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Real-Time Testing of STATCOM and SVC Controllers

Rebecca Rye

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Acknowledgements

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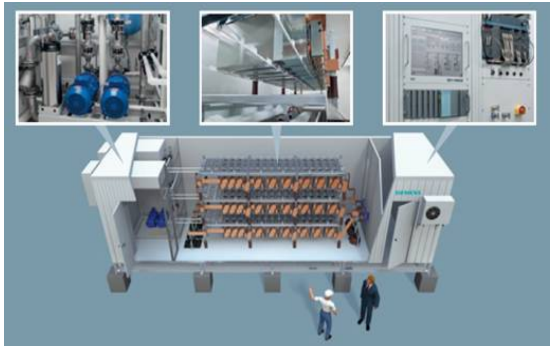
Power Electronic Devices in Power Systems

Solar farm

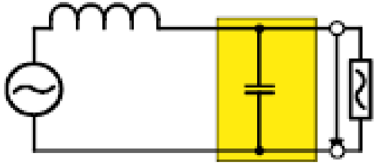
High **V**oltage **D**irect **C**urrent (HVDC)

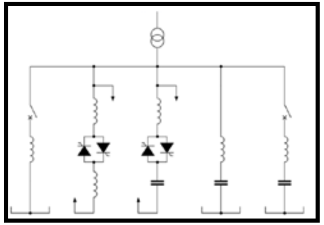
Wind farm

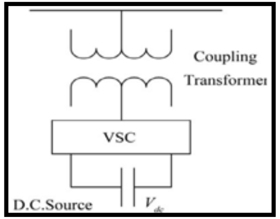


SVC & STATCOM (for voltage regulation)

Types of Shunt Devices for Voltage Regulation

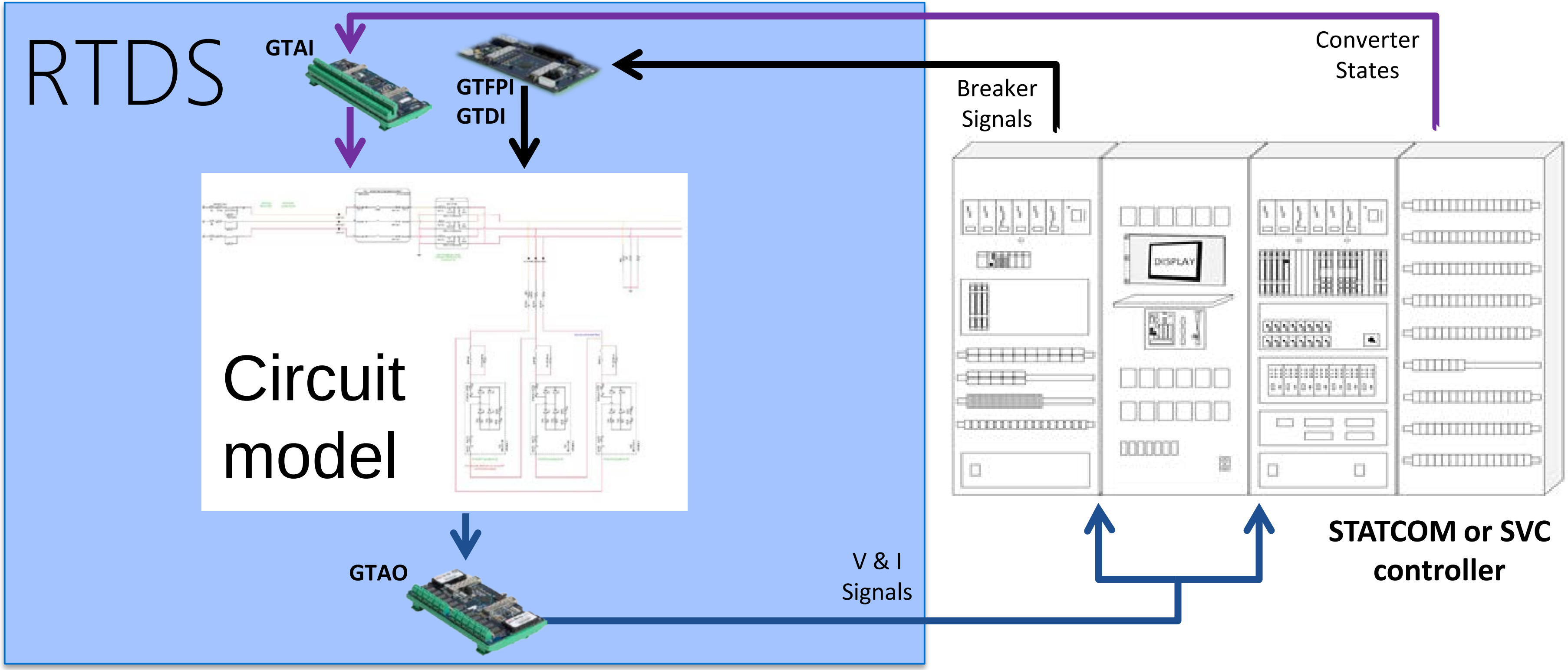






	Fixed Cap/ Fixed Reactor	SVC	STATCOM
Switch mechanism	Mechanical	Power Electronics	Power Electronics
Reactive power (Q) control method	Manual / Automatic	Automatic	Automatic
Q change step size	Large	Small	Small
Both capacitive & inductive?	No	Yes	Yes
Need harmonic filter?	No	Large filter	Small filter

Hardware-in-the-Loop (HIL) Experiments on RTDS



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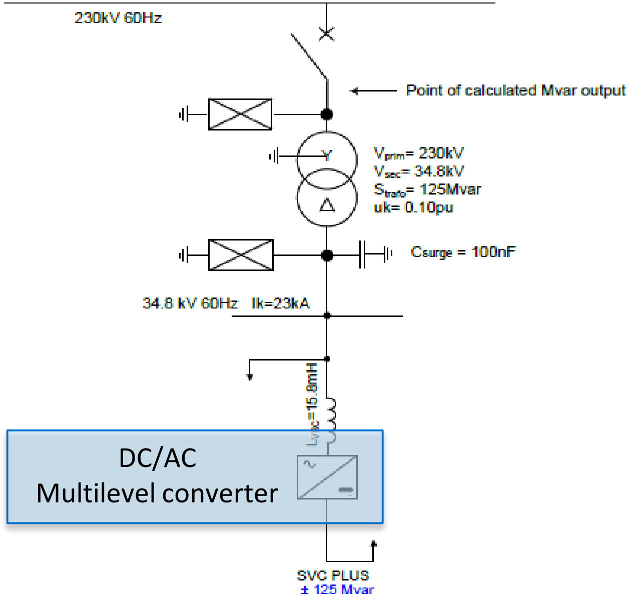
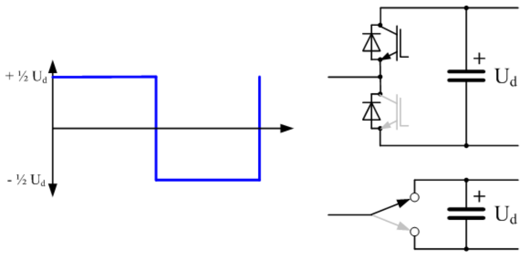
Introduction to the STATCOM

