Distribution Planning Modeling

Integrated Distribution System Planning 2.0: Planning for Load Growth and Local Resources

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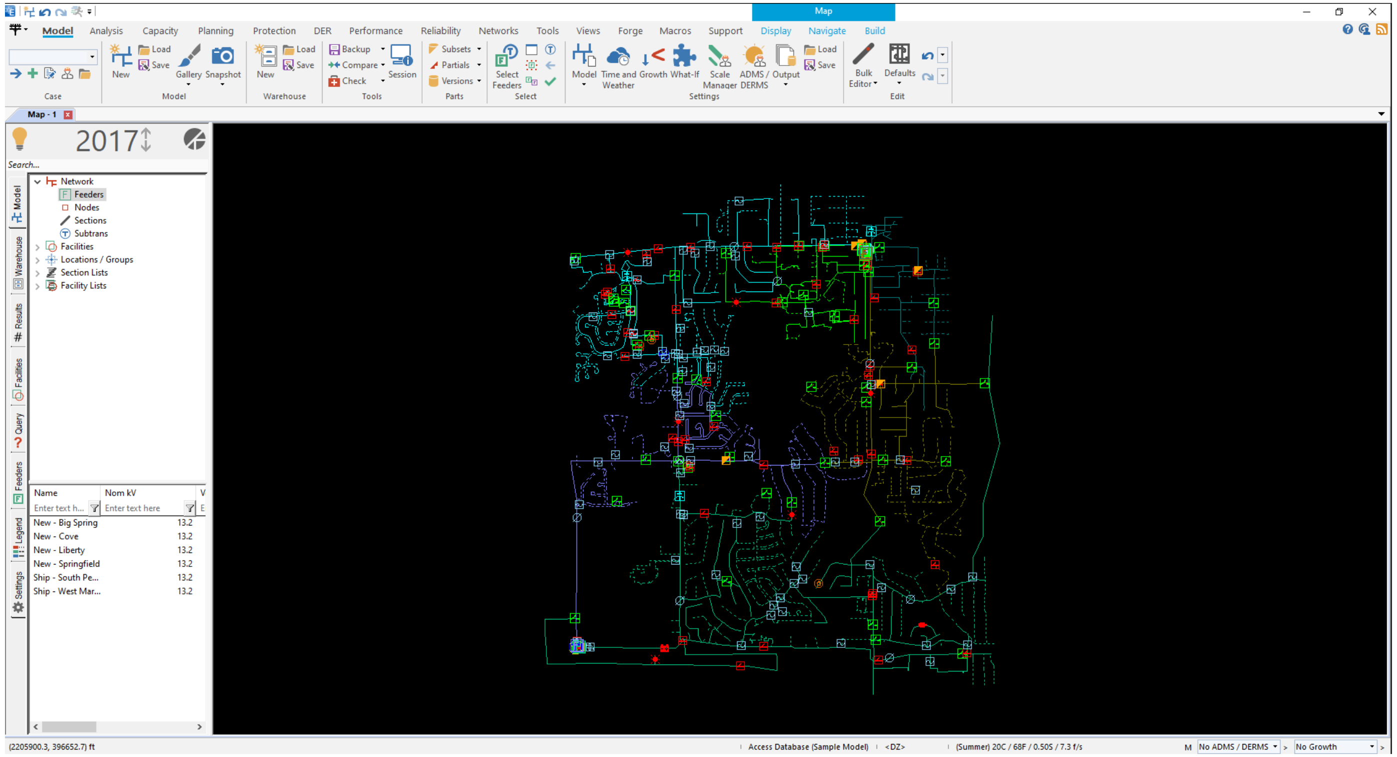
Agenda

- Introduction
- Inputs and Assumptions
- Tools and Methods
- Questions

Introduction

Distribution Modeling Overview

- Distribution Model (Power Flow Model): Digital representation of the distribution network’s connectivity and demand
- The modeling process <u>uses known/measured information</u> to determine unknown values or to study the effects of proposed system changes
- Types of modeling
    - Distribution planning
    - Protection & coordination
    - Subtransmission / networks
    - Dynamics (emerging)
- Accuracy of the underlying models significantly impacts study results



Synergi Electric Sample Model and Interface

Distribution Modeling Tools by Purpose

Distribution Planning

- SYNERGI™ ELECTRIC
- CYME INTERNATIONAL T&D
- MILSOFT Utility Solutions
- DIgSILENT
- DSS

Protection & Coordination

- ASPEN
- etap Powering Success
- PSS®CAPE

Most planning tools also include protection / coordination

Subtransmission / Networks

- PSS®E
- PSLF
- PowerWorld CORPORATION
- PSS®SINCAL

Dynamic Models

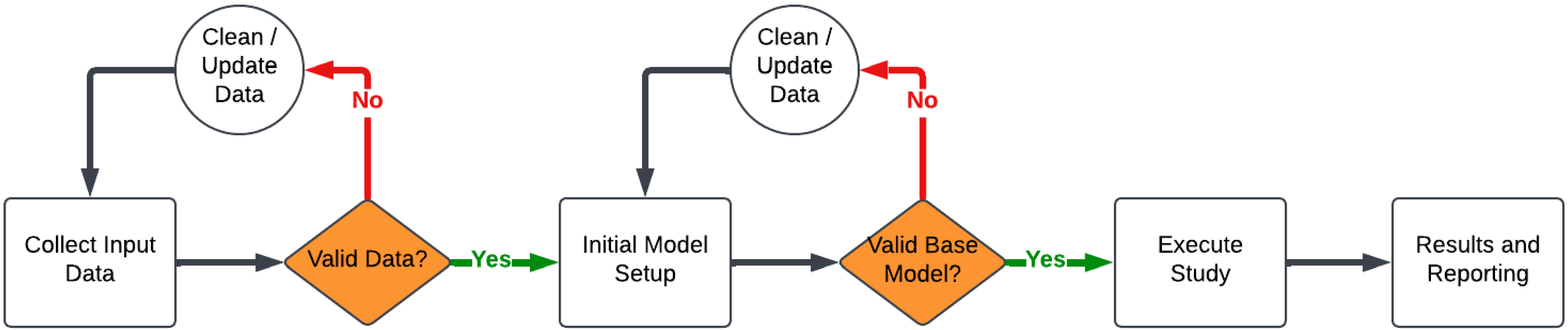
- PSCAD

Distribution Planning Modeling Process and Resulting Studies

- Core Concept: Establish the baseline truth/state, and then make hypothetical changes to understand needs/changes

