Magnetic Amplifier-based Power Flow Control Technology

A Hybrid Approach to Power Flow Control

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Why Power Flow Control?

- In 2008, transmission congestion costs the EI grid around $8 billion, about $40 per person.
- Only 50% of the over 300,000 miles transmission lines in U.S. have been utilized at any given time.
- The median cost for adding new transmission capacity to accommodate the new wind generation is about $300/kW, exceeding the cost of the most expensive FACTS devices.
- Better power flow control can boost the transfer capacity of transmission line up to 2-3 times of the uncontrolled case.

Generations of FACTS

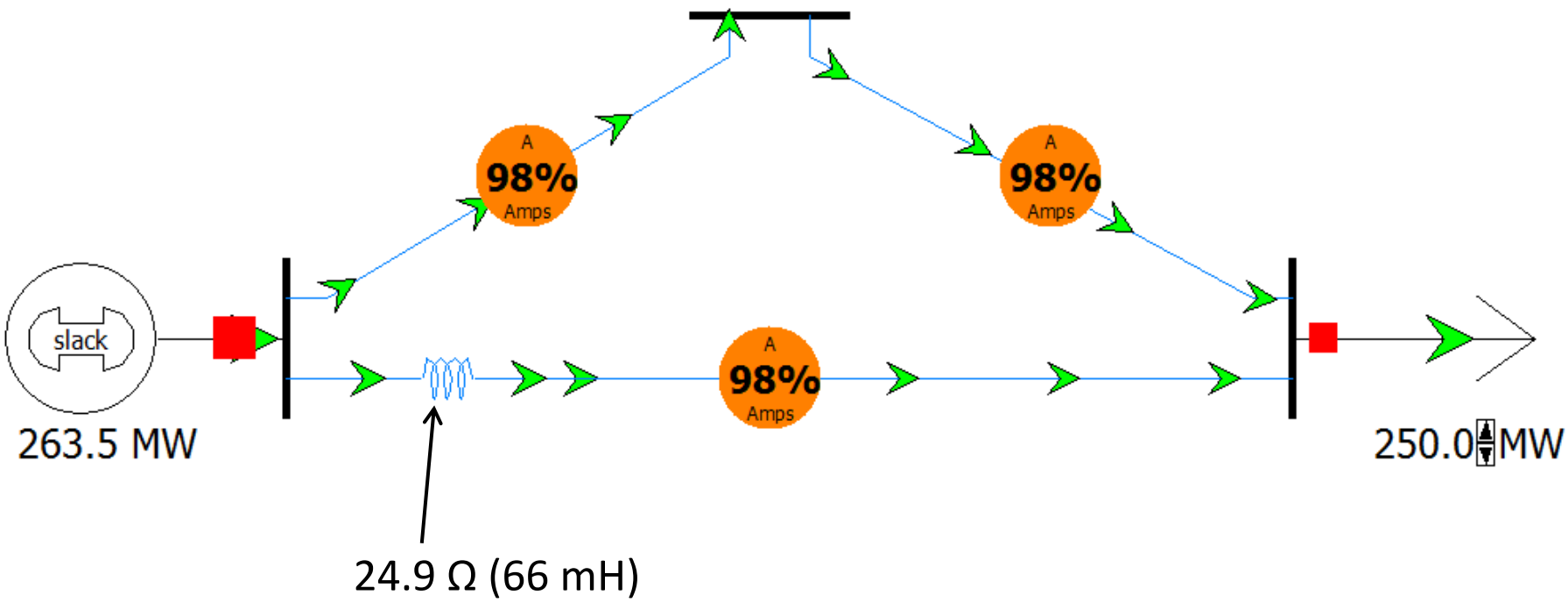
	1st Generation	2nd Generation	3rd Generation
Typical Devices	SVC, TSC, TSR	TCSC, STATCOM, SSSC	UPFC, IPFC
Functionality	Reactive power compensation, voltage regulation, little dynamic & transient capability	Real & Reactive power compensation, voltage/current regulation, oscillation damping, limited dynamic & transient capability	Full power control, voltage/current control, oscillation damping, fault current limiting, full dynamic & transient capability
Control Type	On/Off or Discrete	Continuous	Continuous
Current Cost ($/kVA)	15-25	50-100	100-300

SVC - Static VAR compensator, TSC - Thyristor switched capacitor, TSR - Thyristor switched reactor, TCSC - Thyristor controlled series capacitor, STATCOM - Static synchronous compensator, SSSC - Static synchronous series compensator, UPFC - Unified power flow controller, IPFC - Interline power flow controller.

