# Distribution Systems Planning and Analysis Framework for Indian Feeders – Partnership with BSES/BRPL

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# Distribution Network Modeling

- Generating OpenDSS model
- Data cleaning
- Load allocation

# Challenges and Need for Developing Feeder Models

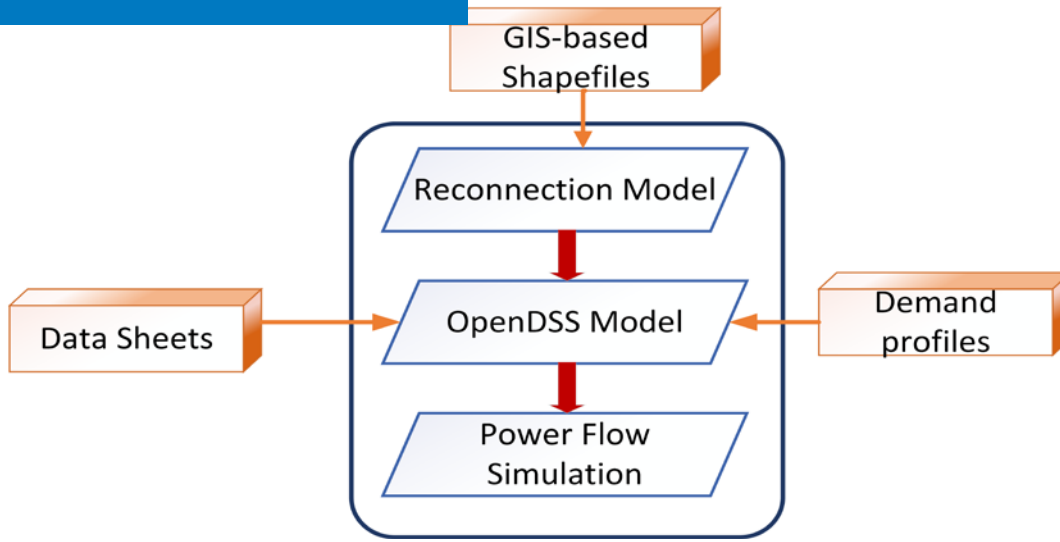
- **Challenges**:
  - Multiple data sources with different levels of completeness (GIS, SCADA, AMI and equipment specification sheets)
  - Assumptions such as line transposition and balanced phase loading cannot be used
  - All the phases of each feeder component must be modelled accurately

- **Need**:
  - Distribution feeders need to include primary and the secondary networks to help in analysis of DER integration
  - Secondary network modelling is essential as each secondary hosts hundreds of customers
  - Local parameters such as voltages can not be sufficiently captured if only the primary networks are modelled

# Generating OpenDSS model

**Steps for creating detailed feeder models in OpenDSS*:**

- Explode each line layer in the GIS file
- Export the geometry of the exploded layer to nodes and attribute files
- Create edges
- Locate Feeder head
- Add nodes and merge neighboring nodes
- Remove loops in feeder layout
- Add new secondary nodes for customer load allocation

