

Faster, Smarter, Controllable, Greener, Distributed, Enhanced, Grid the Key to the “FutureGrid” is?

- Power Electronics -



Satcon



Satcon founded out of MIT/Draper Labs



Developed flywheel engine for Chrysler



Initial public offering on NASDAQ



Introduced first 225 kW PV inverter



Introduced first 1 MW single cabinet PV inverter

Refocused on Utility-scale power electronics. Divests all non-core assets



Introduced first outdoor-rated inverter with 98.5% efficiency

Achieved #1 position in North American PV inverter market

1985

1987

1992

1993

2003

2004

2005

2008

2009

2010

2011

Won landmark defense contract for Star War's initiative



Introduced first 100 kW single cabinet PV inverter



Introduced first 500 kW PV inverter



Awarded SEGIS contract to develop next-generation distributed energy solutions

Introduced first string-level utility-scale central inverter

Introduced first fully-integrated medium voltage inverter solution



Satcon

Solutions Focus



PowerGate Plus

The world's most widely deployed large scale solar PV inverter solutions

Over 2 GW shipped worldwide



Solstice

Increases energy production by 5-12% compared to a centralized inverter system



Equinox

98.5% peak efficiency combined with one of the industry's widest thermal operating ranges



Prism Platform

Factory integrated MV package offering a "plug and play" solution for multi-megawatt utility-scale projects

150 MW sold to date



Satcon

Modern Grid Issues

- Era of Increasing Electrification, Dominant **Secondary** source of energy
 - Instantaneous power
 - Rugged generators
 - Spinning “reserve”
 - Excess capacity (>15% is critical)
 - Low Impedance → Fault clearance
 - Overload Capability

But

- Energy sources (climate, security)
- Poor Power Quality (vs EU)
 - **Slow**, archaic, Hardware & Controls
 - Congestion in T&D infrastructure
- Lack of storage
- Poor Dynamics (generator)
- **Remoteness** (Generation, Utilization and Control)

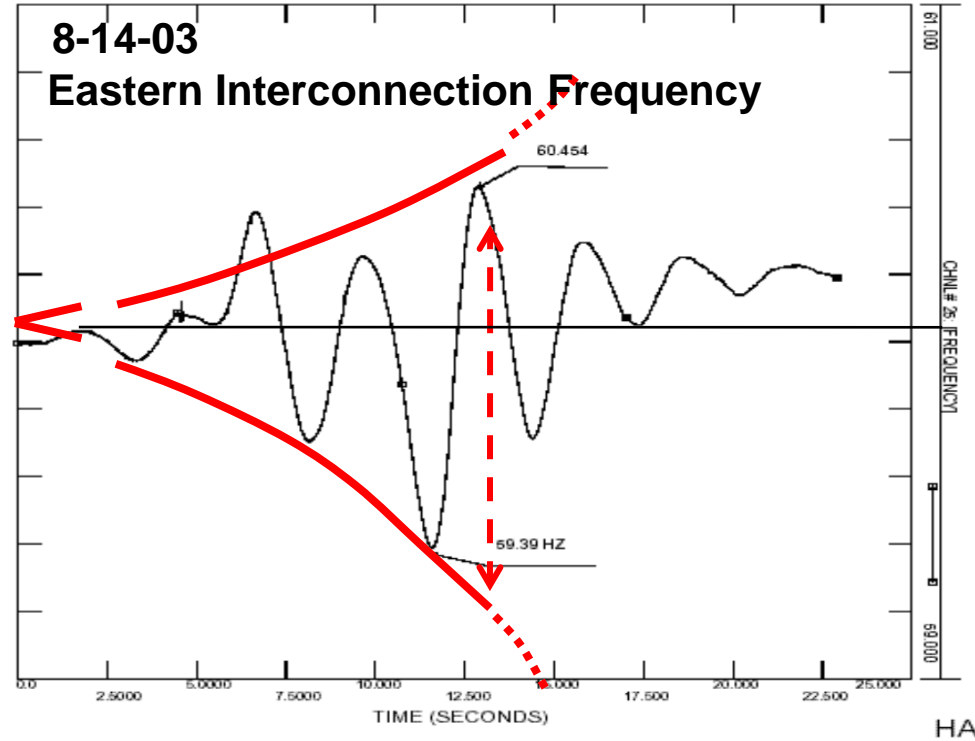
- **Slow** protective devices
- Remoteness of generation and utilization
- Intermittent Renewables (**WIND, PV**)

