STATCOM Technology

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What is a STATCOM?

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

STATCOMs are used extensively in transmission systems and their requirement is growing in distribution systems due to the influx of distributed generation resources.

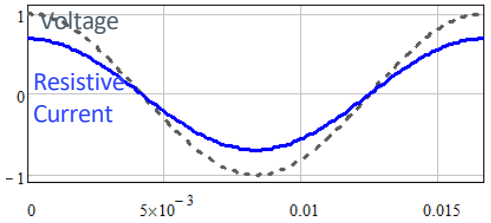
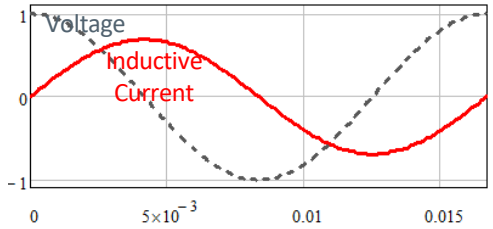
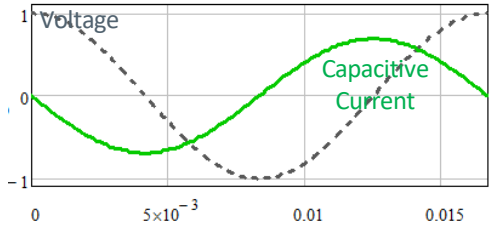
Reactive Power (Current)

- Voltage drop from an inductive load (or inductive cable) can be compensated with capacitive current, and visa versa

Reactive Current	Commonly Seen in	Line Voltage Affect	STATCOM Capability
 Inductive	Motors, Inductors, Overhead Lines	Reduces Voltage	0 to -1.0 MVAR*, cont. 0 to -1.3 MVAR*, 1 min
 Capacitive	Capacitors, Underground Cables	Increases Voltage	0 to +1.0 MVAR*, cont. 0 to +1.3 MVAR*, 1 min

* at 12.47kV

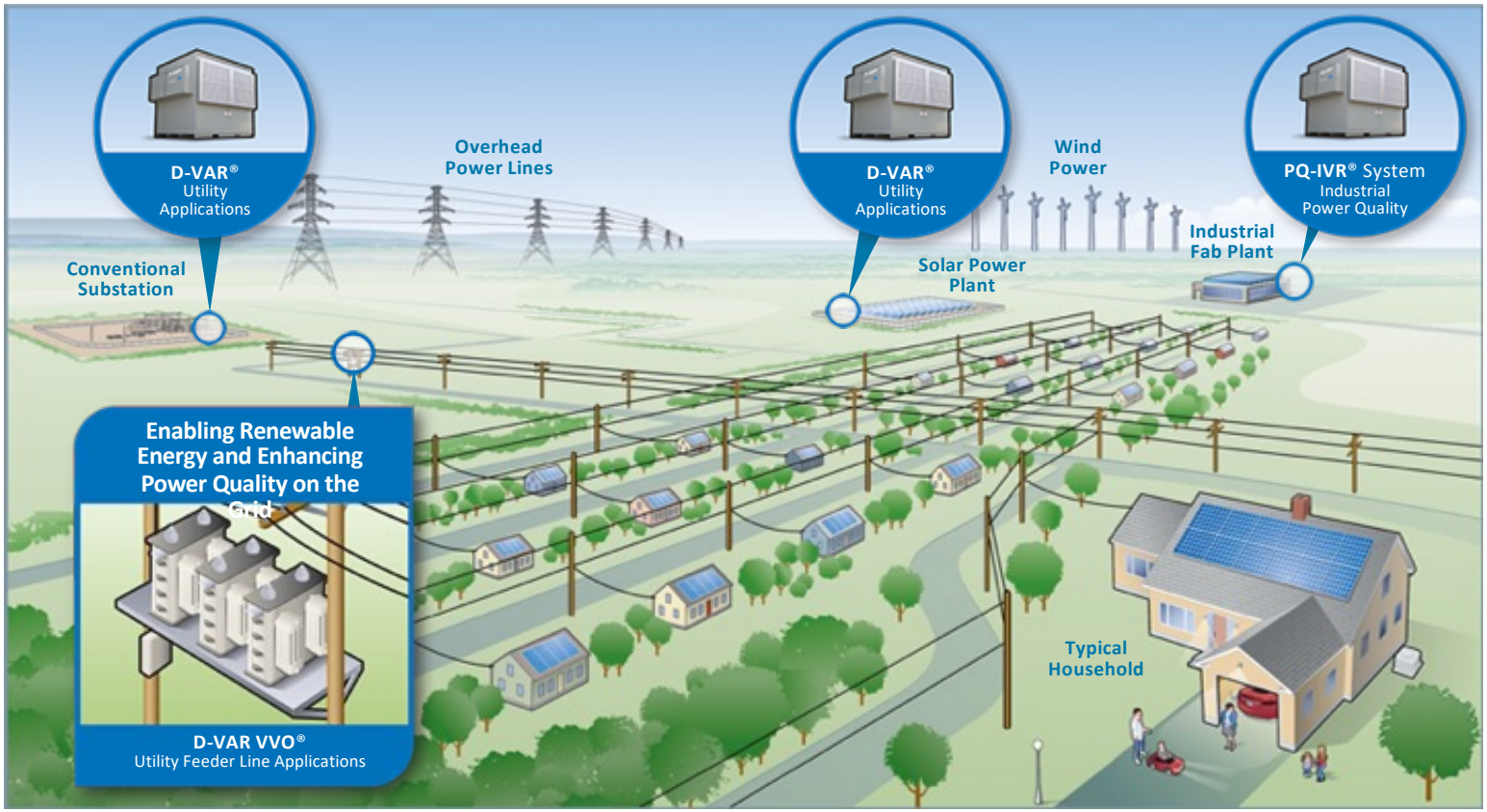
Real & Reactive Power (Current)

Phasor	Wave	STATCOM Capability
Voltage Resistive Current		None
Voltage Inductive Current		*Fine Adjust Between:* 0 to -1.0 MVAR*, cont. 0 to -1.3 MVAR*, 1 min
Capacitive Current Voltage		*Fine Adjust Between:* 0 to +1.0 MVAR*, cont. 0 to +1.3 MVAR*, 1 min

* at 12.47kV

FACTS Solutions

Enabling Renewable Energy integration and Enhancing Power Quality and Stability of the Electric Grid



Distribution Class STATCOM

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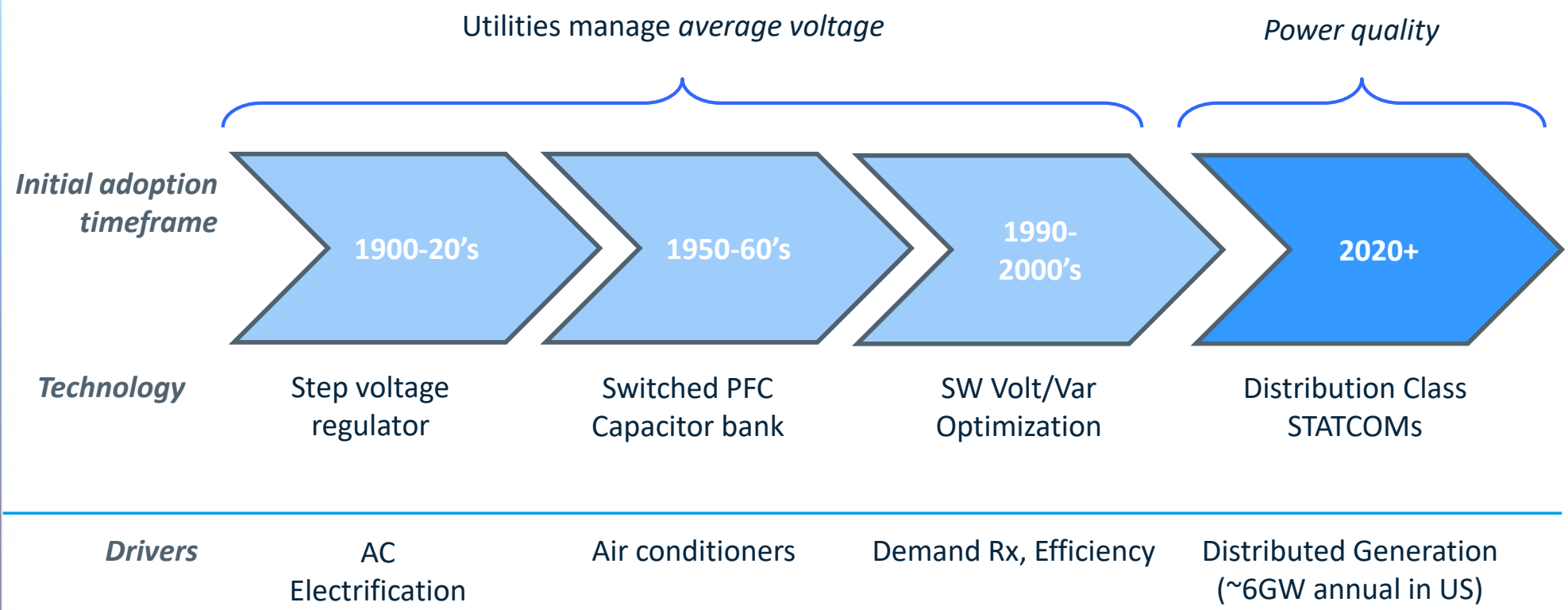
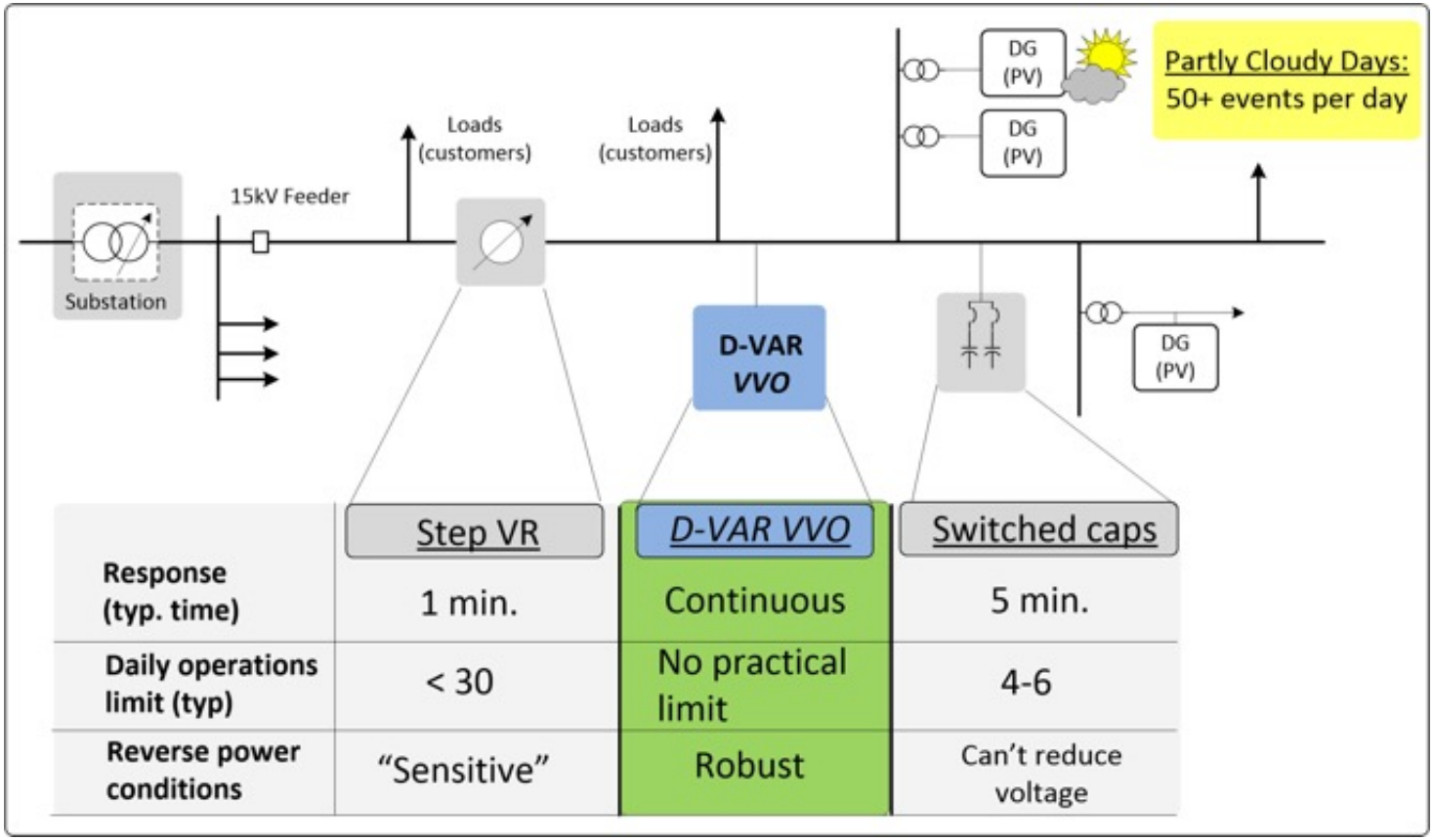
Distribution Volt/Var Evolution Timeline



