

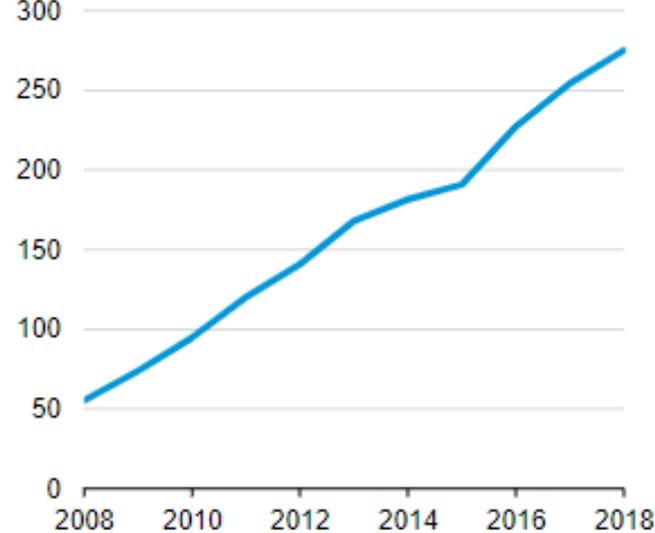
# System Inertia Impact Due to High-Renewable Penetration - Texas Interconnection

FACULTY ADVISOR: AYMAN SAMAAAN

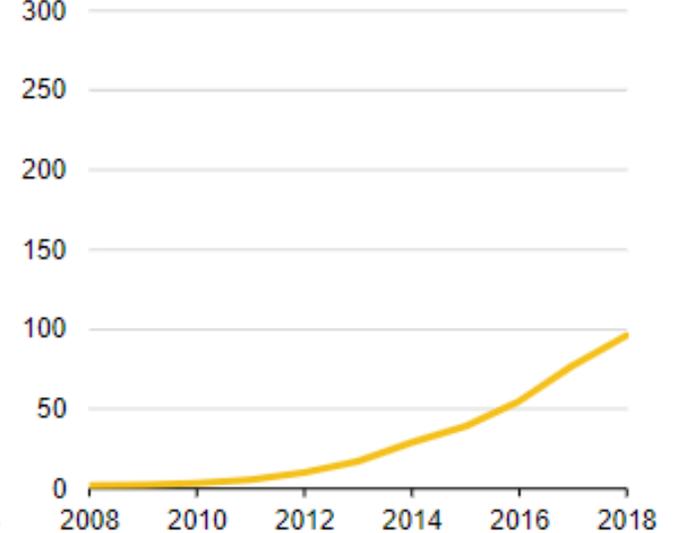
PRESENTED BY SALVADOR ZAMBRANO, JUSTIN  
VERGARA, GONZALO URIAS, ARNUVIO  
HERNÁNDEZ, AND JEREMIAH RODRIGUEZ

- ▶ Wind and Solar energy generation is growing rapidly in the US

U.S. annual net generation, wind  
million megawatthours



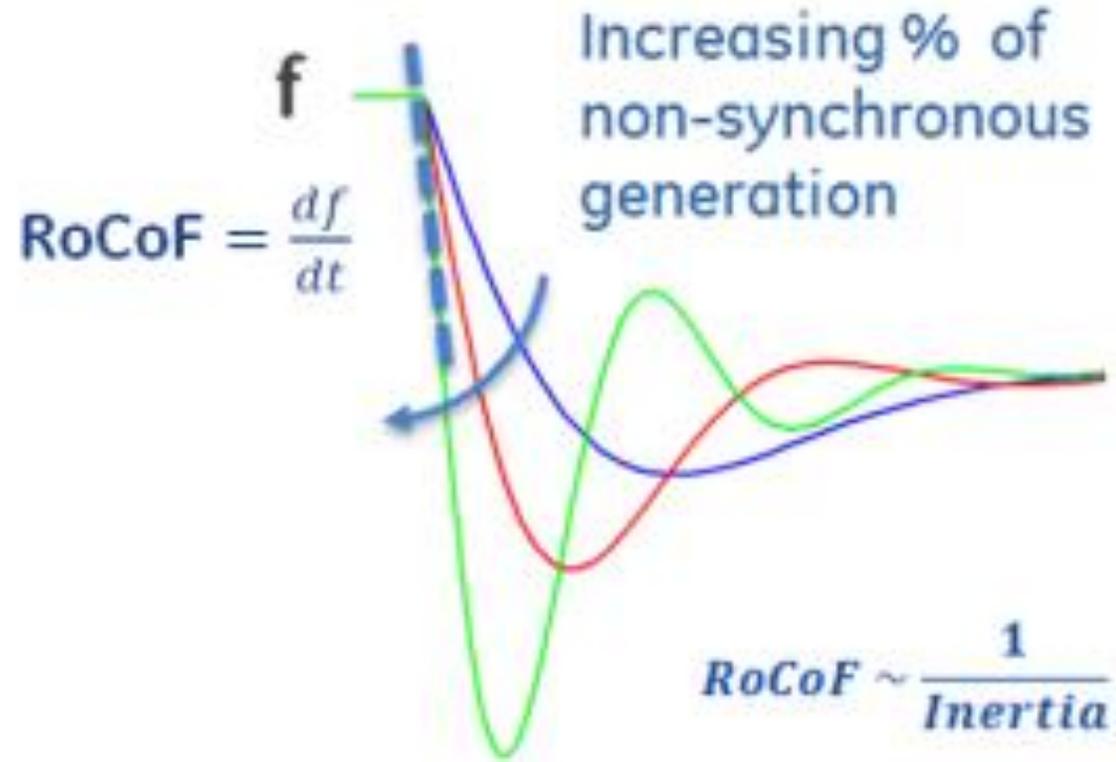
U.S. annual net generation, solar  
million megawatthours



