

Interconnected- Highly Utilized Grid Workshop

September 29-30, 2016

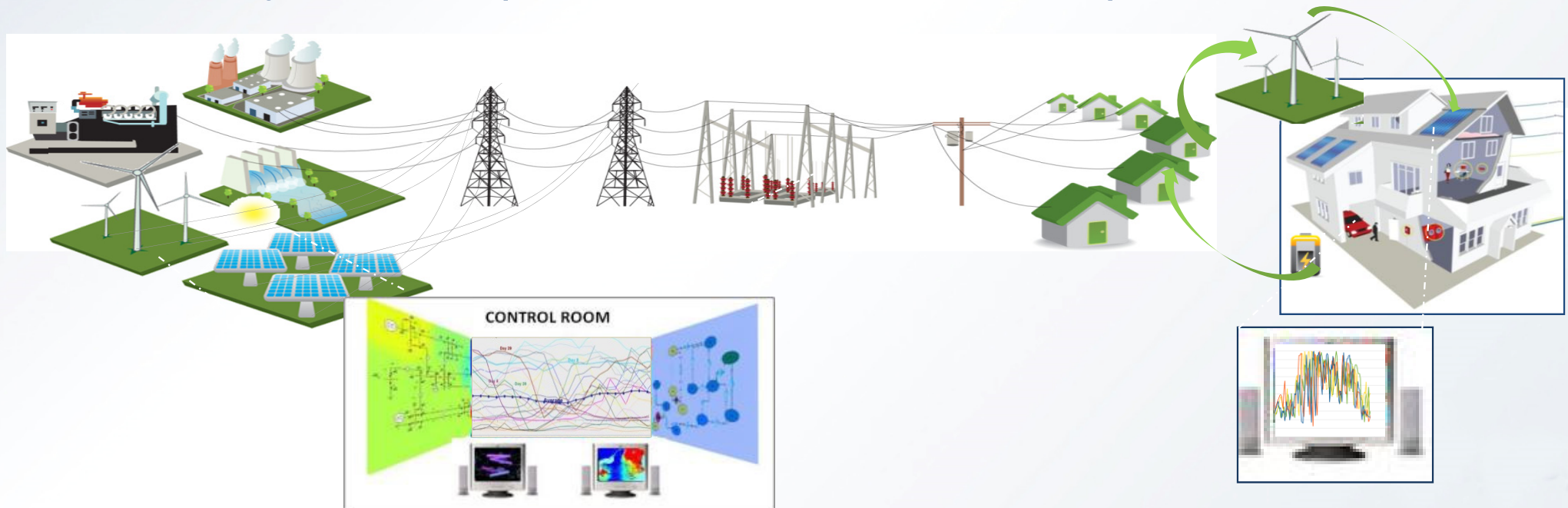


Planning and Operational Challenges in Interconnected DER-based Grids

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Interconnected Grid

- Millions of spatially distributed, variable DERs are being **connected** to the grid.
- Operation needs much better **coordination** across all subsystems: ISO, utilities, microgrids, buildings, homes.
- Grid is cyber-controlled and more **Integrated** with other systems (gas, transportation, etc.)



Overview

1. Transmission

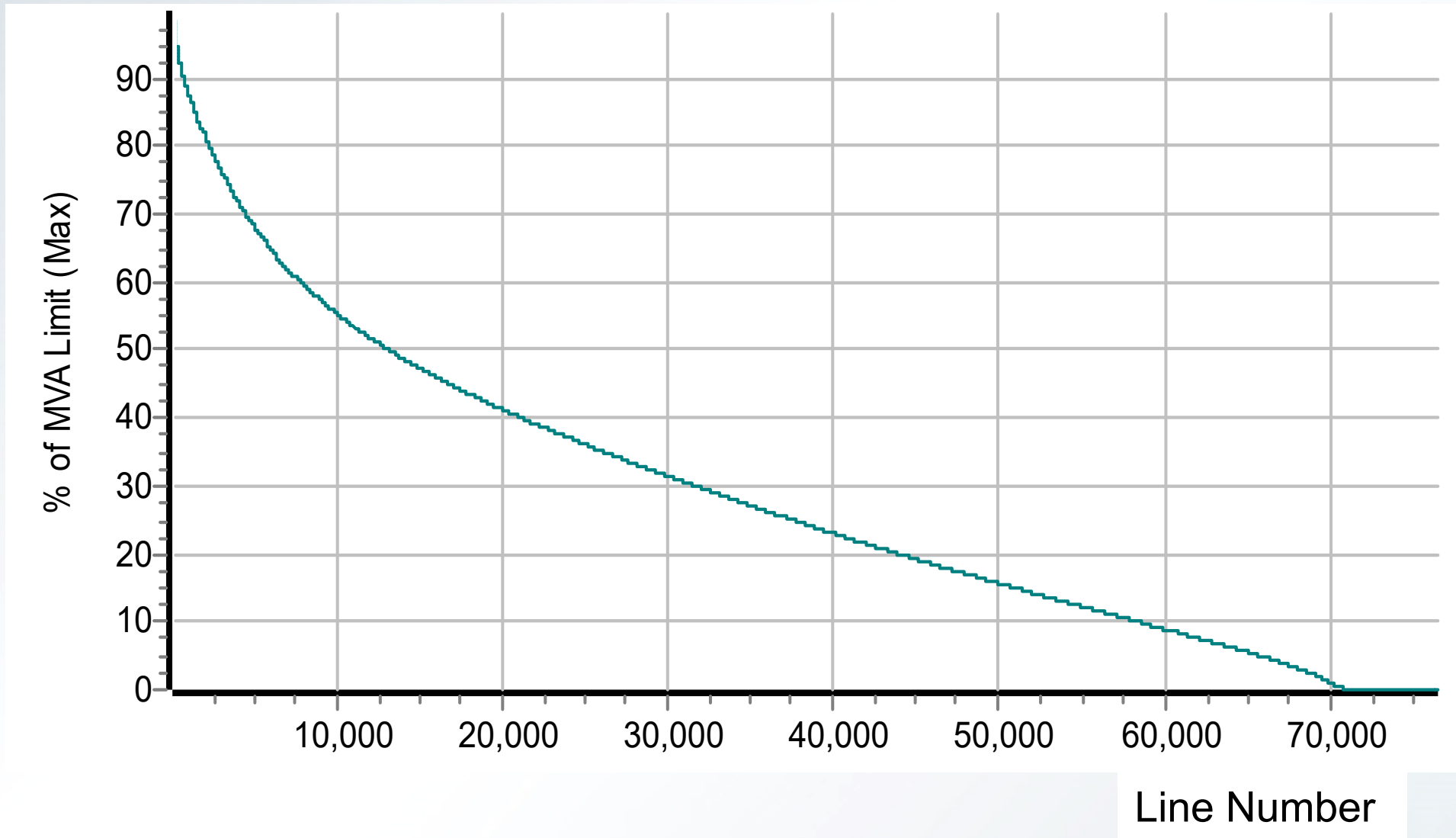
- Spatial Distribution
- Utilization, Contingencies, Metrics
- Scalable Decentralized Optimization