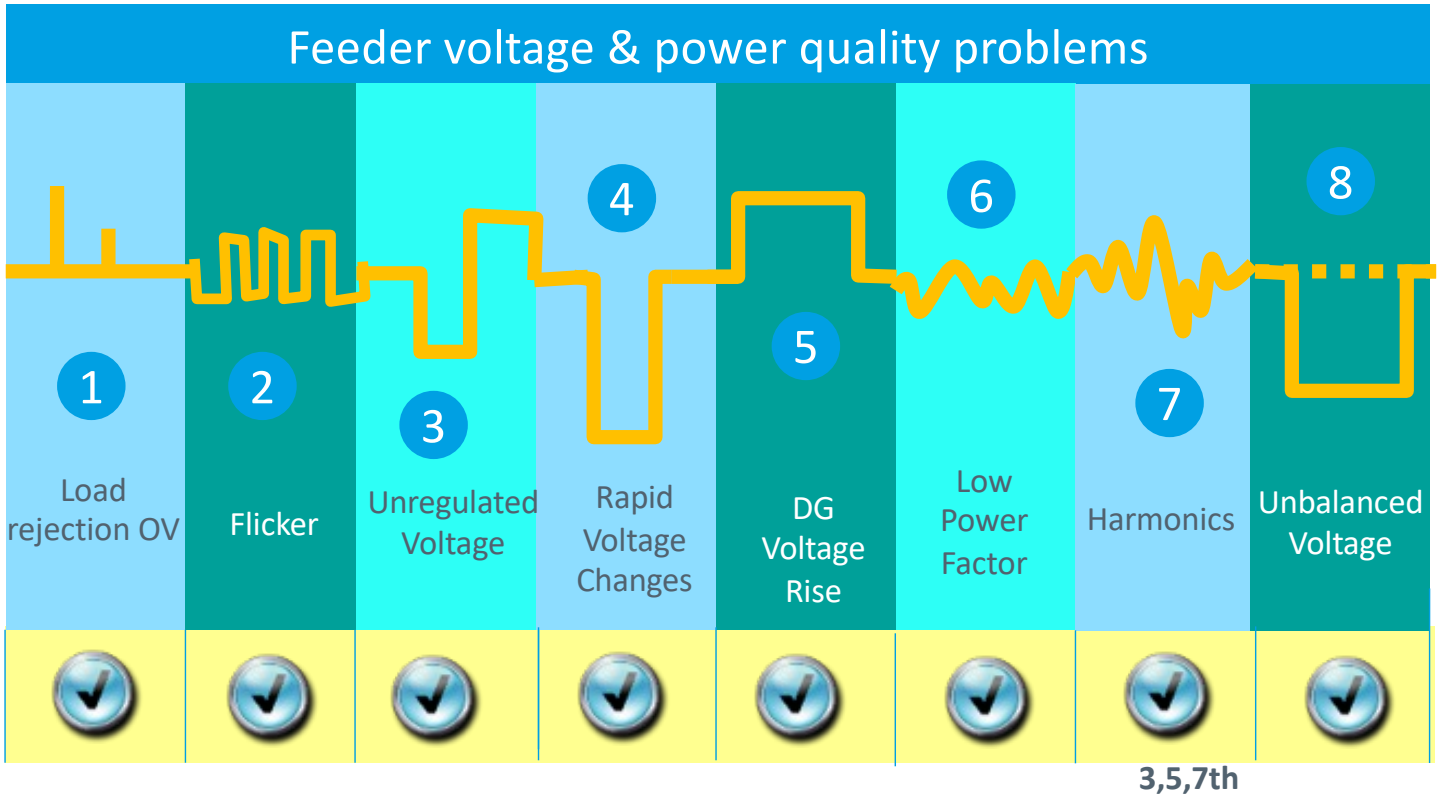
Advantages of Distribution Class STATCOMs



	Step VR	*D-VAR VVO*	Switched caps
Response (typ. time)	1 min.	Continuous	5 min.
Daily operations limit (typ)	< 30	No practical limit	4-6
Reverse power conditions	"Sensitive"	Robust	Can't reduce voltage

Continuous control of power quality with no operation limits

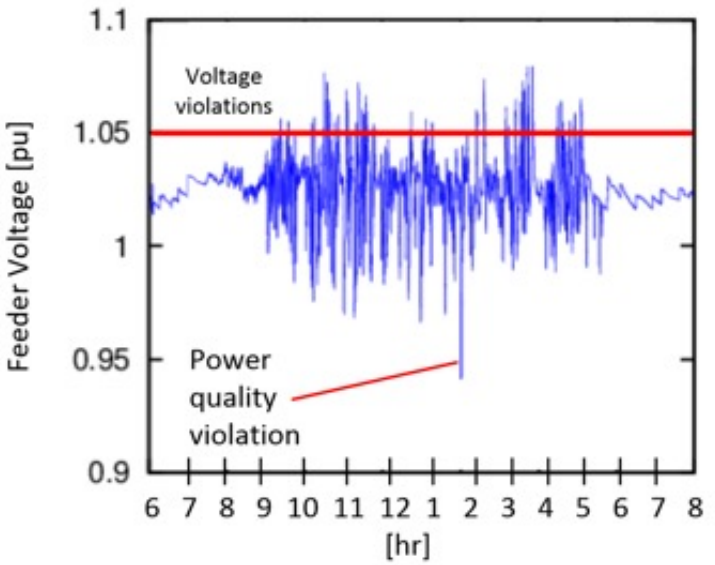
Problems Addressed by the Distribution Class STATCOM



Unique power quality capabilities enabled by fast distribution class power electronics

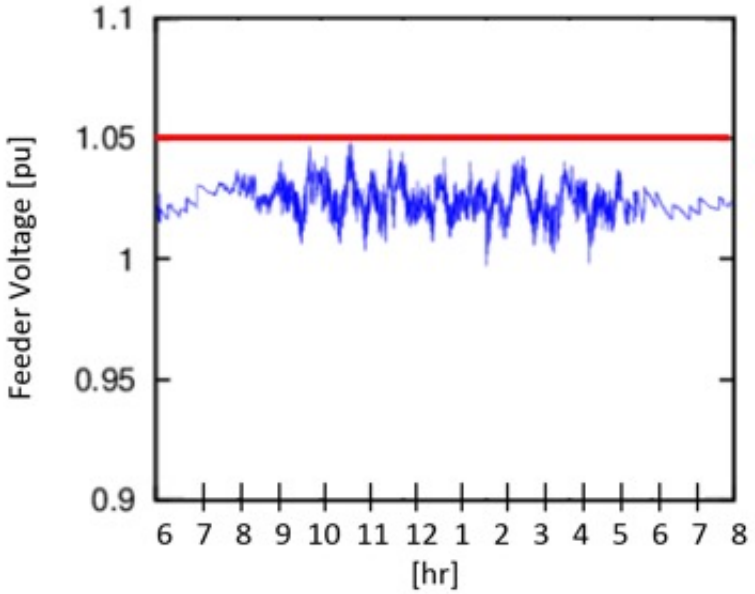
A High-Penetration Solar feeder with Reverse Power Flow

Problem



Measured 10 second feeder data
(Mechanical regulation equipment only)

Solution



Measured 10 second data
(with STATCOM installed on feeder)

Distribution Class STATCOM Compensates for Challenging Power Quality Problems

AMSC's Example of a Distribution Class STATCOM: D-VAR VVO®

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

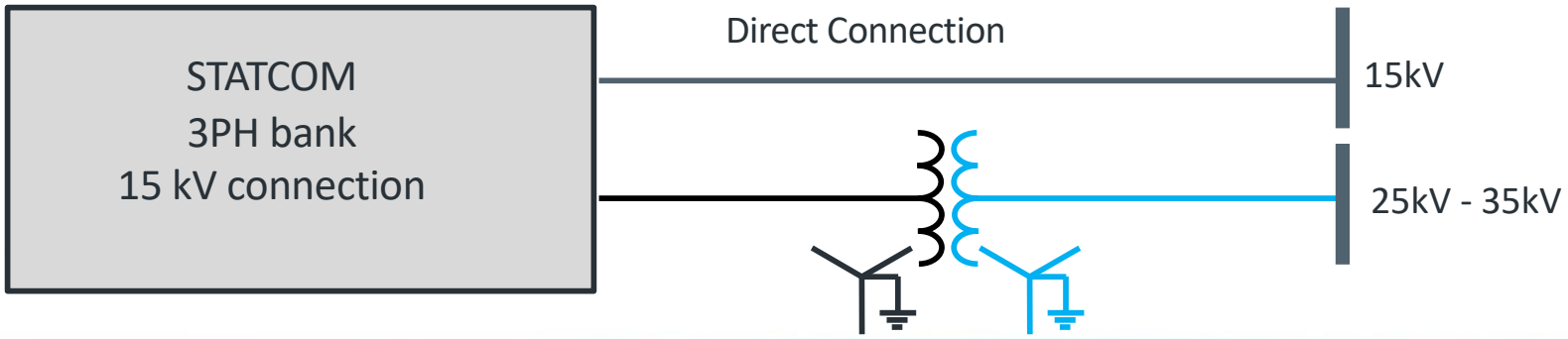
Example of an above ground feeder installation

