

# GridSpice - A Virtual Test Bed for Smart Grid

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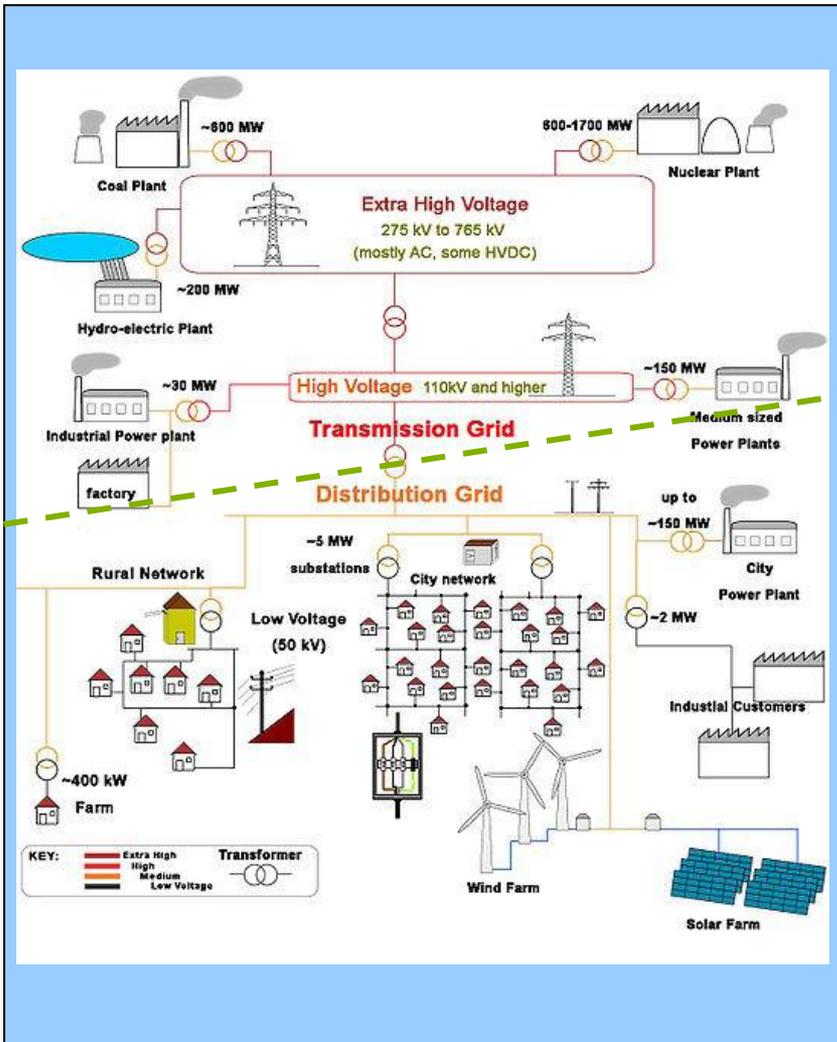


# GridSpice: Project Overview

- 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



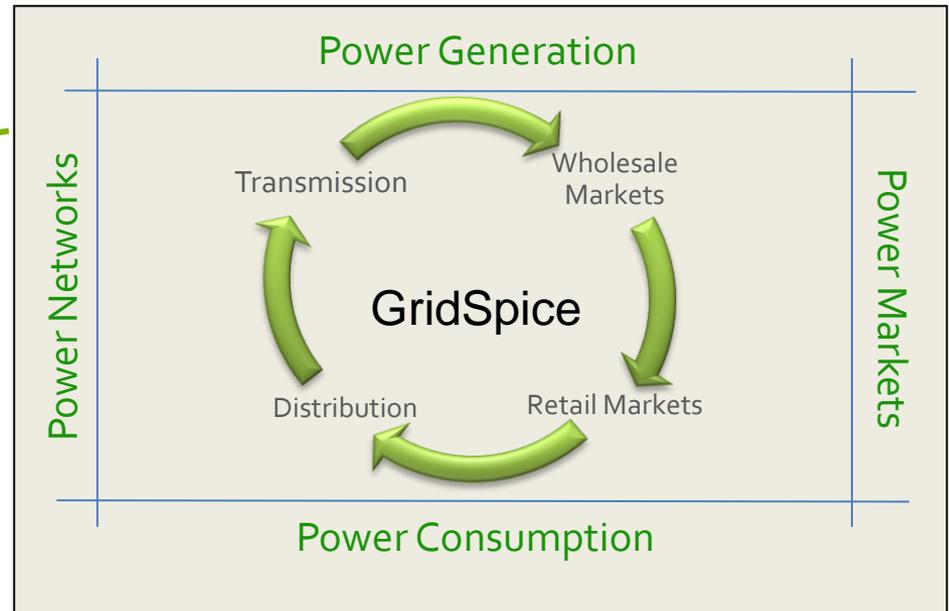
# Motivation



Demand is becoming “elastic”

Supply is becoming “distributed” and “variable”

Storage is becoming “viable”