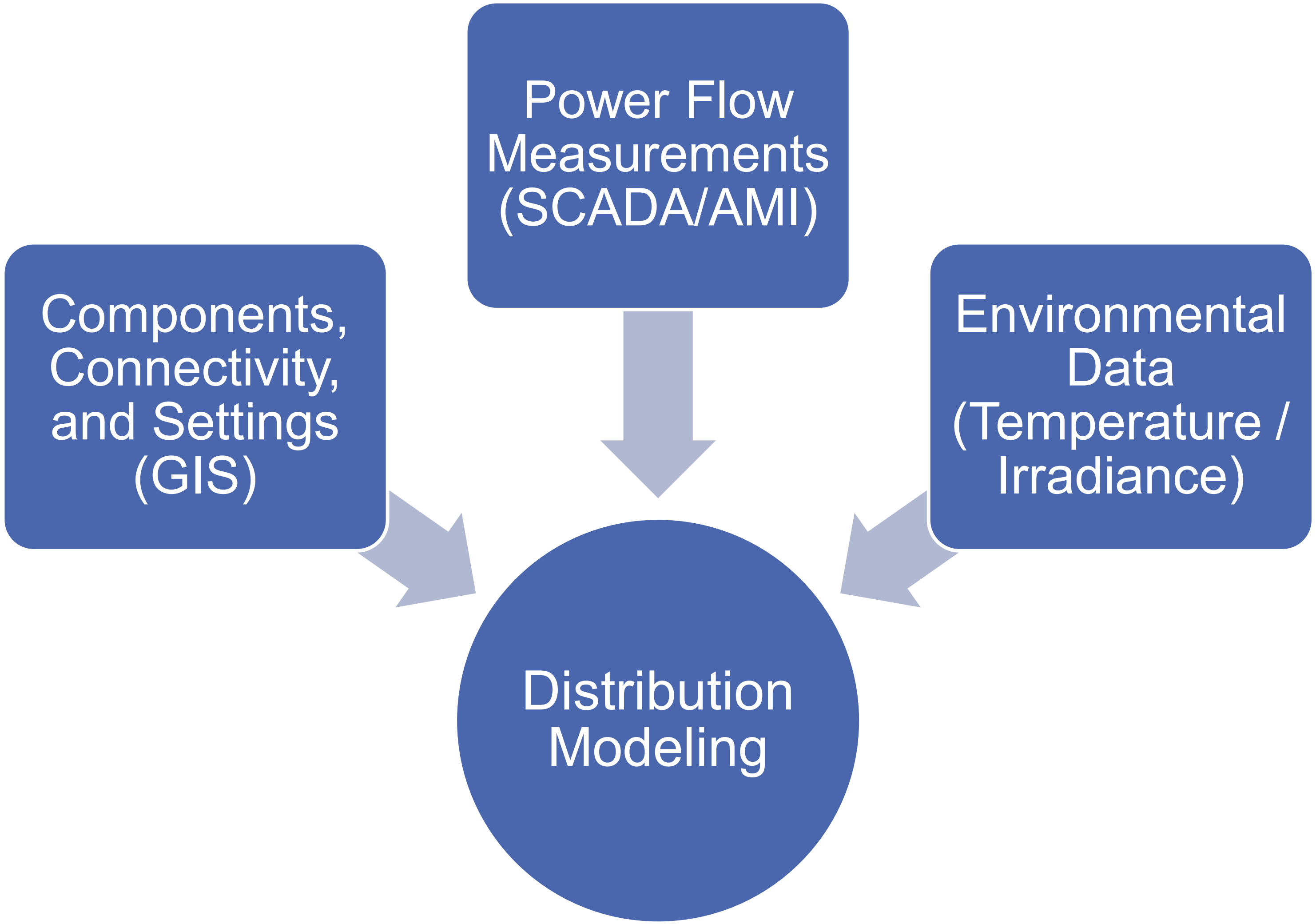
- Types of analyses where models are used
  - Voltage Drop / Power Flow
  - DER Interconnection
  - Contingency Analysis
  - Switching
  - Voltage Optimization

