GridSpice - A Virtual Test Bed for Smart Grid

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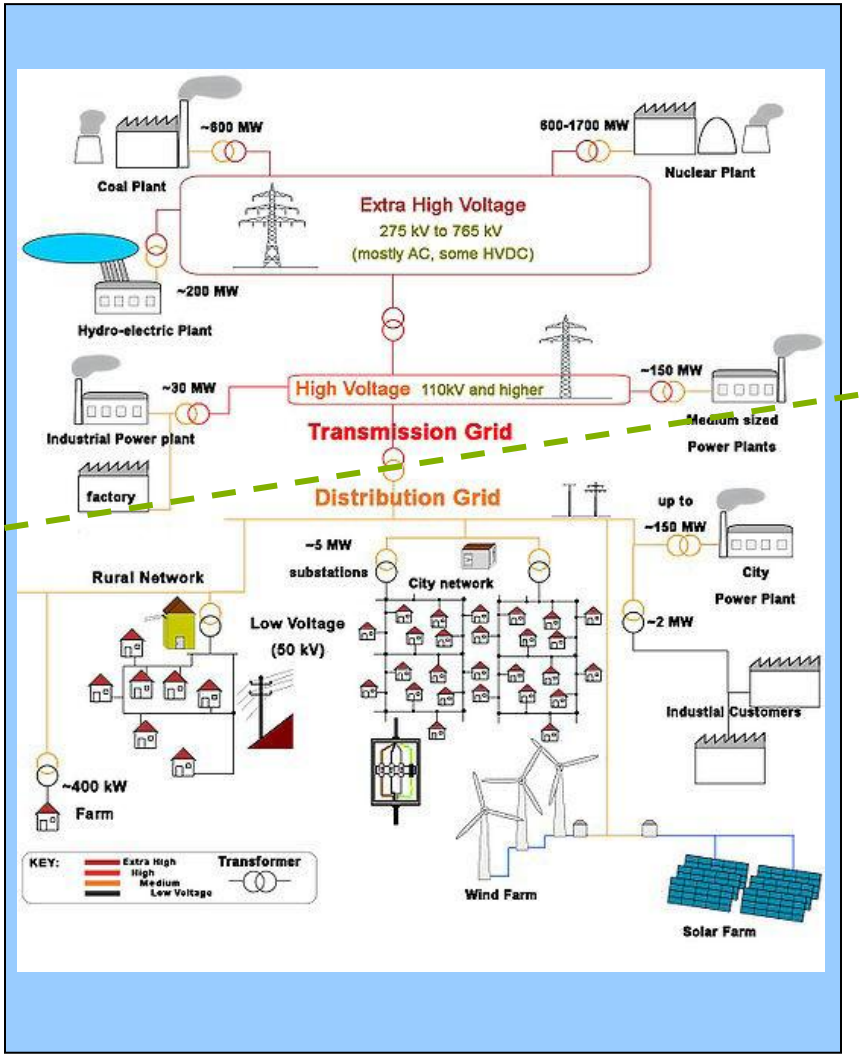
GridSpice: Project Overview

- Team:
  - Kyle Anderson, lead developer, PhD student, CS
  - Jimmy Du, undergrad EE
  - Yizheng Liao, MS student, EE
  - Vikas Yendluri – undergrad, EE
  - Past Students
    - Alex Cousland, Rishi Guarpuay, Vijay Bhatt, Jeffrey Wong
  - Prof Abbas El Gamal, faculty PI
  - Amit Narayan, Project Director
- Funding:
  - TomKat Center
  - Cisco Systems
  - GE

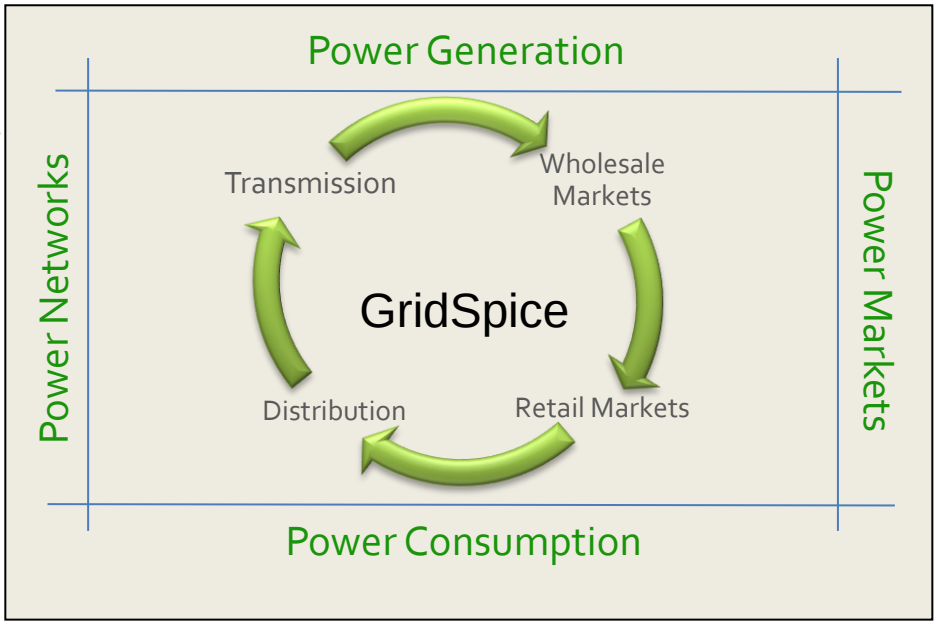
Motivation



Demand is becoming "elastic"

Supply is becoming "distributed" and "variable"

Storage is becoming "viable"

