Secure Power in High Renewable Penetration Environment

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IENE Workshop- Electricity Storage and Grid Management for Maximum RES Penetration

Sept. 28, 2022

US Power Generation

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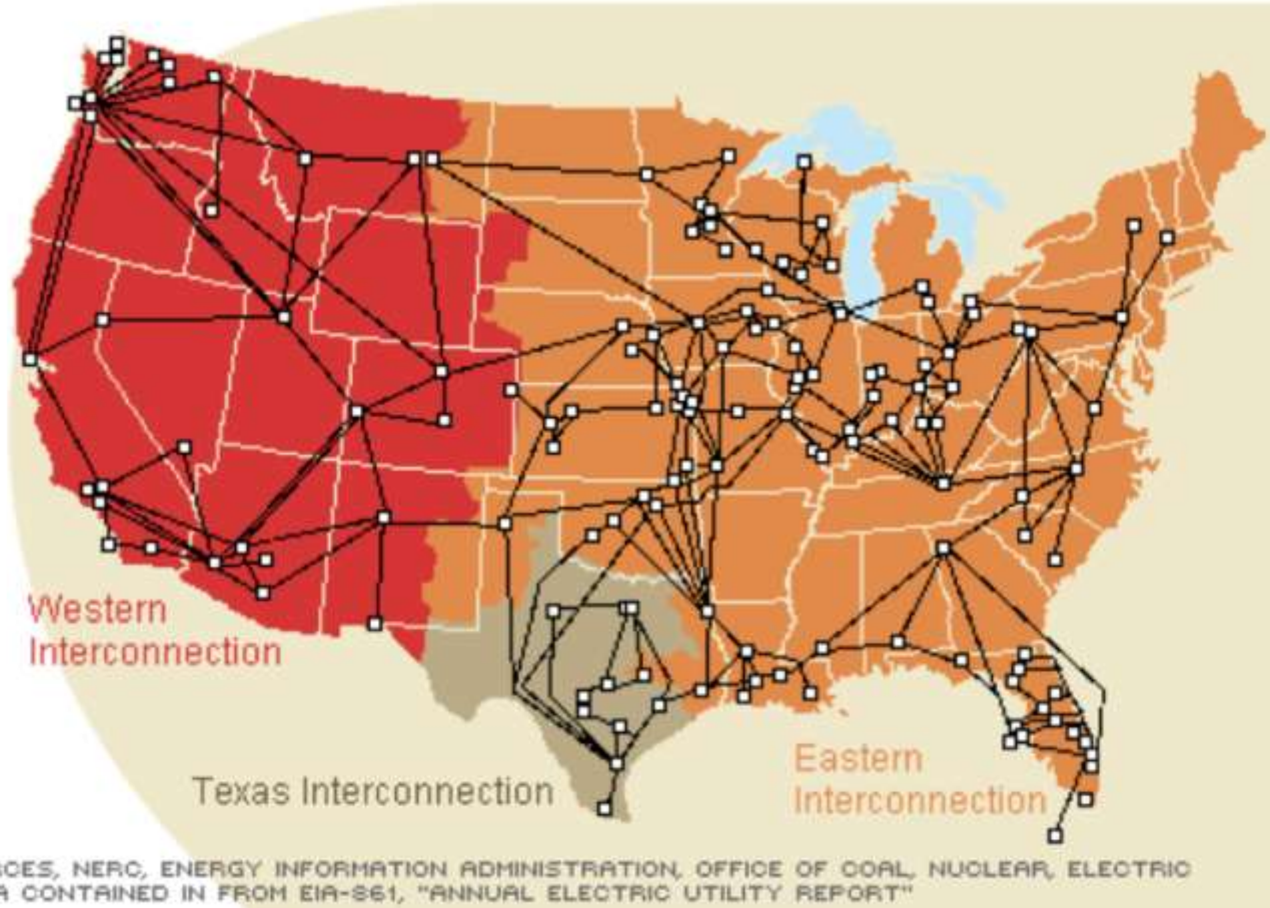
2020:

- 4,009,000 GWh
- 60% Fossil
- 20% Nuclear
- 20% Renewables (including hydroelectric)