Source: U.S. Energy Information Administration, *Electric Power Monthly*

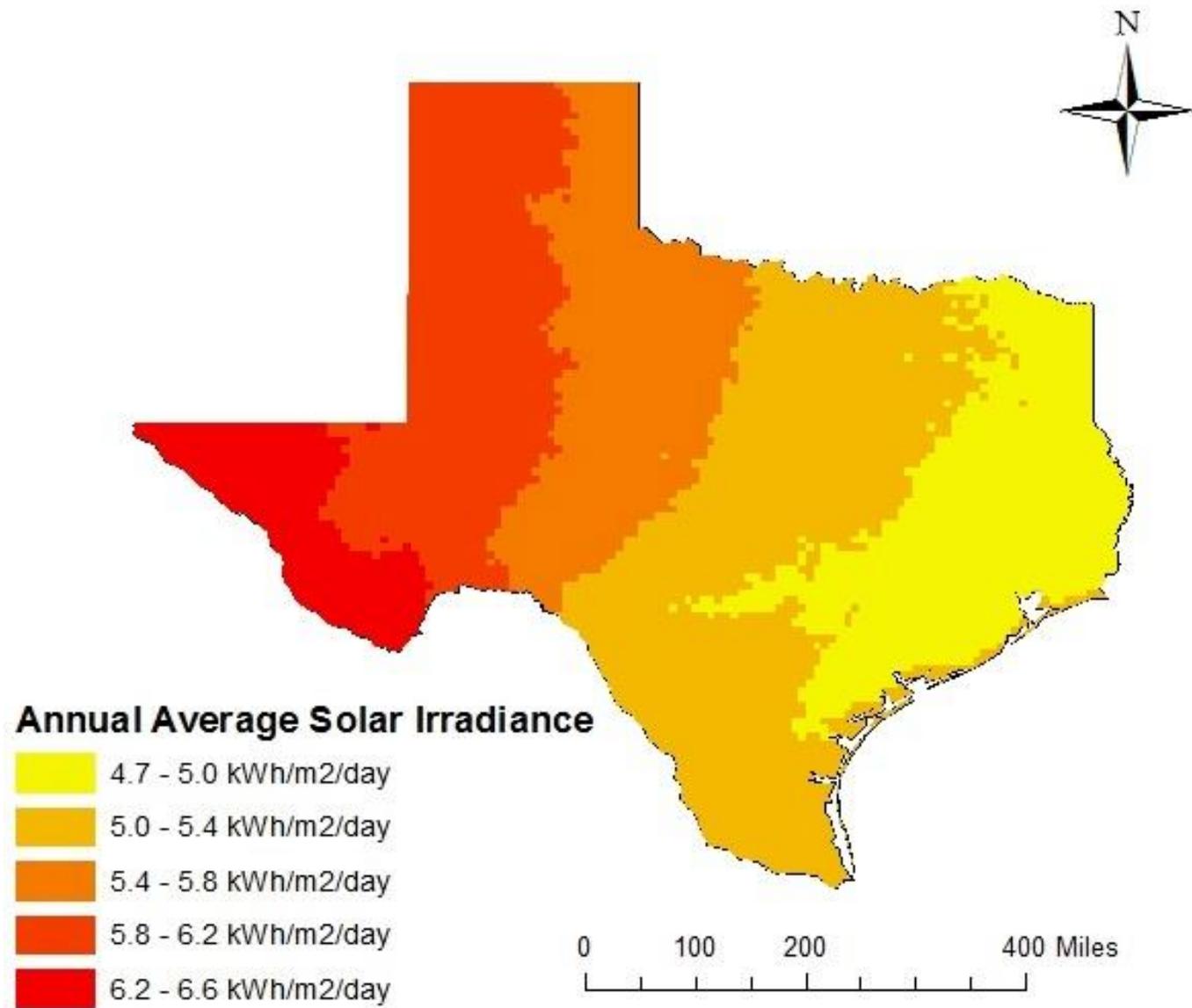


- **Blue Line** – system frequency with traditional synchronous machines (HIGH INERTIA)
- **Red Line** – Some renewable energy penetration (MEDIUM INERTIA)
- **Green Line** – High renewable energy penetration (LOW INERTIA)

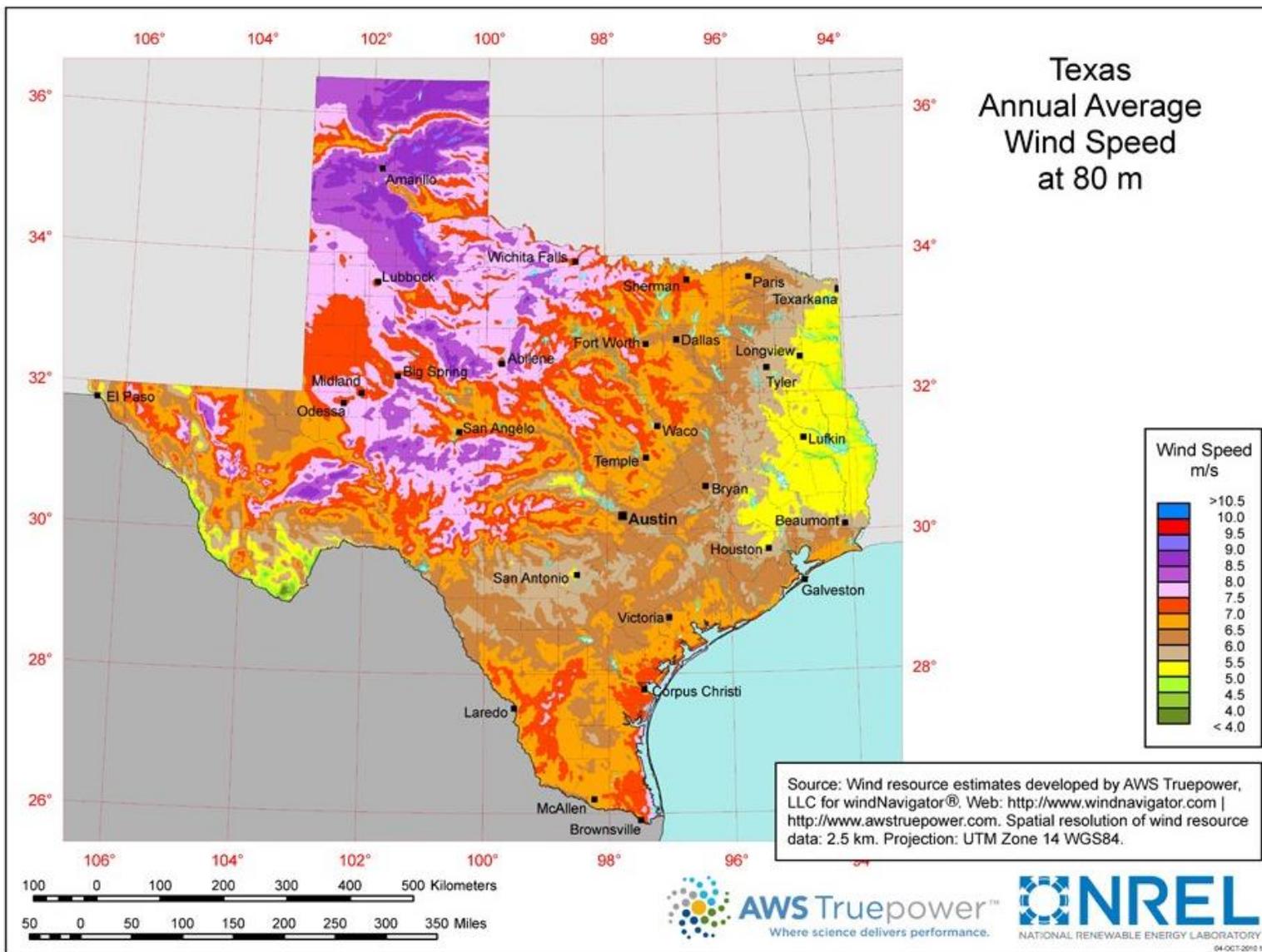


SOURCE: INCITE - INNOVATIVE CONTROLS FOR RENEWABLE SOURCE INTEGRATION INTO SMART ENERGY SYSTEMS

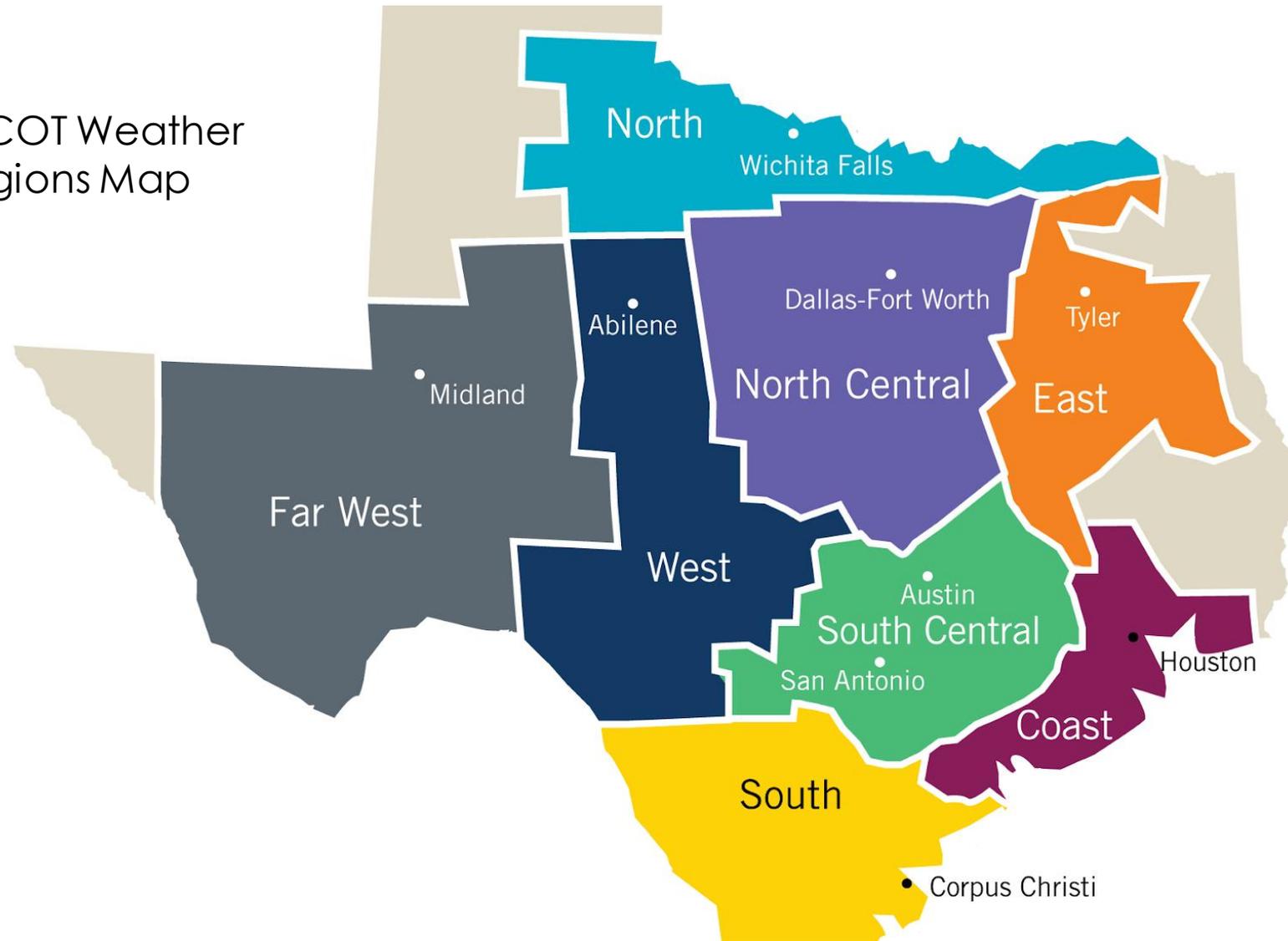
- Solar irradiance levels in Texas



- Wind speeds in Texas



- ERCOT Weather Regions Map



# 2017 Case Values

## Load

Region	MW
Far West	1306.74
North	1473.56
West	1675.54
South	6751.33
North Central	22261.69
South Central	12263.32
Coast	18189.51
East	3187.57
Total	67109.26