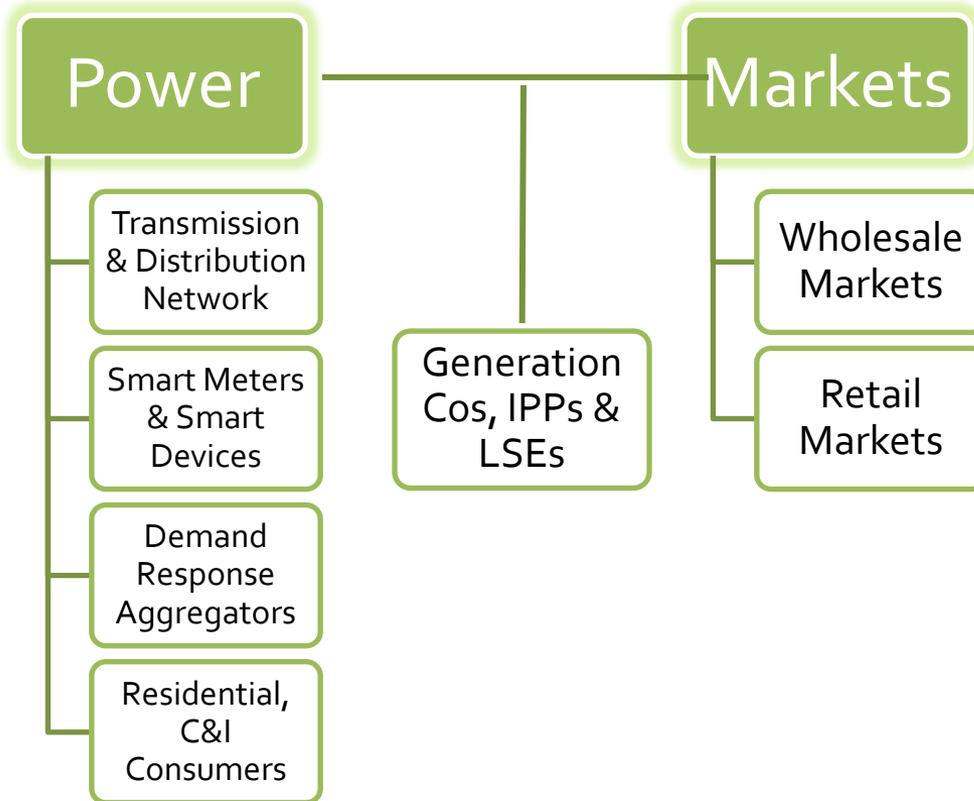
Massive amounts of data - from smart meters, sensors and buildings

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

# GridSpice Status



Available in open source under a BSD License

Code available for download at [www.gridspice.org](http://www.gridspice.org)

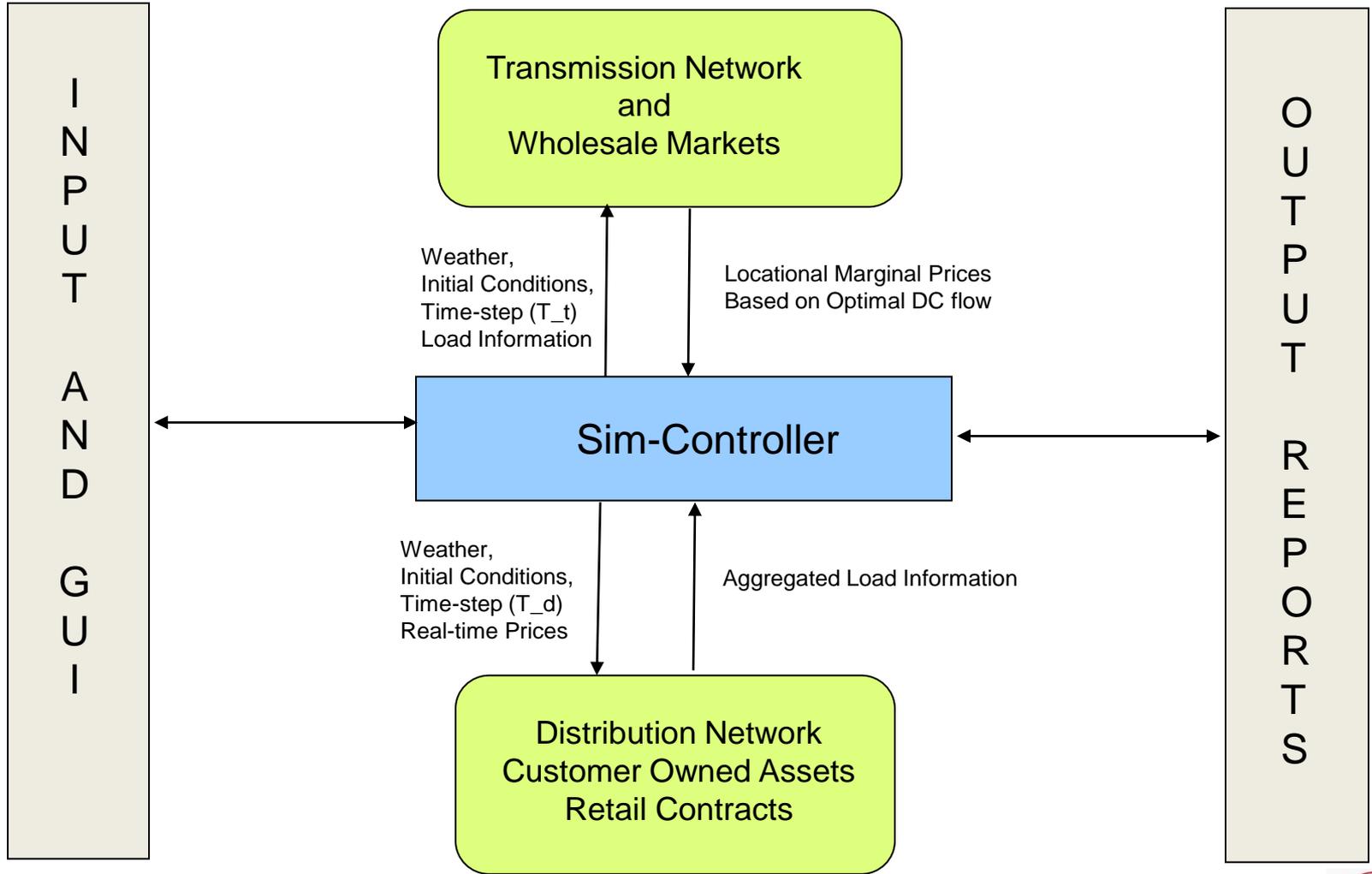
Cloud-hosted version available to Stanford collaborators



