Utility-Owned Power Quality with Distribution Class STATCOMs DVAR-VVO

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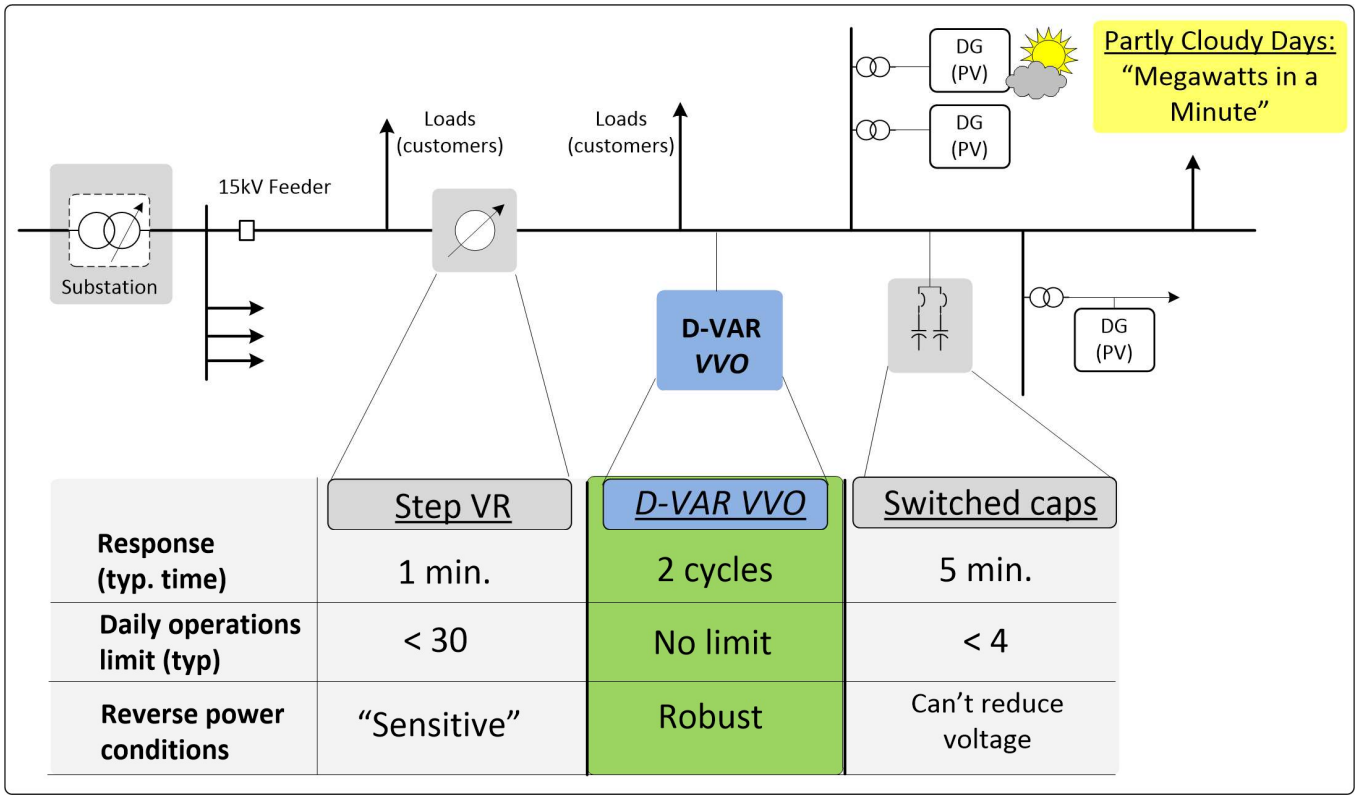
...better energy

What is a STATCOM?

A STATCOM is a shunt-connected power electronics inverter that precisely controls reactive power (both absorb and provide VARS). STATCOMs are capable of controlling Voltage, Vars, or Power Factor.

STATCOMs are used extensively in transmission systems and their use is growing in distribution systems

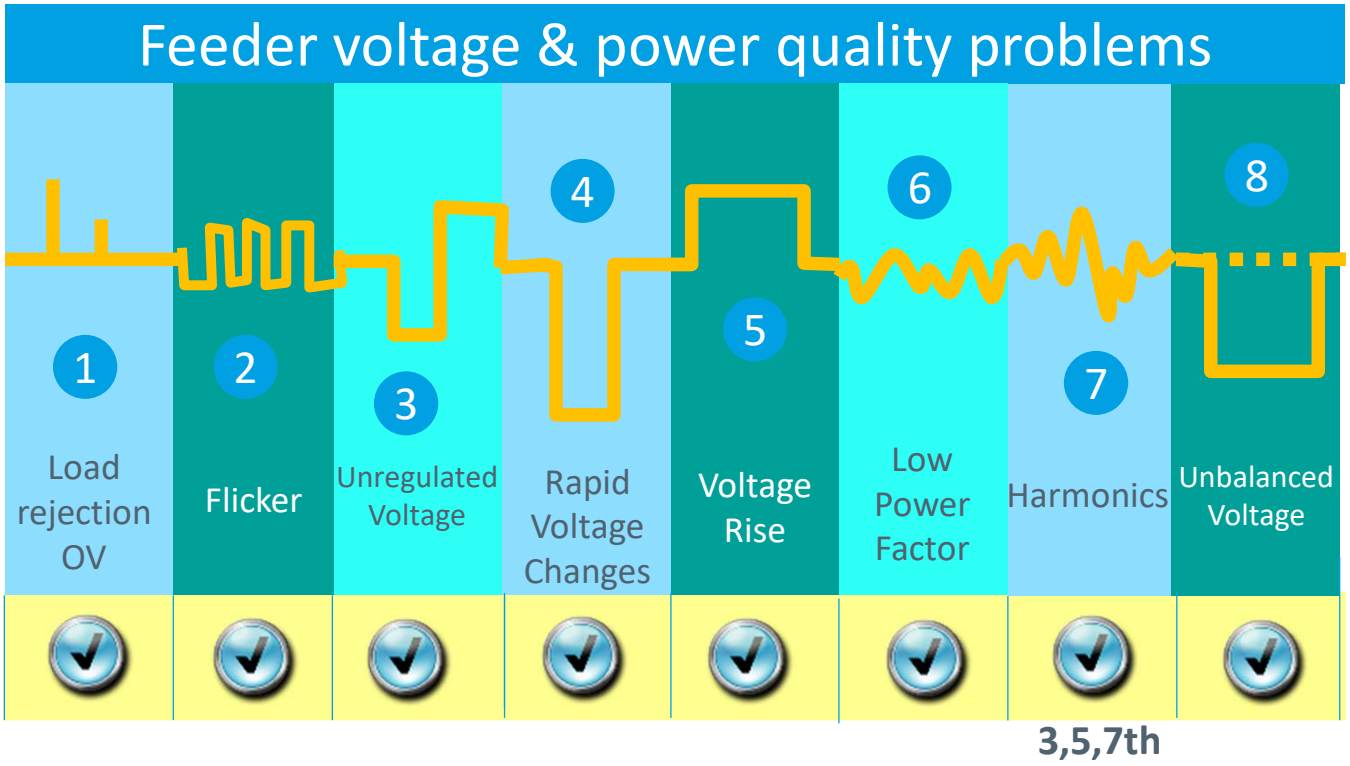
Advantages of Distribution Class STATCOMs



	Step VR	*D-VAR VVO*	Switched caps
Response (typ. time)	1 min.	2 cycles	5 min.
Daily operations limit (typ)	< 30	No limit	< 4
Reverse power conditions	"Sensitive"	Robust	Can't reduce voltage

Continuous power quality with no operation limits

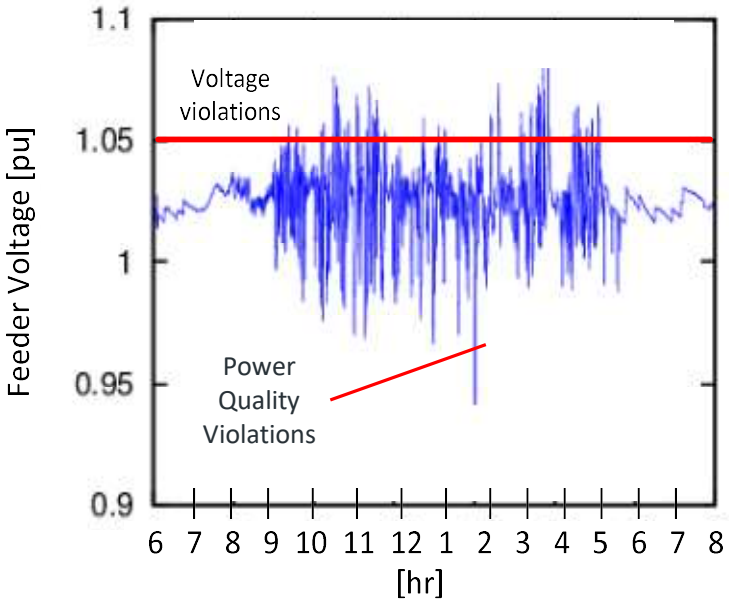
Problems addressed by the D-VAR VVO



Unique power quality capabilities enabled by fast distribution class power electronics