Modeling Process Flow



Inputs and Assumptions

Data Inputs for Modeling



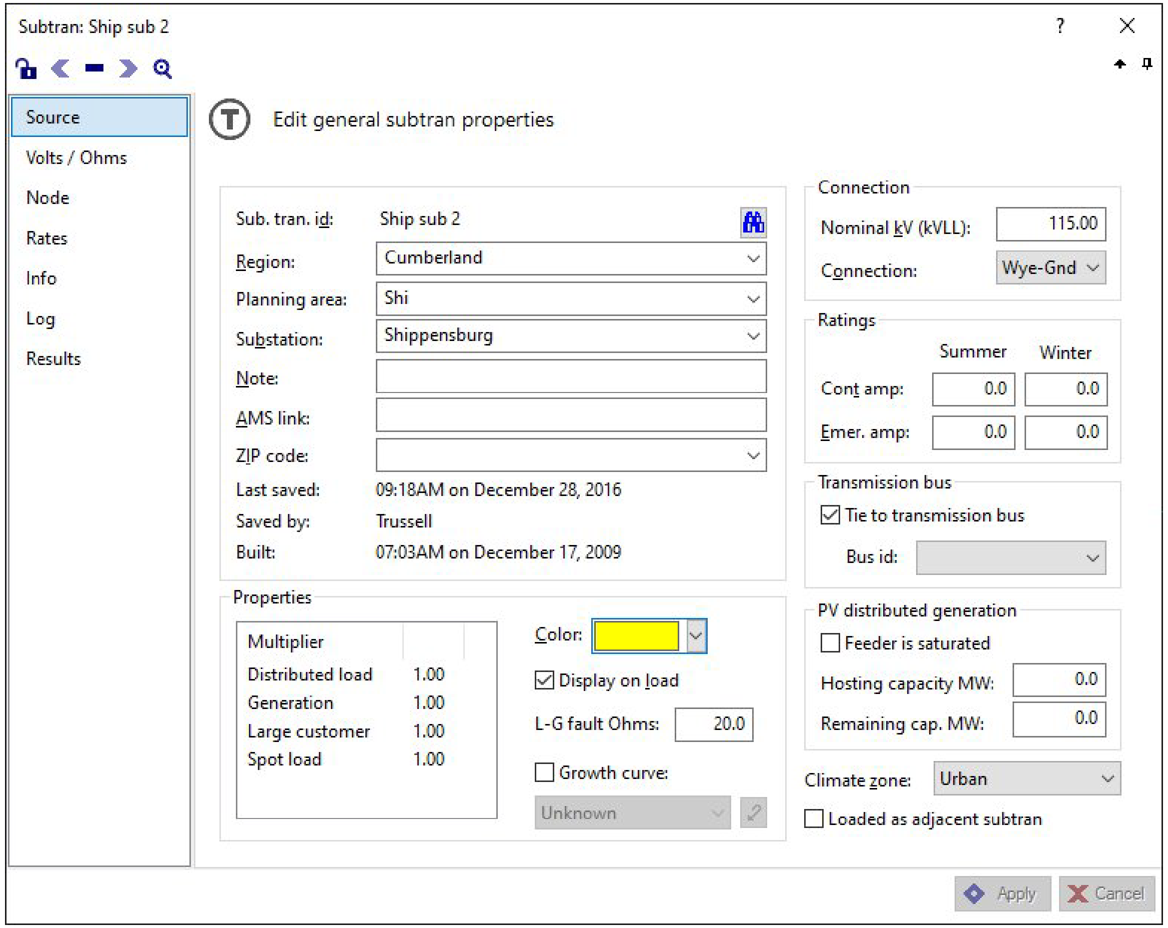
Component Information

- Includes source(s), lines, devices, and similar components

- A Geographic Information System (**GIS**) can provide specific component **type**, **connectivity**, and **location** data

- Modeling softwares typically use an **equipment database for** component nameplate information such as **ratings and impedances**

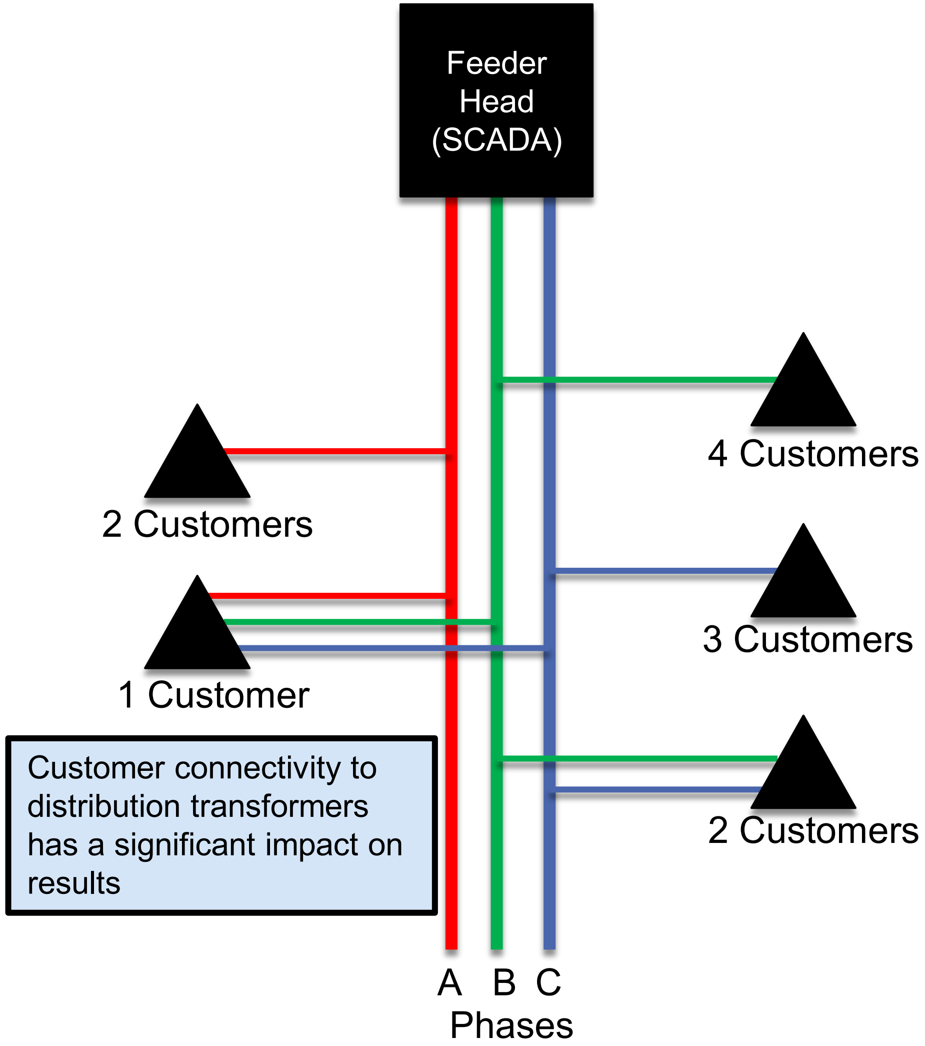
- Engineers may model a transmission source and substation or a singular feeder node to represent the source
  - Source modeling can have a significant impact on study results (Thevenin Impedance, Voltage)



