WASHINGTON STATE UNIVERSITY

Distributed Optimization in Distribution Systems

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Distributed Optimization in Distribution Systems

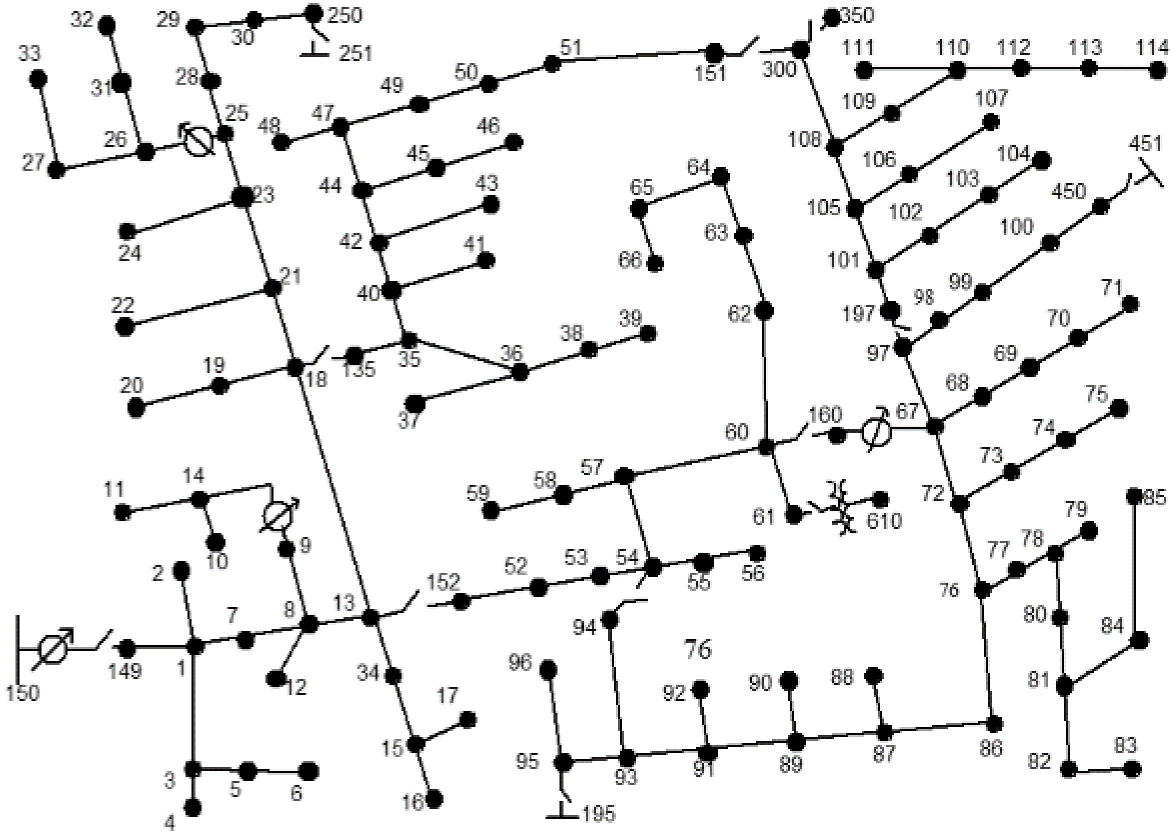
- Current problem statement:
  - Perform Distributed Optimal Power Flow on a Single-phase power distribution network.
- Desired objective(s):
  - Incorporate battery storage into the algorithm.
  - Convert the code (currently in MATLAB) into Python/Julia.
  - Later: Incorporate battery storage into a three-phase network.