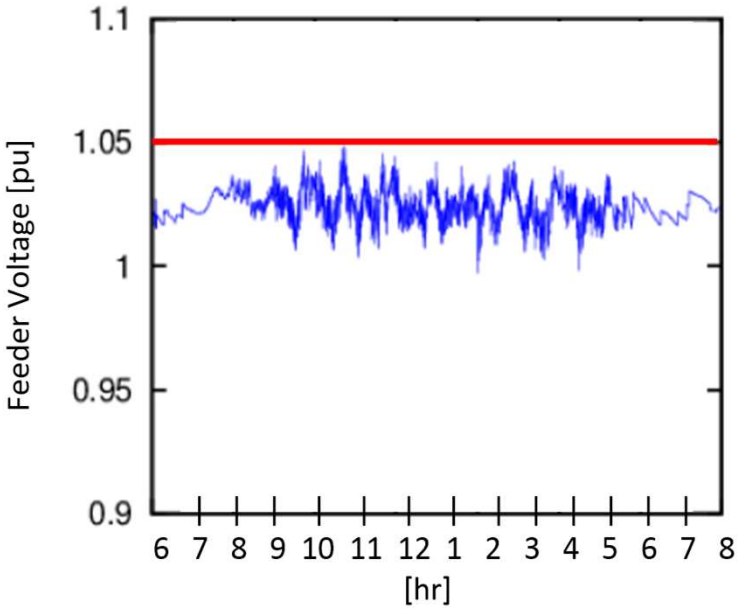
A high-pen solar feeder with reverse power flow

Problem



Measured 10 second feeder data
(Mechanical regulation equipment only)

Solution



Measured 10 second data
(with D-VAR VVO installed on feeder)

D-VAR VVO Compensates for Challenging Power Quality Problems

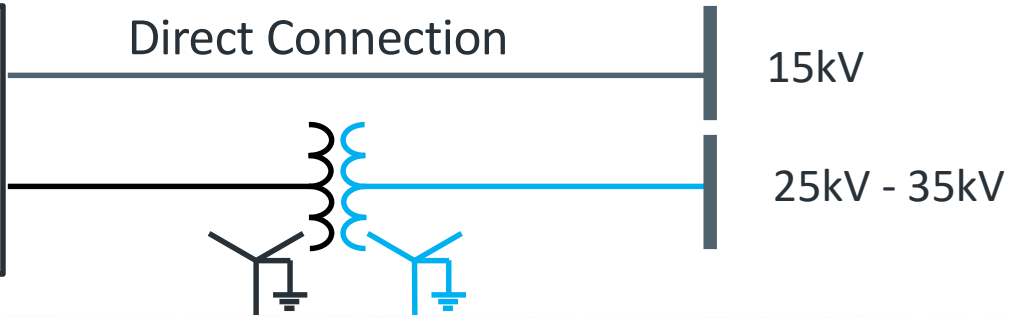
D-VAR VVO Distribution Class STATCOM

D-VAR VVO®

- 1 MVar to 4 MVar configurations
- 15 kV connection
- 25-35kV w/step up

D-VAR VVO®

1 MVAR single 3PH bank
15 kV connection



D-VAR VVO® Solution

Shunt power electronics modules

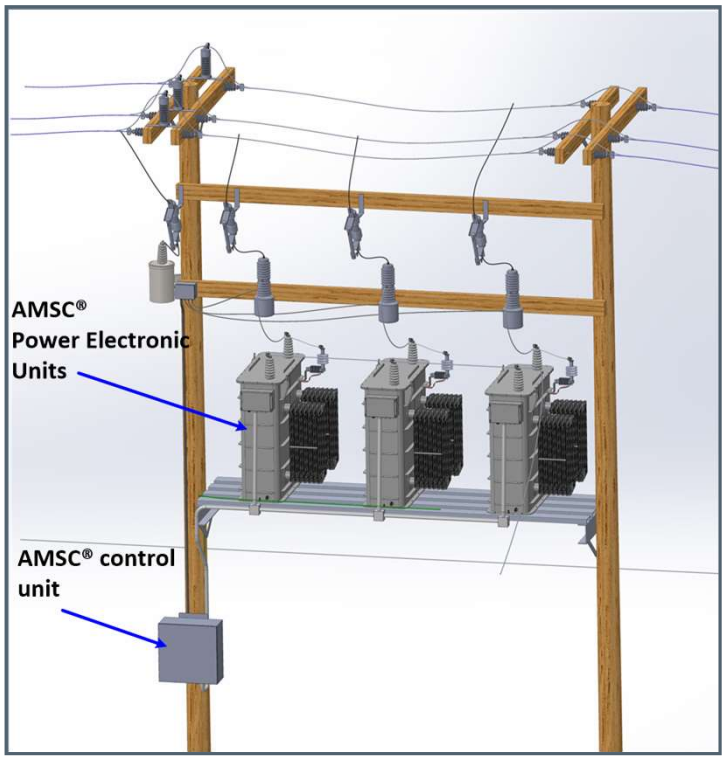
- Absorbs and supplies reactive power
- Continuous control of volt/VAR
- 3ph or 1ph application

Meets distribution class standards

- Dielectric integrity
- Enclosure integrity
- Acoustically Quiet

No routine maintenance

- No moving parts, no pumps, no fans, no tap changers, no air filters
- IP65 Fully-sealed enclosures



Example of an above ground feeder installation

Distribution class equipment with no routine maintenance

D-VAR VVO Applications

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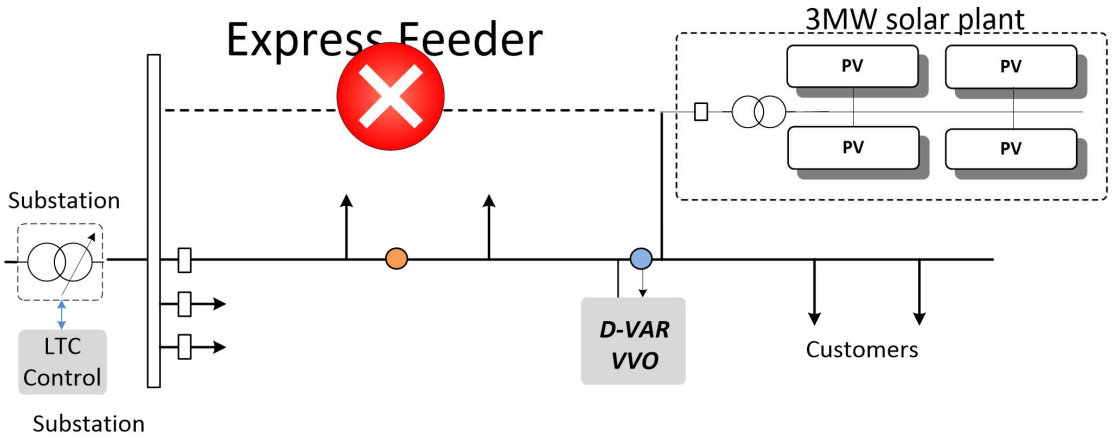
Accelerating Renewables on Existing Circuits

- Voltage Constrained Connections:
  - Power quality issues: large voltage deviations, high voltages> 105%, etc.
  - Excessive LTC tap changes > 30 per day
  - Mis-operating line regs, mis-operating capacitor banks

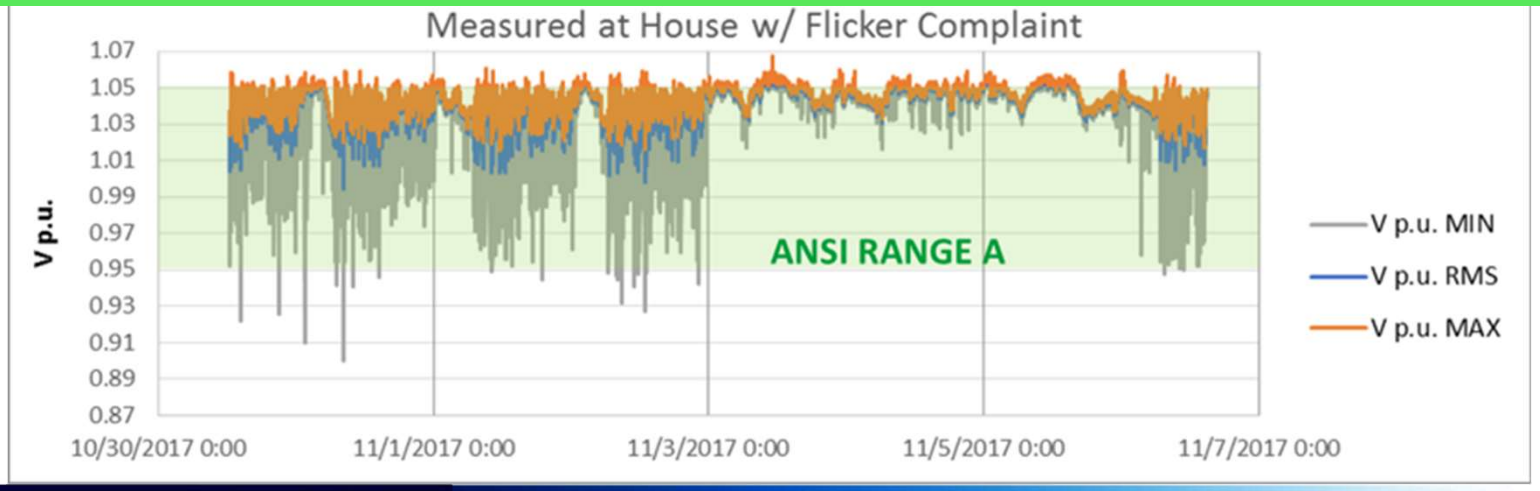
D-VAR *VVO* deployment: Quickly increase DG hosting capacity by 2-4MW per VVO at <20% of the cost of a dedicated feeder