Static Synchronous Compensator

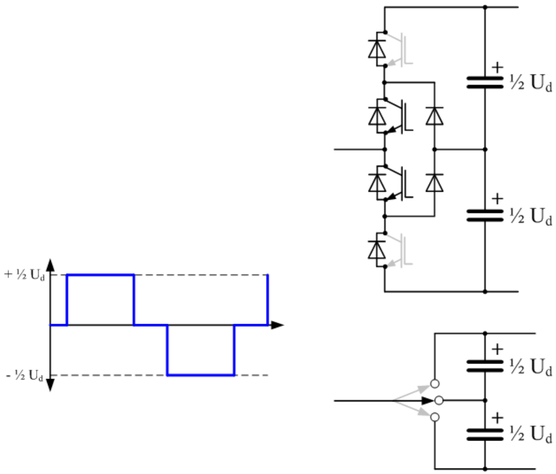
A regulating device that can act as either a source or sink of reactive power using IGBTs



2-level converter



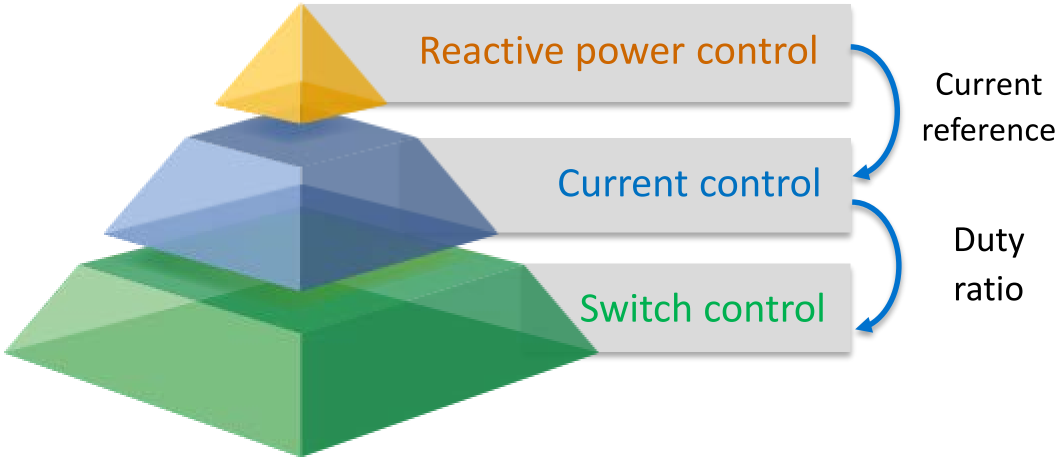
3-level converter



Introduction to the STATCOM

Static Synchronous Compensator

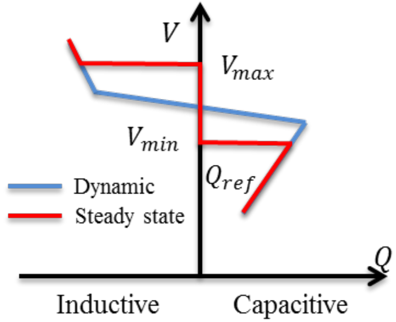
A regulating device that can act as either a source or sink of reactive power



Reactive power control

(1) Fixed Q mode / Manual mode

(2) Voltage Control Mode



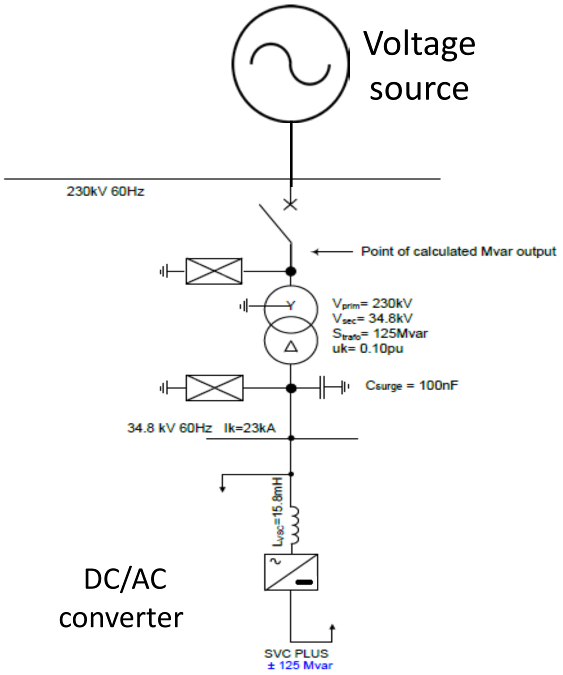
STATCOM RTDS Tests

Functional Performance Tests (FPT)

- Operational behavior

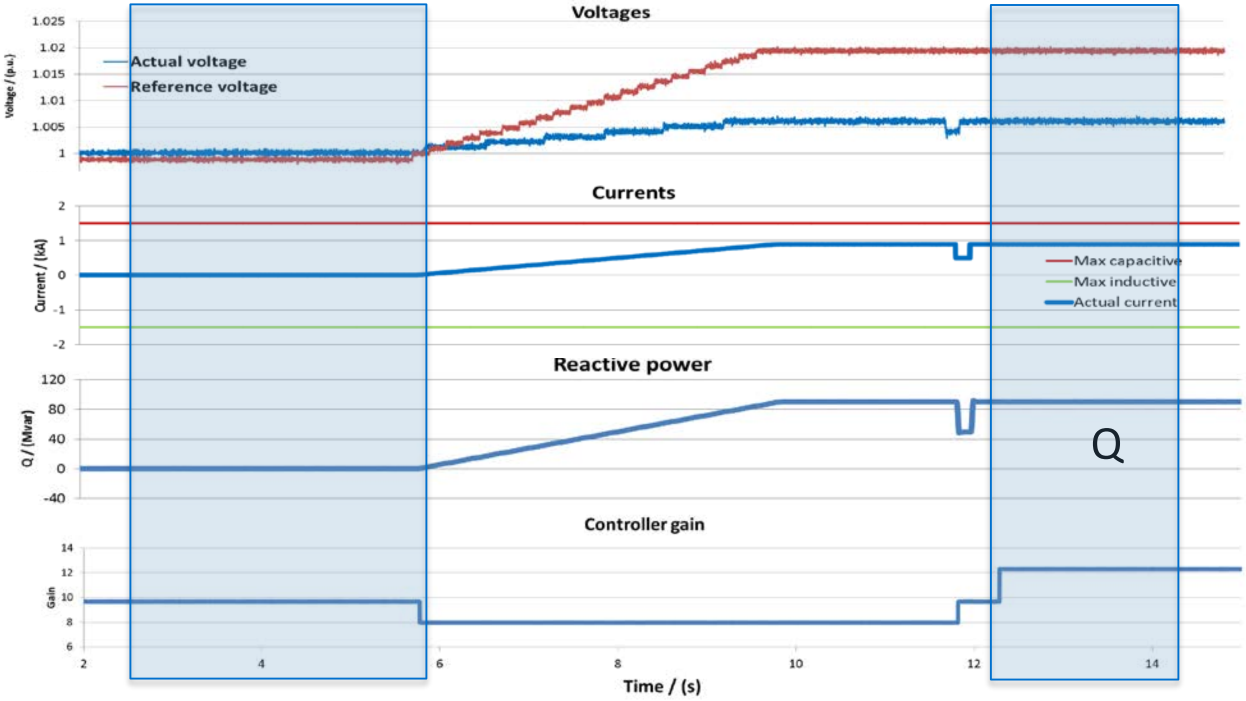
- ✓ Start up and shut down
- ✓ V/Q characteristic
- ✓ Gain controller test
- ✓ Stability controller
- ✓ Redundancy switchover