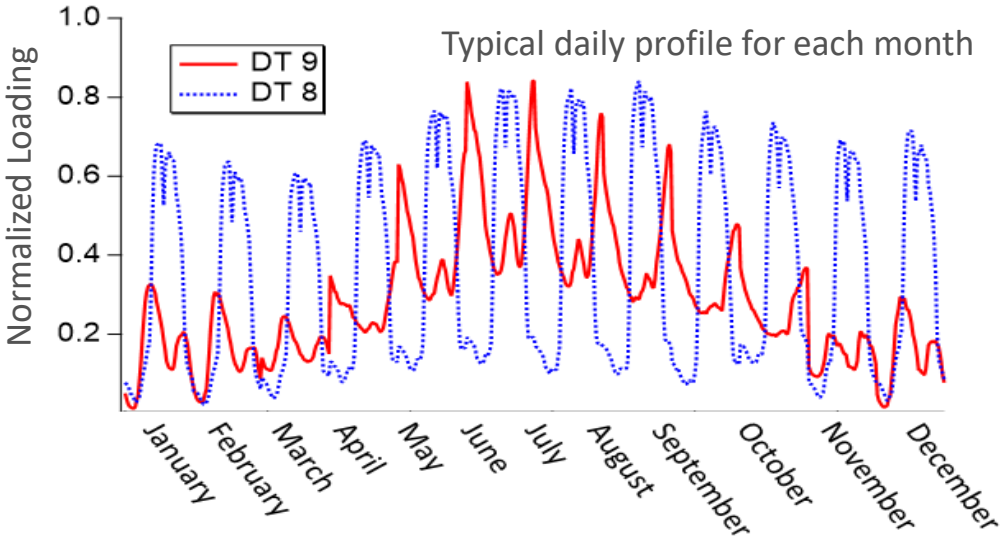


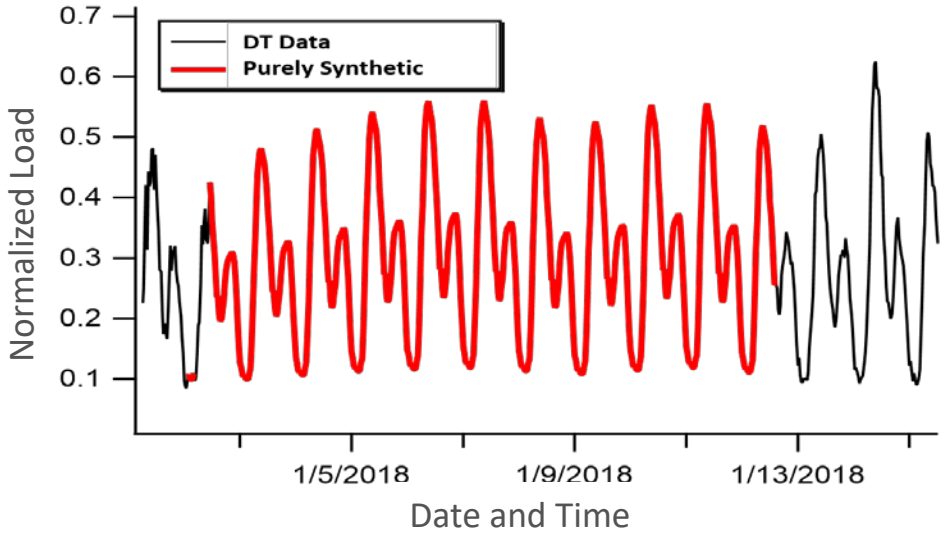


*OpenDSS is an open-source power system simulation tool for distribution systems, developed by Electric Power Research Institute (EPRI), USA

# Average Loading Conditions Provided Input to Missing Data

- **Serially complete DT loading data is required for time-series power flow**
- Field measurements had inconsistencies such as missing data
- Mean loading condition observed during each half-hourly time point was used