2. Distribution

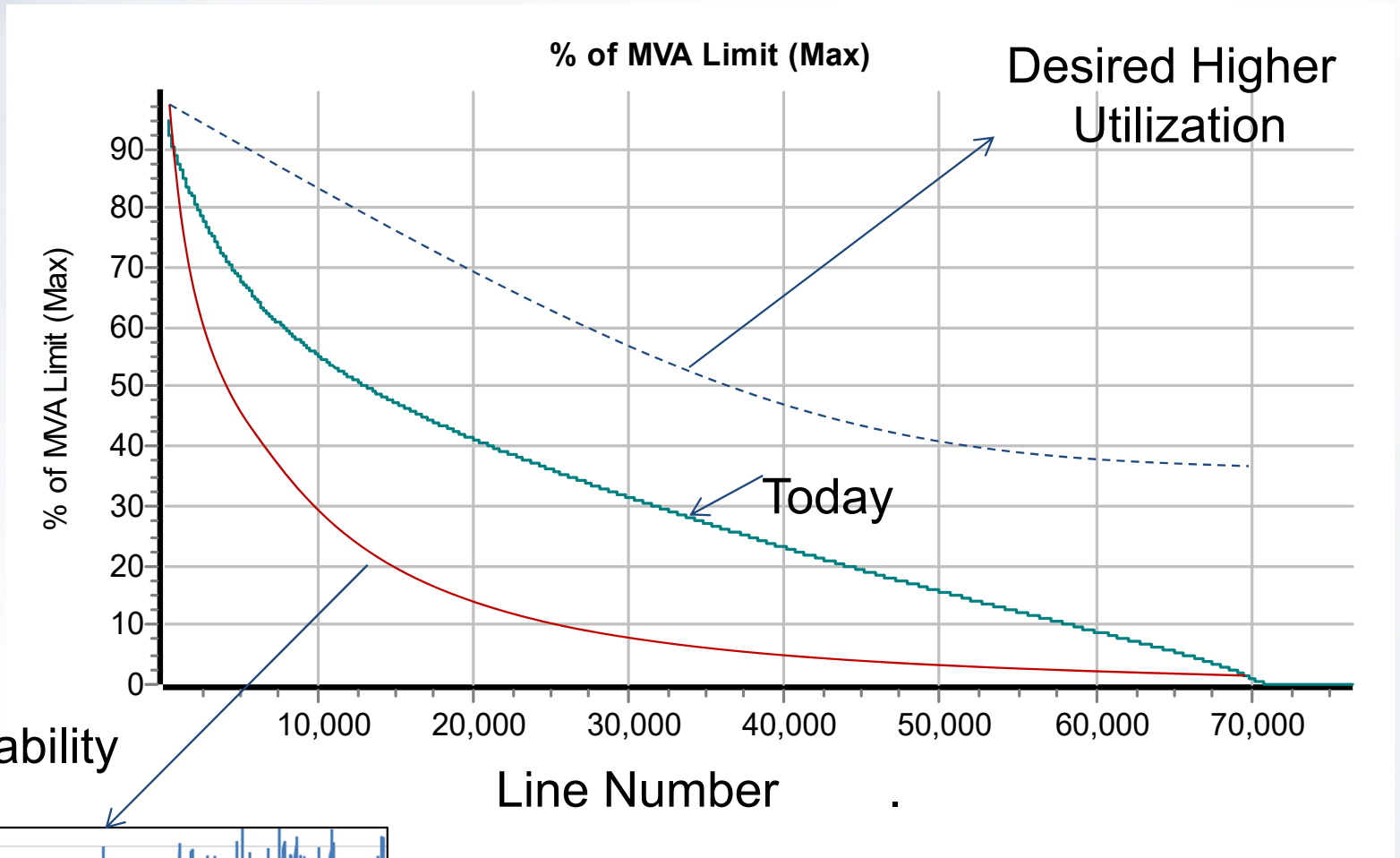
- Multi-layer Cyber-Physical System
- Distribution System Operator (DSO) Simulator
- Distribution PV Hosting Capacity

