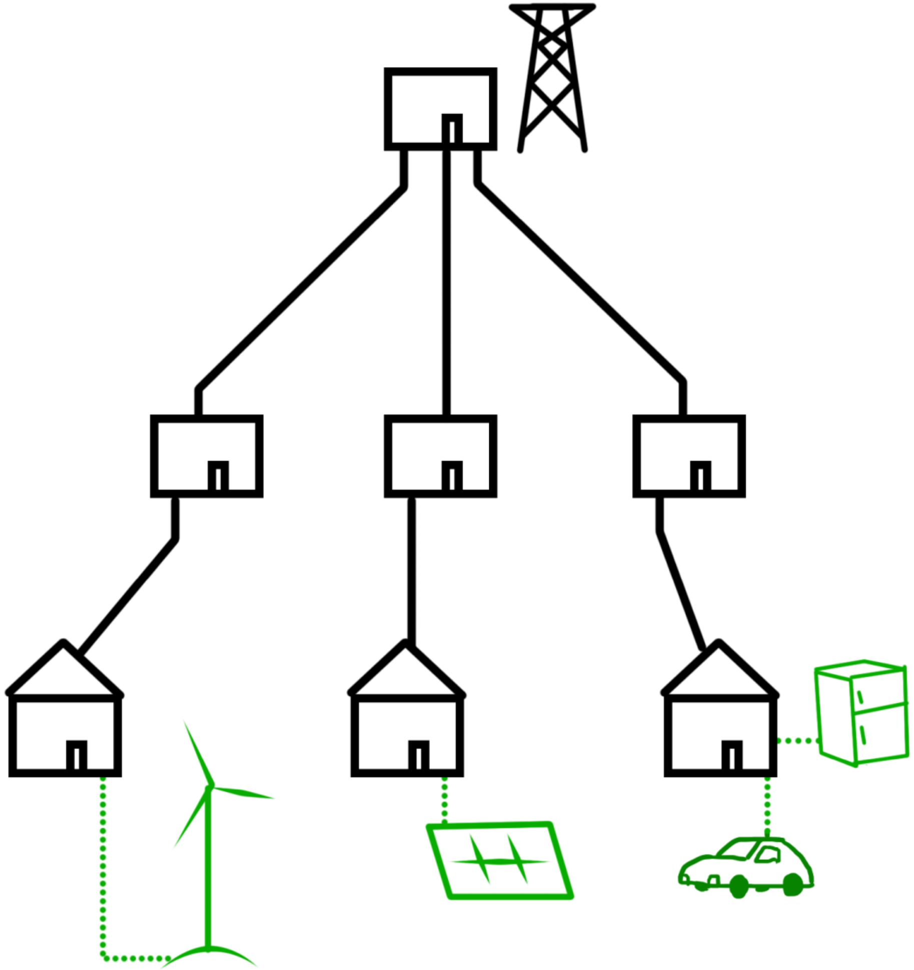
Plug-And-Play For Distribution Networks

- 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



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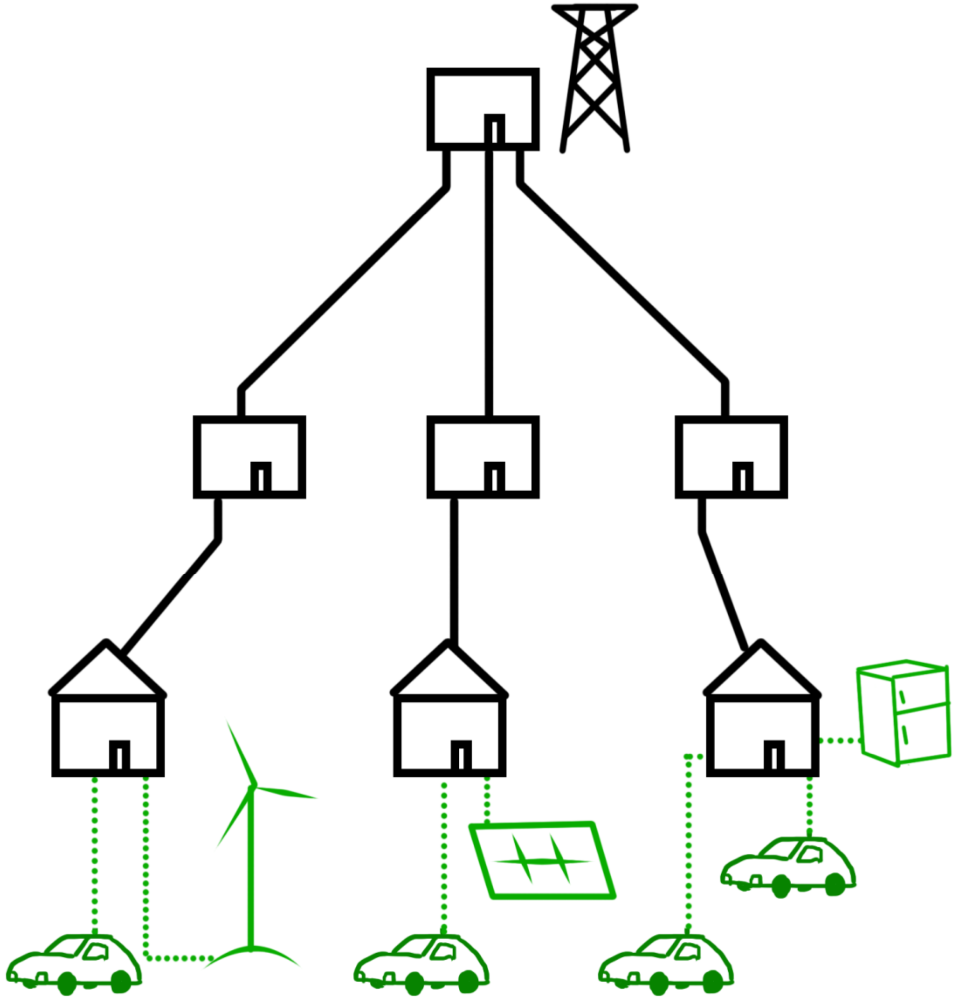