- This process was repeated for each month in the year
- This produced donor profiles to fill missing time points



# Load Allocation

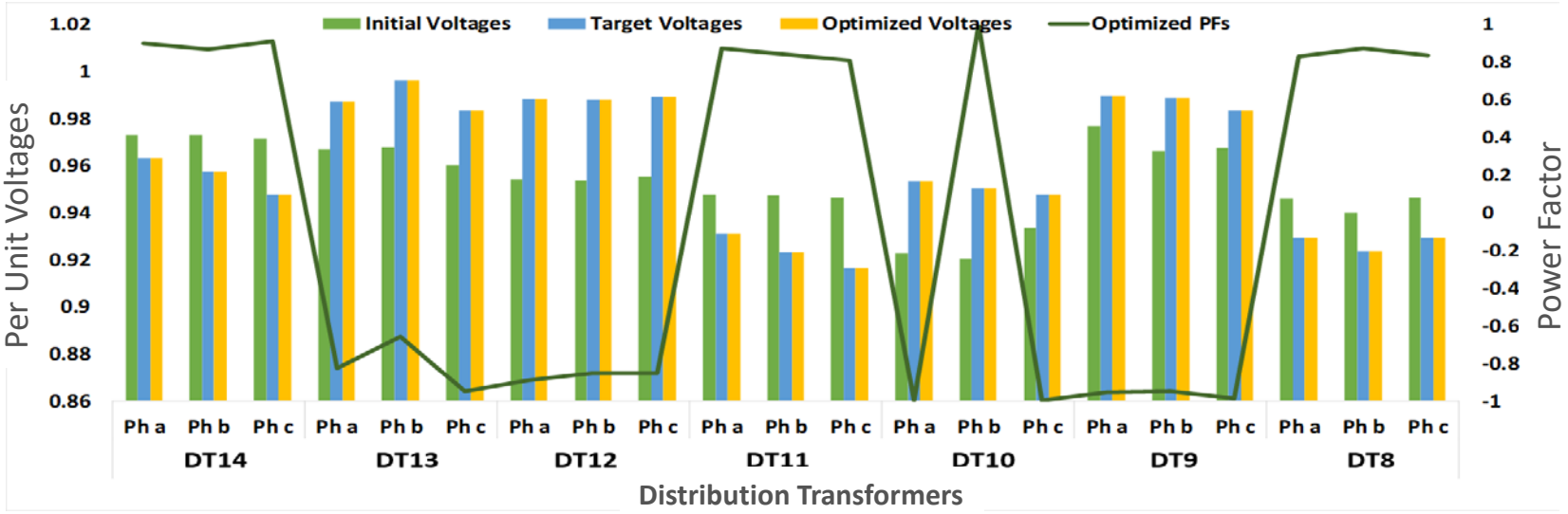
- Developed a load allocation algorithm based on evolutionary algorithm (EA) to help in matching voltage drops from the feeder head to the DT secondaries
- Result is correct per phase load kW and power factors
- Distributed among all secondary customers based on their annual kWh consumption