Unserved Energy due to Power Quality

- Serving intermittent/variable loads
  - Low voltage violations (<96% on feeder)
  - Flicker, voltage sags, and step voltage change violations
- Faster and cheaper than reconductoring

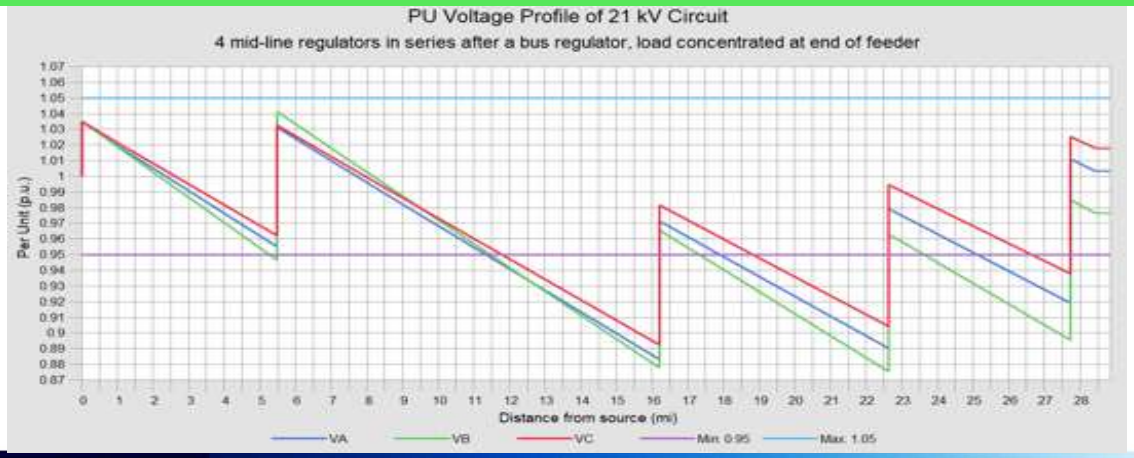
D-VAR *VVO* deployment: Quickly recover unserved energy and eliminate customer downtime, typical pay backs within 18 months



Serving downline load growth

- *Voltage constrained load-serving issues:*
  - Sluggish series voltage regulation 90s +
  - Voltage-constrained circuit reconfigurations/contingencies
  - Load rejection over voltages > 1.1pu
  - Excessive step voltage and harmonics caused by capacitors

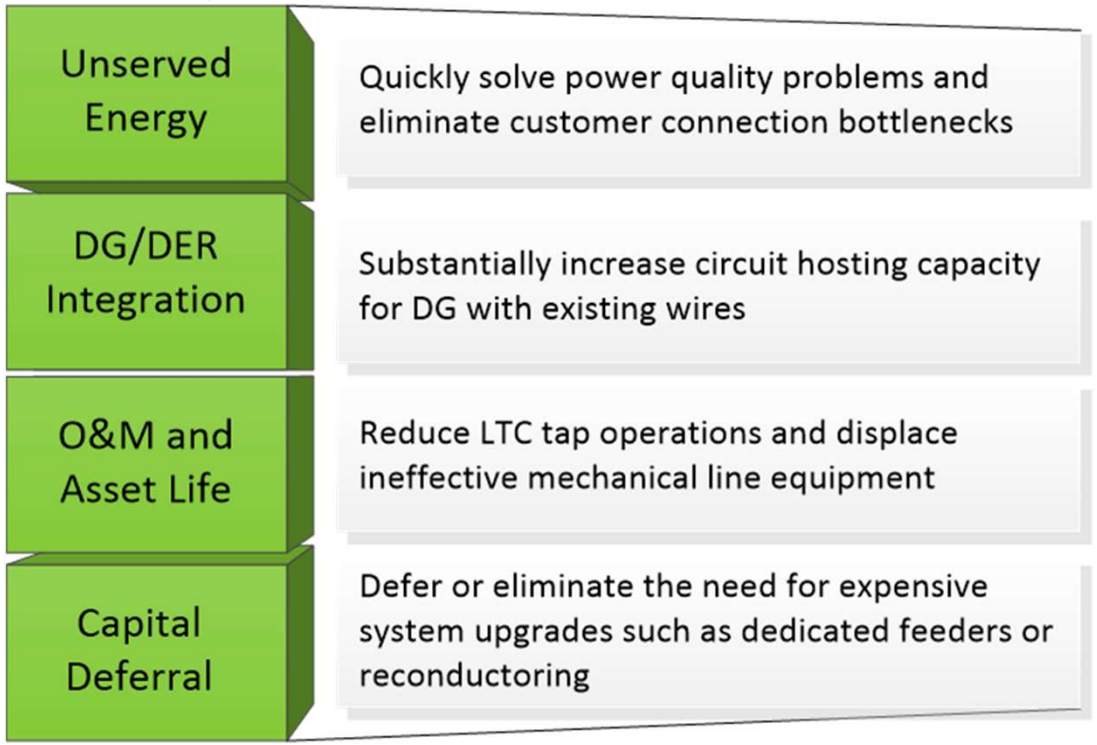
<u>D-VAR *VVO* deployment:</u> Add VVO's downline to quickly release load-serving capacity and defer reconductoring projects



Advantages of Utility-Owned Power Quality

- A Proven & Secure Operational Approach:
  - Utility does what they do best -own assets to manage & control voltage
  - Developer/customer does what they do best –build and operate facilities
- Finance Model 1 (Service): Developer pays, utility owns
  - Similar to other upgrades, eg, new reclosers, etc
- Finance Model 2 (Rate Base): Utility pays, utility owns
  - Enables fast solar interconnection times across service territory
  - Reduces cost of energy/dg by reducing interconnect costs
  - Increases hosting capacity and/or load serving capacity of the utility system

D-VAR VVO Delivering the Value of Utility-Owned Power Quality



Multiple value cases enabled by fast power electronics

Principle of Operation: Regulating Voltage on Distribution Feeders

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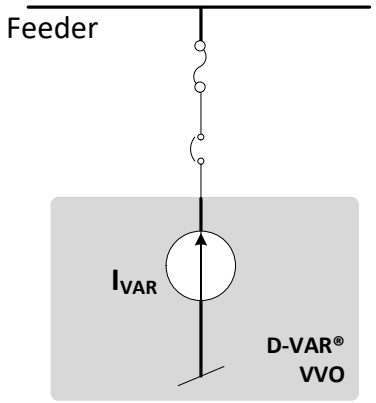
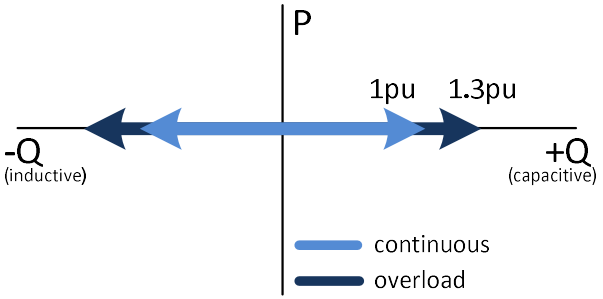
VVO – Shunt Current Source

Grid Attributes

- **High Z Grid attribute**
  - **Naturally insensitive to line voltage**
  - **Avoids system resonance issues with passive VAR compensation**
  - **Sine wave operation < 3% THDi**
- **Shunt connection**
  - **Easy to protect**
  - **No outage to install/service**
- **Very low losses (1%)**
- **130% overload rating**
  - **62 amps for up to 1 minute**