Transmission Utilization

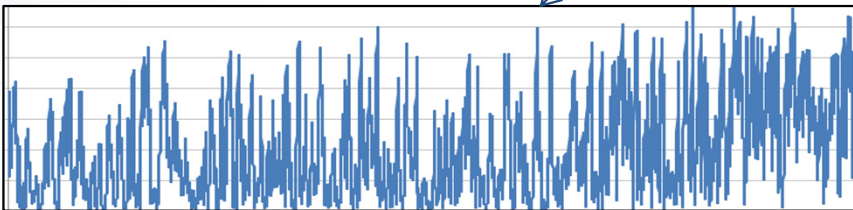
- Line Capacity Utilization
 - Eastern Interconnection, Summer Peak 2016, Normal Operation



Utilization



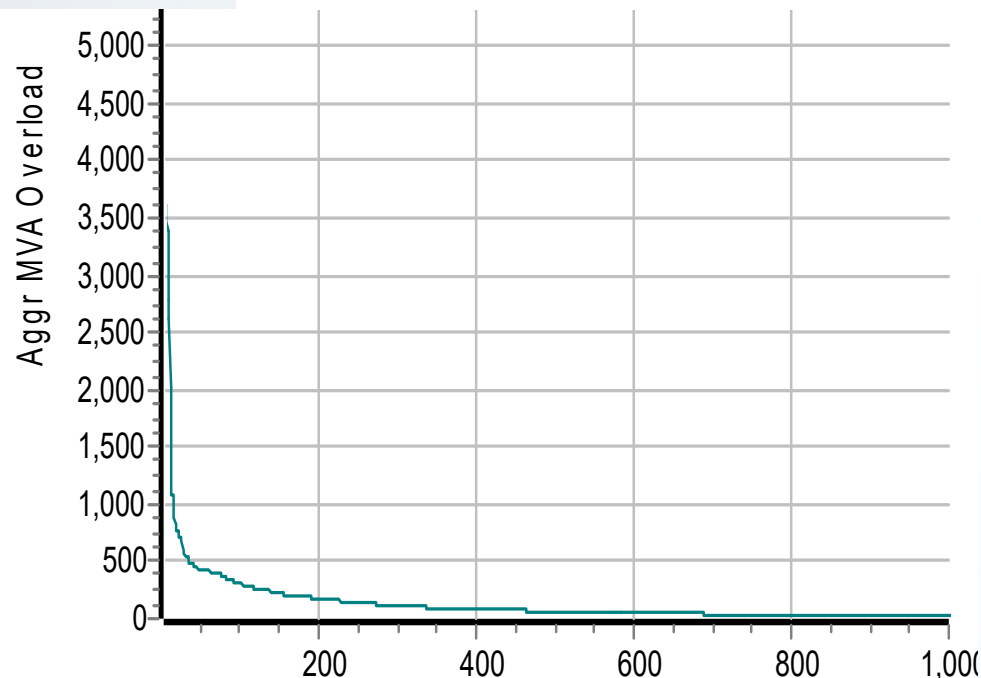
Effect of Variability



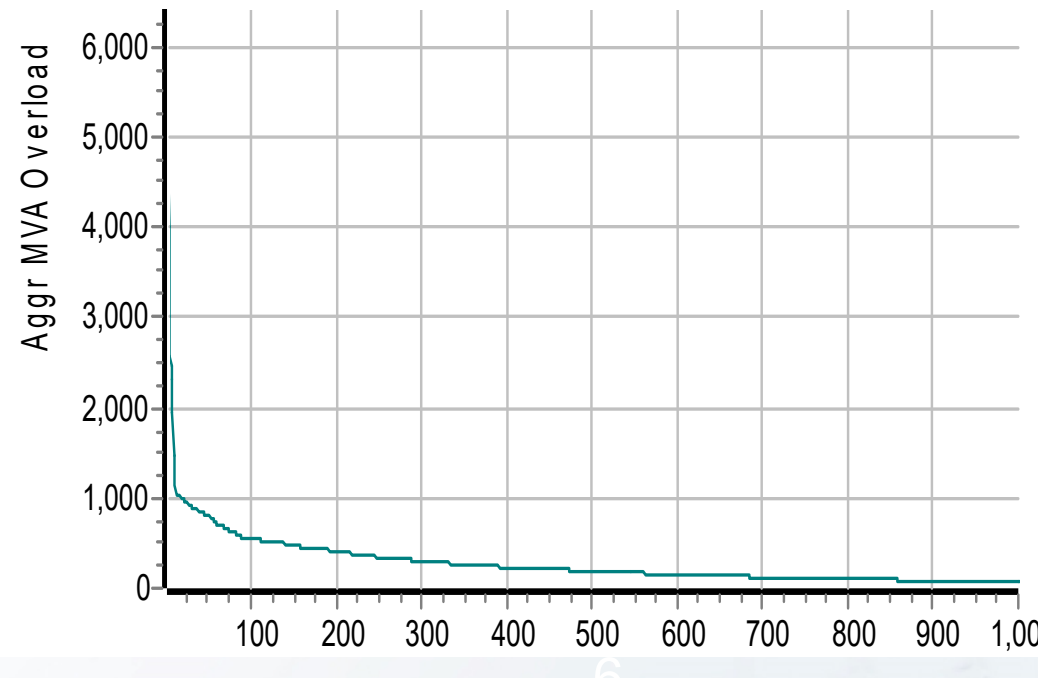
Weak Elements/Severe Contingencies

- Eastern Interconnection, N-1 Contingencies (80k+)
 - **Weak Elements** are overloaded under many contingencies
 - **Sever Contingencies** overload many elements.
- Insecurity Metric: Aggregate MW Contingency Overload.
- Has been increasing year after year.