US Renewable Generation

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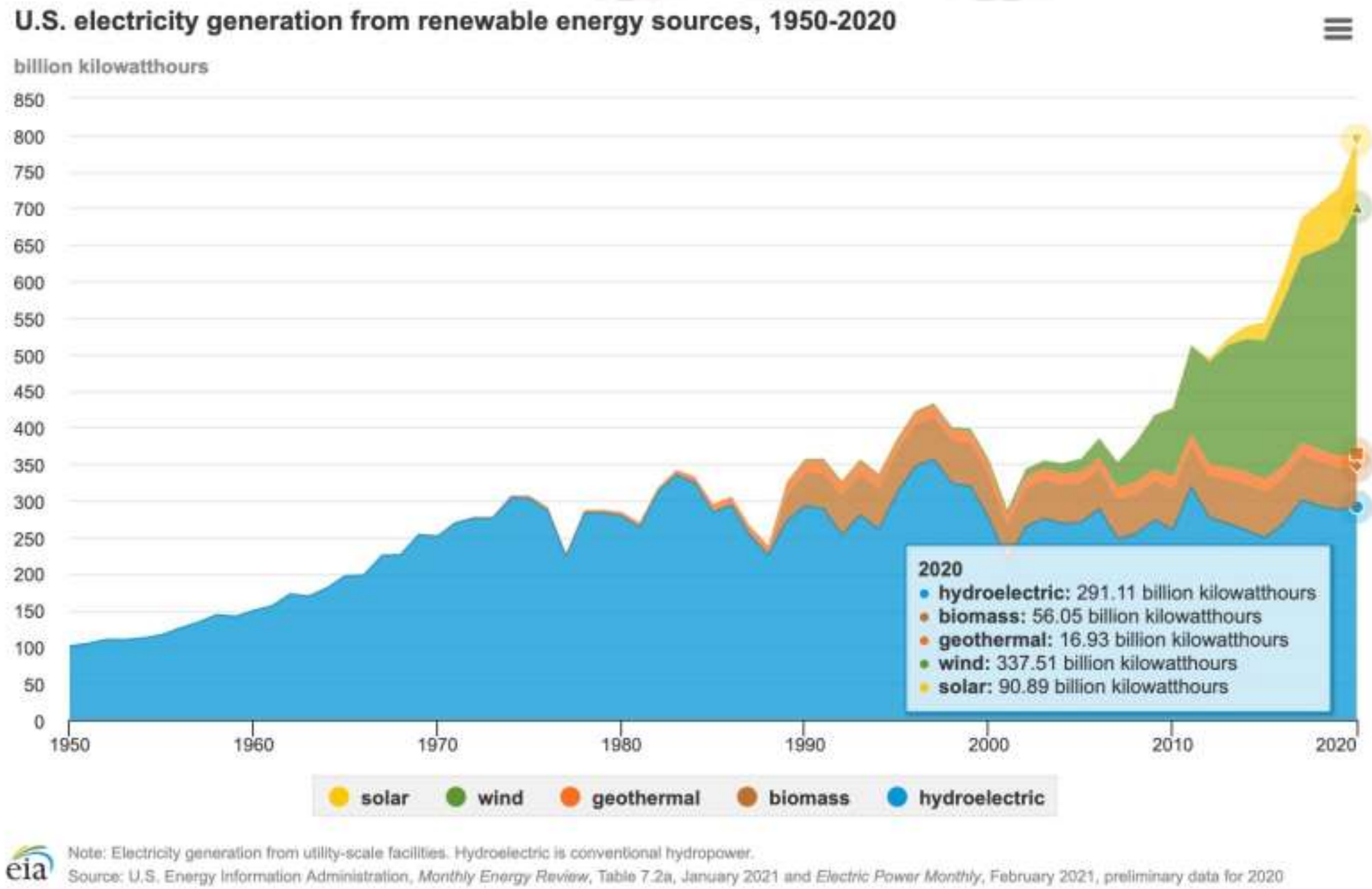


