ETO Device, Converter and Control Development

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Backgrounds and Objectives

- **Gen-I to Gen-III ETOs (Emitter Turn-off Thyristor) have been developed prior to 2006 by PIs at Virginia Tech and later on at NC State University**

- **Gen-IV (Self-powered ETO) has been the main focus of development since 2006**

- **In FY2009 the focus of the work is to design and develop a 10 MVA ETO STATCOM for voltage control of a 50 MW wind farm owned by Bonneville Power Administration**

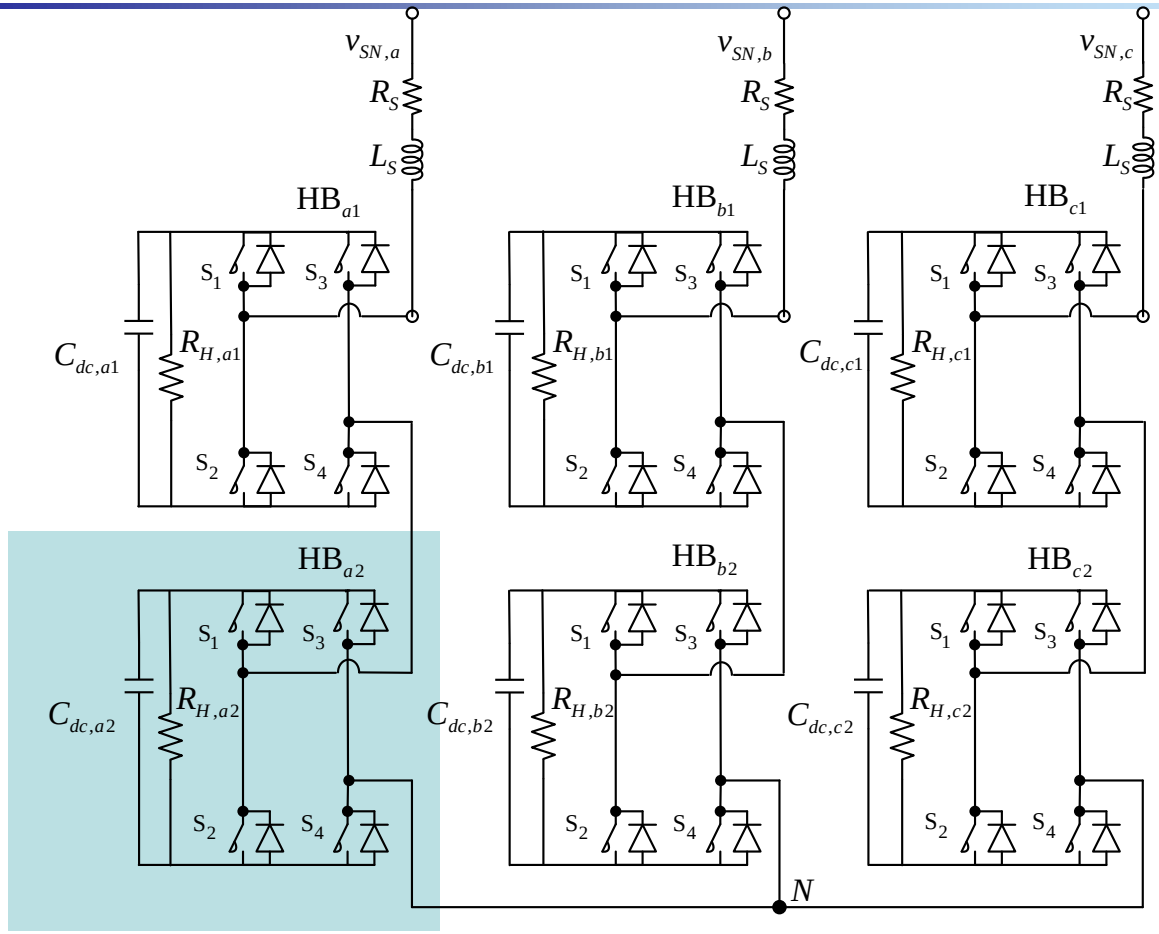
- **In FY2010, the focus of the work is to further develop the series connection capability of Gen-IV ETO for AC breaker application.**