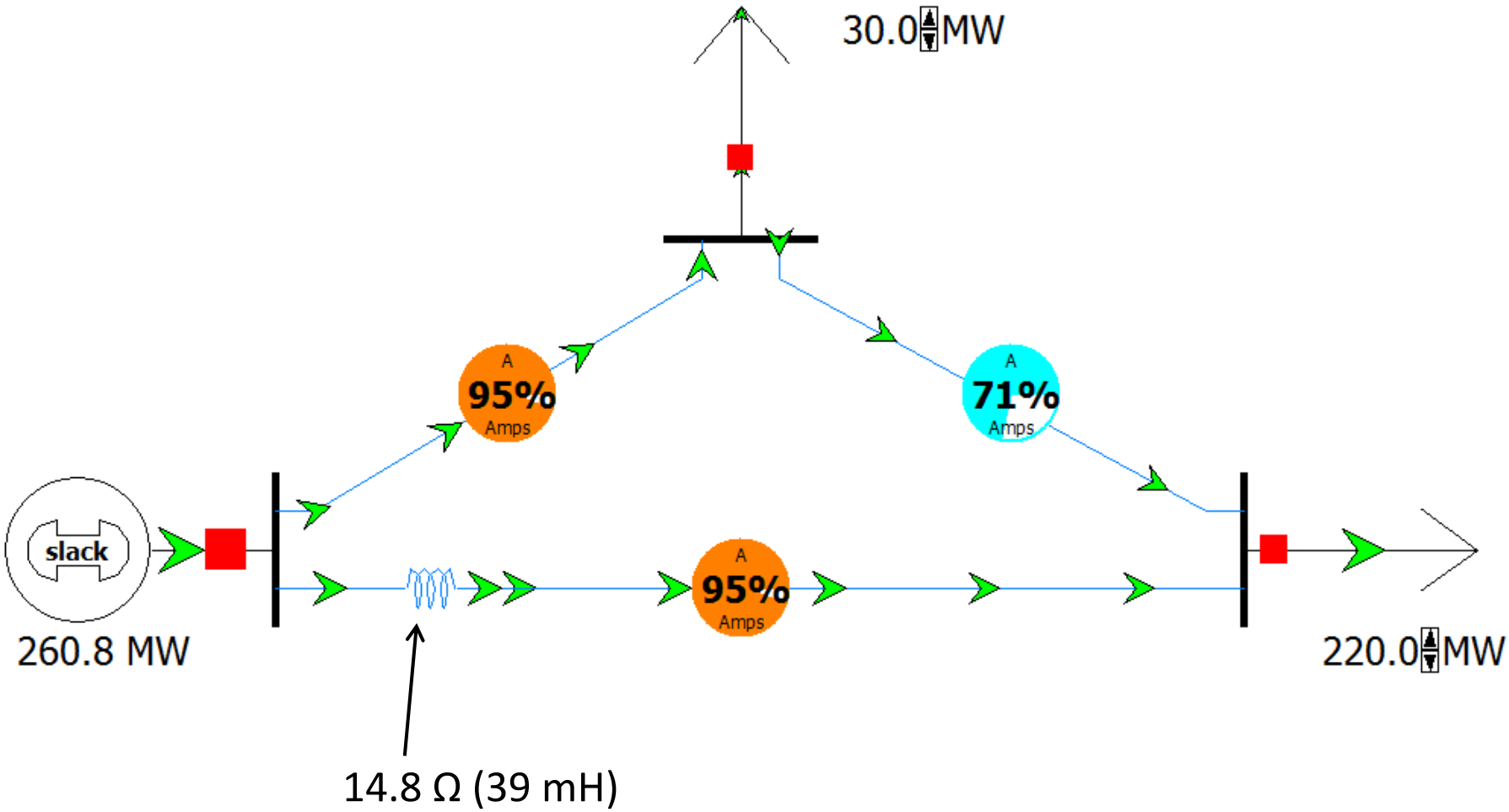
Project Objectives

- Simple, reliable, and efficient power flow control device that is cost-effective for system-wide deployment and full control of the power grid
- Based on a special magnetic amplifier design with:
  - power electronics isolated form the high voltage current and power flow
  - low power dc source without need for super-conductive windings and cryogenic equipment
  - smooth reactance regulation
  - minimized harmonics

