Weekly Summary

by *Aryan Ritwajeet Jha*

This week's contents:

Problem: *Solving for a power flow snapshot by decomposing a meshed grid into two radial grids and solving their individual power flows in parallel*

Problem provided by *Rabayet Sadnan*

The Test Case

- A variation of the 4-bus system available in Grainger and Stevenson was used.

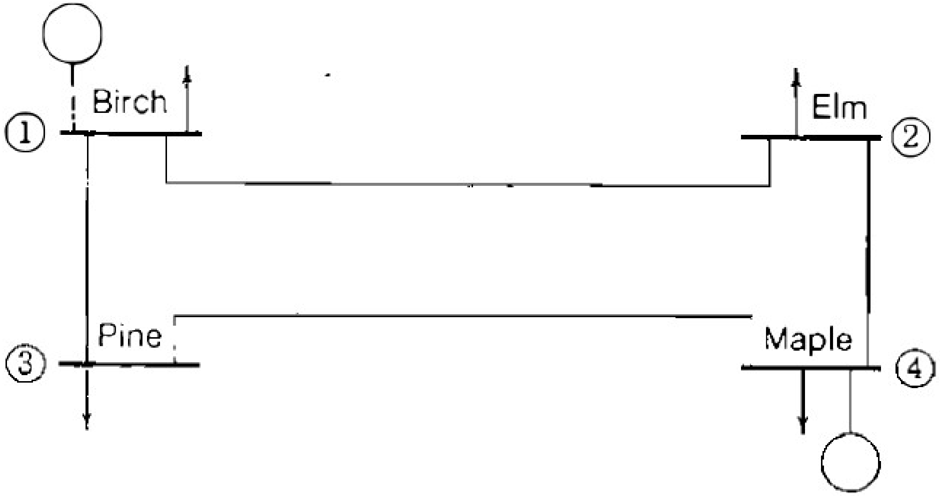
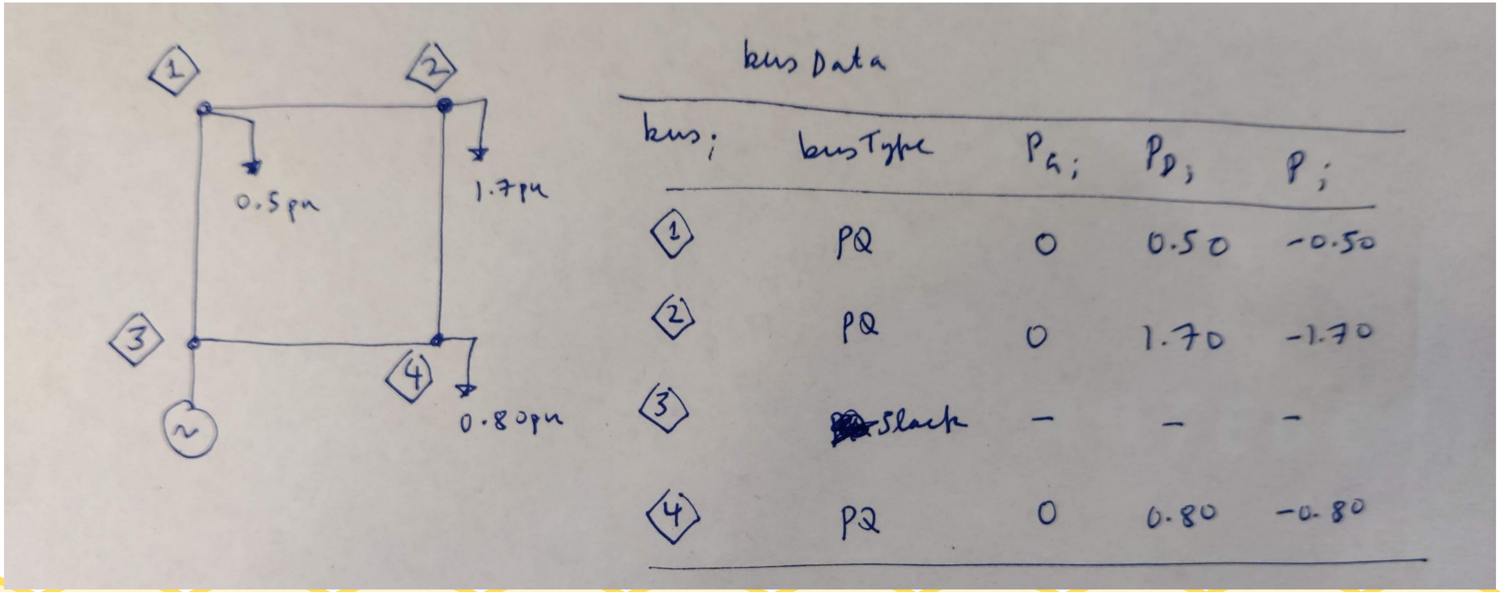