Self-power Emitter Turn-off Thyristor (ETO)

Gen-IV Self-power ETO (4.5kV/4kA)

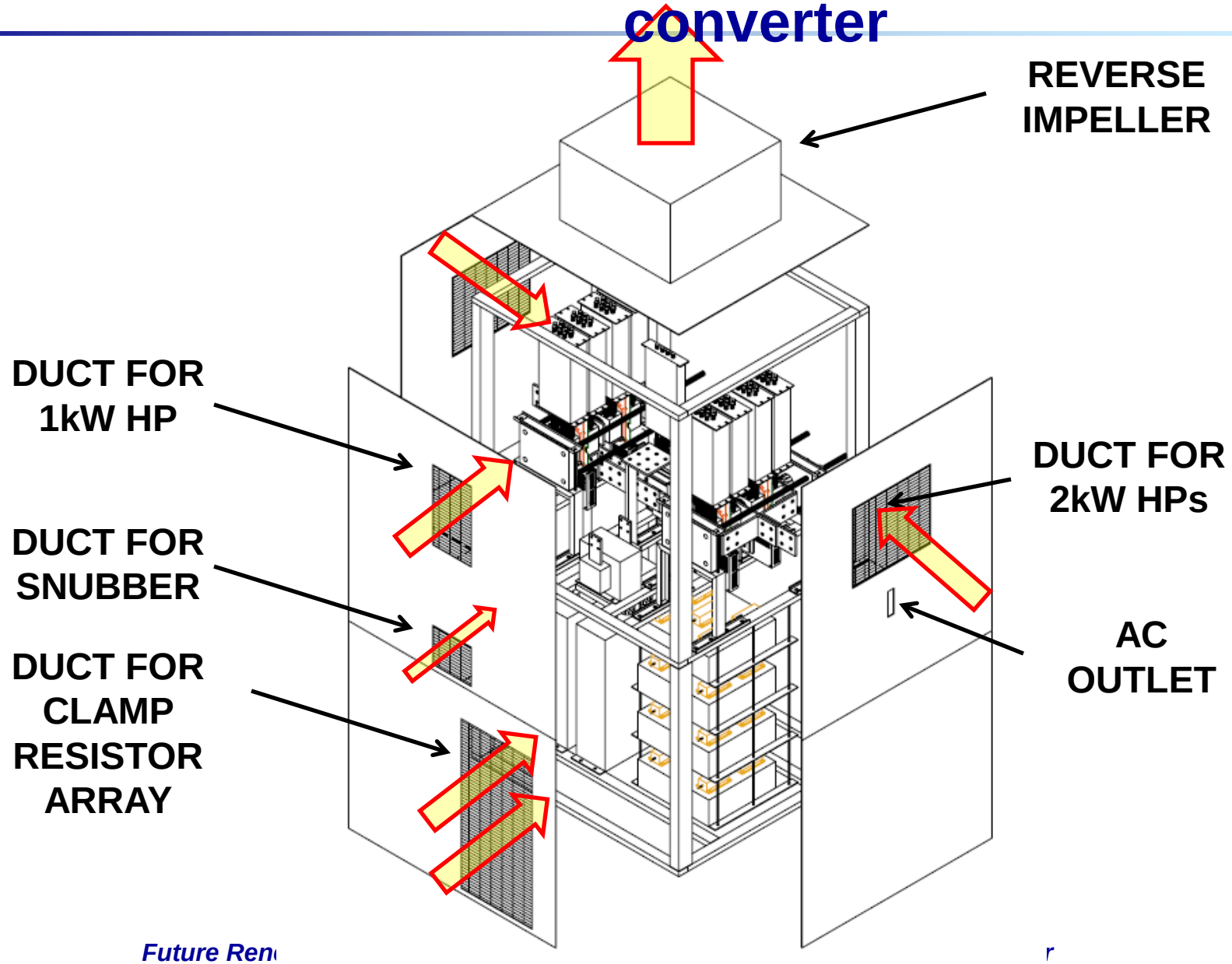
- **Built-in self-power function**
  - **From user point of view, it is a Light Triggered ETO**
- **High current turn-off capability (4kA snubberless)**
- **Built-in V,I T sensor functions**
- **Integrated V,I,T protection functions**