# GridSpice - Applications

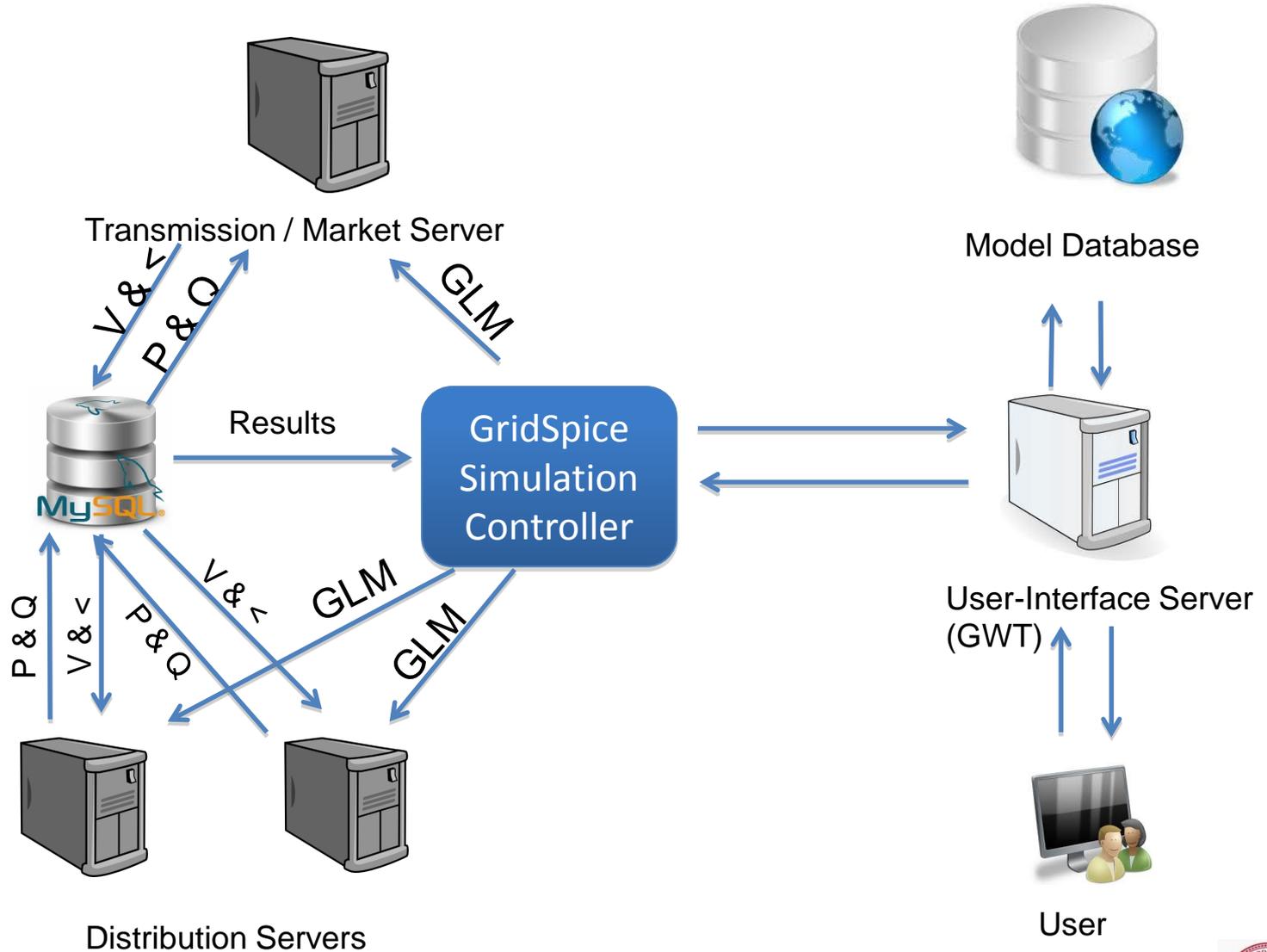


# GridSpice Major Components



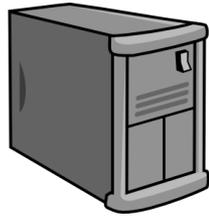


# GRIDSPICE



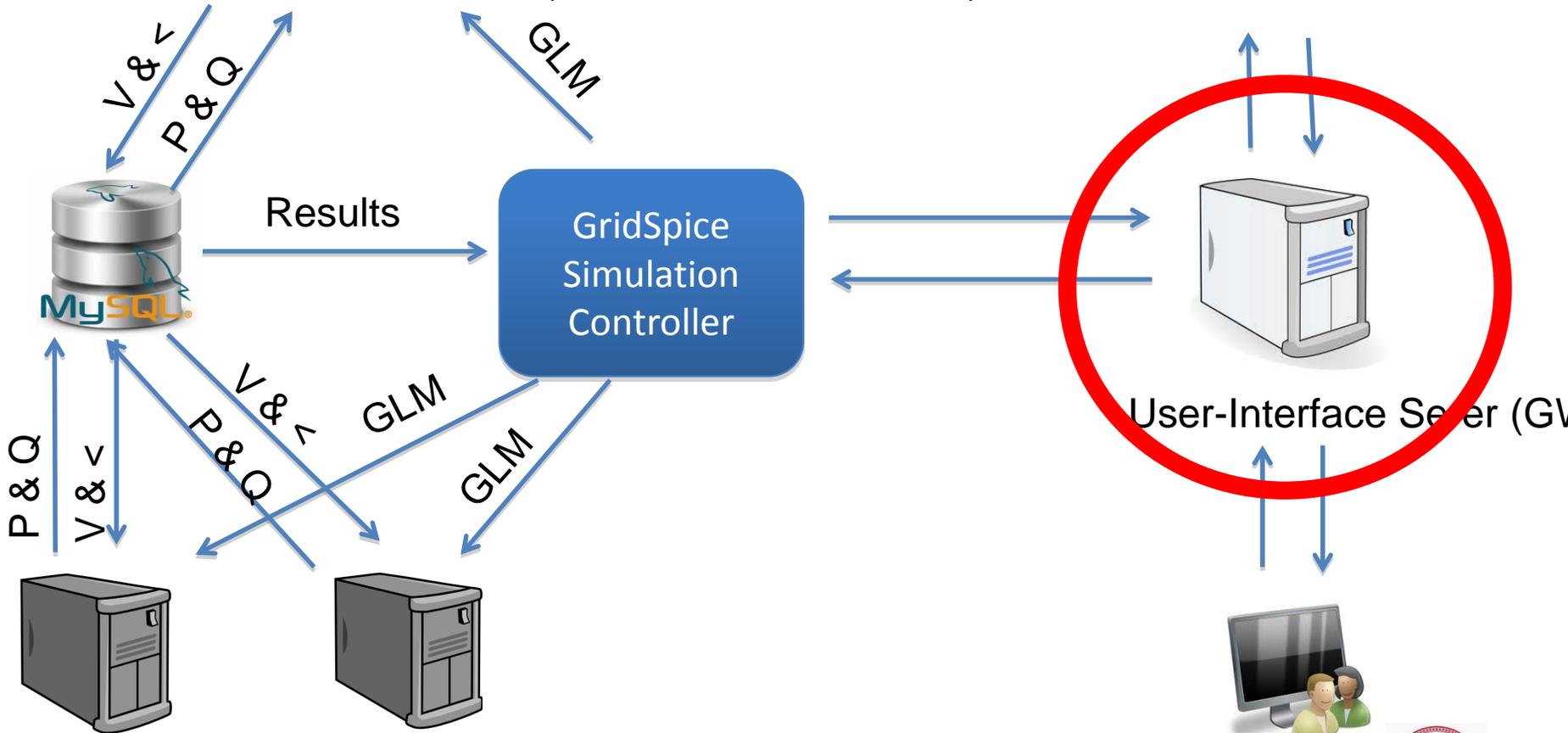


# GRIDSPICE



Transmission / Market Server (MATPOWER & Gridlab-D)

Model Database



Distribution Servers (Gridlab-D)

User-Interface Server (GV)

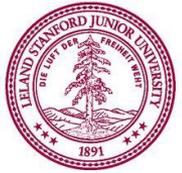
er

Us





# User Interface inside the Browser



User: test@example.com Not test@example.com? (Log Out)

**File Management**

Import Export

New Project Save Project Load Project

**Transmission**

New Switch Editor More

**Distribution**

New Clear Editor More

**Simulation**

Run Stop Validate Reset

**Settings**

Server Background Modules

Climate Clock

**Results**

View Download

First Project WECC

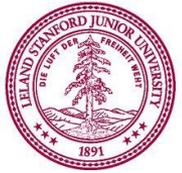
DISTRIBUTION\_NETWORK

- triplex\_meter
- underground\_line
- node
- transformer
- regulator
- triplex\_line
- overhead\_line
- load
- substation

Map showing a power distribution network across the Western United States, including states like Washington, Oregon, California, Nevada, Idaho, Utah, Arizona, and parts of Montana, Wyoming, Colorado, and New Mexico. The network consists of numerous nodes (substations) connected by green lines (transmission lines).