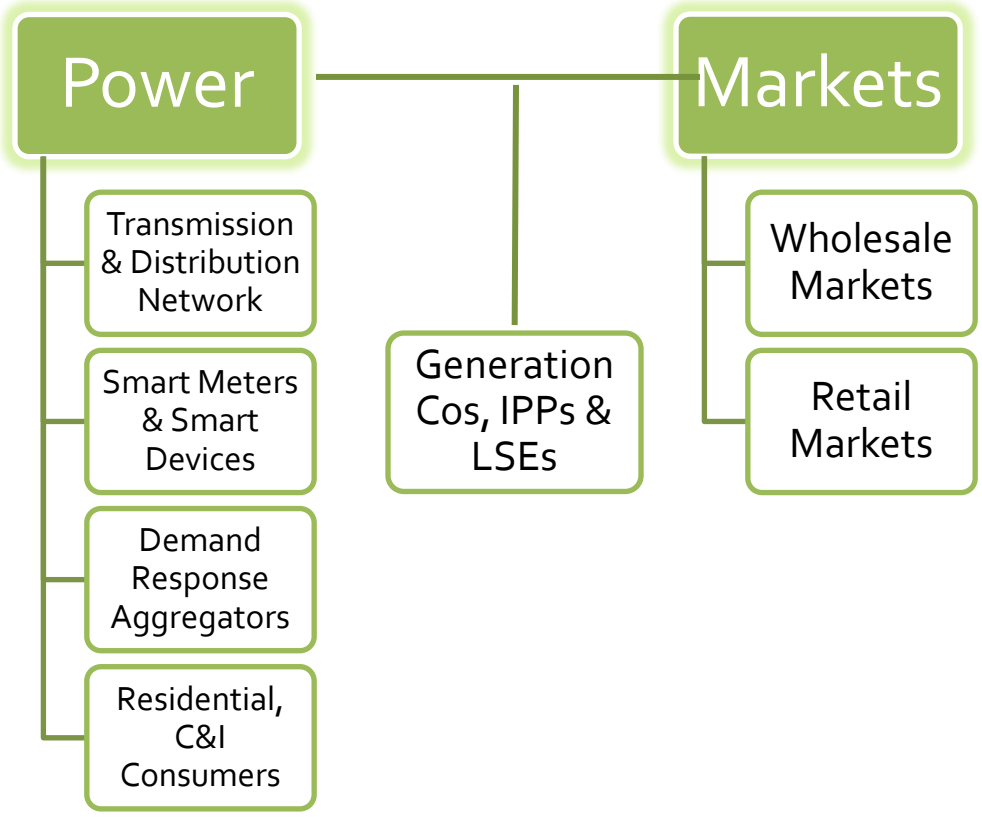


Massive amounts of data - from smart meters, sensors and buildings

Can we *leverage data and computational power to understand & optimize the grid operation?*

Design Objectives

Modeling the interactions between all participants of a smart grid



- Comprehensive Modeling Capability
- "System-level" view instead of "component"-level
- Steady-state operation
- Agent-based modeling
- High-Performance algorithms
- Real-world calibration
- Open-Source availability
- Cloud-Deployment

GridSpice Status

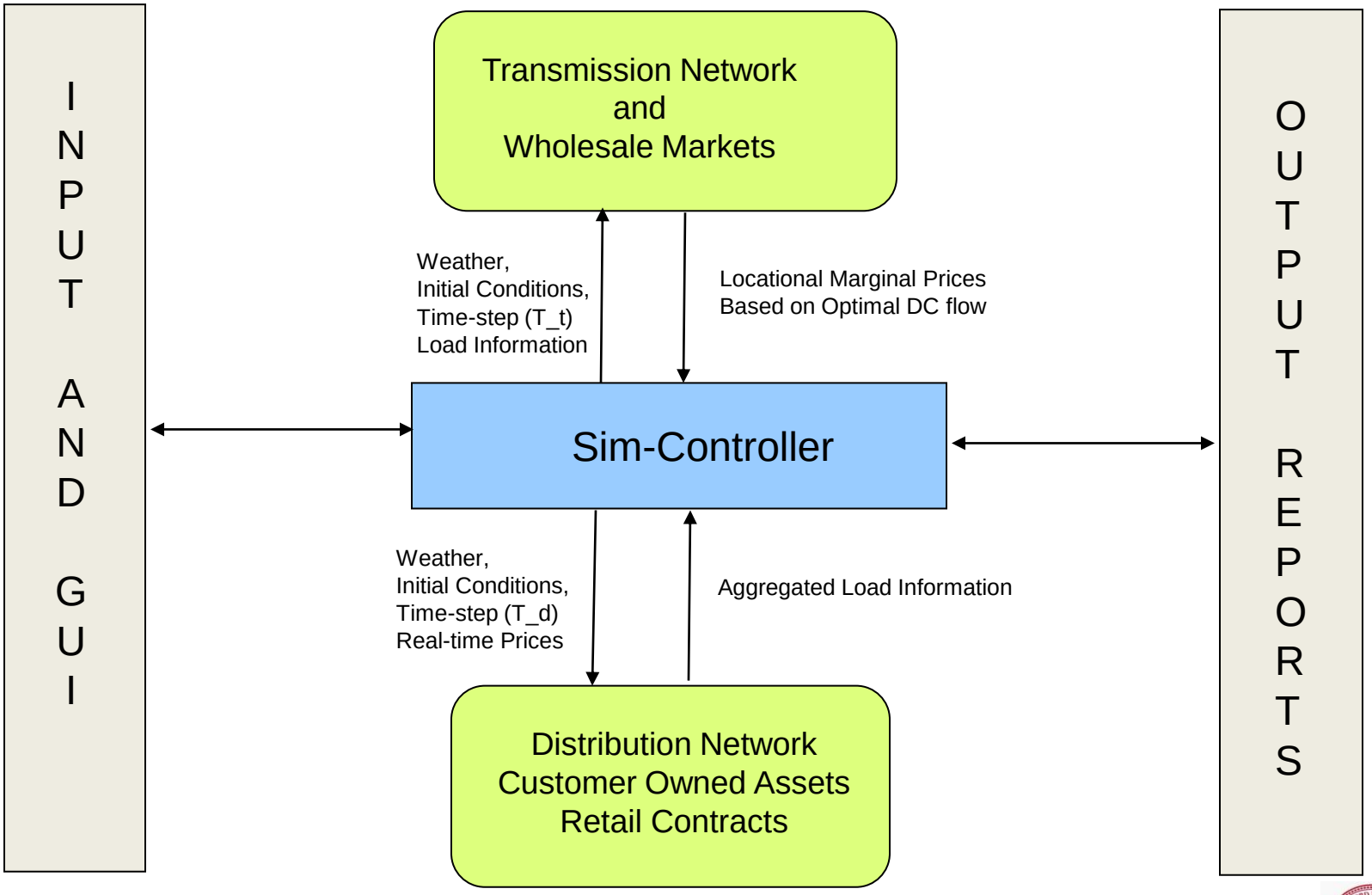
Available in open source under a BSD License

