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Changes for the Better

Value of a VAR Panel

A Solution Provider's Perspective: *Performance, Price, Packaging*

DOE Energy Advisory Committee Meeting

June 29, 2015

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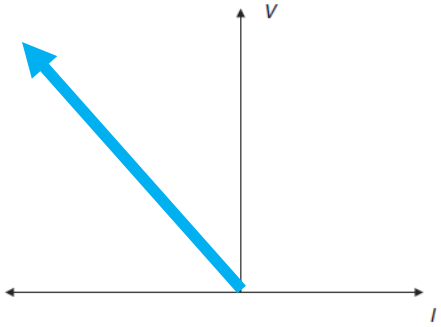
VAR Resource 'Q' Characteristics

Static VAR
1 Quadrant

Capacitor Curve

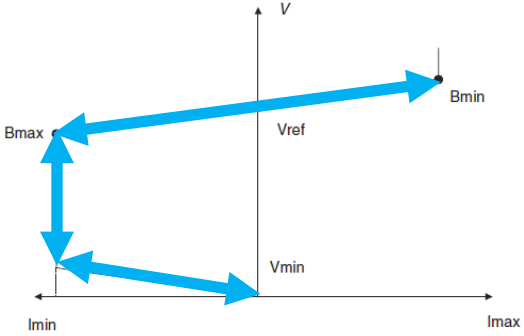


'+' Q, voltage boosting VAR.

Q is not variable, it is dependent on V

Dynamic VAR
2 Quadrant

STATCOM Curve



+/- Q, voltage boosting and bucking VAR. **Q is variable**

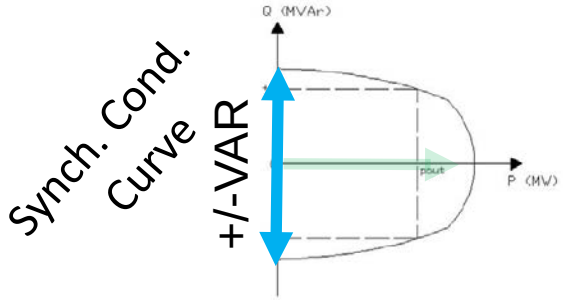
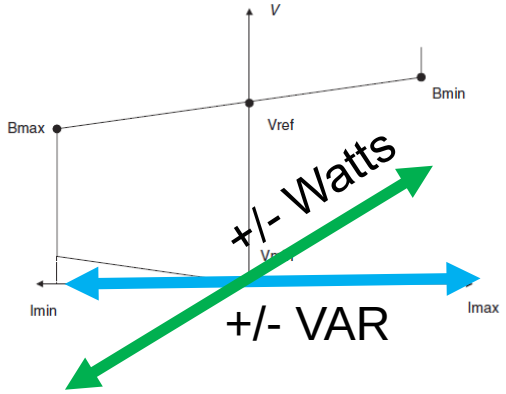


Figure 1. PQ Capability Curve of the Generator (Kundur, 1994)

Dyn. VAR+W
4 Quadrant

UPFC or ES Curve



+/- Q, and +/- P.

Q and P are variable

Performance Adds Value

Changes for the Better

Static VAR 1 Quadrant

Provides

Steady State Voltage boost with a capacitor, or buck with an inductor

But, capacitor's ability to support system voltage diminishes.as system voltage drops

Dynamic VAR 2 Quadrant

Plus

Dynamic V-Boost and V-Buck
Increase V-Stability Margin
Mitigate Voltage Transients
Mitigate Renewable' Impacts
Enable Volt/VAR Optimization
Enable Conservation Voltage Reduction

STATCOM and some inverters will maintain voltage support capability down to very low system voltages during severe system events

Dyn. VAR+W 4 Quadrant

Plus

Provide Peaker Capacity
Provide FR/FRR Capacity
Provide Blackstart Support
Provide Synthetic Inertia
Release Constrained T&D
Incr. XMSN Path Capacity
Recover Renewable Spill
Manage Ramp Rates

UPFC and some Energy Storage Systems provide system frequency support, in addition to system voltage support

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Value, or Benefit, Must Exceed Cost of Performance