RESIDENTIAL\_MODELS





# Explorer View

User: test@example.com Not test@example.com? (Log Out)

File Management: Import, Export, New Project, Save Project, Load Project

Transmission: New, Switch, Editor, More

Distribution: New, Clear, Editor, More

Simulation: Run, Stop, Validate, Reset

Settings: Climate, Clock, Server, Background, Modules

Results: View, Download

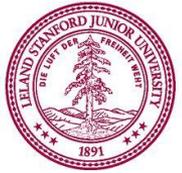
First Project: WECC

DISTRIBUTION\_NETWORK

	Name	latitude	longitude	name	parent	id	out_svc	phases	nomir
triplex_meter									
underground_line	NAVAJO ...	35.576917	-110.148926	NAVAJO 500 {1202}					
node	VALMY 3...	40.806533	-117.127304	VALMY 345 {6403}					
transformer	TERMIN...	39.507418	-119.782476	TERMINAL 345 {6509}					
regulator	RIVER 2...	34.08764	-118.224564	RIVER 230 {2613}					
triplex_line	WESTWI...	33.731085	-112.25152	WESTWING 500 {1402}					
overhead_line	VALLEY ...	34.30647	-118.479052	VALLEY 500 {2403}					
load	CRAIG 2...	40.880295	-107.512207	CRAIG 20 {7032}					
substation	HANFOR...	46.613837	-119.455032	HANFORD 20 {4132}					
	MORRO...	35.398693	-120.839825	MORROBAY 20 {3836}					
	GRIZZLY...	44.626235	-121.276531	GRIZZLY5 500 {4095}					
	INTERM...	34.059486	-118.263702	INTERM1G 20 {2634}					
	OLIVE 23...	32.789265	-117.012978	OLIVE 230 {2611}					
	MIDWAY...	35.513038	-119.424346	MIDWAY3 500 {3894}					
	METCAL...	37.260442	-121.699333	METCALF 20 {3333}					
	MERIDIA...	42.3763	-122.803459	MERIDIAN 500 {4204}					
	Node			Node					
	GREGG ...	37.002553	-119.921265	GREGG 230 {3401}					
	STA B2 2...	34.094559	-118.23967	STA B2 287 {2606}					
	NEWARK...	37.5010494	-121.9852386	NEWARK 230 {3203}					
	MIDPOIN...	42.83528	-114.42	MIDPOINT 20 {6132}					
	RIURNS 5...	43.6	-119.3	RIURNS 500 {4003}					

RESIDENTIAL\_MODELS





# Element Editor

User: test@example.com Not test@example.com? (Log Out)

File Management: Import, Export, New Project, Save Project, Load Project

Transmission: New, Switch, Editor, More

Distribution: New, Clear, Editor, More

Simulation: Run, Stop, Validate, Reset

Settings: Climate, Clock, Server, Background, Modules

Results: View, Download

First Project | WECC | VALLEY 500 {24}

### Attributes

Name	Value	Action
out_svc	H32	
phases	<input checked="" type="checkbox"/> A <input checked="" type="checkbox"/> B <input checked="" type="checkbox"/> C <input type="checkbox"/> D <input type="checkbox"/> N <input type="checkbox"/> S <input type="checkbox"/> G	
nominal_voltage	730000 V	
bustype		
busflags	<div style="border: 1px solid black; padding: 2px;">           SWING            PV            PQ         </div>	
reference_bus		
maximum_voltage_error	780000 V	

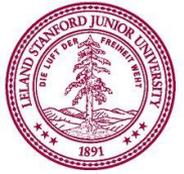
Save

### Child Objects

New Element

Name	Type	Action





# Model Database

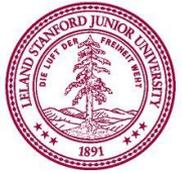
User gets an account on the server

- 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)





# Model Upload

The screenshot shows the Gridspice software interface. A file upload dialog box is open, displaying the contents of a 'Pictures' folder. The dialog box has a sidebar with categories: DEVICES (Macintosh HD, iDisk), SHARED (Alastair, Alsune's MacBoo..., Beidi Zhang's Ma..., Brigid DeCoursey..., Claire Borthwick..., Daniel Welsh's M..., David Kettler's M..., All...), and PLACES (Desktop). The main pane shows a list of files and folders with columns for Name and Date Modified.