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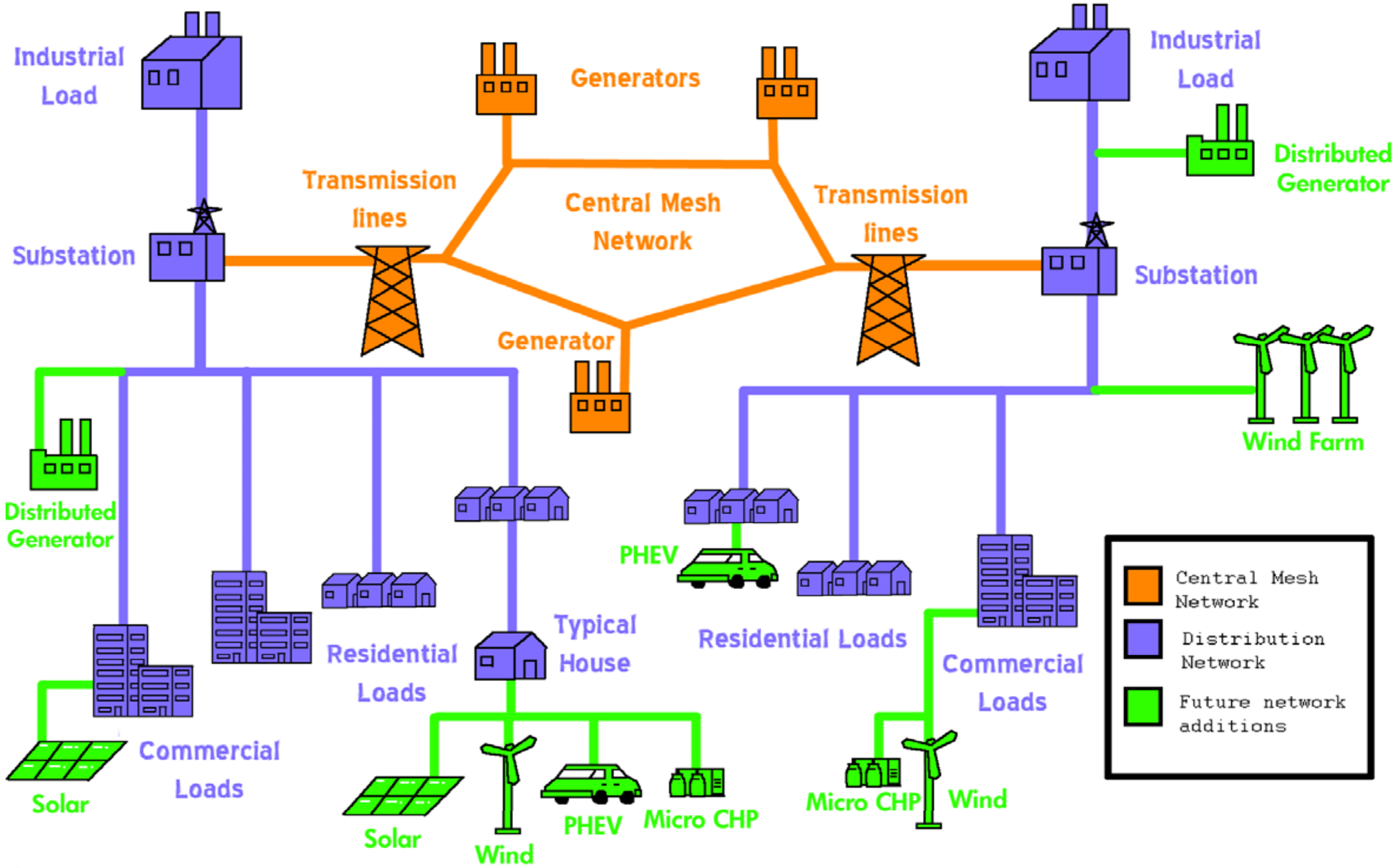
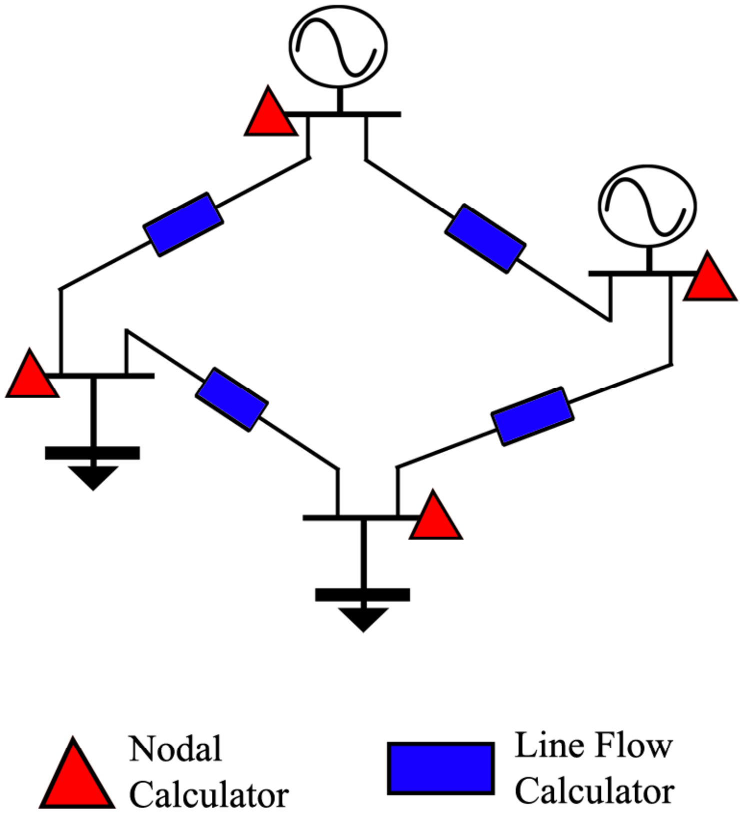
Adding Detail To System



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)



[1] Jadbabaie, A.; Ozdaglar, A.; Zargham, M.; , "A Distributed Newton Method for network optimization," *Decision and Control, 2009 held jointly with the 2009 28th Chinese Control Conference. CDC/CCC 2009. Proceedings of the 48th IEEE Conference on* ,pp.2736-2741, 15-18 Dec. 2009