1000 Weakest Elements



1000 Most Severe Contingencies

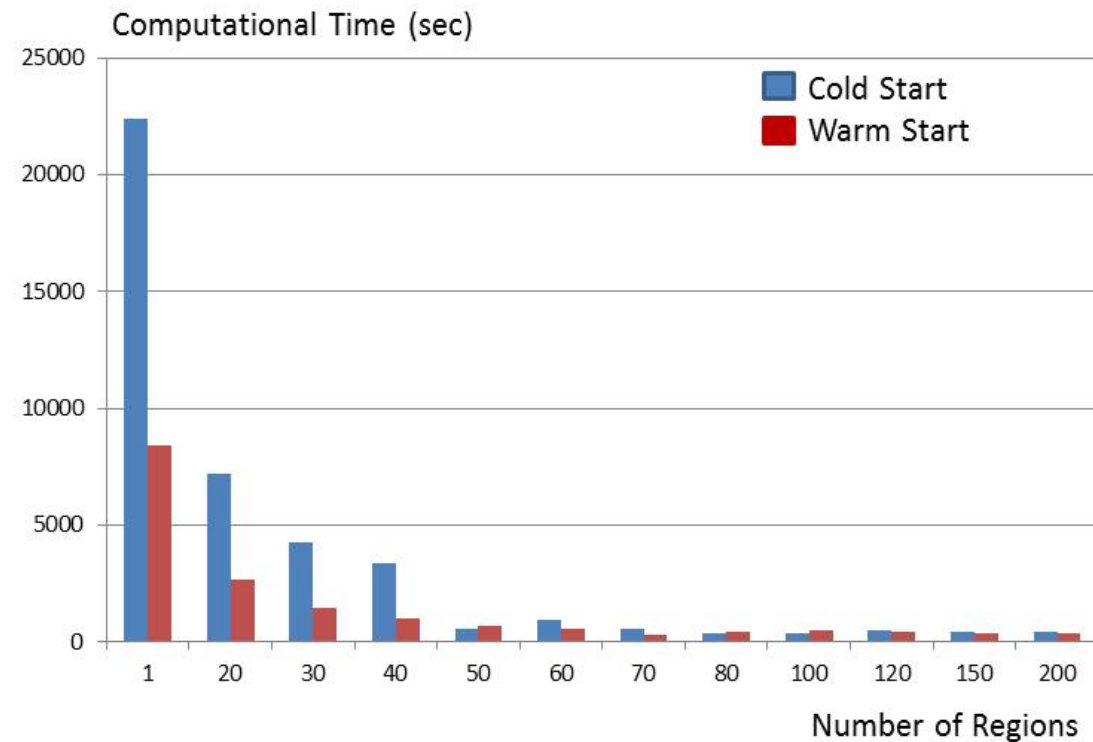
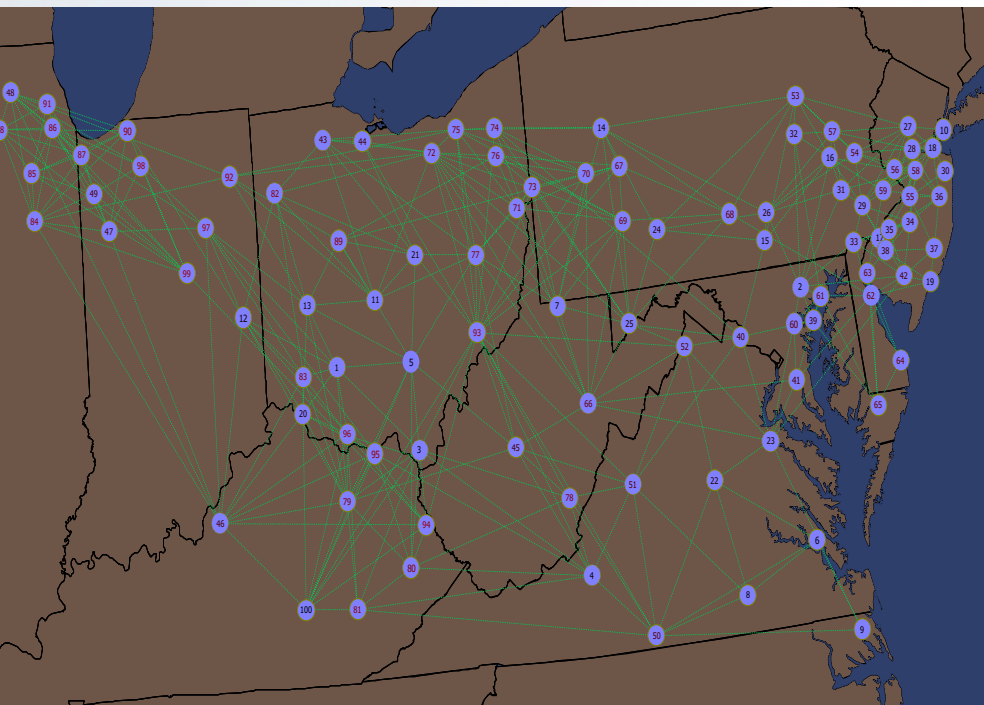


Transmission Planning

- Currently resource and transmission planning are not well integrated. Difficulty handling:
 - Full AC models, voltage constraints, and limits due to voltage and transient stability.
 - Emerging technologies: routers, switching, DC.
 - Large number of scenarios.
- Challenges:
 - Integrated gen + demand + DER, + transmission planning.
 - Must handle order of magnitude increase in control variables.
 - Intertemporal behavior, integer variables, non-convexities.
 - New controls, devices, operational structures.
 - Interactions with other infrastructures.