← Solar

← Wind

← bio/geo

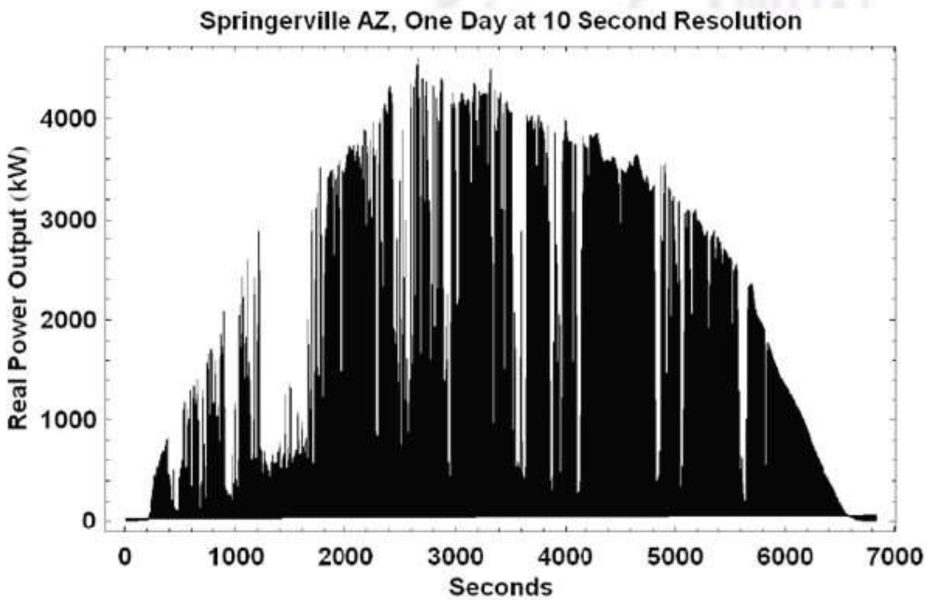
← Hydro

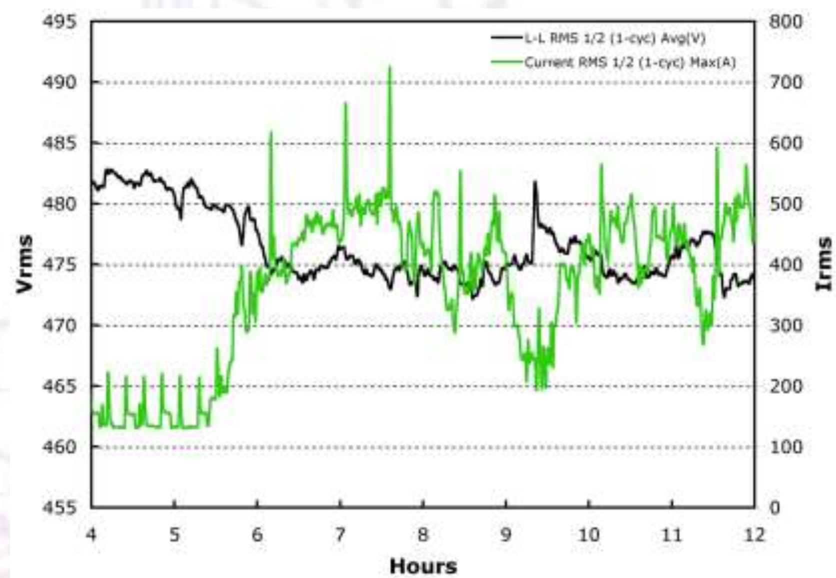
Renewable Challenges

- Intermittency
- Fast Transient

→

- Voltage instability
- Voltage regulation equipment wear out prematurely
- Black out, brown out





Source: http://www.megawattsf.com/gridstorage/gridstorage.htm

Source: One-Cycle Control, Inc.

VARs Stabilize Power Grid

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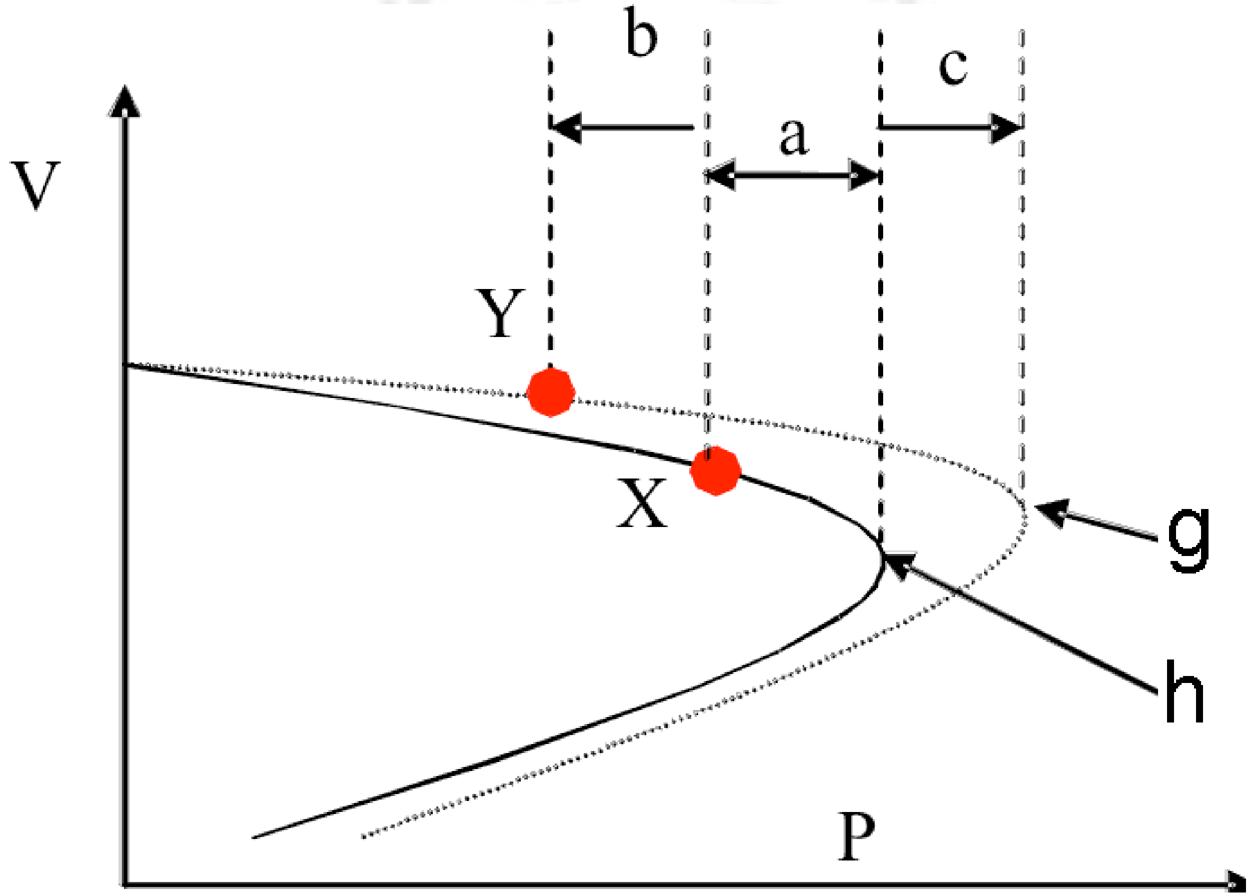

By extending the margin to point of collapse

Crete: Achieve High Penetration?