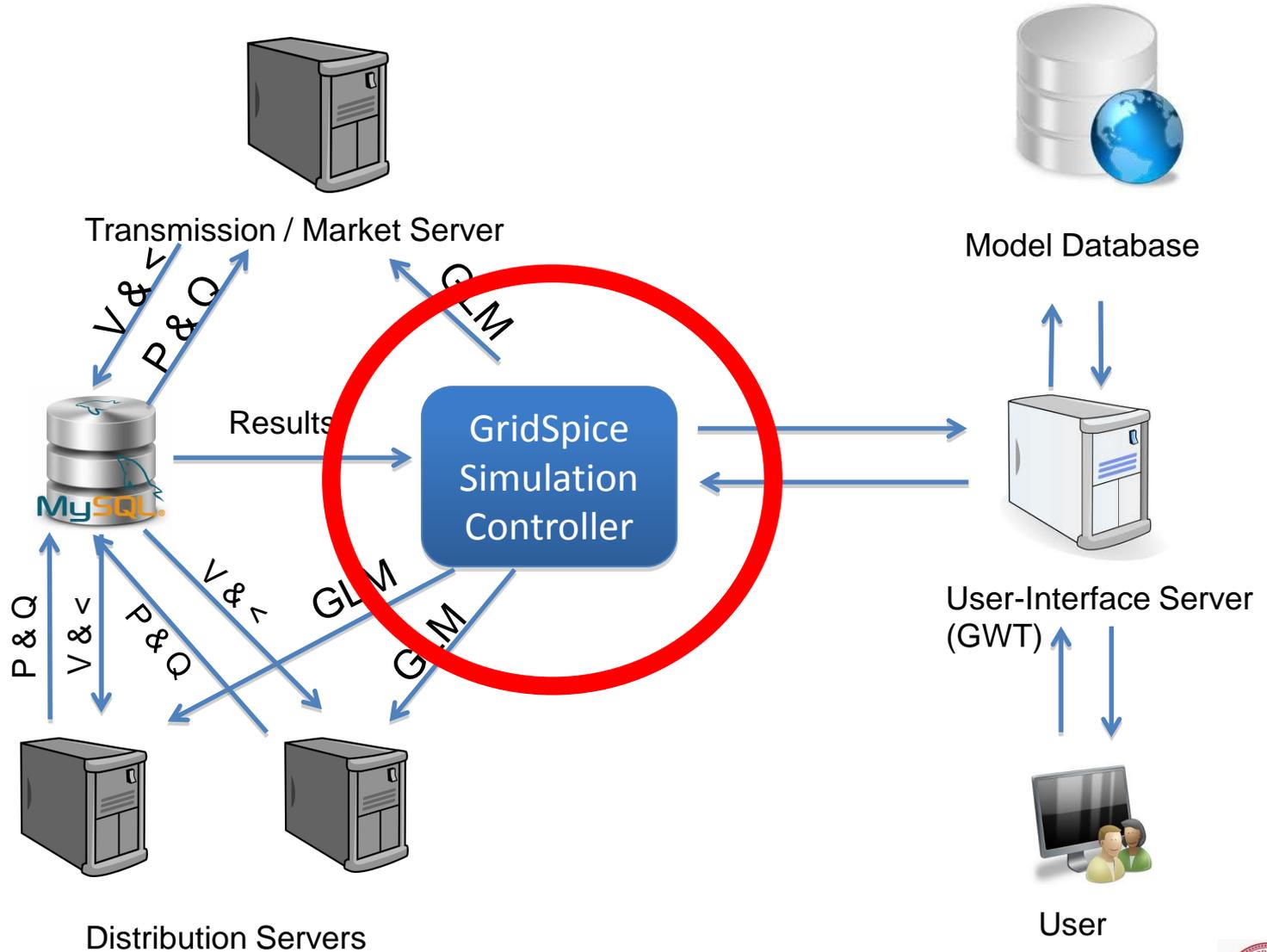
Name	Date Modified
iPod Photo Cache	Yesterday
iPhoto Library	3/3/12
CADENCE_anderson_sig.jpg	12/6/11
CADENCE_anderson_photo.jpg	12/6/11
IMG_0566	12/6/11
Untitled.png	7/18/11
iChat Icons	5/24/11

The background interface includes a top toolbar with 'File Management' (Import, Export, New Project, Save Project, Load Project), 'Transmission' (New, Switch, Editor, More), and 'Distribution' (New, Clear, Editor, Model). Below the toolbar are tabs for 'First Project', 'WECC', and 'VALLEY 500'. The main area is divided into 'Attributes' (Name, out\_svc, phases, nominal\_voltage, bustype, busflags, reference\_bus, maximum\_voltage\_error, Save) and 'Child Objects' (New Element, Name, Type, Action).



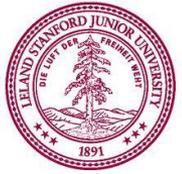


# GRIDSPICE





# 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





GRIDSPICE

# Distribution Network Simulation

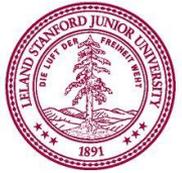


Each feeder is simulated on a separate machine

The powerflow solver is run at the distribution network.

Results passed to the parent bus on the transmission network.





# Prototypical Feeder Models (PNNL)

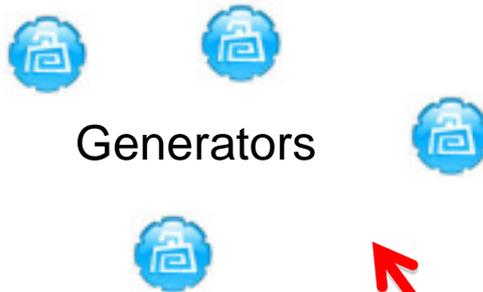
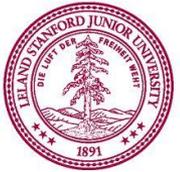
- Feeder models based on prototypical feeders provided by PNNL
- Models for homes and commercial buildings constructed using load forecasting
- Uses smart meter data from SPP pilot program