FY09 Focus: 10 MVA ETO Based STATCOM

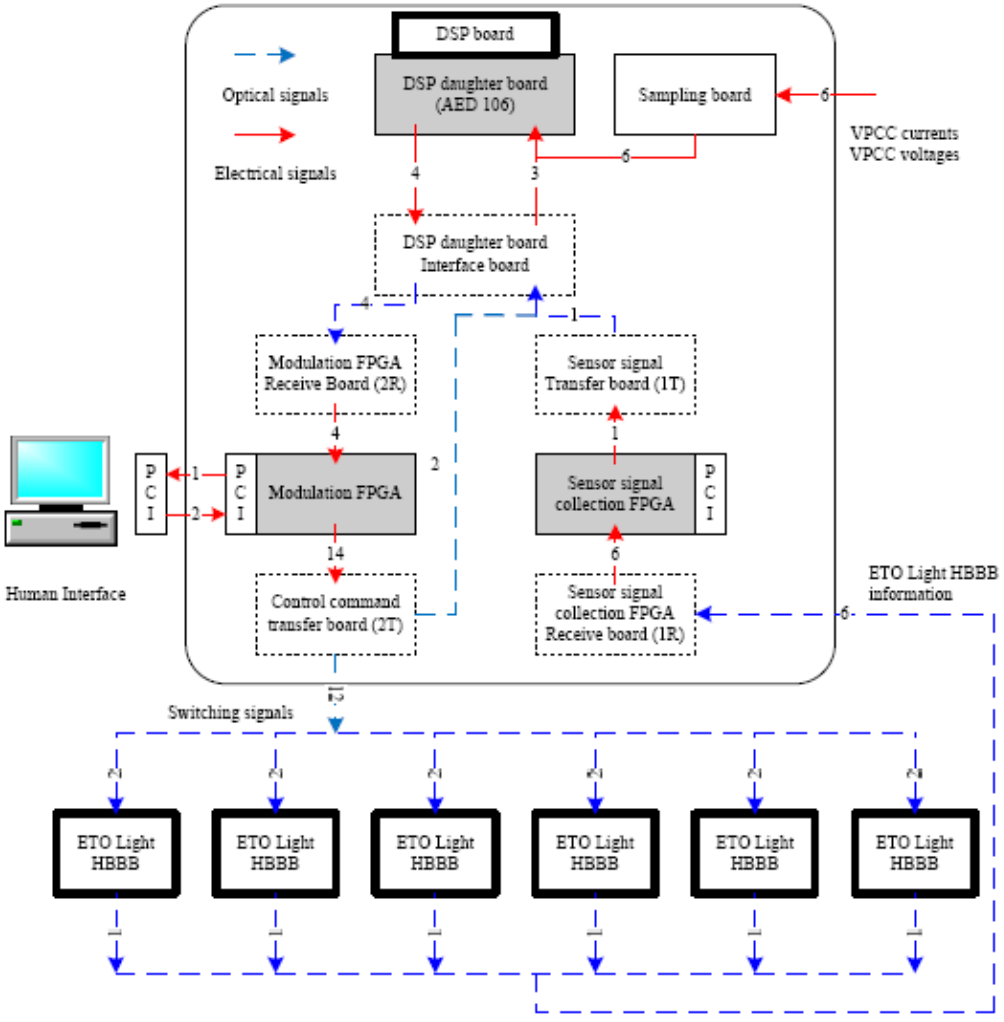


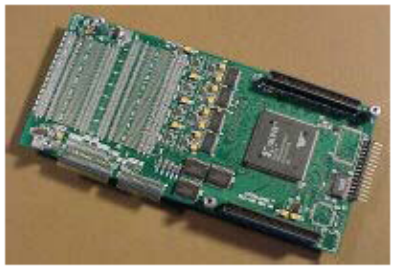
Five-level cascade multilevel converter based on six modular ETO H-Bridge Converters