Scalable Decentralized Optimization

- Example: Unit Commitment
 - Large-Scale ISO realistic data
 - Full UC model: reserve, C^{SU} , C^{SD} ,17k+ constraints.
 - Problem solved orders of magnitude faster.



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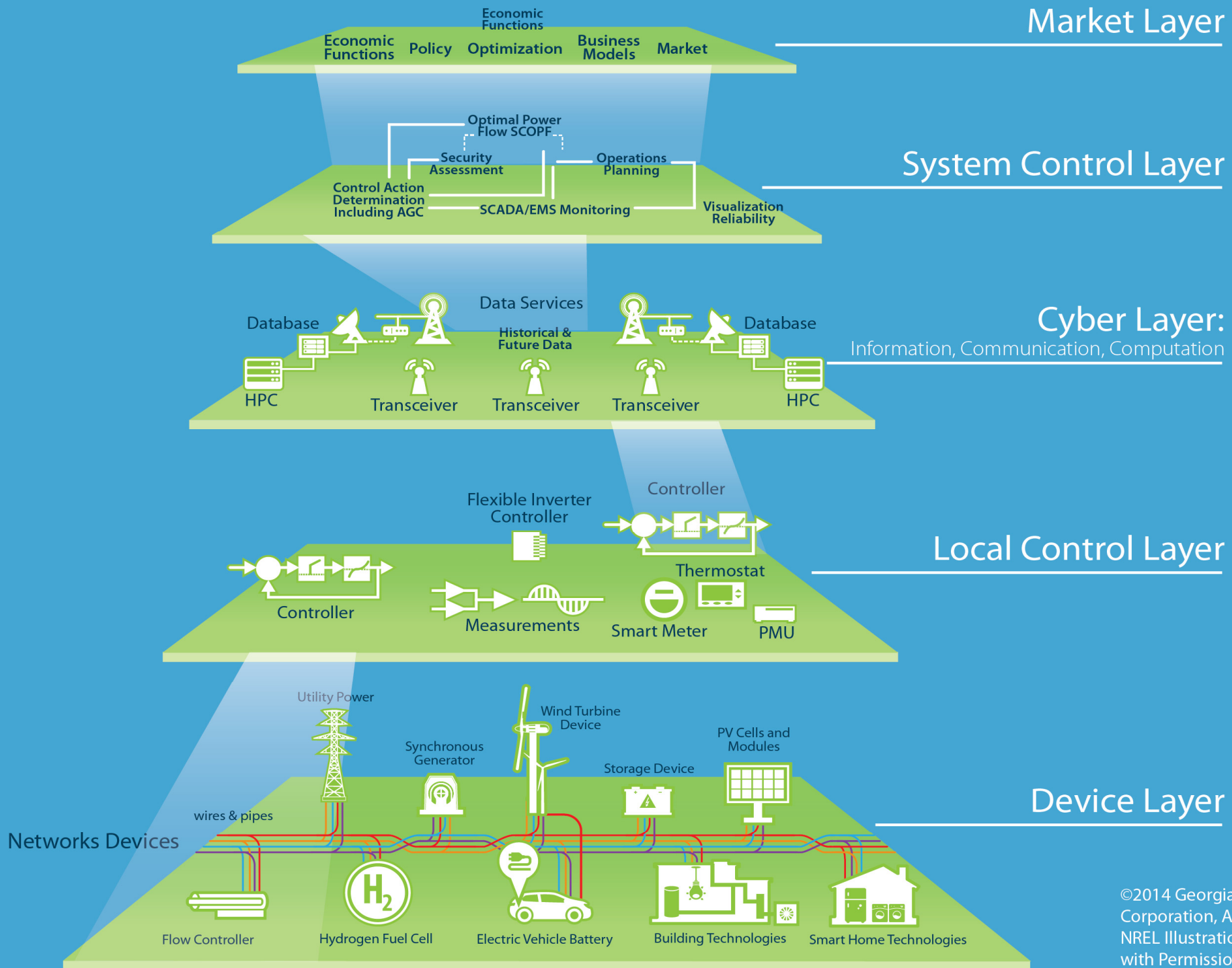
2. Distribution

- Multi-layer Cyber-Physical System
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- Distribution PV Hosting Capacity

