

# UC Berkeley

## Electric Grid

### Title

Excerpt from Edison Electric Institute Webinars: "Current State of the Electric Distribution System" and Future of the U.S. Distribution System"

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### Supplemental Material

<https://escholarship.org/uc/item/3pr6506b#supplemental>

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## Current State of the U.S. Distribution System

EEI Webinar

July 11, 2012 ■ 2:00 – 3:30 p.m. EDT



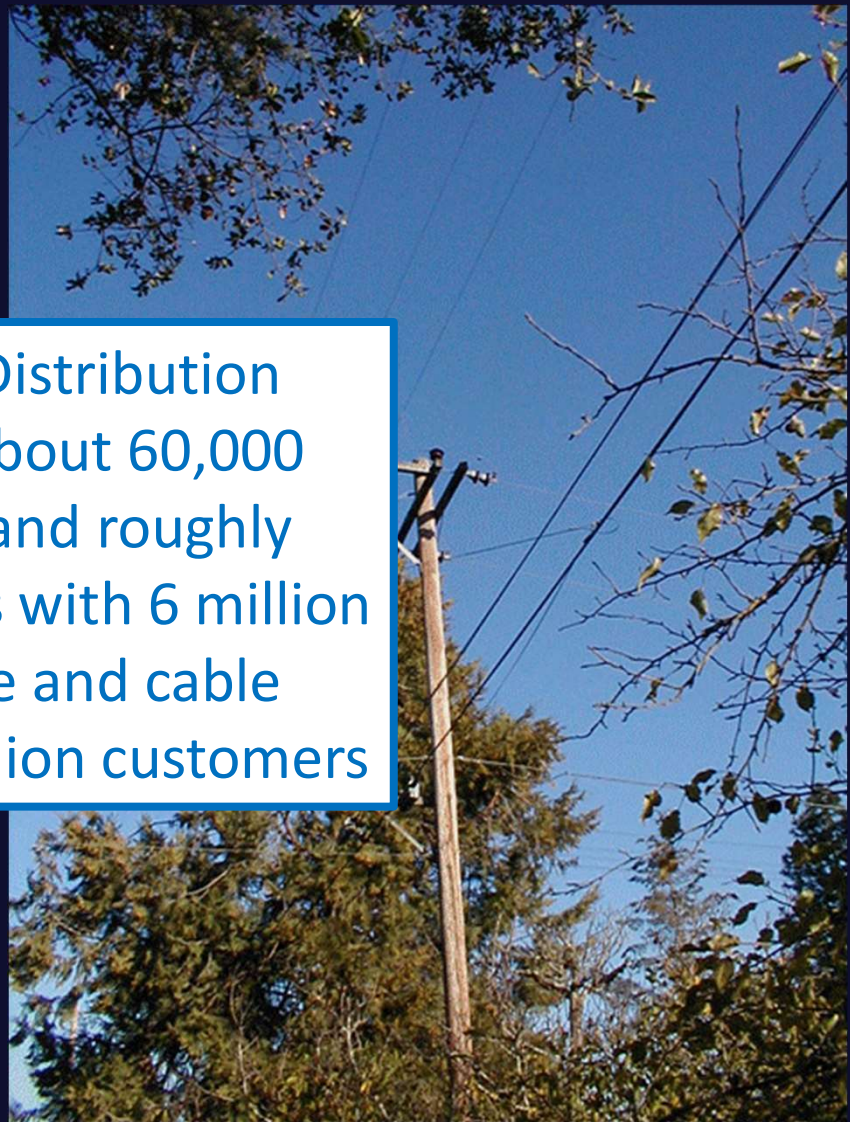
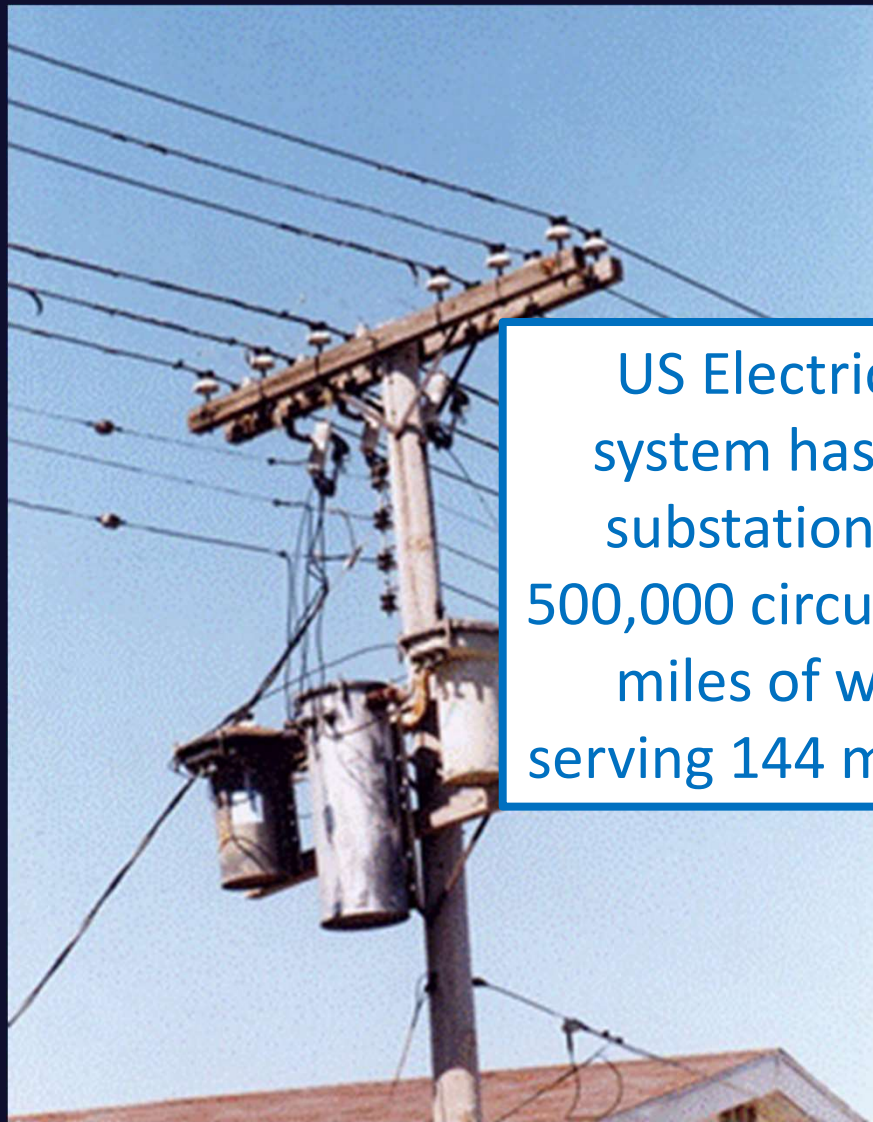
Alexandra von Meier  
Co-Director, Electric Grid Research



Barbara Tyran  
Director, Washington & State Relations  
Jared Green  
Project Manager, Smart Grid







US Electric Distribution system has about 60,000 substations and roughly 500,000 circuits with 6 million miles of wire and cable serving 144 million customers

## Diversity of US distribution circuits:

500,000 circuits, but no two are exactly alike

Differences within and among utilities are

- **historical**
- **geographic** climate  
topography  
population density  
socio-economics

Differences drive load characteristics, system design and operation – many local idiosyncracies...