These load values give the **initial voltages**

These are the **target voltages**

| METERNO | DATETIMET | ACTIVE_B_PH | ACTIVE_Y_PH | ACTIVE_R_PH | VBV | VYV | VRV |
|---|---|---|---|---|---|---|---|
| 29XXXX | 10/1/2017 | 241.5 | 227.7 | 154.1 | 245.41 | 242.88 | 244.95 |

DT metering information and target voltages



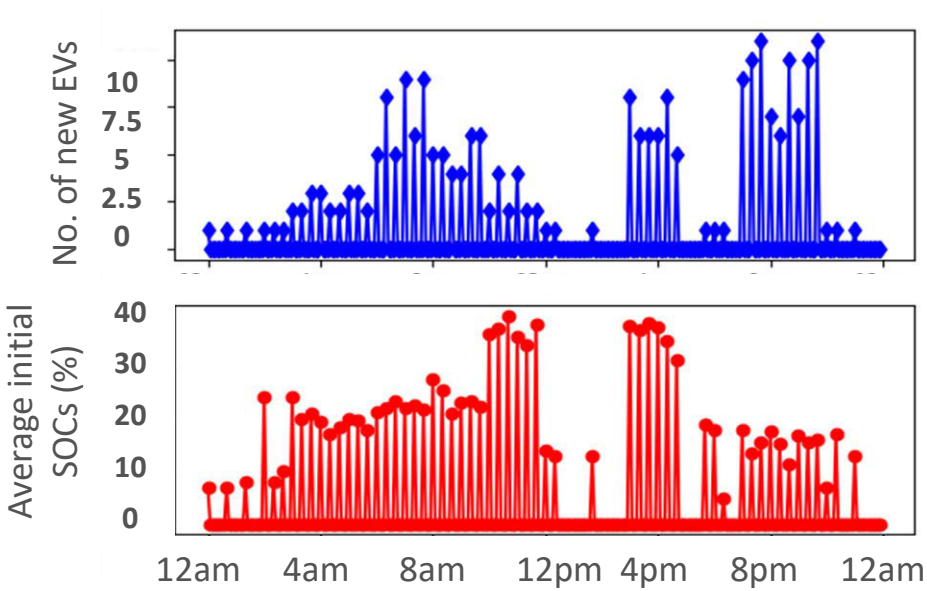

Results of load allocation algorithm

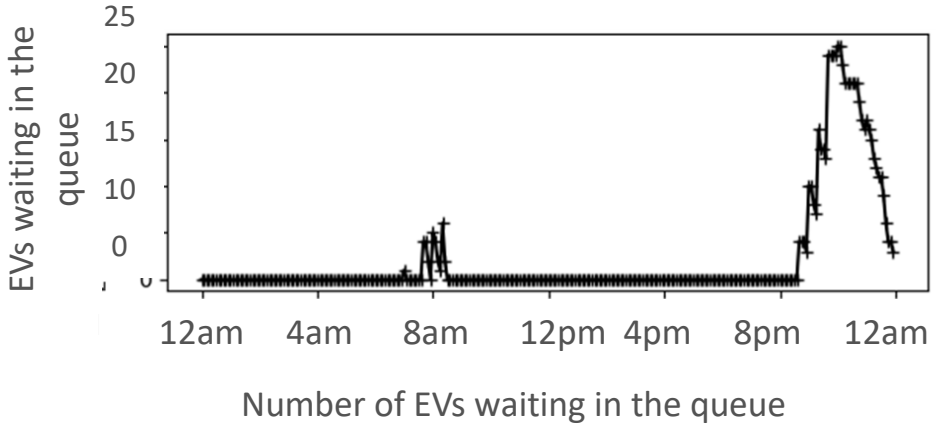