Synergi Electric Sample Model Source Settings Interface

Load Data Sources

- A Supervisory Control and Data Acquisition (SCADA) system can provide load and voltage measured at the substation and at line devices
- An Advanced Metering Infrastructure (AMI) system can provide customer metered demand data
- Forecasted load growth data is typically developed and maintained separately
- GIS can provide customer connectivity to the correct distribution transformer and phase
- Accurately modeling large customers with high demand is important because they have a significant impact on study results



Generation Data Sources and Inputs

Inputs for DERs

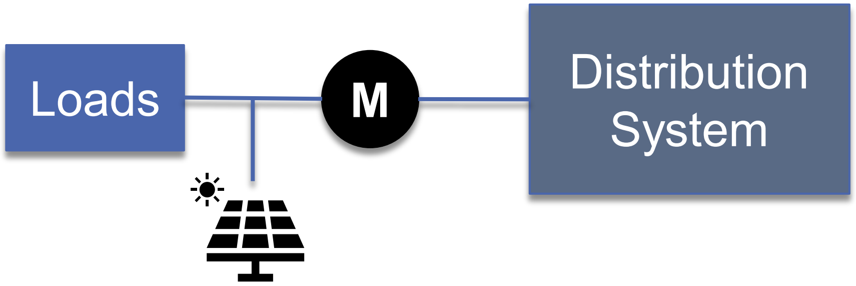
- Type (e.g., solar, storage)
- Maximum generating capabilities
  - Defined by inverter **<u>nameplate rating</u>**
- Output and operational settings
  - May use actual output, estimate output using industry source, or estimate by assuming output
- Smart inverter settings as relevant

Sources for output

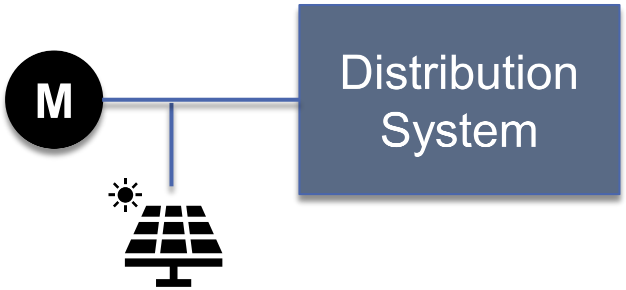
- Measured data could be sourced from SCADA if inverter monitoring capabilities are implemented or via site recloser telemetry
- **<u>Trusted industry sources</u>** such as NREL's PVWatts can estimate solar generation production profiles
- DER production may also be assumed based on the type of resource, season, and time of day

Modeling DERs

- DER generally modeled as stand-alone components in distribution models
  - Depending on utility conventions, may be modeled on primary (separate from load meter point)
- Modeling DERs is complex due to the variable nature of certain distributed generators — for example:
  - Solar generation will only produce when sunlight is available
  - Behavior of energy storage systems may be difficult to predict (depends on use case)
- Engineers must also consider and study DER impact on fault current and protection



Actual Configuration



Model Configuration

- Must be **careful not to double count generation** during model set-up
  - Generation embedded within meter data
  - Explicit DER model may be separate from meter

Interconnection Queues

Interconnection studies require engineers to model the most recent application with the DERs from the **previous applicants in the application queue** and their **relevant system upgrades** necessary to interconnect

This requires modeling the system under multiple scenarios

- First the base case or normal operating state must be modeled
- Then the first DER in the queue and any system upgrades necessary to enable its interconnection
- Any DERs in the queue after that must be modeled similarly before the most recent applicant is reviewed

In the example below, the interconnection study for DER3 would require the engineer to model all the applications listed and the system upgrades for previously studied applications

Example of Planning DER Application Queue

Applications	Size	Circuit	Upgrades Required
DER1	X	1	Regulator
DER2	Y	1	Reconductor
DER3	Z	1	?

Model Source Interoperability

Middleware - Software to feed data and information from relevant sources into the model

- Modeling software vendors provide tools or scripts to pull data from multiple sources and translate into a viable model
  - e.g., CYME Gateway
- This can be a highly complex process due to the amount of data that must be transferred from different sources
  - GIS
  - SCADA
  - AMI
  - DER Application Management Solution