System diagram



STATCOM RTDS Tests

Mode transfer from fixed Q (FQM) to voltage control (VCM)

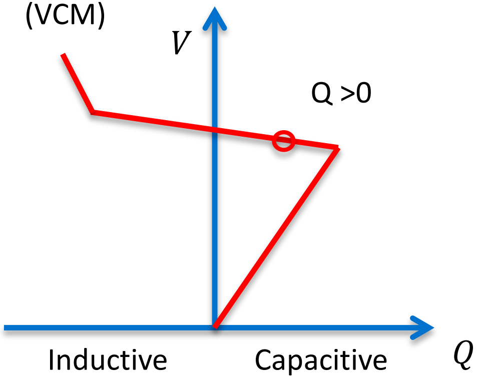


(1) In fixed Q (FQM) Q reference = 0

(2) Mode transfer

(3) Gain of VCM controller is adjusted

(4) Operation point in voltage control (VCM)



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STATCOM RTDS Tests

Dynamic Performance Tests (DPT)

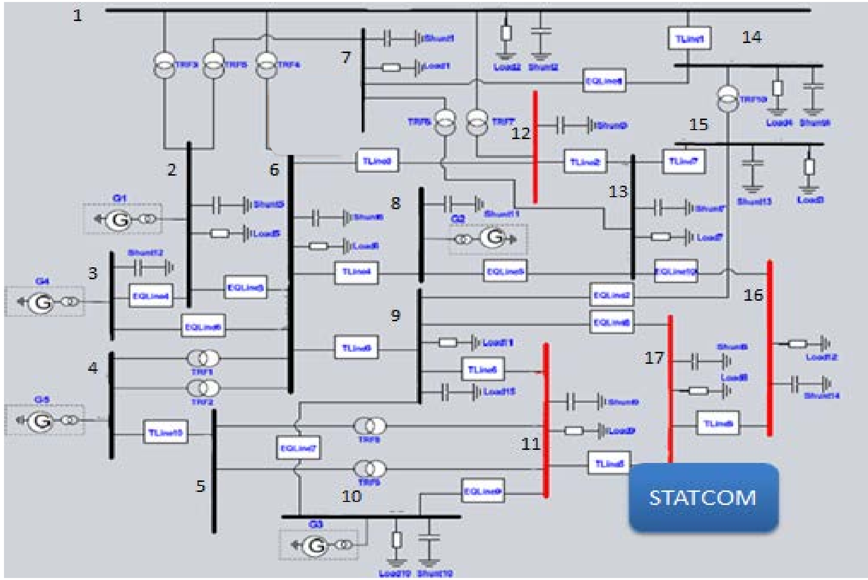
- Transient behavior

✓ Faults

✓ Load switching

✓ External transformer energization

System diagram



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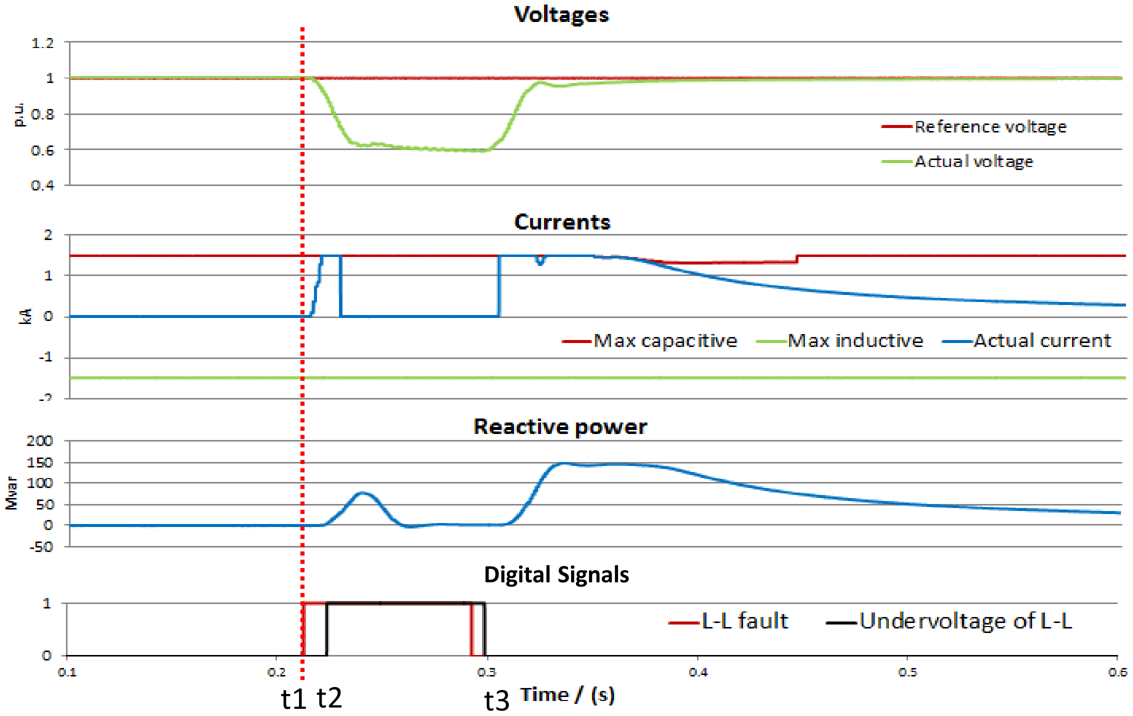
STATCOM RTDS Tests

Dynamic performance of STATCOM in phase to phase fault



t1 : Line to line fault

t2 : STATCOM blocked because of undervoltage

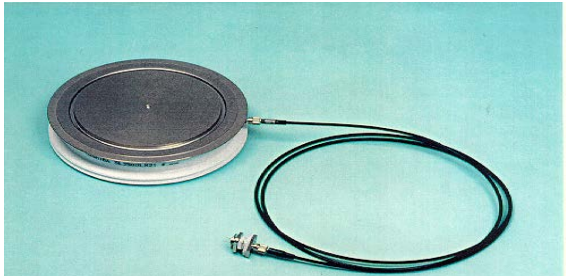
t3 : Fault is clear STATCOM is unblocked