→ Distribution systems are extremely data-rich





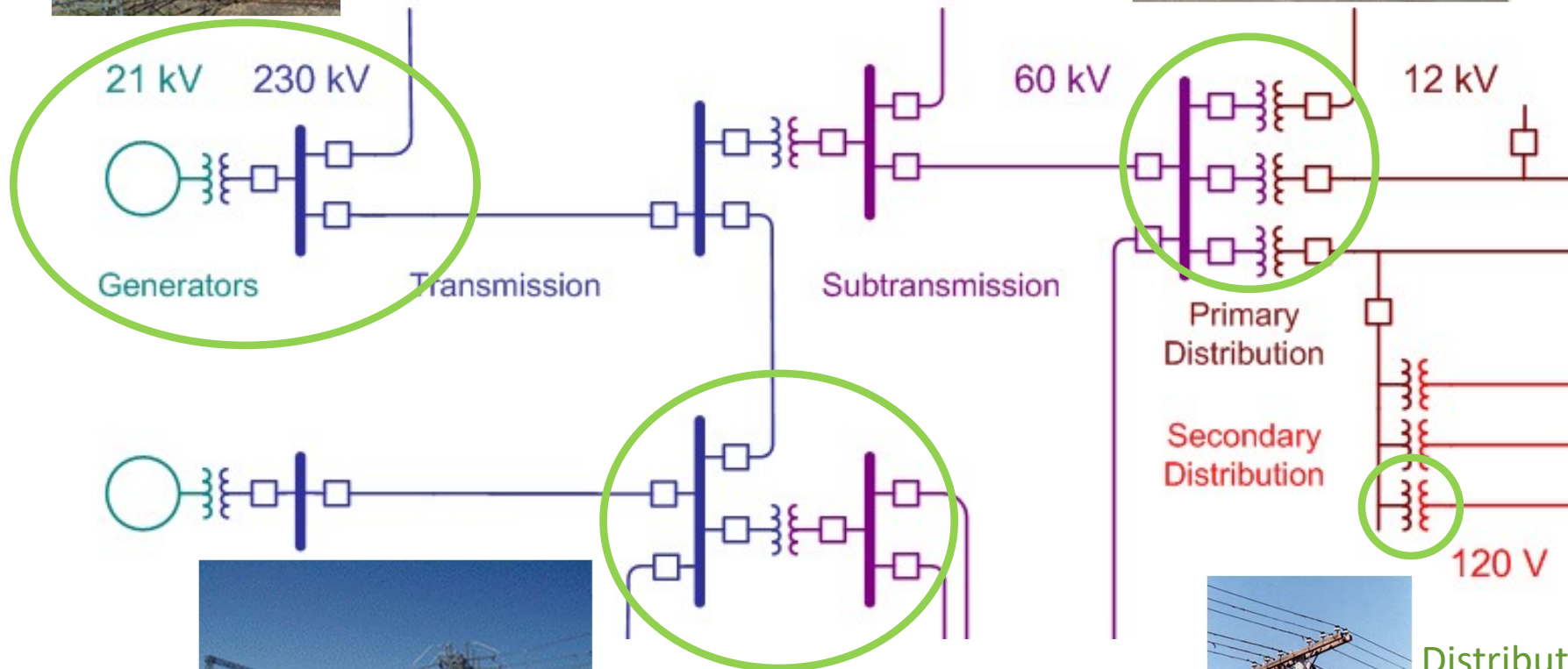


Central Generation

Distribution substation



### Power System Structure with typical voltage levels

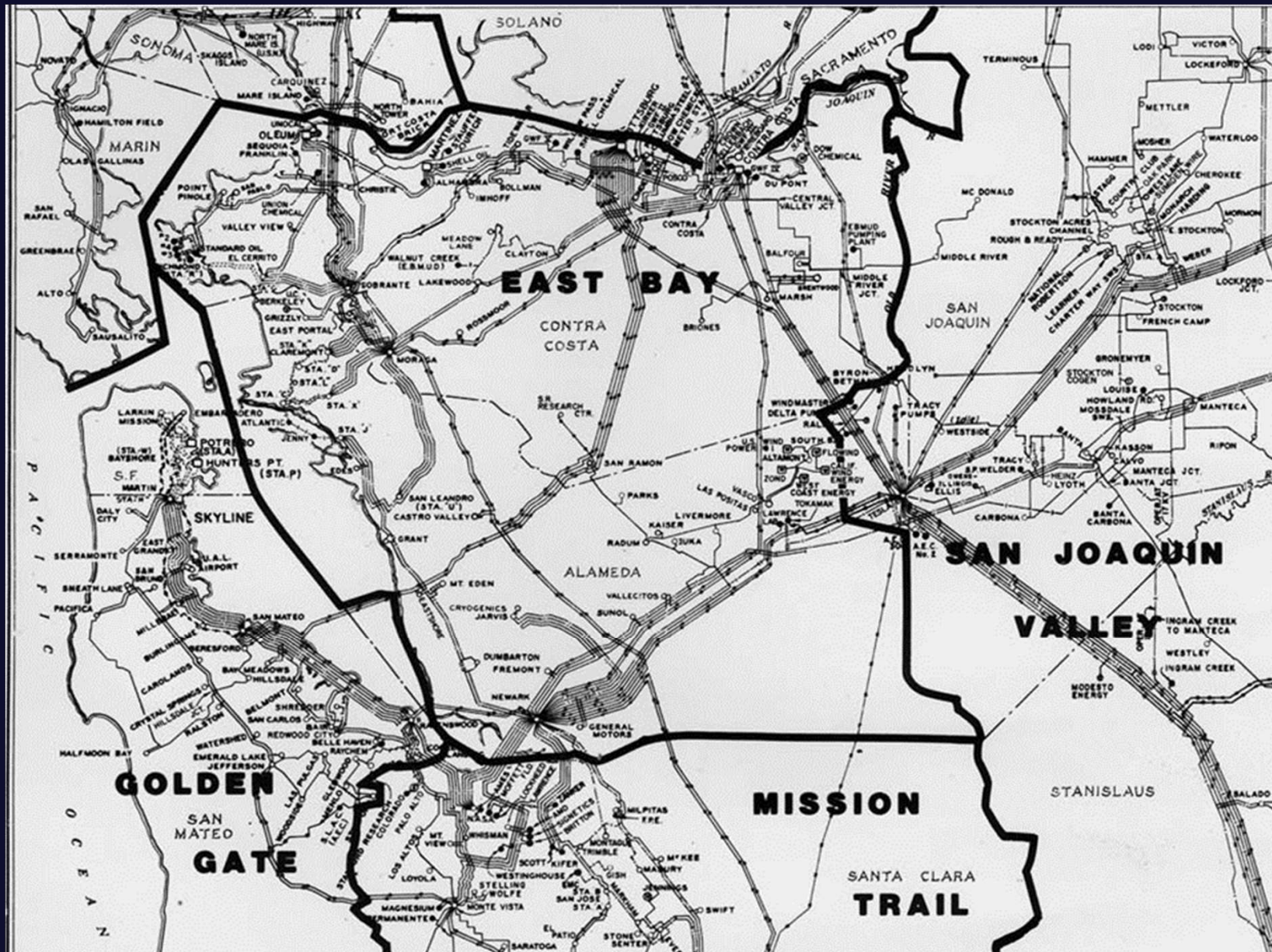


Transmission substation



Distribution transformer

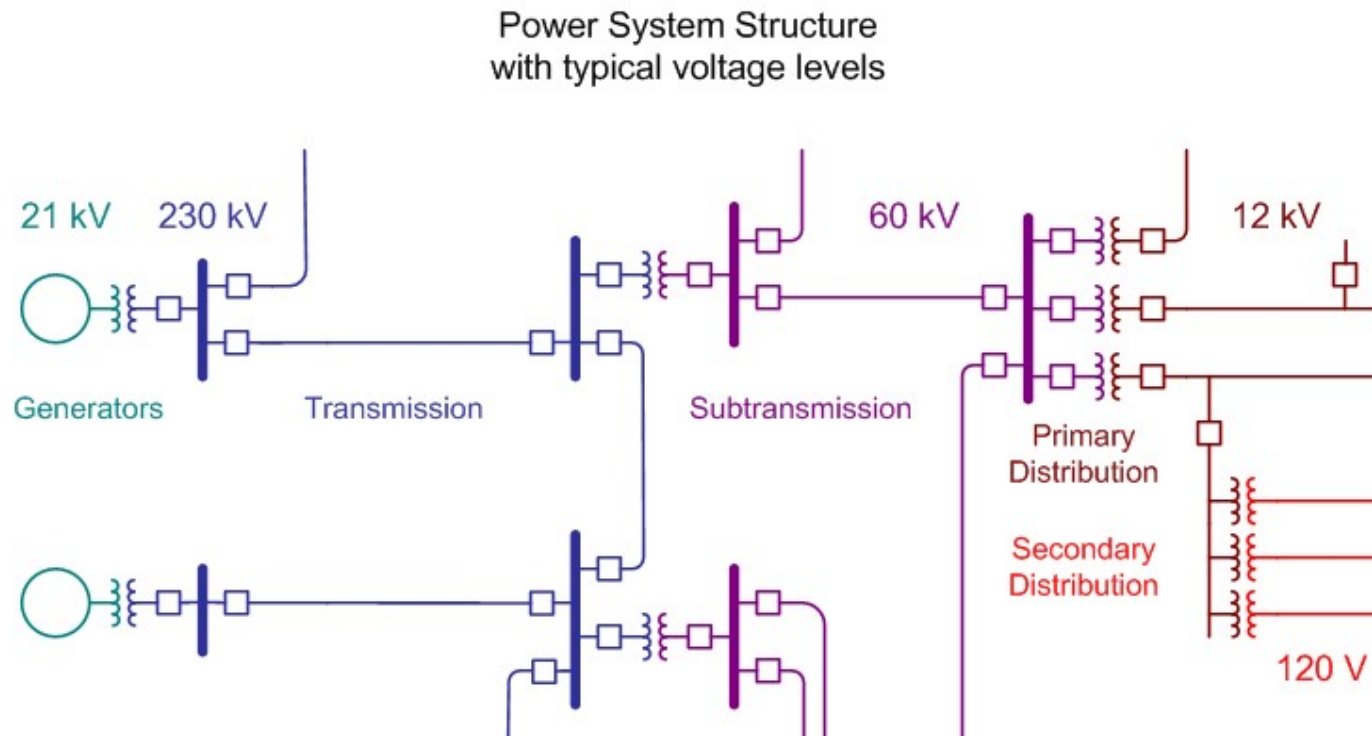






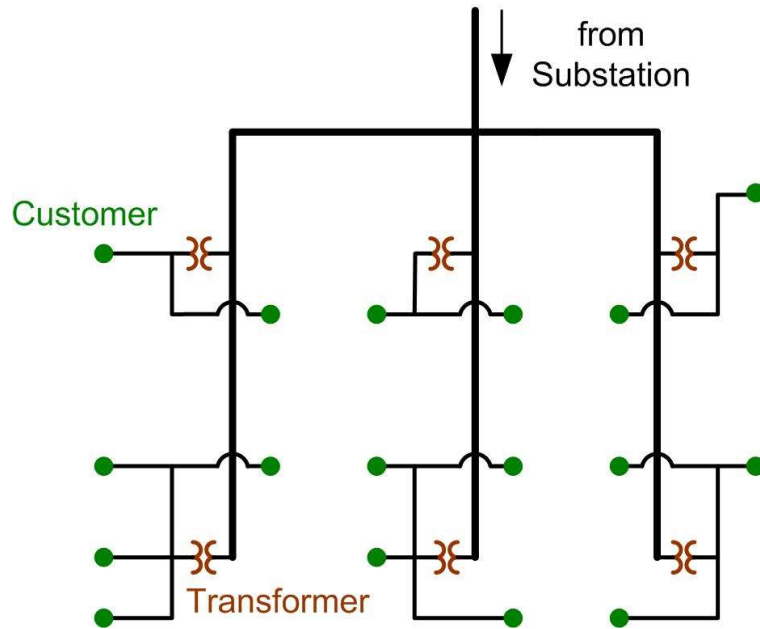
# Distribution System Architecture

radial vs. networked  
designed for one-way power flow

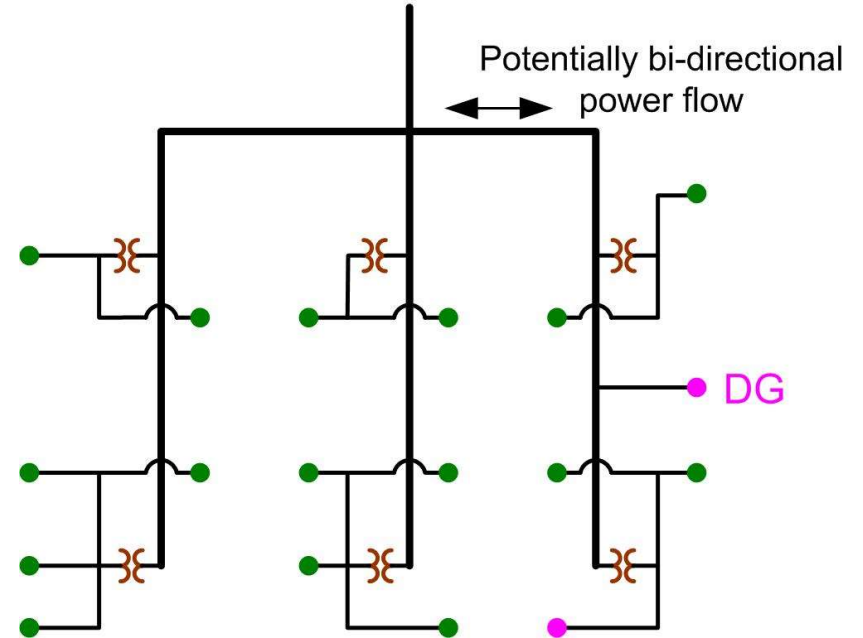


# Distribution System Design

Typical Distribution System Layout with radial topology & power flow



Radial Distribution System with Distributed Generation

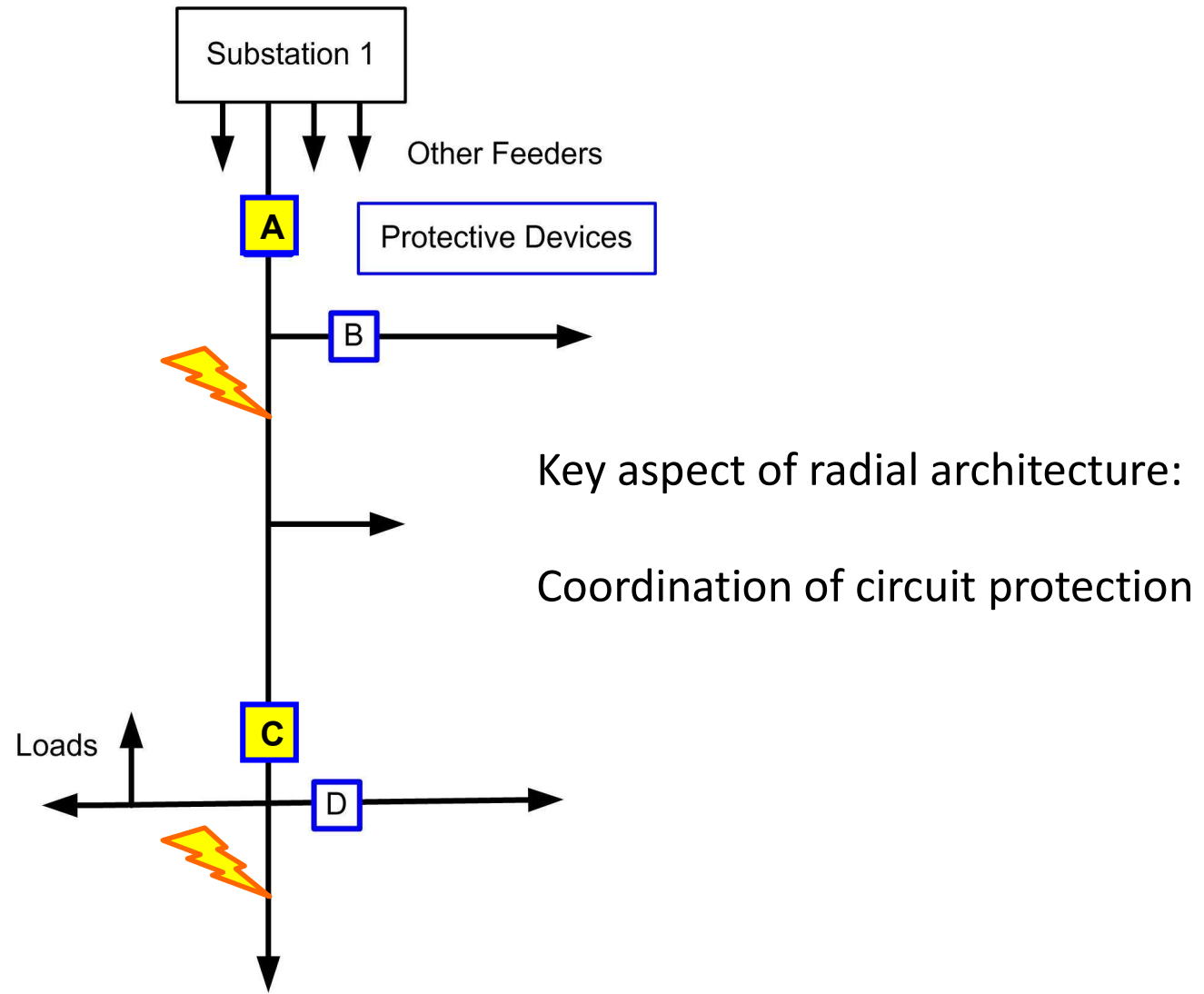


Old design paradigm:  
If it works at peak load, it always works.

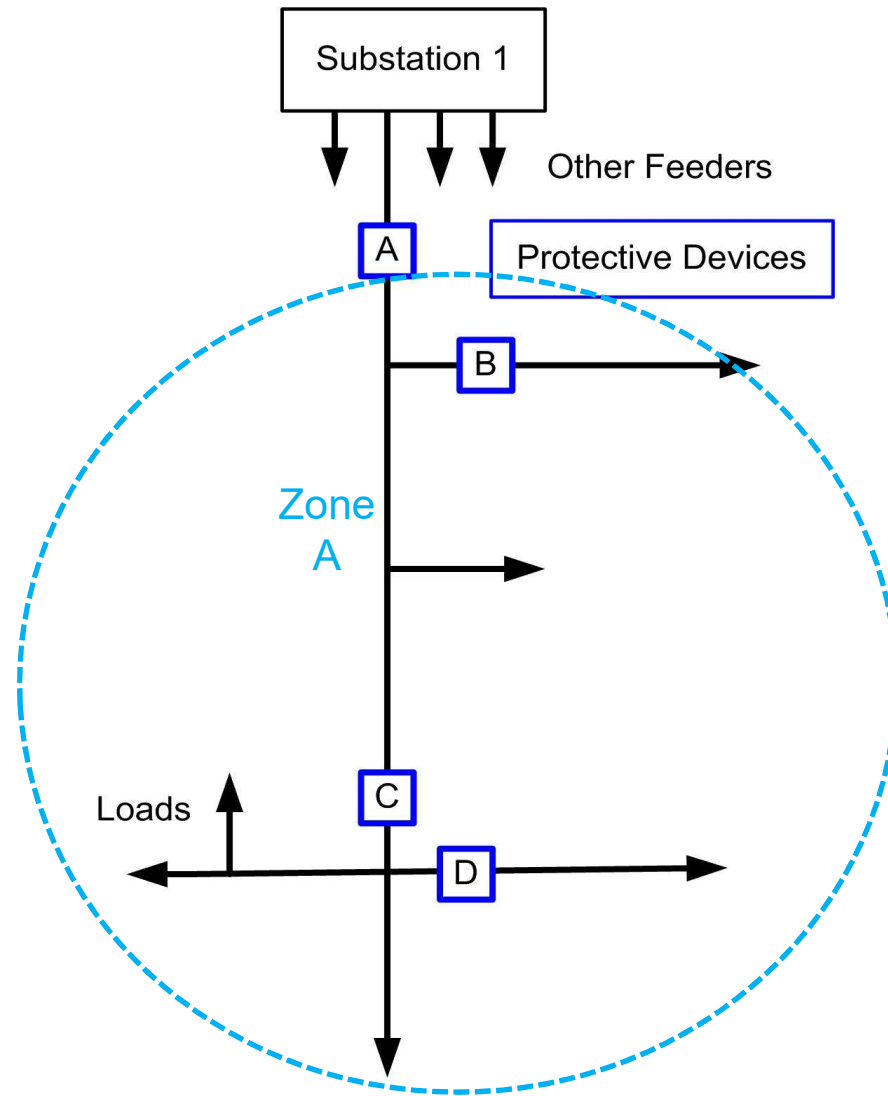
Not.