- Initial values by weather region

## Generation

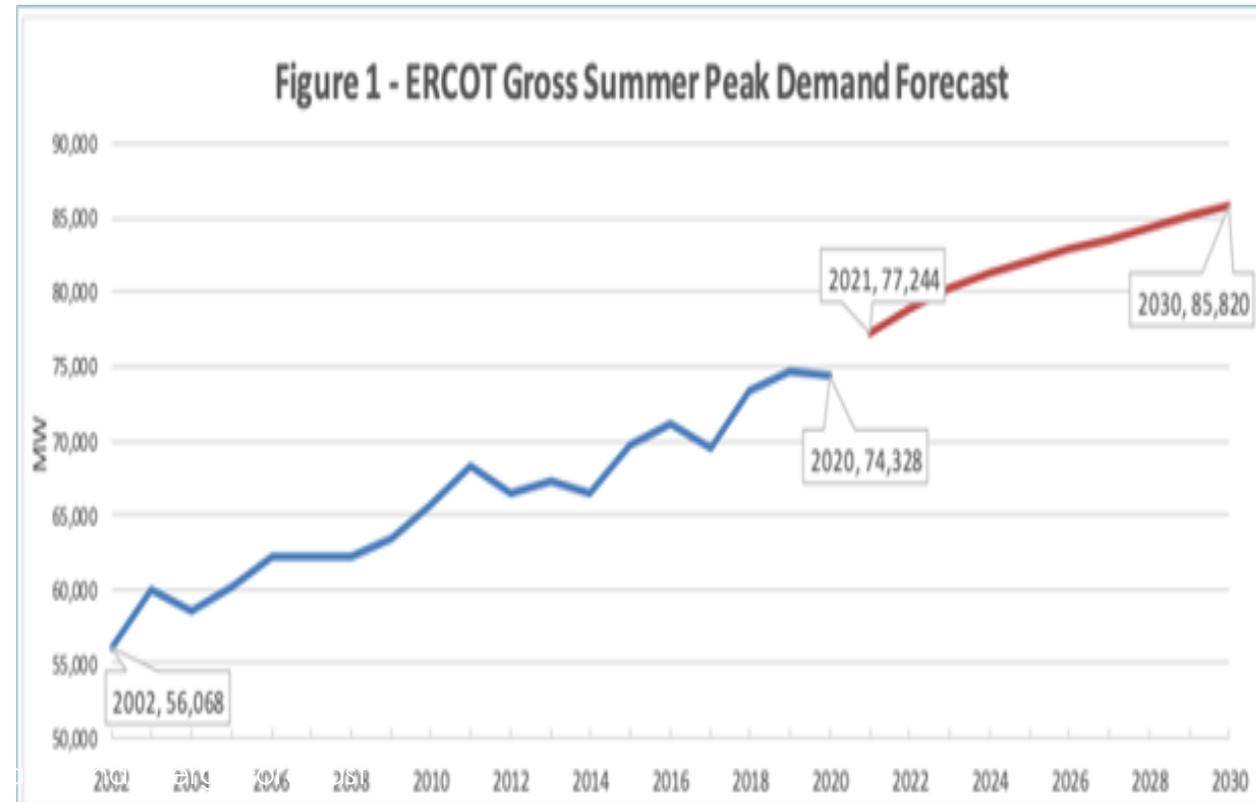
Region	MW
Far West	3007.34
North	1473.56
West	1675.58
South	6570.22
North Central	13,145.79
South Central	10372.81
Coast	22734.62
East	5765.64
Total	68,000
Total Capacity	84,622 MW

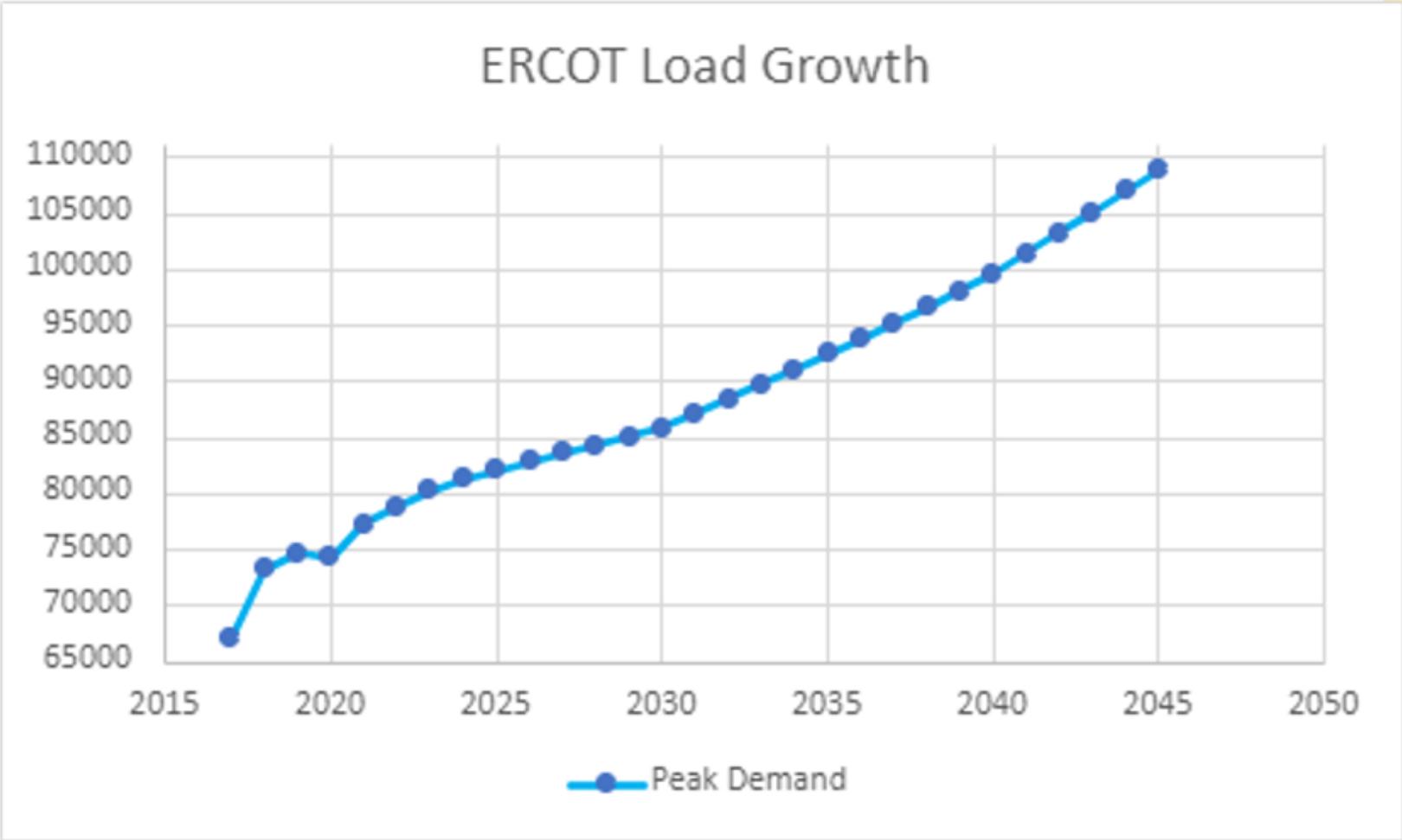
# 2045 Load Projection

AAGR of 0.9% for peak demand 2011-2020

forecasted AAGR of 1.2% from 2021-2030

AAGR = Average Annual Growth Rate





Peak Demand Growth (2017-2045)