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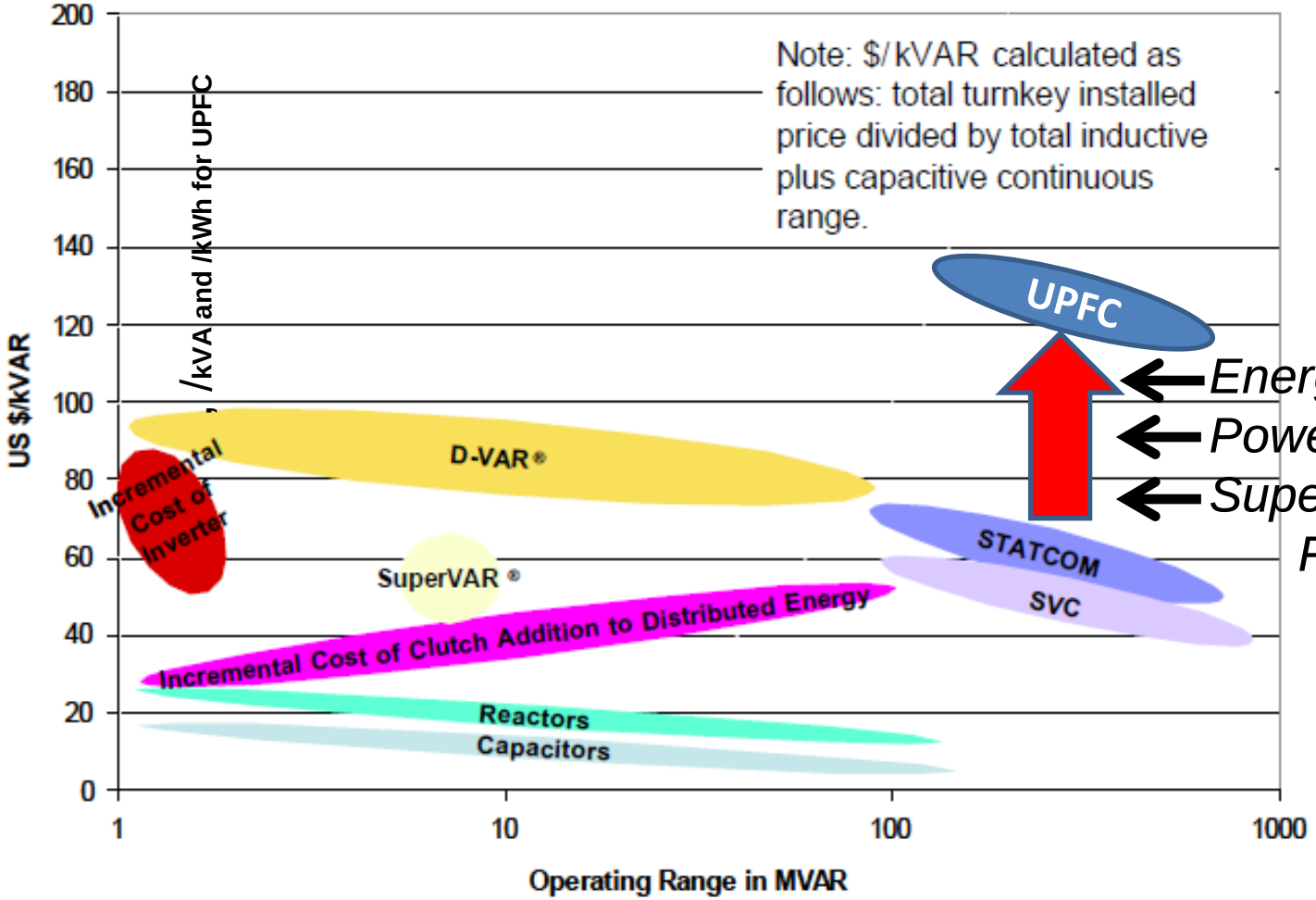