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





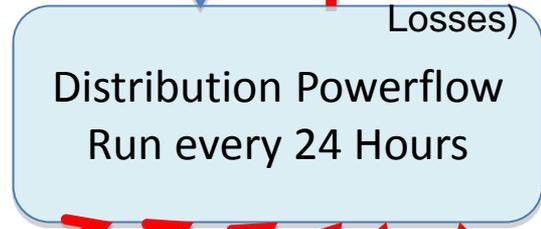
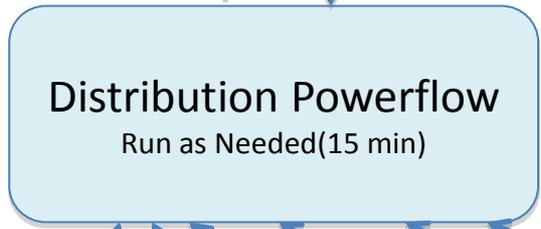
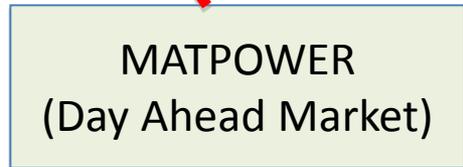
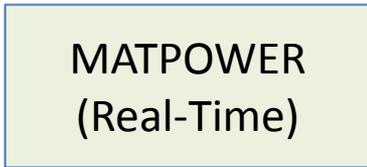
GRIDSPICE



Generators

Current Generator Outputs  
(Tight Min/Max settings)

Next-Day Generator  
Schedules



P & Q

Voltage & Angle  
Prices

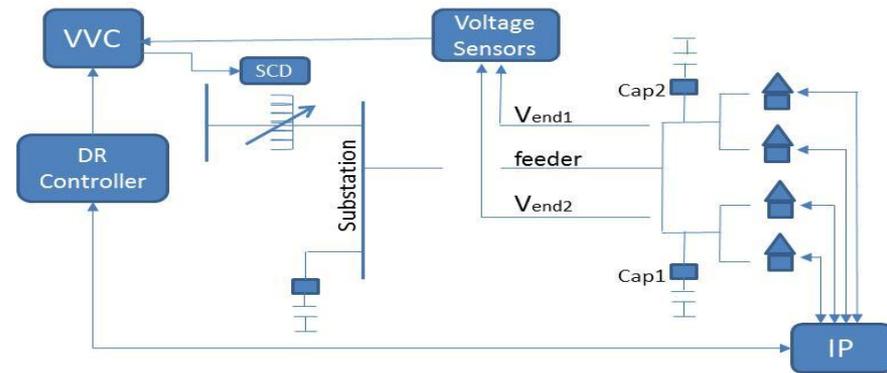
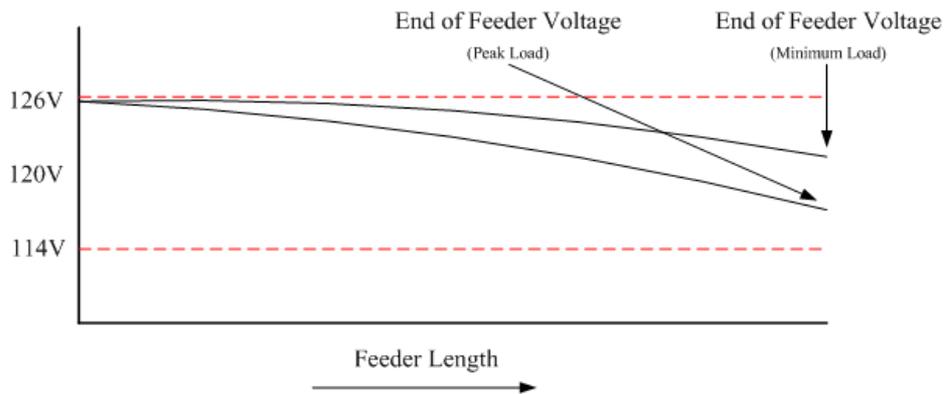
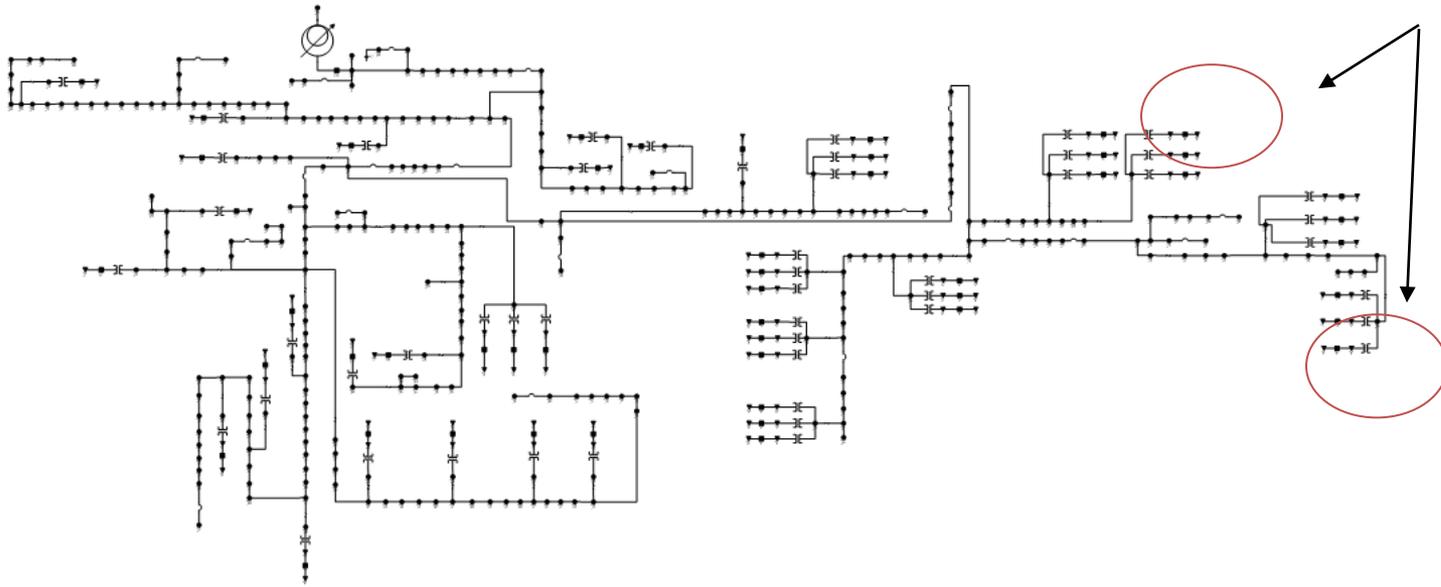
Prices