FIGURE 9.2
One-line diagram for Example 9.2 showing the bus names and numbers.

Original System

The Test Case

- Instead of two generators at buses 1 and 4, the modified system has only one generator at bus 3.



Modified System with Bus Data

The Test Case

- The branch data used is the same.

TABLE 9.2
Line data for Example 9.2†

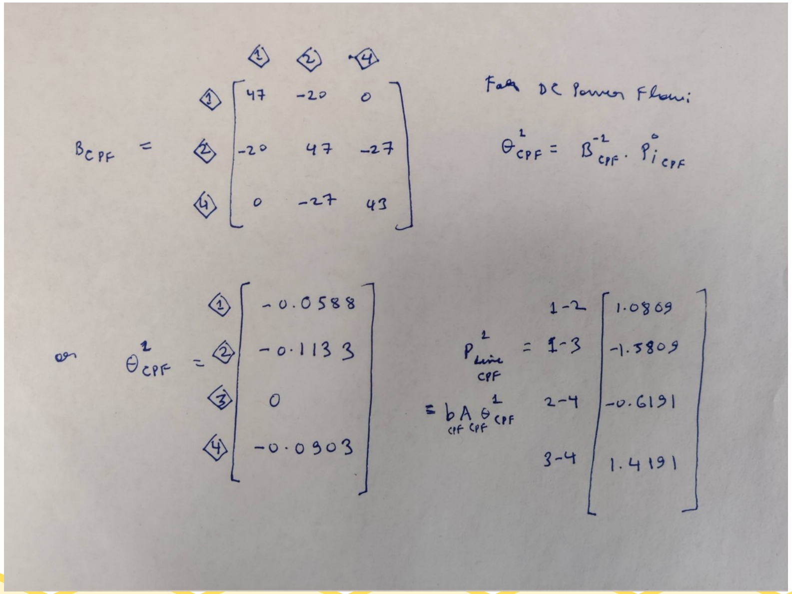
Line, bus to bus	Series Z		Series $Y = Z^{-1}$		Shunt Y	
	R per unit	X per unit	G per unit	B per unit	Total charging Mvar‡	Y / 2 per unit
1–2	0.01008	0.05040	3.815629	−19.078144	10.25	0.05125
1–3	0.00744	0.03720	5.169561	−25.847809	7.75	0.03875
2–4	0.00744	0.03720	5.169561	−25.847809	7.75	0.03875
3–4	0.01272	0.06360	3.023705	−15.1[illegible]8528	12.75	0.06375

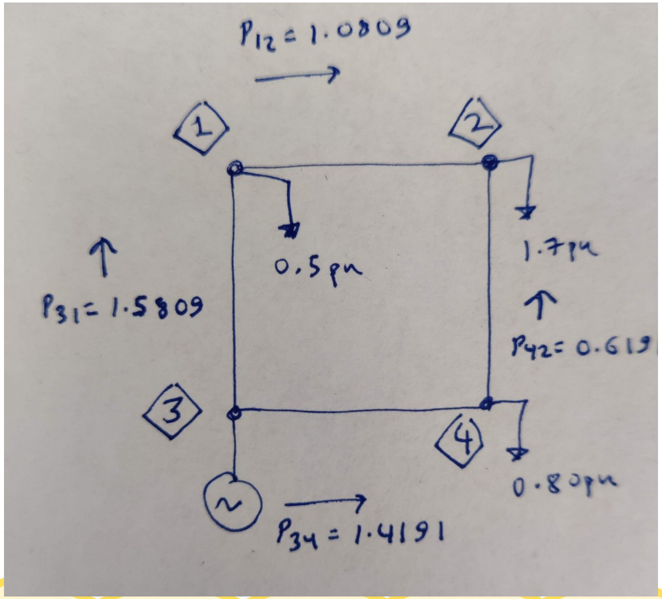
†Base 100MVA, 230 kV.
‡At 230 kV.