This is based on the previous work by:

- *Rabayet Sadnan and Anamika Dubey (2022)* Distributed Computing for Scalable Optimal Power Flow in Large Radial Electric Power Distribution Systems with Distributed Energy Resources
- *Rabayet Sadnan and Anamika Dubey (2021)* Distributed Optimization Using Reduced Network Equivalents for Radial Power Distribution Systems

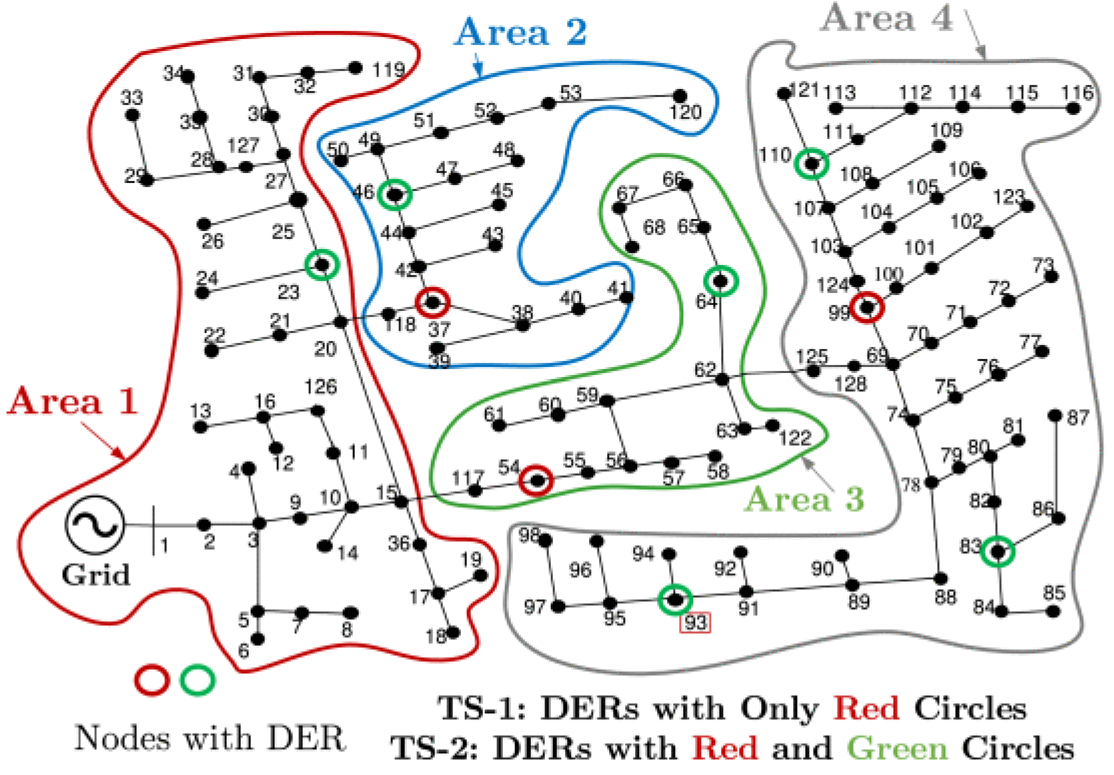
Distributed Optimization in Distribution Systems

- **Current problem statement:**
  - Single-phase power distribution network (Here, the IEEE123 Node Test System)



Distributed Optimization in Distribution Systems

- **Current problem statement:**
  - Divide the network into several areas in order to solve for their Optimal Power Flow solutions separately, with exchange of boundary variables after every ‘macro-iteration’.



Distributed Optimization in Distribution Systems

- **Current problem statement:**
  - Perform a 'Distributed OPF' for minimizing line losses for each area. After every macro-iteration, exchange border variables between connected areas.

$$\textbf{(D1)}\quad \min \; f_m = \sum_{\{ij\}\in\mathcal{E}_m} l_{ij} r_{ij}$$

$$\text{s.t.}\;\; P_{ij} - r_{ij} l_{ij} - p_{L_j} + p_{Dj} = \sum_{k:j\to k} P_{jk}$$