Code available for download at www.gridspice.org

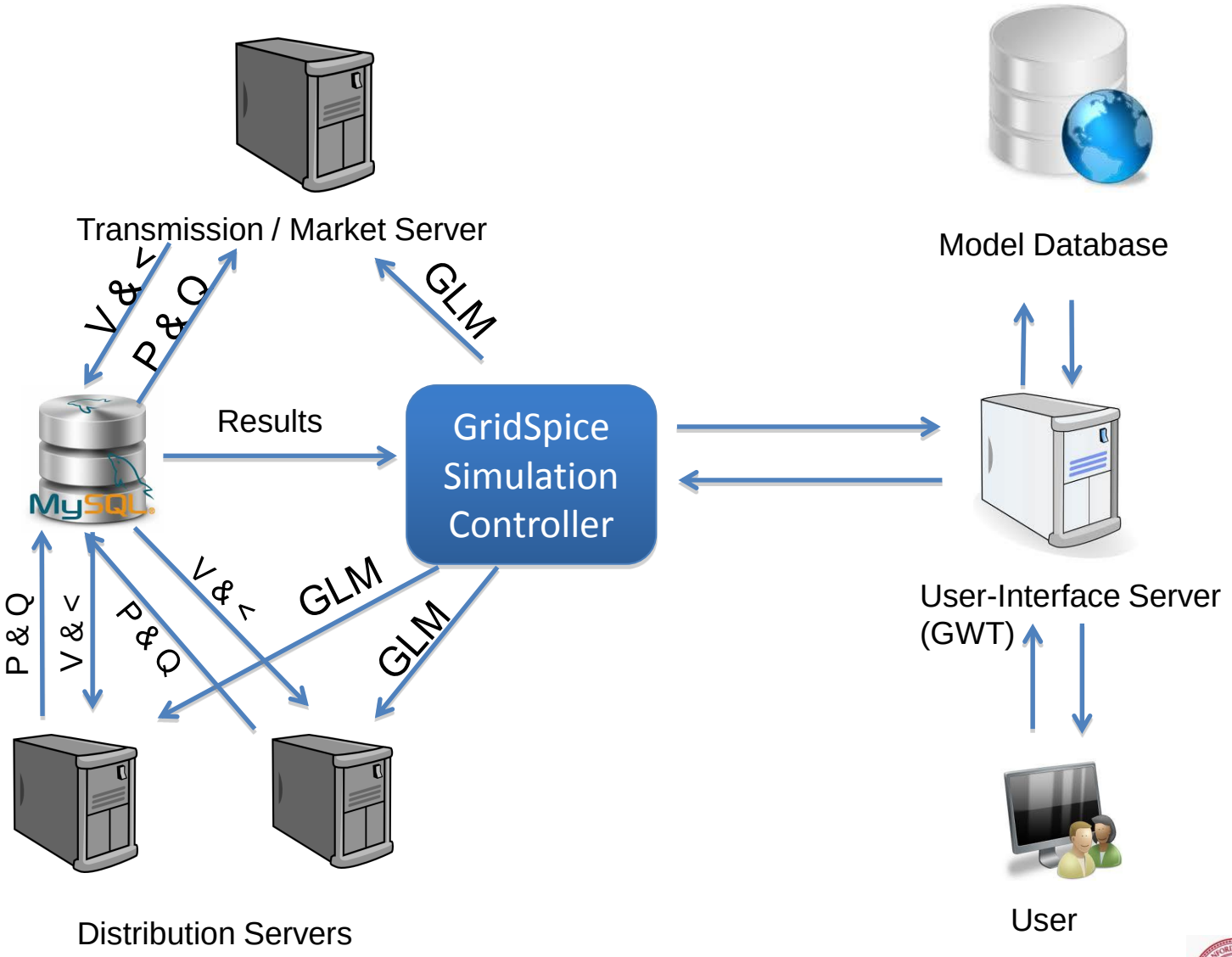
Cloud–hosted version available to Stanford collaborators

GridSpice - Applications

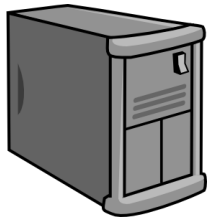
GridSpice Major Components



GRIDSPICE


Transmission / Market Server
Model Database
V & v
P & Q
GLM
Results
GridSpice Simulation Controller
MySQL
User-Interface Server (GWT)
P & Q
V & v
P & Q
V & v
GLM
GLM
Distribution Servers
User

GRIDSPICE



Transmission / Market Server (MATPOWER & Gridlab-D)

Model Database

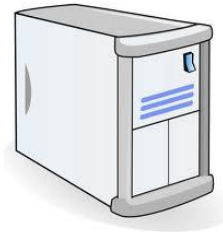
V & ∠

P & Q

GLM

Results

GridSpice Simulation Controller



User-Interface Server (GV

P & Q

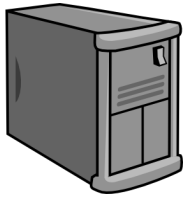
V & ∠

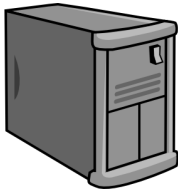
V & ∠

P & Q

GLM

GLM





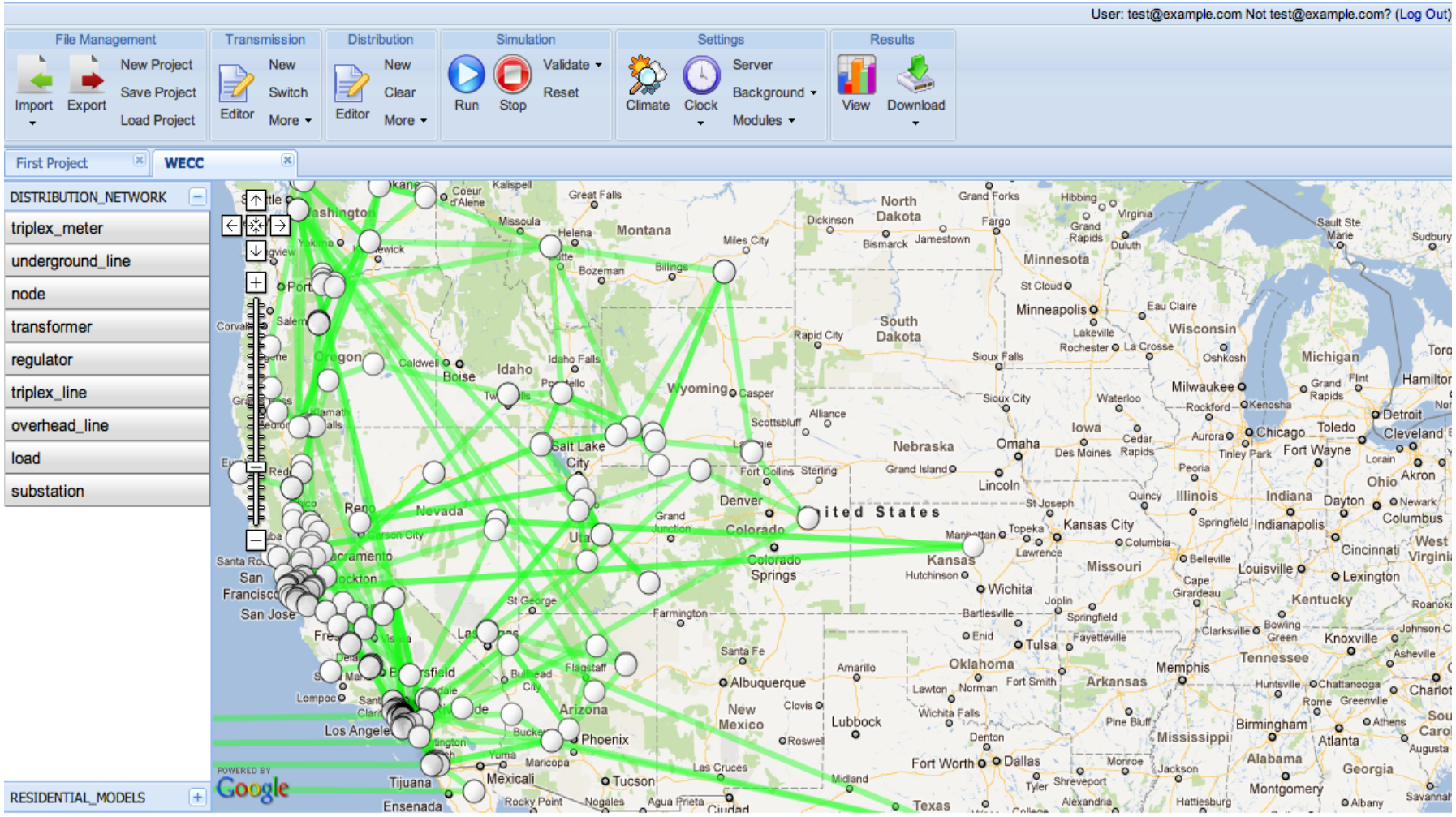
Distribution Servers (Gridlab-D)