Branch Data for the Modified 4 Bus System.

Centralized Power Flow using DC Power Flow

- For a reference, the bus modified 4 bus system was solved using DC Power Flow.

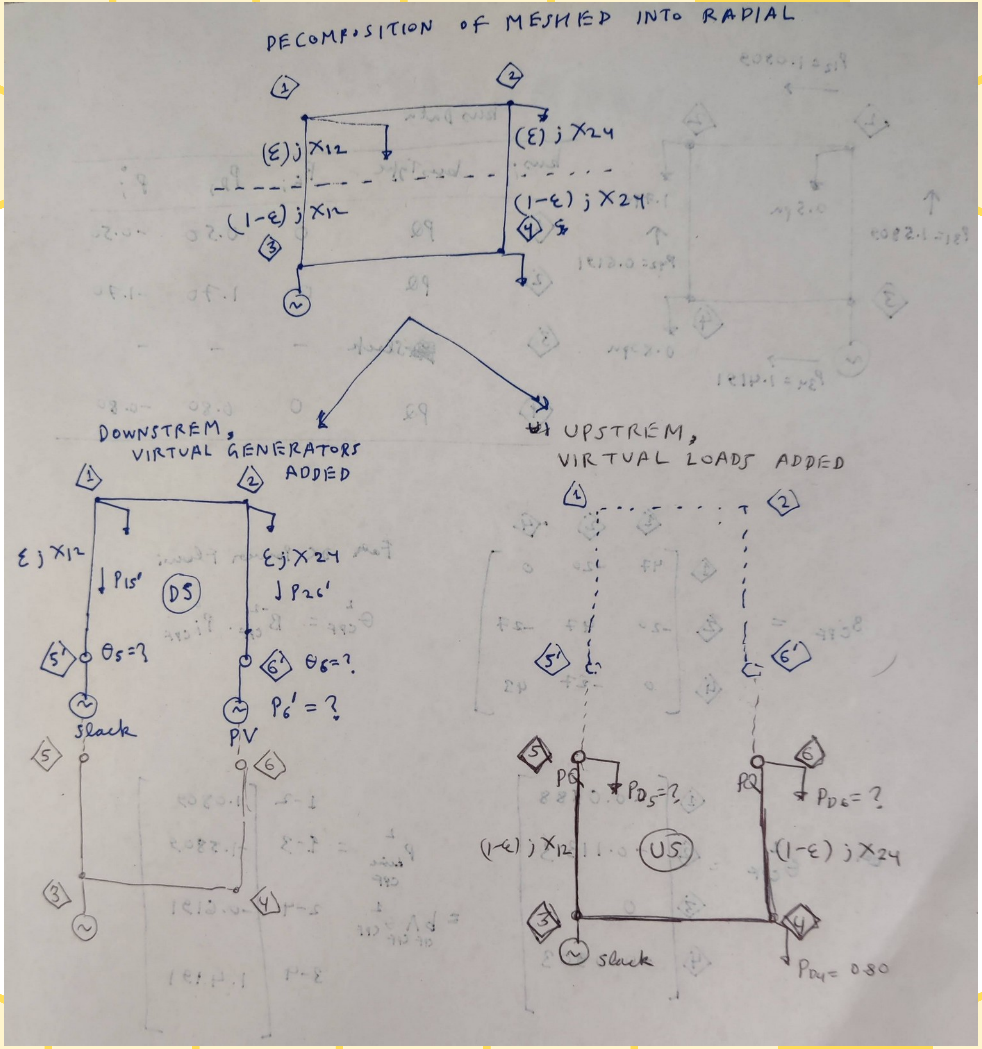




DC Power Flow Snapshot for the Modified 4 Bus System.