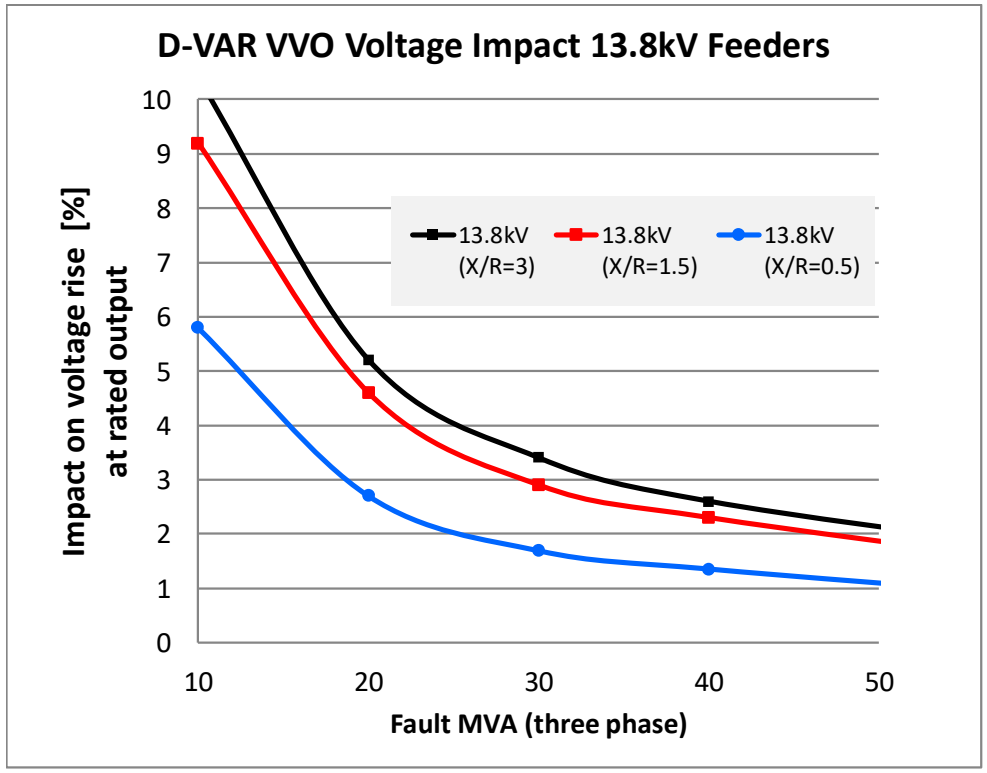


PQ Operating Space



Robust integration into distribution grids

Voltage Boost/Buck from VVO



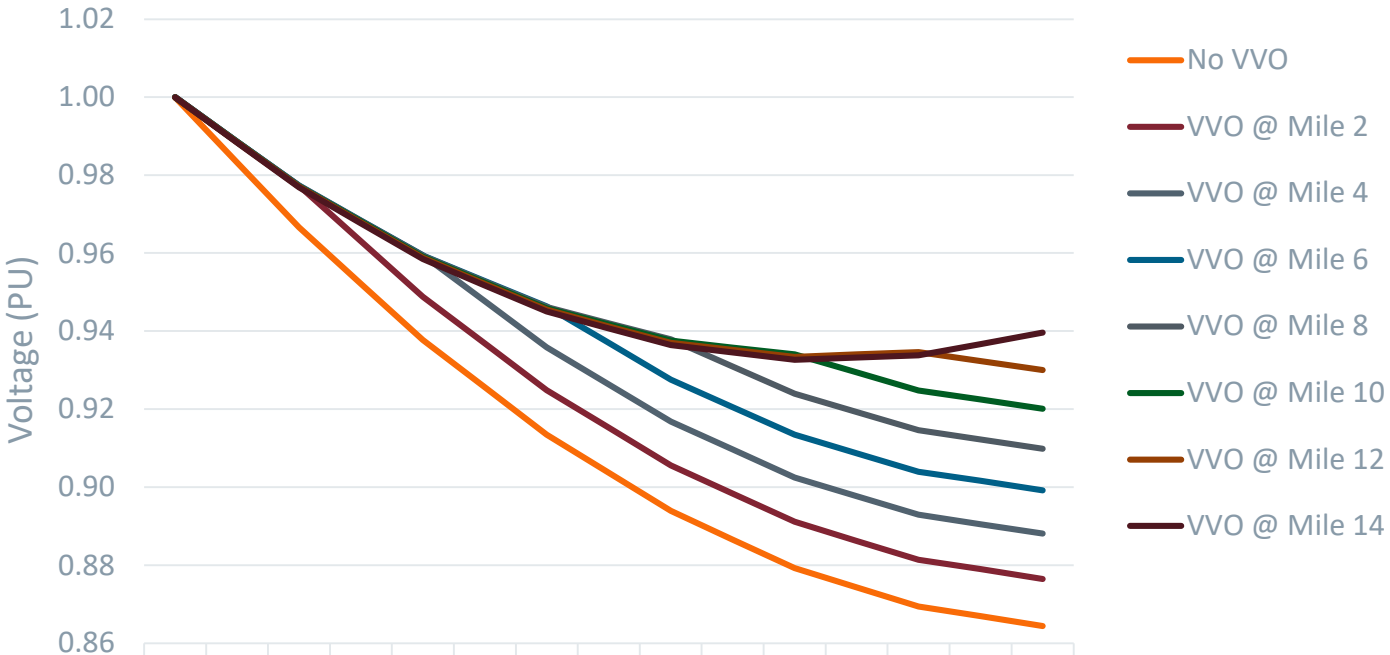
1) Downline feeder locations 7-10 miles in length have 20-30 MVA & X/R >1.5 (red & black curves)

2) **Longer rural** circuits, greater than 10 miles, typically have <20MVA & X/R<1.5 (blue/red curve applies).

Two known power system parameters to determine impact

Feeder profile impact: D-VAR VVO

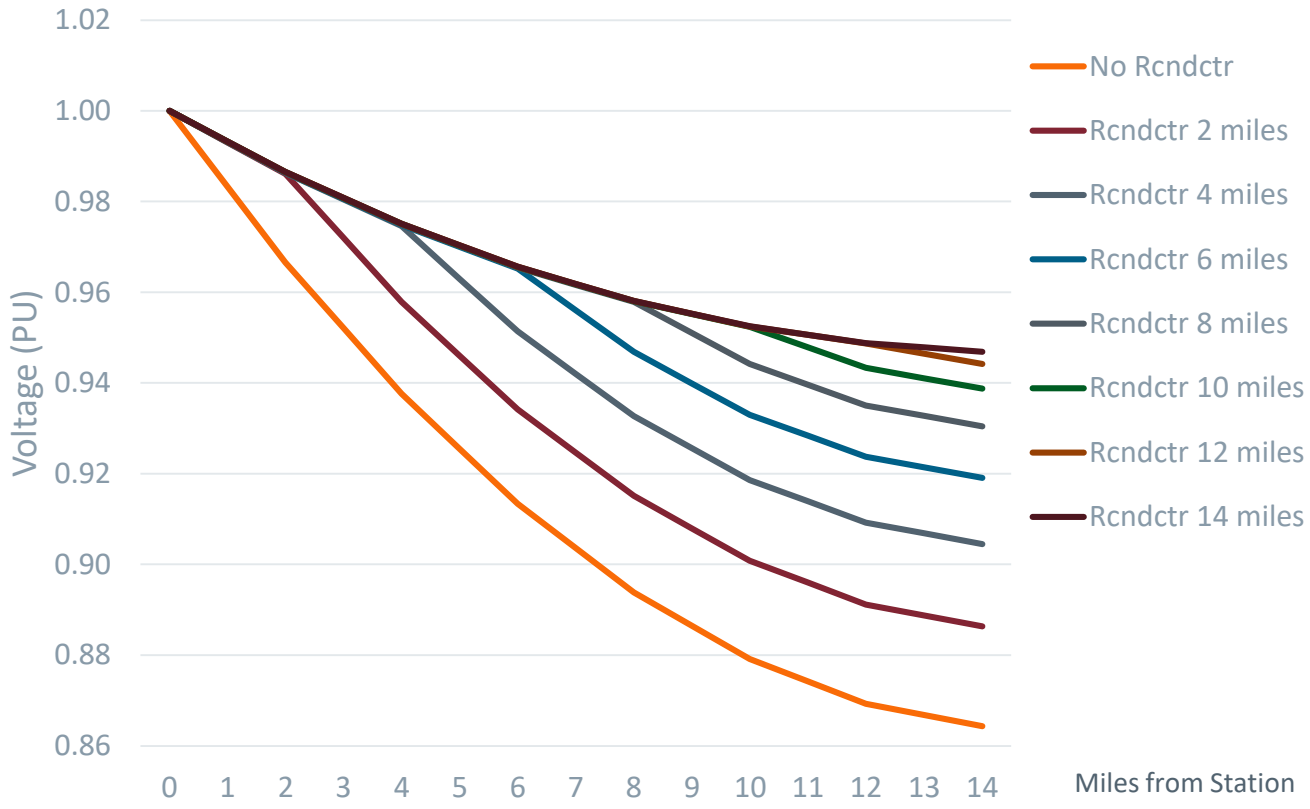
2.1MVA, 92%PF load distributed on 14 miles of 12.47 kV, 1/0 ACSR conductor



Miles from Station	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14
X1/R1 Ratio	8	2	1	1	1	1	1	1	1	1	1	1	1	1	1
Fault MVA	255	92	55	39	30	25	21	18	16	14	13	12	11	10	9

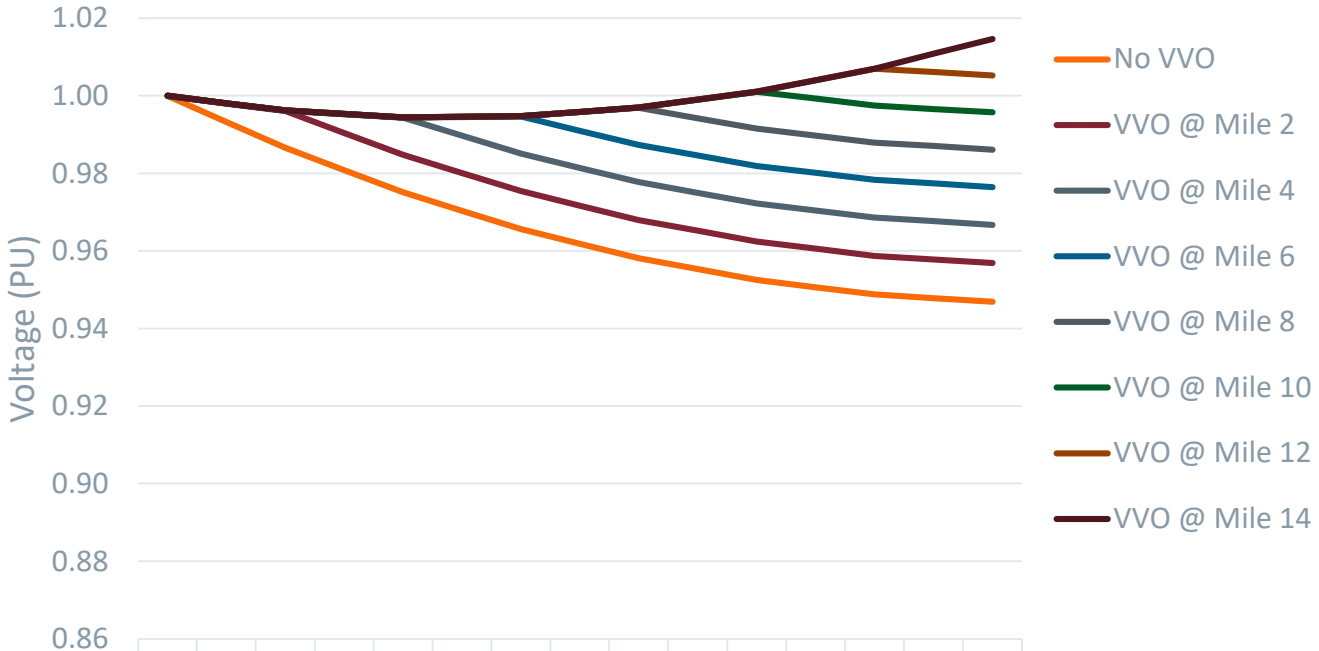
Feeder profile impact: Reconductoring

2.1MVA, 92%PF load distributed on 14 miles at 12.47 kV. Reconductor 1/0 ACSR to 477 ACSR



