WASHINGTON STATE UNIVERSITY

Introducing myself:

Aryan Ritwajeet Jha

***Advisor**: Anamika Dubey*

***PhD Thesis Topic**: Scalable Multi-Period Optimal Power Flow in Active Distribution Systems*

Or simply, Scalable MPOPF in ADS

Bachelor of Engineering in EEE at BITS Pilani, Hyderabad Campus

2018 Summer Internship at **Power Grid Corporation of India**, Gurgaon

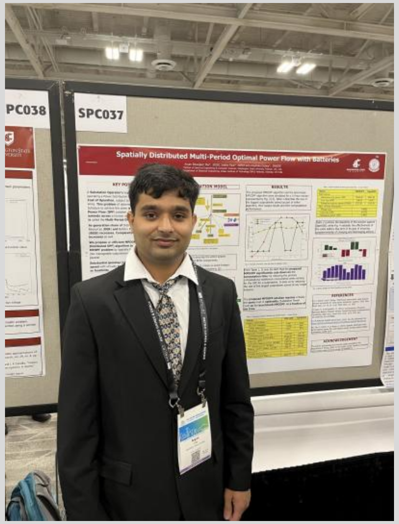
2016 – 2020

Master of Science (Research) in EE (Power Systems) at IIT Delhi

Discontinued after 2 years

2020 – 2022

Pursuing PhD ECE (Power Systems) at Washington State University, Pullman, WA



2024 Summer Internship at **North American Electric Reliability Corporation** (NERC)

2025 Summer Internship at **GE Vernova Advanced Research Center** (GEVARC)

2022 August –

The Multi Period Optimal Power Flow (MPOPF) problem for Active Distribution Systems

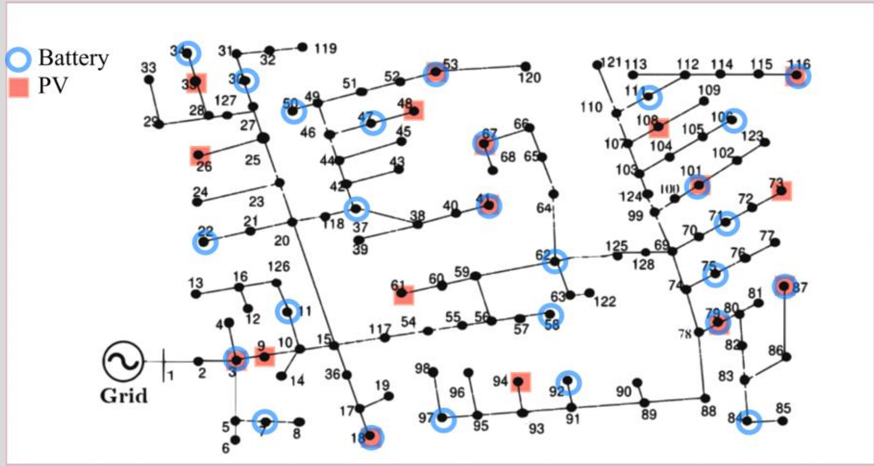
$min.$ Desired Objective Function

subject to

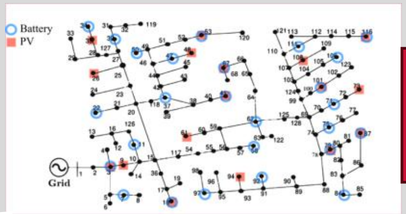
Network Constraints

Engineering Constraints

Component Constraints (DERs, Batteries)

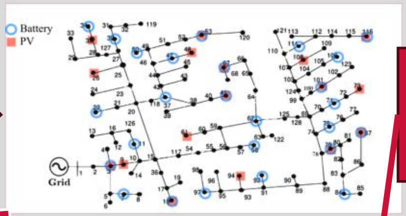


Controllable Components: Grid Edge Devices (GEDs) like Batteries and PVs spread throughout whose real and reactive dispatch may be set every time-period