Tools and Methods

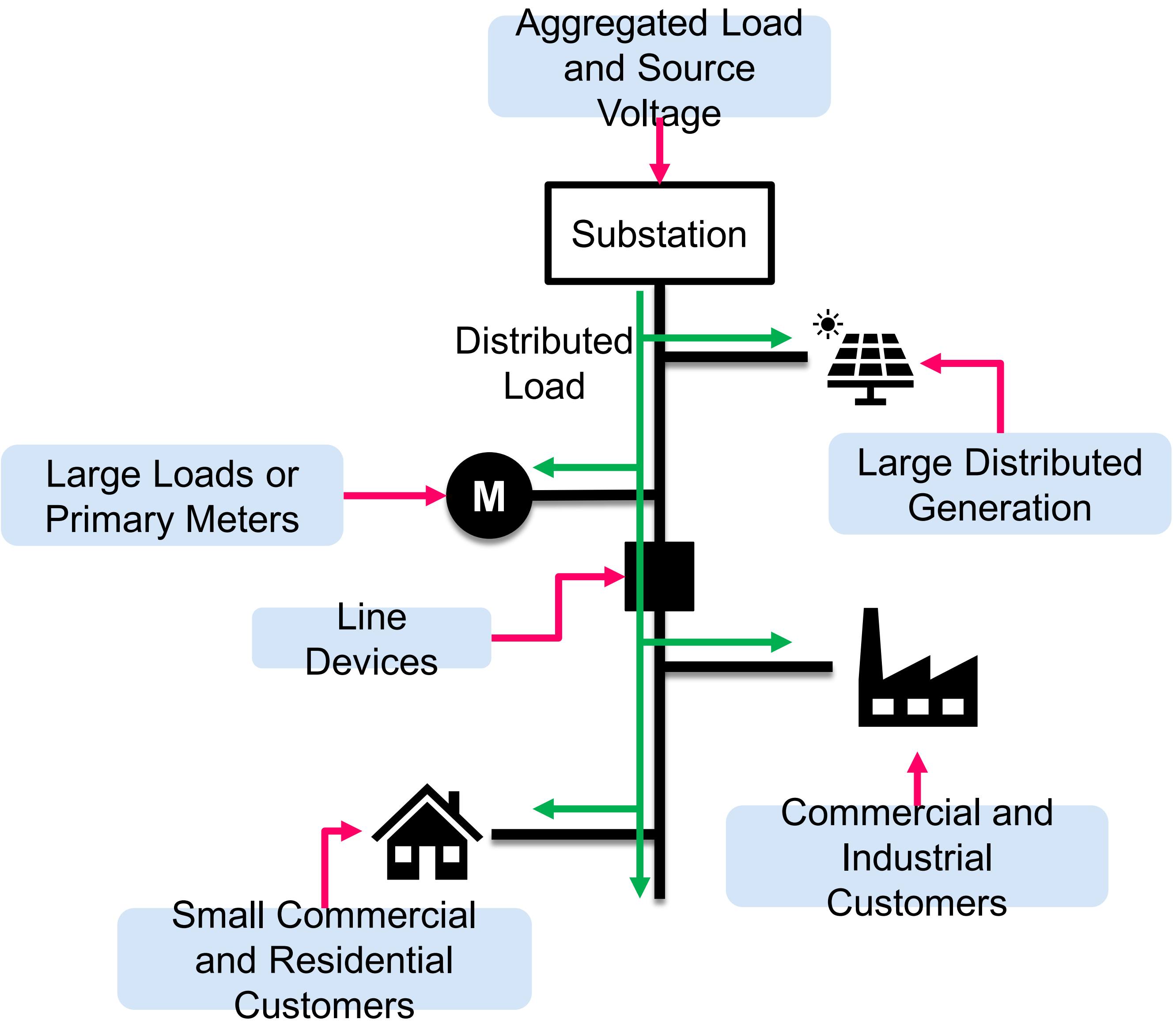
Model Setup

Load Allocation

- The process of distributing the measured load at the feeder head across the meter locations within the model to enable power flow studies
- Multiple methods using varying data sources

Inputs

- Load data at the substation / feeder head
- Source voltage
- Line distances, configurations, and impedances
- Settings for line devices
- Load data and/or factors for customers
- Types of customers



Load Allocation Methods

Connected Capacity Method

- Demand measured at the head of the circuit is distributed across the circuit proportionally to the connected capacity with an applied load factor
  - Service transformer ratings often used as connected capacity values
- Limitations
  - Actual load is not always proportional to the transformer rating
  - Actual loading and customer energy consumption behavior varies across the circuit

Billed kWh Method

Demand measured at the head of the circuit is distributed across the circuit **proportionally to the amount of kWh consumed** at the relevant location

- Monthly customer **billed kWh data** often used due to availability
- Relatively good historical method for determining relative loading

Limitations

- Less effective for time-series analysis (no change in proportions)
- DER reduces accuracy

Actual Load Method

Demand is allocated to each load **proportionally to their metered demand** and adjusted for load factor