[2] Ilić, M. and Hsu, A. "Toward Contingency Screening Using Distributed Line Flow Calculators and Dynamic Line Rating Units (DLRs)" *To appear in HICSS Conference, January 2012*

Information Exchange

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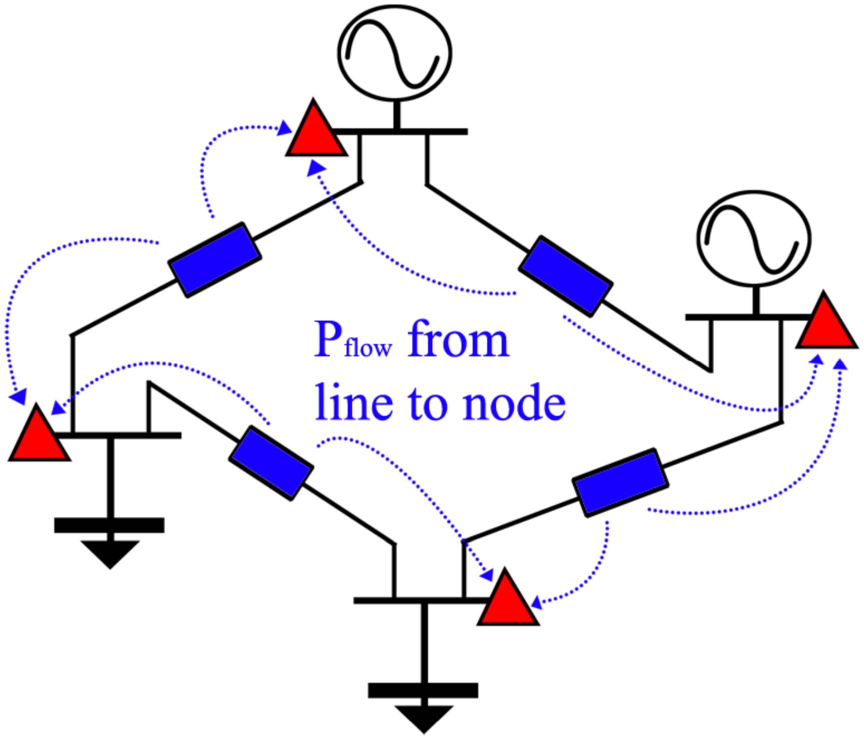
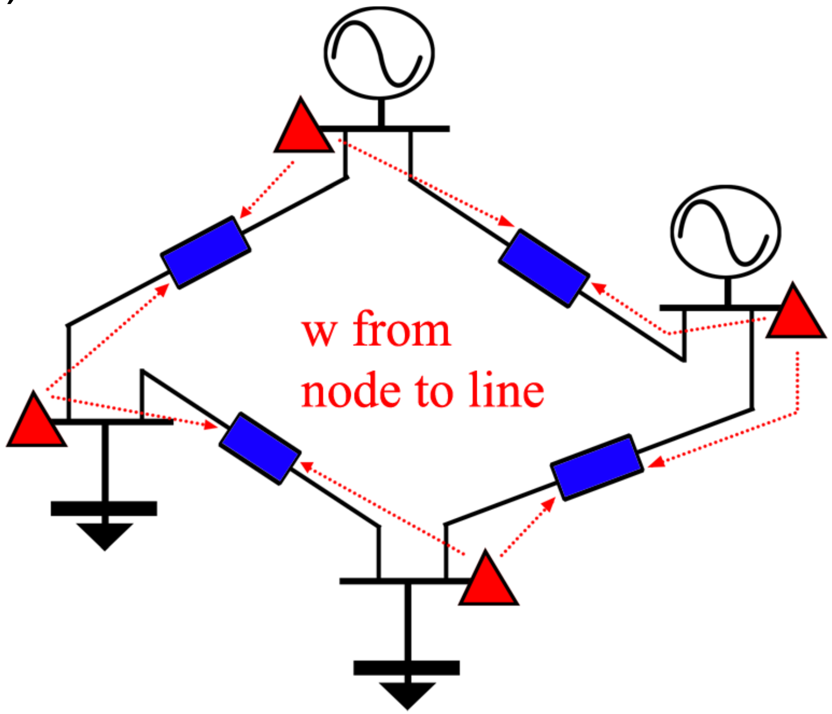