# EV Demand Modelling

- Daily demand profile estimates
- Initial Results

# Daily EV demand profile estimates

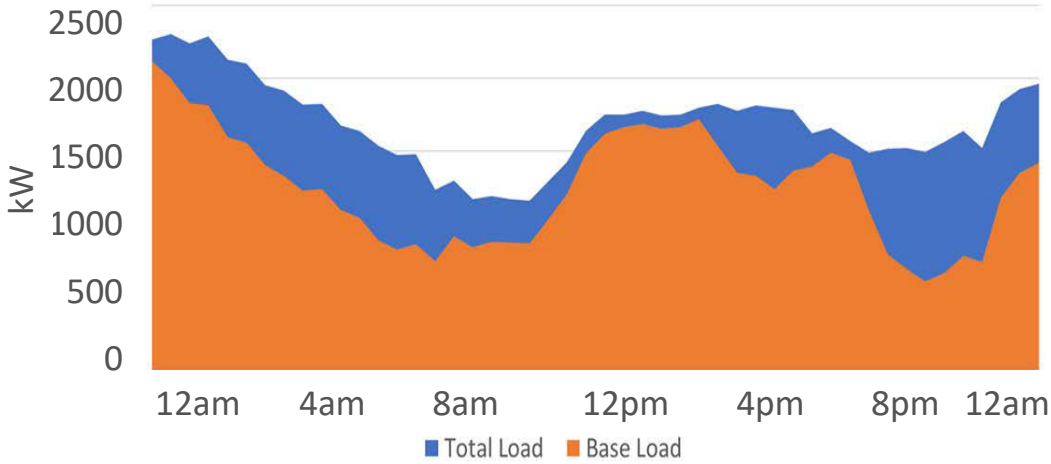
- EV load modeled as spot demand profiles in randomized locations
- Residential EV charger was modelled as an additional load added to base load
- Public charging station was added as a new load
- Number of EVs arriving at the station and initial SOCs



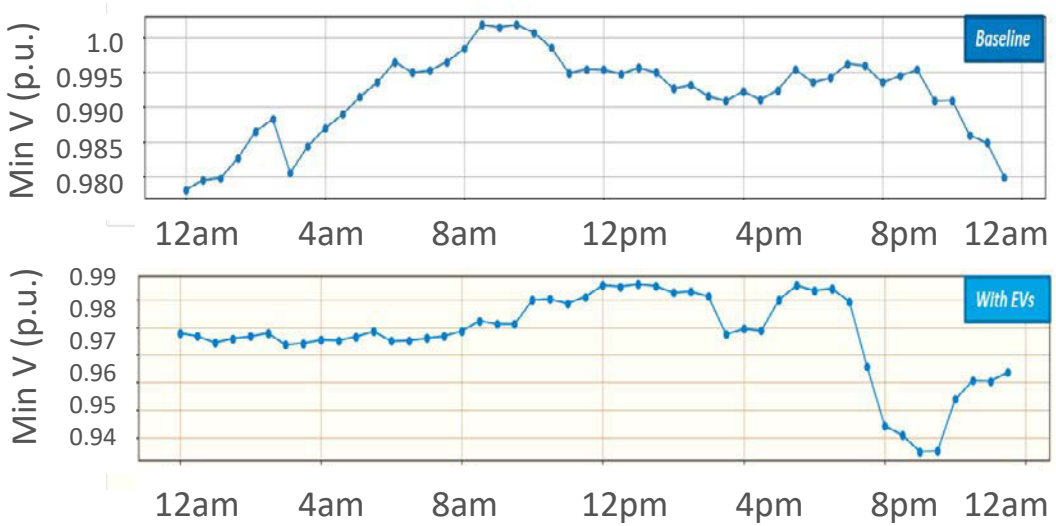
# EV Modeling
# Load and Voltage Profiles