Feeder profile impact: D-VAR VVO + Reconductor

2.1MVA, 92%PF load distributed on 14 miles at 12.47 kV. Reconductor 1/0 ACSR to 477 ACSR



0	1	2	3	4	5	6	7	8	9	10	11	12	13	14
8.0	4.9	4.4	4.2	4.1	4.0	3.9	3.9	3.9	3.9	3.8	3.8	3.8	3.8	3.8
256	117	75	56	44	37	31	27	24	22	20	18	17	15	14

Miles from Station

X1/R1 Ratio

Fault MVA

Key STATCOM Utility Voltage Regulation Concepts

- STATCOMs continuously and precisely control voltage with Vars
- Use Fault Power and X/R to determine voltage impact at the POI
- STATCOMs automatically buck or boost voltage as necessary
- STATCOMs impact voltage both upstream and downstream
- STATCOMs add “voltage stiffening” analogous to reconductoring
- STATCOMs can provide high performance primary voltage regulation on downline circuit locations 10+ miles typical

STATCOM enables cost-effective utility-owned power quality

DVAR-VVO Field Case Study Examples

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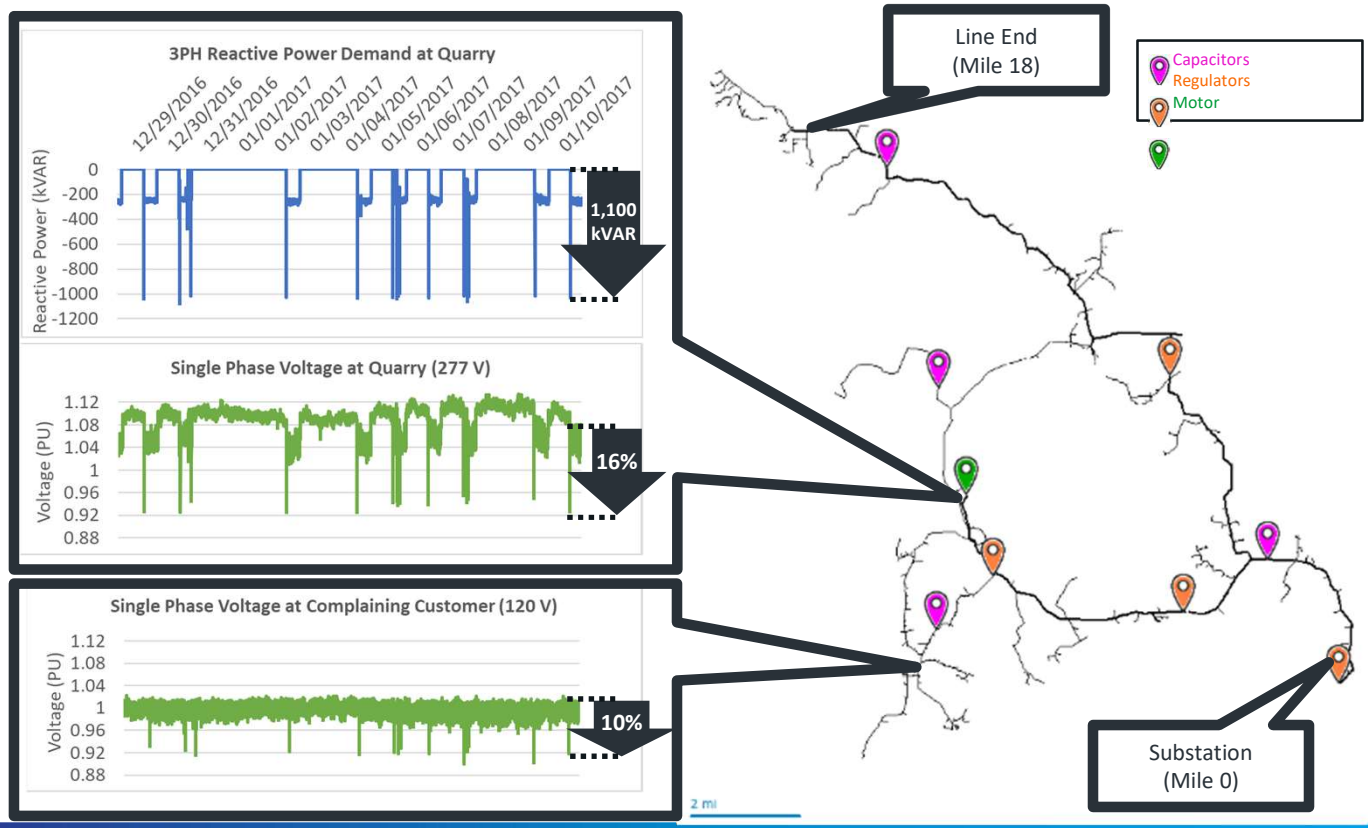
350 HP Rock Quarry Motor Causing PQ Issues

- 7.5 MVA station transformer serves 4 long 12.47 kV circuits
- Circuit serving the quarry extends as far as 18 miles
- Quarry motor is 11 circuit miles from the substation
- Customers miles from the quarry notice lights dim, noisy appliances during motor starts
- Existing motor already has a soft-starter

Soft-starters have limited ability to address power quality issues

Power Quality Recordings



The "trifecta" of stakeholders: utility, "culprit", customers

Motor Nameplate

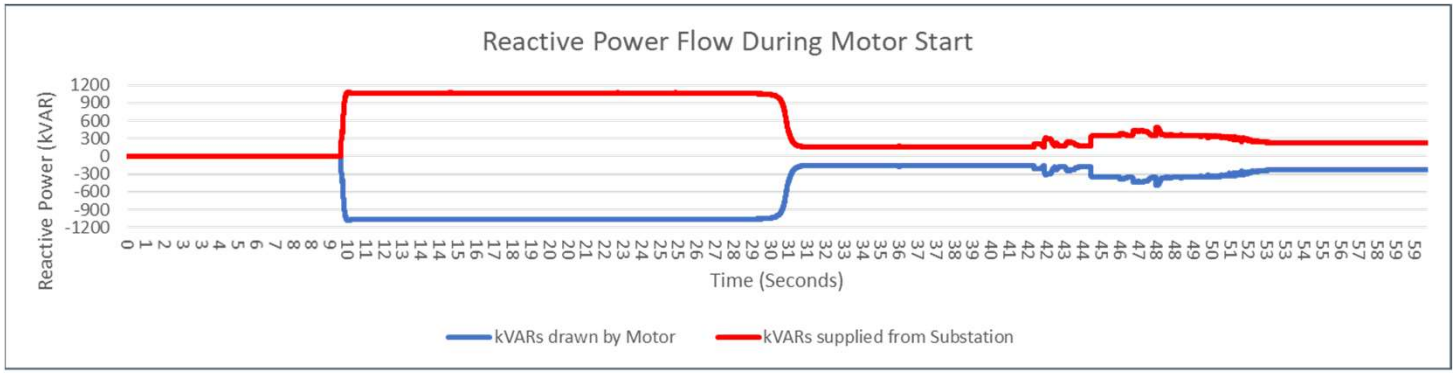
Key motor parameters:

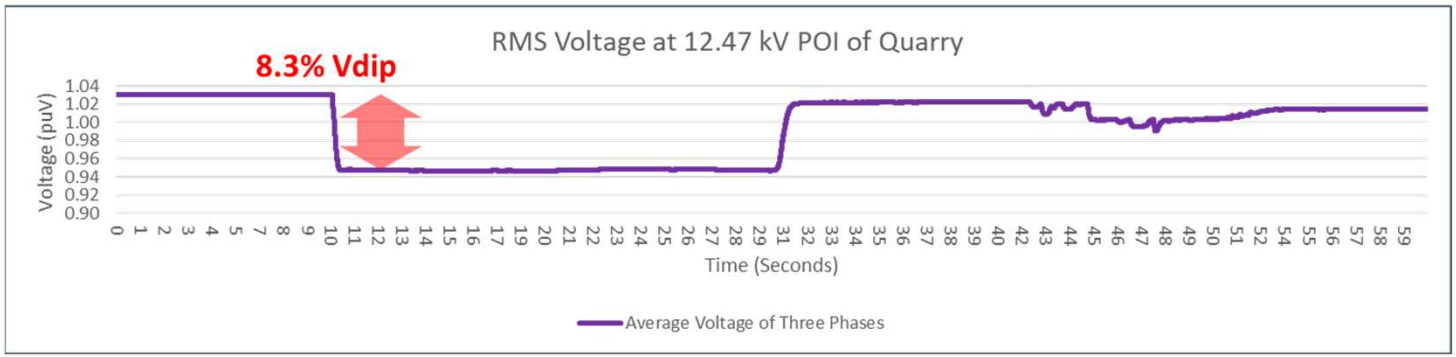
- 350HP
- Code H: 6kVA/HP starting
- Soft starter 75% remaining