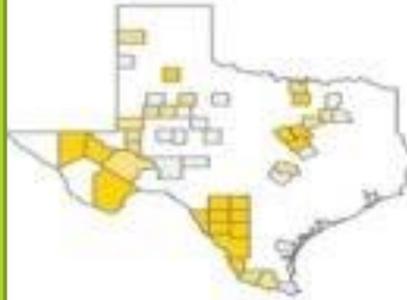
# Projected Renewable Energy Development (ERCOT LTSA)

ERCOT  
SOLAR  
ADDITIONS

CURRENT TRENDS  
(ITERATION 1)

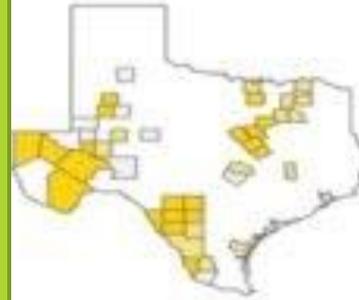


CURRENT TRENDS  
(ITERATION 2)



100 MW - 300 MW 400 MW

EXISTING TRANSMISSION  
CONSTRAINTS



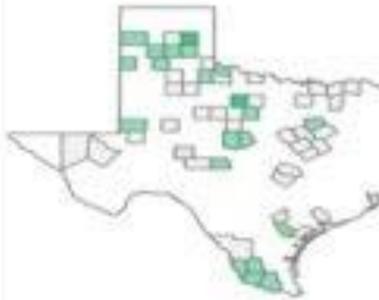
100 MW 700 MW or more

RENEWABLE MANDATE



ERCOT  
WIND  
ADDITIONS

CURRENT TRENDS  
(ITERATION 1)



CURRENT TRENDS  
(ITERATION 2)



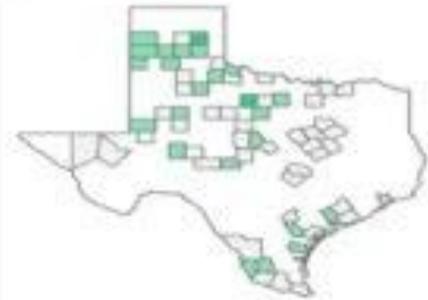
100 MW - 700 MW 800 MW

EXISTING TRANSMISSION  
CONSTRAINTS



100 MW 1,500 MW or more

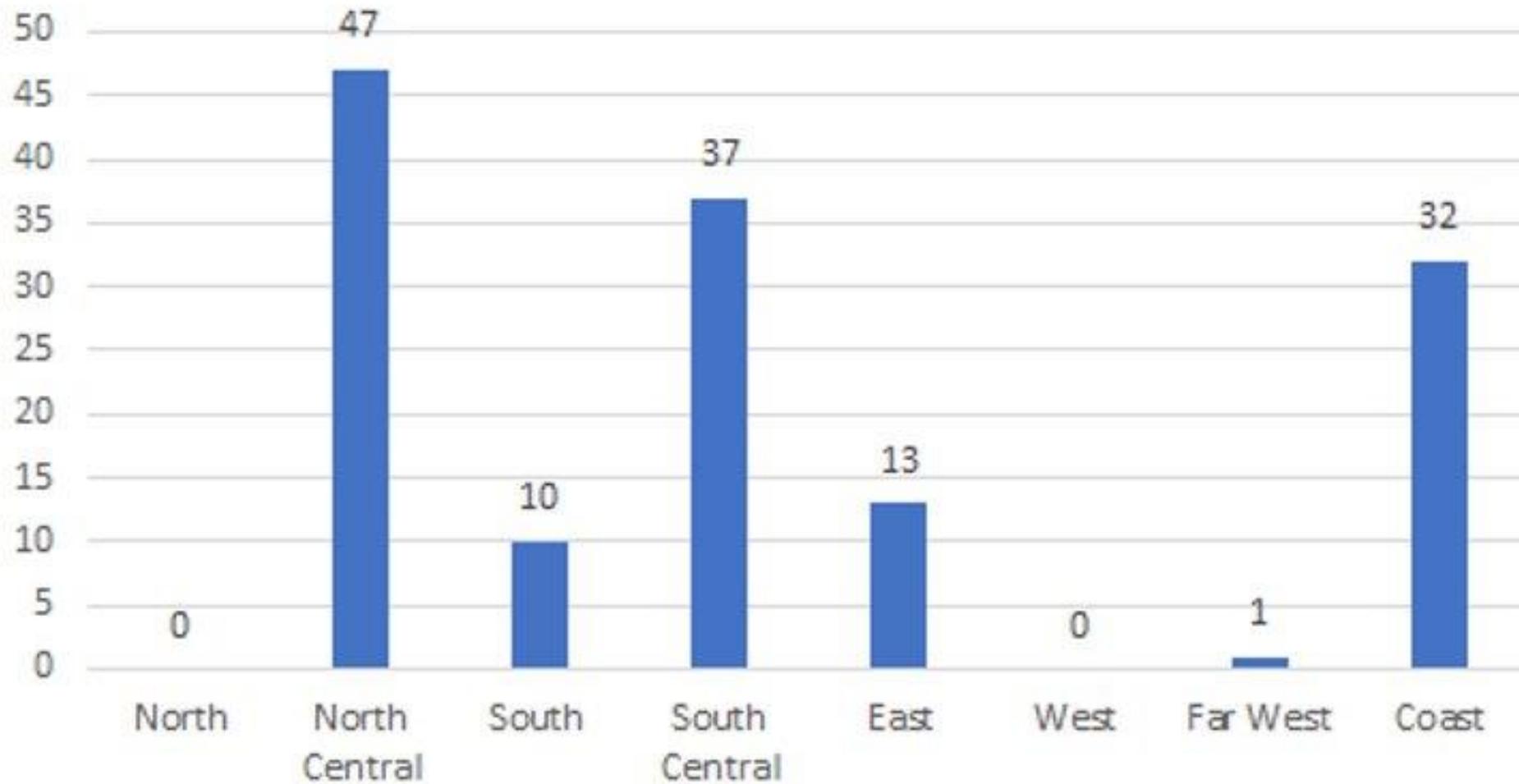
RENEWABLE MANDATE



Region	Wind Addition	Solar Addition
North	34 Units	20 Units
North Central	12 Units	19 Units
South	43 Units	17 Units
South Central	5 Units	14 Units
East	1 Units	5 Units
West	0 Units	7 Units
Far West	0 Units	38 Units
Coast	19 Units	0 Units
Total	114 Units	120 Units