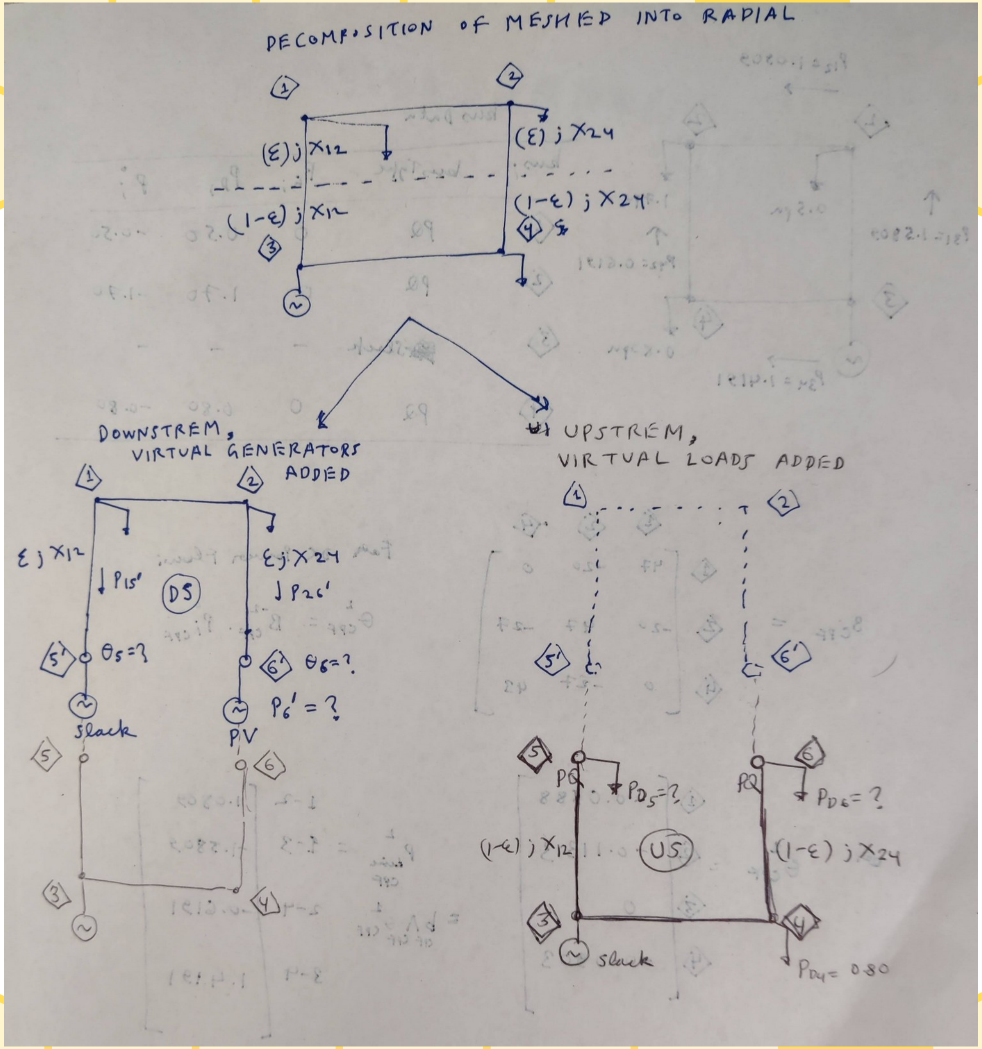
Decentralized Power Flow

- *The Idea:* Instead of solving power flow for the whole meshed system, we can decompose the grid into two radial subsystems (with suitable adjustments) and solve for their individual power flows in parallel.
- System bifurcated into two subsystems at branches 1-3 and 2-4, which led to creation of virtual nodes 5, 5’ and 6, 6’. One one pair of virtual nodes (5’, 6’), virtual generators were added, whereas on the other pair of virtual nodes (5, 6), virtual loads were added.



