One-Cycle Control, Inc.

The Art of Power Processing

OCC-DVC: Fielded Grid Performance

Intro to OCC + OCC-Dynamic VAR Compensator (OCC-DVC)

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

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MADE IN CA a solid economy with manufacturing

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Intro to OCC, Inc.

OCC HQ, Irvine, CA

CALTECH

UCIrvine

Hi-Tech Power Electronics Company
Challenger in the Market
Adaptable

OCC Design, Quality, & Manufacturing

60 kVA
~0.034 m³
~30 kg

Design:

- UL Safety
- Green Design: maximize kVA/m³ & kVA/kg
- MIL-STD Environmental, Safety, Human Factors

Quality:

- ISO9001:2015 Certified (since 2017)
- MIL-STD 1686C [ESD]
- J-STD 001 [Soldering]

Manufacturing:

- Toyota Production System (Visual, KanBan, Material)
- Modular / Scalable [Existing Capacity > 200 MW / yr]
- Build to Order / One-Piece Flow

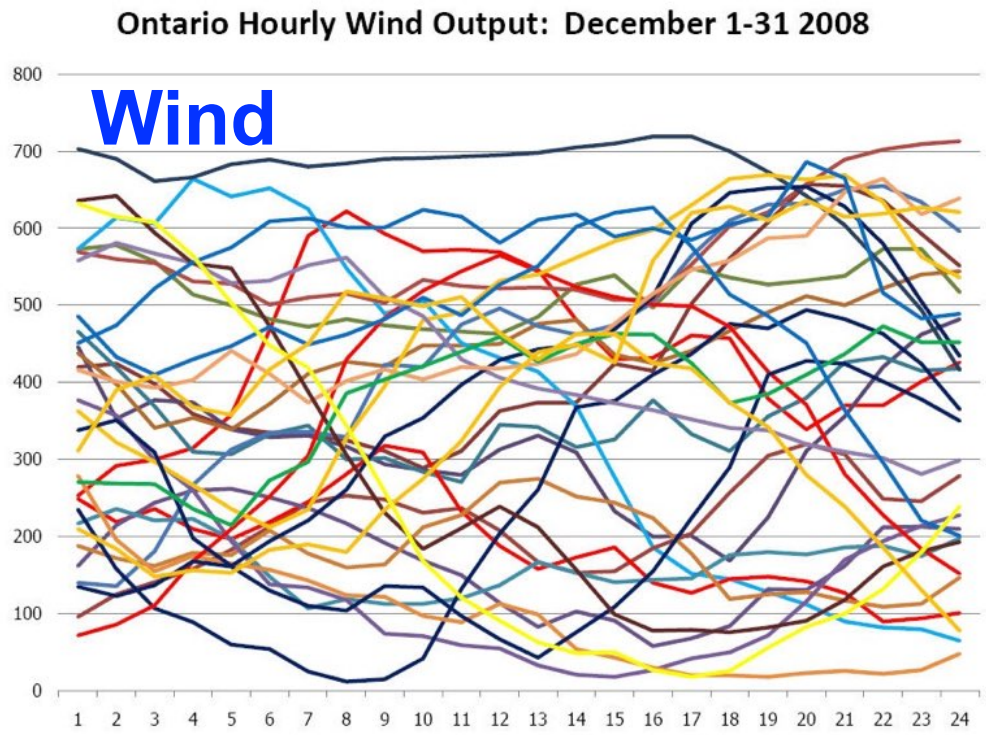
The Present Grid

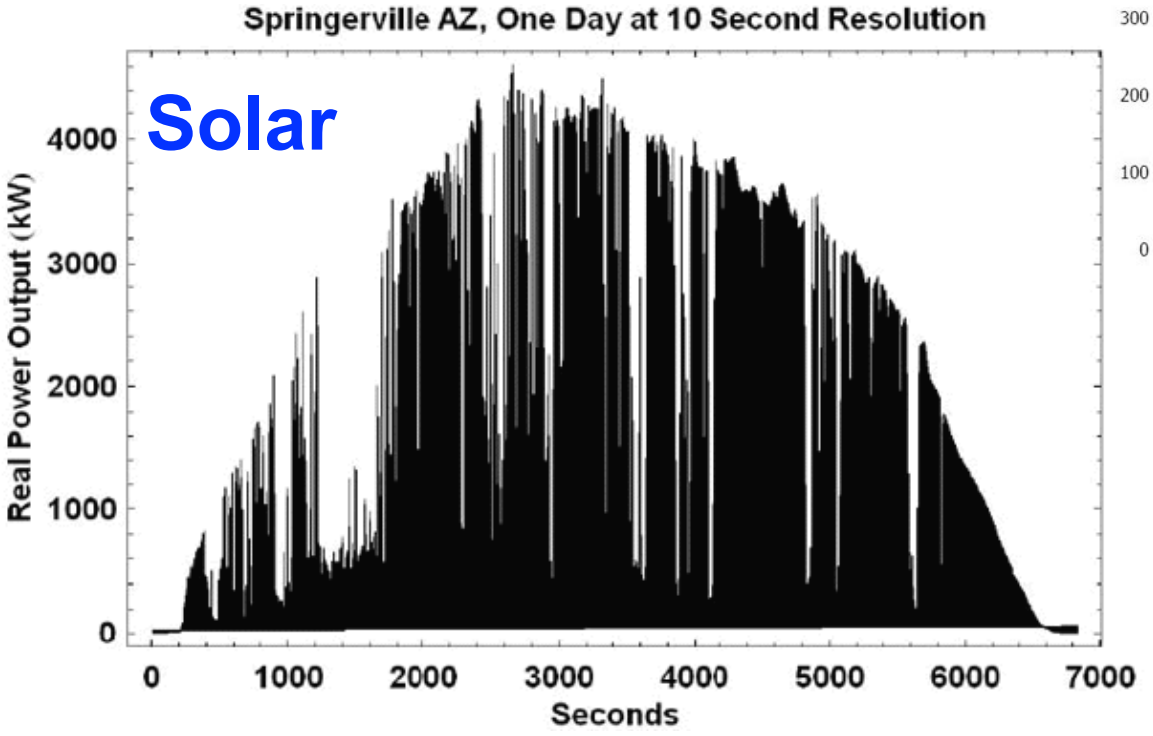
Big

Passive

Dynamically Stressed

Dynamic Sources





Problem:

Dynamic Voltage & Frequency

IF (Island Grid) THEN (less inertia & more dynamic)

Connecting Island to Mainland can help ==> Expensive

VAR & Voltage Regulation Methods

Transmission level

- Synch Condenser
- Switched Cap
- LTC

Distribution level & Low Voltage level

- Switched Cap
- SVC
- STATCON
- OCC-DVC
- LTC

Comparison

	VAR type	Adjustment	Switch transient	Harmonic Effects	Dynamic speed	VAR amount	Peak reactive current	Harmonic effect	Cost