Introduction to the SVC

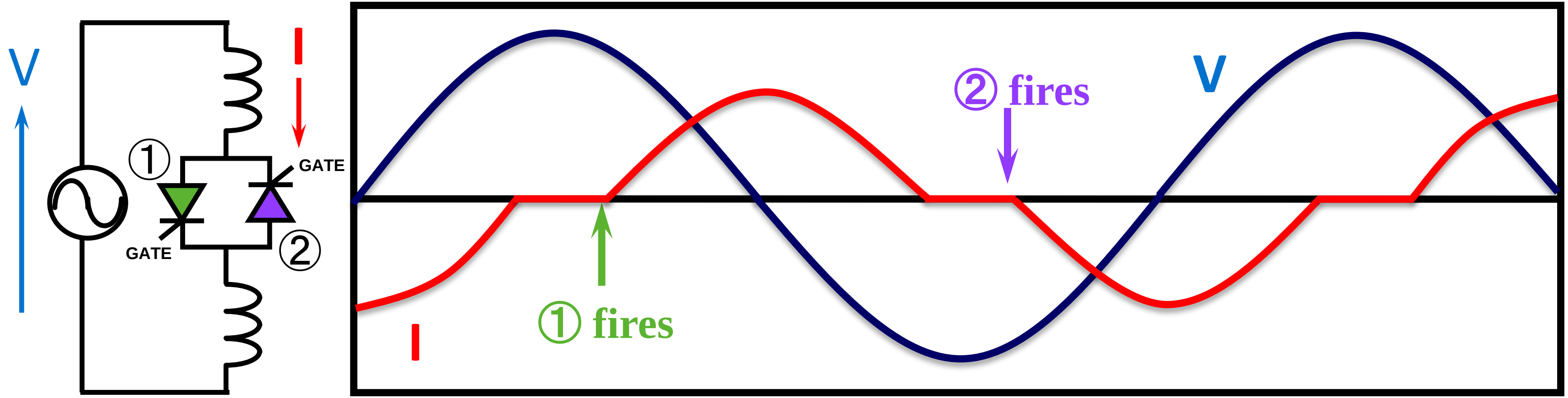
Static VAR Compensator

A device which regulates voltage by injecting or removing reactive power using:

- TCR: Thyristor Controlled Reactor
- TSC: Thyristor Switched Capacitor



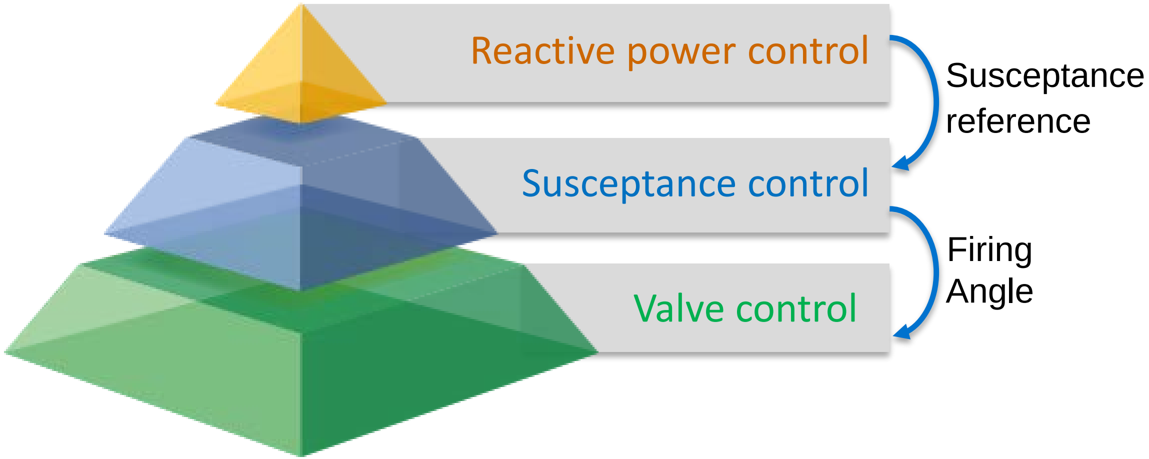
Light Triggered Thyristor:



Introduction to the SVC

Static VAR Compensator

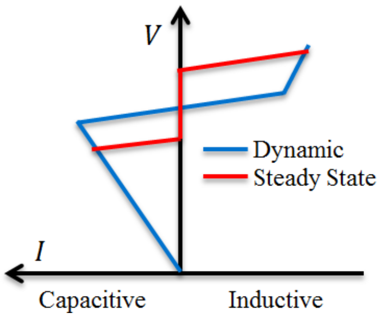
A device which regulates voltage by injecting or removing reactive power



Reactive power control

(1) Susceptance Control (Q-Mode)

(2) Voltage Regulator (AVR)



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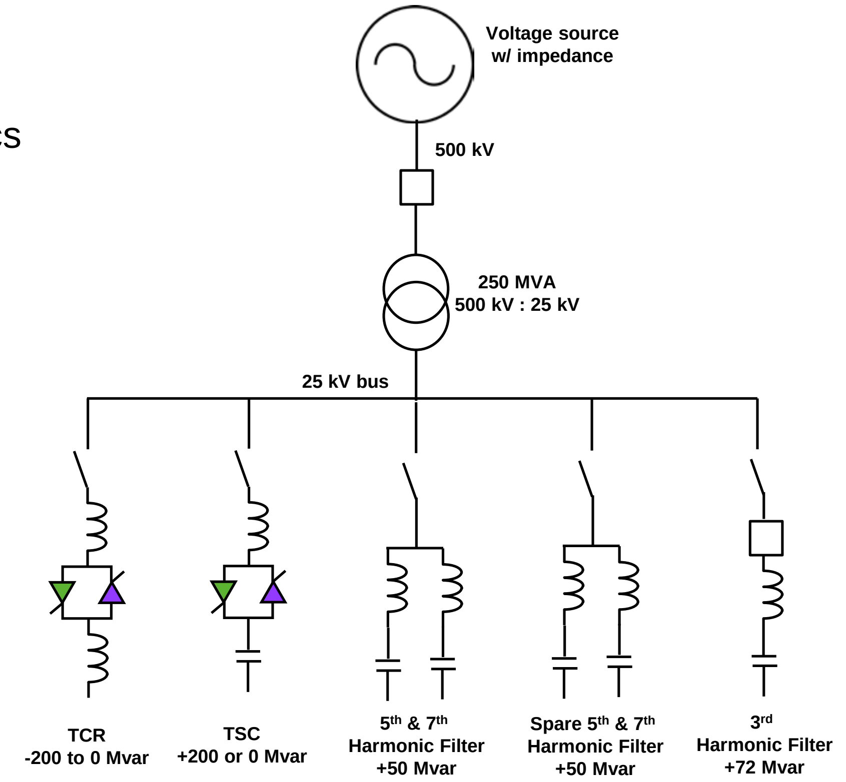
SVC RTDS Tests