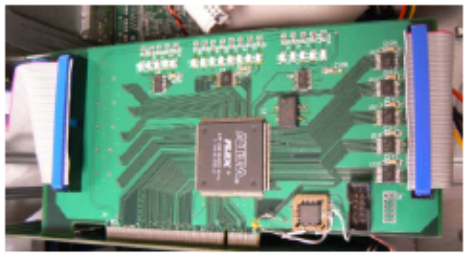
Accomplishment: Completed a mechanical and thermal design of the converter

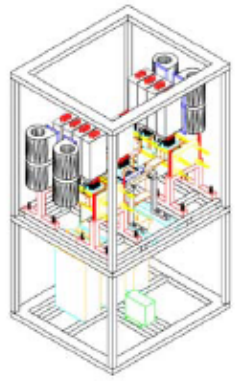


Accomplishment: Developed a STATCOM Controller (co-funded by EPRI)

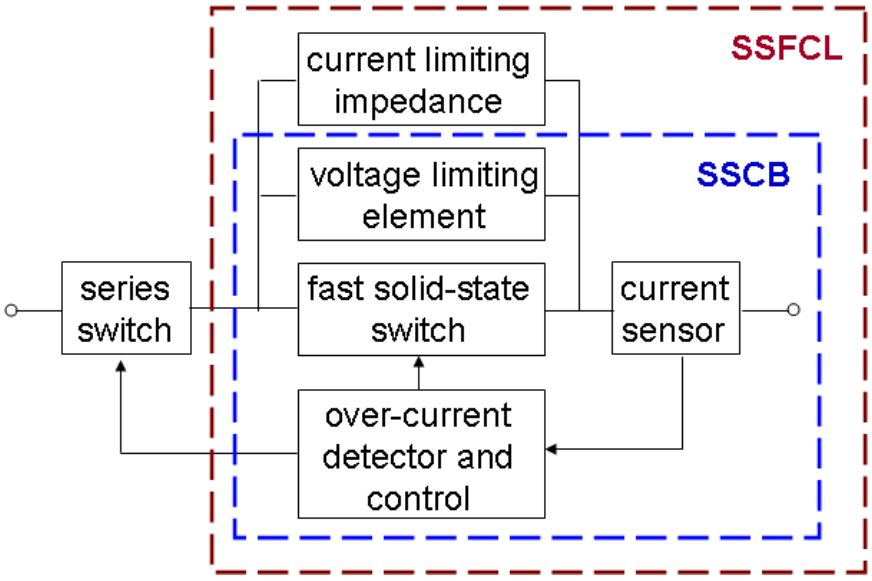




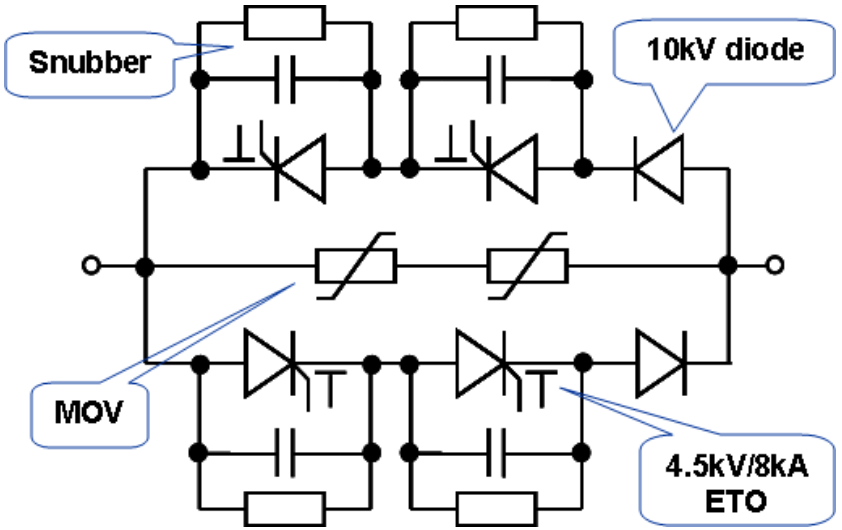




FY2010 Focus: ETO based Solid State Circuit Breaker



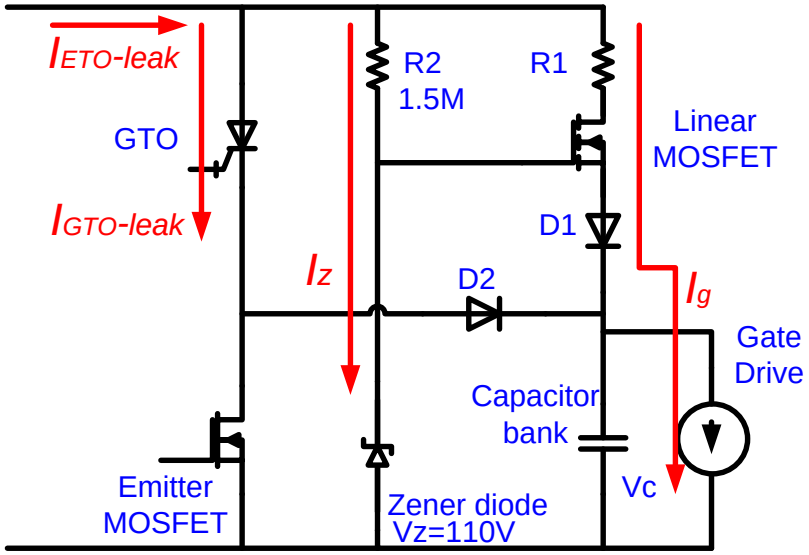
SSCB And SSFCL Configuration