Synchronous Condenser	- &+	Continuous	No	No	Slowest	$\propto V$	Constant	None	Higher
Switched CAP Bank	+ only	Step	Yes	Yes	Slow	$\propto V^2$	$\propto V$	Voltage distortion	Low
SVC	- &+	Continuous	Yes	Yes	Fast	$\propto V^2$	$\propto V$	Voltage distortion	High
STATCOM	- &+	Continuous	No	No	Faster	$\propto V$	Constant	None	Higher
OCC-DVC	- &+	Continuous	No	No	Ultra fast	$\propto V$	Constant	None	Higher
LTC	N/A	Step	Yes	No	Slow	N/A	N/A	N/A	Not comparable

Synch Condenser: high inertia not suitable for fast transients

LTC & Switched Cap: slow speed and discrete step control

SVC: too slow to mitigate fast renewable transients

STATCON: may be adequate if mild transient

OCC-DVC: demonstrated fast transient suppression

Opportunity:

OCC-DVC coordination with LTC, Switched Cap, and SVC

➔ smooth and cost-effective solutions

Future Grid

Distributed

Active

Autonomous “Reflexes”

Enabled by OCC Power Electronics

OCC-DVC

[Autonomous “Reflex”]

Stabilize Voltage
Increase Renewables
Boost Grid Resilience

Grid Challenges

- **Lagging Infrastructure updates**
  - Low Efficiency
  - Limited Operating Margin
  - Network Overload
- **Increased Renewable Generation**
  - Intermittent Supply / Demand
  - Voltage Instability / Flicker
  - Frequent Switching of Load Tap Changers and Switched Cap Banks
- **Grid Resilience**
  - Grid Sabotage (Physical & Cyber Attack)
  - Sudden Load Drop
  - Cascading Blackouts & Economic Loss