System Verification Tests

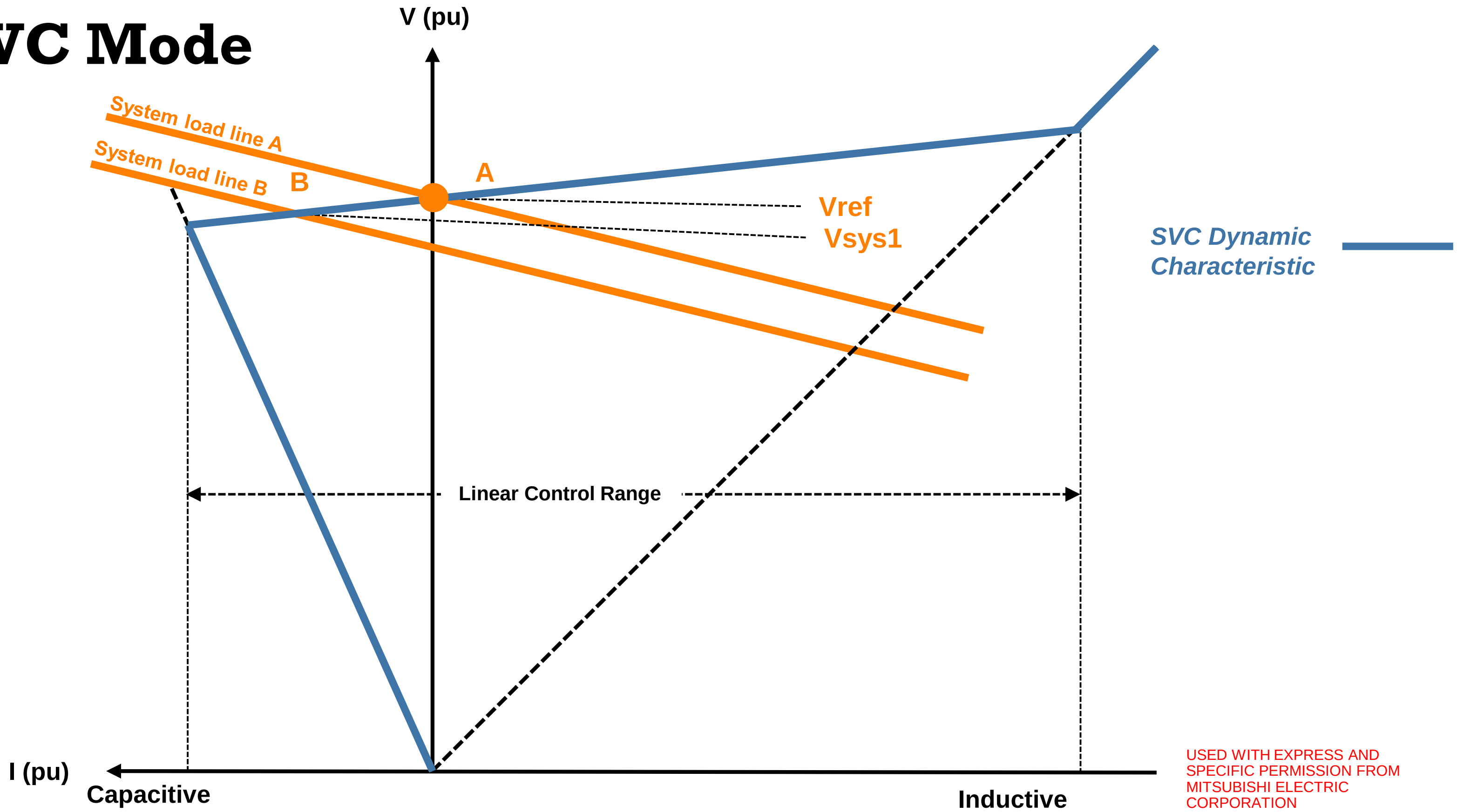
- Operation and static/dynamic characteristics

- ✓ Start up & shut down
- ✓ Protection
- ✓ V-I characteristics
- ✓ Faults

System diagram

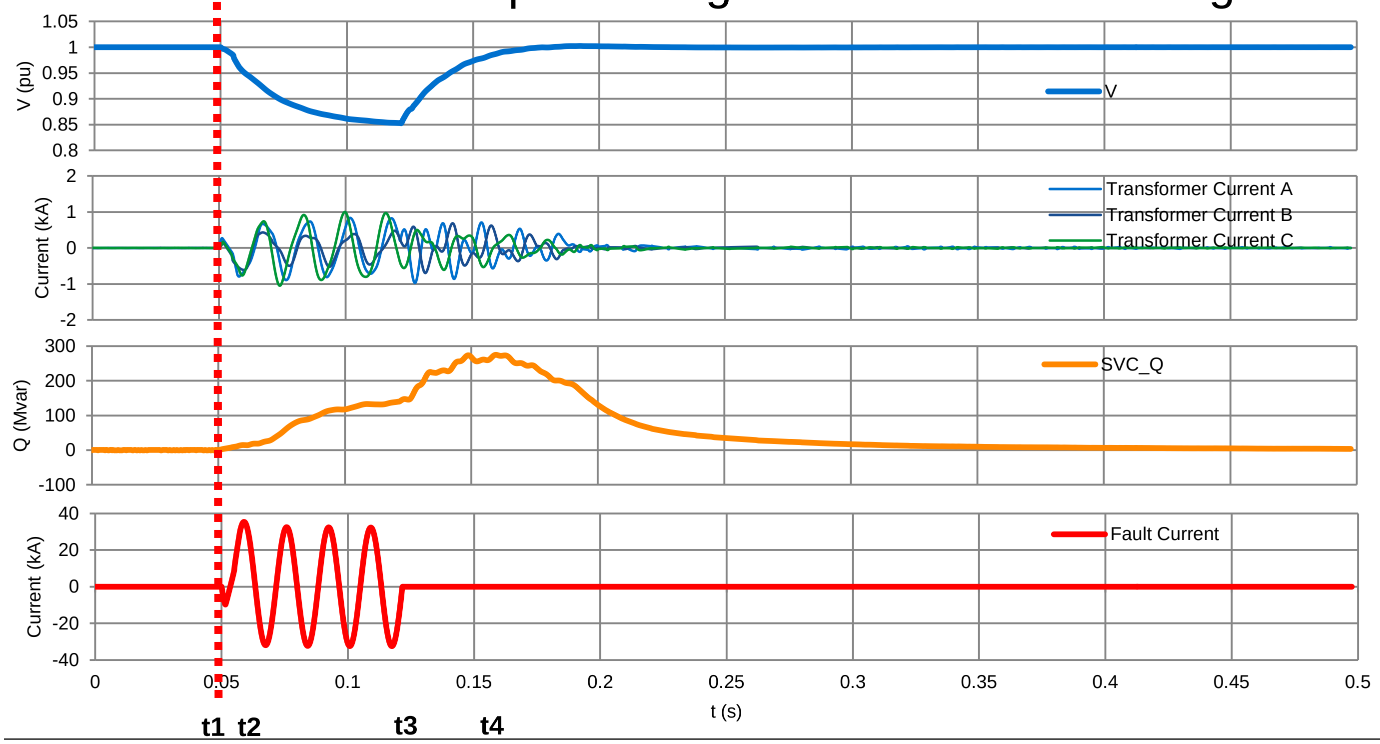


SVC – VC Mode


V (pu)
System load line A
System load line B
B
A
Vref
Vsys1
SVC Dynamic Characteristic
Linear Control Range
I (pu)
Capacitive
Inductive

