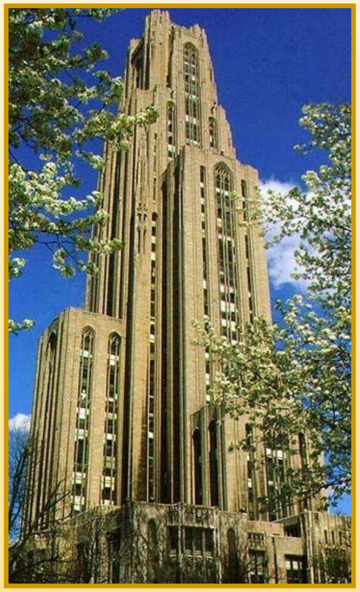
Energy Conversion Trends: High Frequency System Operation and Economic Impacts

7th Annual Electric Power Industry Conference
University of Pittsburgh
November 12th, 2012 – Pittsburgh, PA

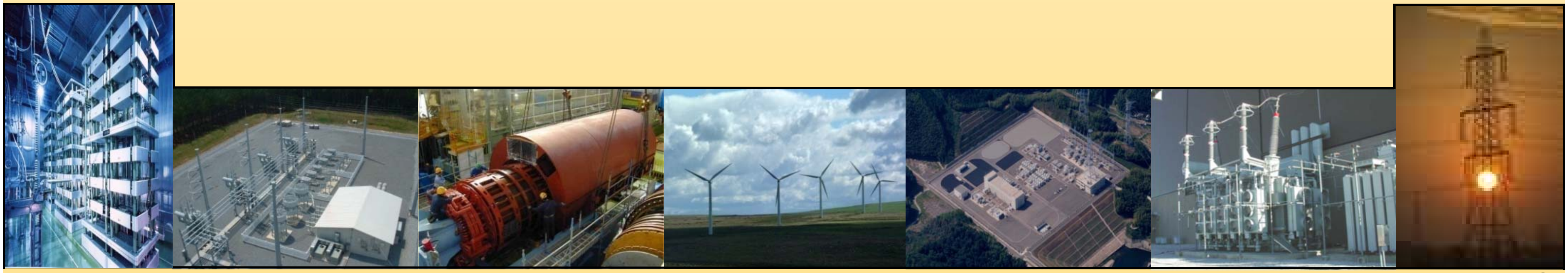


Ansel Barchowsky, Rusty Scioscia, Raghav Khanna, Emmanuel Taylor

Electric **P**ower & **E**nergy **R**esearch for **G**rid **I**nfrastructure
University of Pittsburgh, Swanson School of Engineering
Pittsburgh, Pennsylvania; USA

7TH ANNUAL PITT ELECTRIC POWER INDUSTRY CONFERENCE
Presented by the Swanson School of Engineering & the Center for Energy

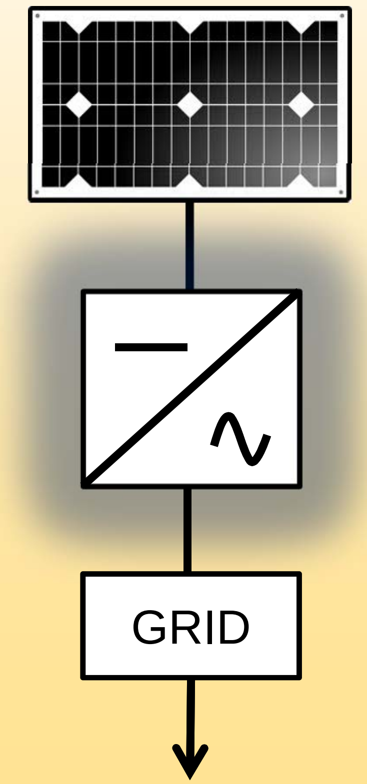
Ansel Barchowsky
Materials and Motivations

