

### One-Cycle Control for Stabilizing Power Grids with High Renewable Penetration and Dynamic Plug Loads

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1. University of California Irvine

2. One-Cycle Control, Inc. Irvine

Calplug Workshop October 24, 2023



## **UC-Irvine**

Founded in 1965 37,000 students, 5 Nobel Prizes Top 10 public Universities

3

The University of California, Irvine

Welcome to UCI!





## **Power Electronics**

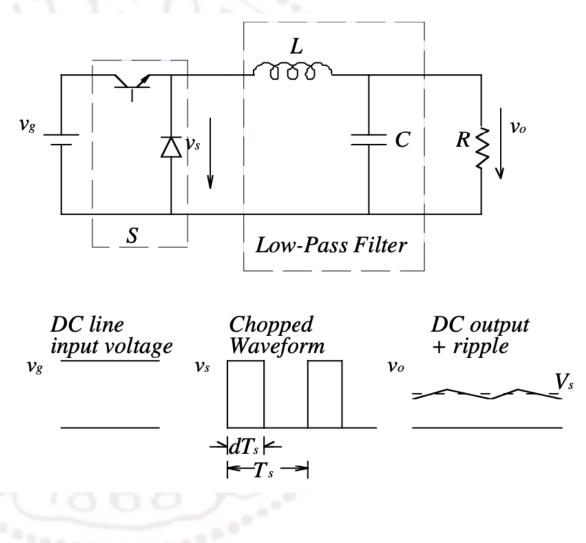
#### **UCI Power Electronics Lab**

→ Work horses of the modern society!

5

Power

- Computers
- Communication
- Lighting
- TV
- EV
- Solar power
- Wind generation
- Energy storage
- Radars
- Spacecraft
- Satellites
- High speed train....

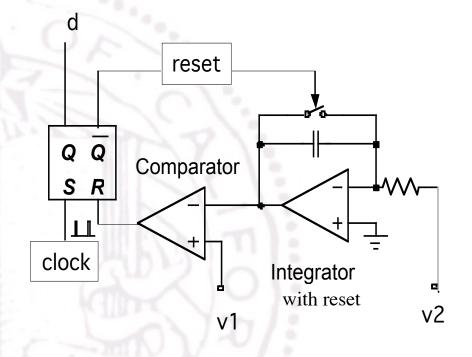


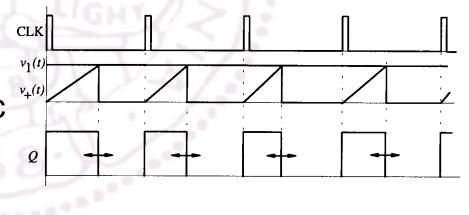


$$\frac{1}{T_s} \int_0^t V_2 \, dt = V_1$$
$$t = dT_s$$

 $v_2 d = v_1$ 

OCC solves the first order polynomial equation => solves most power electronic problems







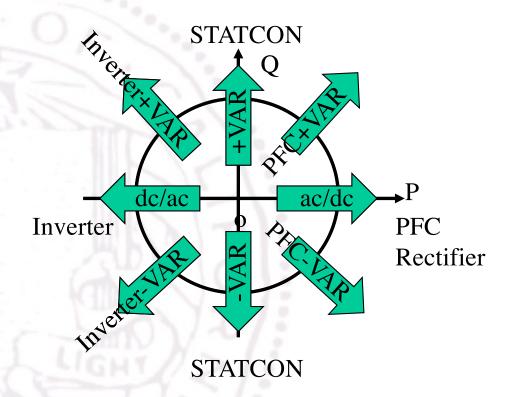
## Power Grid Applications

- Energy harvest
  - Solar: DC/AC
  - Wind: AC/DC and DC/AC
- Power balance
  - Energy Storage: Bidirectional ac/dc
  - Power flow control: VAR STATCON
- Reactive demand
   VAR STATCON
- Power Quality
  - Stabilize dynamic plug loads
  - Unified Power flow control
  - STATCON



- 4-quadrant power converter<sup>2,3</sup>
   => universal grid building block
- Fast precise control