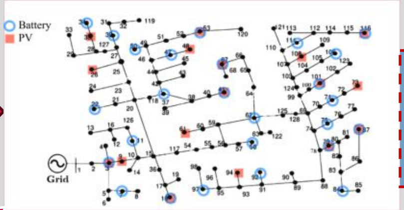
Set Points

Intertemporal Constraints



Set Points

Intertemporal Constraints



Set Points

Intertemporal Constraints

Battery SOC Equation

$$B_j^t = B_j^{t-1} + \Delta t \eta_c P_{c_j}^t - \Delta t \frac{1}{\eta_d} P_{d_j}^t$$

Due to these intertemporal constraints, the optimization problem size becomes T times larger, becoming more difficult to solve.

Full Optimization Model – Balanced Three-Phase Nonlinear/Linear OPF

min. Desired Objective Function, *(appended with an Battery Loss Function) [4]*

subject to

Network Constraints

Engineering Constraints

Component Constraints (DERs, Batteries)

Objective

$$\min \sum_{t=1}^{T} \{f_0^t + f_{SCD}^t\} \qquad (1)$$

where

$$f_0^t = C^t P_{Subs}^t \Delta t$$

$$f_{SCD}^t = \alpha \sum_{j\in\mathcal{B}} \left\{(1-\eta_C)P_{C_j}^t + \left(\frac{1}{\eta_D}-1\right)P_{D_j}^t\right\}$$

Network Constraints

Subject to the constraints (2) to (20) as given below:

$$\sum_{(j,k)\in\mathcal{L}} \{P_{jk}^t\} - (P_{ij}^t - r_{ij}l_{ij}^t) = p_j^t \qquad (2)$$

$$\sum_{(j,k)\in\mathcal{L}} \{P_{jk}^t\} - (P_{ij}^t) = p_j^t \qquad (3)$$

$$p_j^t = \left(P_{d_j}^t - P_{c_j}^t\right) + p_{D_j}^t - p_{L_j}^t \qquad (4)$$

$$\sum_{(j,k)\in\mathcal{L}} \{Q_{jk}^t\} - (Q_{ij}^t - x_{ij}l_{ij}^t) = q_j^t \qquad (5)$$

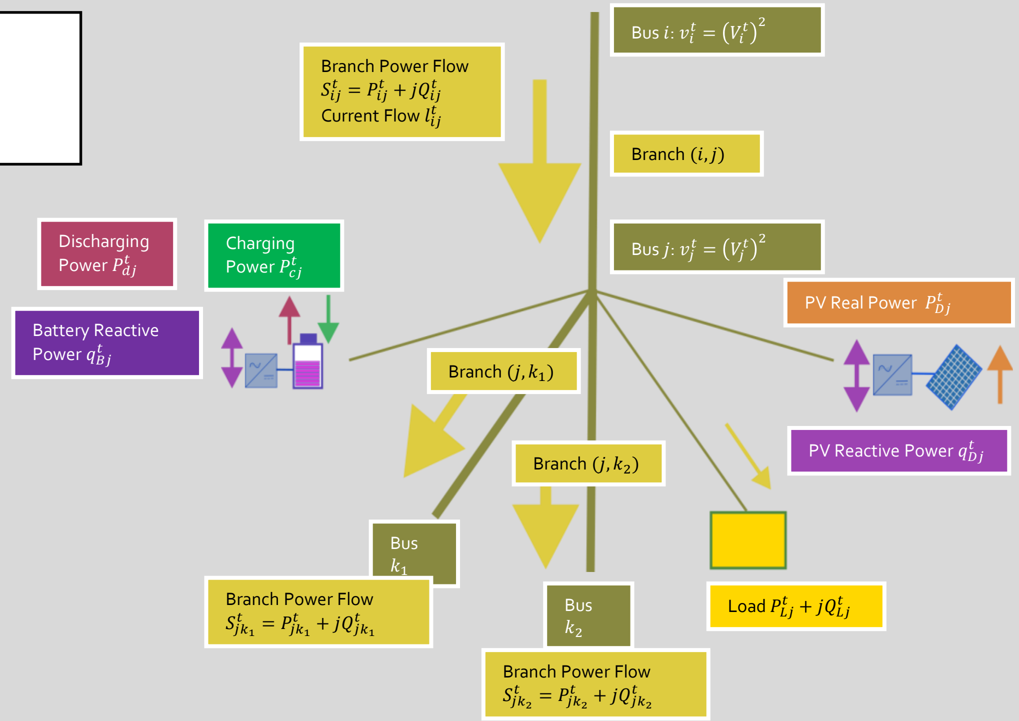
$$\sum_{(j,k)\in\mathcal{L}} \{Q_{jk}^t\} - (Q_{ij}^t) = q_j^t \qquad (6)$$