Grid Solution: OCC-DVC

- **Increase Efficiency & Capacity**
  - Conservation Voltage Reduction (CVR)
  - Volt / VAR Optimization (VVO)
  - Increase Network Operating Margin
- **Enable High-Penetration Renewable Generation**
  - Establish & Control Desired Voltage Profiles
  - Stabilize Fast Dynamic Voltage
  - Reduce Switching of Load Tap Changers and Switched Cap Banks
- **Boost Grid Resilience**
  - Stabilize Grid Against Sabotage
  - Stabilize Grid Against Sudden Load Drop
  - Limit or Prevent Cascading Blackouts & Economic Loss

OCC-DVC: Field Demos

DOE SuNLaMP Project (2016 - 2019)
Sub-Transmission Stabilization

Pacific Northwest
NATIONAL LABORATORY

DUKE ENERGY®

One-Cycle Control
The Art of Power Processing

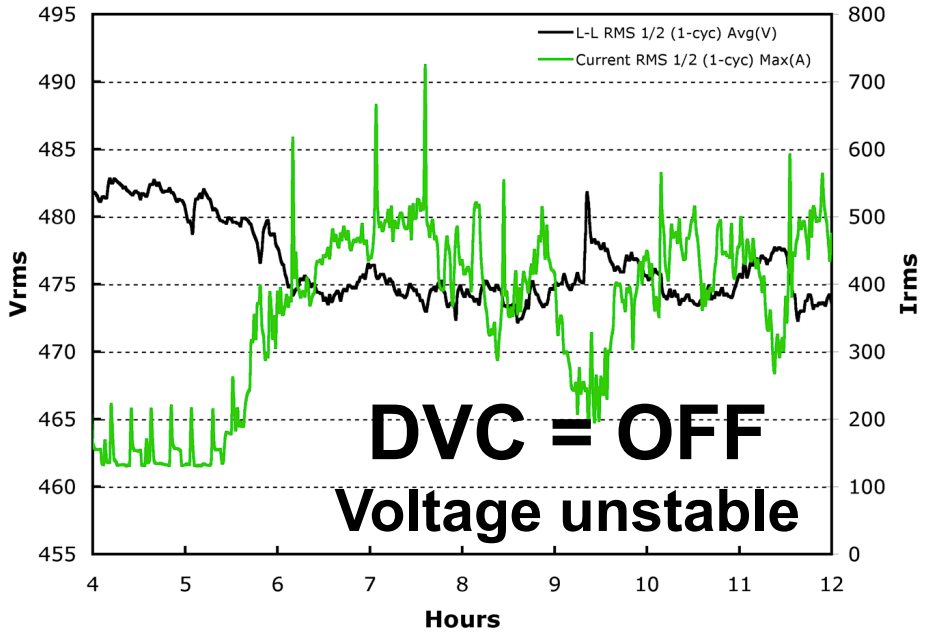
NC STATE UNIVERSITY

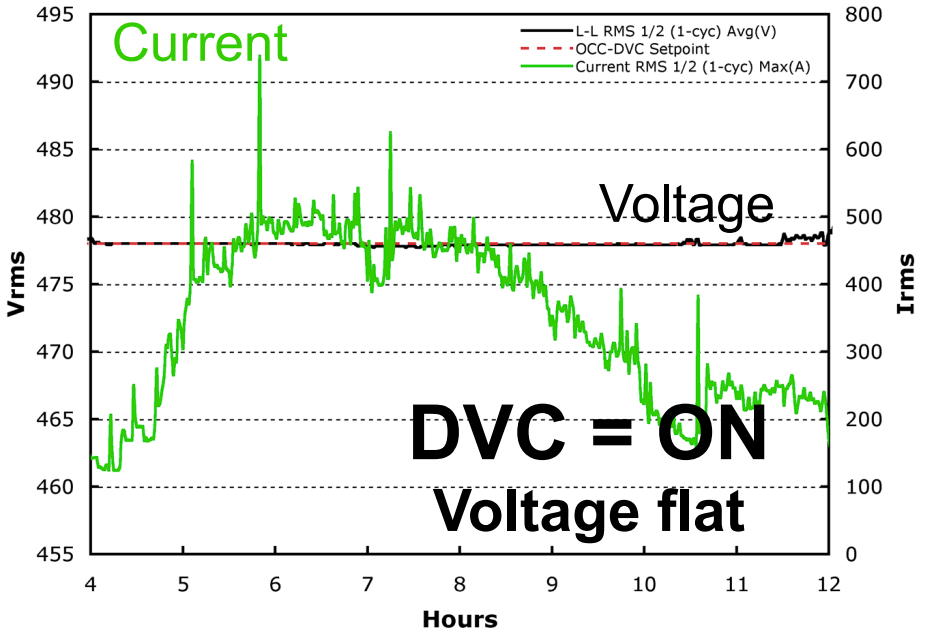
Model/Manage/Control Distribution-Circuit VAR equipment
to stabilize sub-transmission circuits
and enable high-penetration Renewables

http://energy.gov/eere/sunshot/project-profile-enabling-high-penetration-distributed-photovoltaics-through