Some Answers

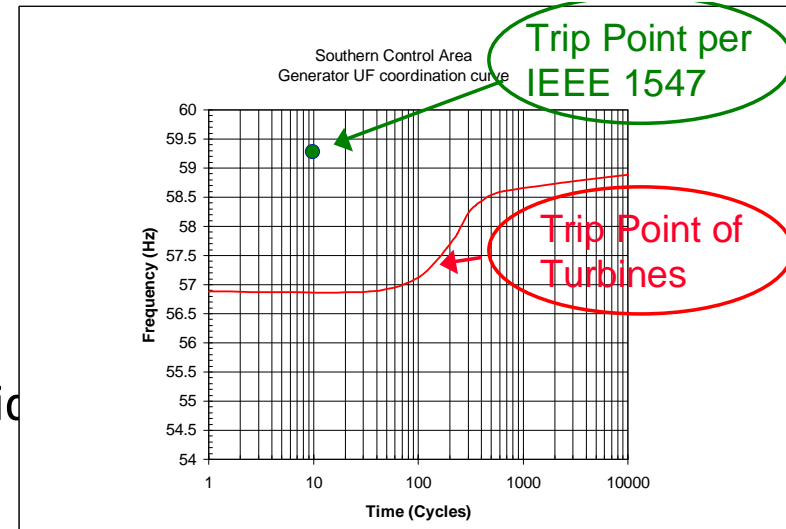
- Cost effective storage (speed?)
- Demand Response (time scale?)
- Efficiencies
- Renewables
- Hi-Speed Controls, Devices
- Reconfiguration (flexible routing for power at T&D level)
- DC transmission
- Segmentation (miniGrids)
- Fault Limiting (**FAST**)

Grid Power Electronics -- Solution not Problem

- Controllable (remotely), high speed
- Dynamic control of Real Power, P
- Dynamic control of Reactive power, Q
- Active Damping (stabilizing)
- Controllable or Synthetic Inertia
- Fault Clearing
- Rapid Dynamics
- Load balancing
- Non-linear sourcing
- Active Filtering
- Harmonic cancellation



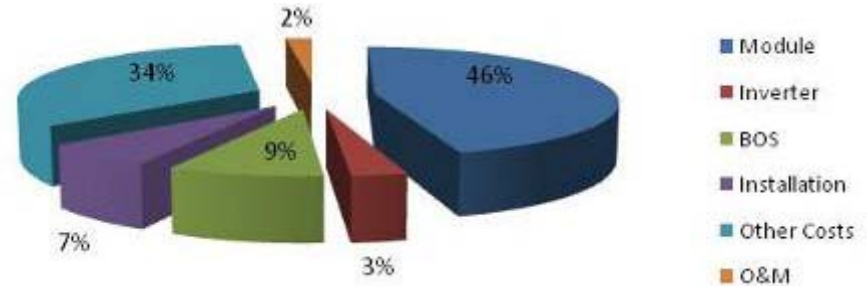
- Also, high speed series devices would
Limit faults and enable robust interactive microgrid



Barriers to High Penetration of Renewables

1. **Cost** (30+% drop in Utility scale solar PV in last 24 months, %5 -> \$3.5 /W)