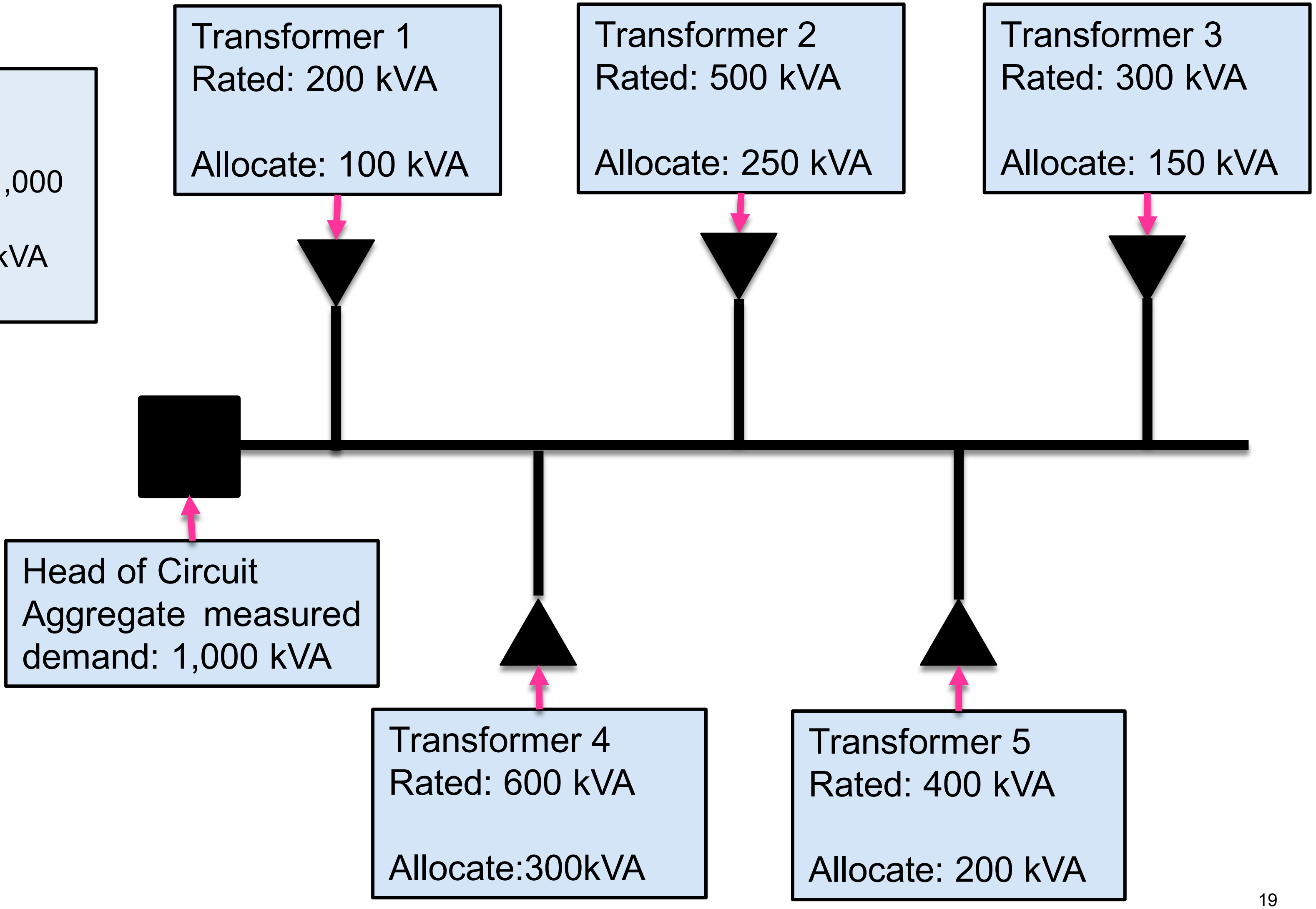
Limitations

- Requires **AMI interval data** and the ability to connect the interval database to the modeling software
- Potential to "overfit" – Actual snapshot is not necessarily representative of future conditions

Load Allocation Method - Connected Capacity

Example: A simple circuit with 5 transformers and their ratings

- Circuit Aggregate Measured Demand: 1,000 kVA
- Aggregate Connected Capacity: 2,000 kVA
- Allocation Factor: 0.5

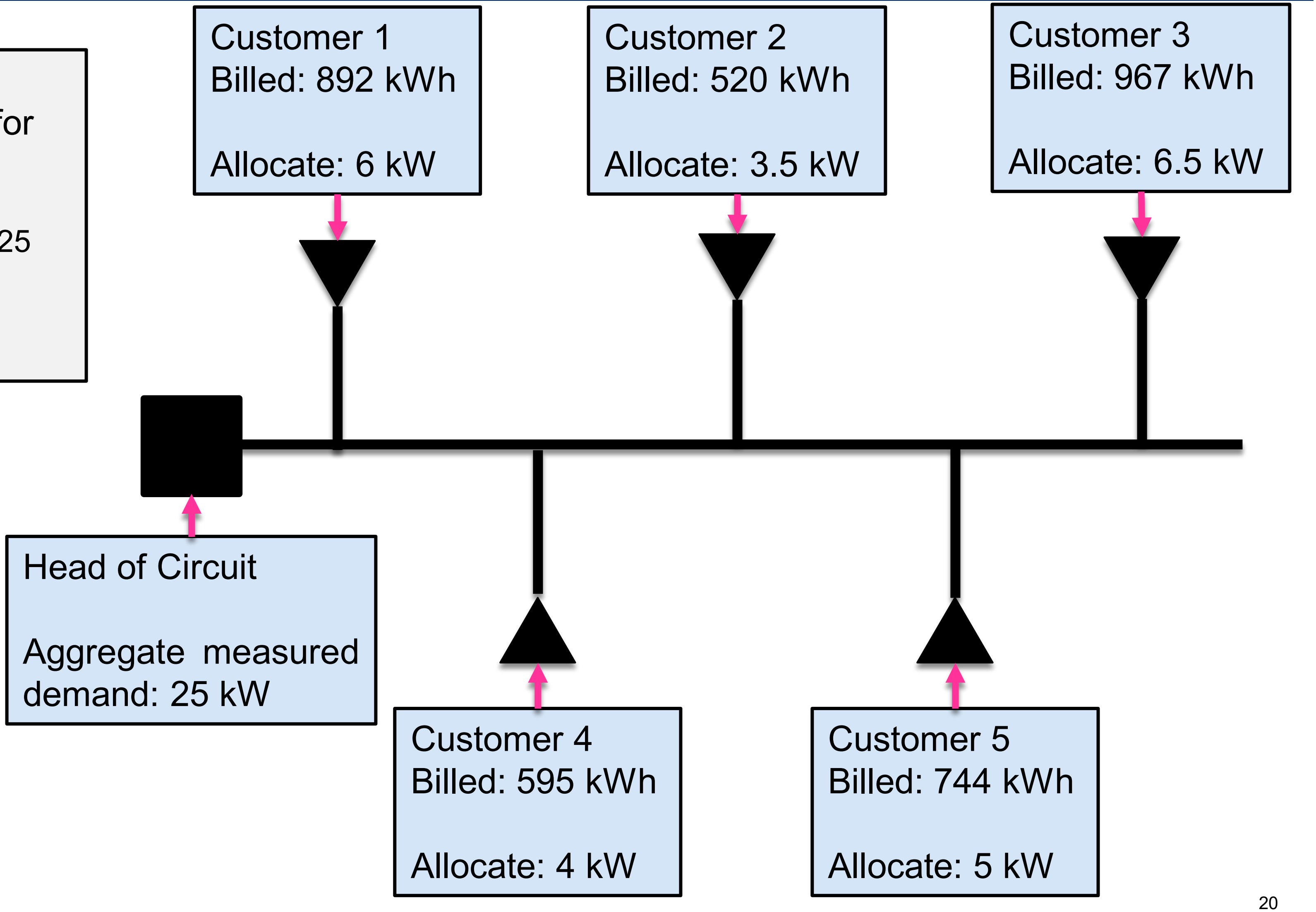


Connected kVA: Relative size of service transformer
Demand: Power delivered during modeled time snapshot

Load Allocation Method – Billed kWh

Example: A small circuit with 5 customers and their billed total kWh for the month

- Circuit Aggregate Measured Demand: 25 kW
- Hours in 31 Days: 744
- Allocation Factor: 0.5

