Current Installed Wind Capacity (MW)

**Total: 60,078 MW**  
(As of 09/30/2013)

*20% Wind Energy by 2030*

*2013*
PV Array IV

Current (A)

Voltage (V)

20-cell stack

30-cell stacks

PV array maximum power point

Direct Coupling

Close Coupling

On average 10% improved energy capture of system capable of switching between direct coupling and power converter

Irradiance [W/m^2]
**Electrolyzer – Grid Frequency Support**

**Purpose** – Compare system-level response of PEM and alkaline electrolyzers

**Result** – Demonstrated ability to quickly mitigate frequency disturbance (i.e., ramping renewable power)

*Ac microgrid*

**AC microgrid**

**PEM Electrolyzer**

**Synchronous Generators**

**Load Simulators**

**Frequency (Hz)**

- 60.5
- 60
- 59.5
- 59
- 58.5

**Time (seconds)**

- 0
- 0.5
- 1
- 1.5
- 2

**Power (kW)**

- 40
- 30
- 20
- 10
- 0

**‘Natural’ Frequency Response due to 0 - 25 kW resistive load step**

- Electrolyzer Command sent at 59.8 Hz
Electrolyzer – Grid Frequency Support

10 kW steps - PEM and alkaline systems shorten magnitude and duration of under-frequency disturbance on AC micro-grid.

25 kW steps - PEM and alkaline systems shorten and reduce magnitude of over-frequency disturbance on AC micro-grid.
Decay Rate – Variable Power Stack Testing

Summary – Completed 10,000 hours on neglected stacks. Variable and constant power decay rates were within 10%.

Path Forward – Two new stacks installed. (1200 hours to date)

Monitoring and Control

- Stack input and output temperature
- Stack voltage and current
- Individual control over each of 3 stacks
- Programmable wind/solar profiles

![Graph showing stack current over time]
**Opportunity** – Intentionally size # of cells to take advantage of variable-speed wind turbines DC buss

**Results** – Demonstrated operation of 20 cell PEM stack with \( \pm 22.5 \) V using power supplies instead of 45 Vdc.
Thank you!

20% Wind Energy by 2030

PV – Stack Coupling

PEM & Alkaline Electrolyzer Response Testing

Giner Electrolyzer and Stack Decay Testing