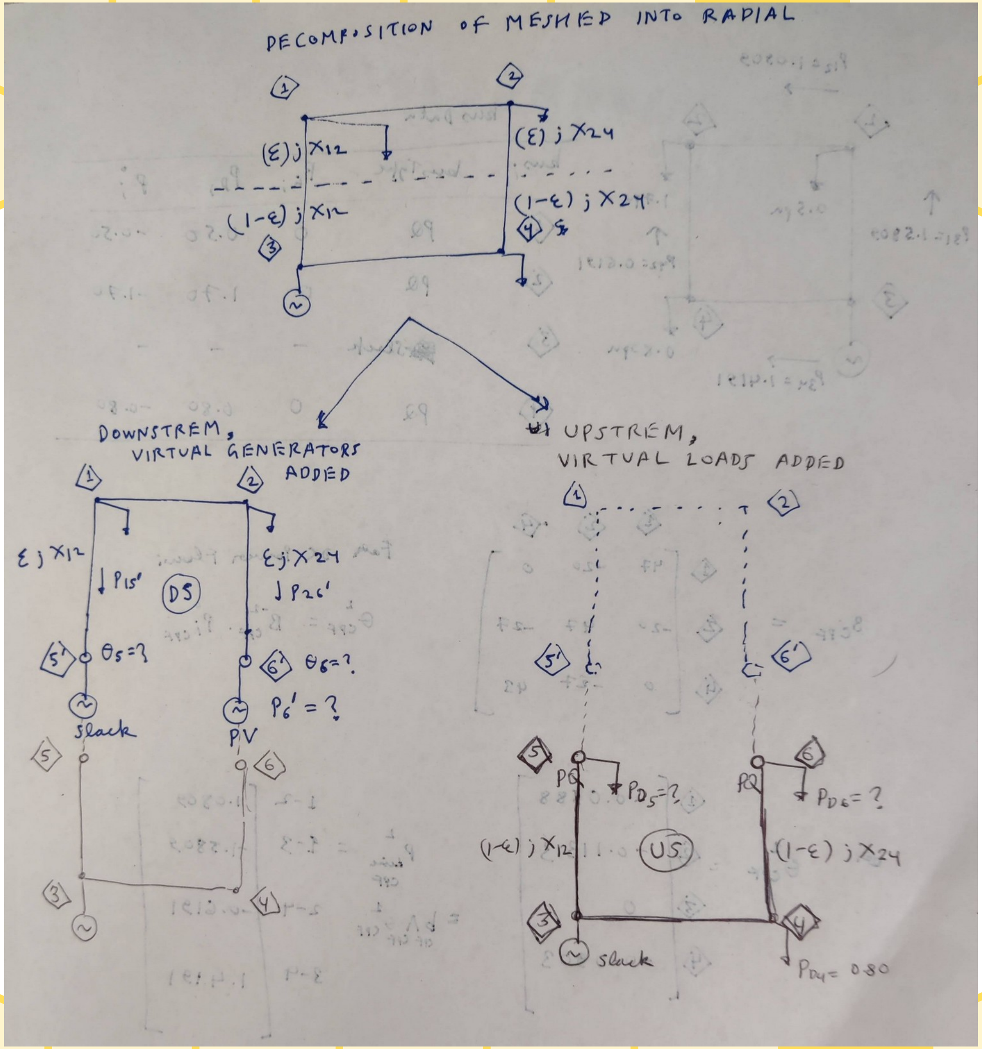
Decentralized Power Flow

- In theory, the virtual generation at virtual node 5' should match the virtual loads at virtual node 5. And similarly for 6' and 6.
- This is because no new power can be generated or demanded at the virtual nodes.
- Sub-systems called 'Donwstream' (only loads) and 'Upstream' (with real generator at bus 3)



Decentralized Power Flow

- For DC Power flows, we require:
- **B Matrix** (**known** for both subsystems, given that we can decide the place at which branches 1-3 and 2-4 are ‘cut’).
- Real Powers injected into the grid by bus i: $\boldsymbol{P_i}$ (**NOT known** for every bus). Here we know the $\boldsymbol{P_i}$ values for buses 1, 2, 4 only.
  - We need to find a way to know the $\boldsymbol{P_i}$ values for buses 3, 5’, 5, 6’ and 6.