SVC RTDS Tests

Performance of SVC in phase to ground fault under voltage-control mode



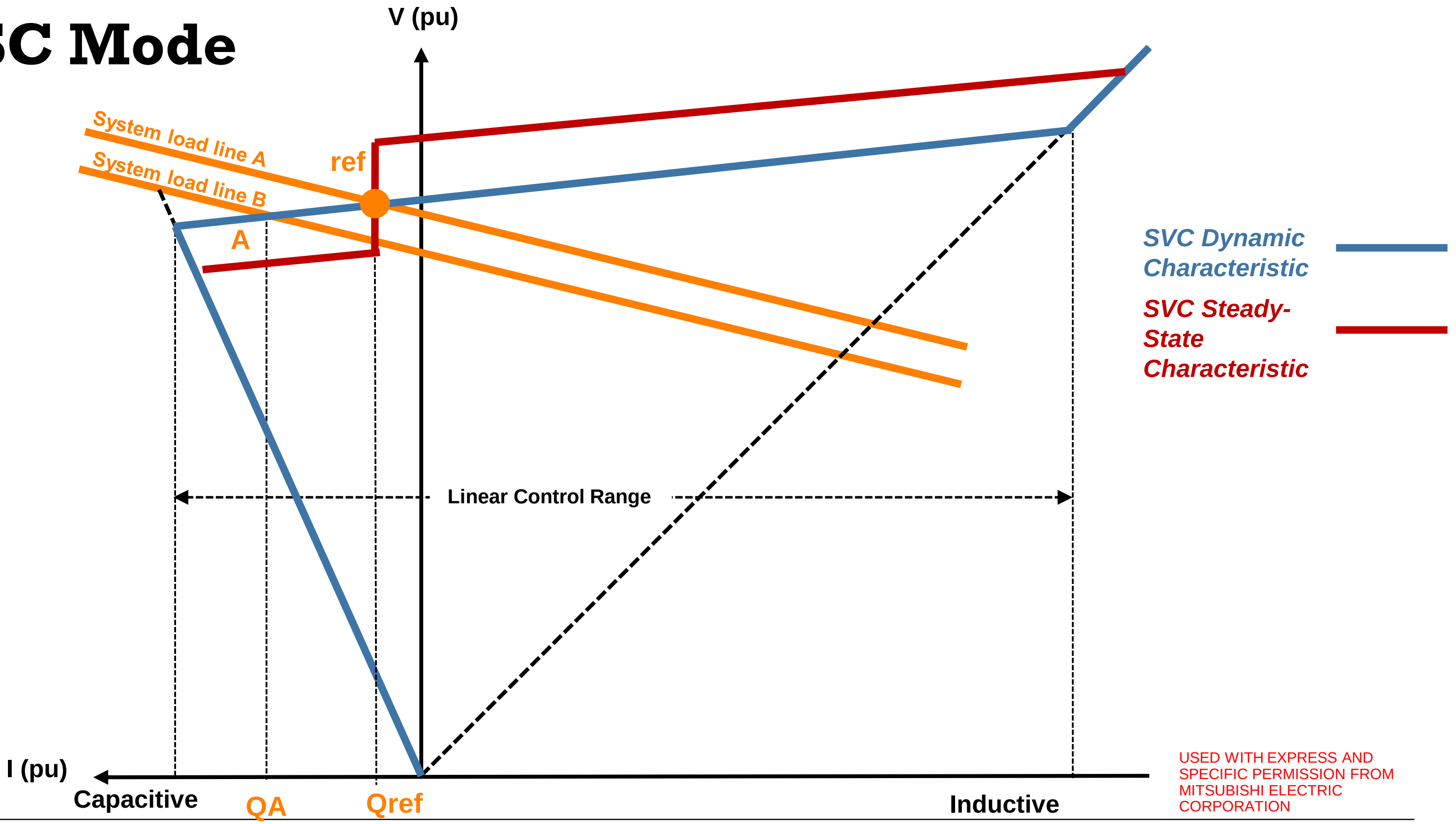
t1 : L-G fault applied

t2 : SVC injects Q to increase V

t3 : Fault is clear; SVC's Q brifely increases to regulate voltage to 1 pu

t4 : SVC injects less Q as voltage is boosted to reference value

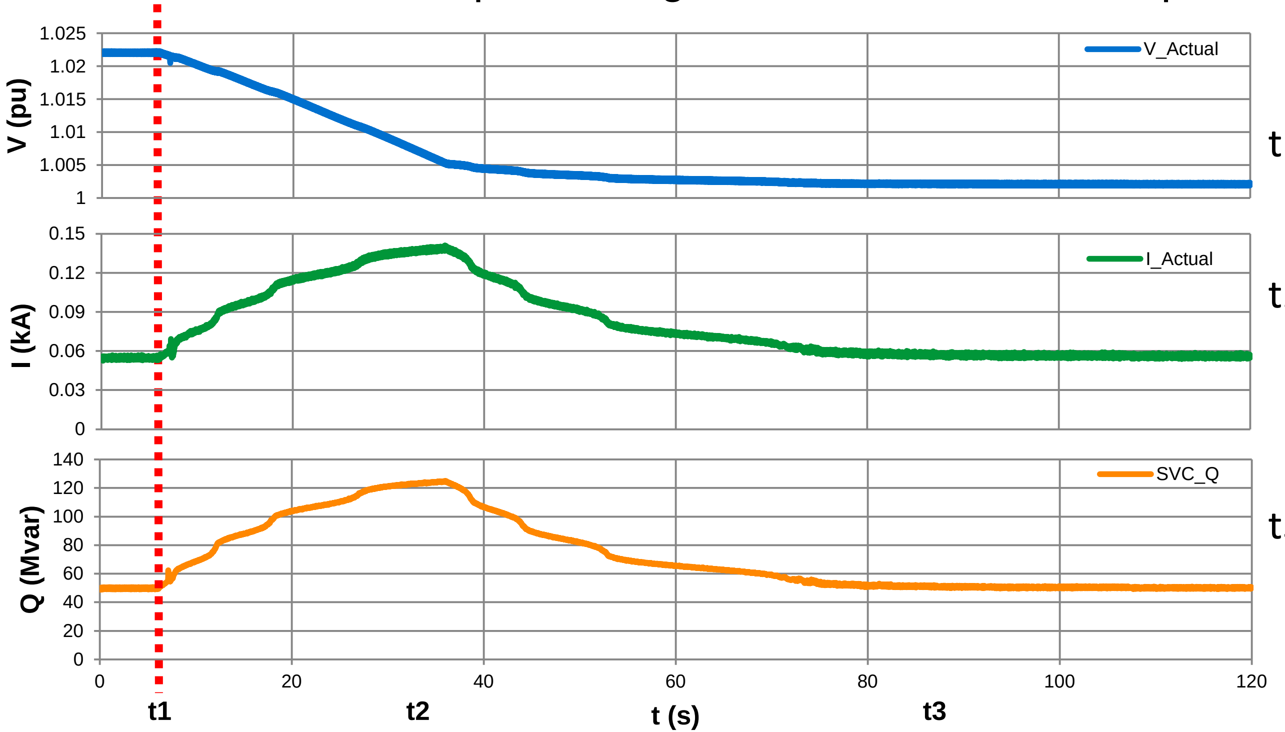
SVC – SC Mode



V (pu)
System load line A
System load line B
ref
A
Linear Control Range
I (pu)
Capacitive
QA
Qref
Inductive
SVC Dynamic Characteristic
SVC Steady-State Characteristic