Frame : 586/7Z
Output : 350 HP
Frequency : 60 Hz
Poles : 6
Full load speed : 1195
Slip : 0.42 %
Voltage : 460 V
Rated current : 428 A
Locked rotor current : 2780 A
Locked rotor current (Il/In) : 6.5
No-load current : 176 A
Full load torque : 1517 lb.ft
Locked rotor torque : 220 %
Breakdown torque : 240 %
Design : A
Insulation class : F
Temperature rise : 80 K
Locked rotor time : 12 s (hot)
Service factor : 1.15
Duty cycle : S1
Ambient temperature : -20°C - +40°C
Altitude : 1000
Degree of Protection : IP55
Approximate weight : 3958 lb
Moment of inertia : 327.96 sq.ft.lb

Motor nameplate is sufficient for sizing

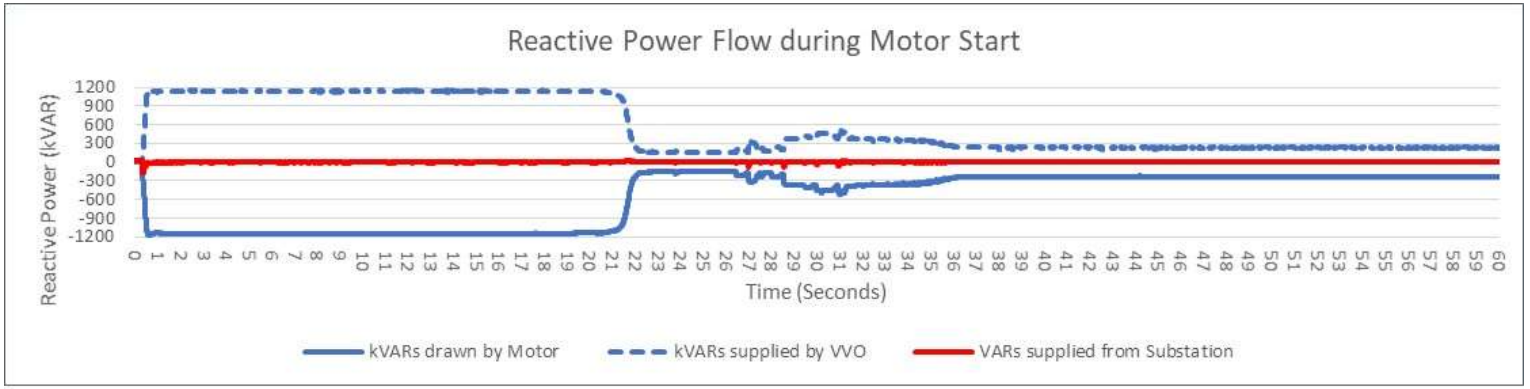
Motor Start without VVO

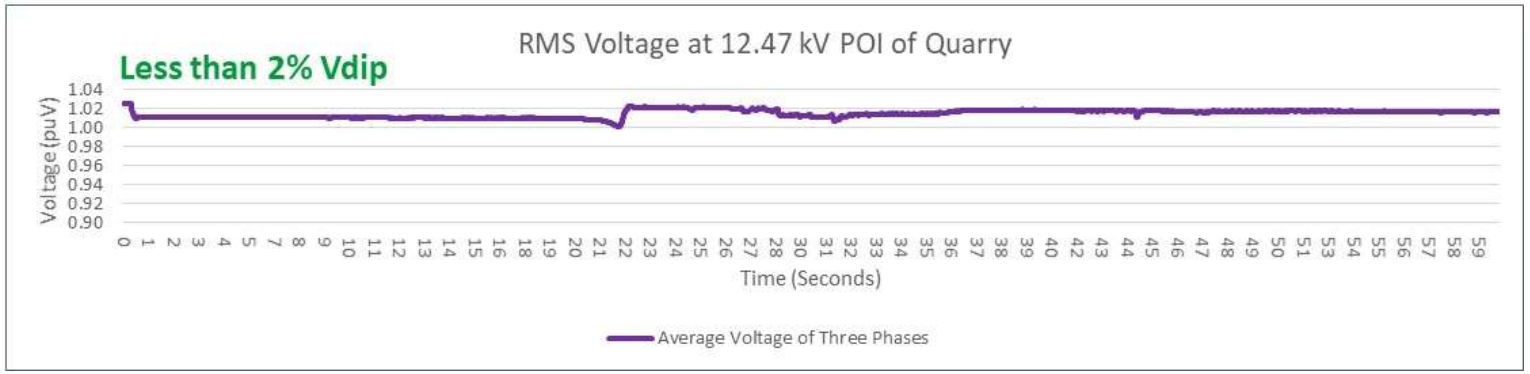




Sudden motor Vars cause excessive voltage drop on the utility feeder

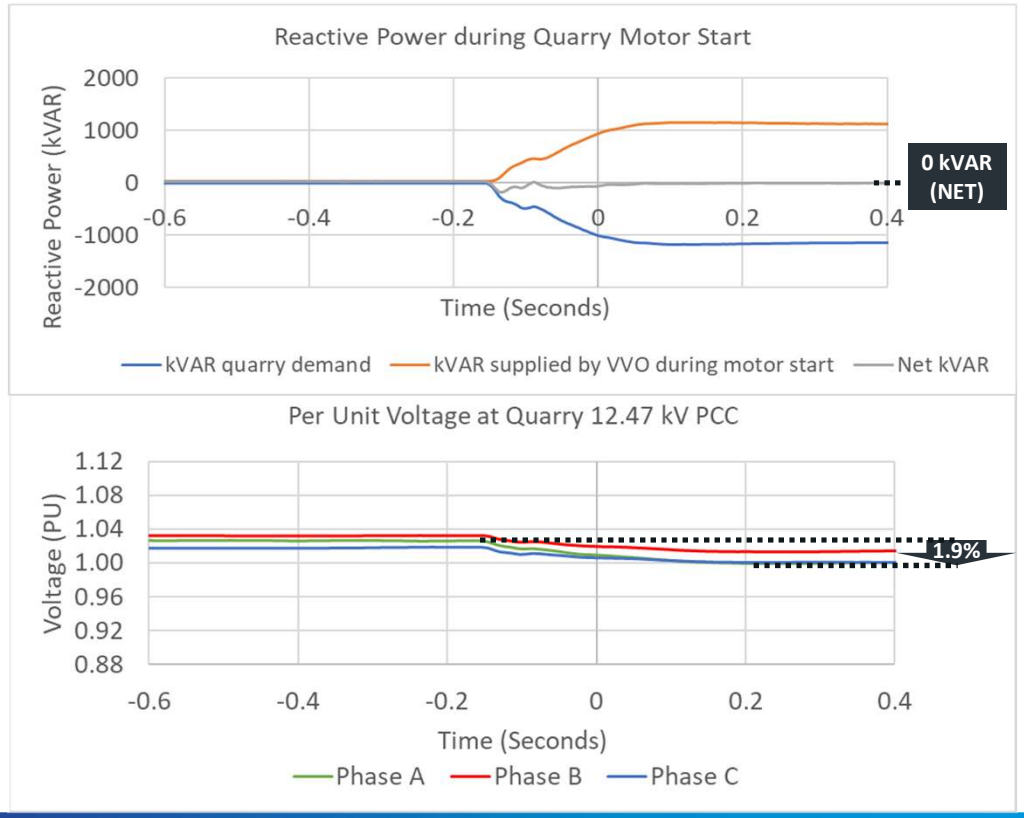
Motor Start with a VVO





VVO near the motor addresses the PQ issue (4% requirement)

Zoom of Locked Rotor



STATCOM is faster than the motor electrical time constant

Summary of motor starting case study

- A motor with a soft starter was causing clear power quality issues for dozens of nearby customers
  - The soft starter was inadequate to address PQ
- A single D-VAR VVO installed on the utility feeder completely addressed the power quality issues
- The D-VAR VVO was installed in the existing utility right-of-way requiring no alteration of the plant and no land acquisition cost
- The D-VAR VVO was operational in less than six months of the "first call"

VVO STATCOM quickly addresses power quality issue

Case Study #2

Solar plant on a long radial feeder

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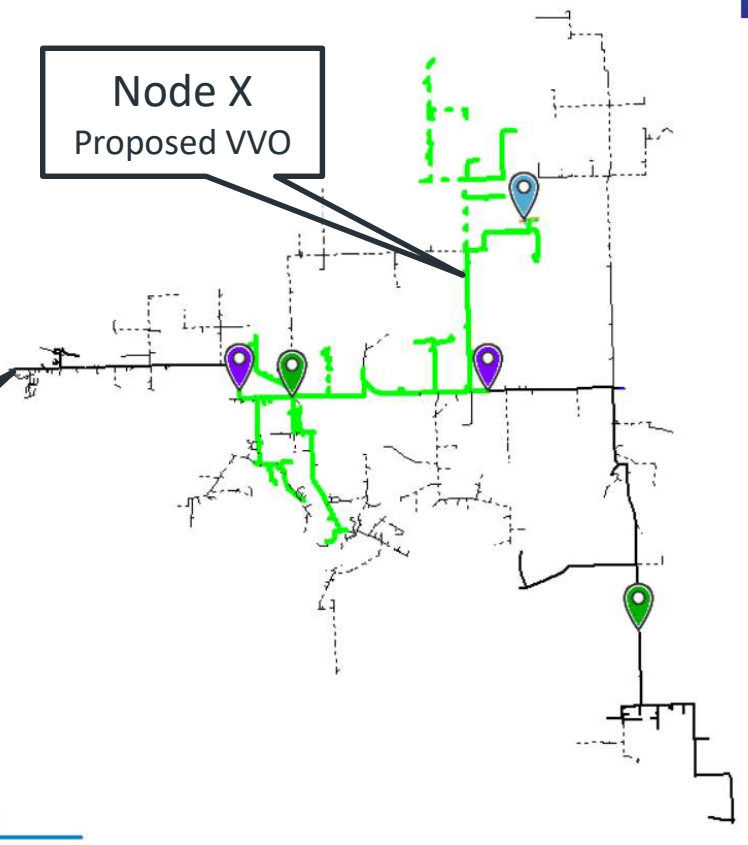
25kV Circuit Overview