# Distribution Protection

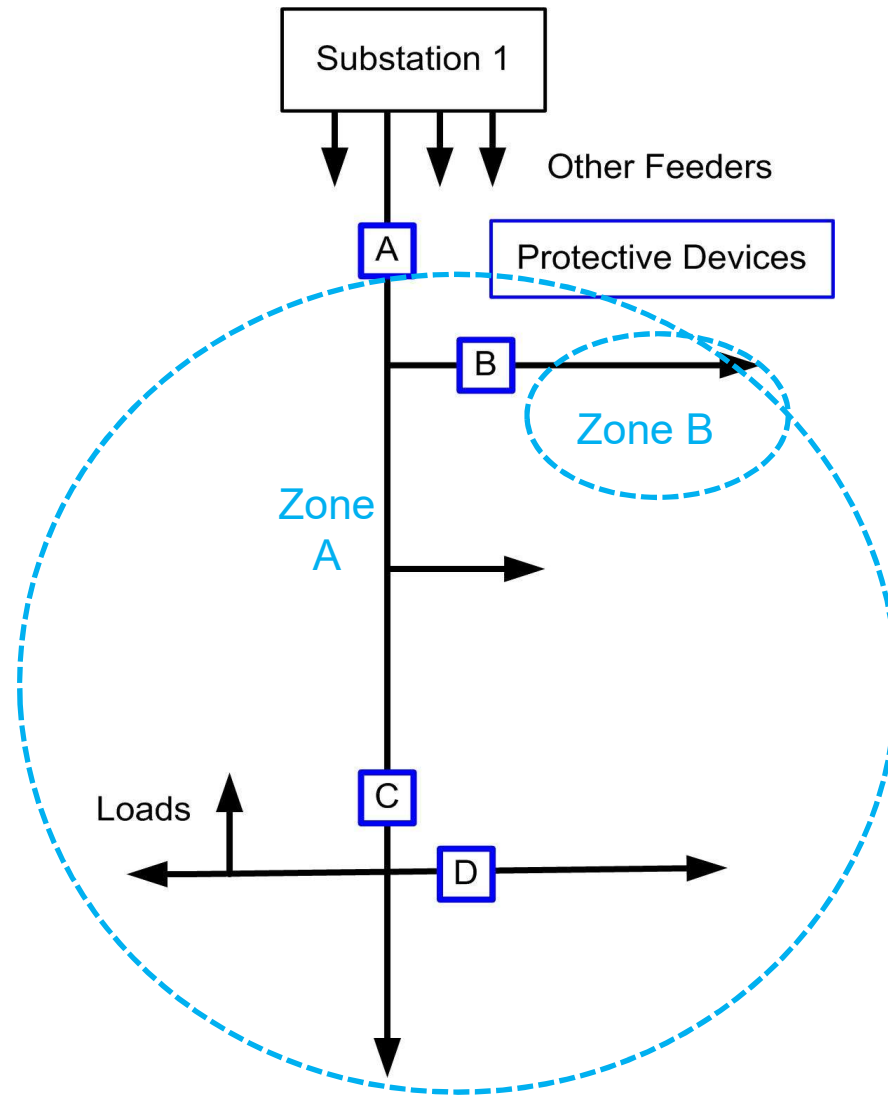


# Distribution Protection

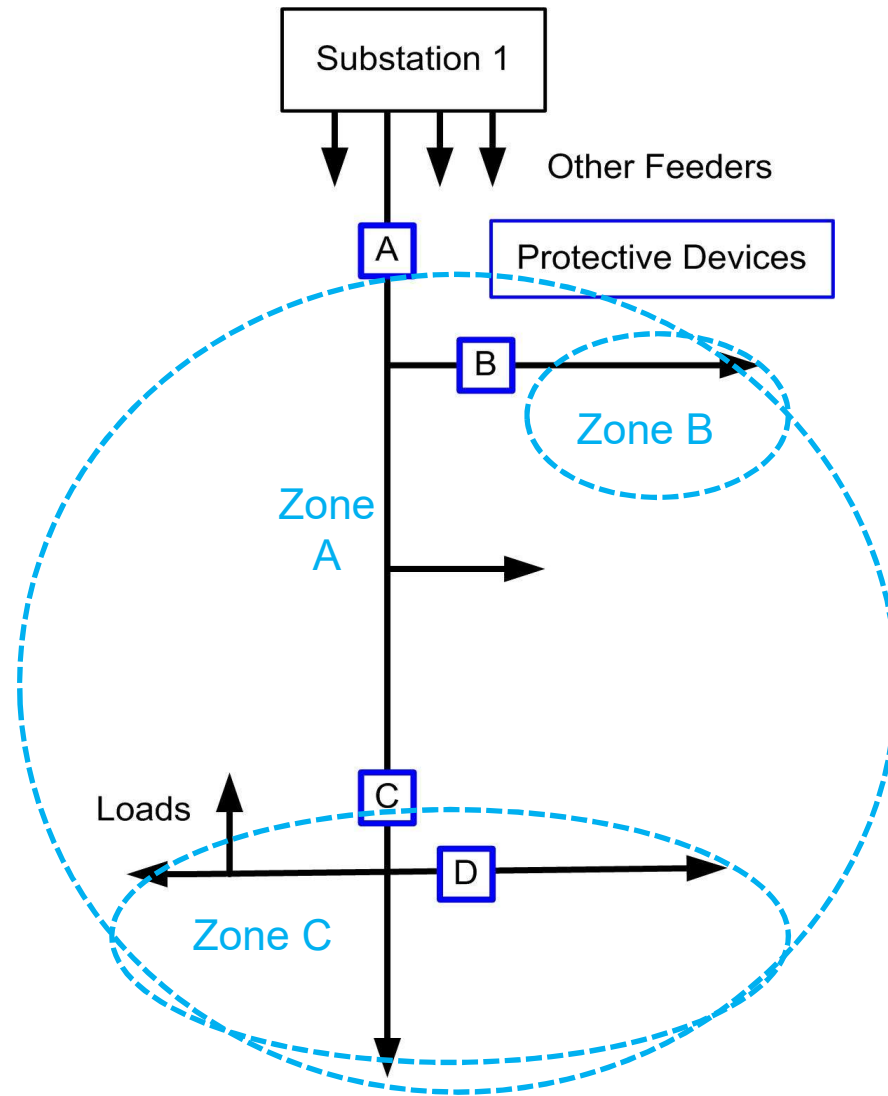




# Distribution Protection

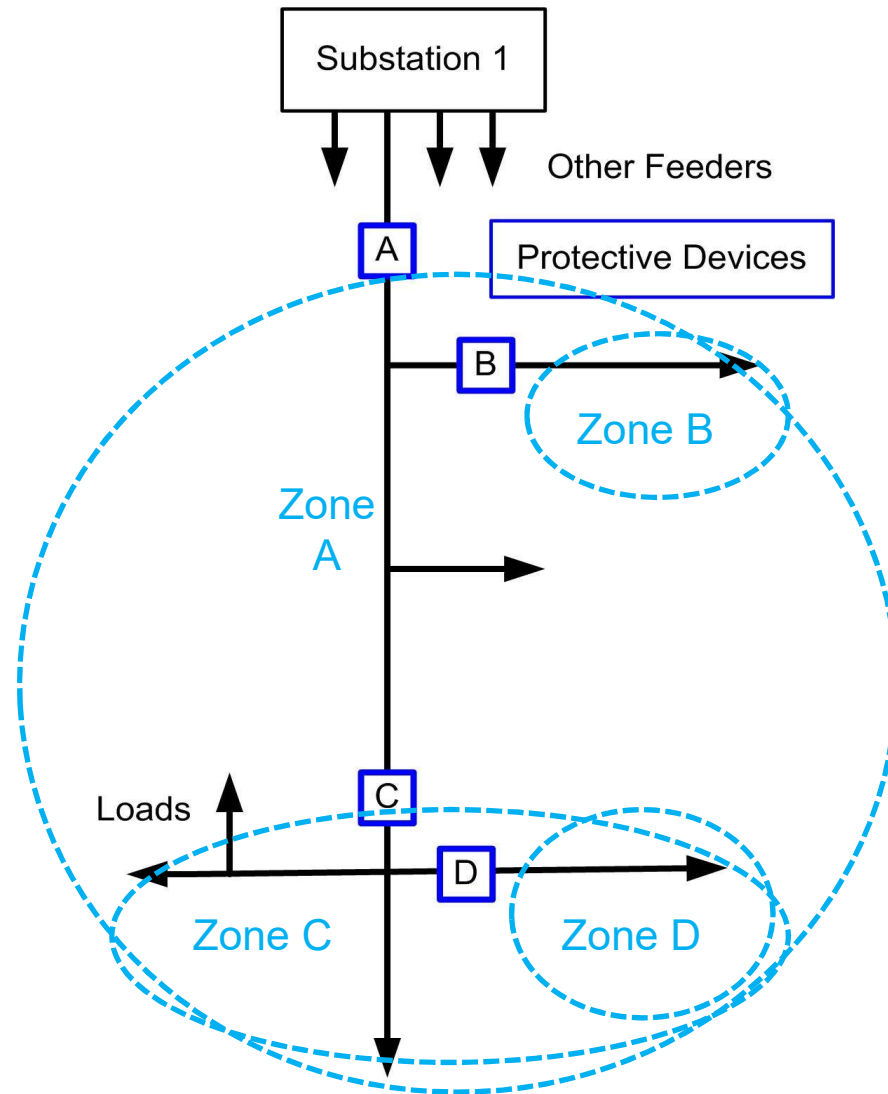


# Distribution Protection

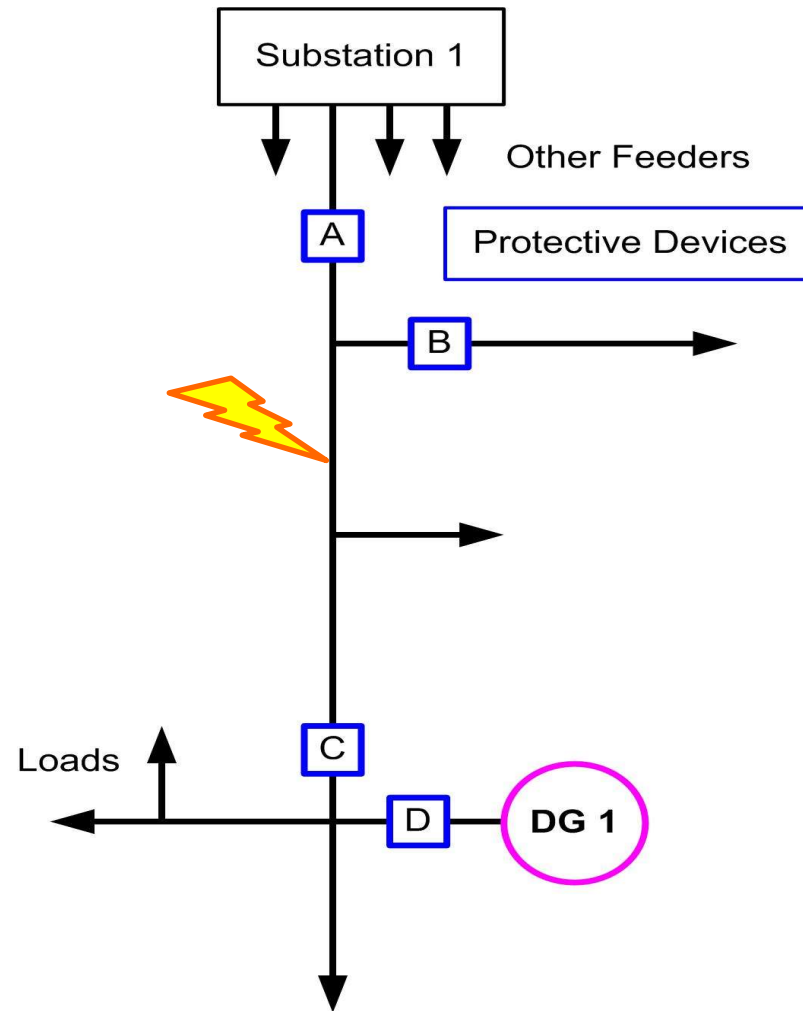




# Distribution Protection



# Distribution Protection with DER



# Distribution Engineering:

Variation of circuits creates engineering challenges with DER

## **Distribution circuit design challenges:**

Less help from statistics

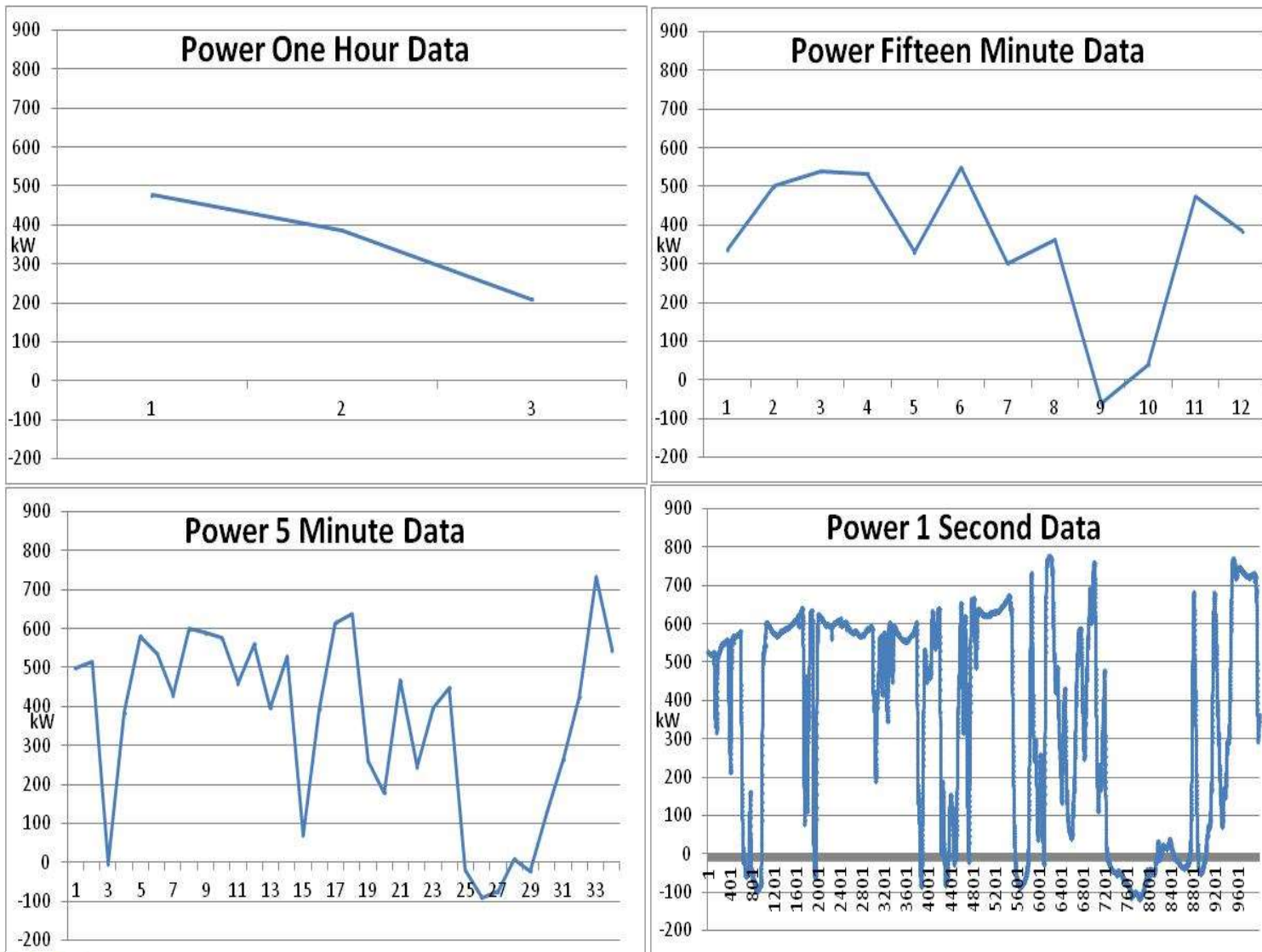