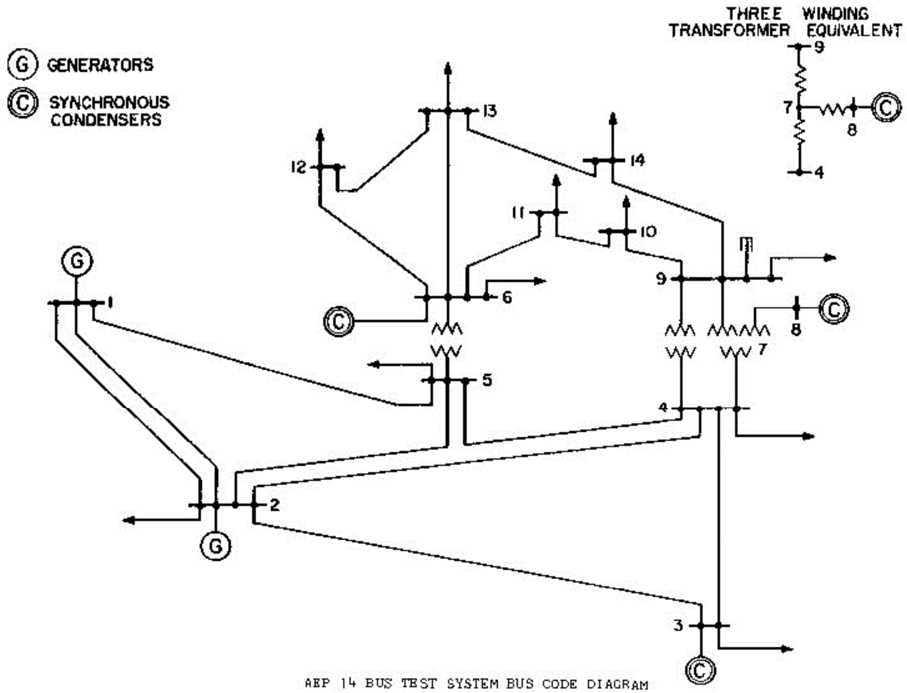


Decoupled Real Power Simulations

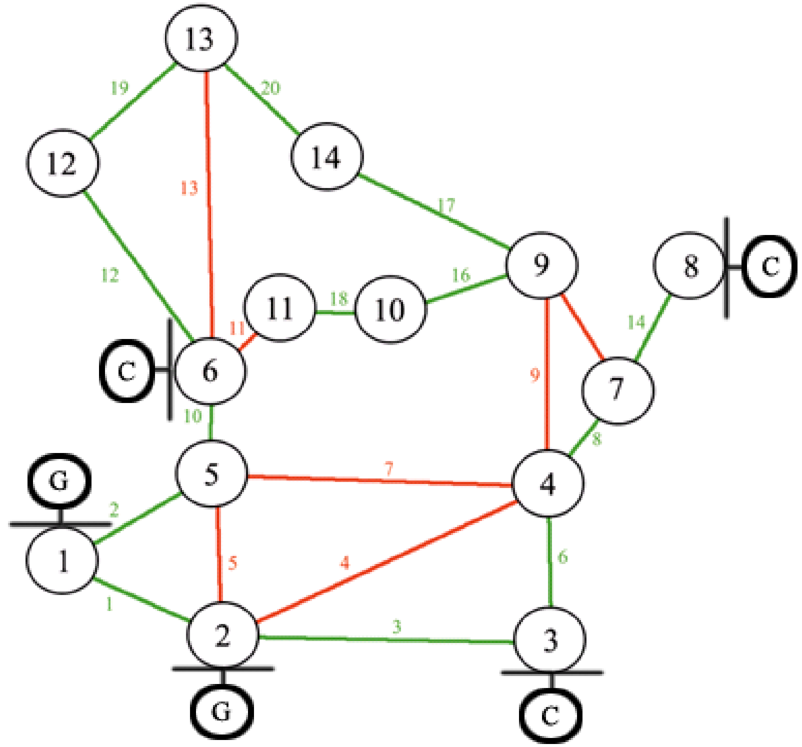
- IEEE 14 bus simulation done for real power decoupled power flow example[2][3]
- Solution checked using simultaneous equation solver in Matlab