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- Small Grid ➔ Low inertia
- How to stabilize power grid?
- Fast Dynamic VAR Compensation — Effective solution

OCC Ultrafast DVC

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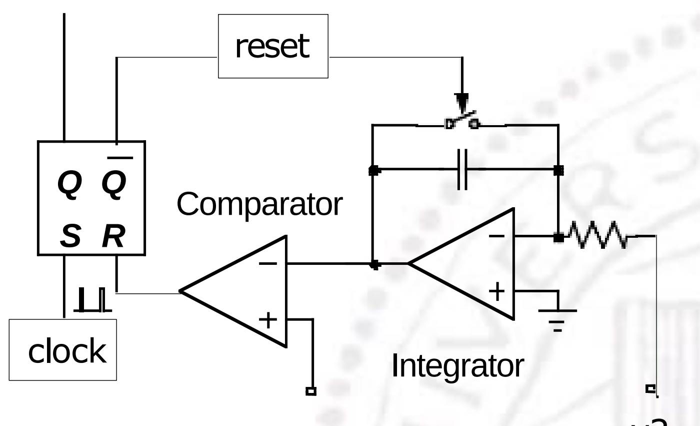
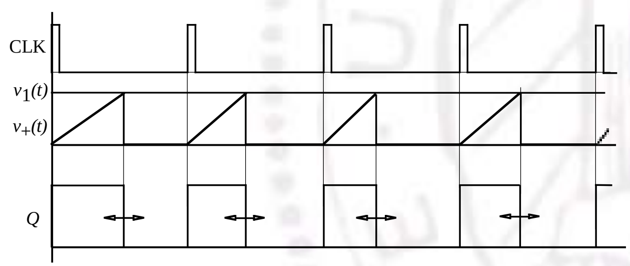


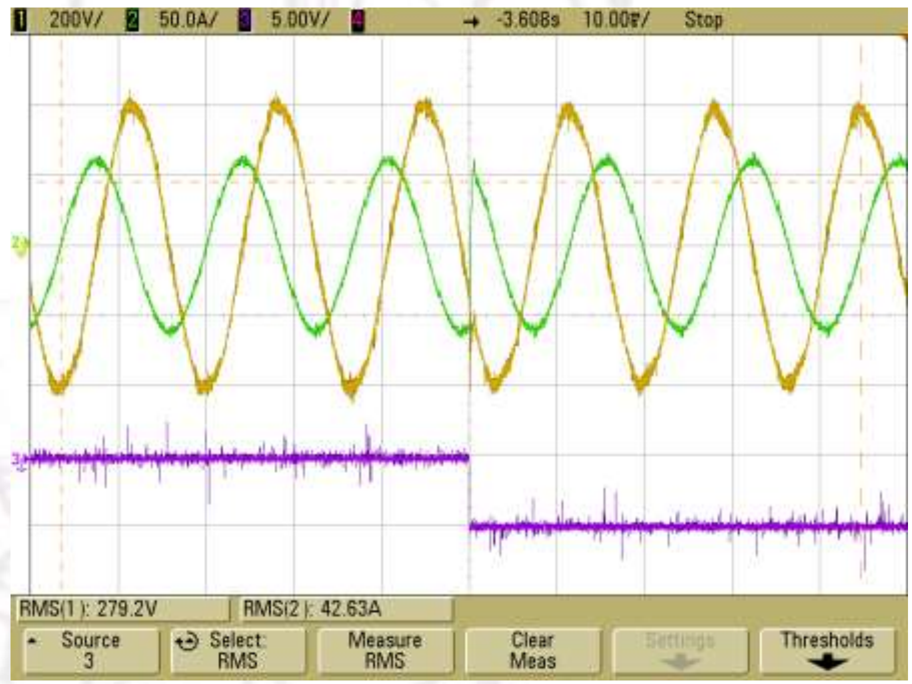
with reset



$$1/T_s \int_0^t V_2 dt = V_1 \quad t = dT_s$$

$$V_2 d = V_1$$

- OCC solves the first order polynomial equation
- OCC solves fast VAR on demand in one switching cycle ~50 μs