- About 2000 EVs considered, adding up to 1 MW of load during some periods of the day




Base load and total load (after EV integration) profiles for a summer day

- Voltage profile altered from EV load, especially during the peak load time in the evening




Comparison of minimum voltages between baseline and EV integration scenario

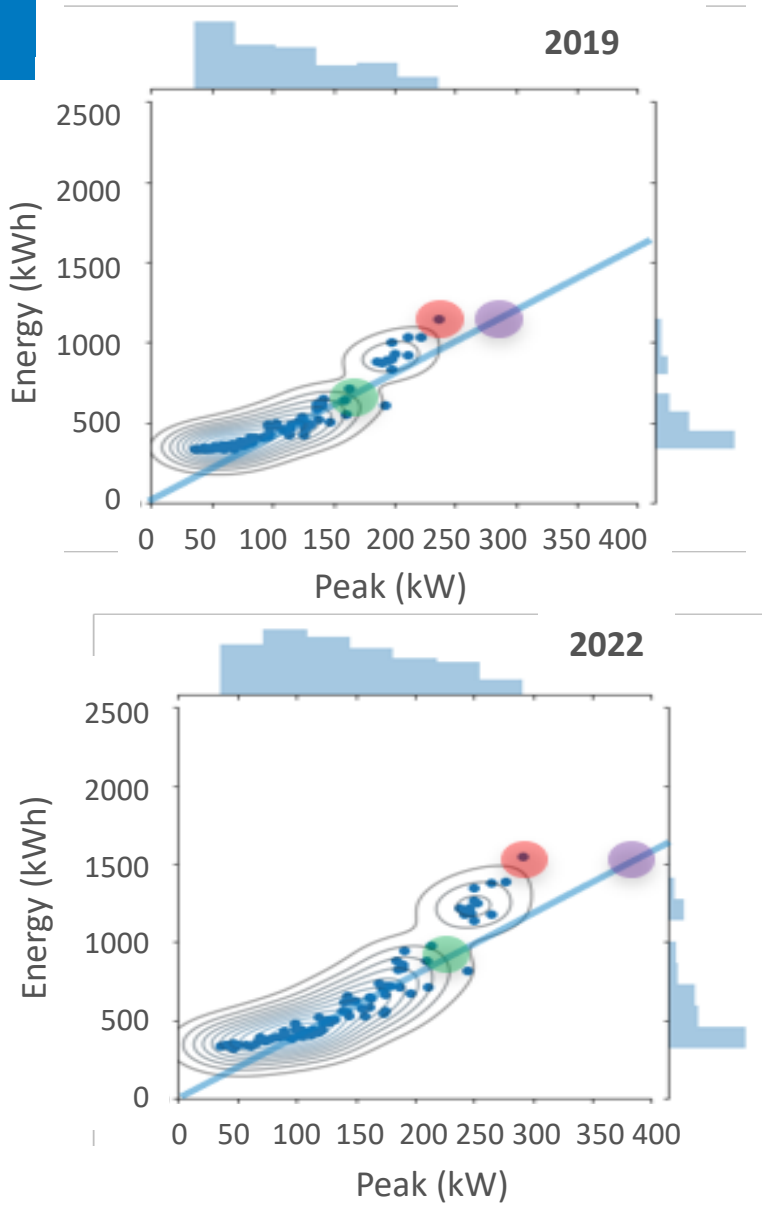
# Battery Energy Storage Systems

- Battery Sizing
- Peak shaving control application
- Results

# Sizing Batteries to Meet *Most* Overloading Conditions

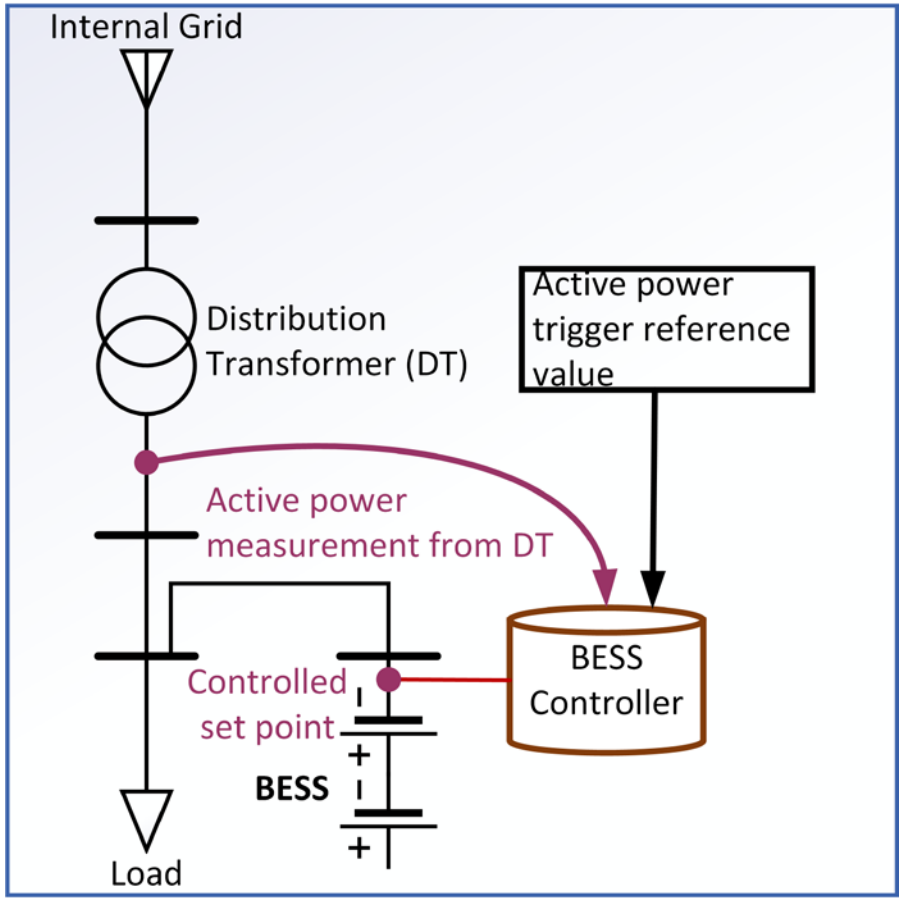
- Commercially available batteries are assumed to have a 4:1 ratio between energy and power.
- There are three points of interest, these are:
  - the peak power overloading instance point shown in red,
  - the projected peak power point to the 4:1 ratio line shown in purple, and,
  - the 70th percentile point in green
- 70th percentile point represents the point on the 4:1 ratio line simultaneously at the 70th percentile of power and energy for all overloading instances