   => stabilize grid against rapid transient



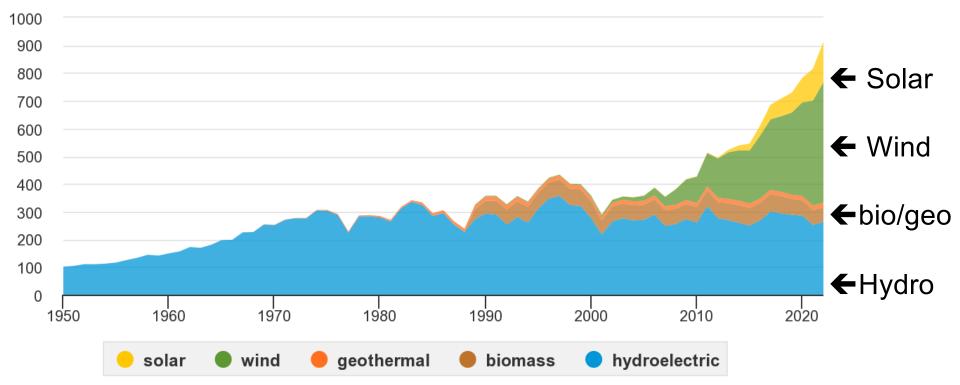
- 1. Keyue Smedley, "One-Cycle Control and Its Applications in Distributed Generation" COBEP 2004, Brazil.
- 2. K. Smedley and C. Qiao, Unified Constant-frequency Integration Control of Three-Phase Rectifiers, Inverters, and Active Power Filters for Unity Power Factor, US Patent filed 9/99, 6297980. 2001 and more.
- 3. Taotao Jin and Keyue Smedley, "T. Jin, L. Li, and K. Smedley, Universal OCC Converter for Distributed Generation, Power Electronics Technology Conference, Chicago, 2004.

# US Renewable Generation

#### **UCI Power Electronics Lab**

#### U.S. electricity generation from renewable energy sources, 1950-2022

billion kilowatthours



Data source: U.S. Energy Information Administration, *Monthly Energy Review* and *Electric Power Monthly*, February 2023, preliminary data for 2022



Note: Includes generation from power plants with at least 1 megawatt electric generation capacity.

Hydroelectric is conventional hydropower.

### Solar + Wind ~ 12% of total generation

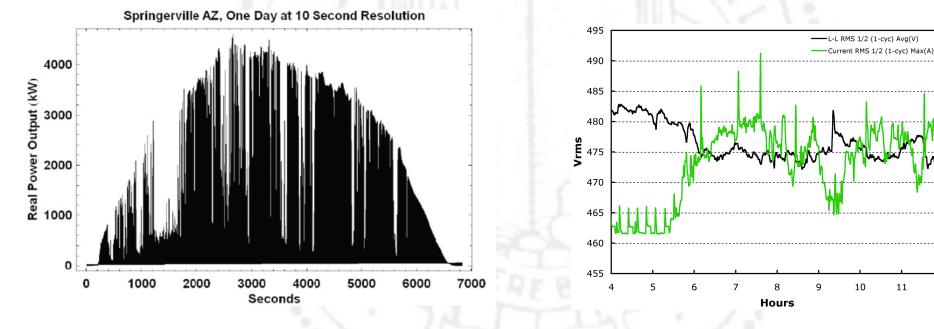


### **Renewable Challenges**

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- 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.