Distribution class equipment with no routine maintenance

Distribution Class STATCOM

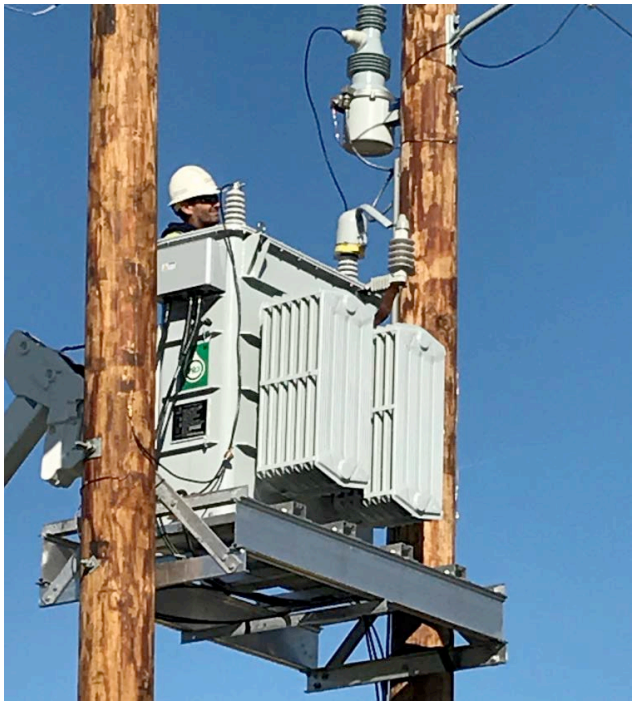
Typical Ratings

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



Distribution STATCOM Installation Examples

Midwest Utility – October 2017



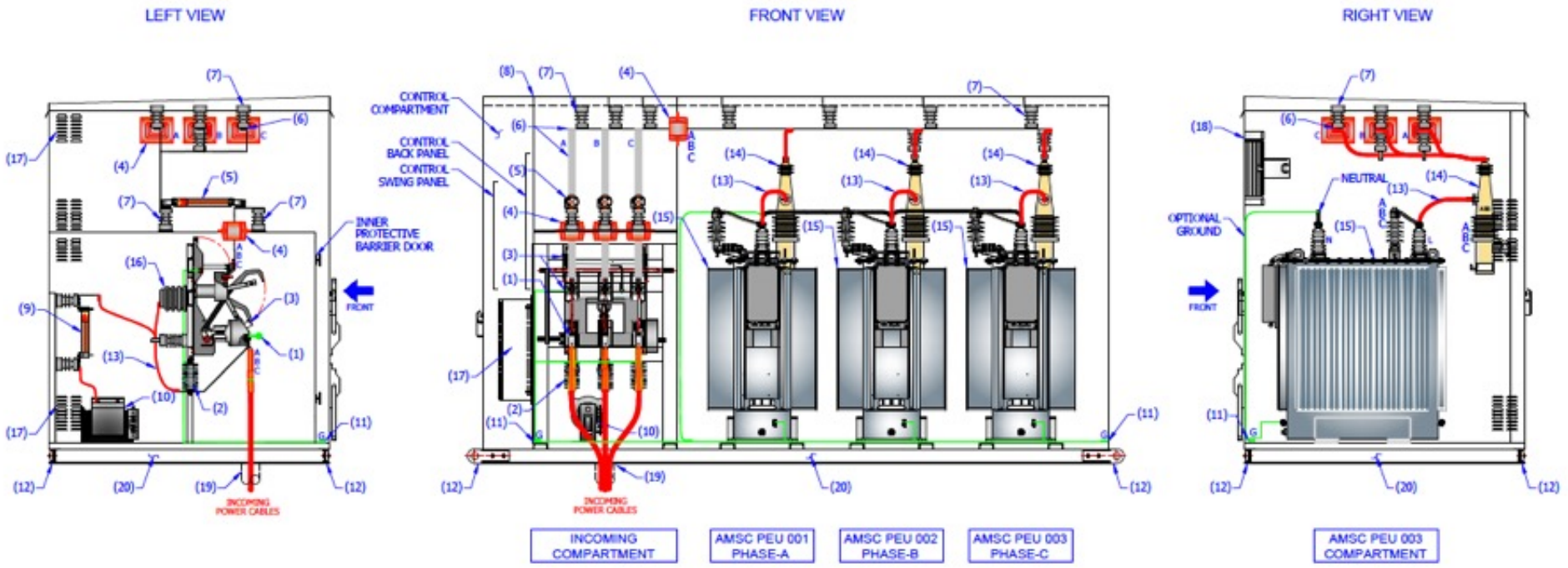
Distribution STATCOM Installation Examples

Southern Utility – June 2021

2 Systems,
1 span apart

Distribution STATCOM Installation Examples: Metal Enclosed Config

Distribution STATCOM Installation Examples: Metal Enclosed Config



INTERNAL EQUIPMENT LAYOUT

Principle of Operation: Regulating Voltage on Distribution Feeders

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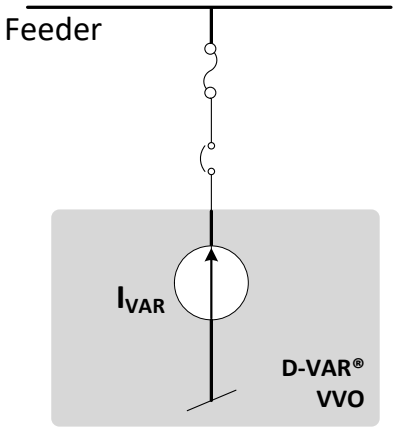
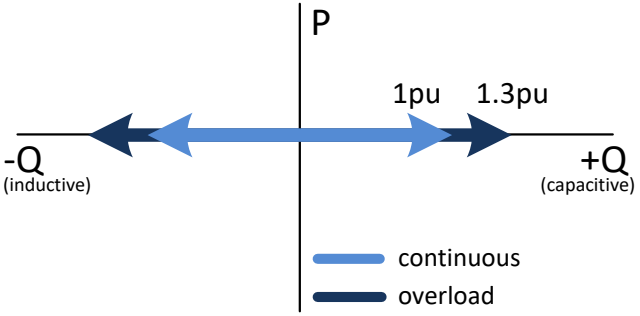
STATCOM – Shunt Current Source

Grid Attributes

- **High Z Grid attribute**
  - Naturally insensitive to line voltage
  - Avoids resonance/harmonic issues
  - 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

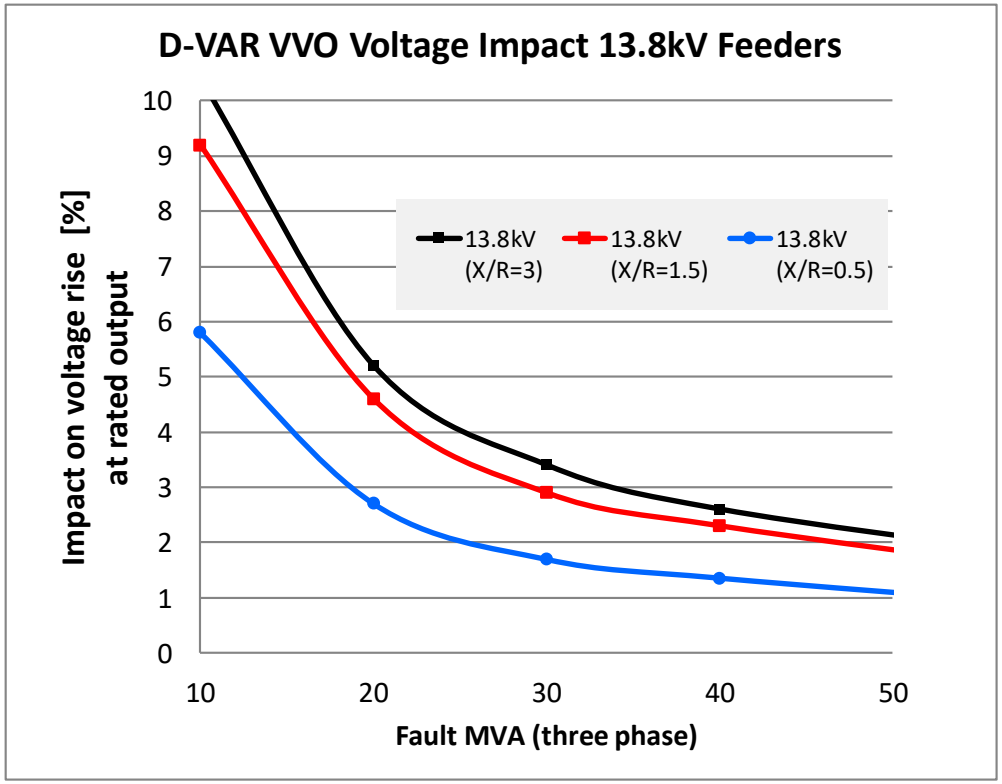


PQ Operating Space



Robust integration into distribution grids

Voltage Boost/Buck from Single Stage STATCOM



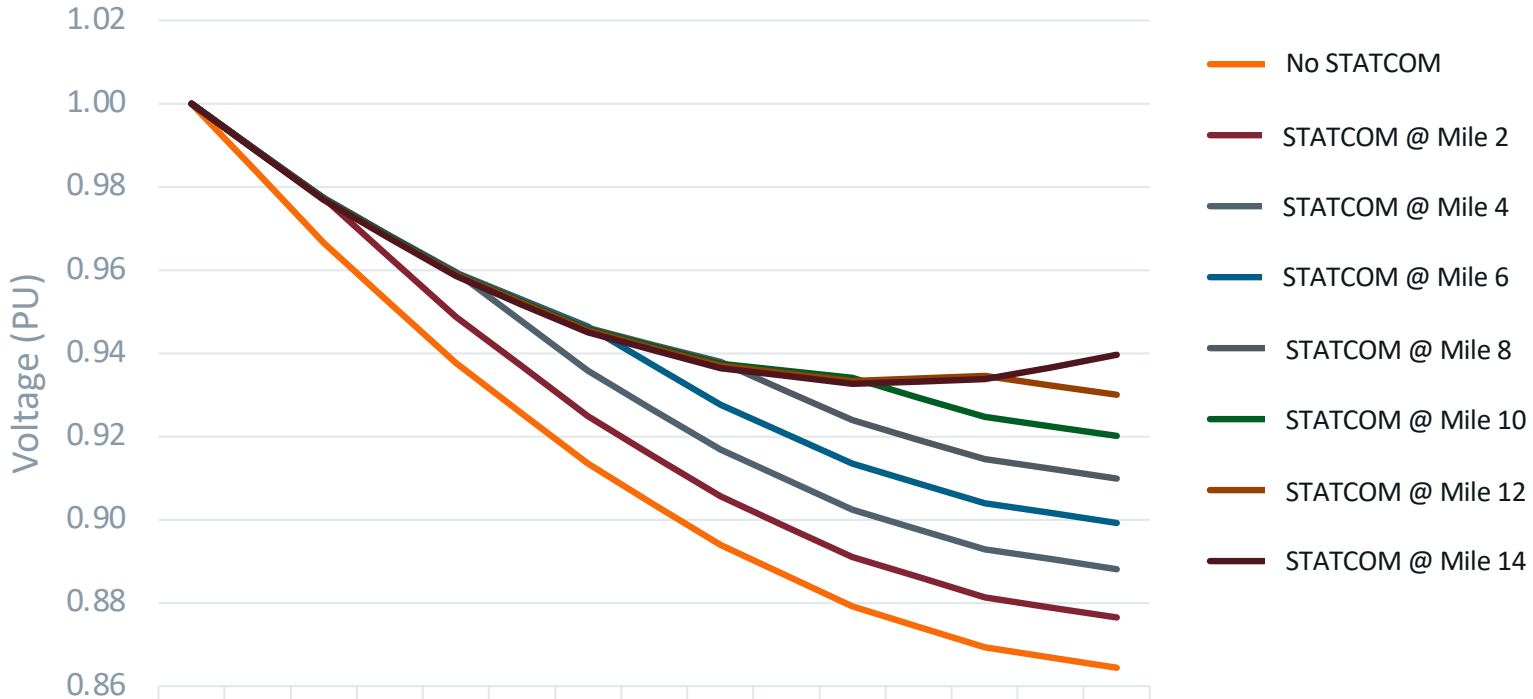
1) Downline feeder locations 7-10 miles in length typically have 20-30 MVA & X/R >1.5 (red & black curves)