- Panels
- Inverters, BOS
- O&M

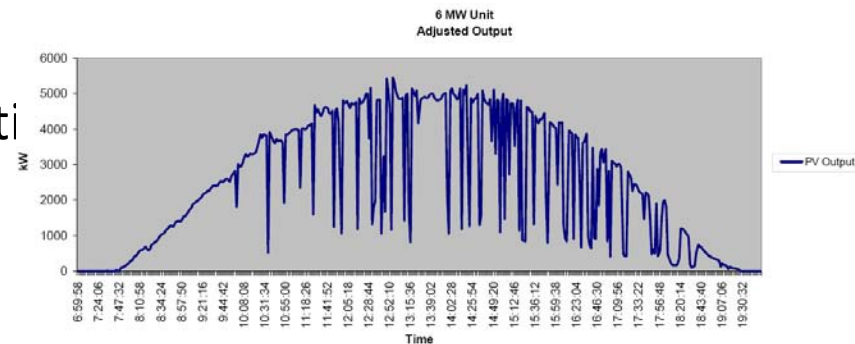


2. Controllability

3. **Intermittency** (Variability/Capacity Factor/Capacity Value)

4. Utility Industry Acceptance/Adoption

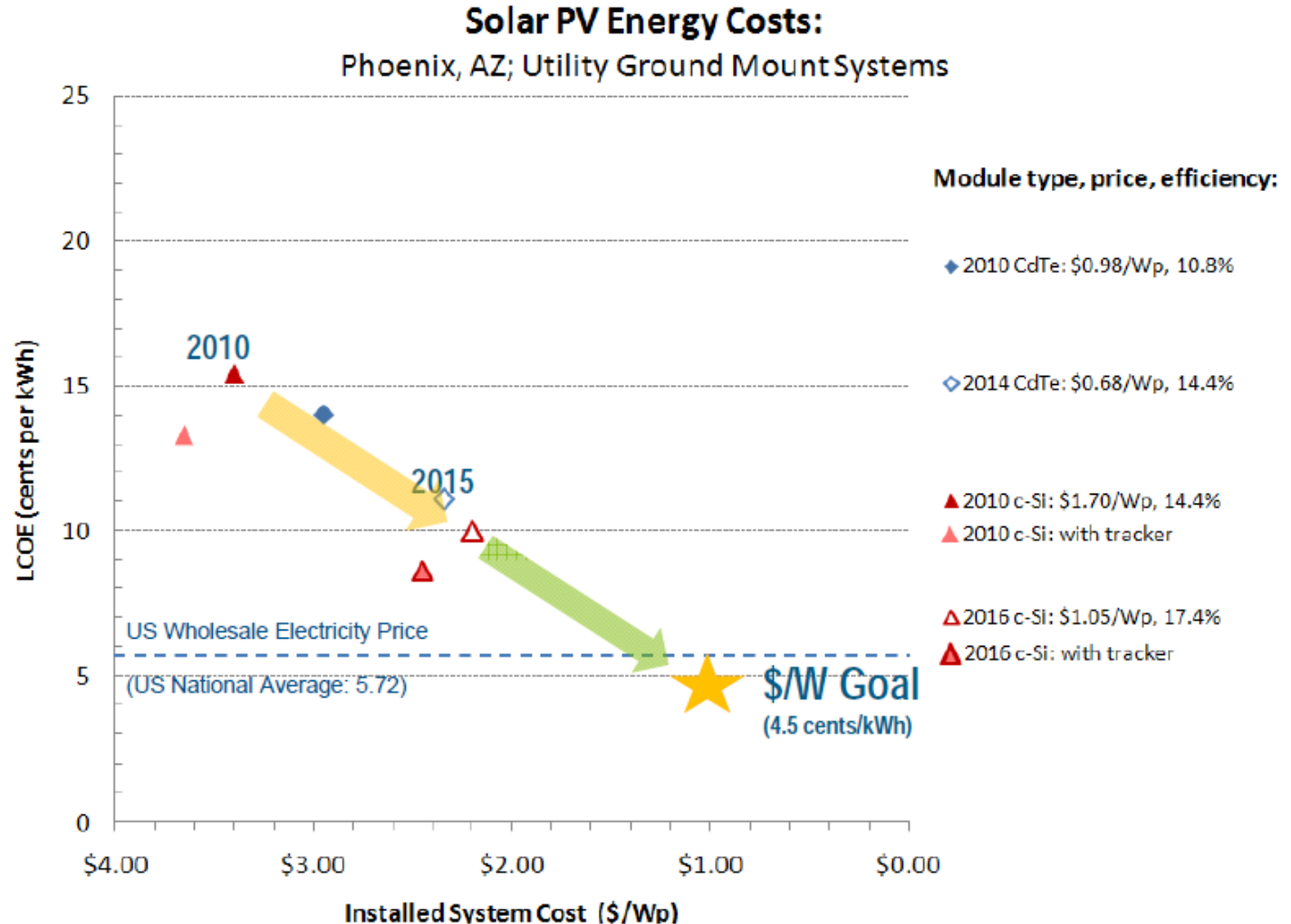
- Scale
- Performance
- Standards
- Familiarity (interconnection, protection)