Us

er

GRIDSPICE

User Interface inside the Browser



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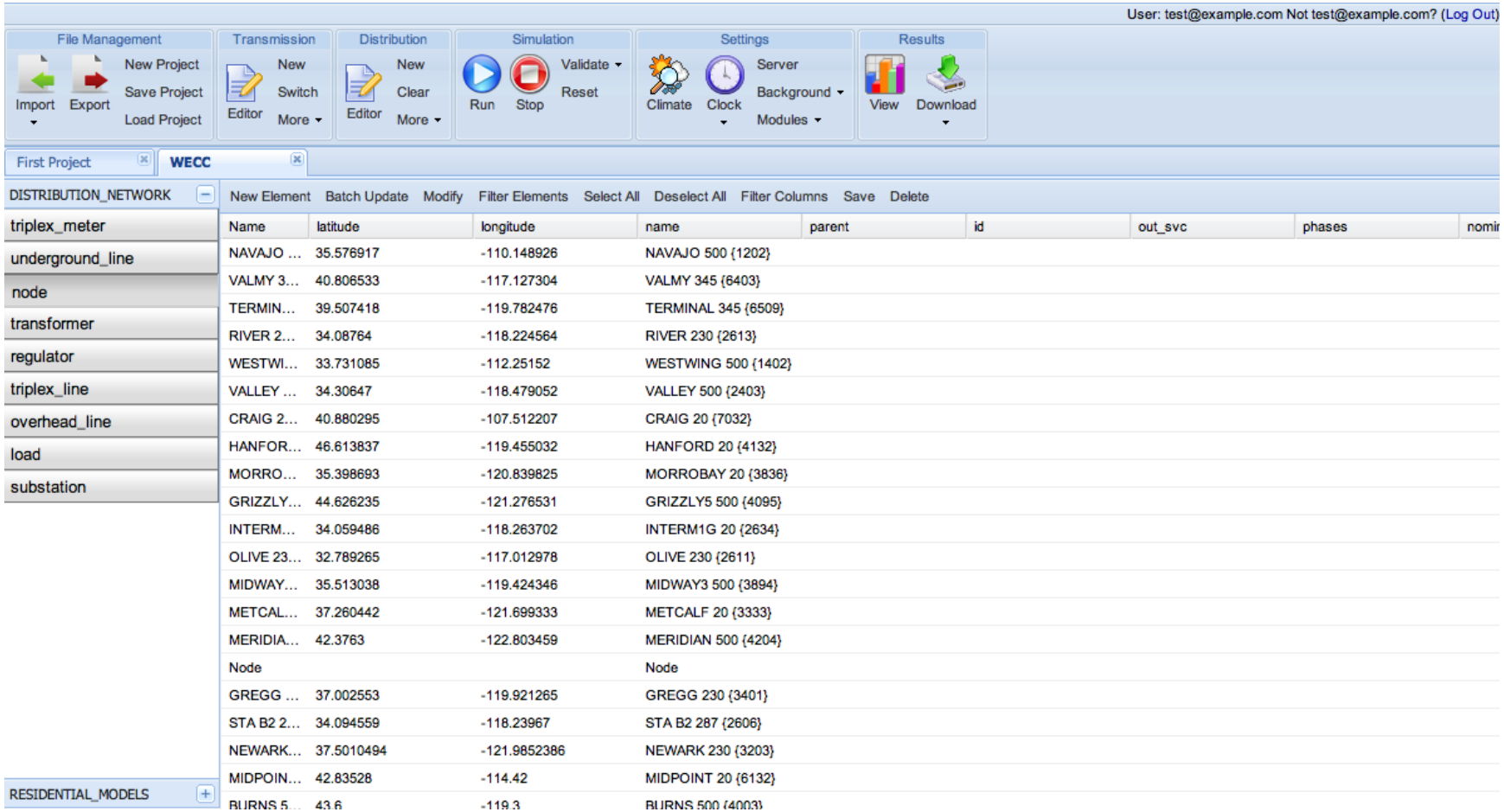
Explorer View