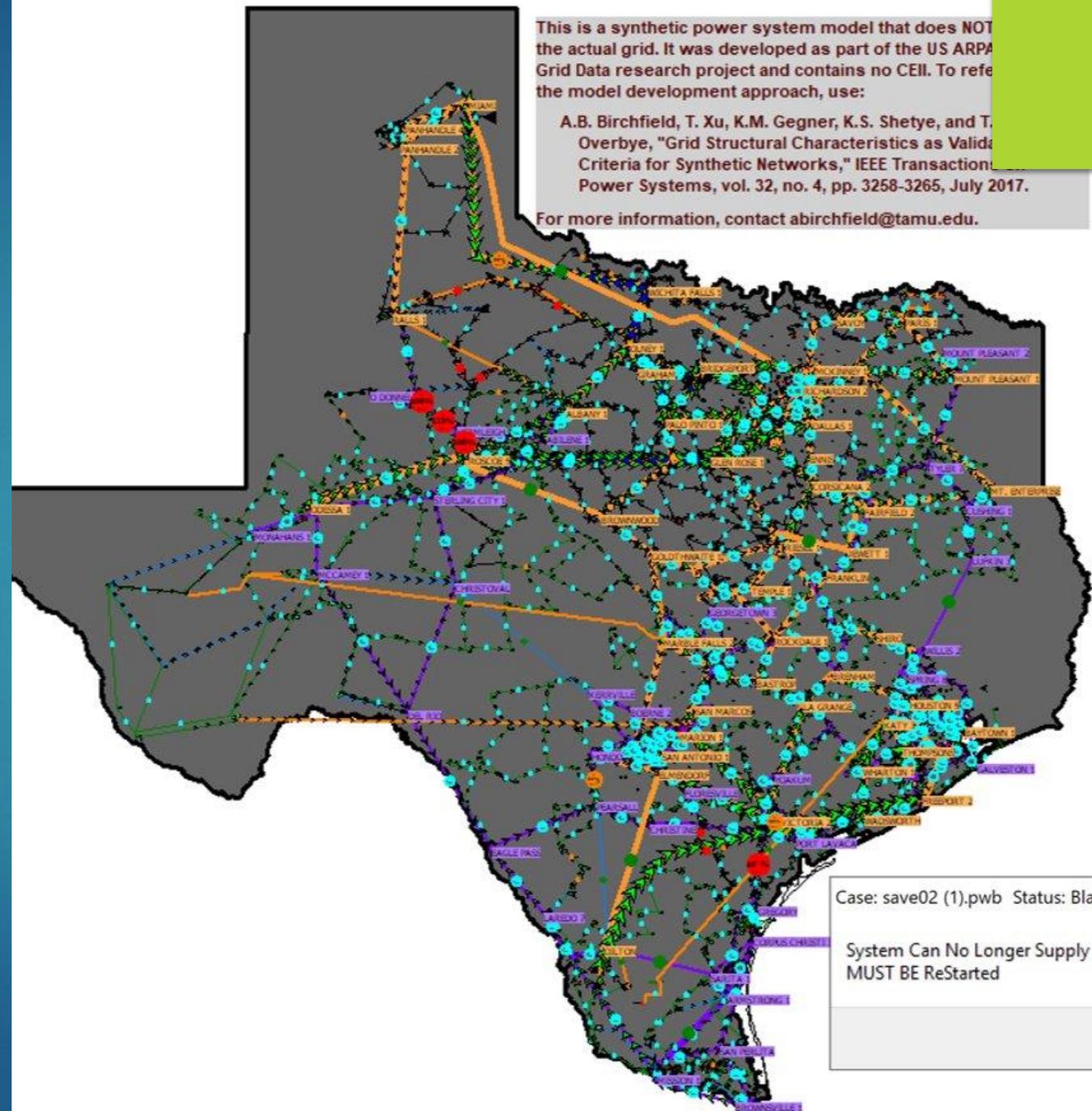
- **2045  
Generation  
Additions**

### Battery Addition (21 GW Total)

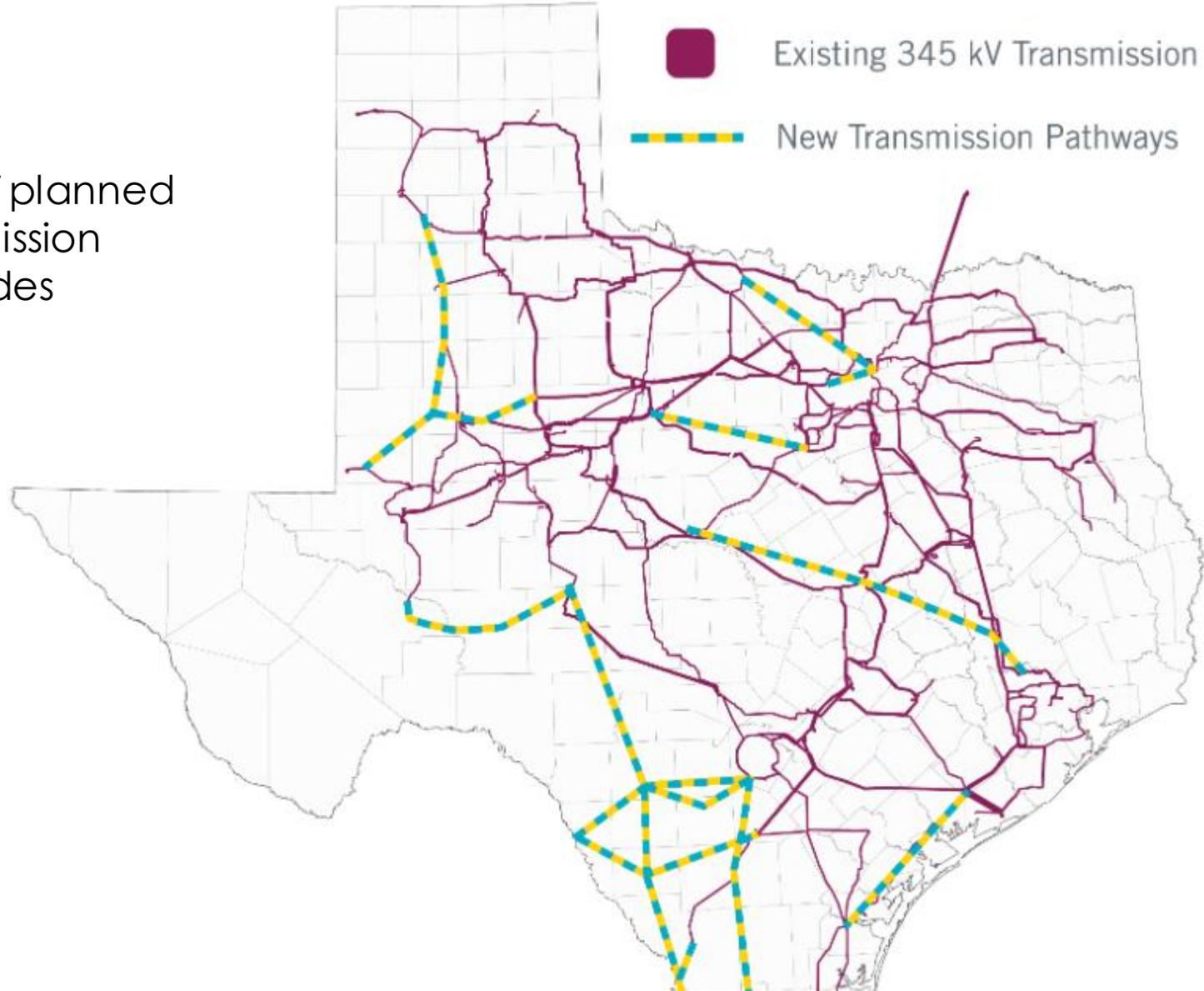


- 2045 Battery Additions

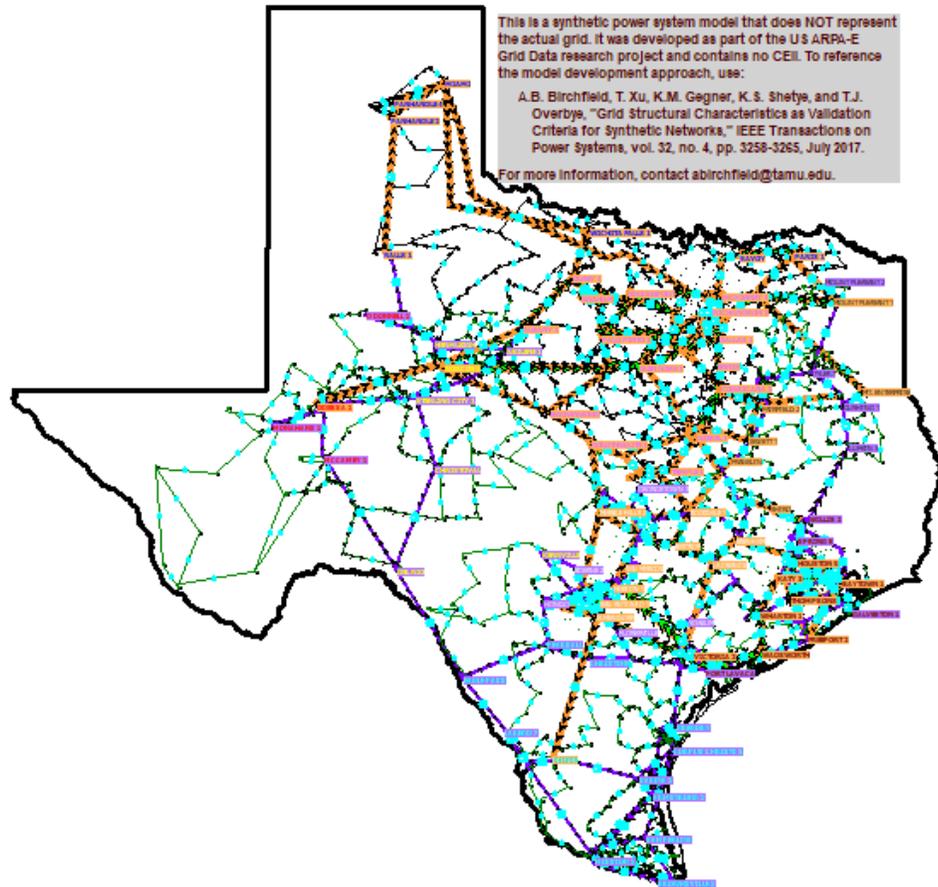
► Thermal Overloads in Steady-State (Lines with Red Bubbles)