DOE's Projected PV System Cost Goals – Upcoming \$1/W PV Solicitation

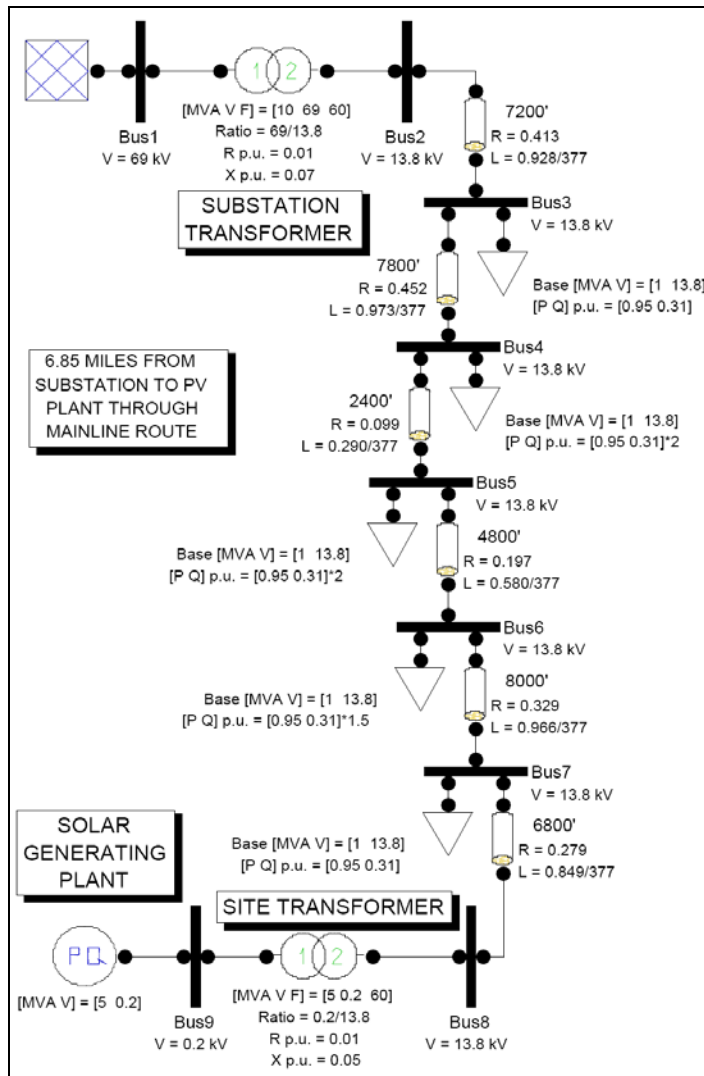
DOE \$1/W Goal

- **PV Module:**
\$0.50/W
- **BOS/
Installation:**
\$0.40/W
- **Inverter:**
\$0.10/W