$$q_j^t = q_{D_j}^t + q_{B_j}^t - q_{L_j}^t \qquad (7)$$

$$v_j^t = v_i^t - 2(r_{ij}P_{ij}^t + x_{ij}Q_{ij}^t) + \{r_{ij}^2 + x_{ij}^2\}\, l_{ij}^t \qquad (8)$$

$$v_j^t = v_i^t - 2(r_{ij}P_{ij}^t + x_{ij}Q_{ij}^t) \qquad (9)$$

$$(P_{ij}^t)^2 + (Q_{ij}^t)^2 = l_{ij}^t v_i^t \qquad (10)$$



Battery Reactive Power Constraints

$$q_{B_j}^t \in \left[-\sqrt{3}(P_{B_j}^t + S_{B_{R,j}}), -\sqrt{3}(P_{B_j}^t - S_{B_{R,j}})\right] \qquad (18a)$$

$$q_{B_j}^t \in \left[-\frac{\sqrt{3}}{2}S_{B_{R,j}}, \frac{\sqrt{3}}{2}S_{B_{R,j}}\right] \qquad (18b)$$

$$q_{B_j}^t \in \left[\sqrt{3}(P_{B_j}^t - S_{B_{R,j}}), \sqrt{3}(P_{B_j}^t + S_{B_{R,j}})\right] \qquad (18c)$$

$$P_{B_j}^t = P_{d_j}^t - P_{c_j}^t \qquad (19)$$

$$B_j^t \in [soc_{min}B_{R,j}, soc_{max}B_{R,j}] \qquad (20)$$

PV and Battery Real Power Constraints

$$P_{Subs}^t \geq 0 \qquad (11)$$

$$v_j^t \in [V_{min}^2, V_{max}^2] \qquad (12)$$

$$q_{D_j}^t \in \left[-q_{D_{Max,j}}^t, q_{D_{Max,j}}^t\right] \qquad (13)$$

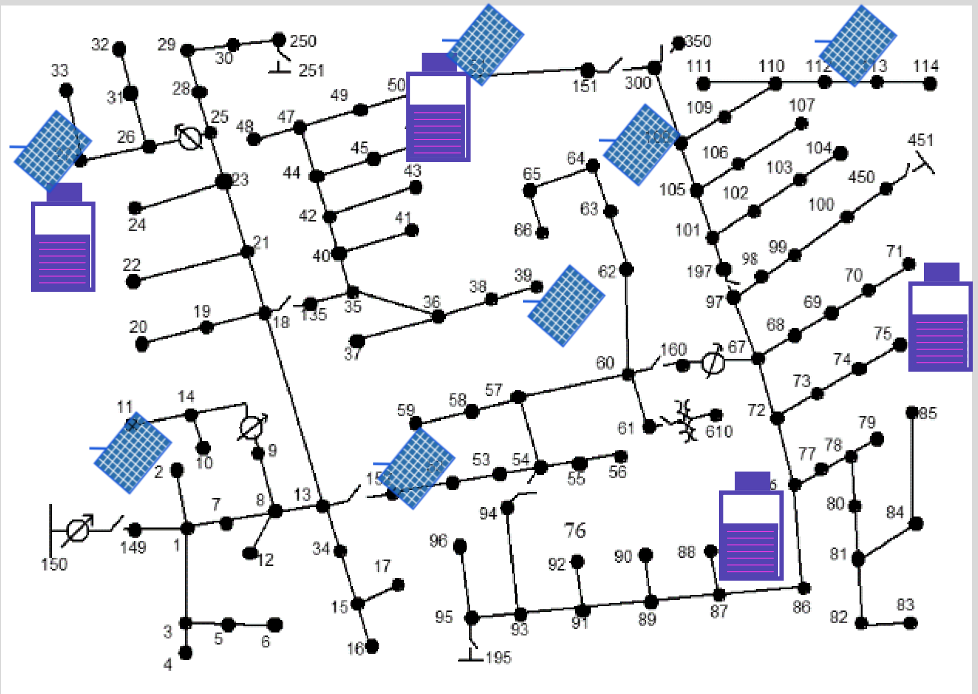
$$q_{D_{Max,j}}^t = \sqrt{{S_{D_{R,j}}}^2 - {p_{D_j}^t}^2} \qquad (14)$$