Emerging Complexity in Distribution

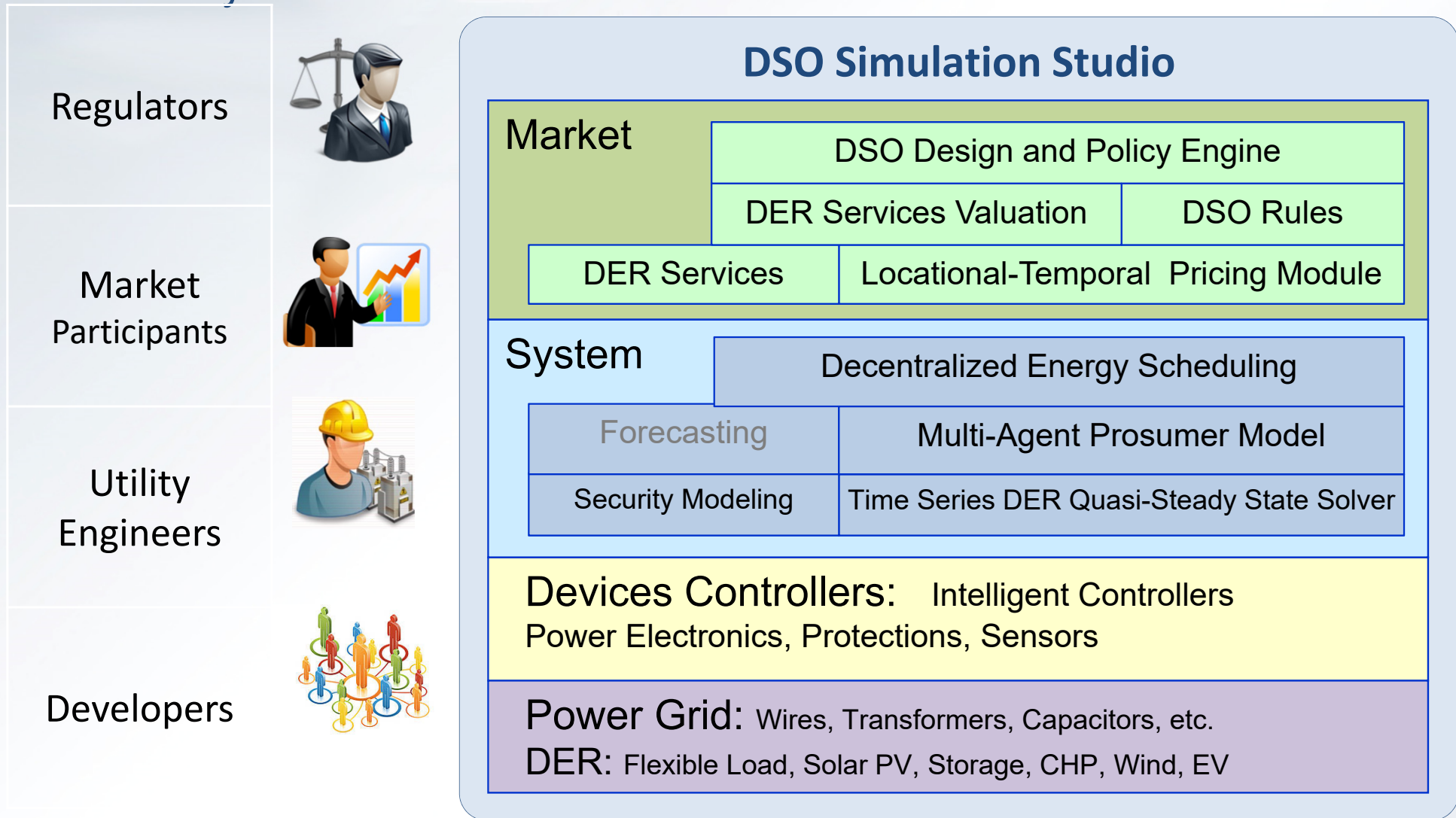
- DER integration:
 - PV, Wind, EV, Demand Response, CHP.
 - Microgrids, Virtual Power Plants
- Active customers/prosumers
- Microgrids
- Smart distribution devices/smart appliances
- AMI creates a wealth of data that can be exploited
- Evolving marketplaces
- Utility business models

Layered Energy Cyber-Physical System



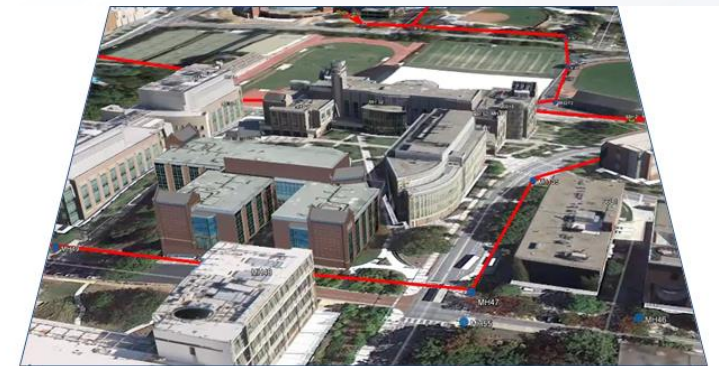
DSO Simulation Studio (ARPA-E Open 2015)

- A Multi-Layer Simulator



DSO Simulator Expected Features

- Decentralized energy scheduling of DER-rich systems of arbitrary size.
- Explicit modeling of energy services transacted in the DSO.
- Locational and time-vector pricing of P/Q, ancillary, and security services.
- 3D Interactive Visualization
- Analytics and valuation of DER services, DSO rules, and business models.
- Simulation of multi-scale interactions of DSO with up-stream ISO, same level DSOs, and downstream (microgrid, building, and home) prosumer subsystems.