Ultrafast VAR step response

OCC-DVC Stabilizes Voltage

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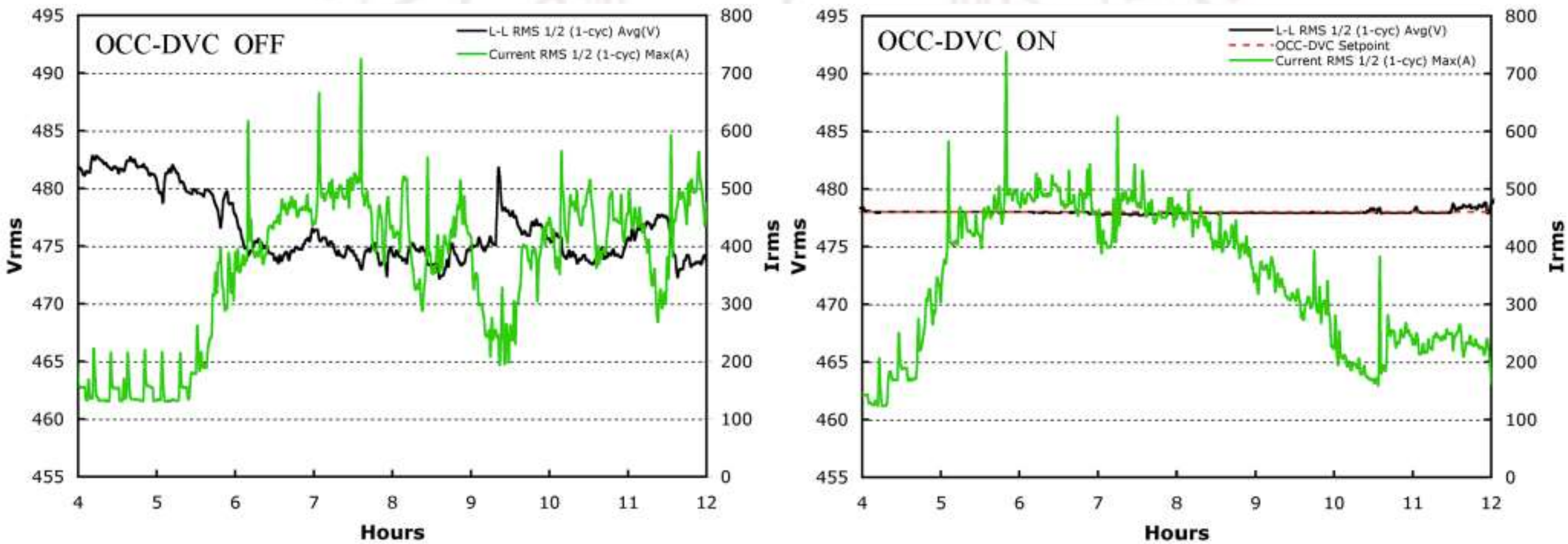
OCC-DVC — Ability to regulate voltage to a flat line

- Stabilize voltage and improve grid resilience
- Quench fast transient disturbances
- Deliver inductive and capacitive VARs for smooth power regulation
- Modular, scalable, and small foot-print
- Field proven (SDGE)



Simulation with IEEE 9-Bus

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Ref: EPRI Power System Dynamic Analysis, EPRI EL-484 (Research Project 670-1) , 1977