2) **Longer rural** circuits, greater than 10 miles, 1/0 ACSR typically have <20MVA & X/R 1-1.5 (near red curve)

Two known power system parameters to determine impact

Feeder profile impact: Single STATCOM

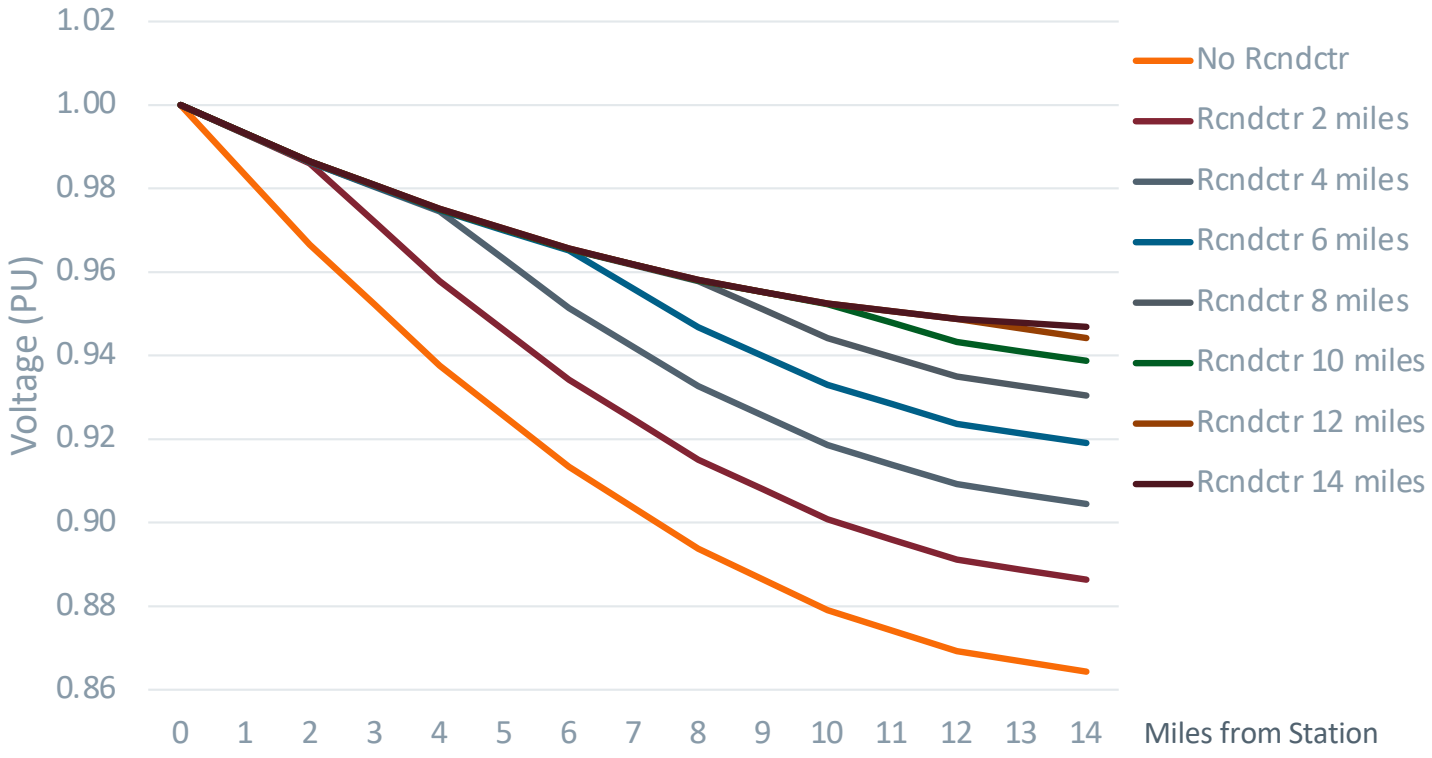
2.1MVA, 92%PF load distributed on 14 miles of 12.47 kV, 1/0 ACSR conductor



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



STATCOM Applications

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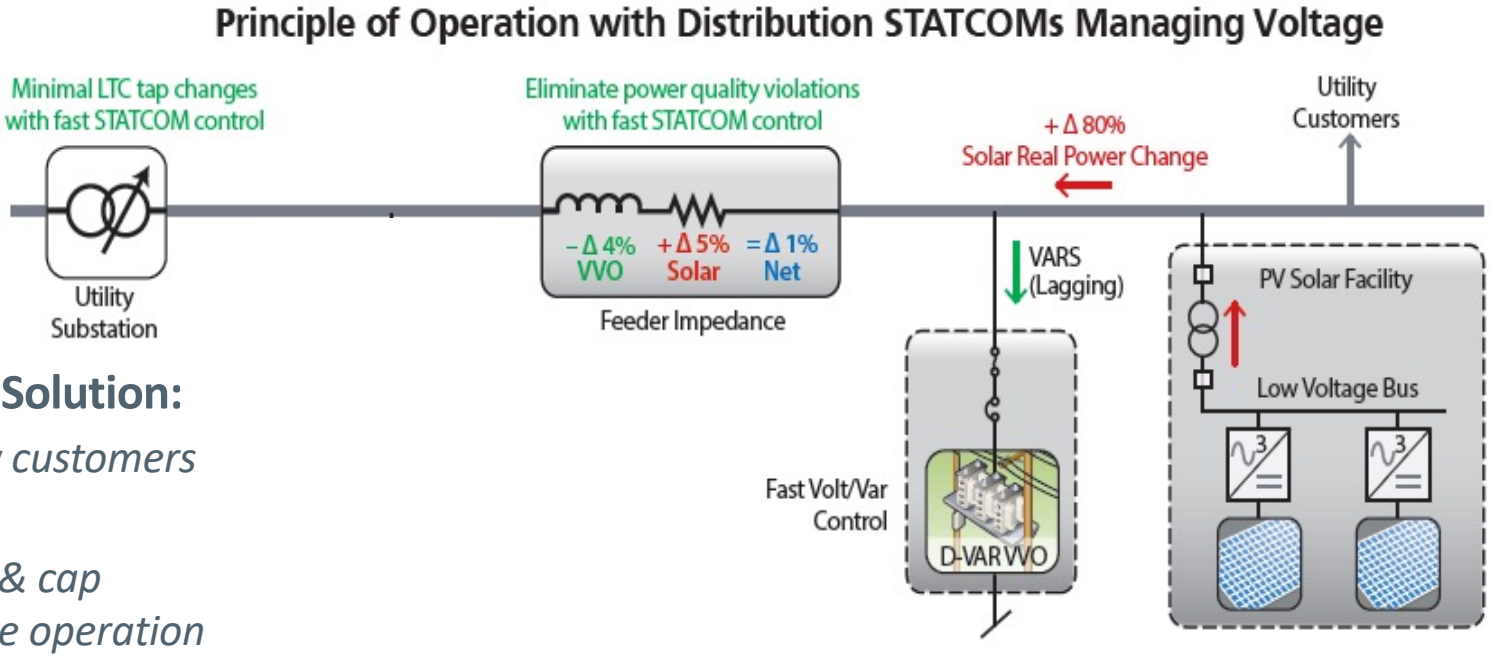
Accelerate Renewables on Existing Circuits

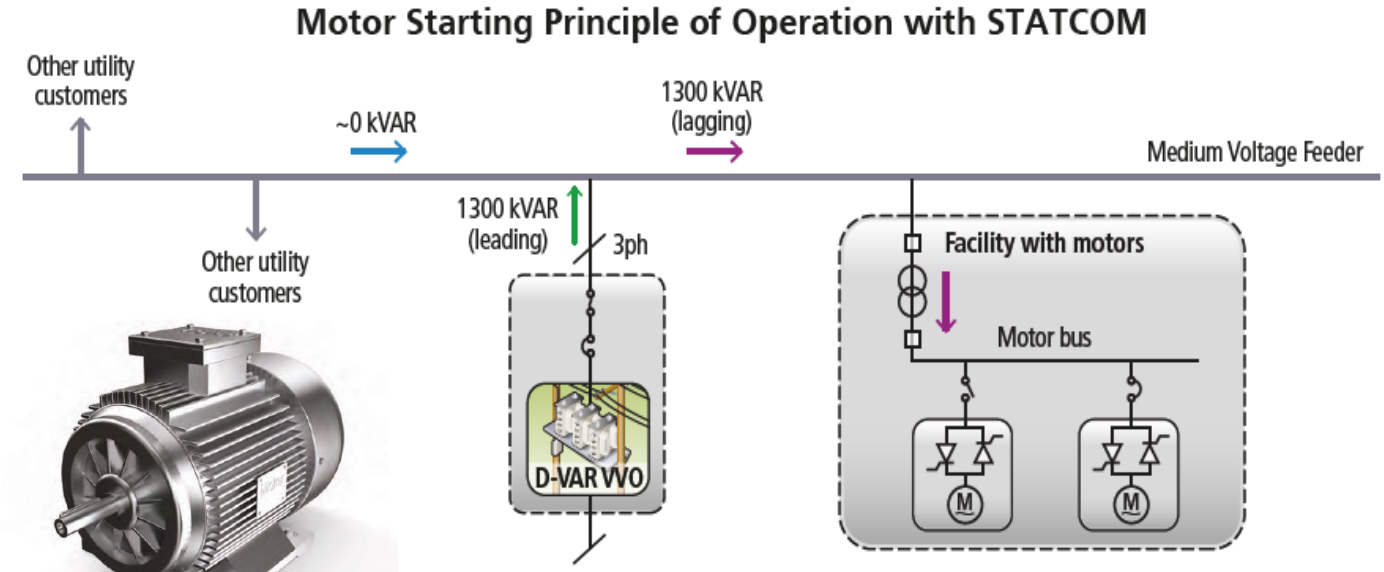


Distribution STATCOM Solution:

- *Protects existing utility customers from PQ problems*
- *Protects tap changers & cap switches from excessive operation*

Leverage existing distribution circuits for renewables by increasing hosting capacity by 3-4MW per STATCOM

Solving Motor Starting Power Quality Issues



Distribution STATCOM

Solution:

- Eliminate voltage dips
- MV device protects against multiple motors/sites
- Solve PQ issues w/o altering plant

Quickly solve expensive downtime due to motor starting power quality problems up to 2000HP motors