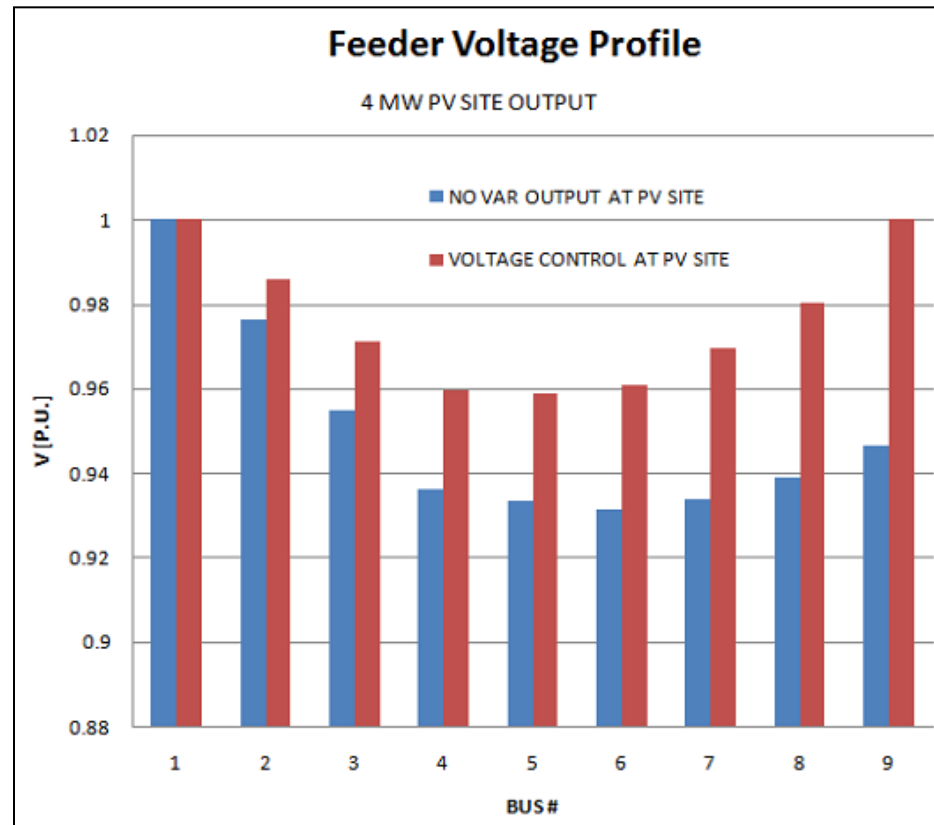


Inverters can Control Local Voltage (droop)

Automatic Voltage Control On a Long 13.8 kV, 10 MVA Feeder With 5 MVA PV Plant Connected