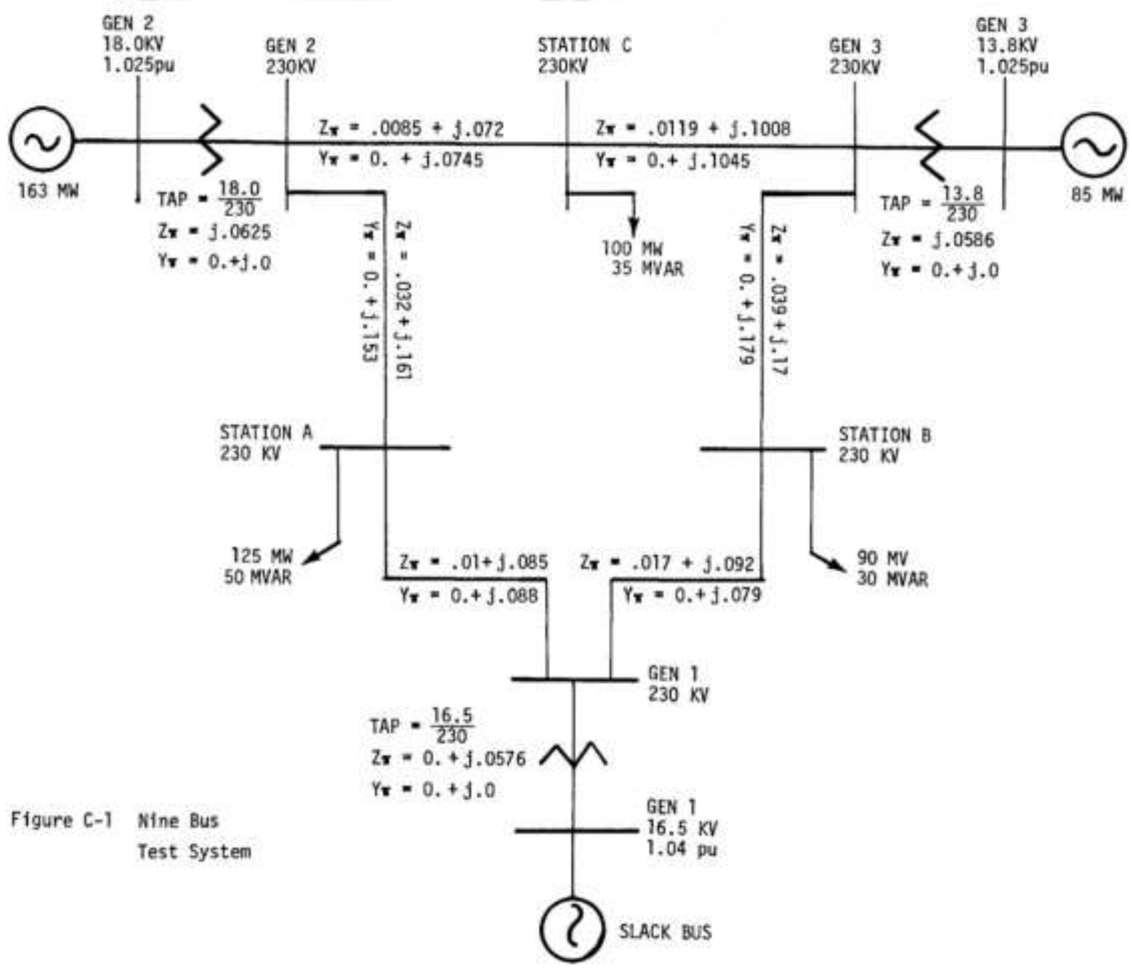

Figure C-1 Nine Bus Test System

- Representative small power grid configuration
- With capacity ~2/3 of Crete

MATLAB Model of IEEE 9-Bus

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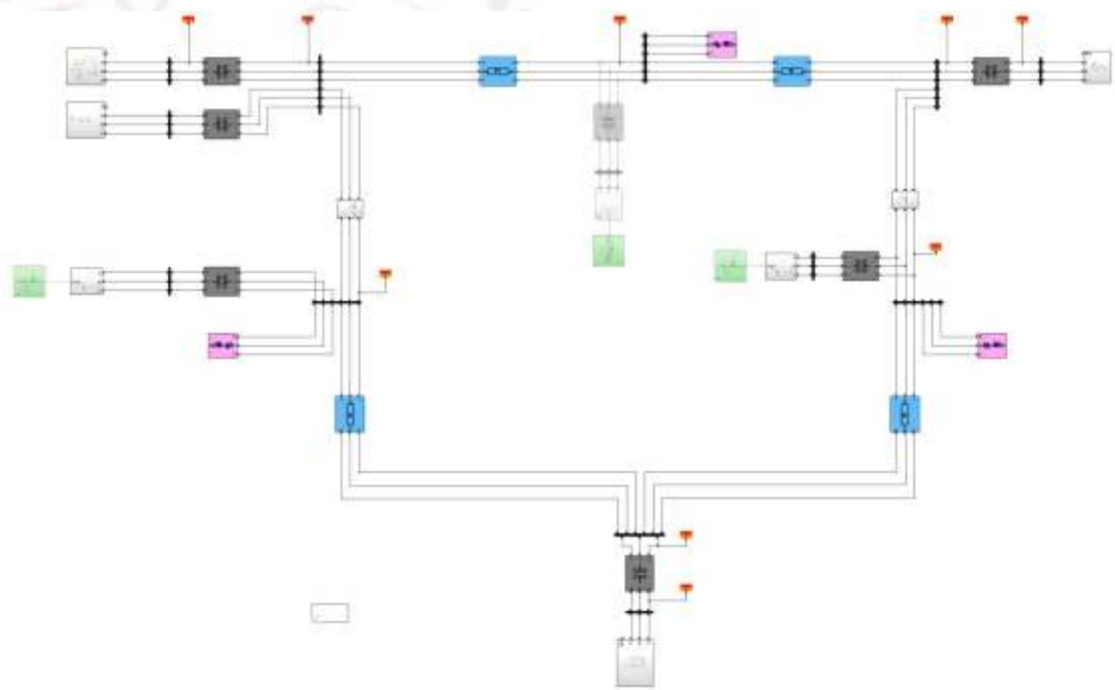
- Generators ~500 MVA
- 315 MW load Bus 5, 6, 8
- 3 RES @ Bus 1, 2, 3
- 3 DVC @ Bus 5, 6, 8
- ΔV measurements (1-9)



ID	*Rating*	*Rated kV*	*MW*	M_{var}	*Amp*	*% PF*	*% Generation*	*% Loading*	V_{termal}
G1	*247.5 MW*	*16.5*	*71.337*	*26.96*	*2566*	*93.54*	*28.8*	---	---
G2	*163.2 MW*	*18*	*163*	*6.562*	*5105*	*99.92*	*99.9*	---	---
G3	*108.8 MW*	*13.8*	*85*	*10.88*	*3498*	*99.19*	*78.1*	---	---
Load A	*135.532 MVA*	*230*	*124.761*	*49.895*	*338.8*	*92.85*	---	*99.6*	*99.57*
Load B	*92.449 MVA*	*230*	*89.939*	*29.98*	*235*	*94.87*	---	*101.3*	*101.27*
Load C	*102.637 MVA*	*230*	*99.975*	*34.977*	*261.7*	*94.39*	---	*101.6*	*101.59*