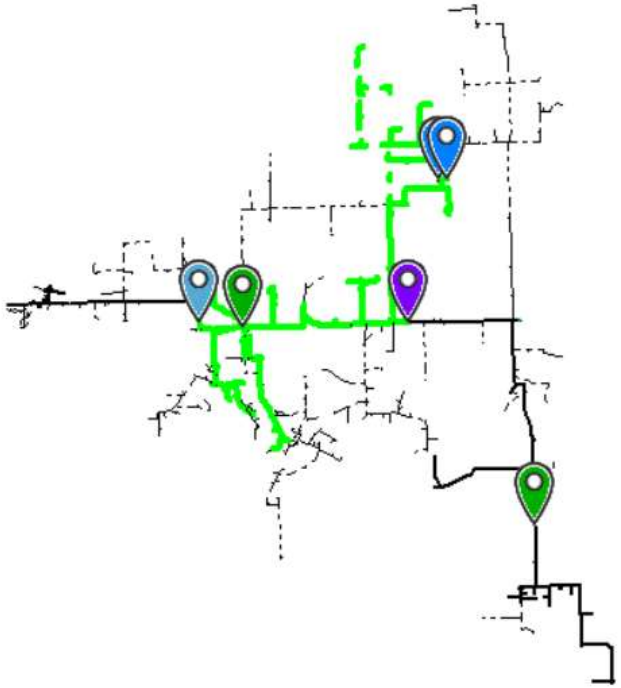
Legend:

- Solar: 1,620 kW
- Regulator: Vtarg = 125V, BW = 2V
- Capacitor: 300 kVAR Fixed
- Overvoltage

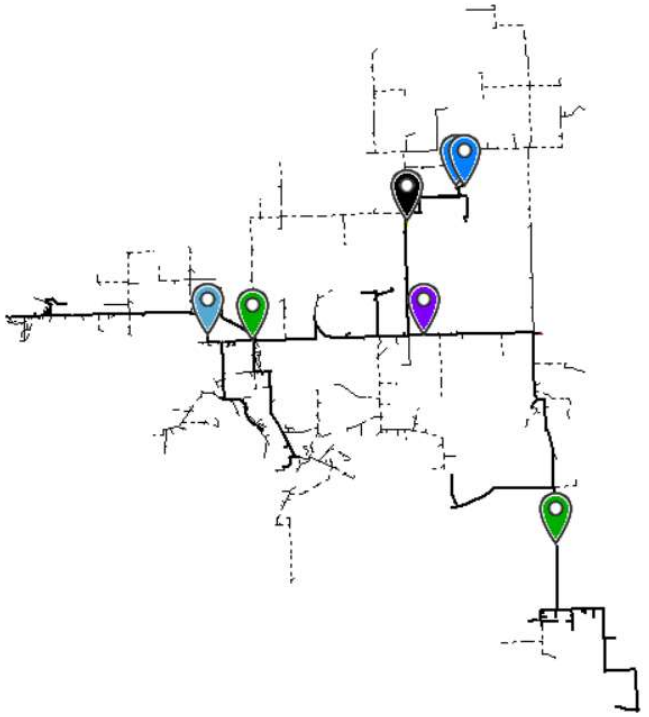


Basic Load Flow Simulation

A VVO at full 1000 kVAR inductive eliminates overvoltage



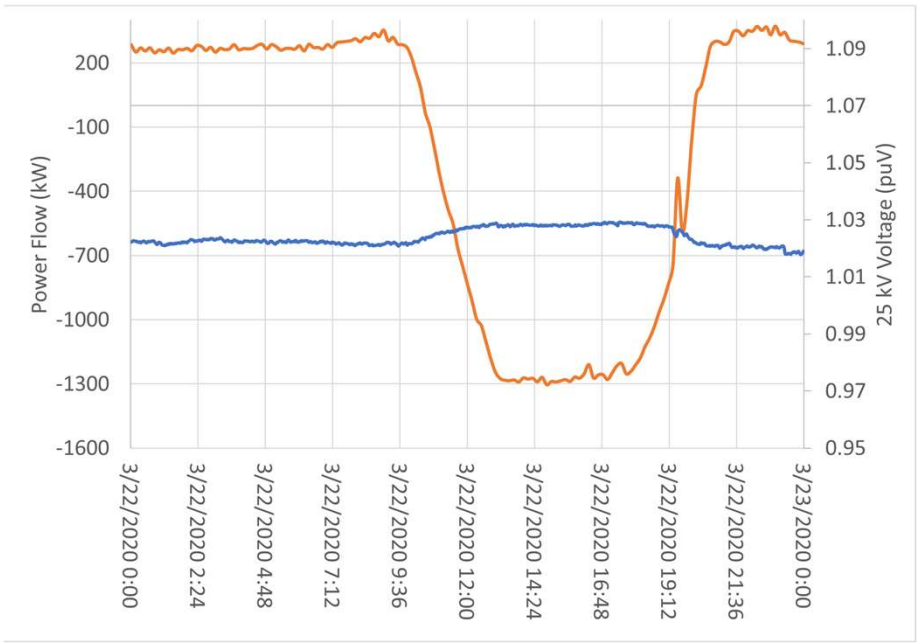
Minimum Load, Peak PV



Minimum Load, Peak PV with VVO

Field Results

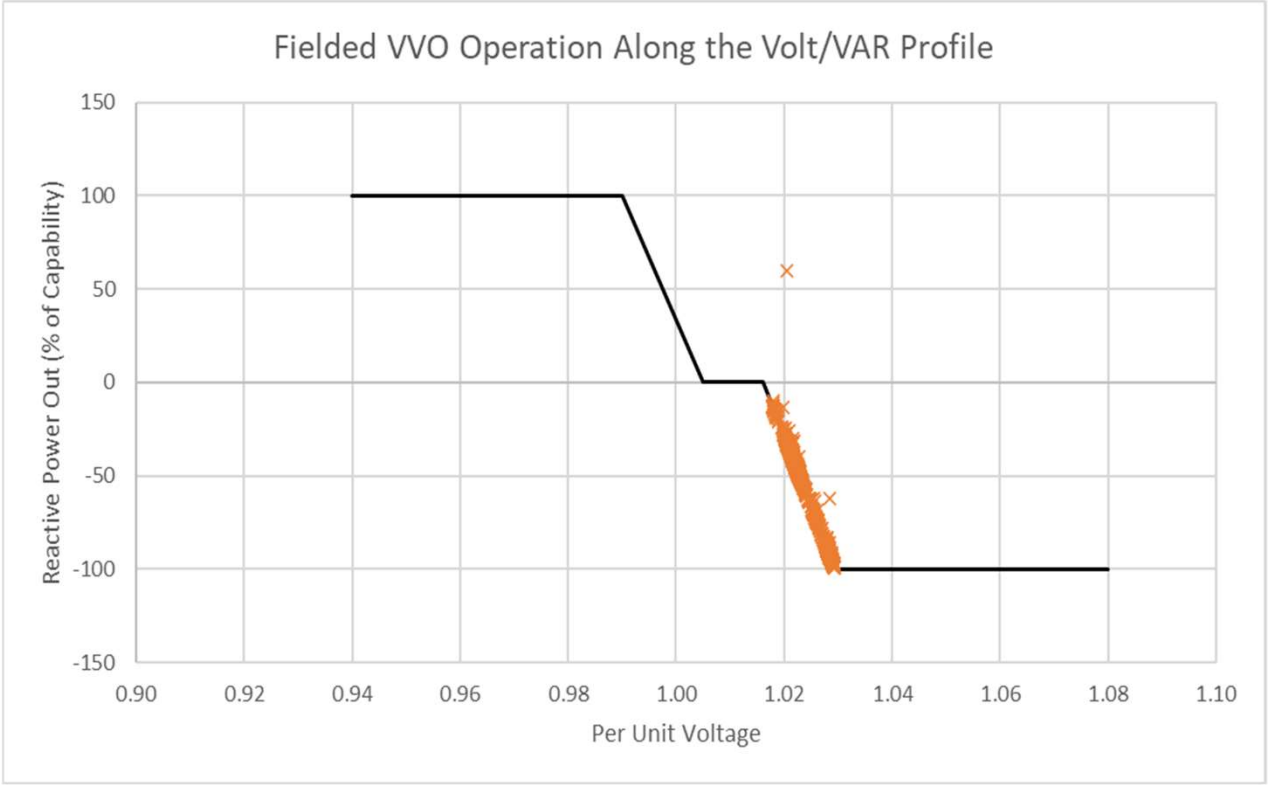
This is power flow and voltage measured by the VVO on a sunny day



Field Results

Performance measured by the VVO Console during a sunny day

- Field results show VVO tracking volt/var curve
- Absorbing Vars expected for generation/reverse power flow