→ Irregularities play a greater role

- load (real power)
- power factor (reactive power)
- voltage drop
- phase imbalance
- generation

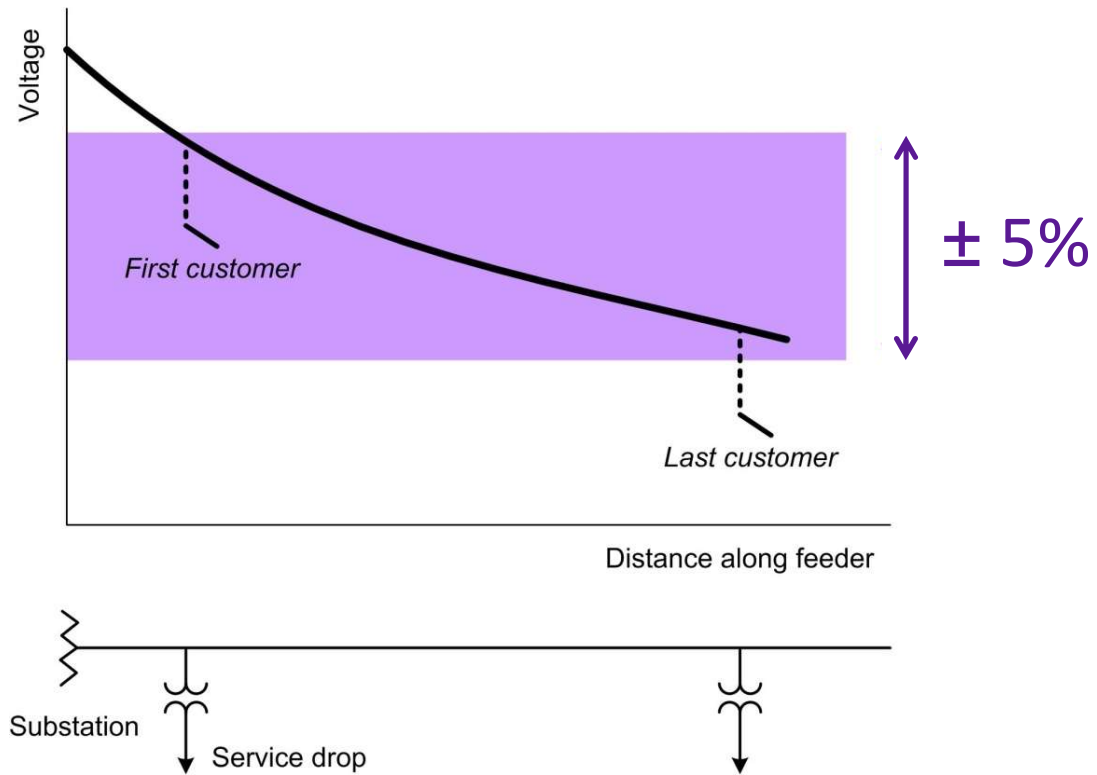


# Distribution System Loading: Micro View on feeder w/DER

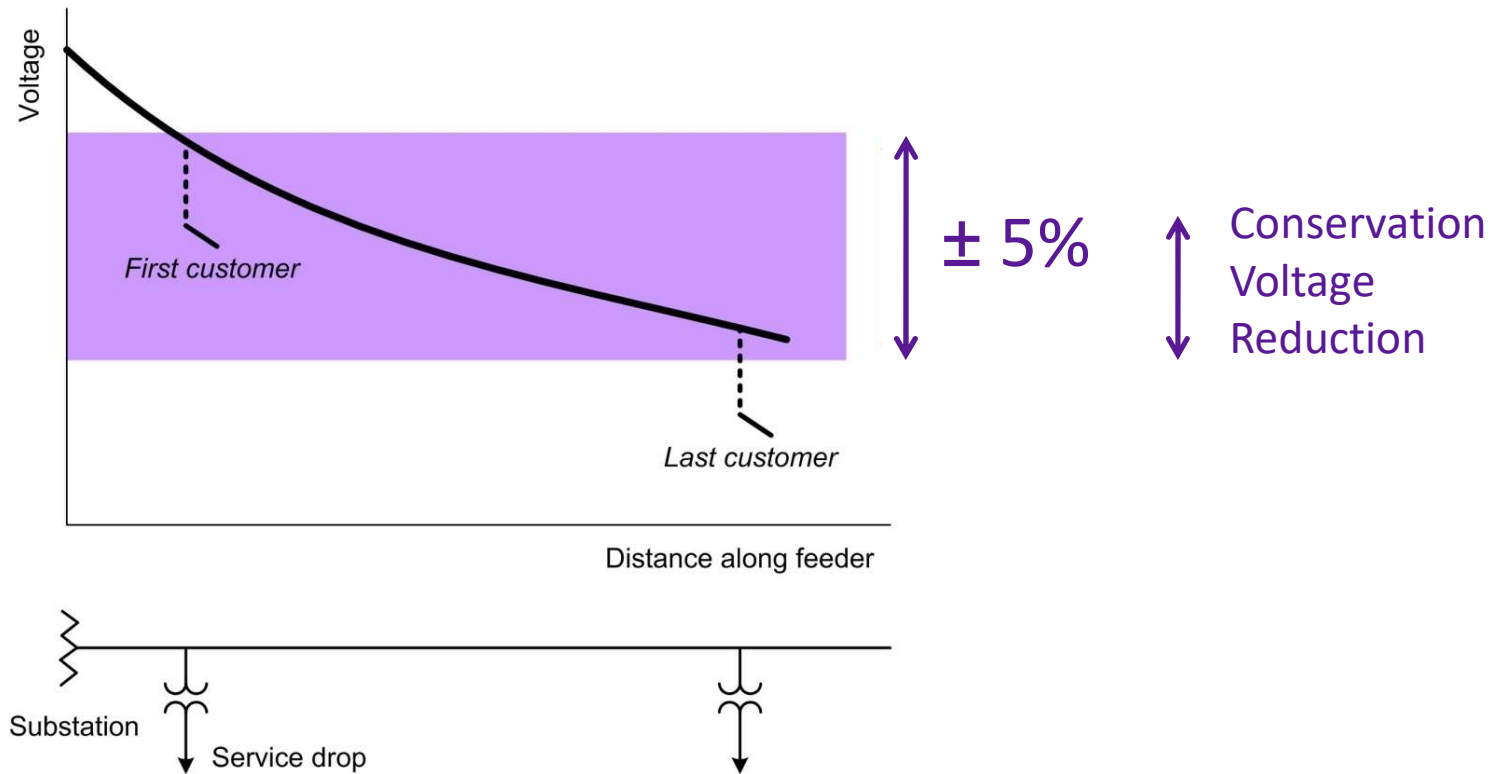
Graphs courtesy of Tom Bialek, SDG&E



# Voltage regulation



# Voltage regulation

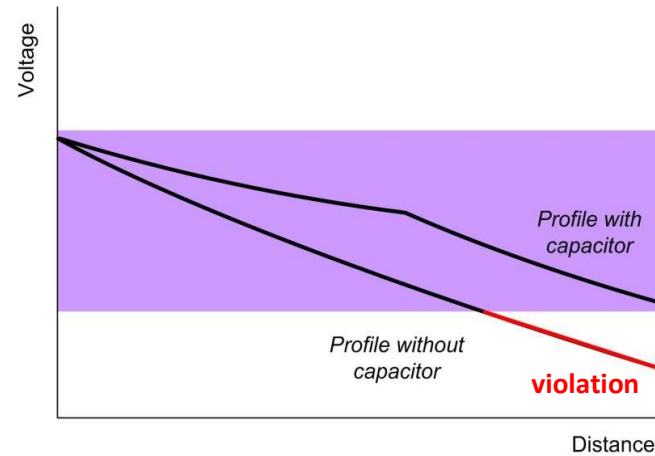
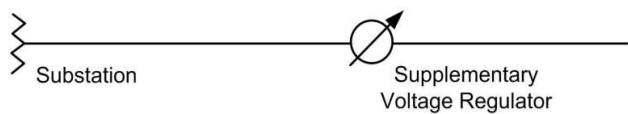
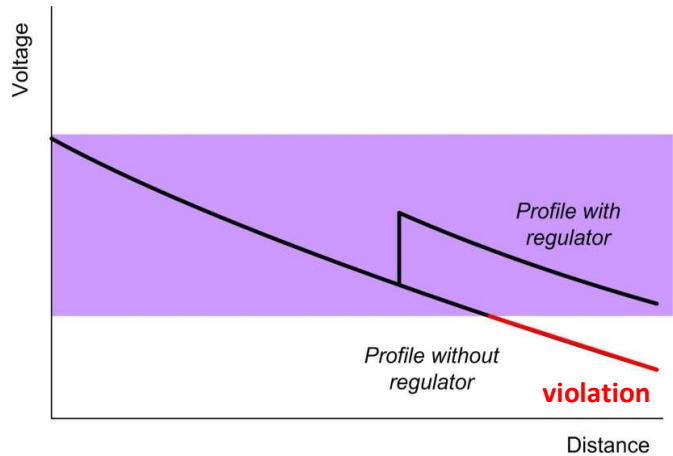
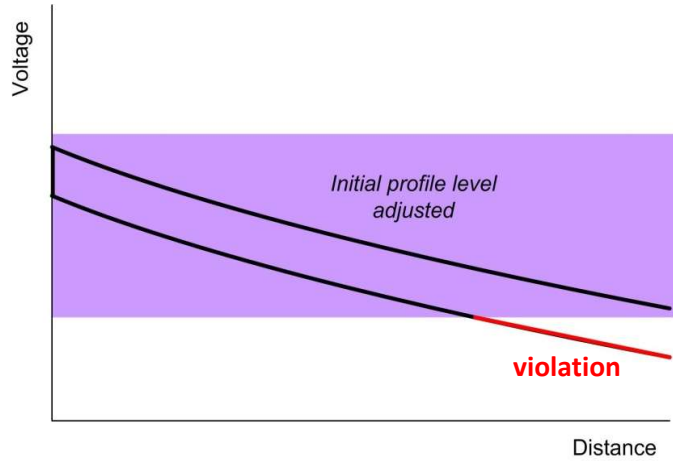