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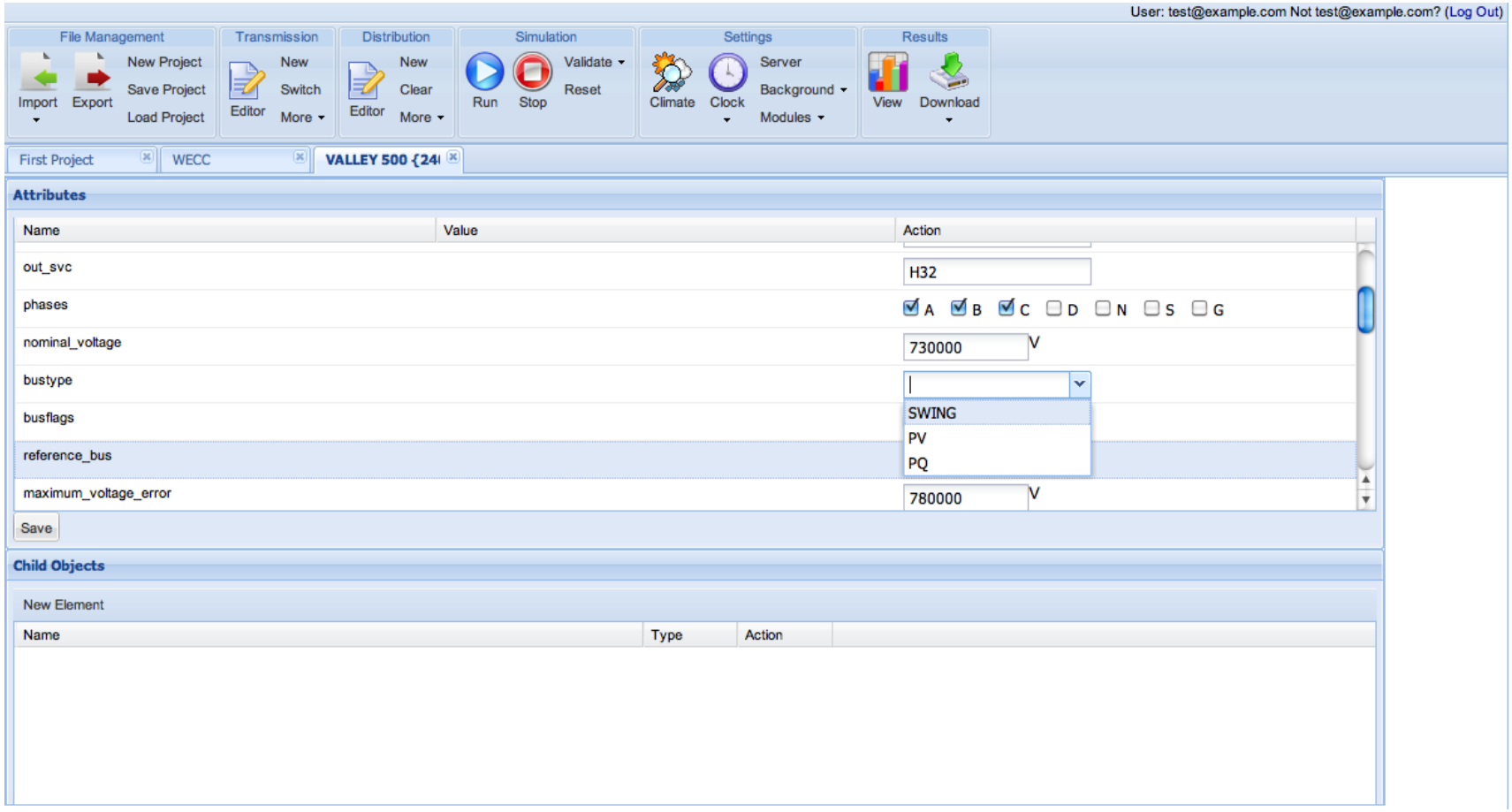
Element Editor



Model Database

User gets an account on the server

- Account tied to Google ID

User can upload models to the account

- User defines permissions for model (shared or private)
- Private models encrypted using AES and user-provided key
- Client authenticated using gmail (all models) & encryption key (private models)

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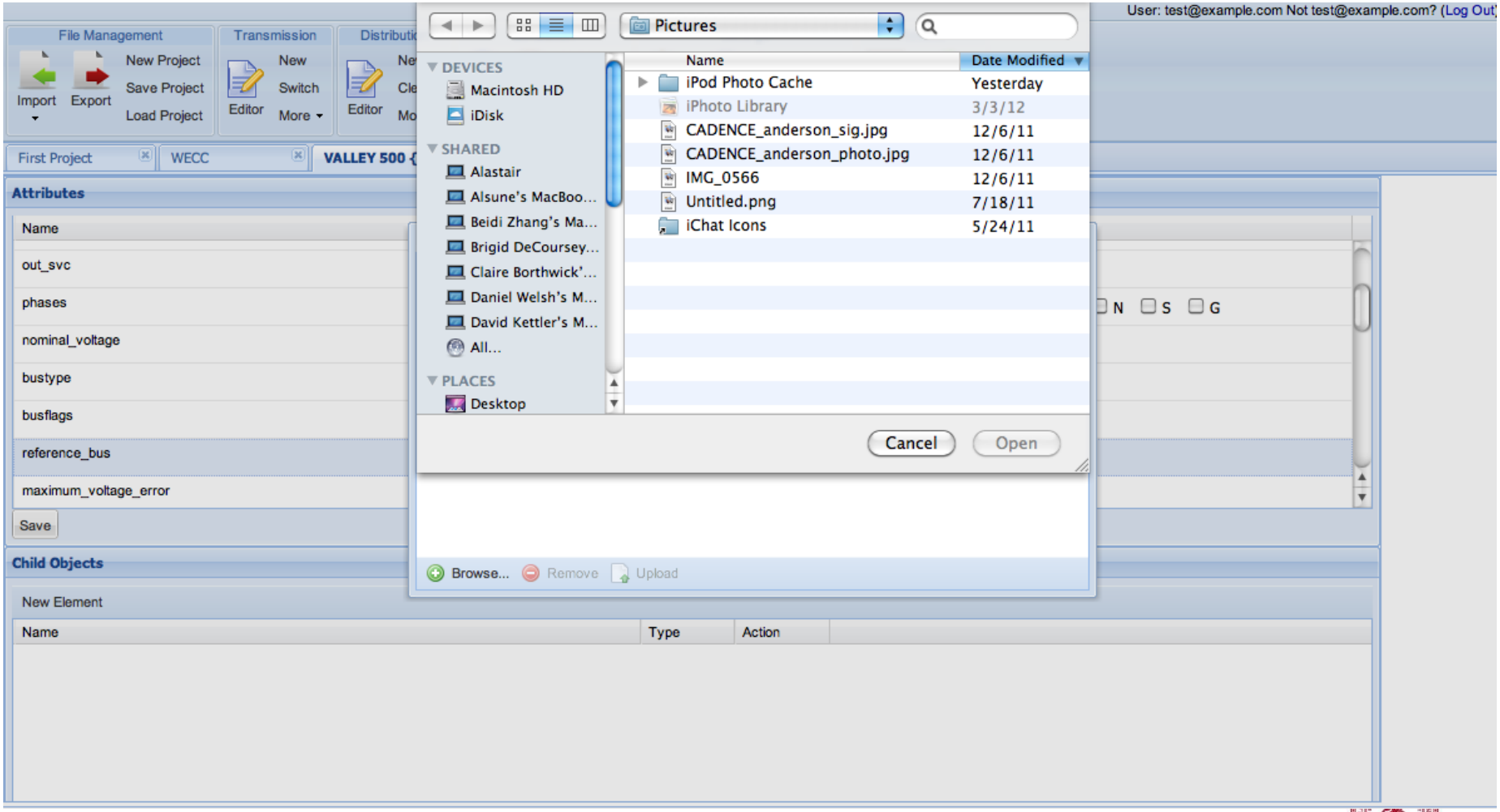
Model Upload