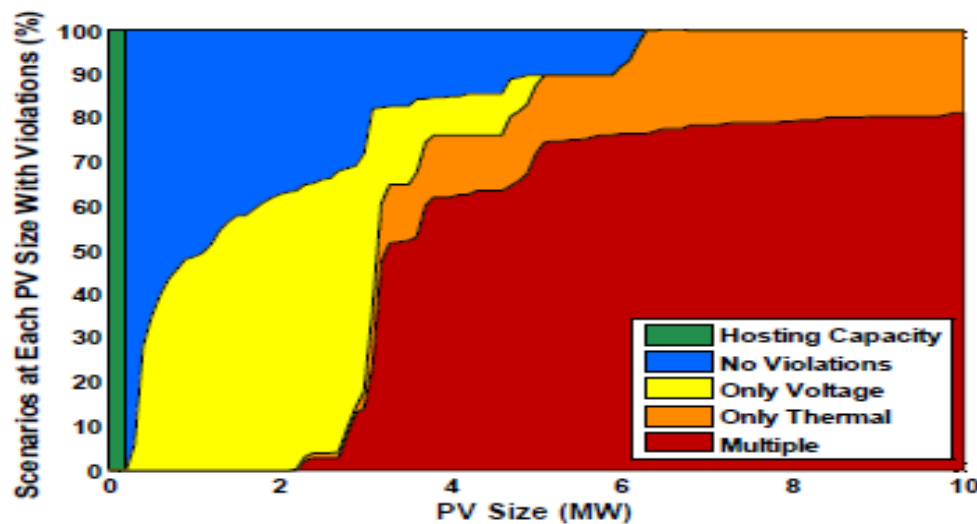
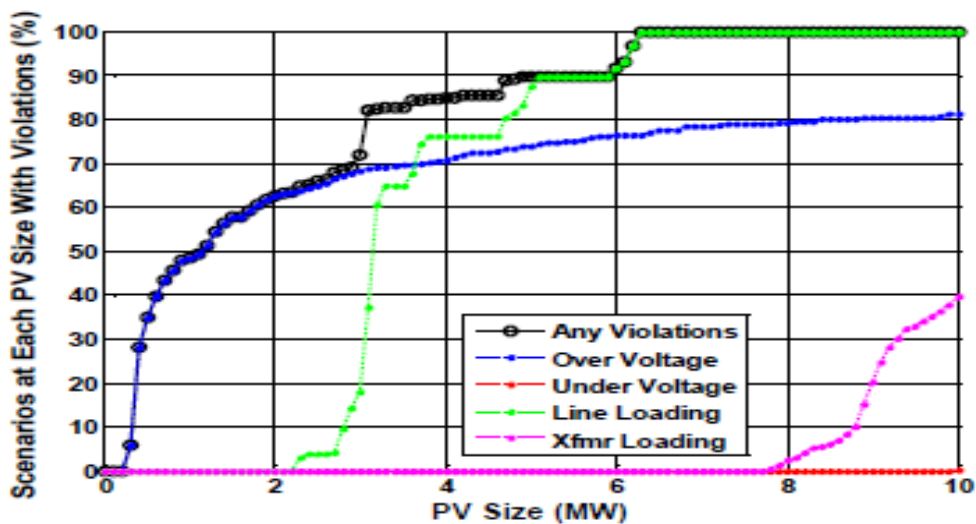


PV Hosting Capacity

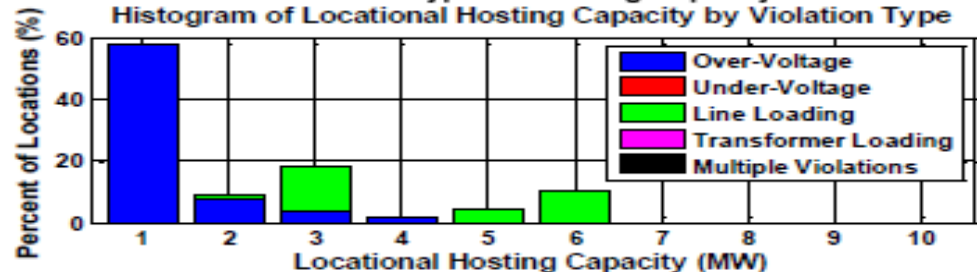
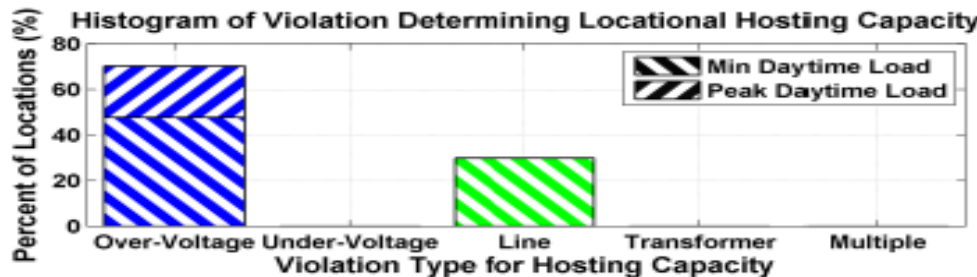
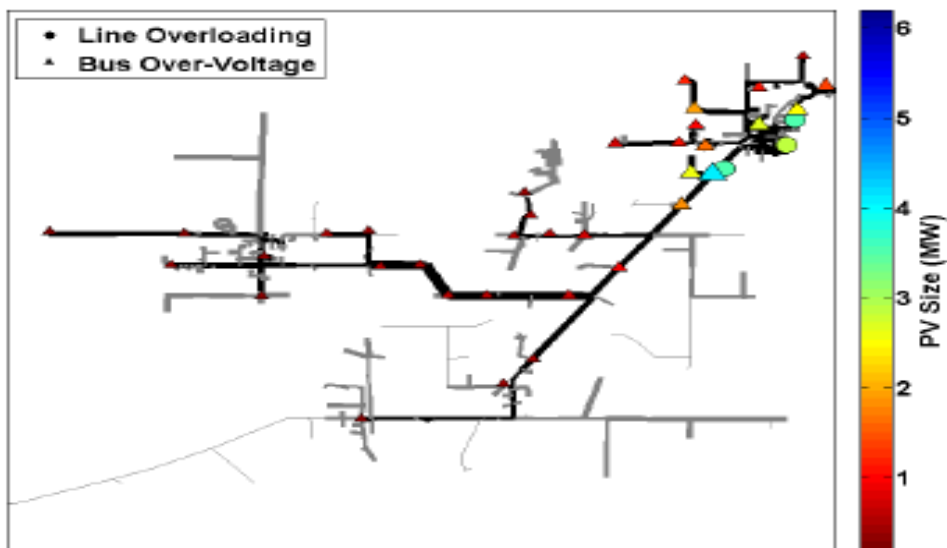
- How much PV can we put on a distribution circuit?
- Constraints:
 - Under and over-voltages
 - Thermal limits
 - Protections
 - Back-feeding
- Complexity
 - Variability (seasonal, daily, second to second).
 - Need quasi-static time series (QSTS) Simulation
 - One-year, at 1 sec granularity (31M solutions).
 - Local and distributed PV
 - Effect of controllers and smart inverters