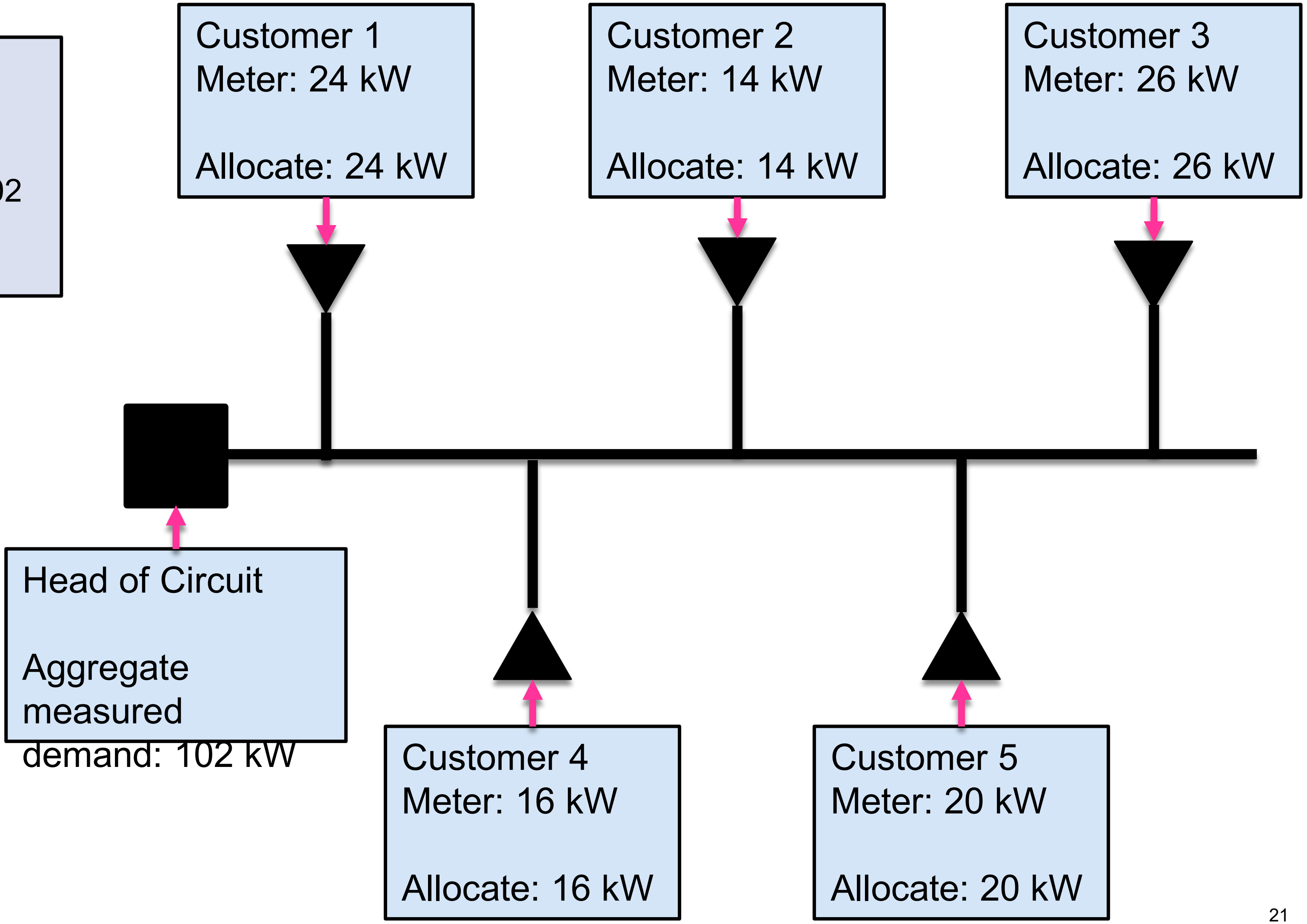


Billed kWh: Amount of energy used in one billing cycle
Demand: Power delivered during modeled time snapshot

Load Allocation Method – Actual Demand

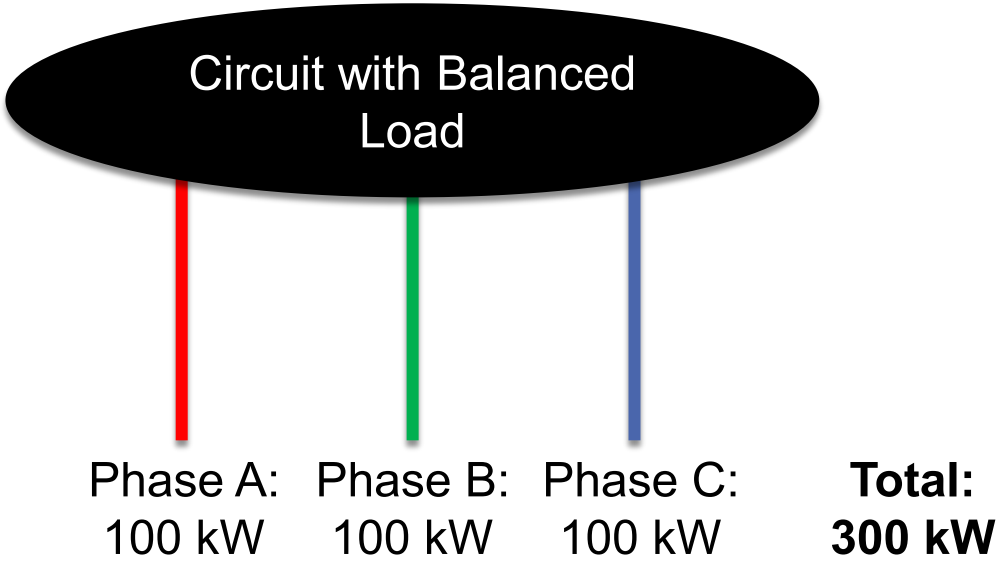
Example: A small circuit with 5 customers and their metered demand