SVC RTDS Tests

Performance of SVC in phase to ground fault under susceptance-control mode



Qref = 50 Mvar

t1 : System voltage change; SVC responds dynamically

t2 : System voltage settles; SVC's reactive power begins to move to reference value

t3 : SVC's reactive power returns to Qref value

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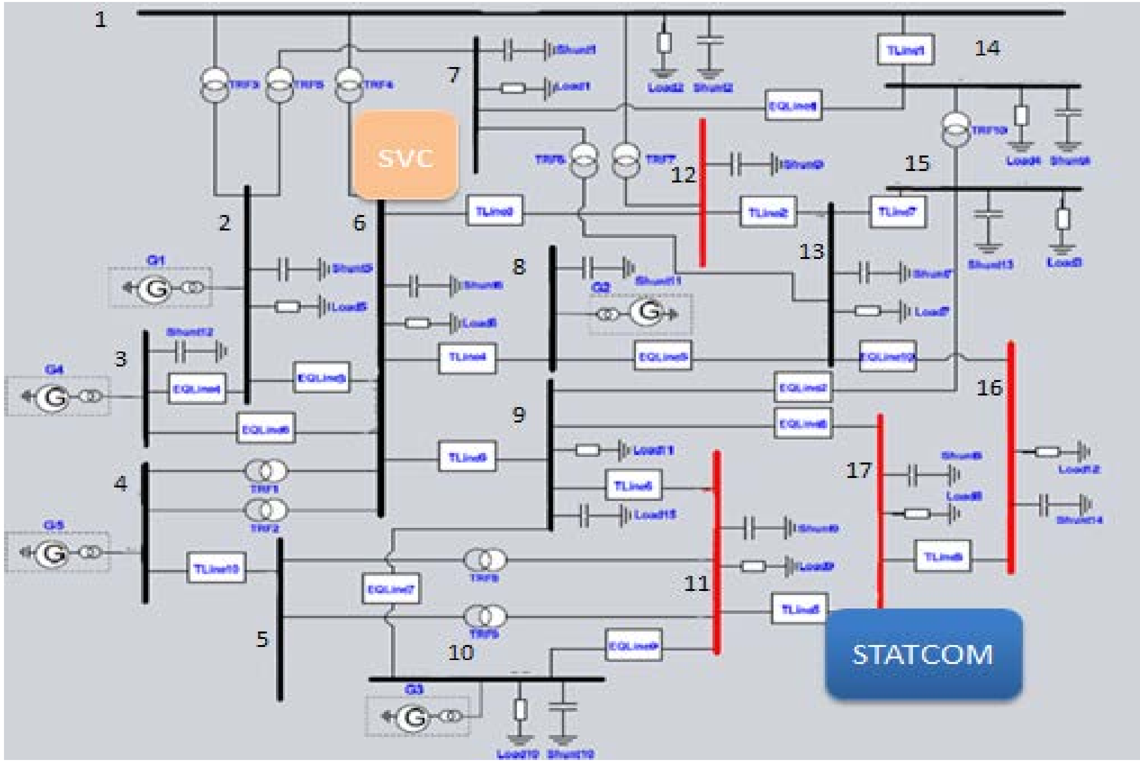
RTDS Tests – Conclusions

1) Real STATCOM & SVC controllers can be tested using hardware-in-the-loop technology on RTDS racks.
2) Verified the functionality and operation of Dominion Energy's new controllers per the manufacturers' specifications.
3) Understand the controllers and able to predict the response of the controllers in various scenarios.
4) Further tested the functionality of the controllers by performing more protection sequences and various kinds of faults in the simple model.

Interaction of the STATCOM and SVC



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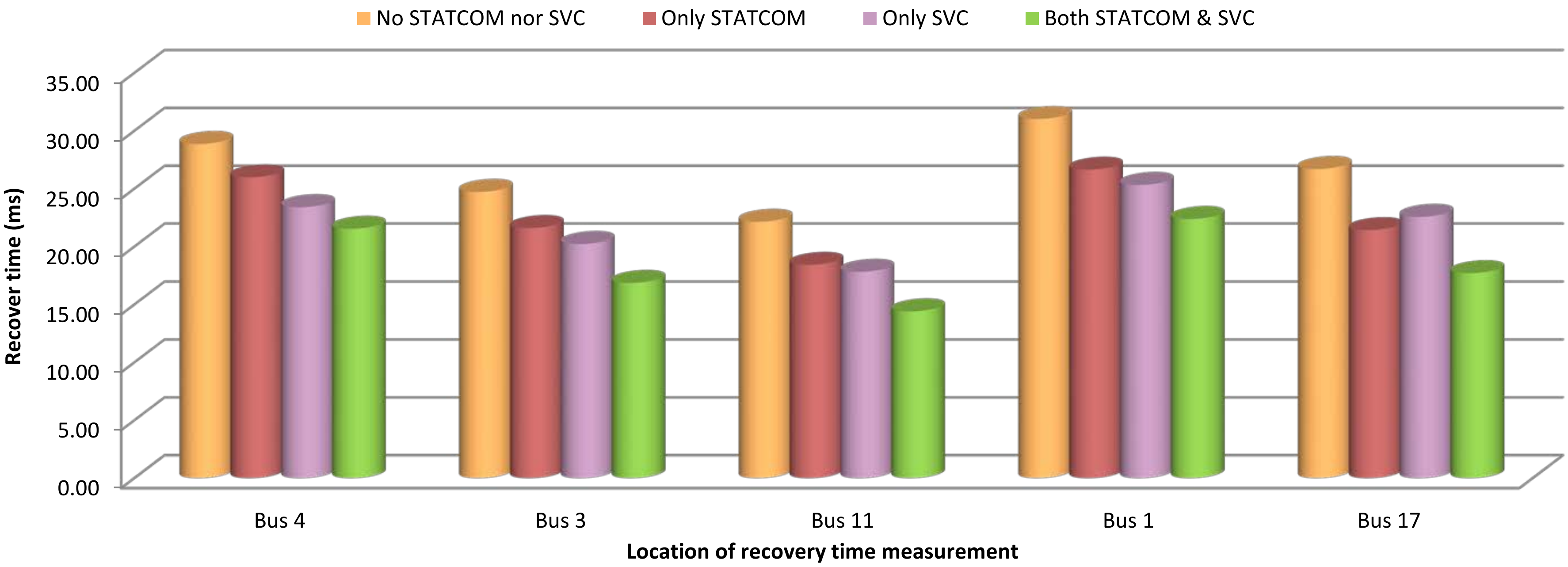
Interaction Assessment of the STATCOM and SVC

Dynamic interaction - voltage recovery time during faults



Progress

- ✓ Individual simulations of the real SVC and STATCOM controllers are completed using the RTDS simulation equipment and hardware-in-the-loop functionality.
- ✓ Operational and dynamic performances of the STATCOM and the SVC are tested and meet the criteria from vendor reports.
- ✓ Using an equivalent system model of an urban area, the STATCOM and the SVC controllers are successfully included in the same simulation. No negative interactions are found between the SVC and STATCOM when in close proximity.
- ✓ All tests procedures & results obtained are documented; documentation can be used for training purposes

Future work

(1) Build virtual STATCOM or SVC models in RTDS that emulate the real controller.