Load Forecast  
(including Distribution  
Losses)



# Example: CVR and DR

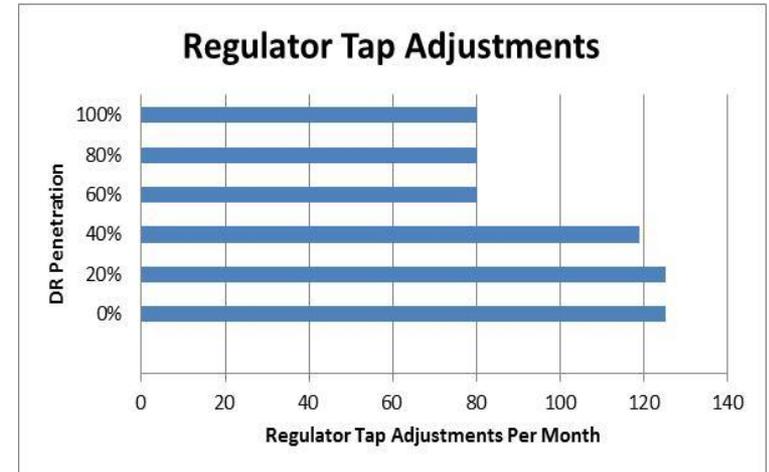
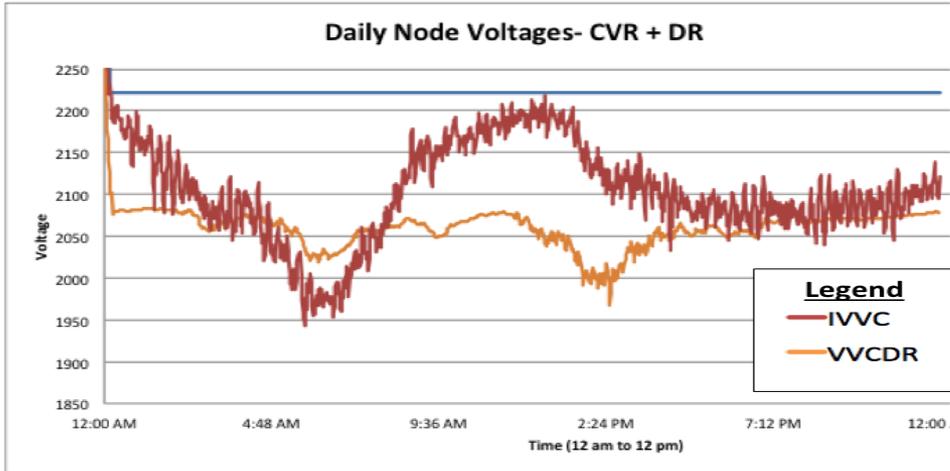
Hot-spots – can DR be used?



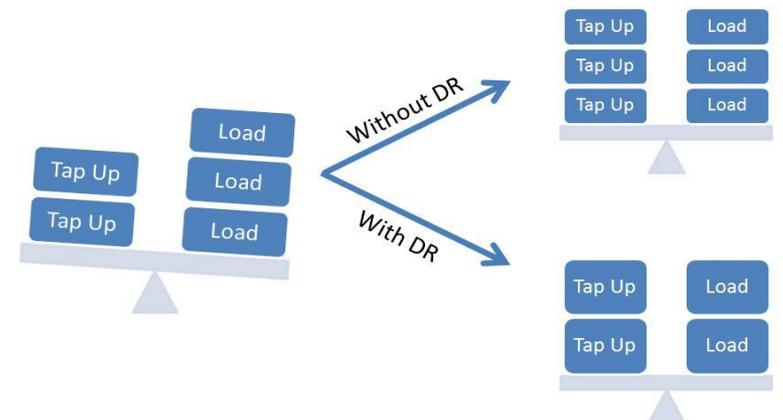
IVVCDR – Anderson, Narayan,  
IEEE SmartGridComm 2011



# 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