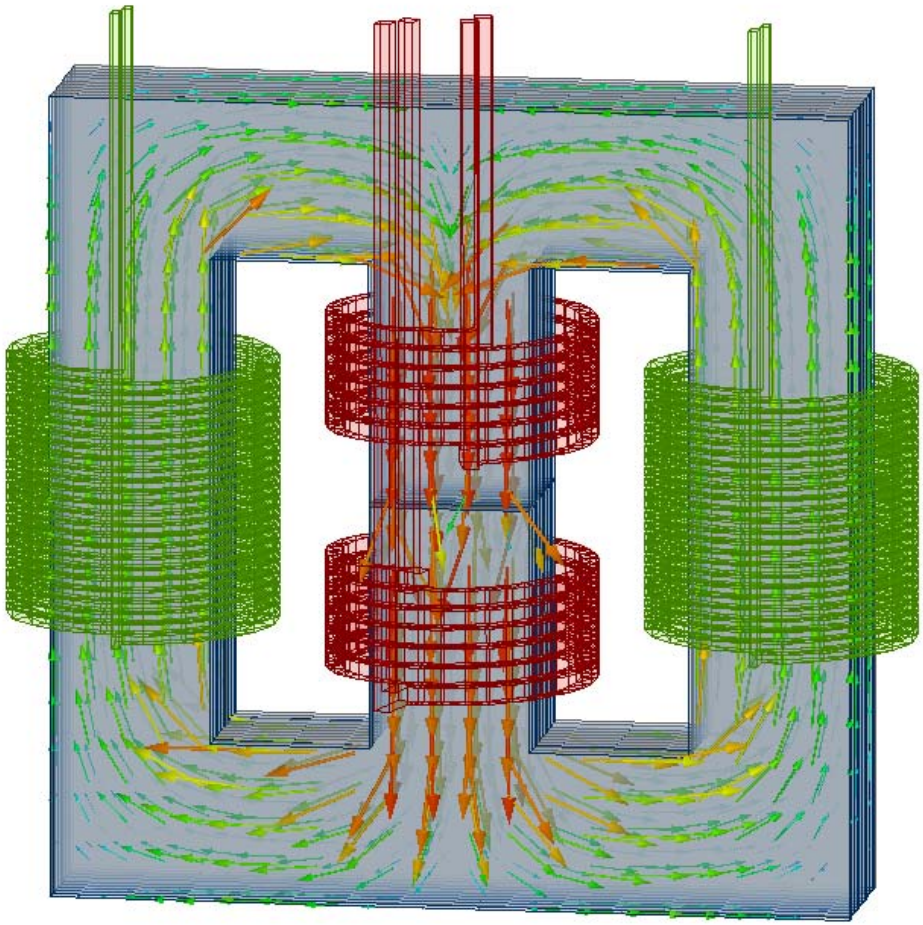
Series Reactor Controlled Flow



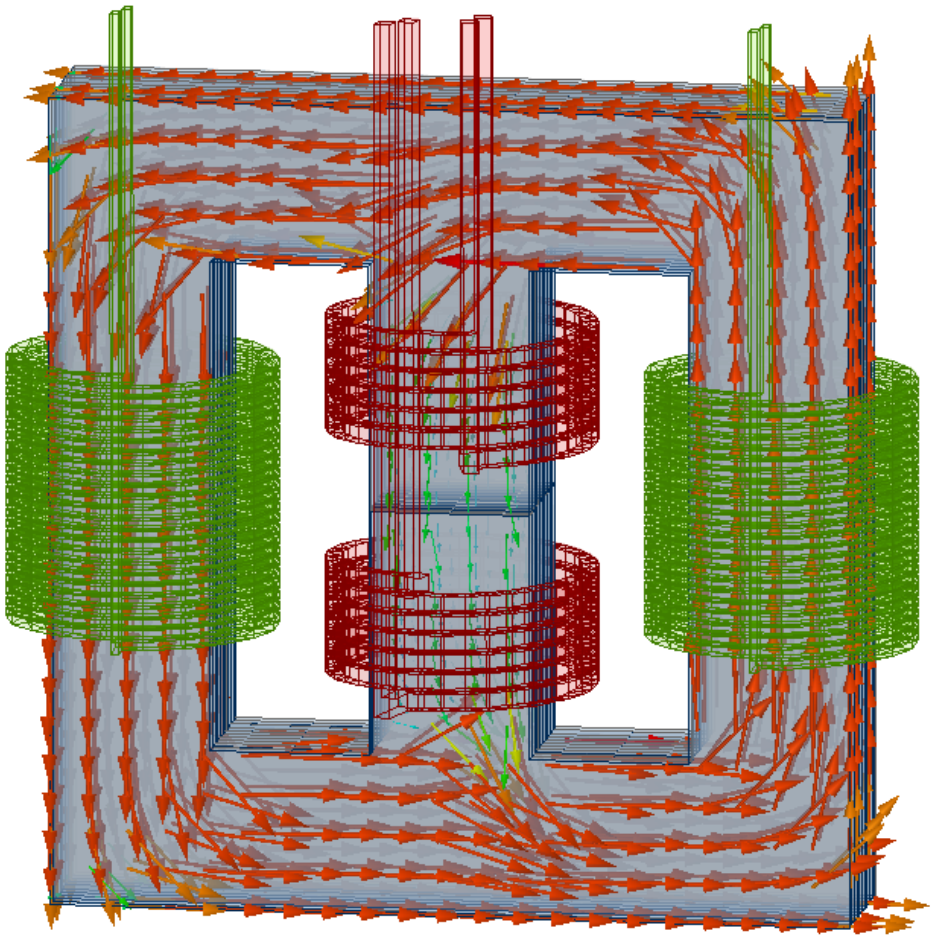
Variable Reactor Provides Flexibility



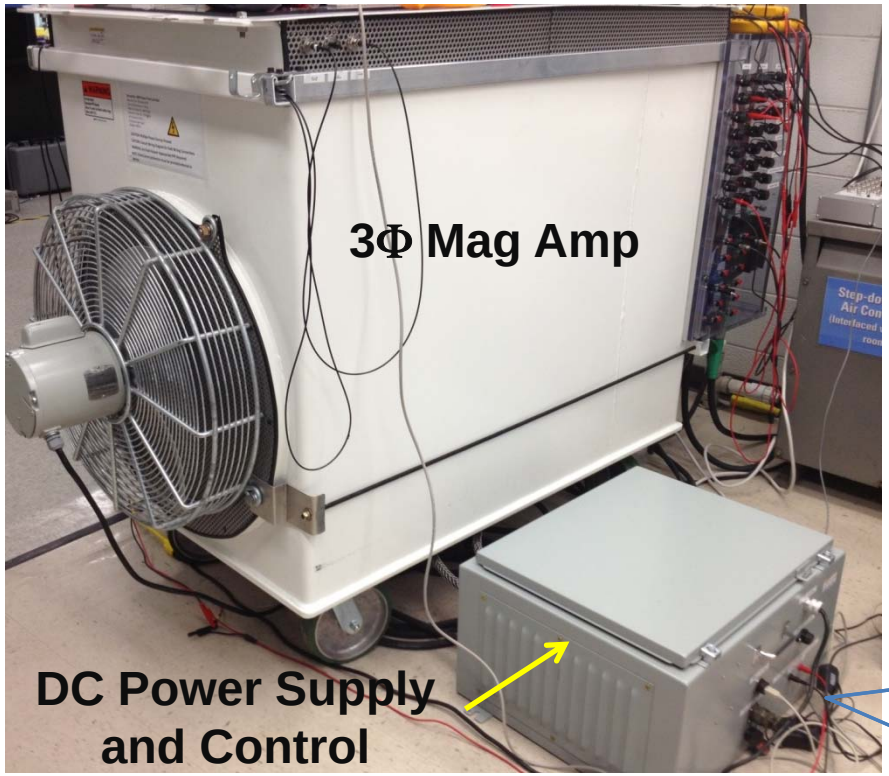
Maximum Reactance



Minimum Reactance