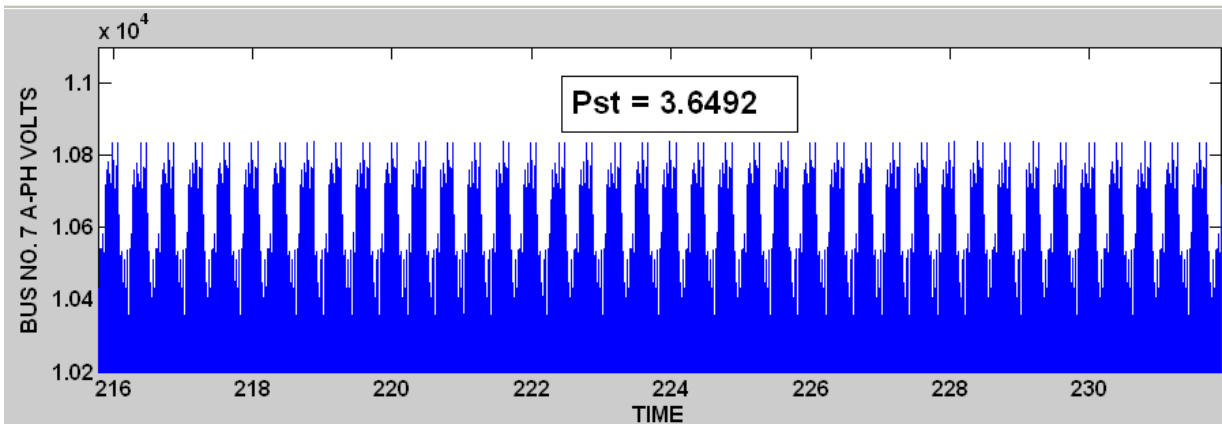


- No tap changers, line regulators, or capacitors
- Balanced feeder, balanced three-phase loads
- 9 buses - 7.5 MVA 0.95 p.f. constant power loads
- PV plant output, P = 4 MW

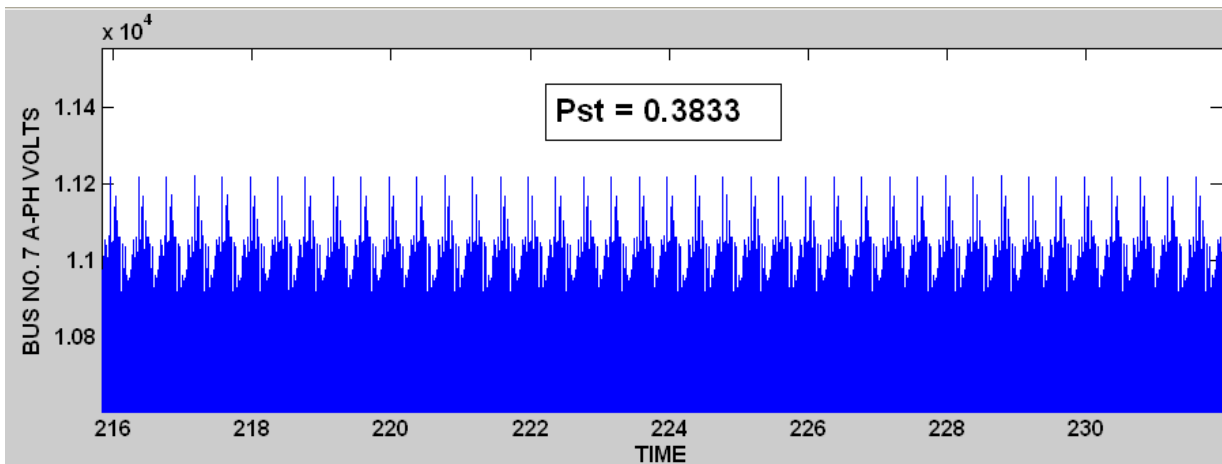


Inverters can Control Local Voltage (flicker)

- Short term flicker assessed from simulated voltage at Bus #7
- Post-processed through IEC Flickermeter
- Event repeated continuously for ten minutes



No Voltage Control
 $P_{st} = 3.6492$
(>0.9 - unacceptable)



Fast Voltage Control
 $P_{st} = 0.3833$
(< 0.9 - acceptable)

Summary

- **Many Economic Values to Distributed Renewables (Power Quality (\$100B + ?, Health & Environment, Labor (local 25% of installed cost), Key to FutureGrid, ...**
- **Controllability and Intermittency are the issues**
- **Inverters can solve some challenging problems, including the local effects of intermittency**
- **In many cases (faults a good example) Inverters and other high speed devices are the solution not the problem**
- **These high speed grid devices can truly enable a Faster, Smarter, Controllable, Greener, Distributed Grid**
- **High speed devices? STS, SDS, FCL, Breakers, ...**
- **Inverters as StatComs**
- **Distributed “shock absorbers” (disturbance mitigation)**
- **More DC, infrastructure, transmission, ...**
- **Control, local-autonomous-high speed, slower regional/area**