[2] Ilić, M. and Hsu, A. "Toward Contingency Screening Using Distributed Line Flow Calculators and Dynamic Line Rating Units (DLRs)" *To appear in HICSS Conference, January 2012*
[3] Ilić, M. and Hsu, A. "GENERAL METHOD FOR DISTRIBUTED LINE FLOW COMPUTING WITH LOCAL COMMUNICATIONS IN MESHED ELECTRIC NETWORKS." Application number: 13/343,997. Filed: January 5, 2012

14 Bus System



14 bus example



14 bus example
graphical representation

14 bus – Results

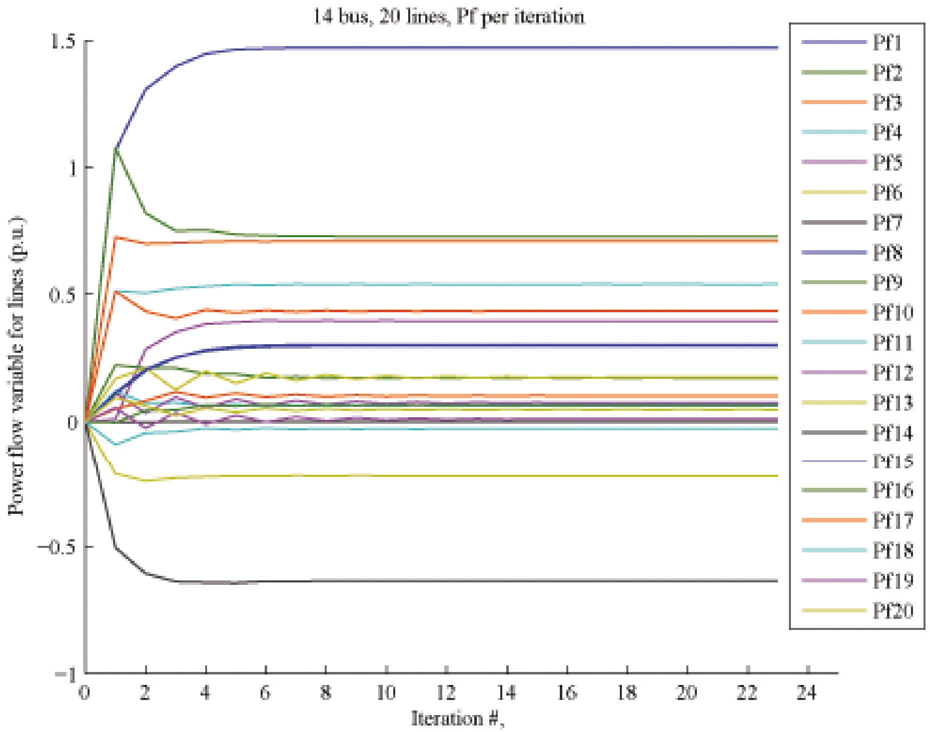


Table VII

P_f SOLUTIONS OF IEEE 14 BUS SYSTEM

Centralized vs. Distributed Solution		
Line No.	P_f Centr.	P_f Distr.
1	1.4889	1.4705
2	0.7408	0.7285
3	0.7246	0.7115
4	0.5467	0.5395
5	0.4047	0.3957
6	-.2285	-.2217
7	-0.6260	-0.6331
8	0.2907	0.3031
9	0.1666	0.1727
10	0.4196	0.4349
11	0.0634	0.0650
12	0.0732	0.0752
13	0.1728	0.1752
14	0.0000	0.0014
15	0.2907	0.2975
16	0.0619	0.0658
17	0.1014	0.1028
18	-0.0281	-0.0272
19	0.0119	0.0116
20	0.0487	0.0482

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

[1] Jadbabaie, A.; Ozdaglar, A.; Zargham, M.; , "A Distributed Newton Method for network optimization," *Decision and Control, 2009 held jointly with the 2009 28th Chinese Control Conference. CDC/CCC 2009. Proceedings of the 48th IEEE Conference on* ,pp.2736-2741, 15-18 Dec. 2009

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