9kV SSCB module diagram for 4.16kV, 2kA distribution line

Device Series Connections are needed to reach high voltages

Static Voltage Balance Issue Identified

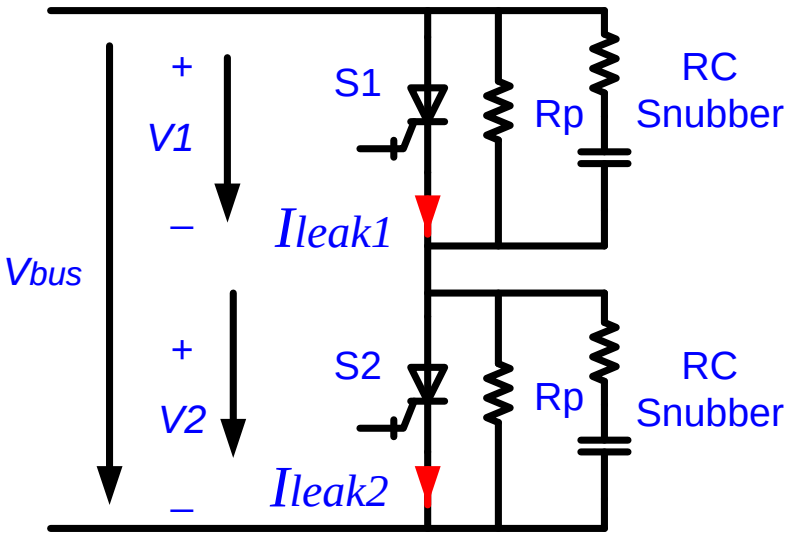


ETO leakage currrent

$$\Delta I_{ETO-leak} = \Delta I_{GTO-leak} + \Delta I_z + \Delta I_g$$

$$\Delta I_g \in (0 - 5mA)$$

$$P_{loss} \approx \left(\frac{V_{bus}}{2}\right)^2 / R_p = \frac{V_{bus}^{\ 2} \cdot \Delta I_{leak}}{4\Delta V}$$