STATCOM Control Functions Examples

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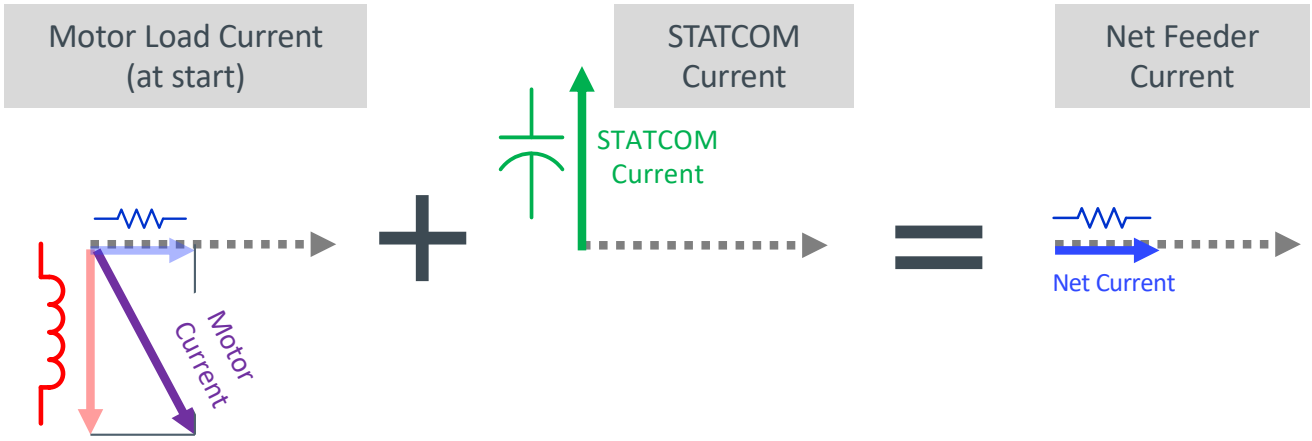
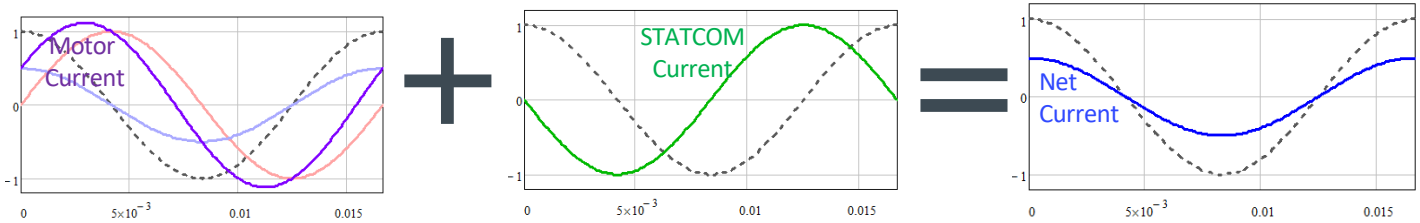
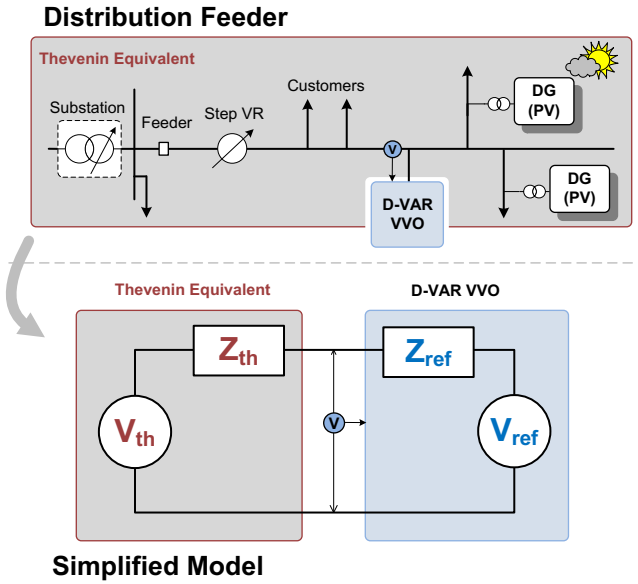
Example: Var Type Control Mode for Motor Compensation

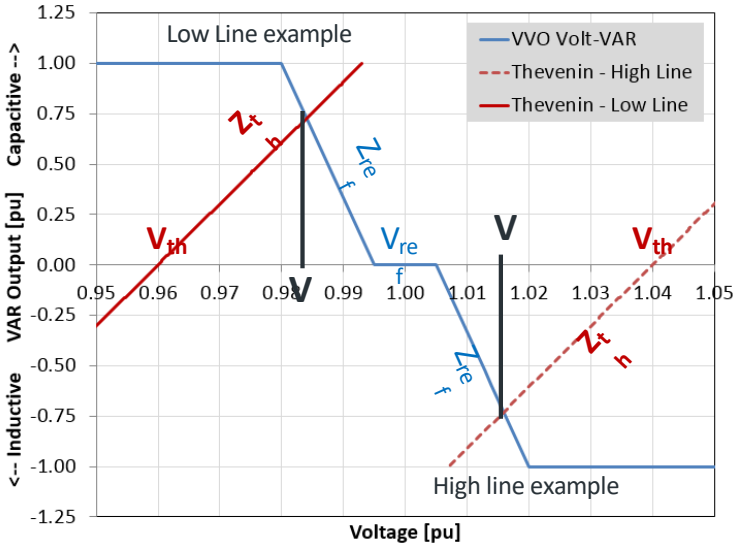




- *Reactive part of the motor load is cancelled by STATCOM current.*
- *Significantly reduces voltage drop due to motor load*

Example: Voltage and VAR control mode for Voltage Correction





- STATCOM looks capacitive at low line, inductive at high line
- Naturally compatible with existing voltage regulation equipment

STATCOM Data & Performance Monitoring Examples

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Online Monitoring

Dashboard

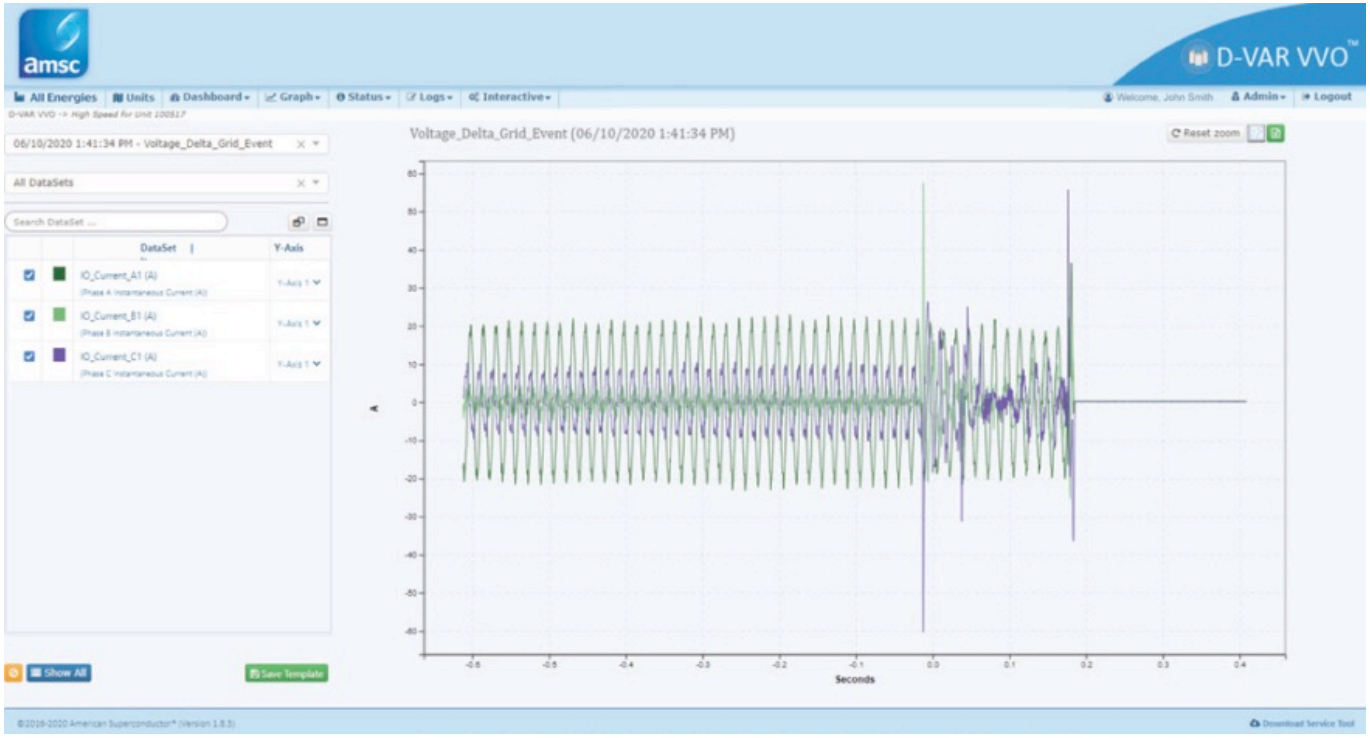
Live monitoring of your STATCOM fleet:

- Includes live kVar, Current, and Voltage readings
- Current state and operating mode

Online Monitoring

Data Graphs

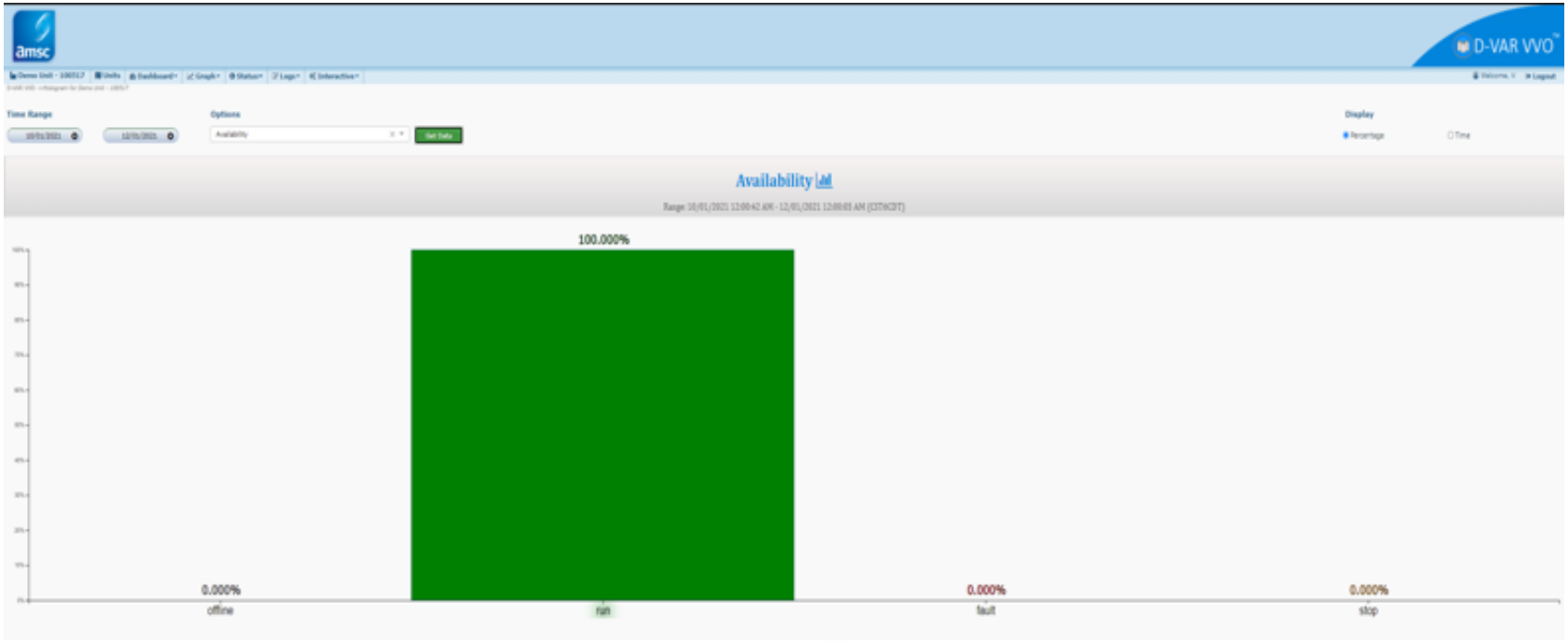
- High Speed Event Data - High resolution data captured on occurrence of an event such as large voltage sags/swells and out of range measurements
- Trend Data - Long term trending of measurements min/max/avg.