Energy Battery
Power Battery
Super Capacitor, Flywheels

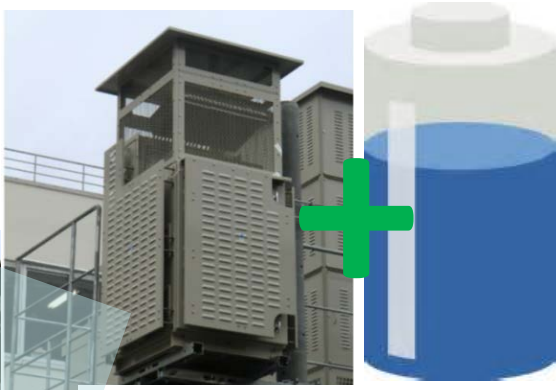
Original Image Source, ORNL DECC

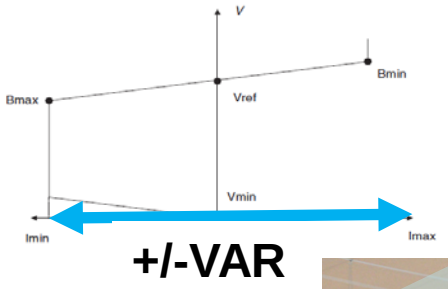
Advances in VAR Packaging

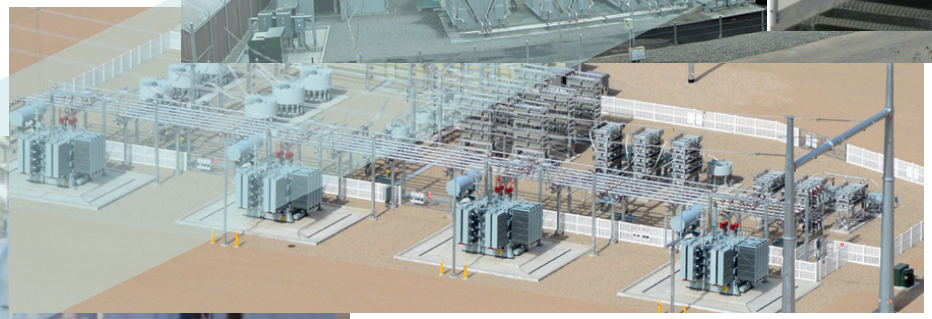
Changes for the Better

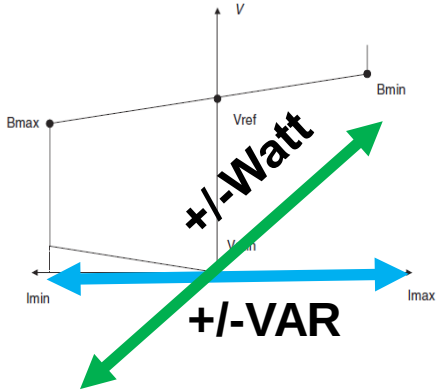
= More Cost Effective Solutions = More Net Value Delivered

VAR's located closer to load via distributed resources, e.g. 'smart' PV Inverters and D-STATCOM, can increase the relative Value/VAR









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Thank You

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References and Further Reading

Value of Dynamic VARs

ORNL report on valuing dynamic VARs,
http://web.ornl.gov/sci/decc/Reports/Economics%20of%20DE%20for%20Reactive%20Power%20(ORNL-TM-2006-014).pdf

Early Thought Leadership and Action on Storage, Synthetic Inertia, and Frequency Responsive Reserves (FRR)

Energy Storage Association comments to FERC,
http://energystorage.org/system/files/resources/ferc_esacomments_ad13_8_10_18_13.pdf

SDG&E comments to CAISO,
http://www.caiso.com/Documents/SDGEComments_EnergyStorageRoadmapWorkshop_Sep4_2014.pdf

AES paper on storage projects delivering synthetic inertia and low voltage ride through (LVRT) support,
http://www.aesenergystorage.com/wp-content/uploads/2014/03/AES_Inverter_Capabilities_-_Version_1.0.pdf

ACRONYMS

FR,	**Frequency Regulation**
FRR,	**Frequency Responsive Reserves**
STATCOM,	**Static Compensator**
VAR,	**Volt Ampere Reactive**
UPFC,	**Unified Power Flow Controller**
XMSN,	**Transmission**