Power loss on parallel resistors

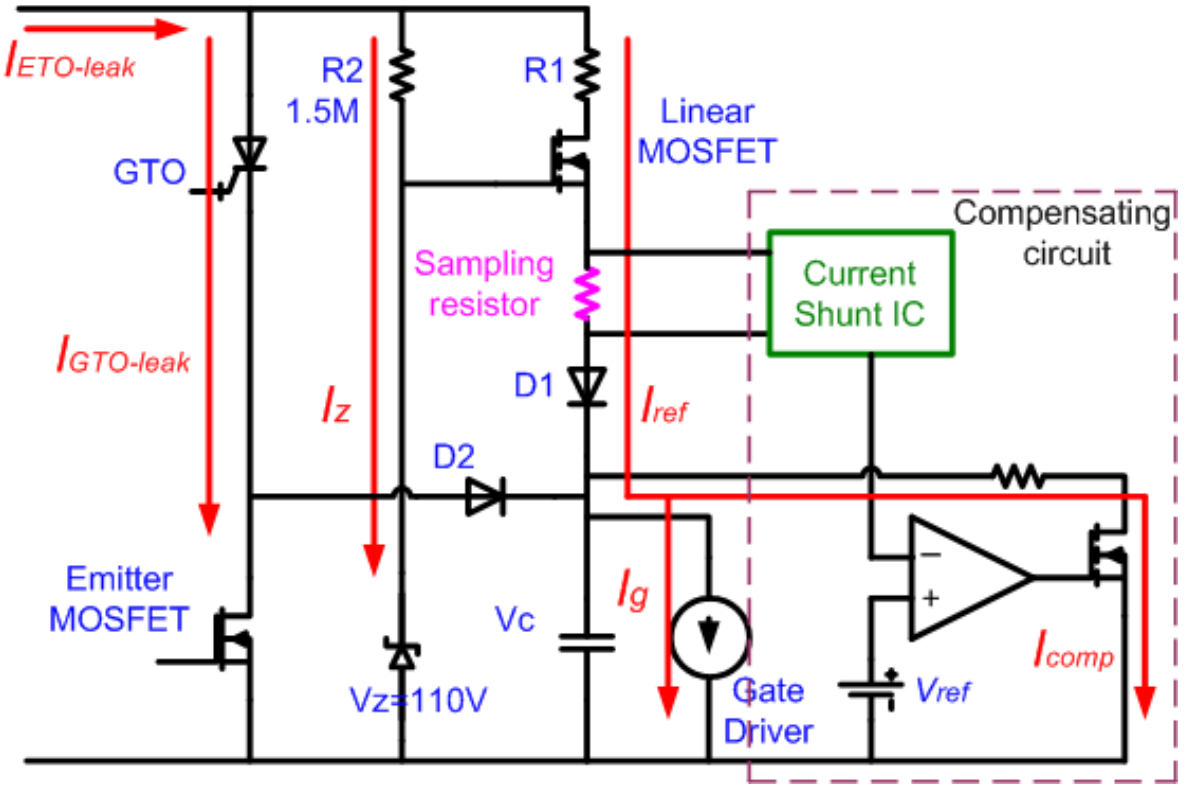
$$V_{bus} = 4160V, \Delta V = 100V$$

$$\Delta I_{leak} = 5mA$$

$$R_p = 20k\Omega$$

$$P_{loss} = 216.3W$$

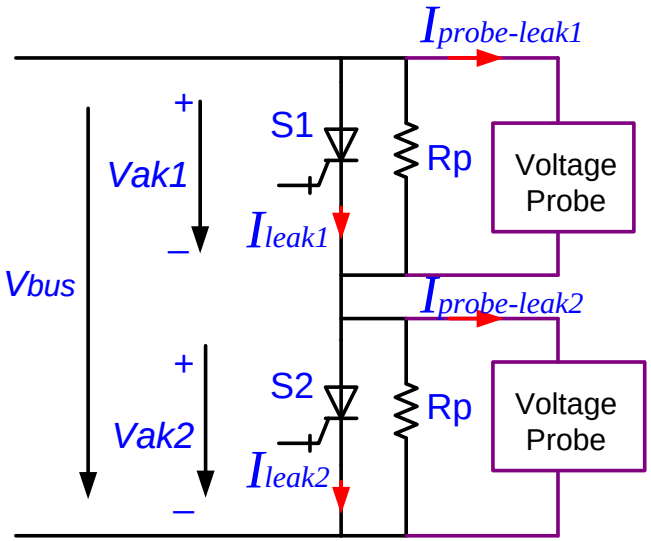
Solution: Compensating Circuit

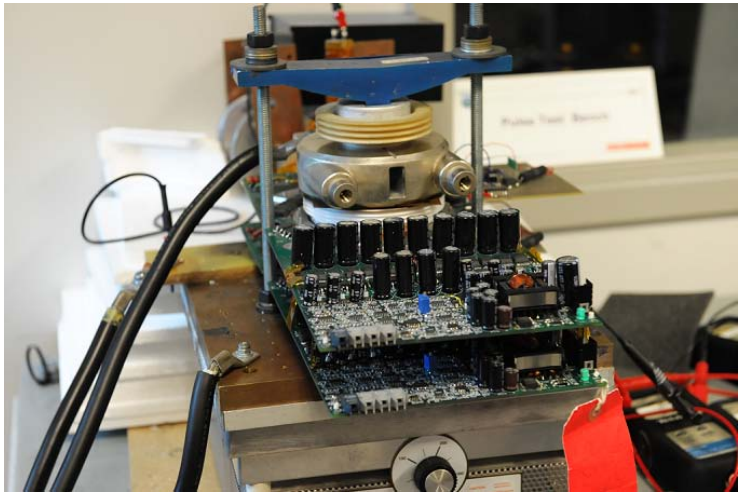