(2) Use the virtual models to study the interactions of multiple devices in the same network.

Thank you!

Appendicies

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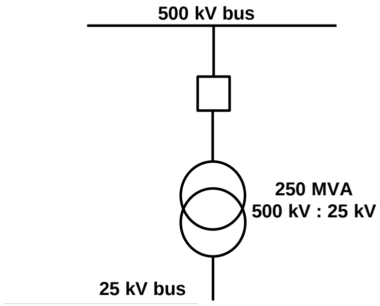
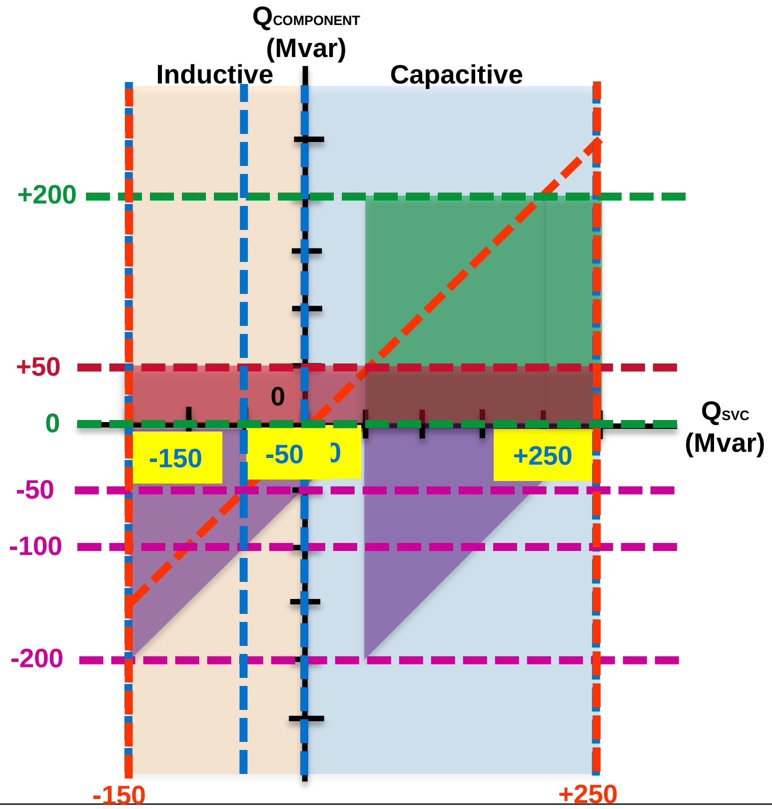
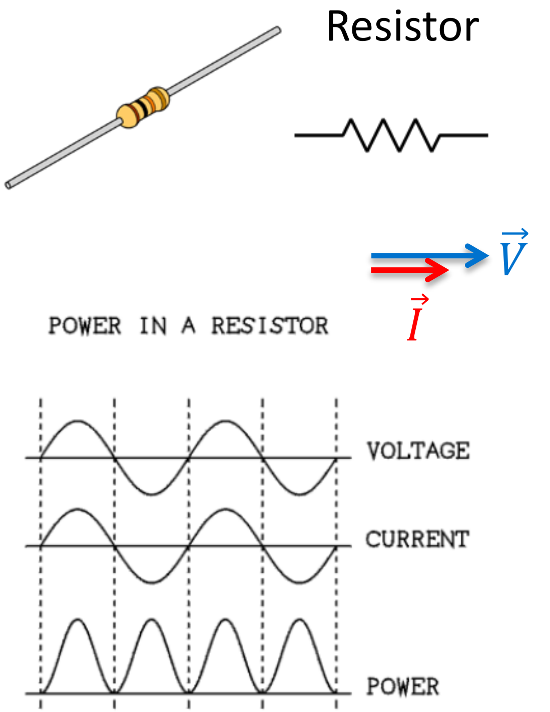
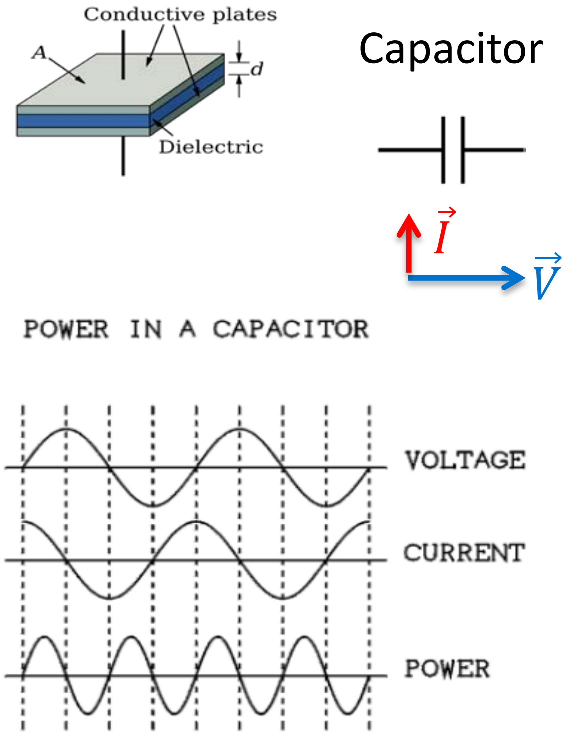
Dominion Energy's SVC - Hardware

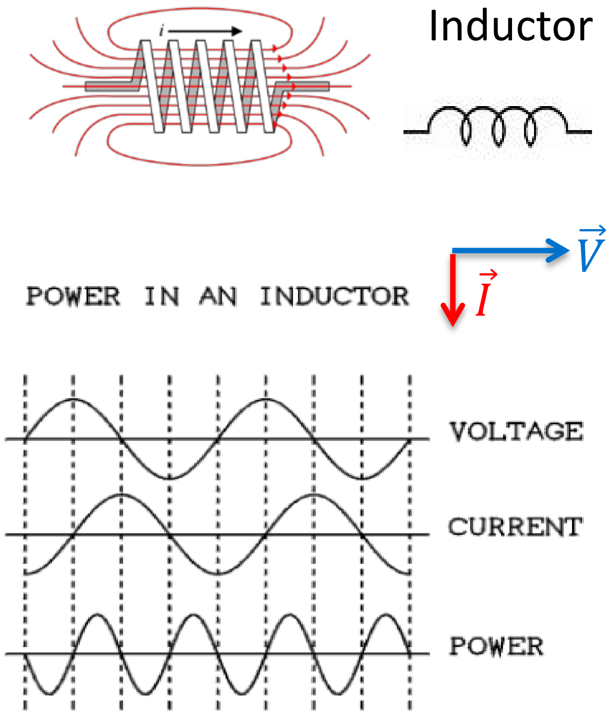




Using Reactive Power for Voltage Regulation







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Reactive Power for Voltage Regulation