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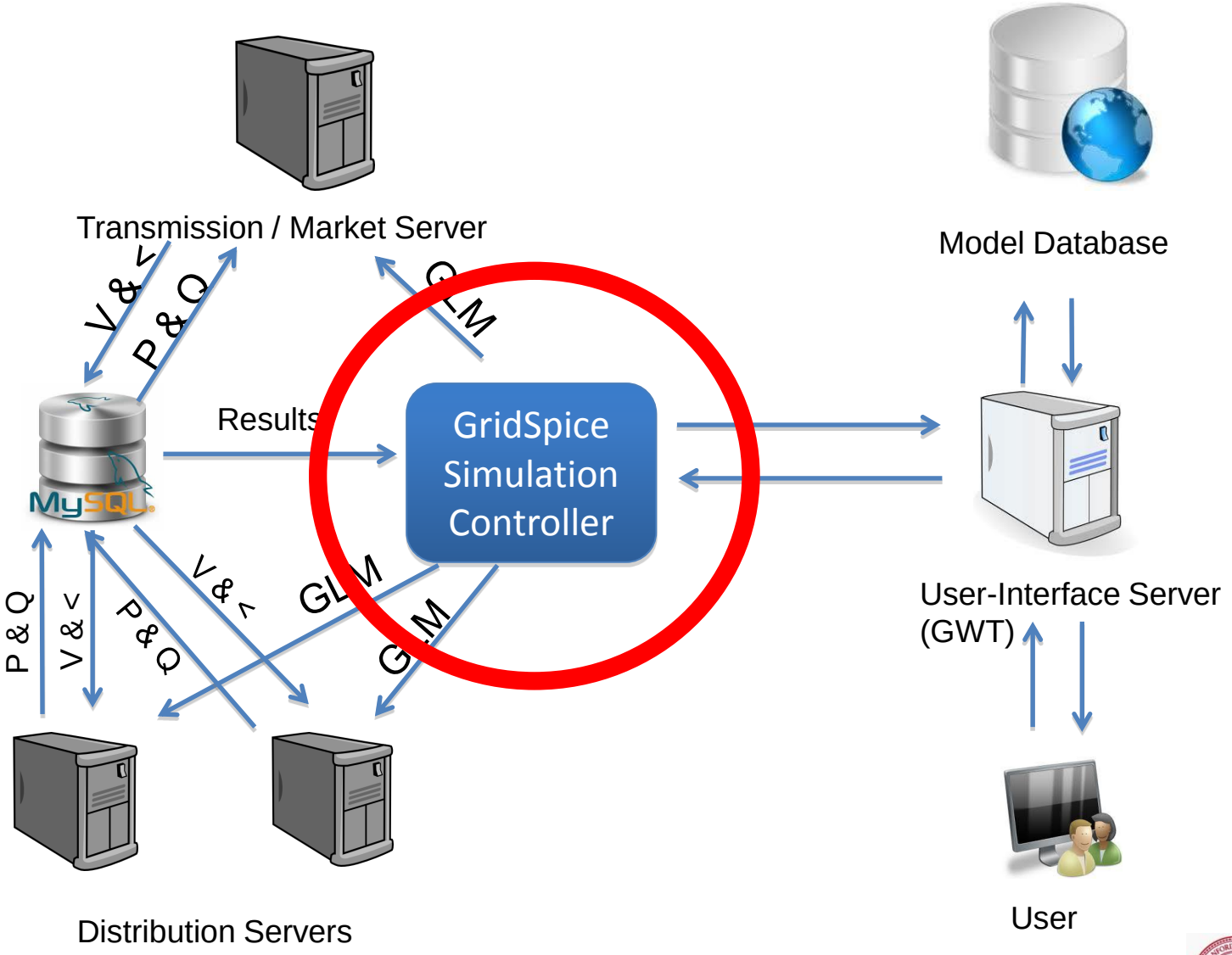
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Distribution Servers
User

GridSpice Simulation Handler

Initialization

- Validates models and returns results to user
- Partitions simulation agents into logical subgroups (Transmission & Distribution)
- Provisions available machines for simulation.

Monitoring

- Polls simulation servers for errors
- Reports simulation progress & intermediate results to client UI

Completion

- Aggregates result output files from all recorded agents
- Sends results to client UI
- Turns off machines if necessary

Distribution Network Simulation

Each feeder is simulated on a separate machine

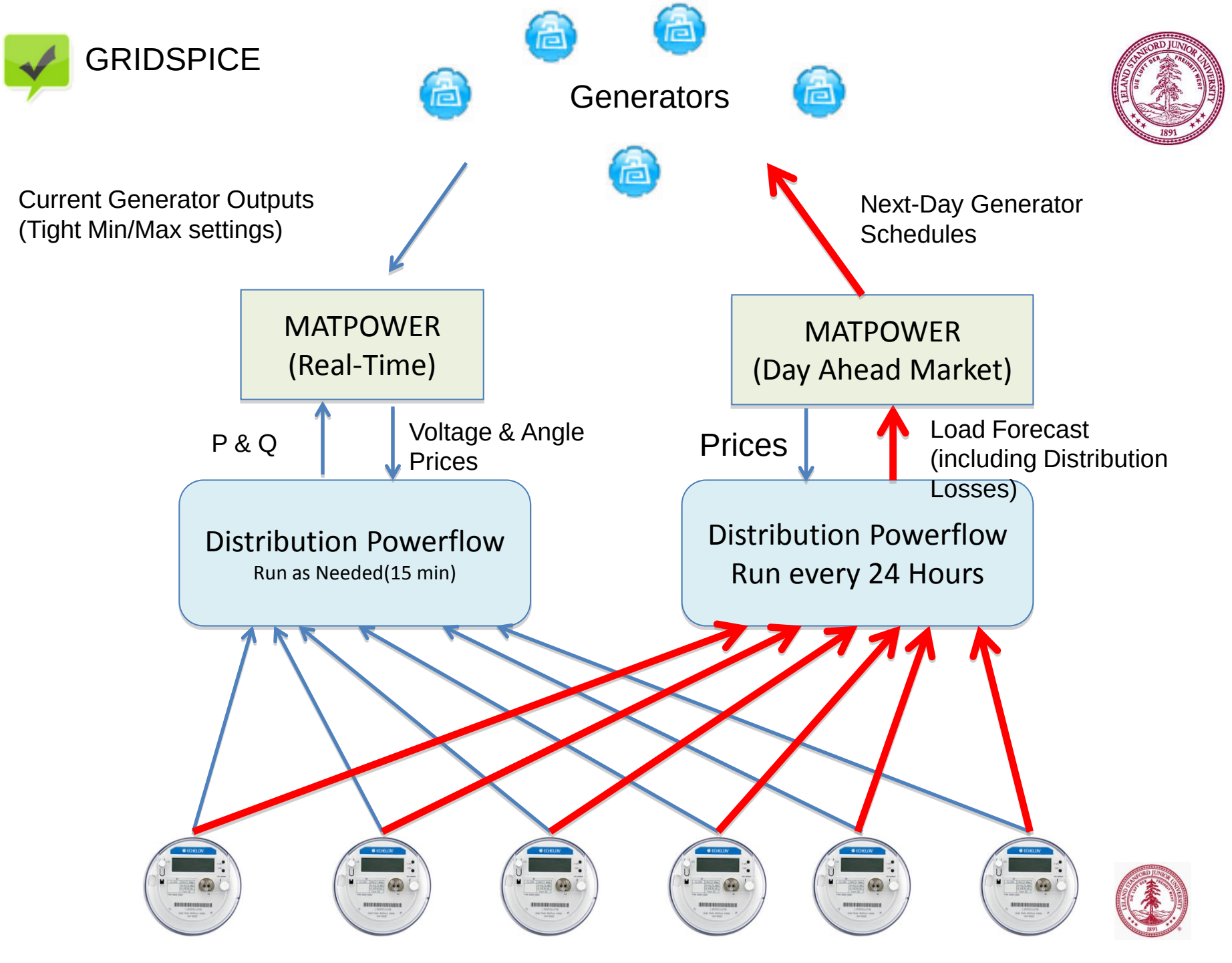
The powerflow solver is run at the distribution network.