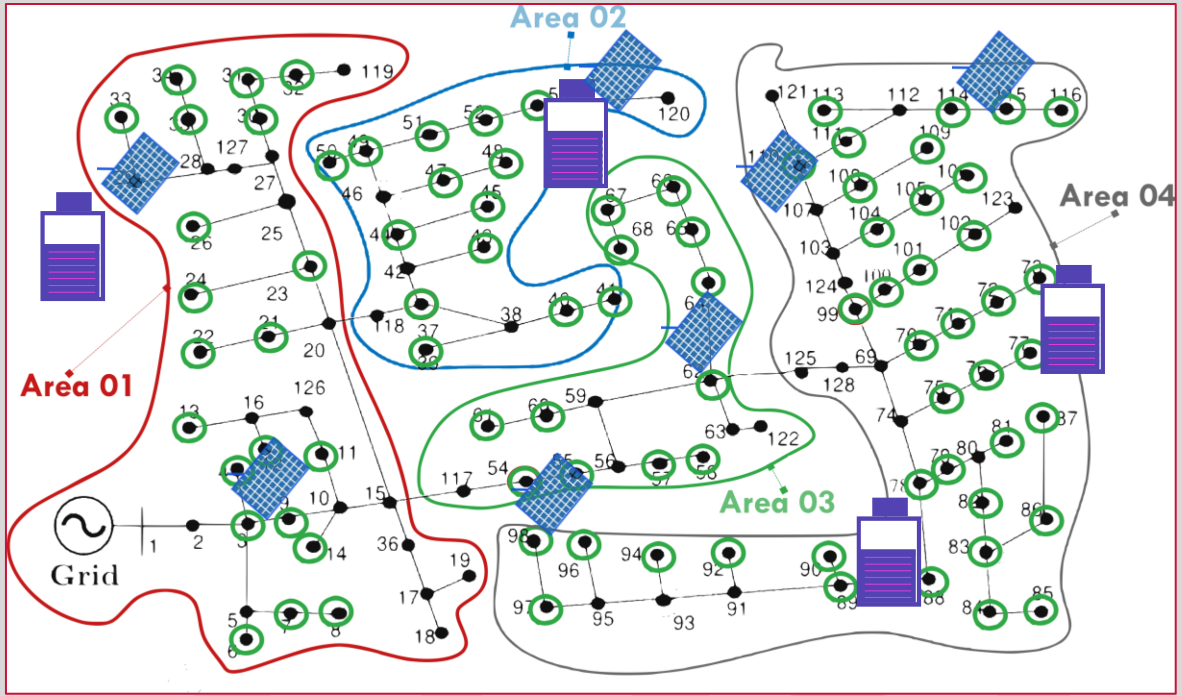
$$B_j^t = B_j^{t-1} + \Delta t\left(\eta_c P_{c_j}^t - \frac{1}{\eta_d}P_{d_j}^t\right) \qquad (15)$$