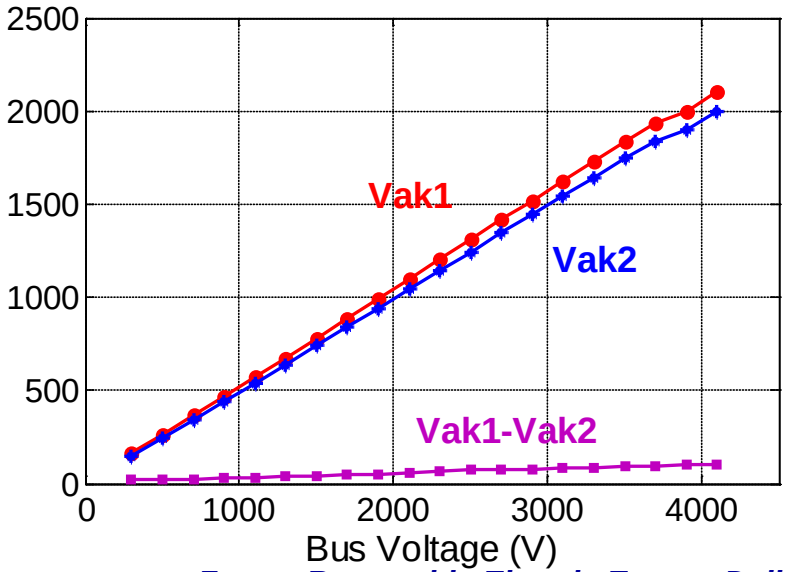
$$I_{ETO-leak} = I_{GTO-leak} + I_z + I_{ref} \qquad I_{ref} < I_g$$

$$\Delta I_{ETO-leak} \approx \Delta I_{GTO-leak} + \Delta I_{ref} \qquad \Delta I_{ref} \square \Delta I_g$$

Static Voltage Balance: Experimental Result







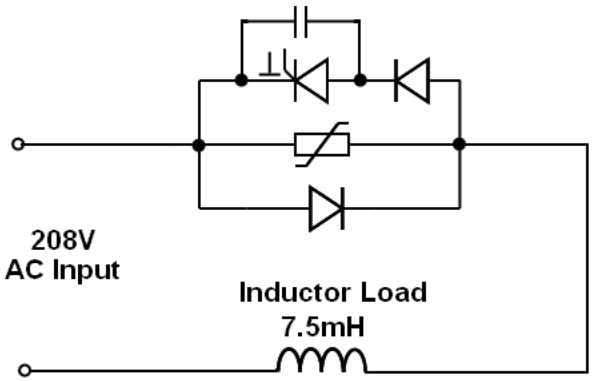
Experimental conditions:

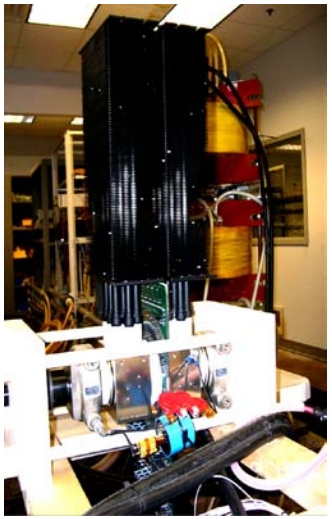
Rp: 100 kohm

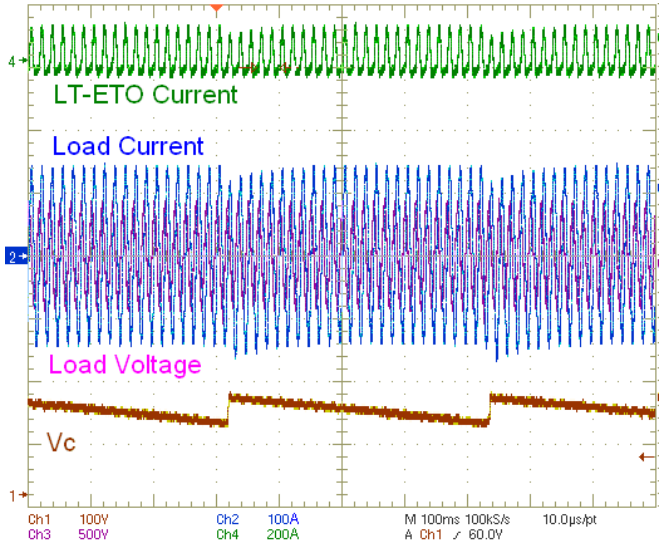
Bus voltage: 300 - 4160V

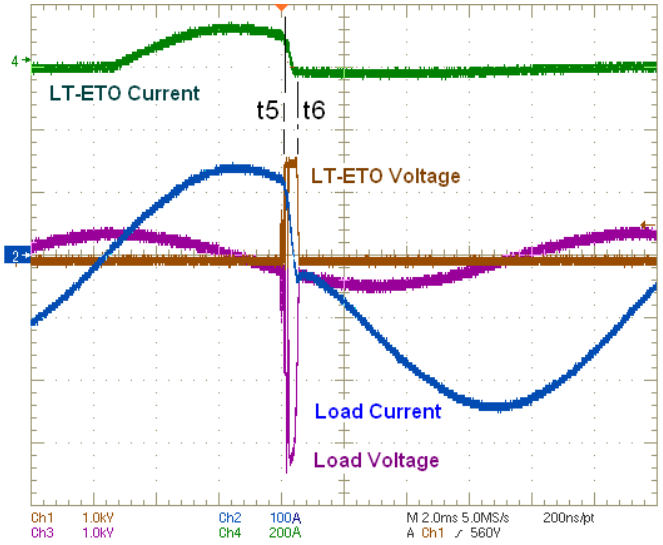
Ploss: 43.2W

Test Setup and Experimental Results









Continuous operation

Current cut-off

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Summary and Conclusion

- **Gen-IV devices, converters and controllers have been developed for high power applications such as the 10 MVA STATCOM**
- **Devices and converters designs have been delivered to SPCO**
- **The voltage balance issues between series connected Gen-IV ETOs are investigated, solutions are proposed and verified by experimental results.**
- **ETO based circuit breaker are built and tested partially.**

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Future Work

- **The DOE project ended September 2010.**
- **NCSU plans to continue the research in the following areas:**
  - **On reducing power loss on gate drive and improve self-power performance further.**
  - **Conduct test on ETO based circuit breaker (series connected ETOs) in AC configuration, verify fault current cut-off and self-power performance.**
  - **Conduct test on ETO based H-bridge to verify its design and performance under continuous operating mode.**
  - **Promoting the application and commercialization of ETO**
  - **Provide consulting services to the Phase II SPCO StatCom Project if funded**

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