$$Q_{ij} - x_{ij} l_{ij} - q_{L_j} + q_{Dj} = \sum_{k:j\to k} Q_{jk}$$

$$v_j = v_i - 2(r_{ij}P_{ij} + x_{ij}Q_{ij}) + (r_{ij}^2 + x_{ij}^2) l_{ij}$$

$$v_o = v_{o'};$$

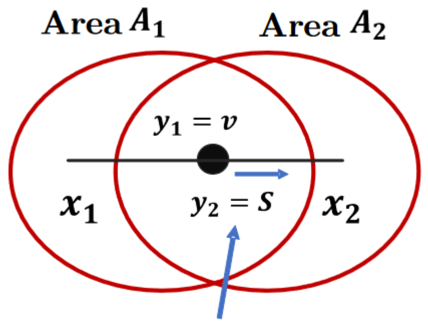
$$P_{jk} = p_{k'} \quad ;\forall\{jk\}\in\mathcal{E}_m, \text{ where } k \in C_h$$

$$Q_{jk} = q_{k'} \quad ;\forall\{jk\}\in\mathcal{E}_m, \text{ where } k \in C_h$$

$$-\sqrt{S_{DRj}^2 - p_{Dj}^2} \le q_{Dj} \le \sqrt{S_{DRj}^2 - p_{Dj}^2}$$

$$\underline{V}^2 \le v_j \le \overline{V}^2 \qquad ;\forall j\in\mathcal{N}_m$$

$$l_{ij} \le \left(I_{ij}^{rated}\right)^2 \qquad ;\forall\{ij\}\in\mathcal{E}_m$$



Complicating Variables at the Shared Node

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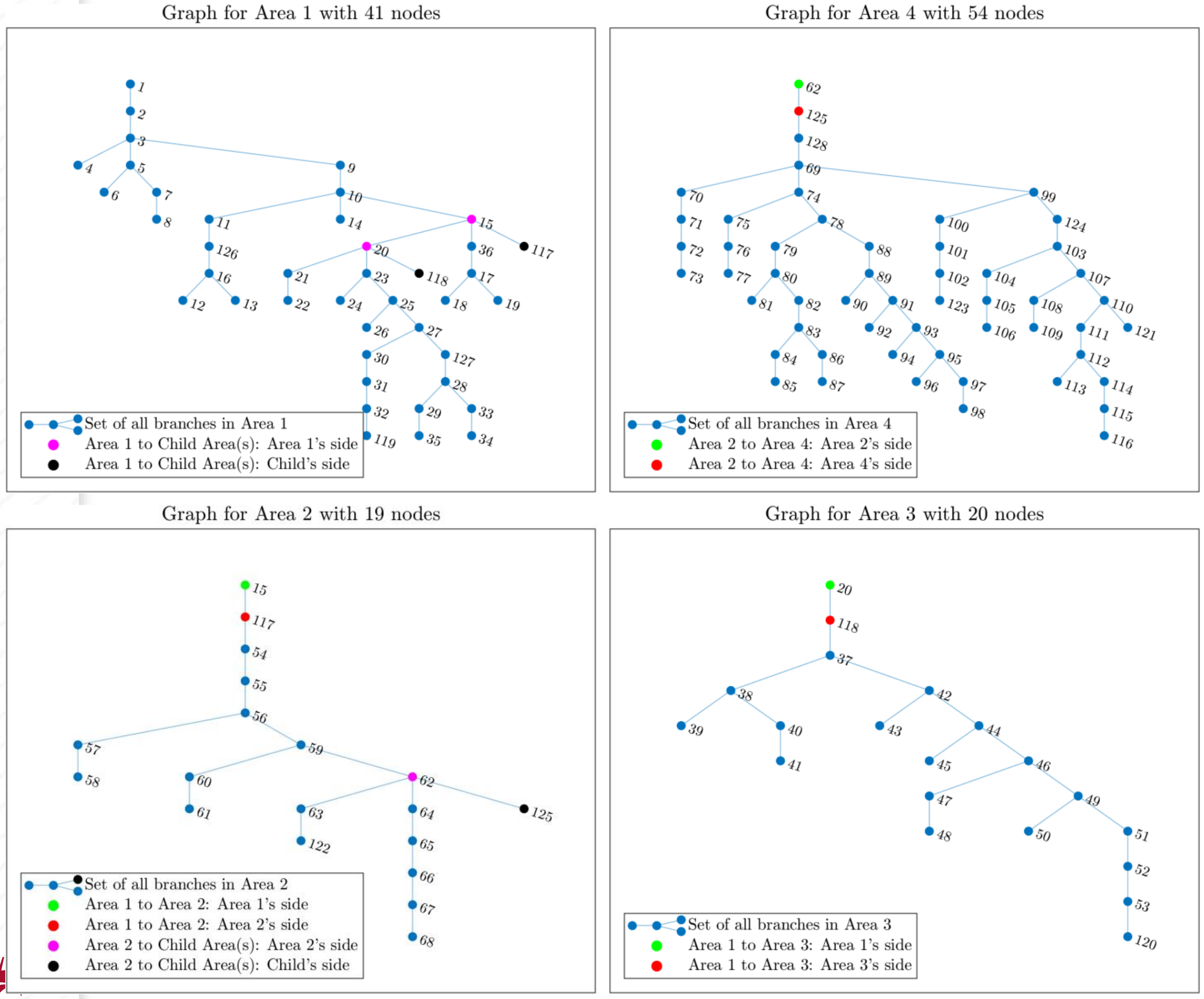
Some test runs over different area divisions