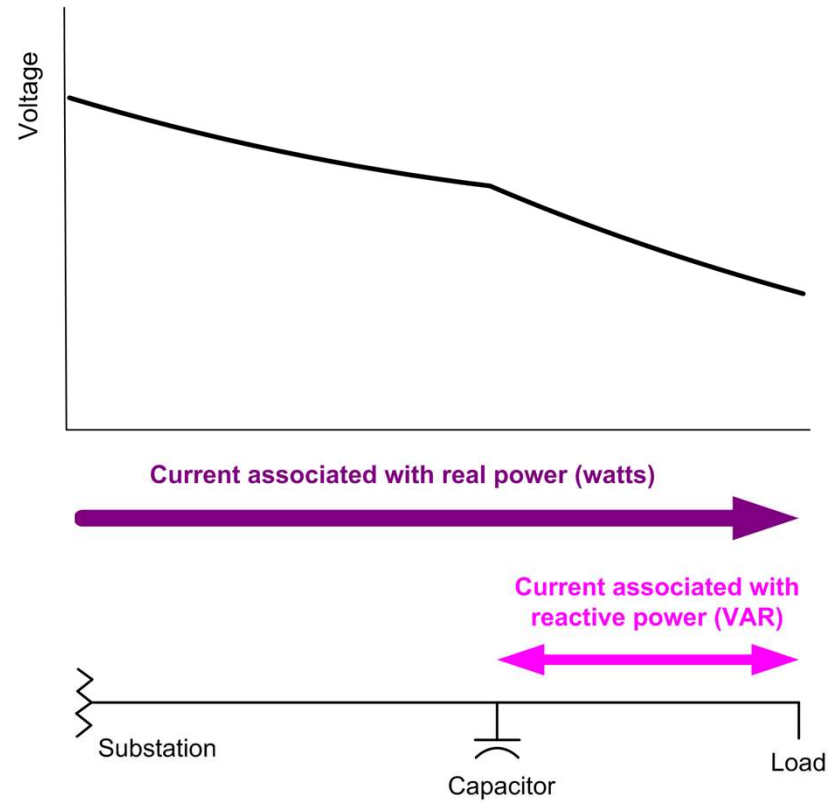
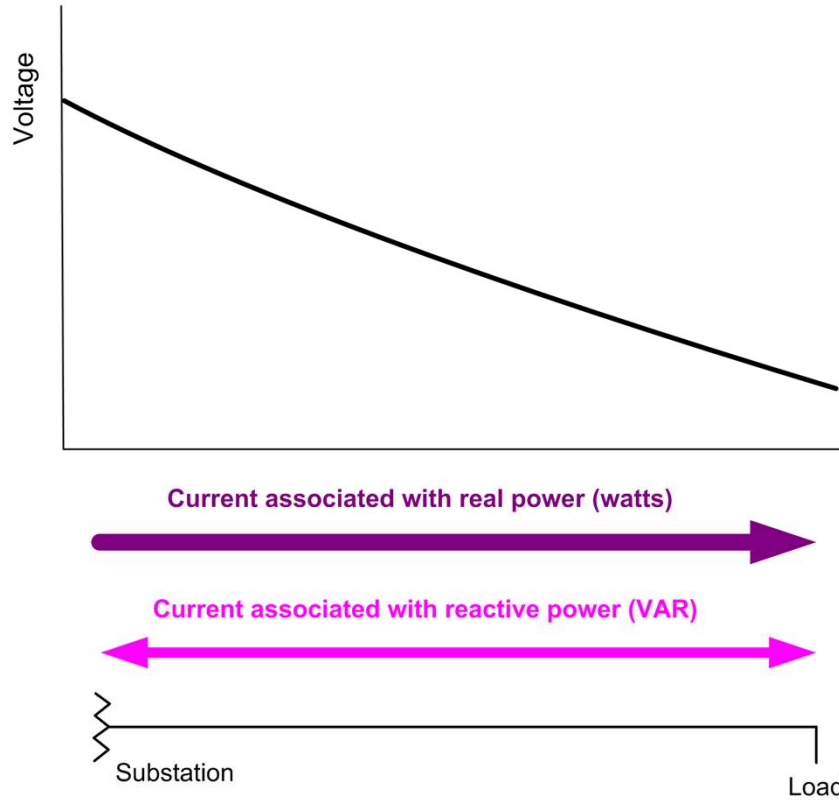
## Voltage regulation

Substation transformer allows adjustment of initial voltage level through moveable connection (load tap changer, LTC).

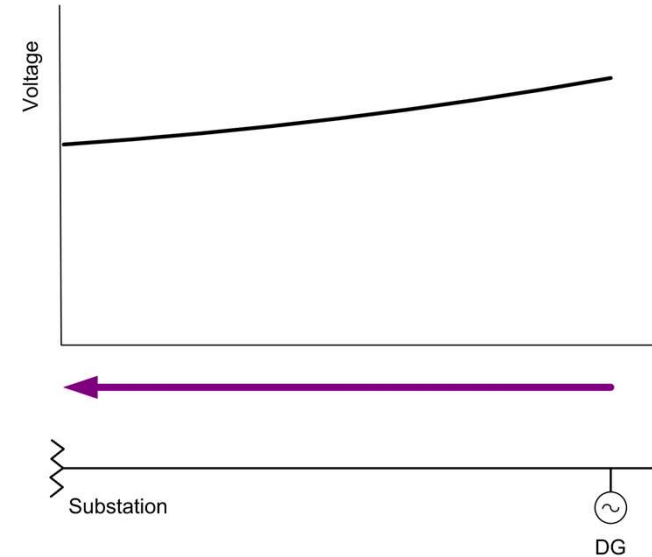
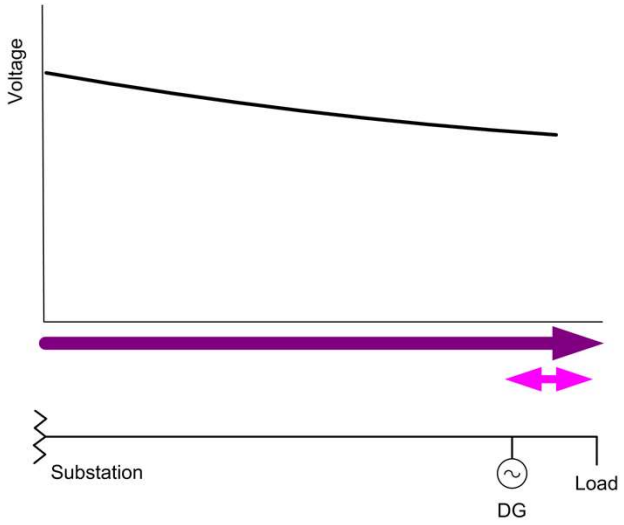
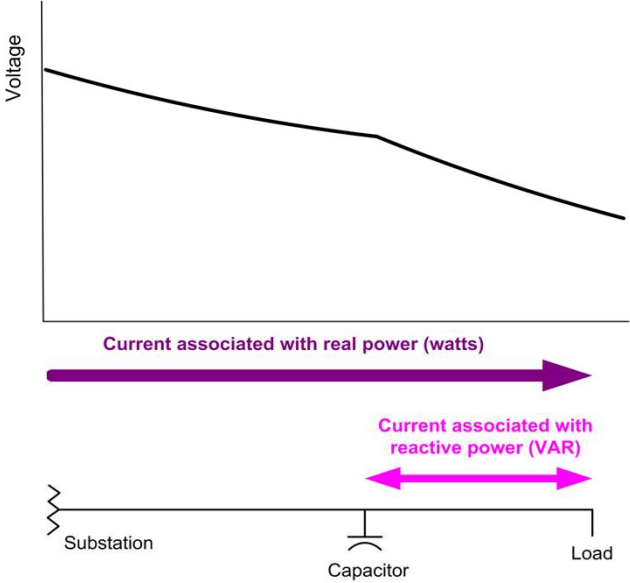
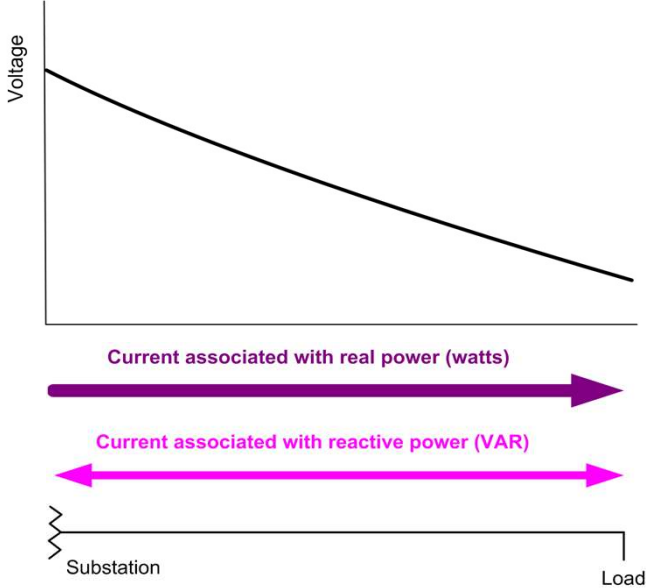
If feeder is long and voltage drop is too steep to stay within range throughout, further adjustments are made along the way (voltage regulators or capacitors).



# Real vs Reactive Power



# Real vs Reactive Power w/DER

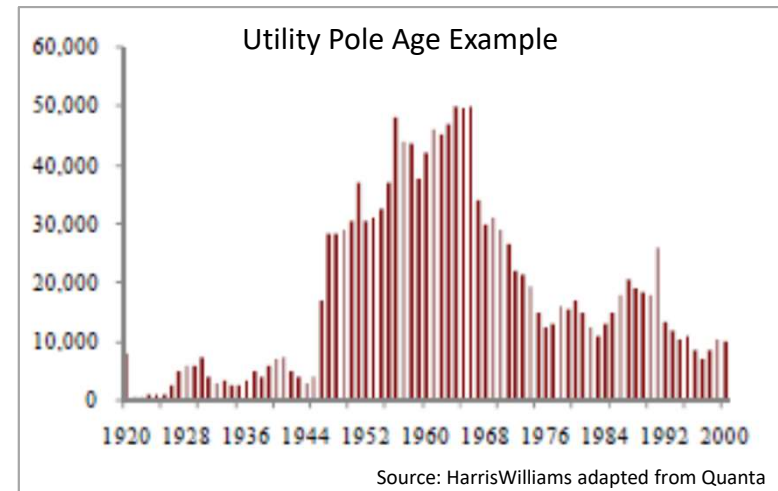
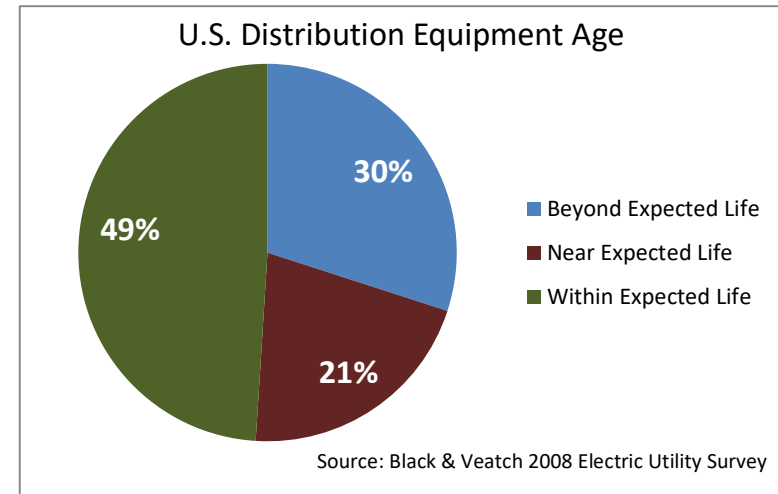