Results passed to the parent bus on the transmission network.

Prototypical Feeder Models (PNNL)

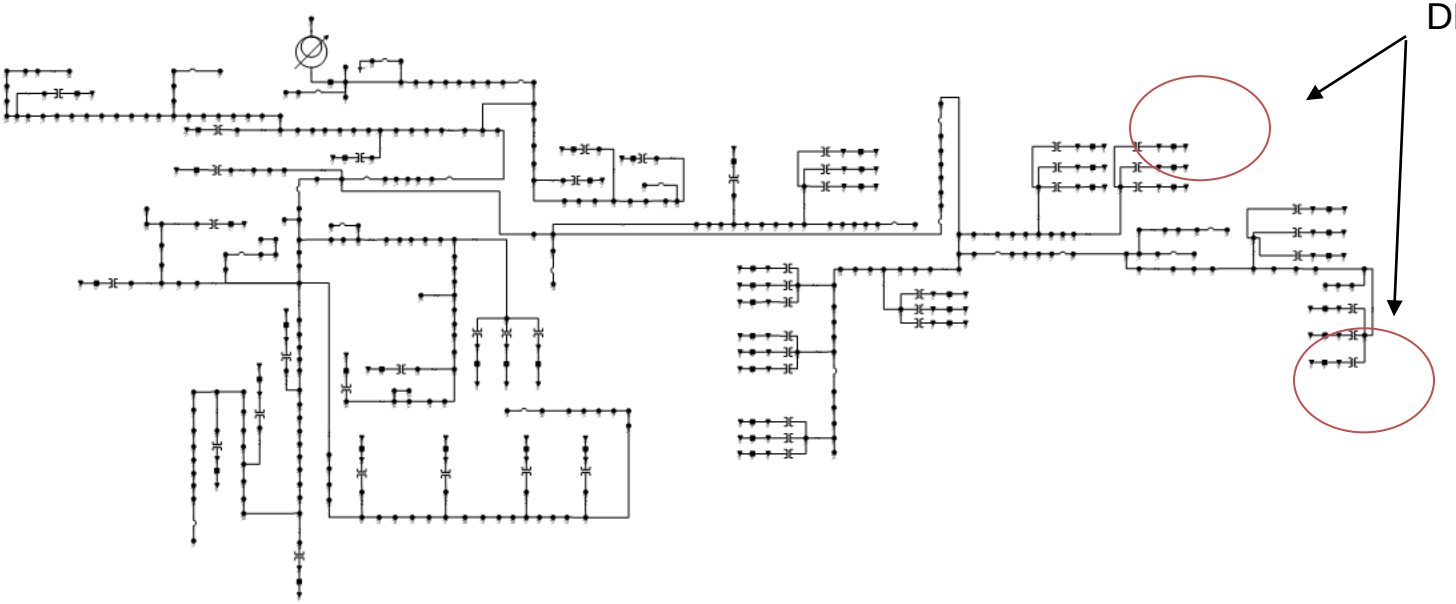
- Feeder models based on prototypical feeders provided by PNNL
- Models for homes and commercial buildings constructed using load forecasting
- Uses smart meter data from SPP pilot program

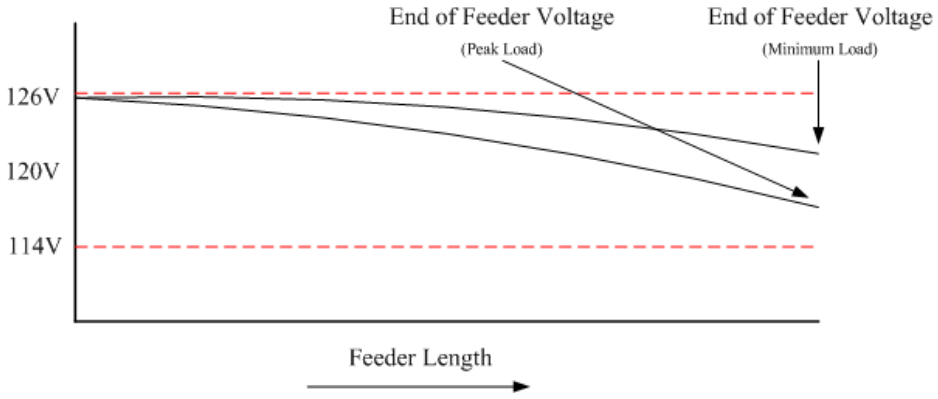
kV	kVA	Description
12.5	7152	Moderate suburban and rural
12.47	2836	Moderate suburban and light rural
12.47	1362	Small urban center
12.47	5334	Heavy suburban
24.9	2105	Light rural
12.47	6046	Light urban
12.47	6098	Moderate suburban
12.47	1411	Light suburban
24.9	17021	Moderate urban
34.5	8893	Light rural
12.47	8417	Heavy urban
12.47	4322	Moderate urban
12.47	7880	Heavy suburban
13.8	5530	Heavy urban with rural spur
12.5	2218	Light suburban and moderate urban
24.9	948	Light rural
13.8	9430	Heavy suburban and moderate urban
12.47	4500	Moderate suburban and heavy urban
13.8	9200	Moderate rural
12.47	7700	Moderate suburban and urban
12.47	8700	Moderate suburban and light urban
22.9	12050	Heavy suburban and moderate urban
34.5	11800	Moderate suburban and light urban
12.47	5200	Single large commercial or industrial