OCC-DVC: SDGE Install (Jan 2013)

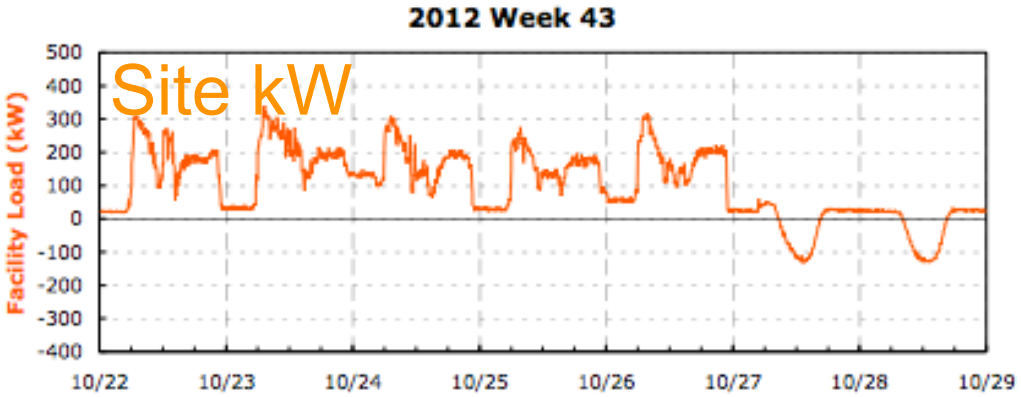
- Remote Setpoint Control
- Distributed, Small, Fast, Precise "Reflexes"
- Low V ride-thru
- **Field Proven**
- **Utility Scale**

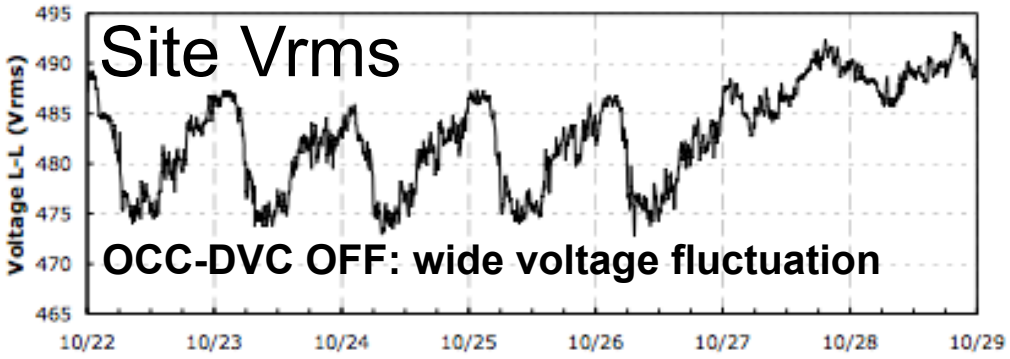


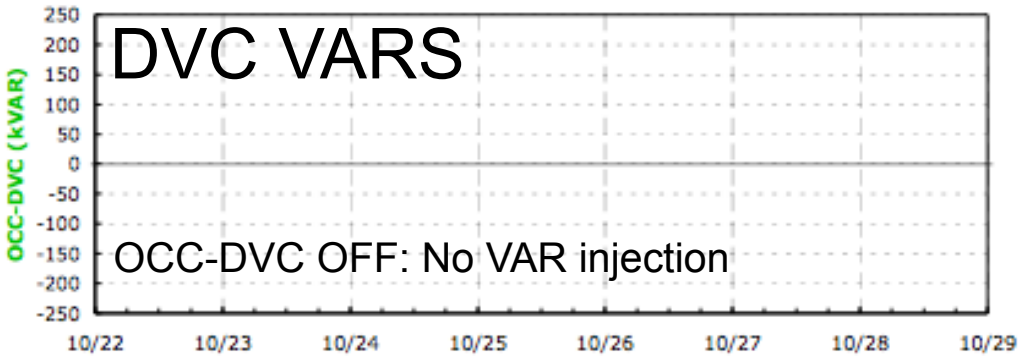


OCC-DVC (Voltage Schedule)