Utility-owned STATCOM Accelerates Solar Interconnect

- One VVO enabled a solar plant to connect in a weak power system
- Solar inverter in lagging power factor mode insufficient to address the power quality issues
- Load flow to estimate initial volt/var settings/Field data used to fine-tune volt/var settings
- VVO installed in existing utility right-of-way
- Solution purchased, installed & operational in <6mos

Case Study #3

High Rooftop PV Penetration

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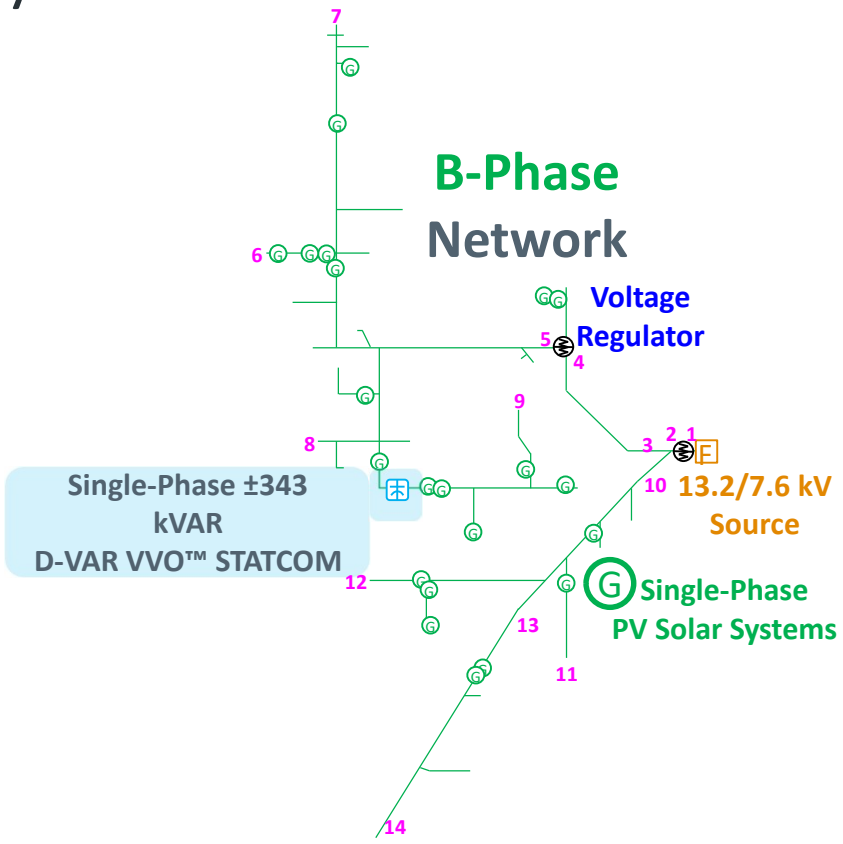
Situation: High penetration of residential and commercial PV solar systems

System set-up: Source voltage set at 125 volts,

Voltage regulator fixed, for tap delay

Capacitor bank off-line,

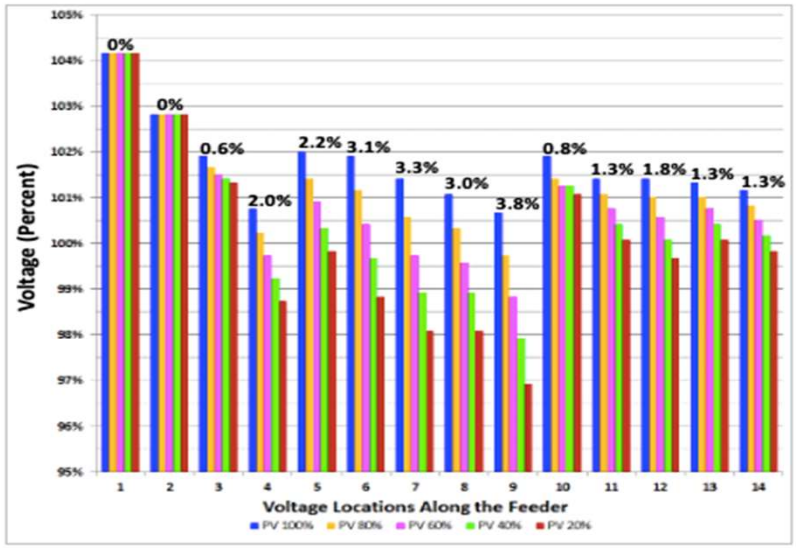
Solar PV @ **1100**, **880**, **660**, **440**, and **220** kW

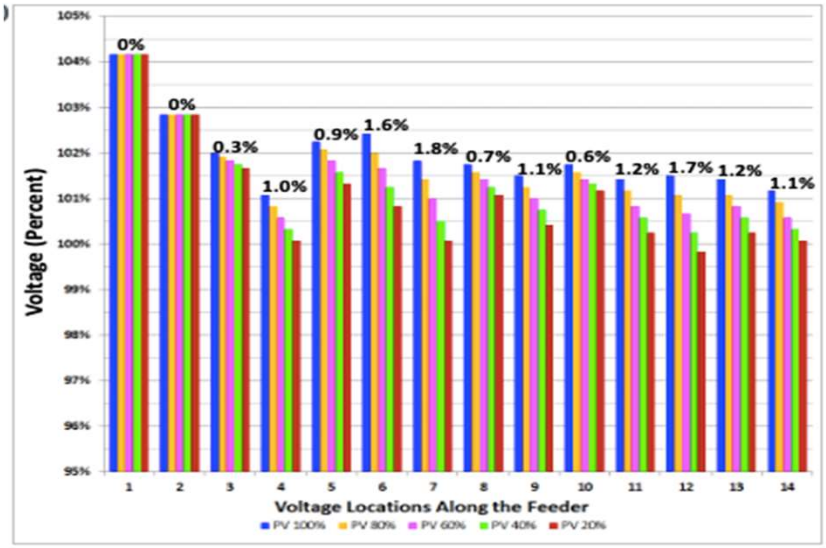


Problem: Excessive Voltage deviation

- As the PV solar generation changes throughout the day, the voltage varies widely
- The sudden changes in the voltage happen before mechanical equipment can respond
- The voltage difference is **3.8%** between **1100 kW** and **220 kW**

- The STATCOM is operating on a 1% droop
- The sudden changes in the voltage are easily covered by the single-phase STATCOM
- Offloads tapping of upstream voltage regulator
- The maximum voltage difference is **1.1%** between **1100 kW** and **220 kW**





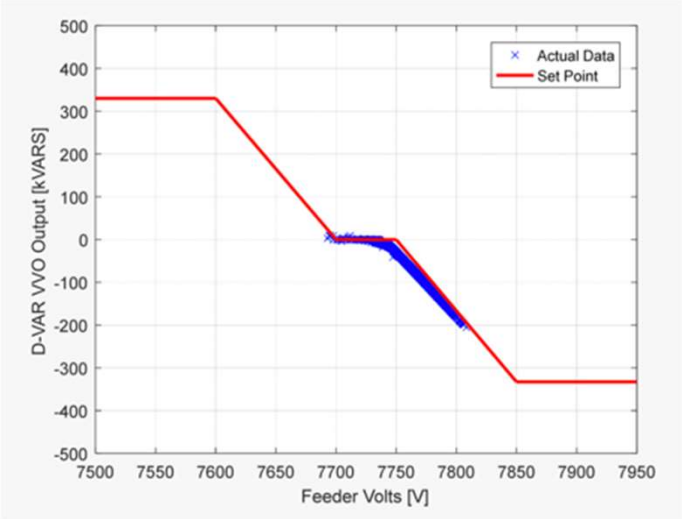
The D-VAR VVO® STATCOM

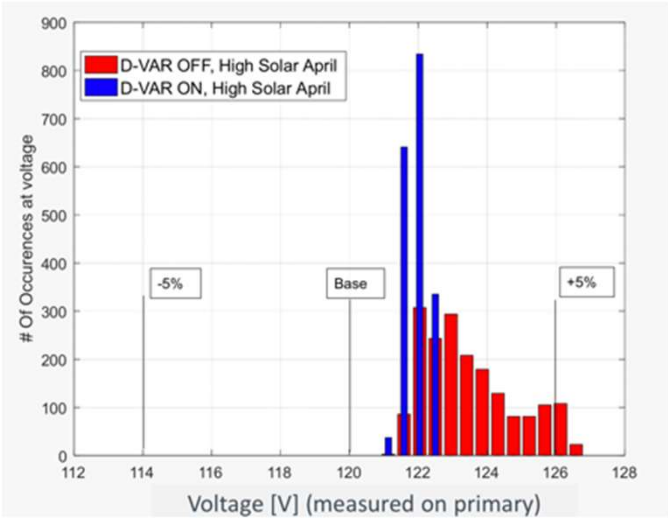
In the field, the single-phase installation

High Solar Season Performance Data

Washington single phase April solar season

- Three days
  - Without VVO: 130 high voltage violations (over 5%)
  - With VVO: voltage between 121V and 123V





*2min avg data shown

High voltage violations & voltage deviation violations addressed,
Peak voltage reduction is 3.2%, average 24hr voltage reduction is 1.25%

Thank You!

sales@amsc.com

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Contacts

- North America Regional Sales Managers
  - Bob McFetridge (Eastern US): bob.mcfetridge@amsc.com

- Dave Oteman –Product Manager
- Dave.oteman@amsc.com
- 262-844-7043

- Ryan Rainville – Planning
- Ryan.rainville@amsc.com
- 978-549-5481

- Please visit website and D-VAR VVO product page
- https://www.amsc.com/gridtec/distributed-generation-solutions/#dvarvvo