Battery sizing map

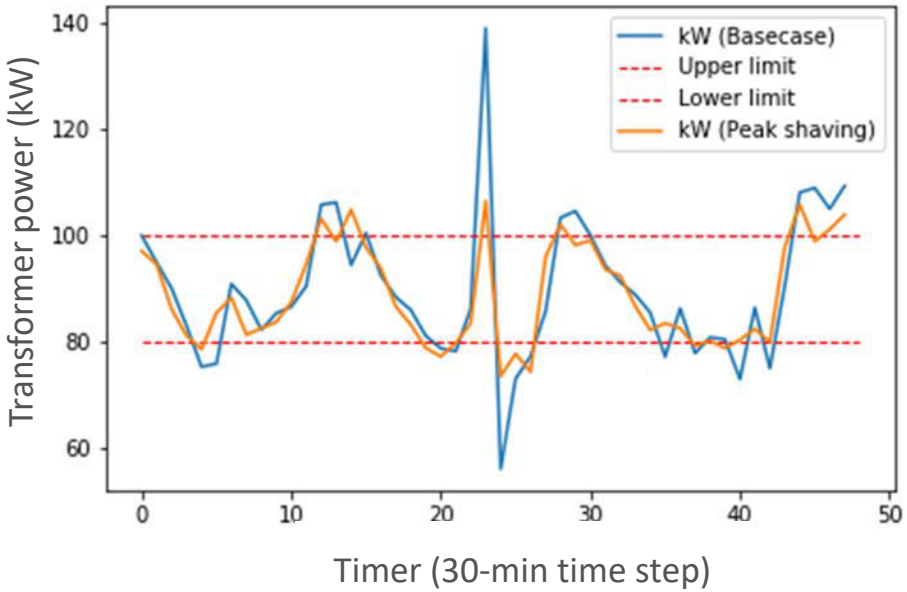


# Controlling the BESS to Control Loading on Transformers

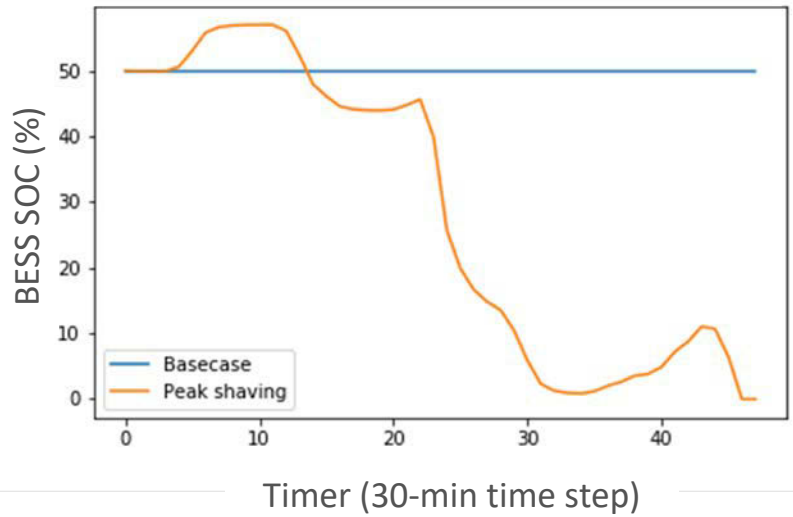
- In peak shaving mode service operator provides trigger values
- BESS discharges power into the grid when active power demand is greater than the peak shaving upper reference limit
- BESS will charge if the load consumption is lower than the base loading limit

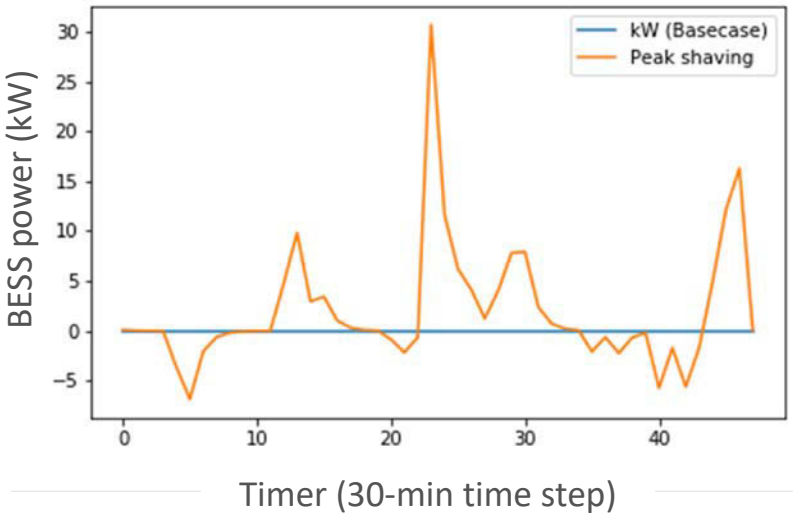


# Peak Shaving with BESS




Energy storage integration at a distribution transformer for one feeder



# Simulation Architecture

# Scenarios!

- Parallelizing these processes can help in robust conclusions

**Inputs**

- Feeder (Feeder1, ..)
- EV Penetration Levels (low,..)
- EV Charging Scenarios (home, ..)
- DT Loading Thresholds (70,..)
- Battery Use Cases (peak shaving,...)
- Total Simulation Time (1year,..)
- Simulation start time and time-step

**Simulation Handler**

- Check input validity
- Create simulation batches
- Submit jobs to the HPC

Batch 1

Batch 2 – Individual Parallel Simulations

(Feeder1, low, residential, 70%, peak shaving)

(Feeder1, medium, residential, 70%, peak shaving)

Batch 2

(Feeder1, high, residential, 70%, peak shaving)