800

700

600

500

400 **E** 

300

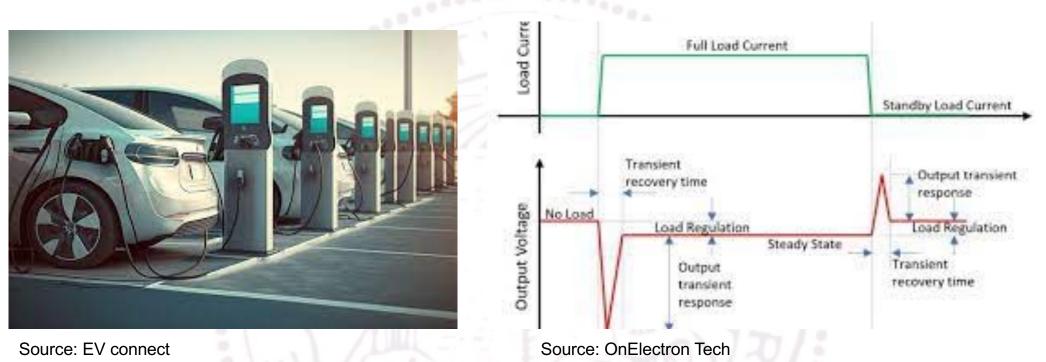
200

100

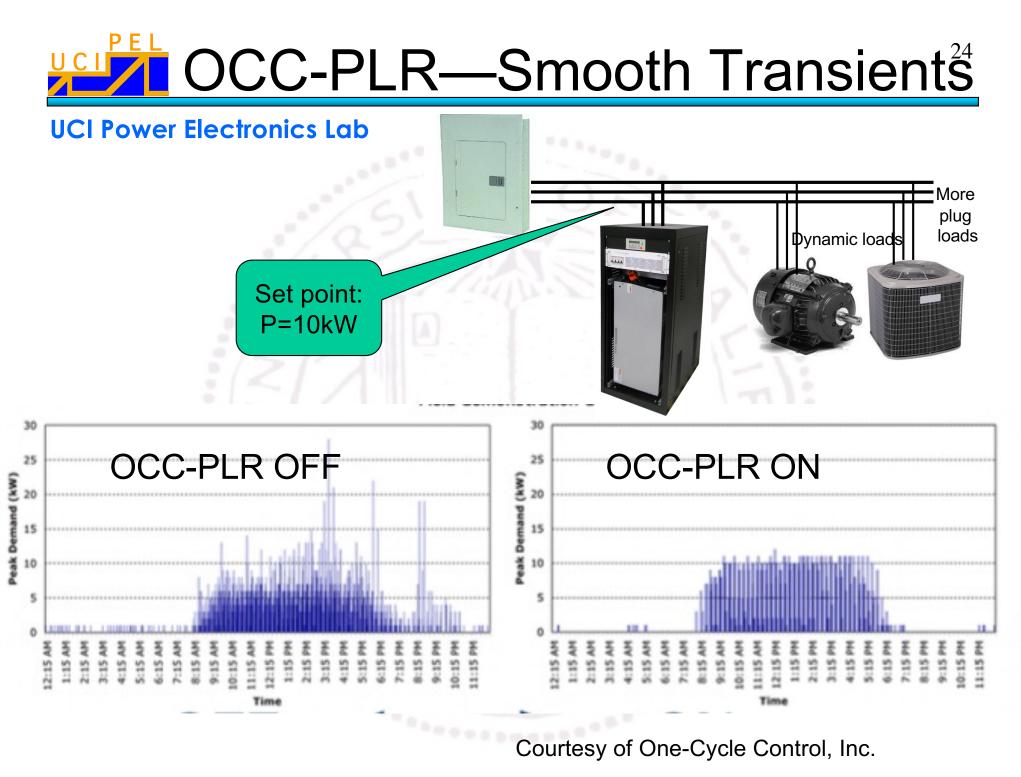
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# Plug Load Challenges