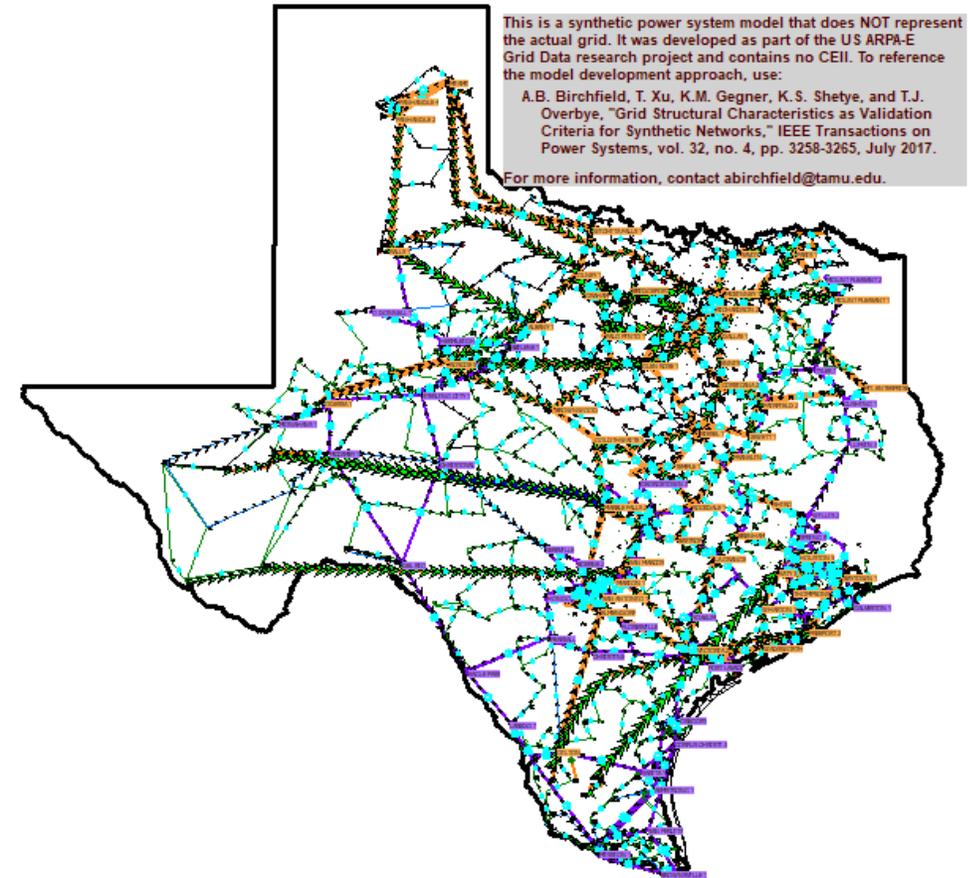
- ERCOT planned transmission upgrades



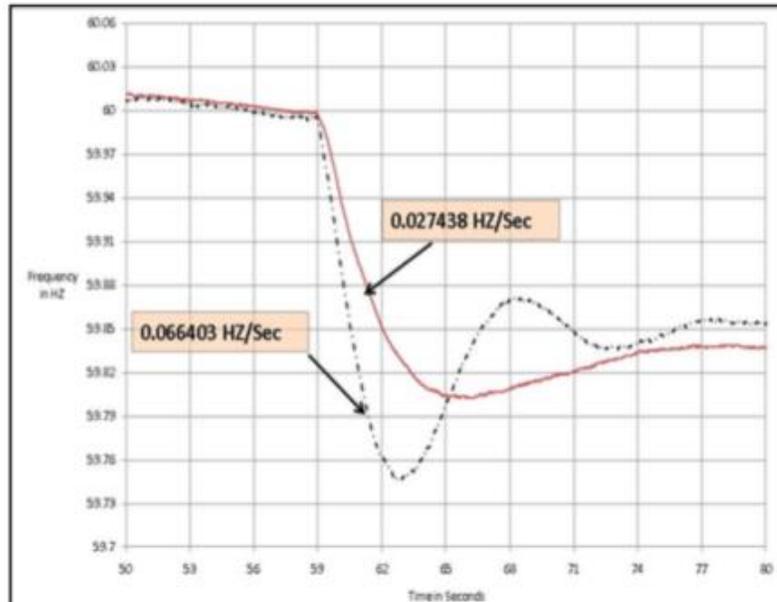
## 2017 Case Transmission System



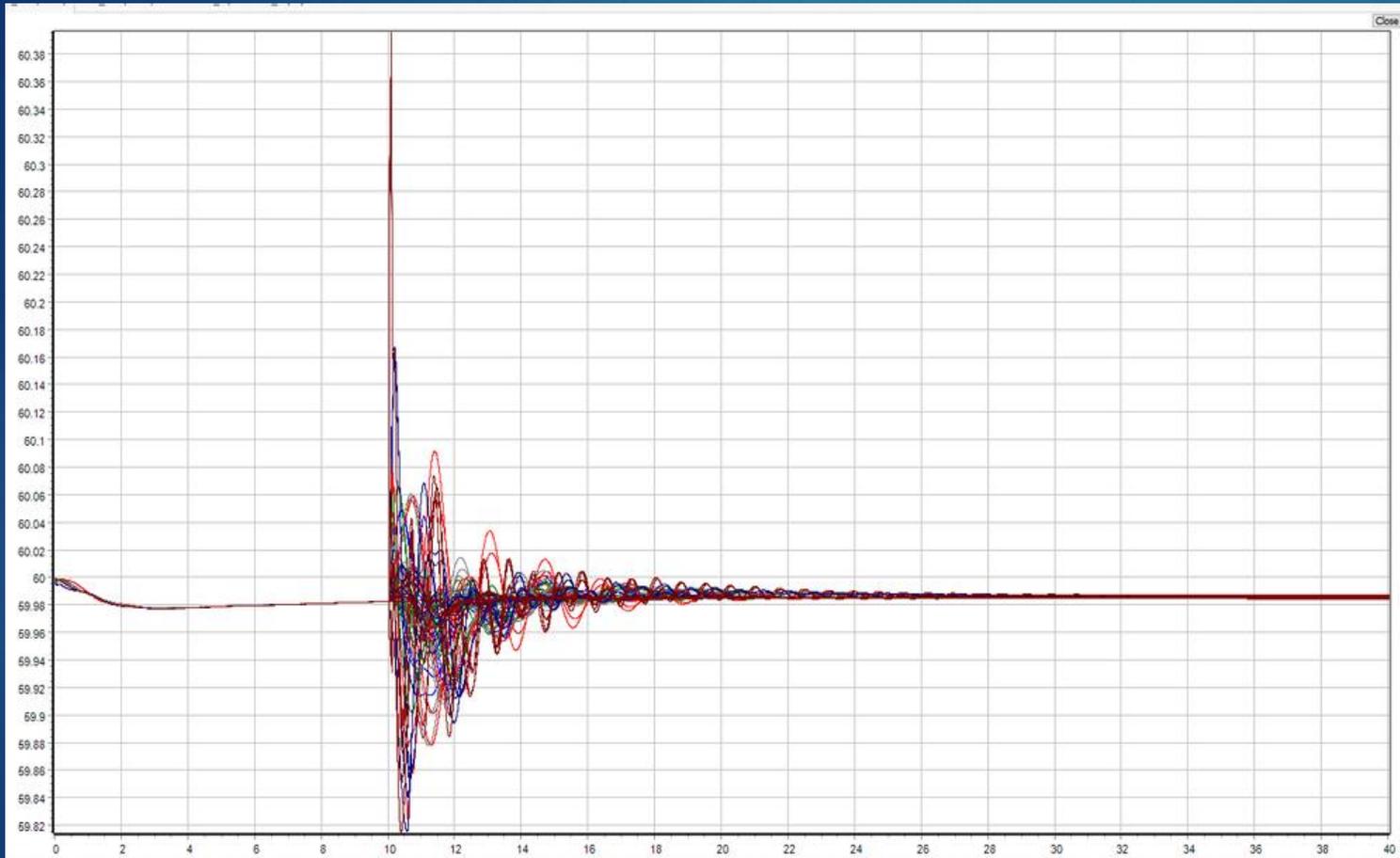
## 2045 Case Transmission System



# Basics on Transient Stability



- Underfrequency Load Shedding (forced blackouts) occur at **59.3Hz**
- **Critical busses** – faults applied where there is high generation
- **Monitoring busses** – used to represent the case