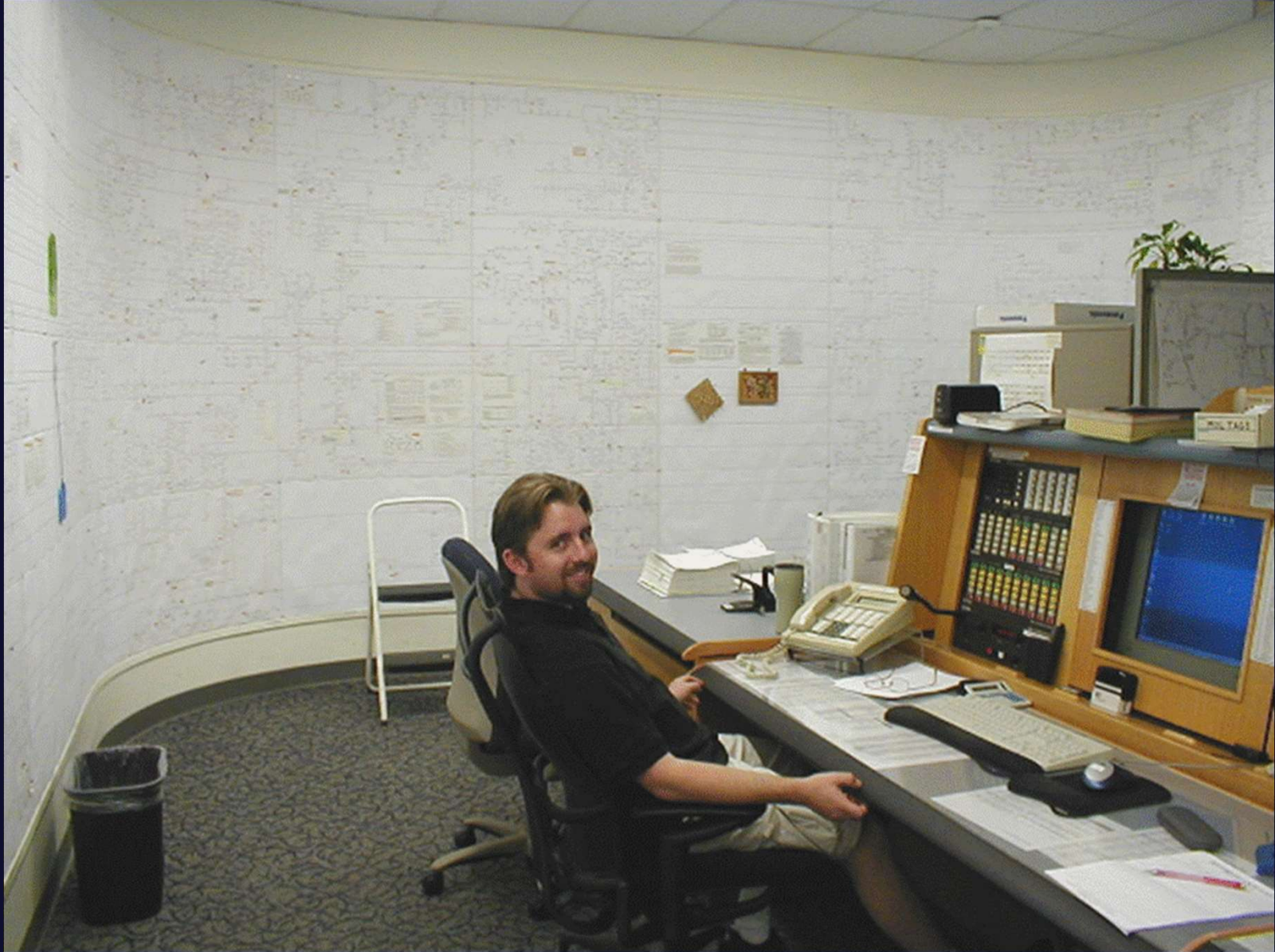


# Distribution Reliability:

Aging infrastructure compounding traditional reliability management

- External influences are always nearby
  - weather
  - trees
  - animals
  - Vehicles
  - ...?
- Aging infrastructure is increasingly a major factor
  - Average age of systems are increasing
  - Individual components are operating beyond expected life
  - Dynamic operating conditions may accelerate failures of older equipment





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# Future of U.S. Distribution System

EEI Webinar

July 18, 2012 ■ 2:00 – 3:30pm EDT



Alexandra von Meier  
Co-Director, Electric Grid Research



Paul De Martini  
Managing Director



Barbara Tyran  
Director, Washington & State Relations  
Jared Green  
Project Manager, Smart Grid

# Webinar Objectives

- Discuss the evolution of the distribution systems thru 2030
- Discuss growing use of distribution system for DER within an operational, reliability and cyber security context
- Discuss key technologies and their development/adoption
- Highlight key strategic issues to consider in 2012-15 to enable longer term success

## Presenters:

**Paul De Martini** Managing Director, Newport Consulting

**Alexandra von Meier** Co-Director, Electric Grid Research, Calif. Inst. for Energy & Environment

**Jared Green** Project Manager, Smart Grid, Electric Power Research Institute

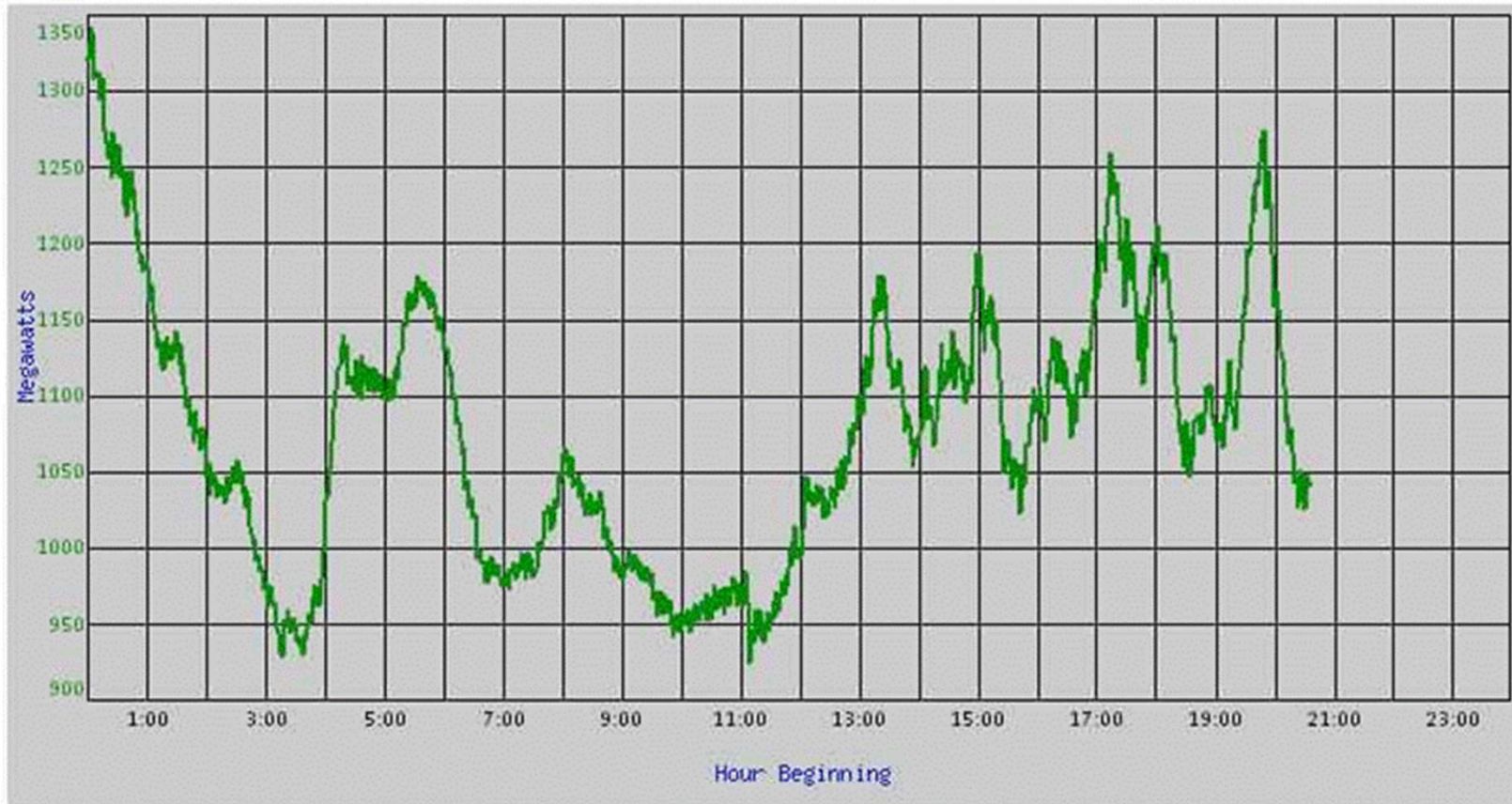
**Barbara Tyran** Director, Washington & State Relations, Electric Power Research Institute



# Wind Variability

Today's Wind

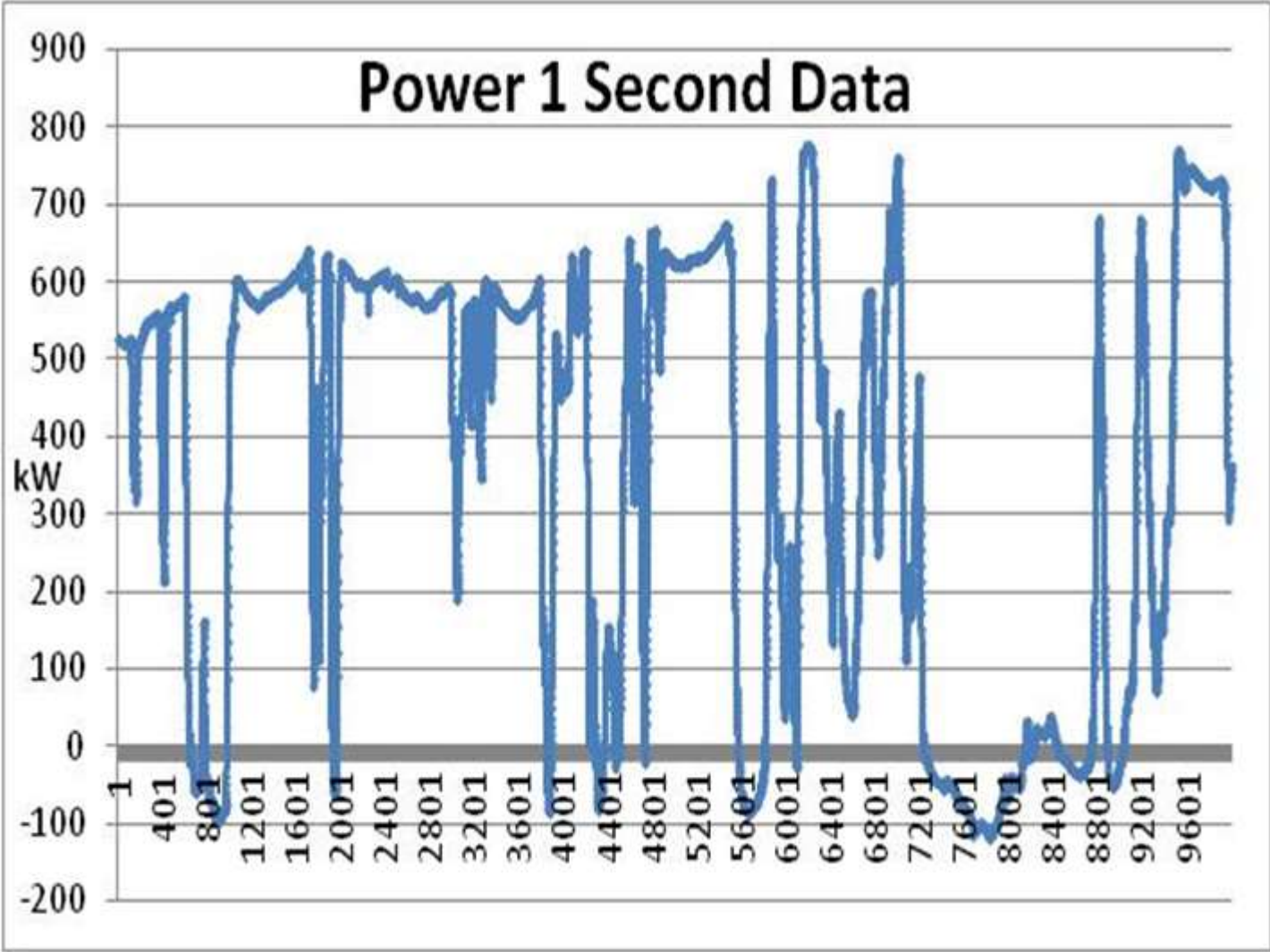
Current Wind: **1043.80 MW**



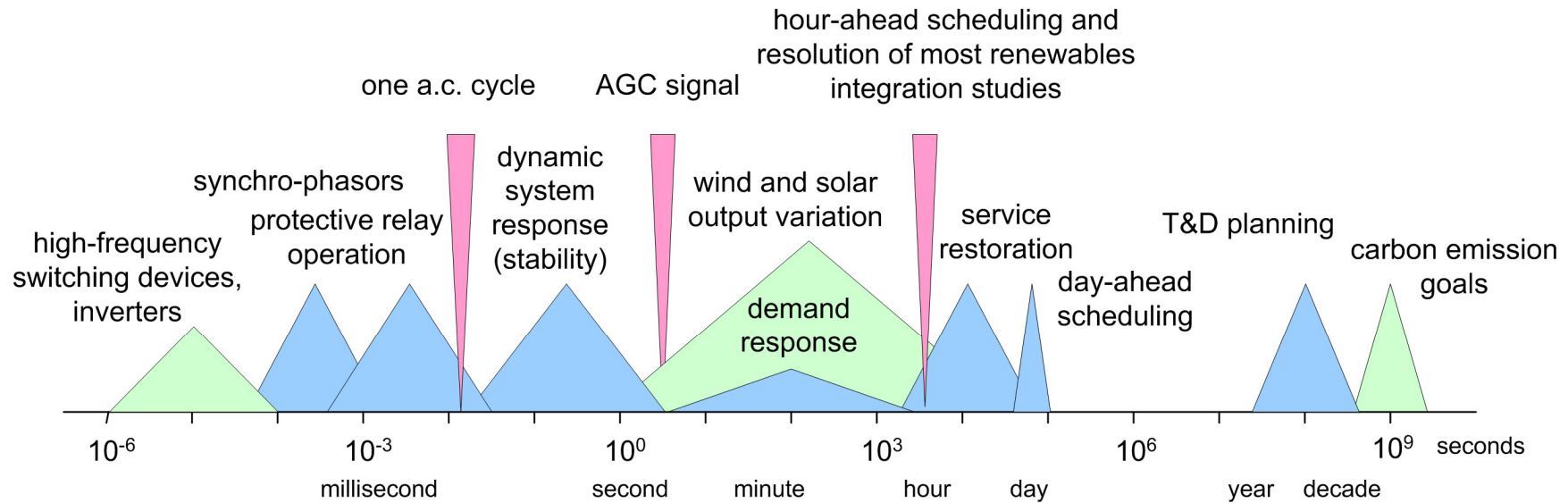
This graph shows the aggregated output from the wind generation connected directly to the California ISO Balancing Area.