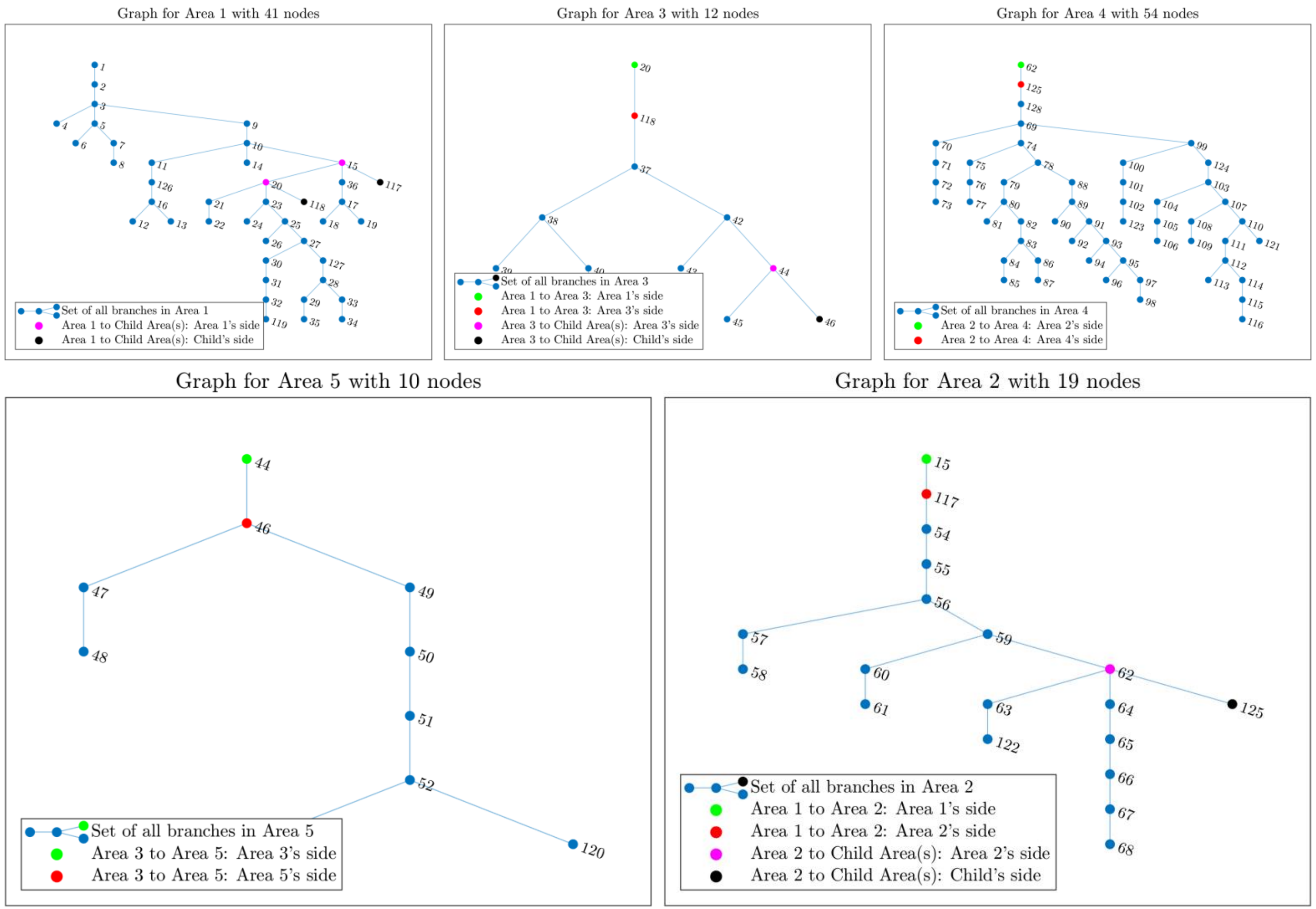
The Distributed Optimization Algorithm was run on the IEEE 123 Node Test Feeder, which was divided into three, four and five Areas in separate runs.