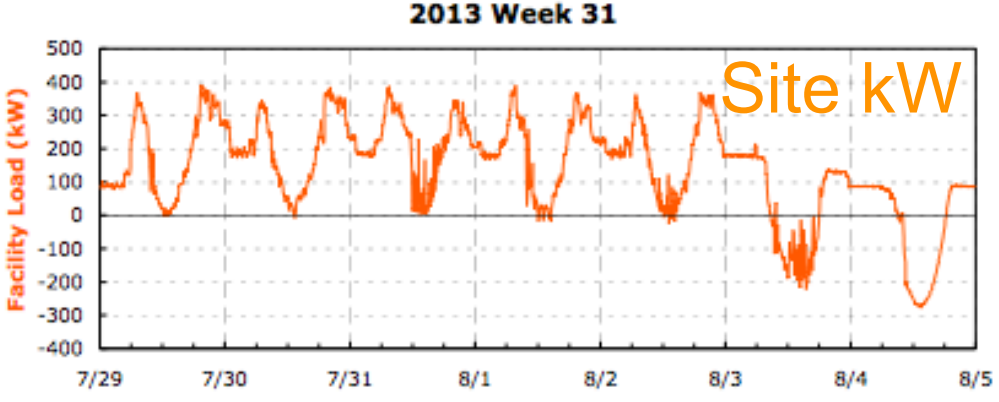
DVC = OFF

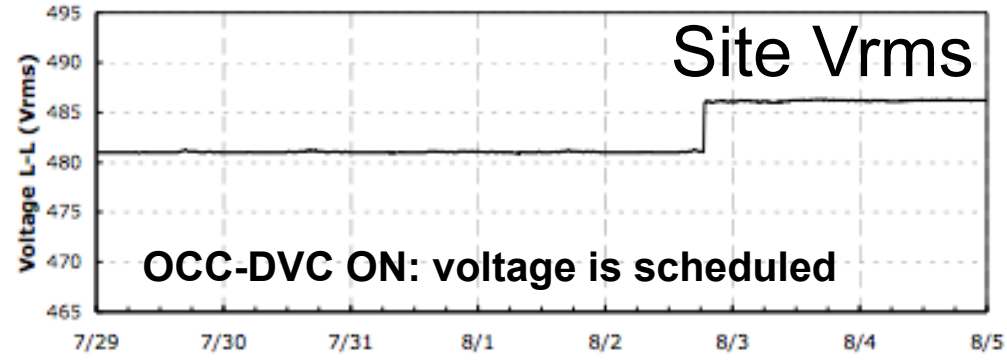


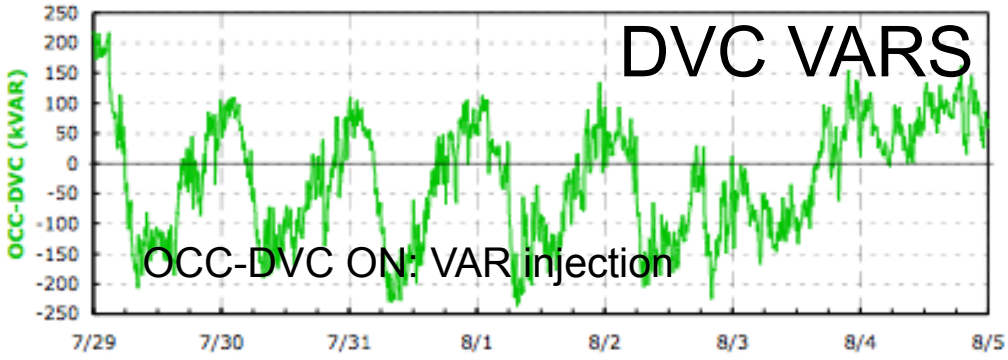




DVC = ON







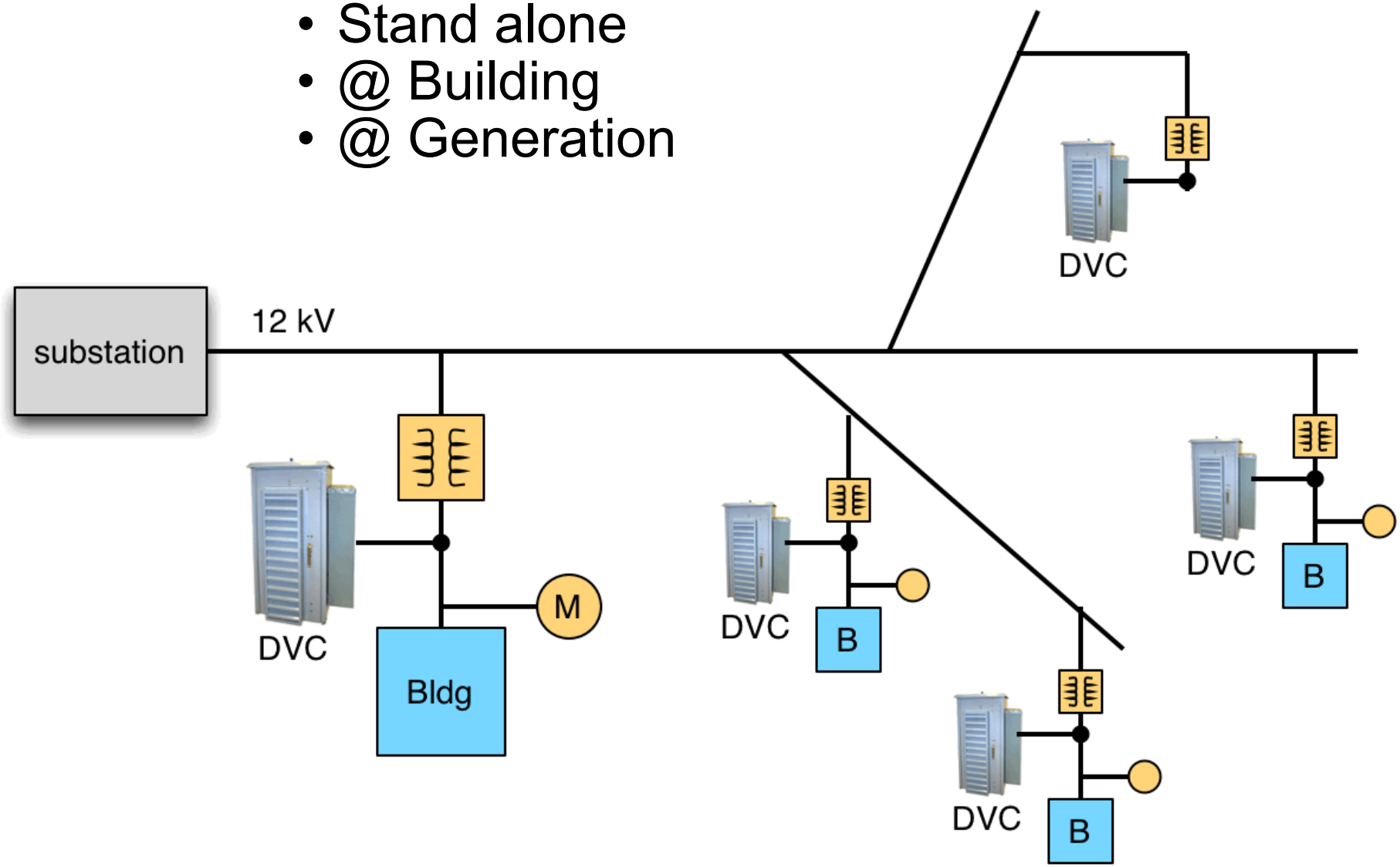
500kV Line Fault ==> October 18, 2013 @ 9:03 am

- Voltage sag was detected in every SDG&E substation
- except the one with OCC-DVC = ON

Where to Install ?

LV side of Distribution XFMRs:

- Stand alone
- @ Building
- @ Generation



How to Service ?

- Rack Mount Modules
- Blind Mate
- Hot Swap
- Remove / Replace ~ 5 min

- Stock Spares Locally
- Ship Modules for Repair

OCC-DVC Benefits

- **Fast Dynamic Grid Voltage Stabilization**
  - Increase renewables (+/- kVARs)
  - Boost Resilience — Limit/Quench cascading blackouts
  - Improve system capacity/efficiency (VVO/CVR)

- **Modular ==> Flexibility with Low OPEX Cost**
  - 1-Person In-Field Module Replacement ~ 5 min
  - Ship for Repair; Stock Spares
  - Relocate modules as Grid configuration changes
  - Scalable: +/- 60 to +/- 360 kVAR (per cabinet)

- **Hardware-Enabled ==> Cyber Secure**
  - Hardware Limits on Set-Point Range
  - Autonomous Operation

Thank you !

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