Online Monitoring

Data Graphs

- Availability Histograms: Unit's state (offline, run, faulted, stopped) over a chosen time interval
- STATCOM Output Histograms: Unit's output over a chosen time interval



Case Study:
Variable solar generation on a long radial feeder

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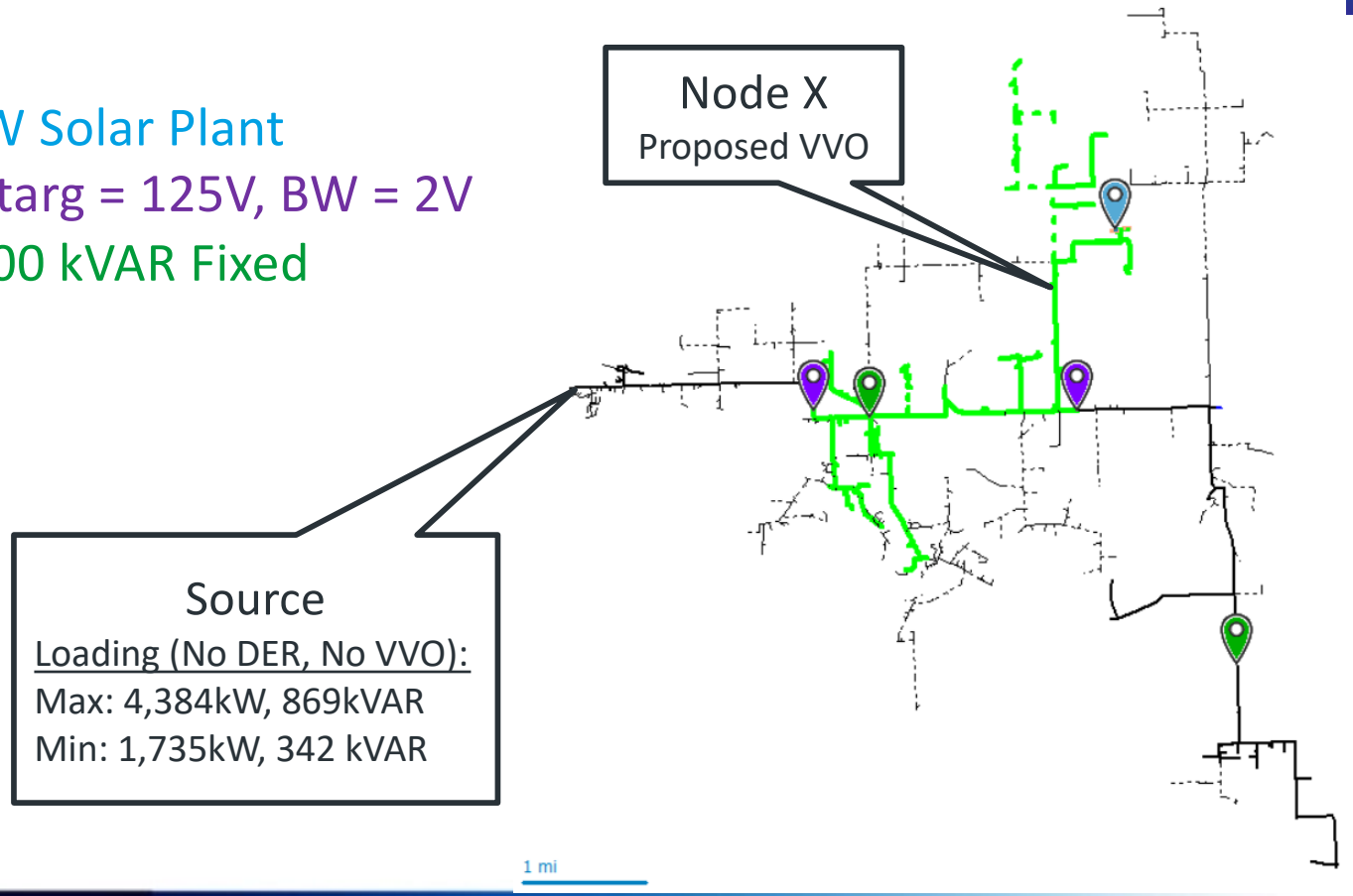
25kV Circuit Overview

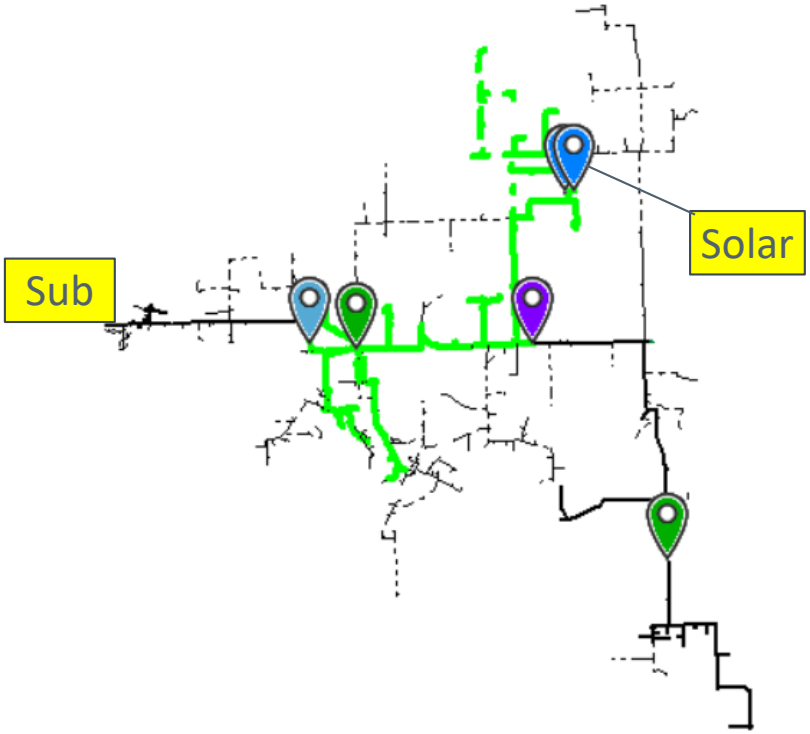
Legend:

- Solar: 1.7MW Solar Plant
- Regulator: Vtarg = 125V, BW = 2V
- Capacitor: 300 kVAR Fixed
- Overvoltage

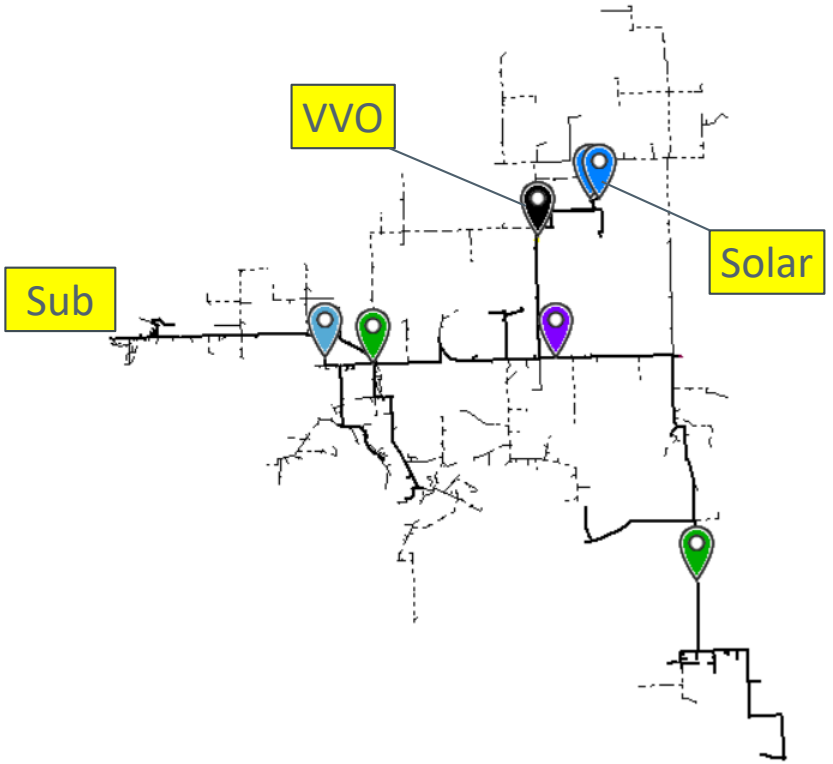


Basic Load Flow Simulation

VVO operating up to 1000 kVAR inductive eliminates overvoltage



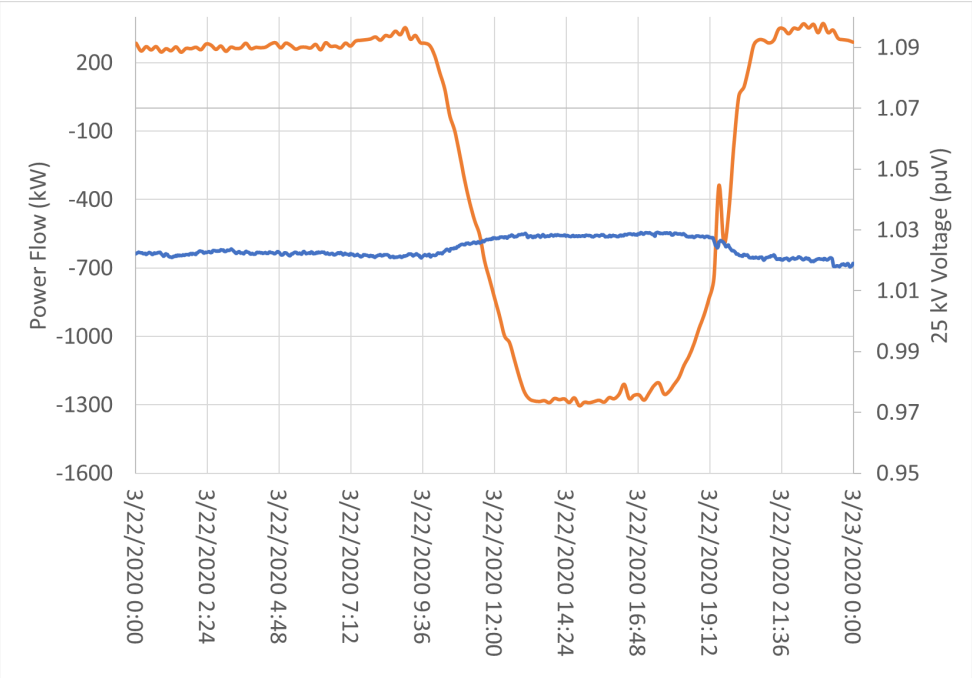
Minimum Load, Peak PV (1.8 MW)