$$P_{c_j}^t, P_{d_j}^t \in [0, P_{B_{R,j}}] \qquad (16)$$

$$(P_{B_j}^t)^2 + (q_{B_j}^t)^2 \leq S_{B_{R,j}}^2 \qquad (17)$$

MPOPF Problem Decomposition - Spatial

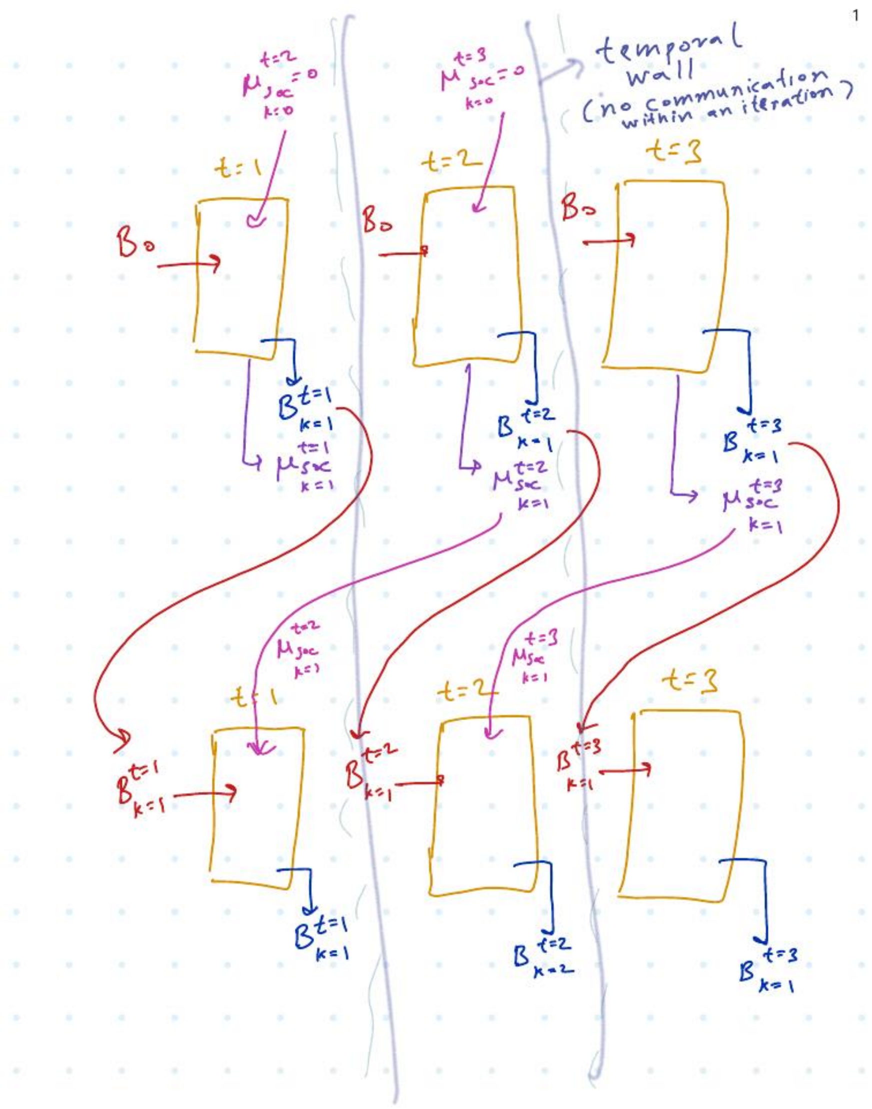




Previously utilized* and proven to cut down computational costs!

*A. R. Jha, S. Paul and A. Dubey, "Spatially Distributed Multi-Period Optimal Power Flow with Battery Energy Storage Systems," *2024 56th North American Power Symposium (NAPS)*, El Paso, TX, USA, 2024, pp. 1-6, doi: 10.1109/NAPS61145.2024.10741846.*

MPOPF Problem Decomposition - Temporal



Tested with good results!
Currently being perfected..

WASHINGTON STATE UNIVERSITY

My reasons to take/ My expectations from EE 582

Slides End Here.
Thank you!