Running a bit short on time, so the rest will be explained in person.

End of *This week’s contents.*

Weekly Summary

by *Aryan Ritwajeet Jha*

This week's contents:

Distributed Computing for Scalable Optimal Power Flow in Large Radial Electric Power Distribution Systems with Distributed Energy Resources
by *Rabayet Sadnan* and *Anamika Dubey*

PowerModelsDistributions.jl: An Open-Source Framework for Exploring Distribution Power Flow Formulations
By *David M Fobes*, *Sander Claeys*, *Frederik Geth* and *Carleton Coffrin* from LANL, KU Leuven

Weekly Summary

by *Aryan Ritwajeet Jha*

This week's contents:

Network-Level Optimization for Unbalanced Power Distribution System: Approximation and Relaxation
by *Rahul Ranjan Jha* and *Anamika Dubey*

Distributed Optimizations Using Reduced Network Equivalents for Radial Power Distribution Systems
By *Rabayet Sadnan* and *Anamika Dubey*

Network-Level Optimization for Unbalanced Power Distribution System: Approximation and Relaxation

- *Non-Linear Programming (NLP)* to solve *Distribution Level – Optimal Power Flow (D-OPF)* poses <u>convergence issues</u> and <u>not scalable for</u> unbalanced power distribution systems <u>(*upds*)</u>**.**
- Existing scalable solutions to D-OPF problem either use <u>approximations</u> that are <u>not valid for *upds*</u> or <u>relaxation techniques</u> <u>not guaranteeing feasible power flow solution</u>.

Network-Level Optimization for Unbalanced Power Distribution System: Approximation and Relaxation

- The authors scalable D-OPF algorithms have been proposed that simultaneously achieve optimal and feasible solutions by solving multiple iterations of approximate, or relaxed, D-OPF subproblems of low complexity.
- Algorithm 1 is based on successive linear approximation of Nonlinear Power Flow equations around the current operating point, where the D-OPF solution is obtained by solving multiple iterations of a linear programming problem.
- Algorithm 2 is based on the relaxation of the nonlinear power flow equations as conic constraints together with directional constraints, which achieves optimal and feasible solutions over multiple iterations of a *second-order cone programming* (*SOCP*) problem.

Network-Level Optimization for Unbalanced Power Distribution System: Approximation and Relaxation

- Applications of OPF algorithms:
  - Loss minimization
  - Volt-Var Optimization
  - Effective Management of DERs
- Need for Advanced Distributed Management Systems (ADMS)
  - Increasing penetration of DERs
  - Proliferation of Proactive loads
  - Interest in Demand Response Programmes

Distributed Optimizations Using Reduced Network Equivalents for Radial Power Distribution Systems

- Centralized Optimization Methods have limitations.
- Existing D-OPF algorithms not viable as they require a large number of macro-iterations (10^2 to 10^3 iterations of communication rounds) between computing agents to solve one instance of the optimization problem.
- So in the paper, the authors propose a new scalable D-Optimization method based on Equivalent Network Approximation (*ENApp*) to solve D-OPF for a balanced power distribution system (*bpds*).
- Specifically, the bpds's radial topology is leveraged to reduced the decomposed systems into upstream and downstream network equivalents.
- Validated on IEEE 123 and IEEE 8500 systems and checked against the solution of a centralized optimal power flow (*C-OPF*) model.

Distributed Optimizations Using Reduced Network Equivalents for Radial Power Distribution Systems

- Typically C-OPF (which uses NLP) used to determine a pds's operation == computational challenges and susceptibility to single point failure.
- In such a case D-O methods have these advantages:
  - Less computation load on a single machine
  - Less susceptibility to single-point failure due to multiple interacting agents
  - Relax the need between communication between a central controlling machine and connected controllable/non-controllable assets.