PV Impact and Hosting Capacity

PV Impact Signature

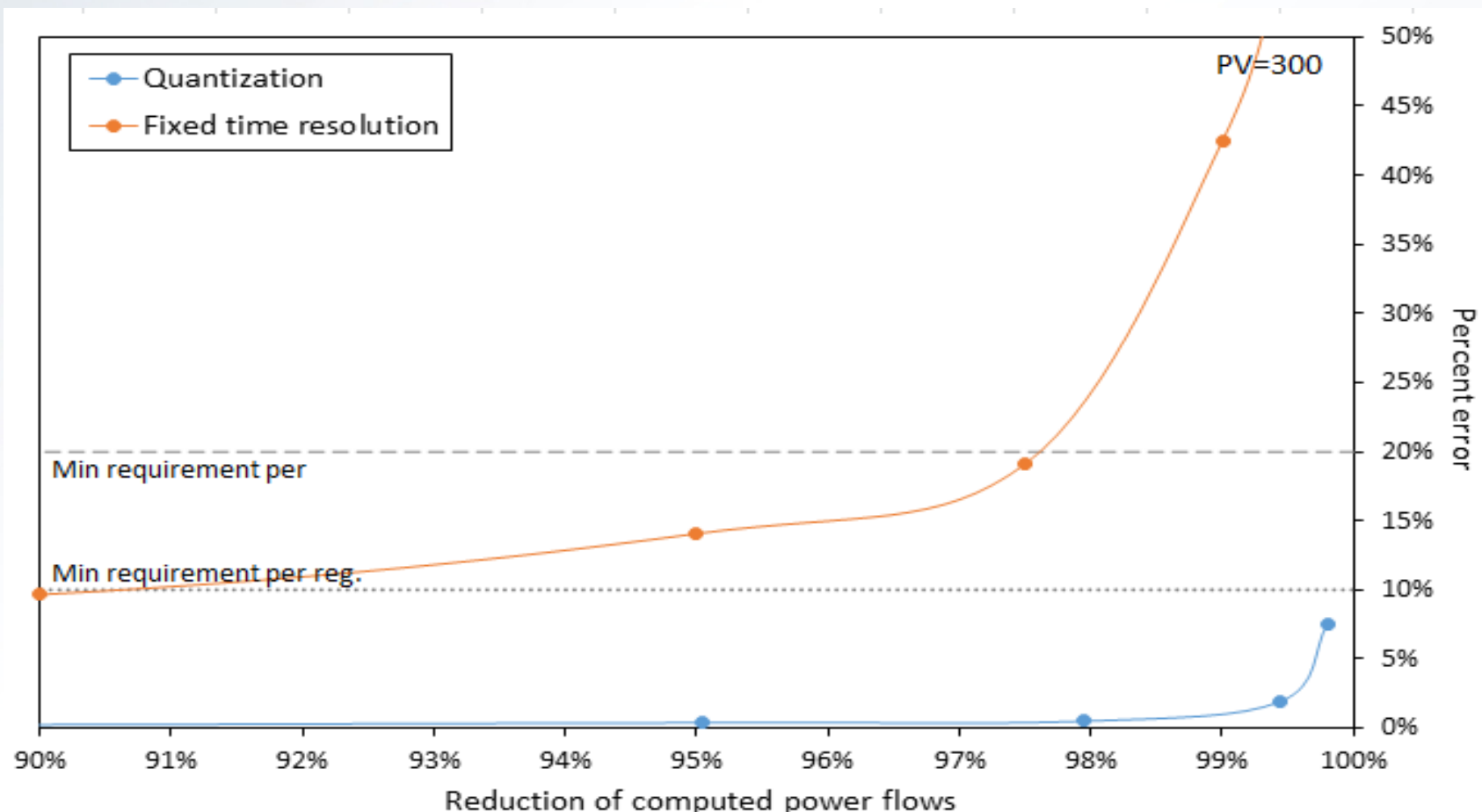


Locational Hosting Capacity



Quantization

- Various methods for computation improvement: circuit reduction, parallelization.
- Recent improvements: quantization
 - Accurate results, ~ 5% of solutions compared to brute-force.



Towards DER Hosting Capacity

- Challenges:
 - System impact and hosting capacity determination for solutions with all types of DERs, (e.g. solar + storage).
 - Hosting capacity for circuits that already host complex DERs.

Thanks

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