High Penetration ➔ Destabilizes Grid

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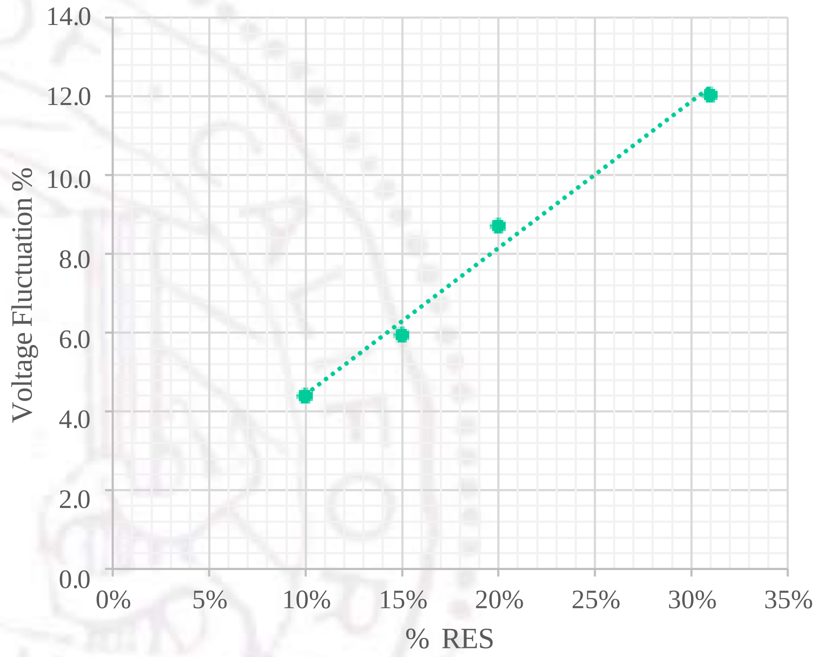
Voltage Error (%)	10% IBR	15% IBR	20% IBR	31% IBR
ΔVb1	4.4	5.9	8.7	12.1
ΔVb2	4.7	7.5	10.1	13.0
ΔVb3	4.3	6.9	9.8	12.9
ΔVb4	4.3	6.4	9.3	12.4
ΔVb5	4.2	6.7	9.5	12.4
ΔVb6	4.2	6.5	9.4	12.3
ΔVb7	4.4	7.1	9.9	12.8
ΔVb8	4.3	7.0	9.8	12.6
ΔVb9	4.3	6.9	9.8	12.8
AVG	4.4	6.8	9.6	12.6



- Voltage fluctuation increases when % RES increases
- High voltage fluctuation ➔ lower stability margin

OCC-DVC: Quenches Fast Transient's[1][2]

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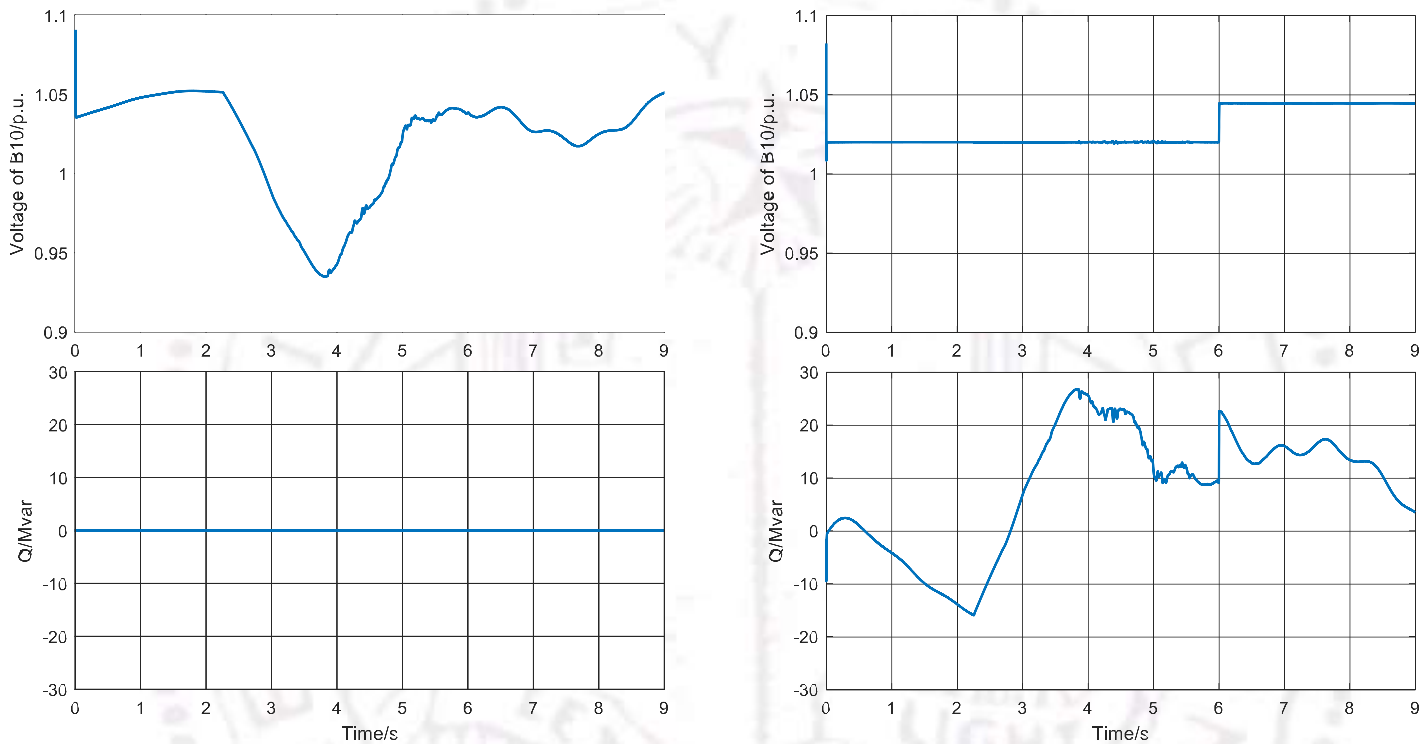
ΔV