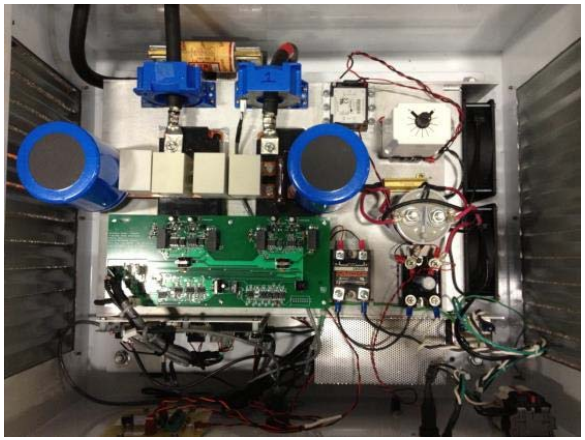


MAPFC in Service at ORNL's µGrid



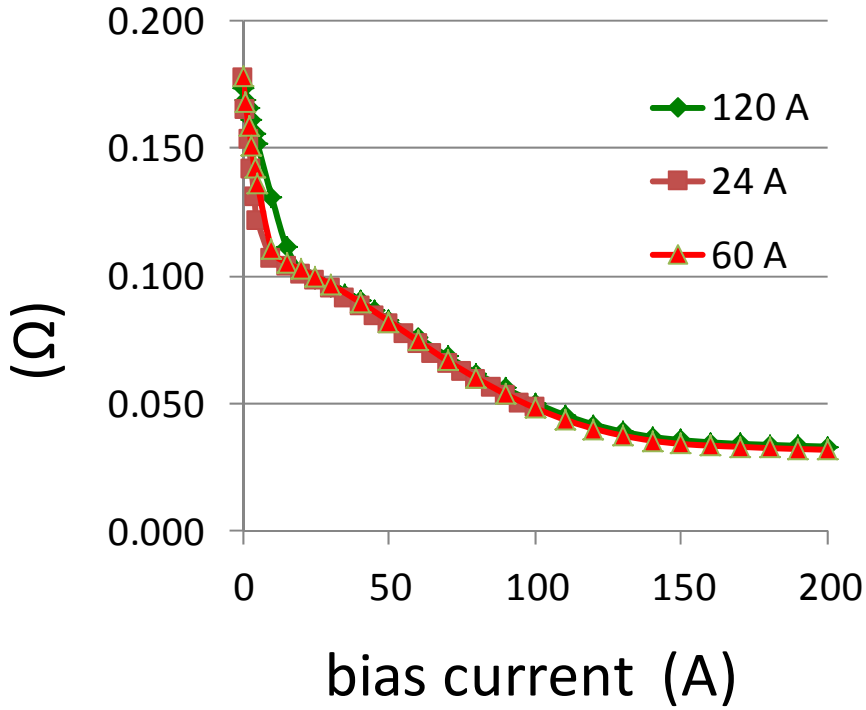
480 V, 200 Aac, 150 Adc

H-bridge inverter and
DSP-based control system

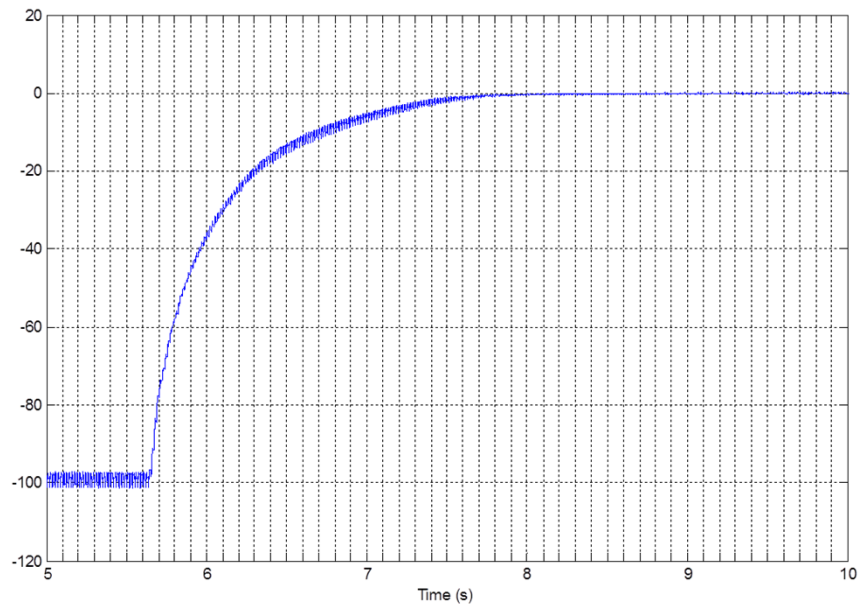