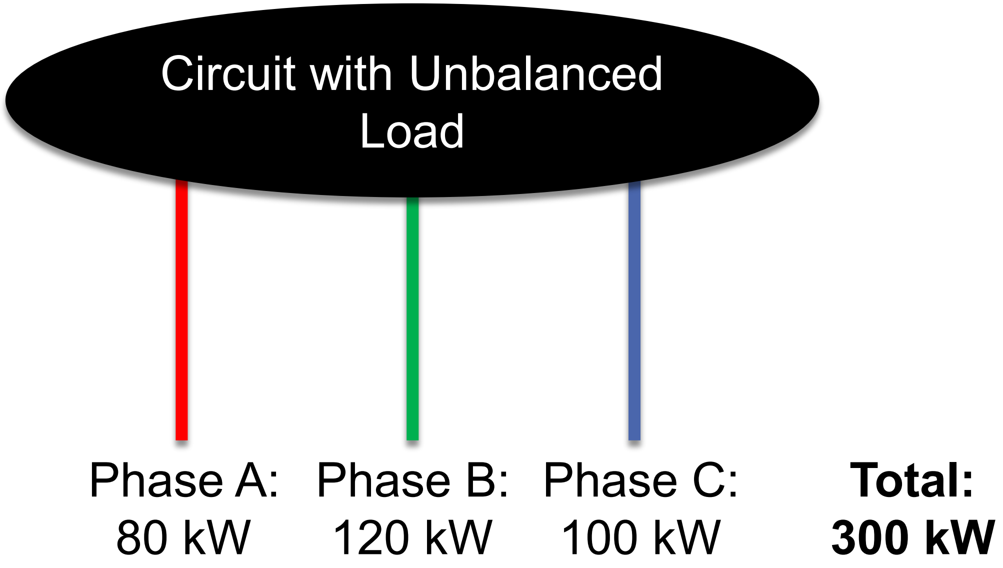
- Circuit Aggregate Measured Demand: 102 kW



Power Flow Analysis

- Power Flow
  - Power flow (also referred to as load flow) analysis is used to determine the voltages and currents during steady-state operation of an electrical power system
- Protection Analysis
  - Protection studies are based on the response to short-circuit conditions (fault current)
  - Includes protection device coordination and location studies, as well as arc flash studies
- Balanced vs Unbalanced Power Flow
  - Power flow can be performed using a balanced or unbalanced load
  - The distribution system is generally unbalanced, meaning the load across the three phases varies
  - Using a balanced power flow forces the system load to be balanced evenly across the phases
    - Used when GIS connectivity and phase mapping is unreliable
    - Does not properly represent single-phase laterals
    - Results are more conservative than for unbalanced power flow





Time Series Power Flow

Time-Series Analysis (576 / 8760)

- Power flow is run many times covering hourly variations over a year
- **More complex** to setup/analyze due to the volume and accuracy of data
- A **576 analysis** consists of two 24-hour days per month for a year
  - Monthly peak and minimum loading
  - Monthly weekend and weekday
- An **8760 analysis** consists of analyzing every hour of the year

Curtailment (MWh) Weekday Graph

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
12:00 AM	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1:00 AM	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2:00 AM	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
3:00 AM	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
4:00 AM	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
5:00 AM	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
6:00 AM	0.00	0.00	0.00	0.00	1.72	2.12	0.00	0.00	0.00	0.00	0.00	0.00
7:00 AM	0.00	0.00	1.19	11.63	11.36	12.38	7.15	5.26	1.60	0.00	0.00	0.00
8:00 AM	0.00	2.55	15.89	15.68	13.67	20.23	11.47	12.10	7.44	2.12	0.00	0.00
9:00 AM	0.68	5.44	23.24	22.61	14.90	19.09	14.37	13.19	7.85	3.36	0.00	0.00
10:00 AM	0.18	3.01	20.54	22.77	16.33	11.52	11.77	9.47	4.79	0.58	0.00	0.00
11:00 AM	0.00	1.63	17.71	20.44	18.19	10.63	9.00	8.92	3.26	0.09	0.00	0.00
12:00 PM	0.00	2.36	15.29	20.17	15.84	12.76	8.25	8.41	3.13	0.32	0.00	0.00
1:00 PM	0.00	4.62	19.13	21.45	13.30	15.50	4.47	8.59	5.60	1.67	0.00	0.00
2:00 PM	0.49	6.23	23.33	22.67	14.51	10.76	6.06	8.52	8.23	2.94	0.15	0.00
3:00 PM	0.00	3.91	20.78	20.31	9.27	11.76	4.38	7.05	5.36	0.49	0.00	0.00
4:00 PM	0.00	0.00	2.92	9.66	4.05	4.67	1.64	1.64	0.08	0.00	0.00	0.00
5:00 PM	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
6:00 PM	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
7:00 PM	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
8:00 PM	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
9:00 PM	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
10:00 PM	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
11:00 PM	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Example of 576 Results Showing Hours and Amount of Curtailment of Flexible DER

Closing

Actions States Can Take

- <u>State Regulators Can:</u>
  - Encourage utilities to drive towards adopting time-series analysis where practical
  - Review utility modeling practices and impacts on planning and interconnection study results
  - Review utility data availability and quality, especially:
    - Availability and degree of utilization of AMI data for modeling
    - Prevalence of feeder-level SCADA monitoring and historical data
  - Driver adoption of modeling, data, and process improvements
  - Incorporate modeling practices into public distribution plans

- <u>State Energy Offices and Utility Consumer Advocates Can:</u>
  - Recommend modeling practice improvements that can positively impact planning and load/DER interconnections
  - Participate in technical working groups related to modeling

Questions States Can Ask

- What types of modeling software is the utility using?
- How accurate / trusted is the GIS component and connectivity data?
- What assumptions and data are used to model DERs?
- How is the utility modeling large loads?
- What method(s) of load allocation is the utility using in modeling?
- Is unbalanced power flow used for all power flow modeling?
- Is time-series analysis in use today? For what purpose(s)?
- What barriers exist to expanding the utility's use of time-series modeling and how can they be resolved?

Contact

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