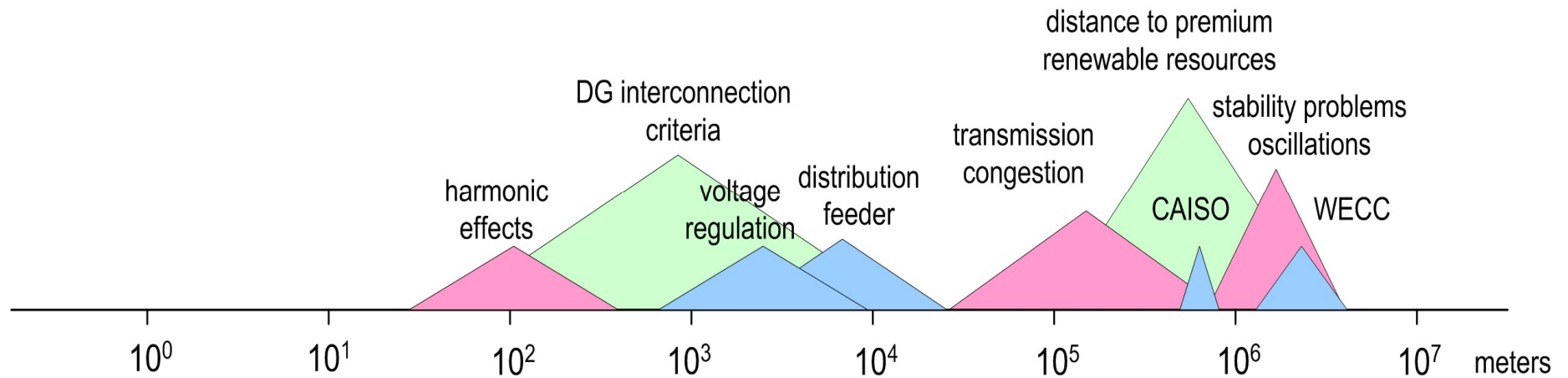
# DER Driven Distribution Feeder Volatility



# Time Scales in Electric Operations



# Distance Scales in Electric Operations



# Coordination challenges in time

- Matching  $P_{IN} = P_{OUT}$  on different scales
- Constrained by ramp rates ( $dP/dt$ ) of resources
- Maintaining stability on the scale of seconds, cycles
- Impact of switch-controlled generators (inverters) on angle stability not yet well understood

Requires management at the sub-second level:

phasor measurement units

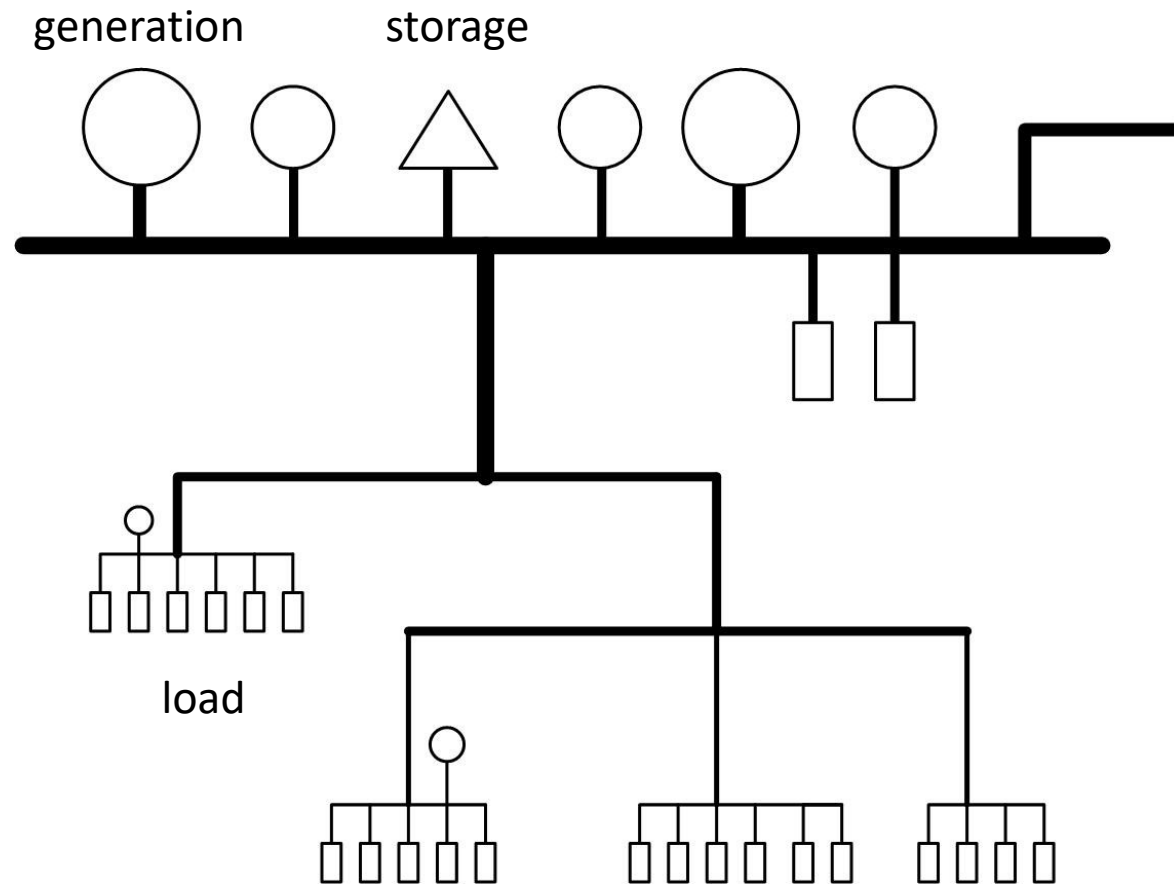
ac-dc-ac conversion

power flow control devices



chopping up waveform  
with solid-state technology

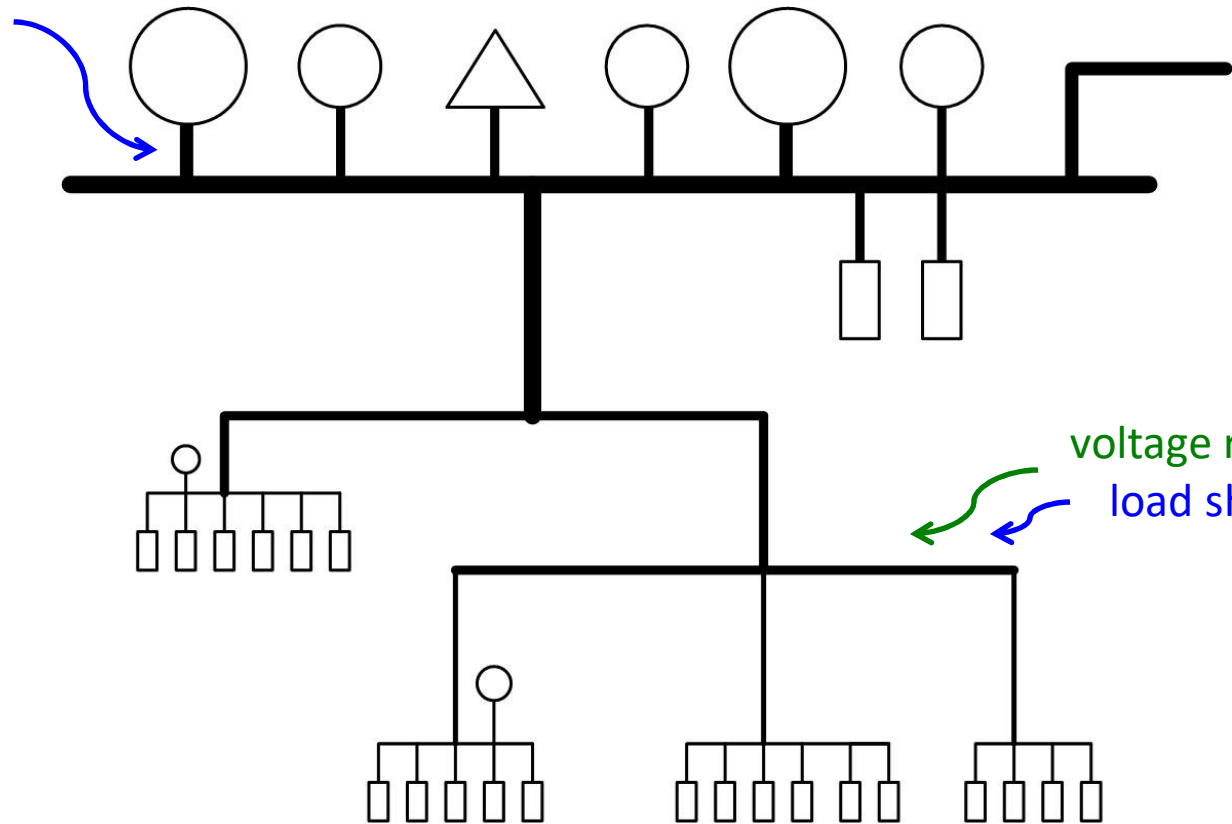
# Today's Grid





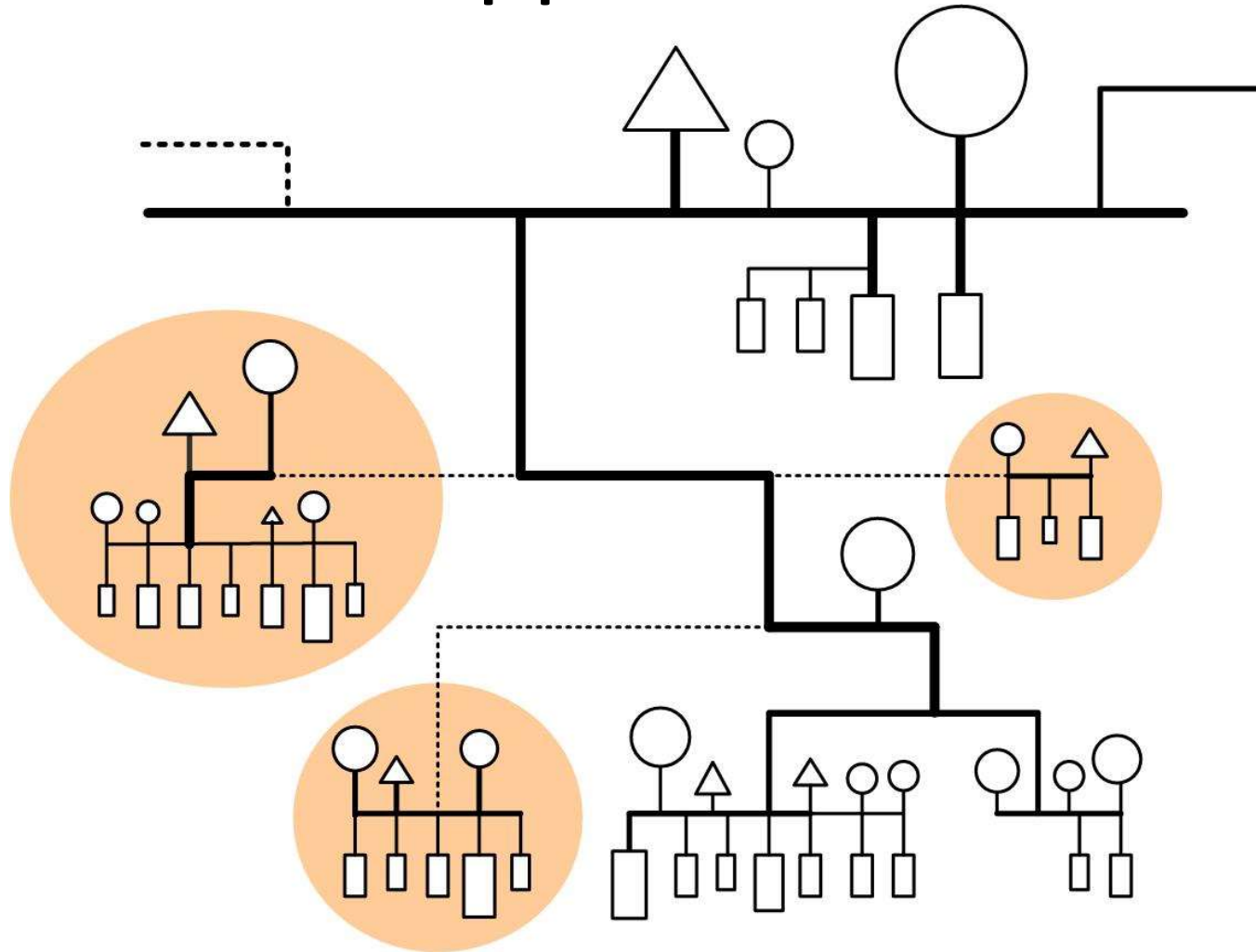
# Today's Grid

bulk generation scheduling  
frequency regulation



voltage regulation  
load shedding

# Supple Grid?





storage



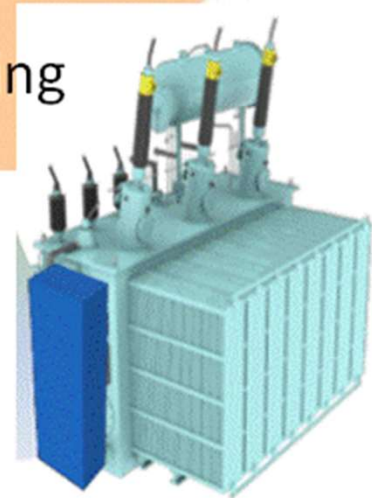
generation

intelligent switching:  
coordination

responsive  
loads

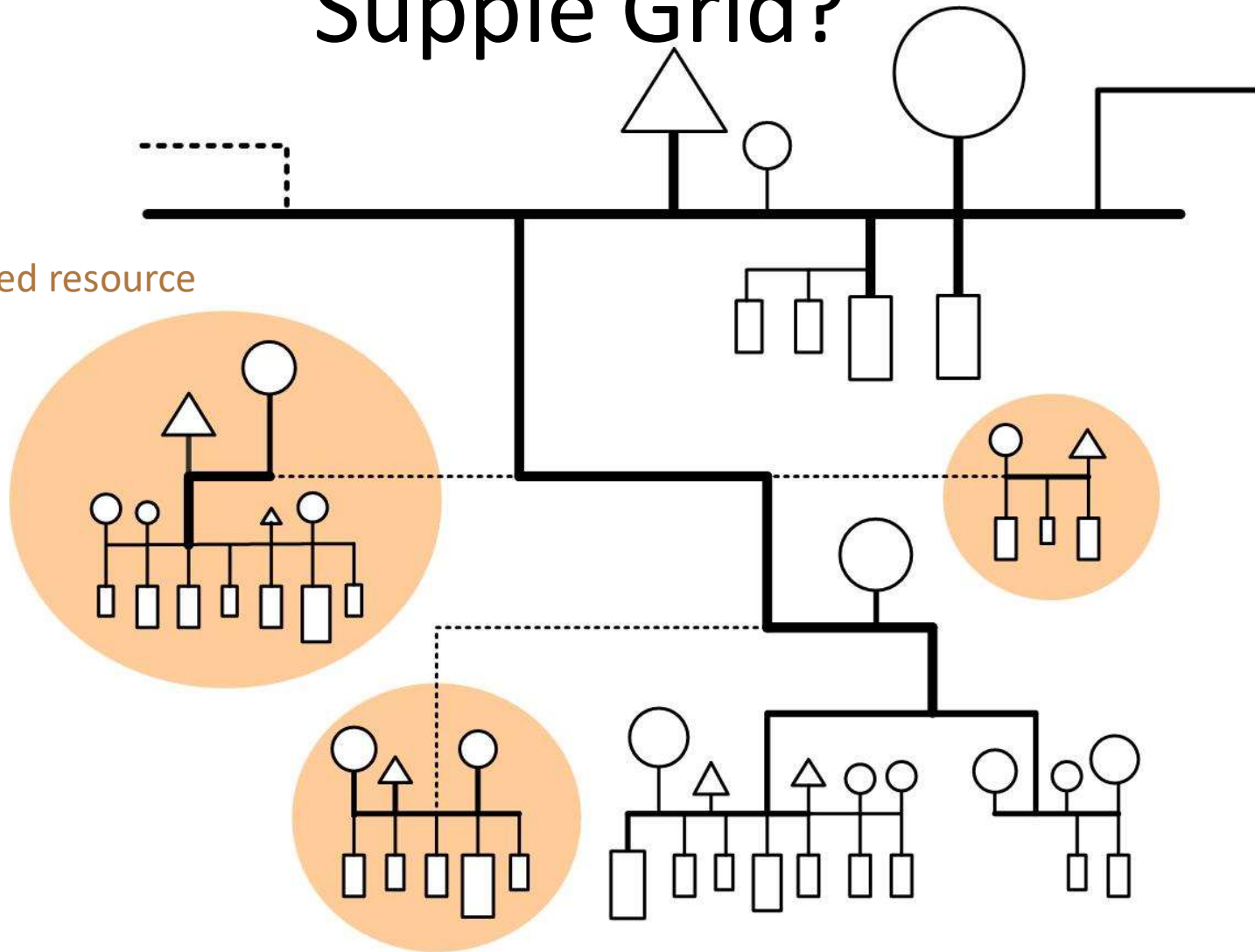


power  
conditioning

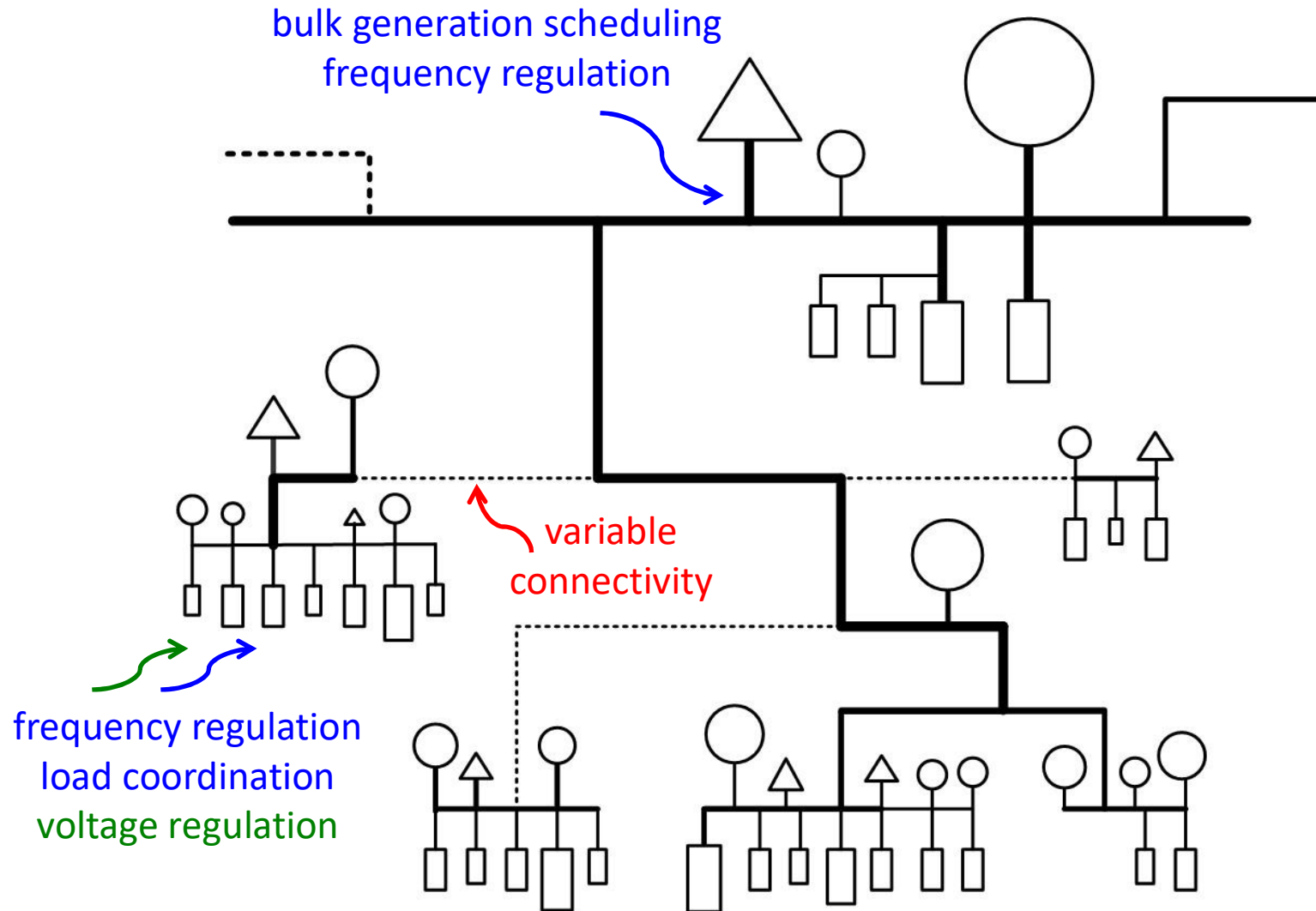


# Supple Grid?

Balanced resource cluster

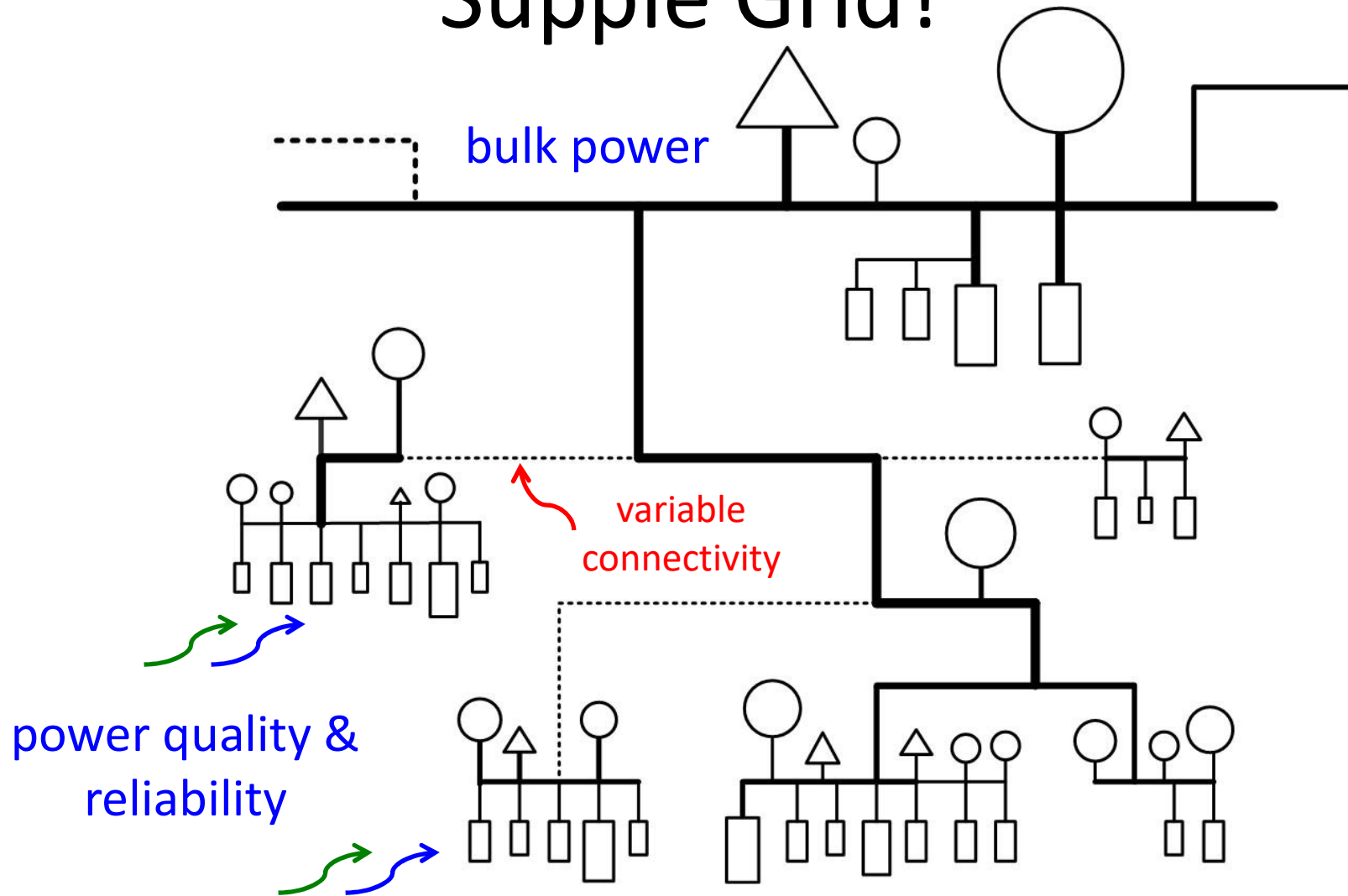


# Supple Grid?





# Supple Grid?



# A taxonomy of electric grid subsets

	physically co-located	able to disconnect from grid	matches generation & load	coordinates diverse resources	crosses property lines
power island	✓	✓	✓		(✓)
microgrid	✓	✓	✓	✓	
balanced cluster	✓	✓	✓	✓	✓
virtual power plant				✓	✓
RESCO	✓			✓	✓

# Future Directions

## Refined observation and control in time and space

- driven by the need to mitigate pre-existing vulnerabilities of the legacy system, much amplified by intermittent renewable resources
- providing the means to observe, communicate and control at higher resolution while maintaining large-scale awareness

## Trend toward adding new capabilities on the grid's periphery

- resonant with philosophical and aesthetic preferences of many ratepayers who embrace “going local, going green”
- may enable more local diversity, flexible management options and more systemic value derived from renewable and distributed resources

# Technologies under development

for refined observation and control

- four-quadrant (P,Q) inverters  
voltage-VAR control
- advanced inverters  
harmonic cancellation  
transient mitigation
- distributed storage
- micro-synchrophasors
- power routers
- solid-state transformer
- responsive loads
- communication networks

distributed resources  
& coordination tools

*increasingly provide the  
capability to balance power  
and manage power quality  
& reliability locally*