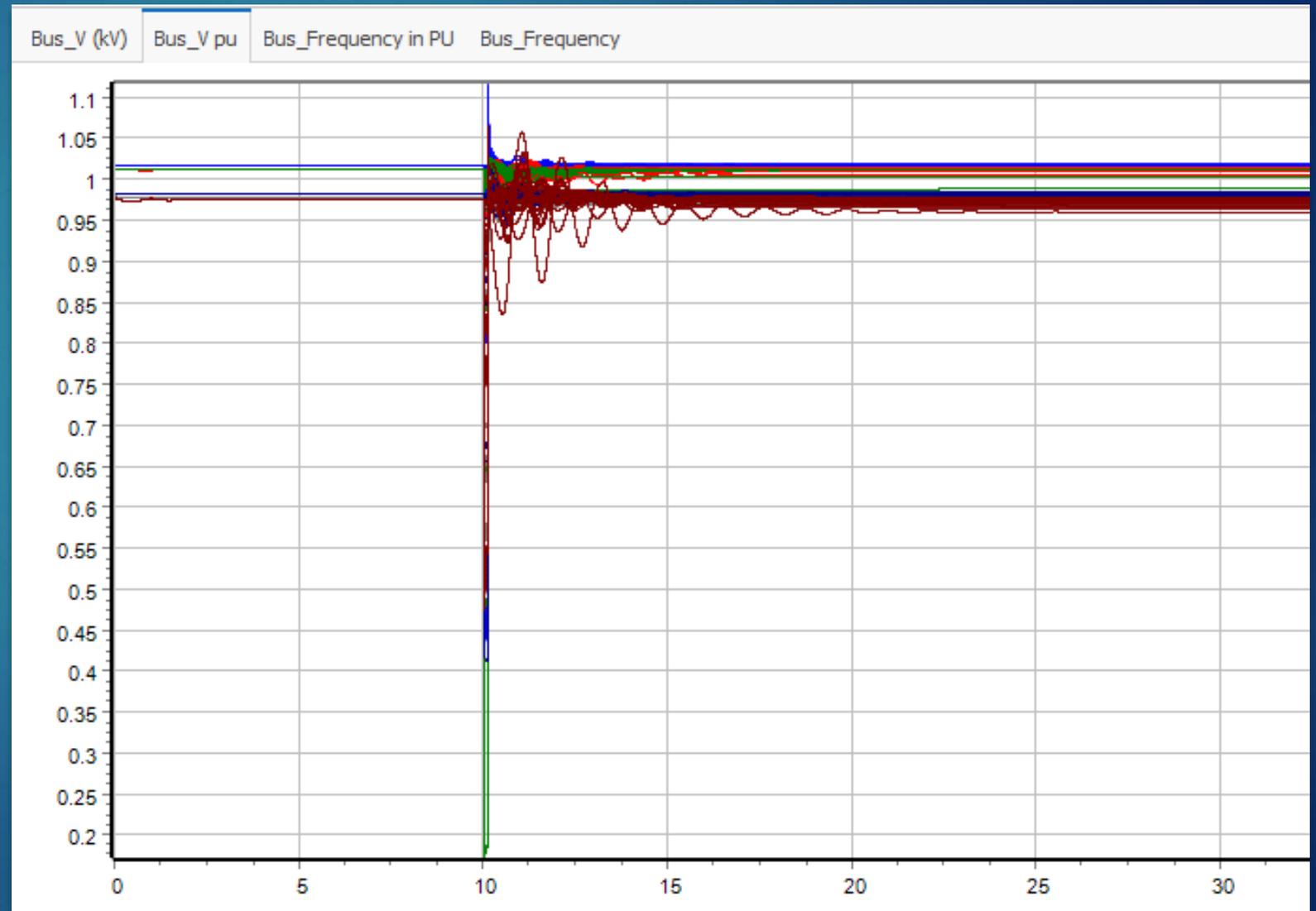


# Max Penetration Threshold – 71%

- ▶ Frequency
- ▶ No UFLS
- ▶ 0.1 Hz Reliability Margin

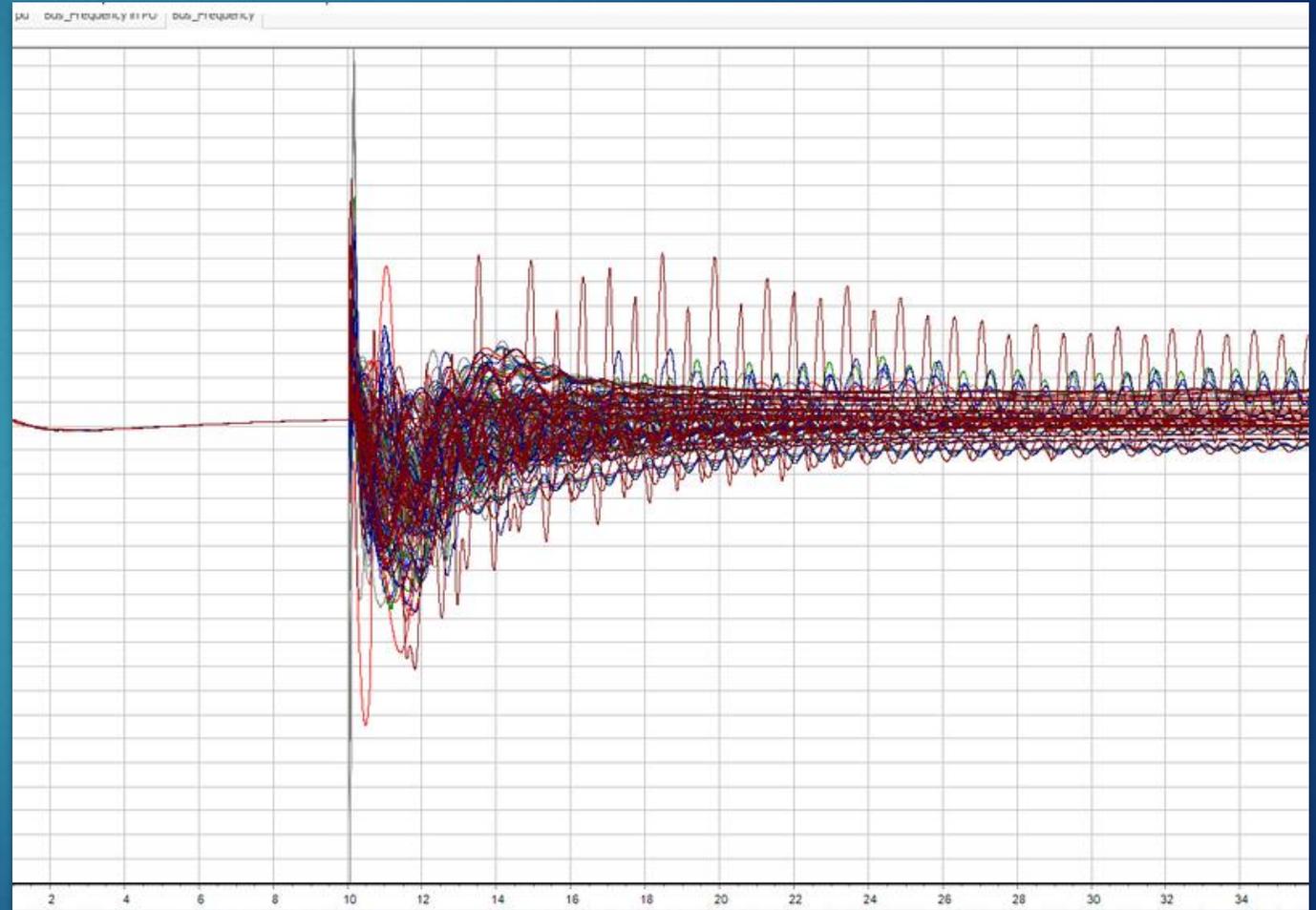
# Voltage - 71% Penetration

- ▶ The system converges



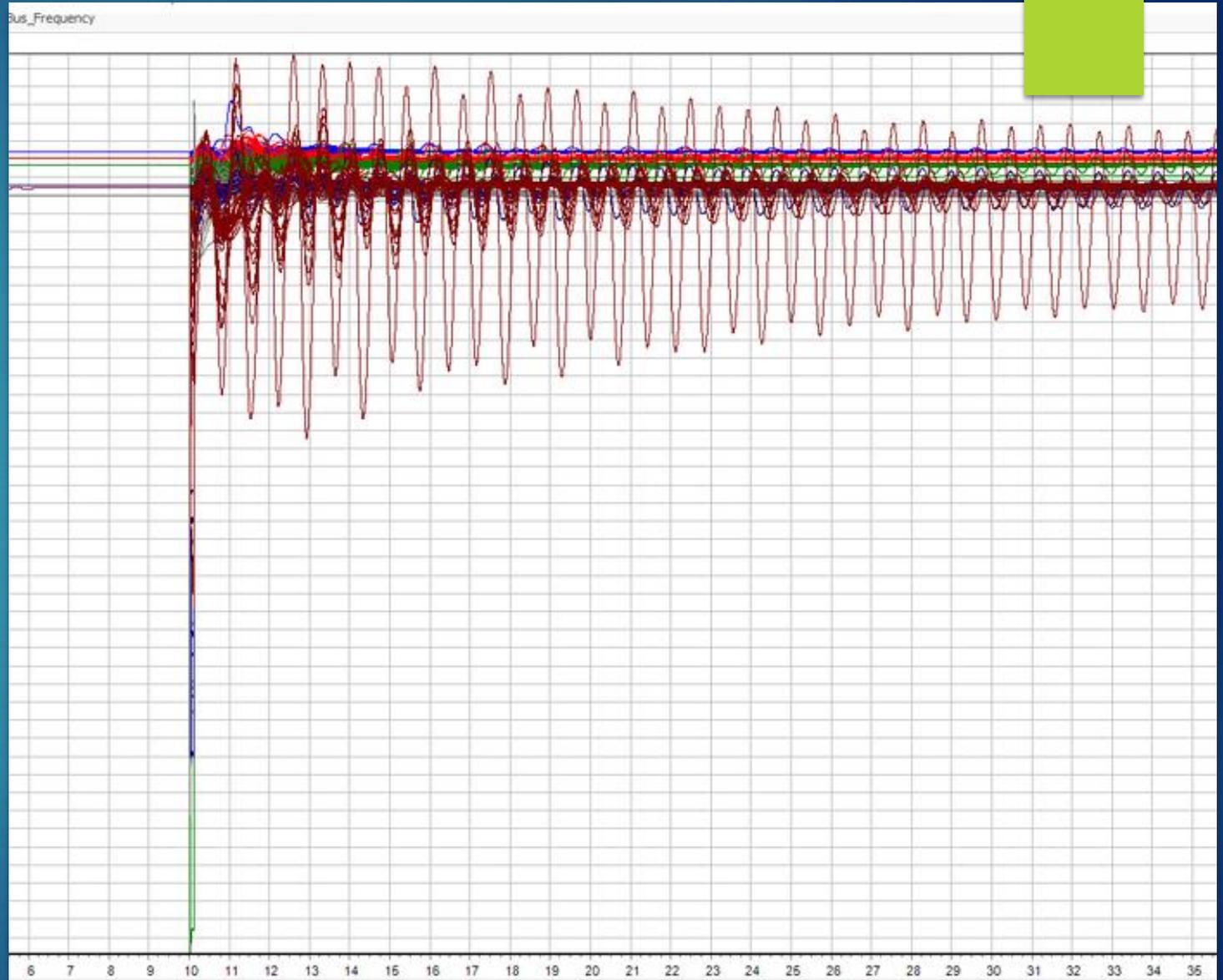
# 76% Threshold - Frequency

- ▶ UFLS
- ▶ Oscillation



# 76% Threshold - Voltage

- ▶ Oscillations do not show any sign of converging



# Off-Peak Load and Resource Balance (Steady-State)

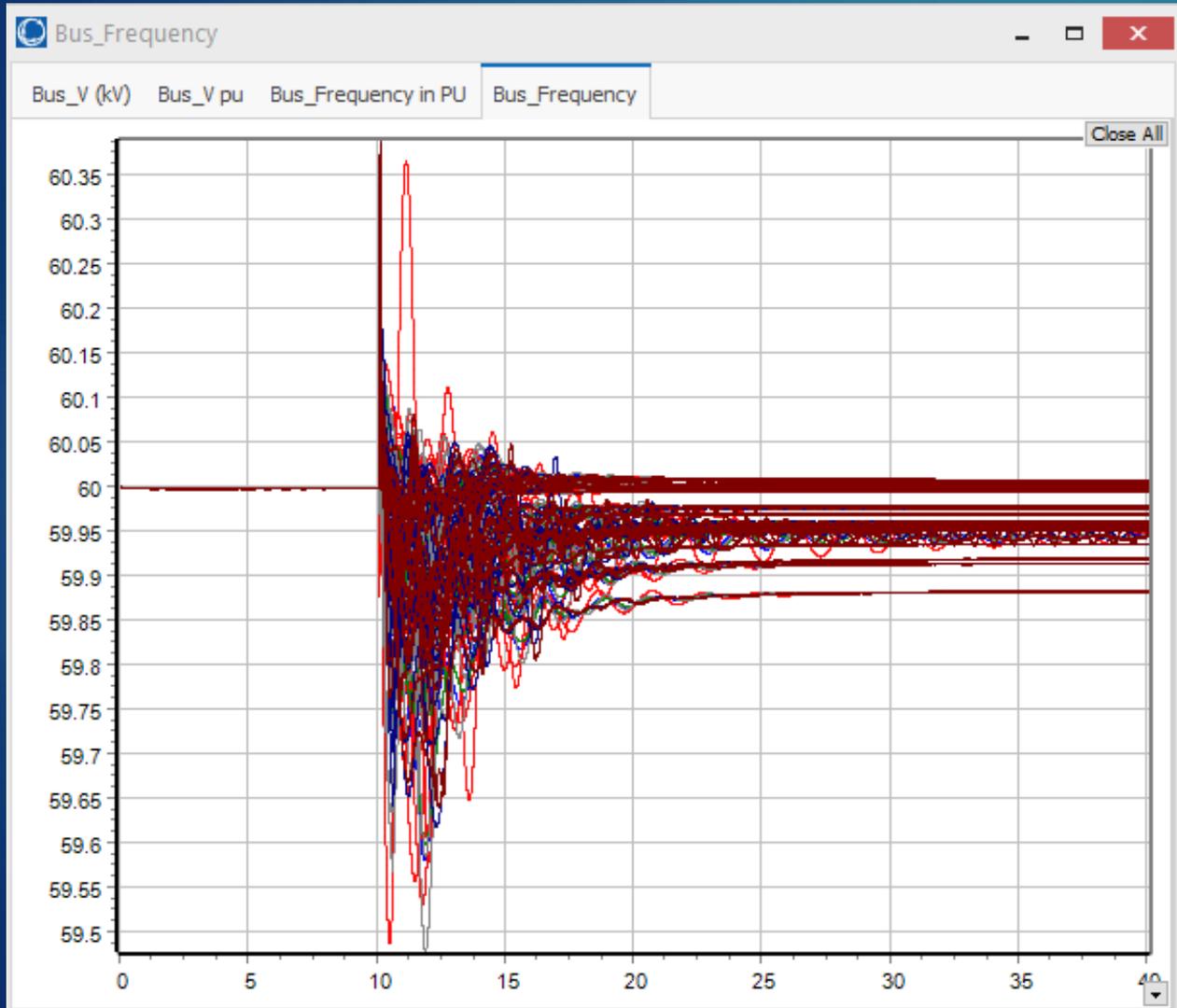
Fuel Type	GW
WND (Wind)	33
SUN (Solar)	0
NG (Natural Gas)	30
BIT (Bituminous Coal)	7
WAT (Water)	3
NUC (Nuclear)	5

Total Generation Capacity: 78 GW

Load	GW
40% Demand	44
Battery Load	39

Total Demand: 83 GW

# Frequency – Off Peak



Staggered Charging Scheme



# Voltage – Off Peak

VOLTAGE STABILIZES

# Short Circuit Duty

- ▶ Significant decrease in short circuit current in some areas
- ▶ May need to change/update protection elements
- ▶ May need to watch inverter parameters for weak fault current