Q



OCC-DVC OFF
Voltage fluctuates

OCC-DVC ON
Voltage scheduled

OCC-DVC: Increases RES Penetration

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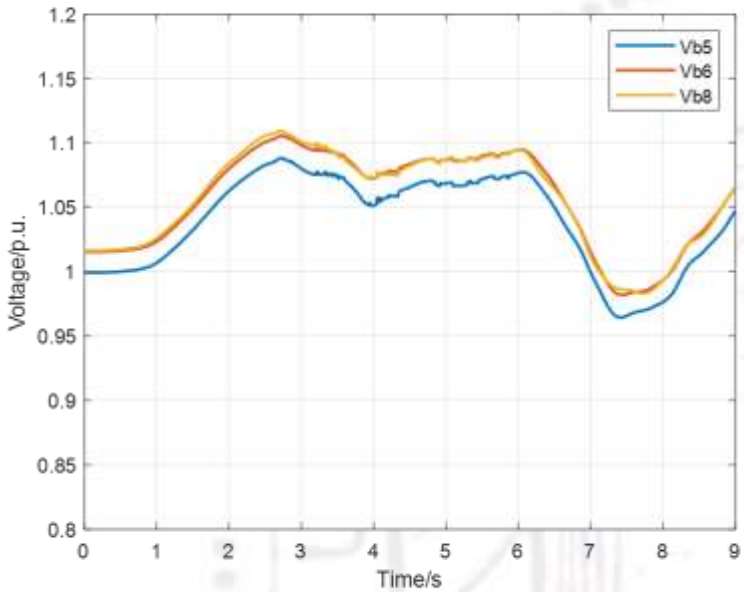

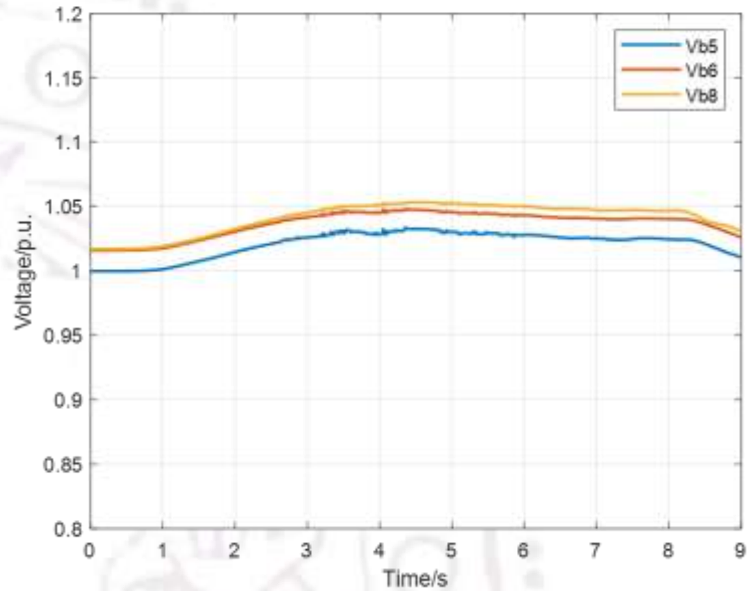

31% Renewable penetration ——

OCC-DVC.OFF
Voltage fluctuation 12.5%

With OCC-DVC ON
Voltage fluctuation 3.5%

- OCC-DVC enables high renewable penetration
- >30% penetration is feasible
- ± 80MVAR injection

Summary

- RES stresses power grid
  - Fast transients
  - Voltage disturbances
- Ultra fast VAR enables high RES penetration
  - Quench fast transients
  - Stabilize voltage
- OCC-DVC technology
  - Breakthrough in precision and speed
  - Modular flexible small footprint
  - Field and simulation proven

Thank you !