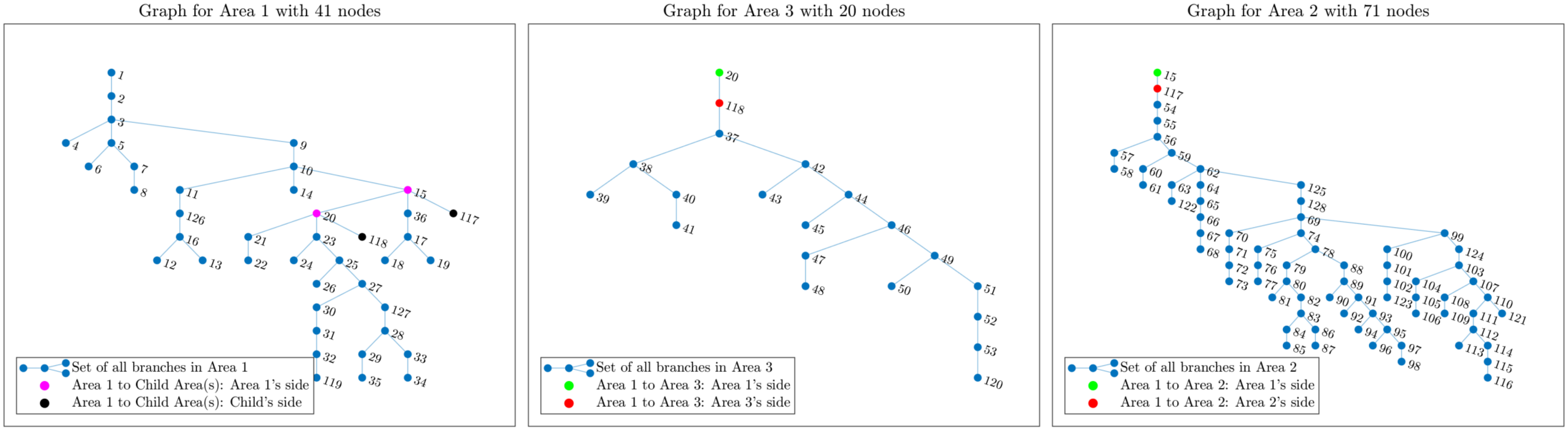
This was to check if the results of the algorithm are consistent irrespective of the number of areas the system was divided into.

4 Area System



5 Area System





3 Area System

Some Test Runs over Different Area Divisions

- Optimal line losses match for all sets of areas.

- 5 Area:
  - Line Loss = 12.18kW
  - Substation Power = 768.24kW
- 4 Area:
  - Line Loss = 12.18kW
  - Substation Power = 768.24kW
- 3 Area:
  - Line Loss = 12.09kW
  - Substation Power = 768.16kW

Next Objectives

Desired objective(s):

- Incorporate battery storage into the algorithm using Multi-Period Optimization.
- Convert the code (currently in MATLAB) into Python/Julia.
- Later: Incorporate battery storage into a three-phase network.