Minimum Load, Peak PV (1.8 MW) with VVO

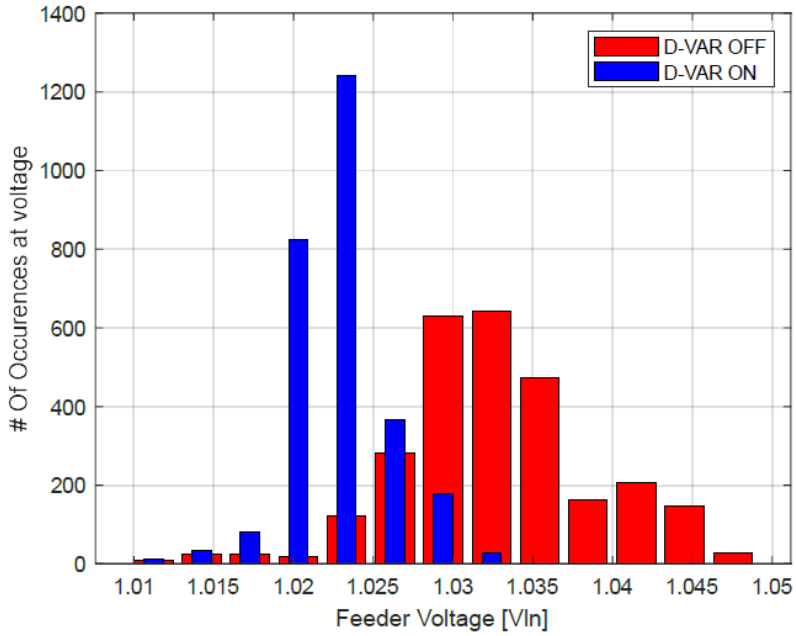
Field Results

Feeder power and voltage measured at VVO on a sunny day

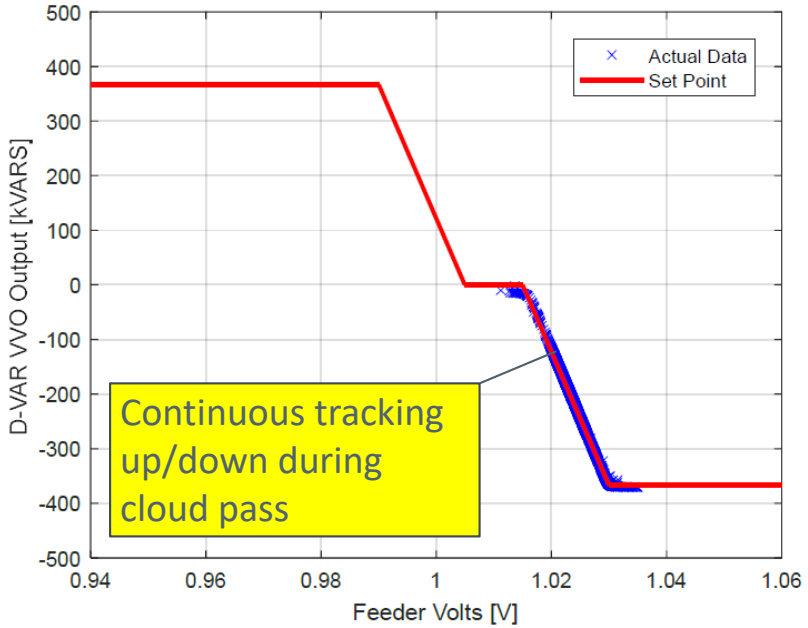


Field Results

VVO Console monitoring data from the site



VVO is the primary voltage regulator in this protection zone



Absorbing Vars expected for generation/reverse power flow

Case Study:
Power Quality Violations with Motor Starts

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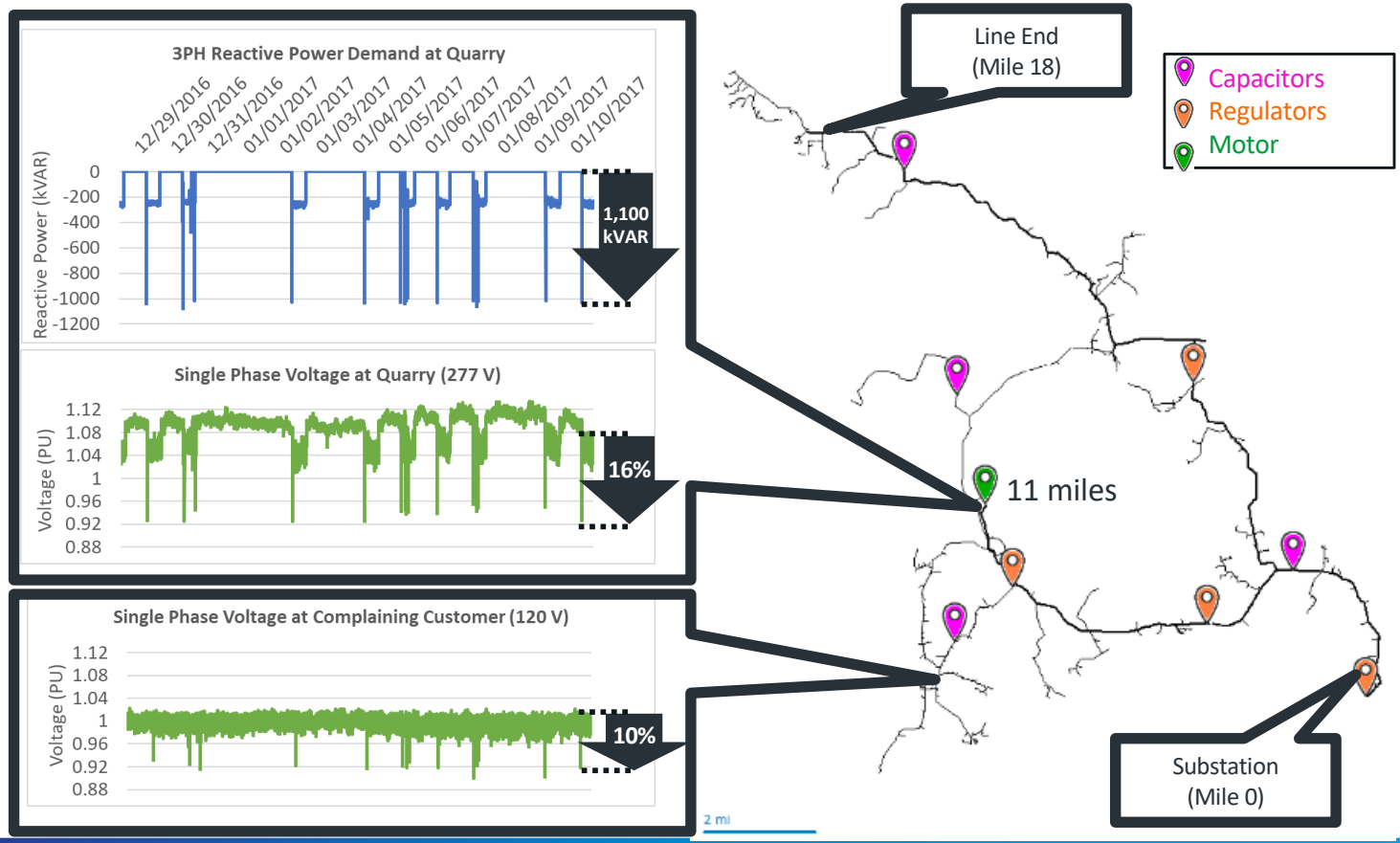
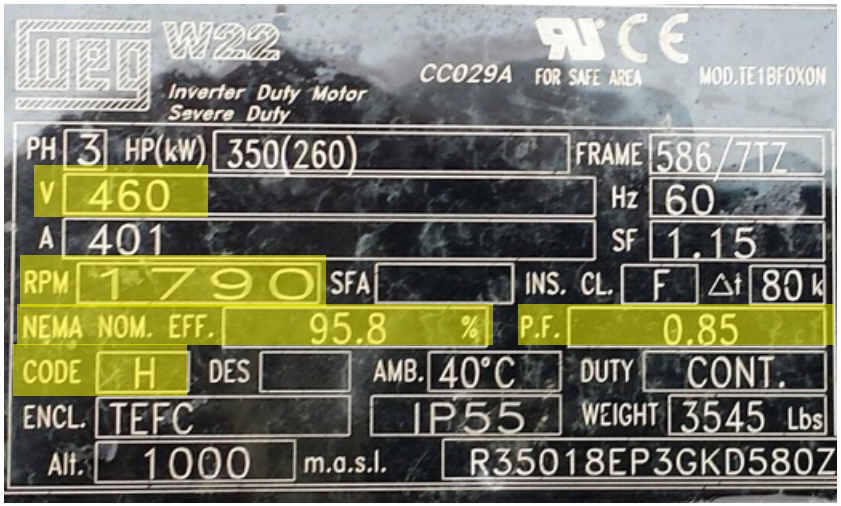
Power Quality Recordings



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

Motor Nameplate



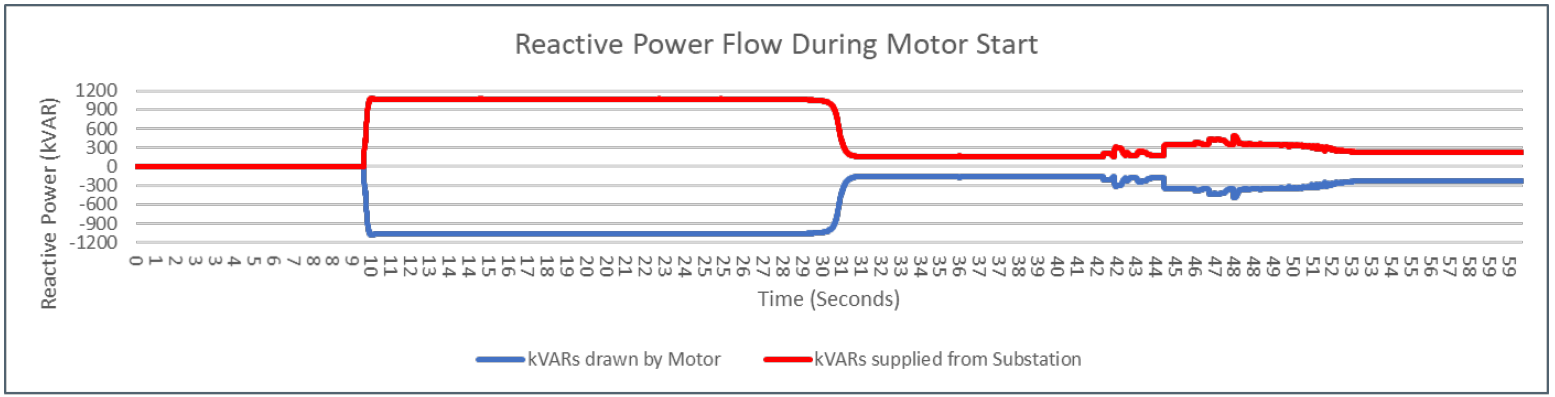
Key motor parameters:

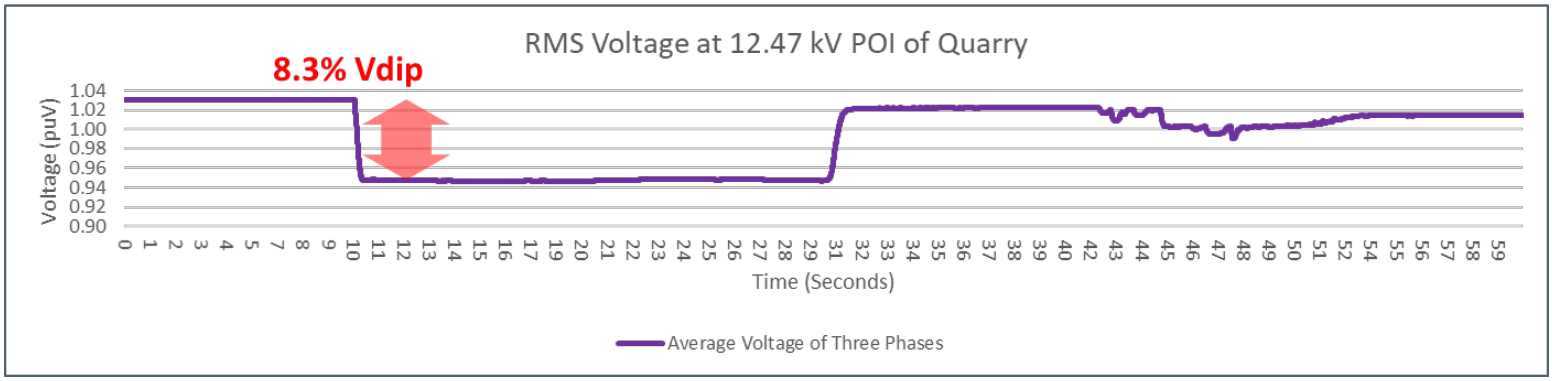
- 350HP
- Code H: 6kVA/HP starting
- Soft starter 75% remaining

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 (II/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 VVO

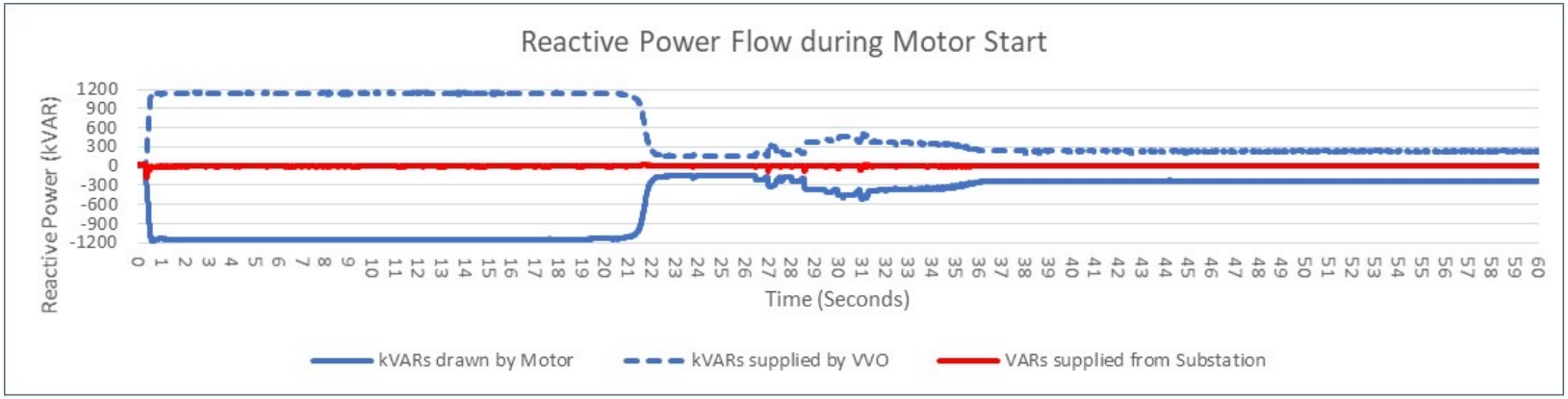
Motor Start without STATCOM

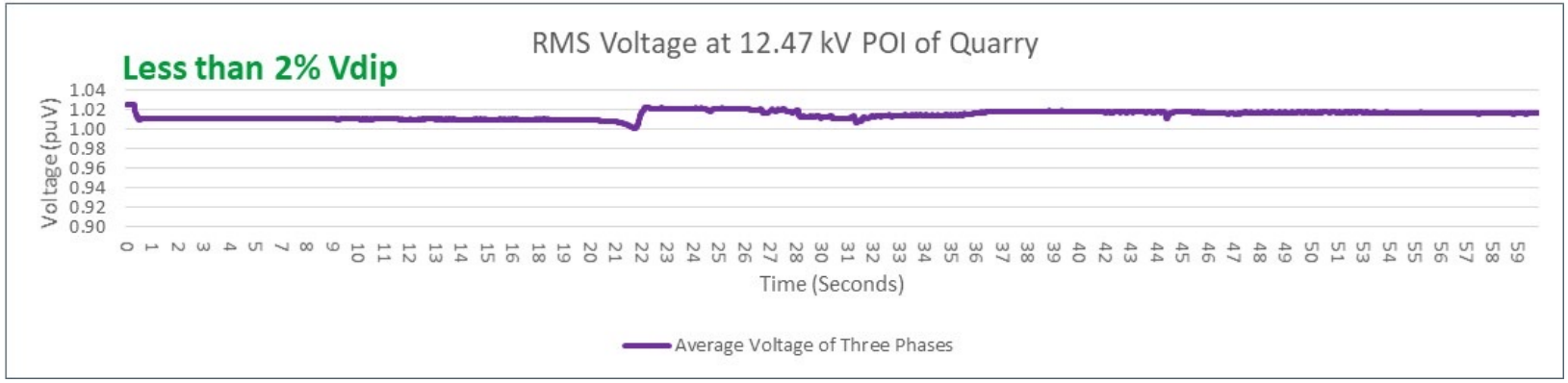




Sudden motor Vars cause excessive voltage drop on the utility feeder even with soft starter

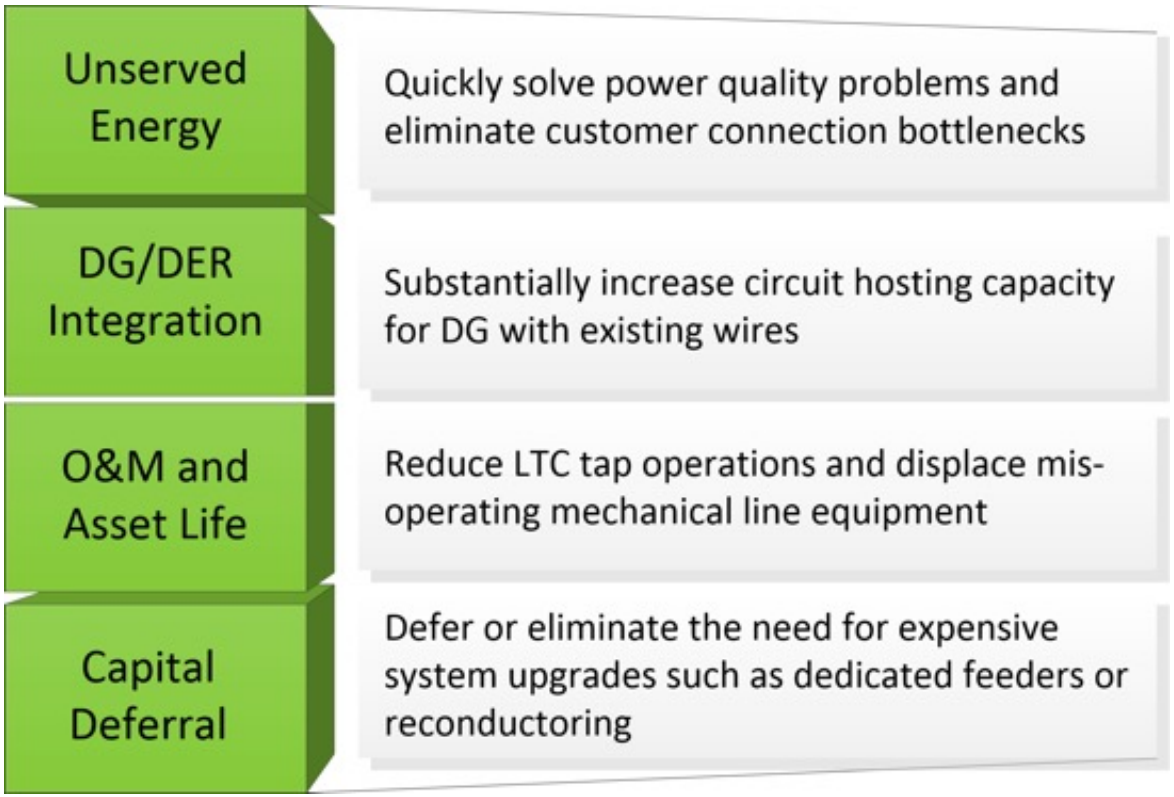
Motor Start with a STATCOM





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

Distribution Class STATCOMs: The Value of Distribution Power Quality



Value cases enabled by fast distribution class power electronics

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Please visit website and D-VAR VVO product page

https://www.amsc.com/gridtec/distributed-generation-solutions/#dvarvvo

Answers to follow-up questions

- **Mark Metzdorf : When a STATCOM goes inductive and absorbs VARS, is that energy dissipated as heat?**

The only amount or real power that goes in and out of the VVO STATCOM is the small real power losses into the product. Like a capacitor, the VVO STATCOM doesn't supply real power and like a reactor that doesn't absorb (much) real power. However, there is a small amount of heat generated due to the losses, but that overall amount is very minimal (approximately than 1% of the STATCOM's VA rating is dissipated as Watts)

- **Zobayer Khizir: You mentioned about the overloading capacity is in the range of 1.33; but the utility scale PMU from AMSC can do 3 times overload within 2 seconds. why the distribution module can do only 133%**

To provide a bit more background:

AMSC has two STATCOMs. One is called the DVAR which is a 480V STATCOM that requires a transformer to connect to primary voltages. It's a 4MVAR STATCOM that is typically used for substation and transmission applications. It has an overload rating of 3x for 2 seconds.

The other STATCOM is the DVAR VVO, which is a medium voltage device. It is 1rating for 1MVAR and has an overload rating of 1.3x for 60 seconds. This STATCOM was designed specifically to help with Distribution systems.

There is a combination of factors on why these two STATCOMs have different overload ratings. To list a few:

- The application and market needs (distribution vs transmission) made us feel that the 3x overload may not be needed for the VVO.
- The VVO is medium voltage device while DVAR is a low voltage device (480V) and to achieve a 3x overload with a medium voltage device would have a sizable impact on the VVO's design.

End

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