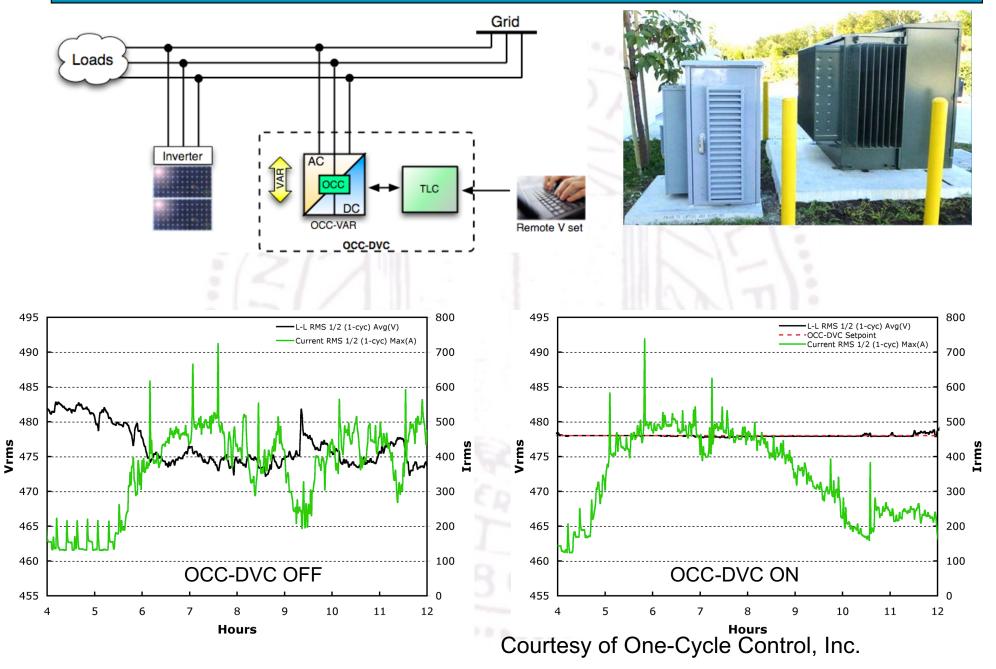
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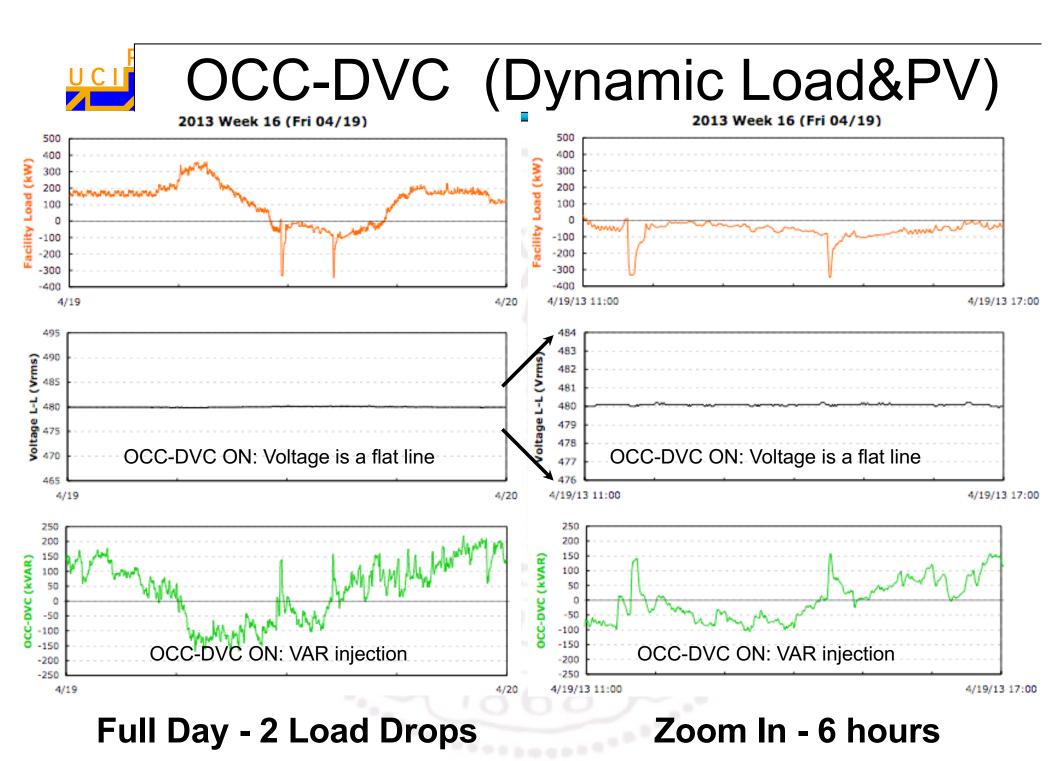


### Transients → Voltage instability Voltage instability → EV Charger trip



## OCC-DVC--Stabilizes Voltage<sup>27</sup>







- Renewables and EV loads stress power grid
  - Fast transients
  - Voltage disturbances
- Ultra fast DVC and PLR enable high RES penetration and EV loads
  - Quench fast transients
  - Stabilize voltage