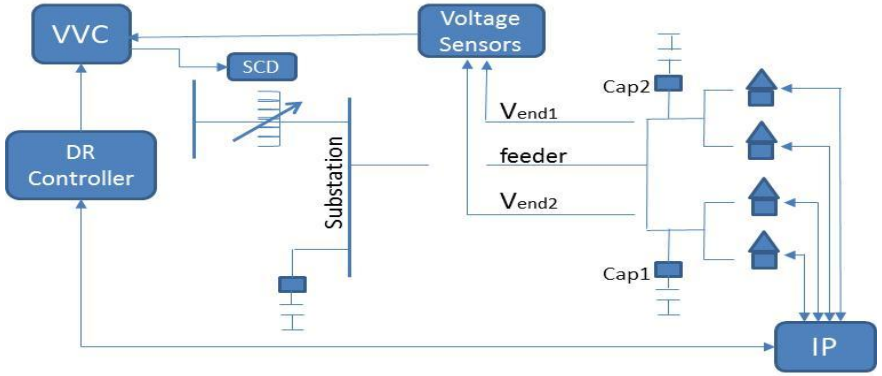

GRIDSPICE
Generators
Current Generator Outputs
(Tight Min/Max settings)
Next-Day Generator
Schedules
MATPOWER
(Real-Time)
MATPOWER
(Day Ahead Market)
P & Q
Voltage & Angle
Prices
Prices
Load Forecast
(including Distribution
Losses)
Distribution Powerflow
Run as Needed(15 min)
Distribution Powerflow
Run every 24 Hours

Example: CVR and DR

Hot-spots – can DR be used?

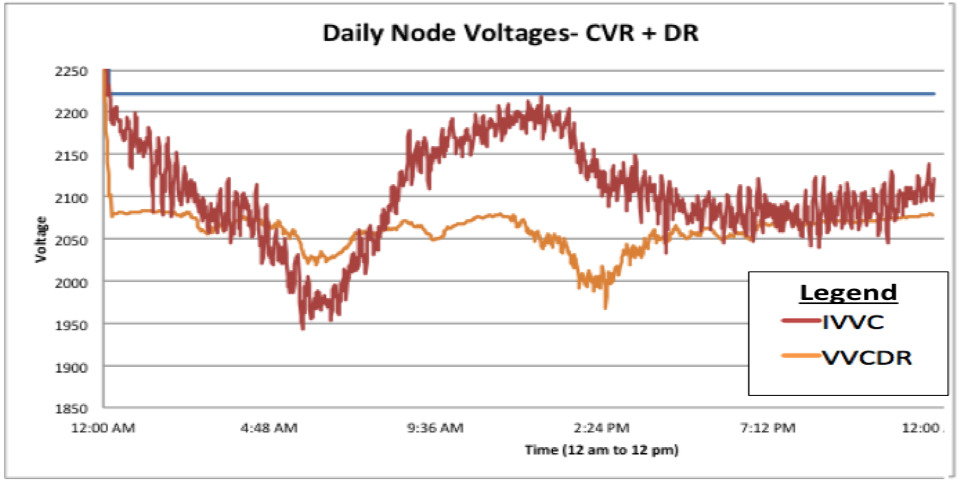


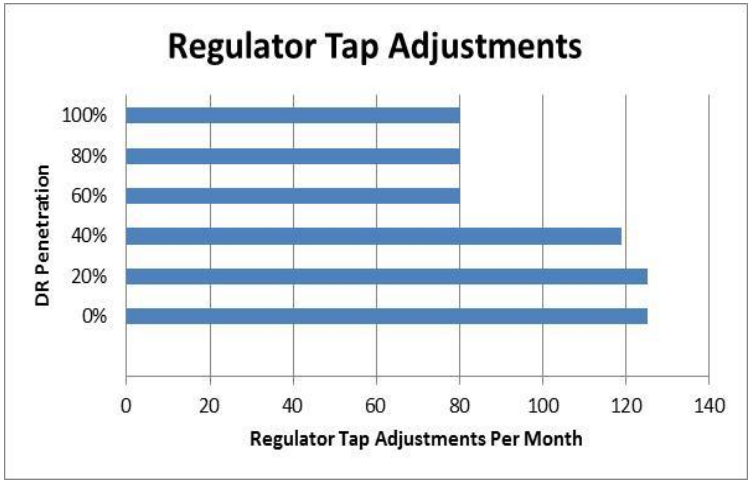




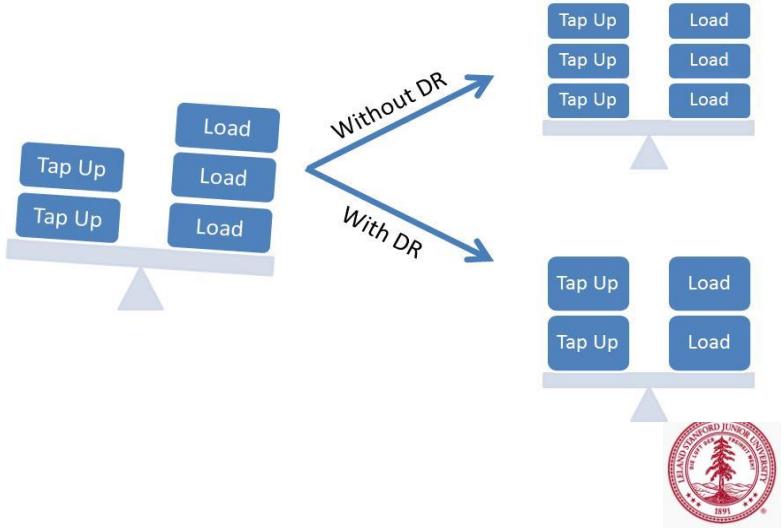
IVVCDR – Anderson, Narayan, IEEE SmartGridComm 2011

Node Voltage for Hot Summer Day





DR Penetration	V_{set} TWA	Minimum V_{des}
0%	122.1V	120V
20%	122.6V	120V
40%	123.1V	120V
60%	119.2V	118V
80%	118.8V	118V
100%	118.8V	118V
IVVC	122.1V	120V



Conclusion

GridSpice: Open Source Cloud Based Platform for Modeling and Simulation of Smart Grid.

- ✓ No Hardware to Purchase
- ✓ No Software to Install
- ✓ Available in Open Source