Device Performance

Reactance



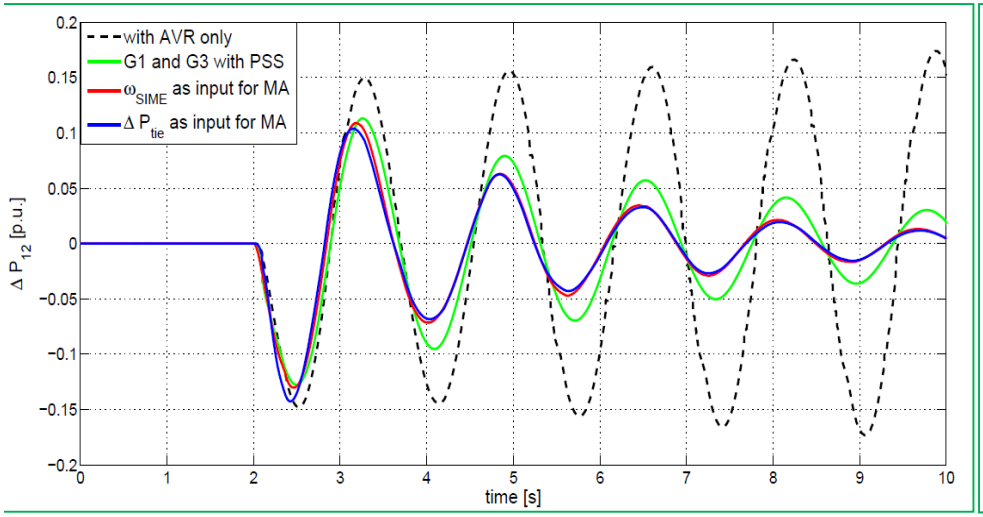
Transient response



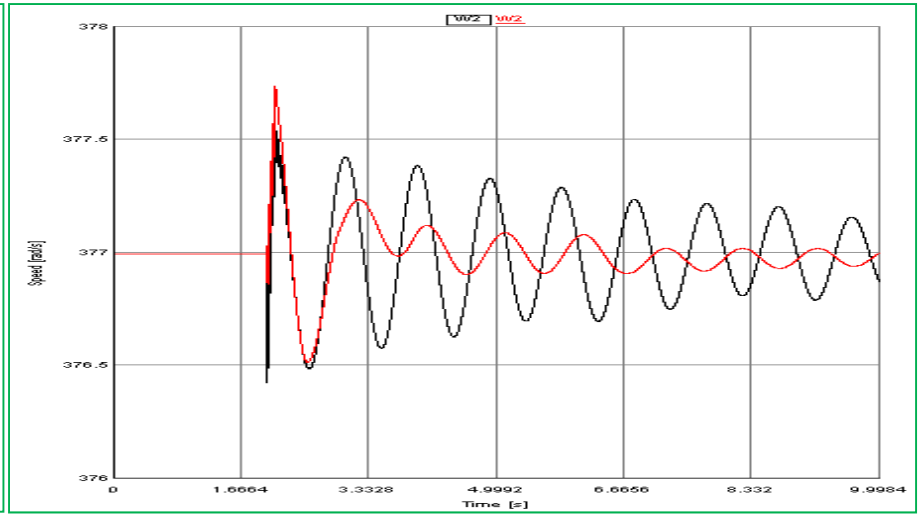
Use in Transient Conditions

Inter-area oscillation simulation of Kundur's two-area system:

A single MAPFC performs better than two PSSs

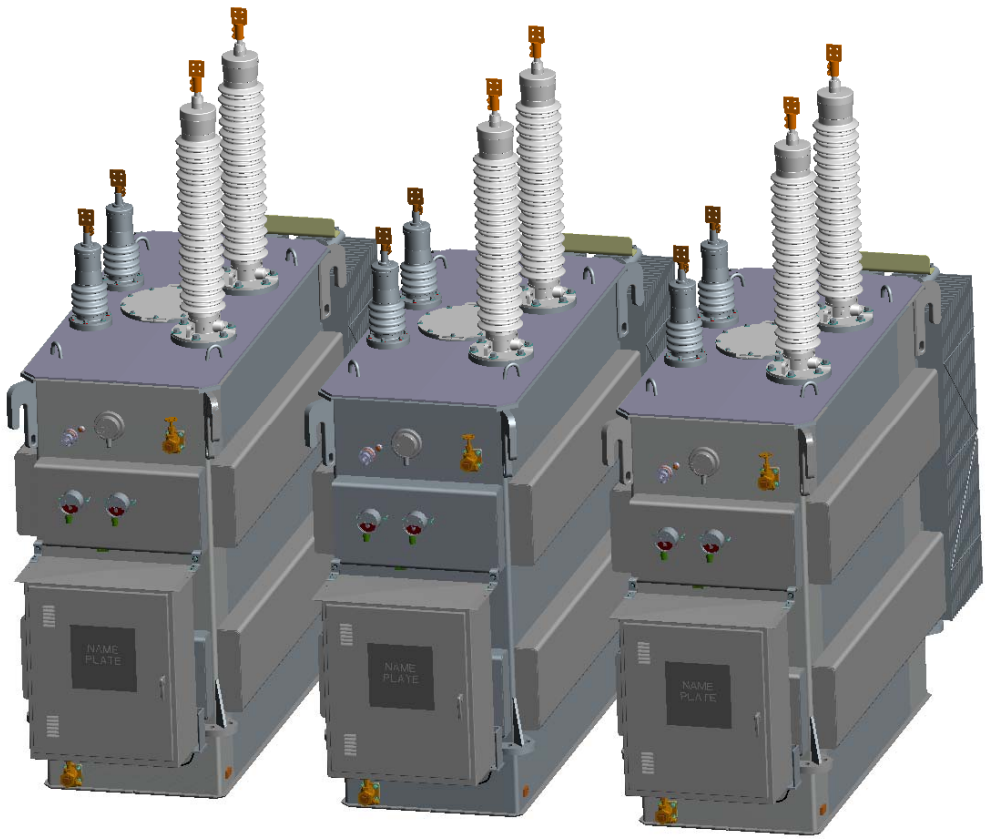


Rotor angle stability



Field Demonstration

115 kV, 1500 A unit under construction



Conclusions

- Magnetic amplifier concept for continuous power flow control
- Combination of familiar and proven with modern technologies
- Cost-effective for system-wide deployment and comprehensive grid control
- Potentially a versatile control tool for other applications
- Straightforward path to commercialization