Batch n

**NREL's High Performance Computers**


**Time Series Simulations**

Get the time-series DT profiles and apply them to all downstream loads

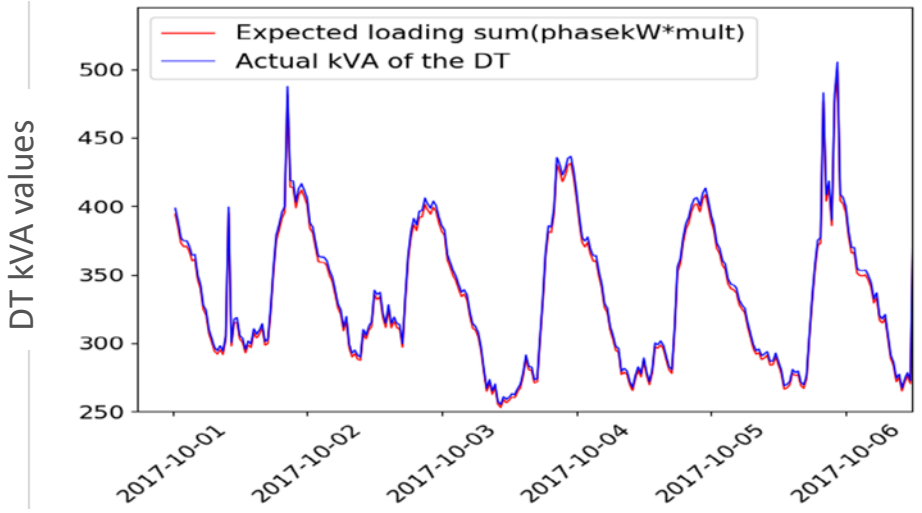
Get the time-series EV profiles and apply them to all EV loads

Record metrics for voltage and thermal violations

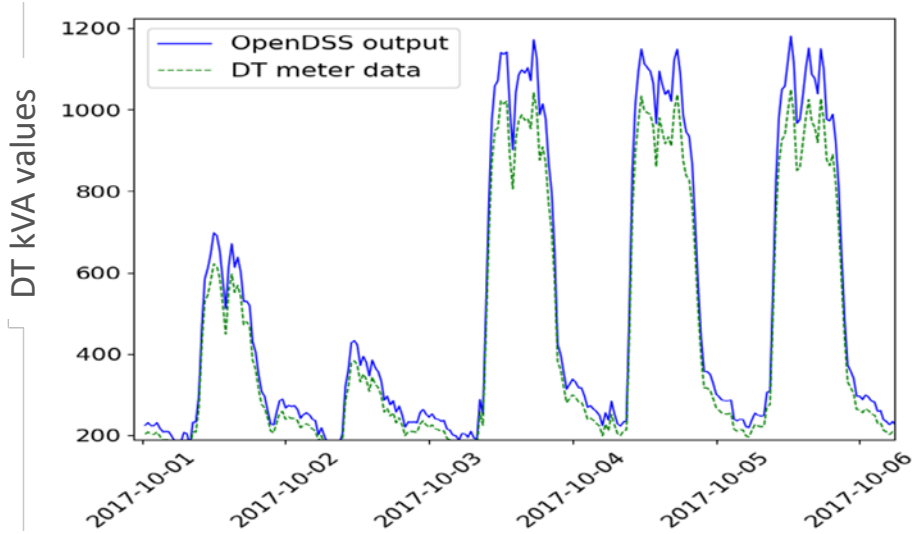
Compile the results so that network upgrade costs and EV charging schedules may be determined

# Validating accuracy of developed models

- 10-year baseline simulations were run on the OpenDSS feeder models
- First year-long baseline loading profile was compared with the expected loading of each DT.
- Expected load is load allocated using EA multiplied with time series profile multiplier.
- Original DT meter data and OpenDSS outputs were also compared.
- OpenDSS output looks very similar to the raw input data.




Expected vs actual DT loading




DT Meter data vs OpenDSS outputs

# Conclusions and Future Work

# Conclusions and Future Work

**Conclusions:**

- Modeling networks down to the secondary level is going to be important as DERs grow
- Developing reproducible methods for load allocation and data cleaning can help to ease challenges in answering new questions
- Use-cases are more easily extended if the framework is built in a modular nature, starting with a robust network model

**Next steps:**

- For each of the multi-year time series simulations, a suite of grid readiness metrics will be evaluated, which will provide information about the required network upgrades to mitigate violations
  - –BRPL plans to use this information to help make decisions about investments
- EV and BESS combination scenarios to help determine how these technologies will impact one another and the network

# Thank You!

**www.nrel.gov**

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