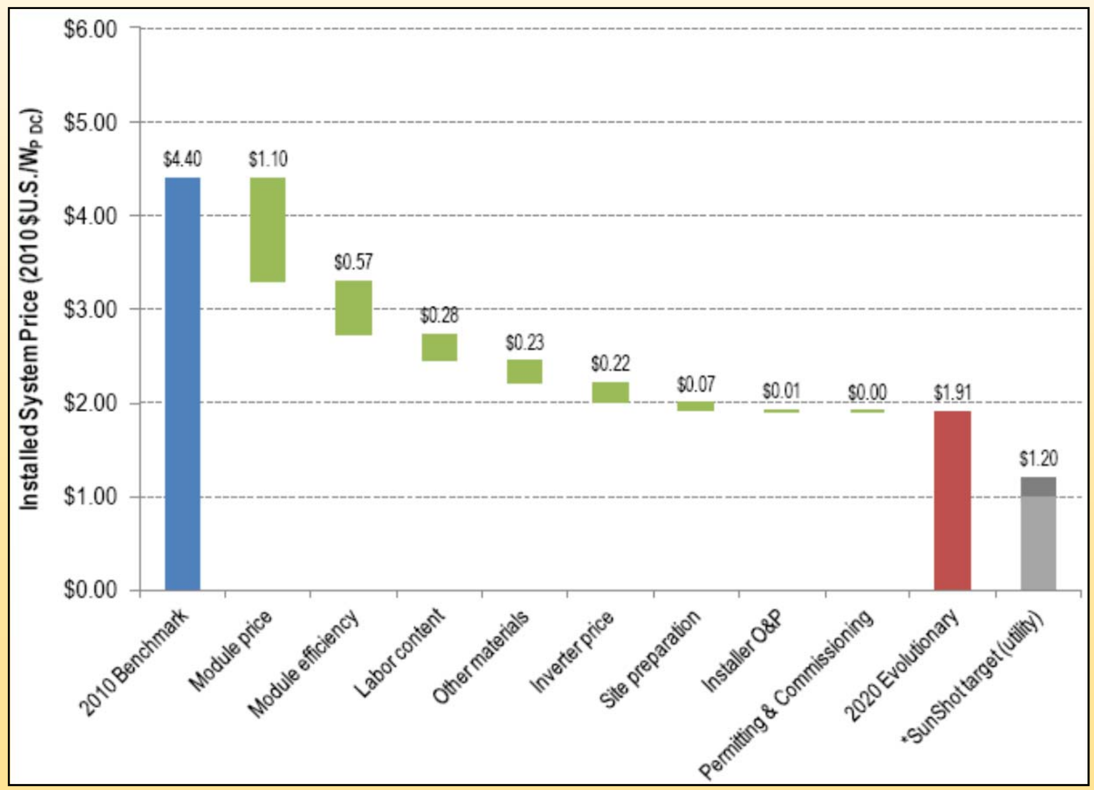


ARPA-E Sunshot Program

GOAL: Reduce the cost of complete photovoltaic installation to $1 per Watt.

FOCUS: Using high frequency materials, reduce the cost of the converter system while maintaining its efficiency





Program Partners and Tasks

Carnegie Mellon University

- Develop nanocomposite magnetic materials for efficient high frequency switching
- Design and manufacture transformer for use in converter

Los Alamos National Labs

- Design of DC/DC isolation converter using HF transformer.
- Design of DC/AC inverter incorporating properties of the transformer core

The University of Pittsburgh

- Economic analysis of new converter and comparison with industry costs.
- Development of technology to market plan including:
  - Potential marked for novel PV inverter topology
  - Exploration of other converter designs using DC/DC isolation converter
  - Analysis of losses at various switching frequencies

High Frequency vs. Low Frequency

Advantages:

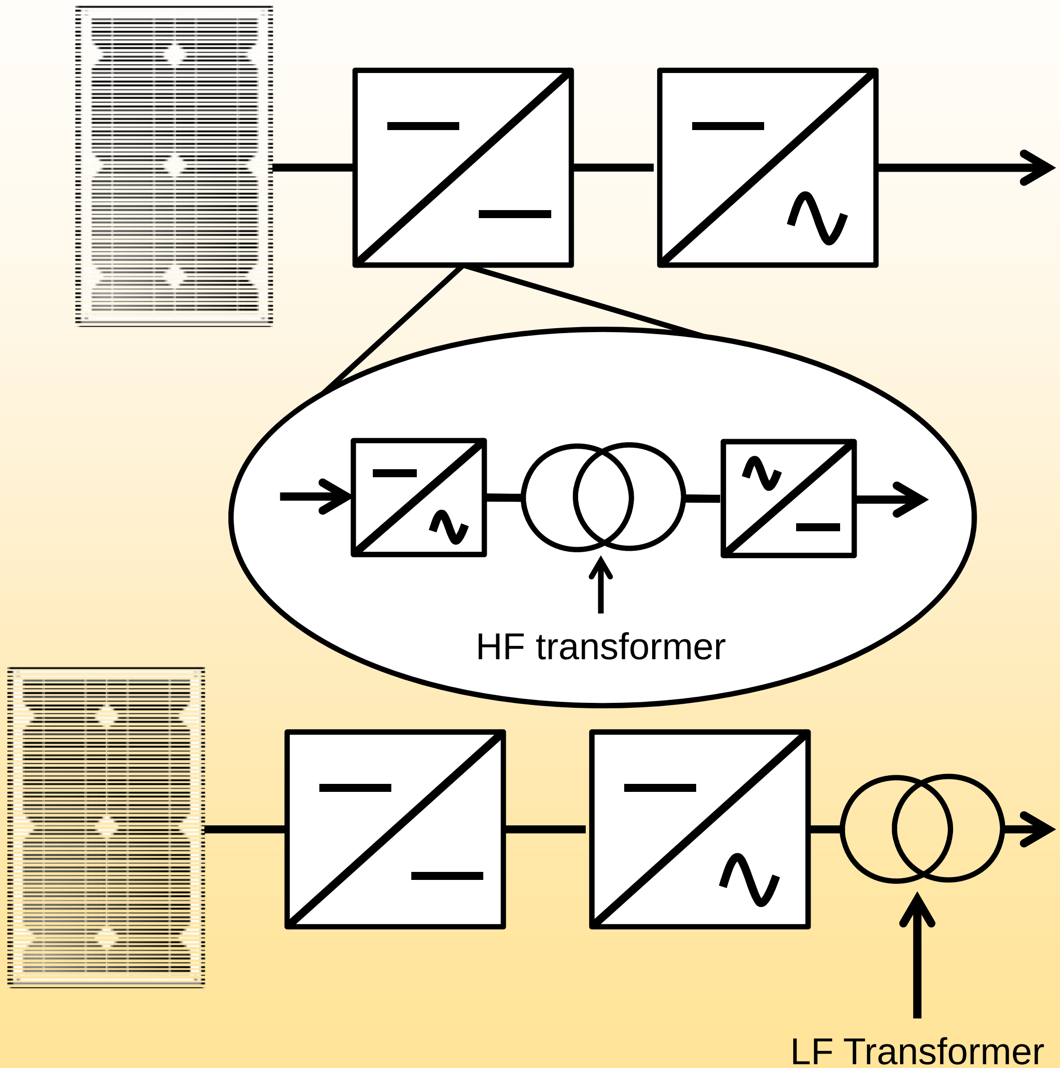
- Faster switching in DC/DC branch
- No low frequency transformer (saves space and cost)
- Reduced overall converter size

Disadvantages:

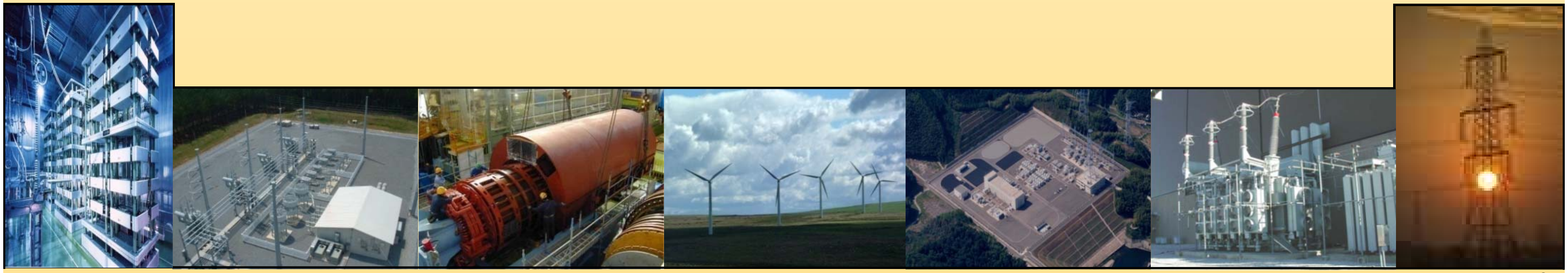
- Faster switching leads to higher losses
- Novel technology required

Goal:

- Reduce losses in HF system by improving the magnetic materials in transformer



Rusty Scioscia
HF Materials in Electric Machines



HF Materials in Electric Machines

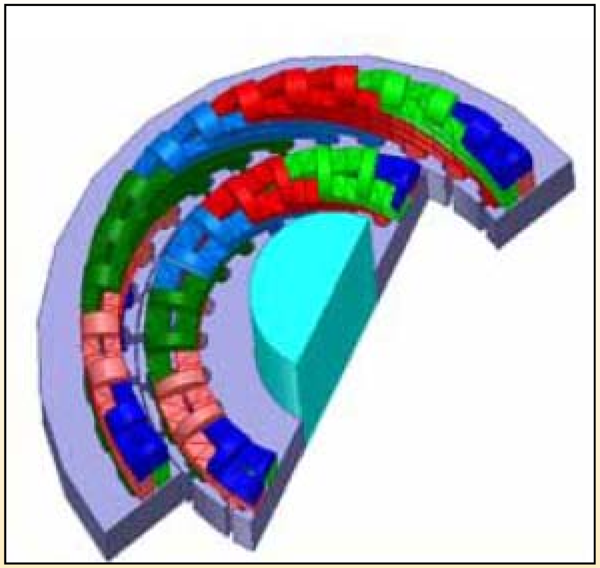
Simulation with Ansys Maxwell:

- Set up simulation of induction motor and PM motor using state of the art materials for the core

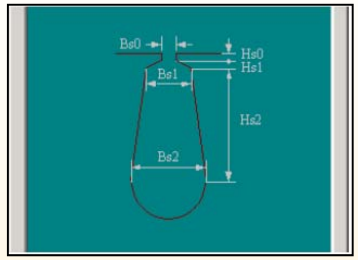
- Compare performance of these with that of the novel material
  - At standard operation
  - At high frequency operation

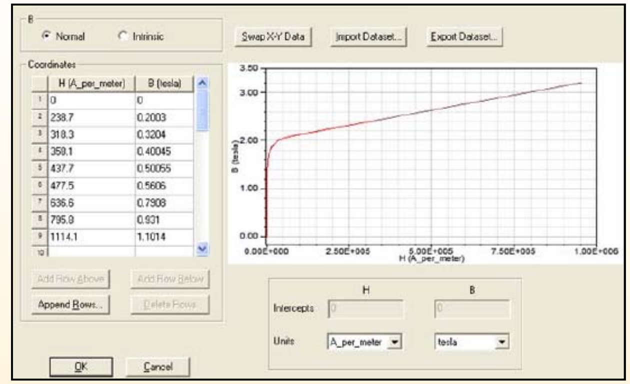
- Continue analysis by varying core structure, slot dimensions, and winding configuration

- Pair motor designs and performance outputs with current applications for which they are best suited and create circuit models for more comprehensive system modeling.



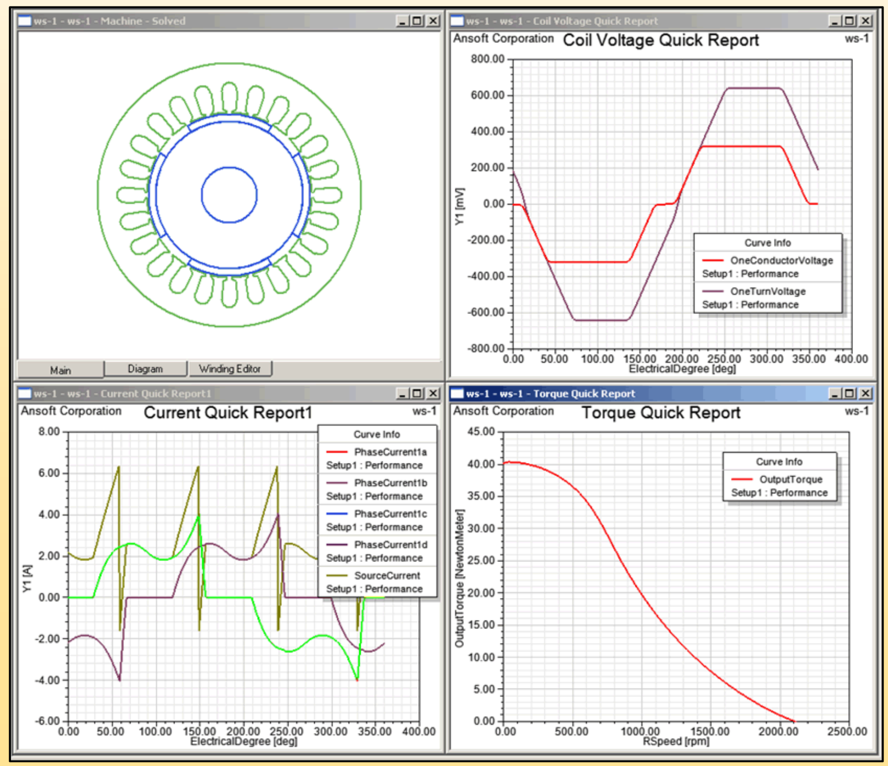
HF Materials in Electric Machines





Maxwell Capabilities:

- Inputs
  - Geometry
  - Material Properties
  - B-P & B-H Curves
  - Desired Outputs
  - Slot Size, Coil Turns, Wire Gage
  - Winding arrangement
  - Starting capacitance

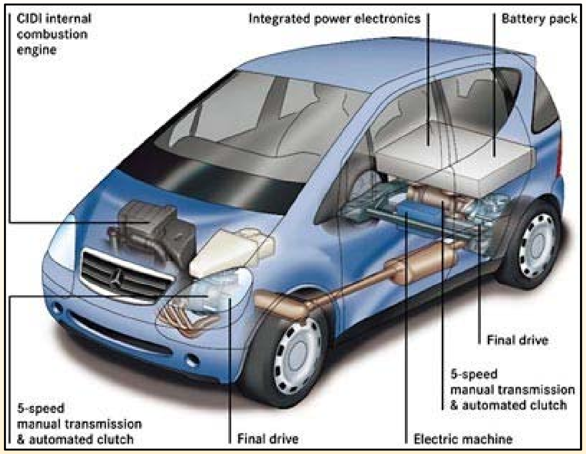


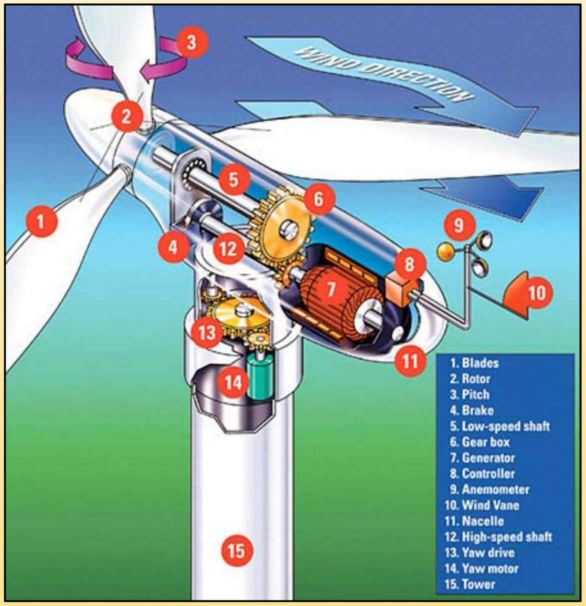
- Outputs
  - Solves AC electro magnetic, magnetostatic, DC conduction, and electric transients
  - Generates nonlinear equivalent circuits
  - Torque vs speed curves, power loss, flux in air gap, power factor, effeciency

HF Materials in Electric Machines

Tech to Market Strategy:

- Novel material promises to increase power density ratio.
    - Motor size reduction
        - E.V.s
        - wind turbines
        - military and naval applications.
- Optimize design with new material
    - reductions in Eddie current losses
    - improvements in torque vs. speed curves.
- Use this data to perform economic analysis and comparison against current technologies.





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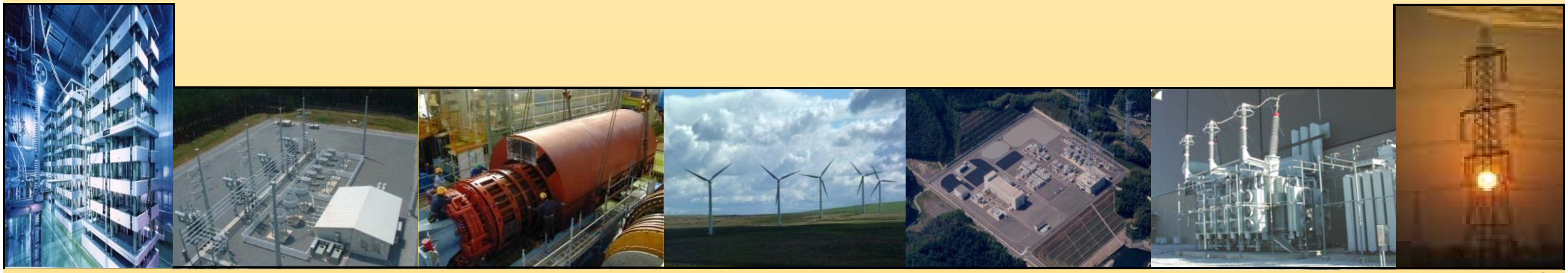
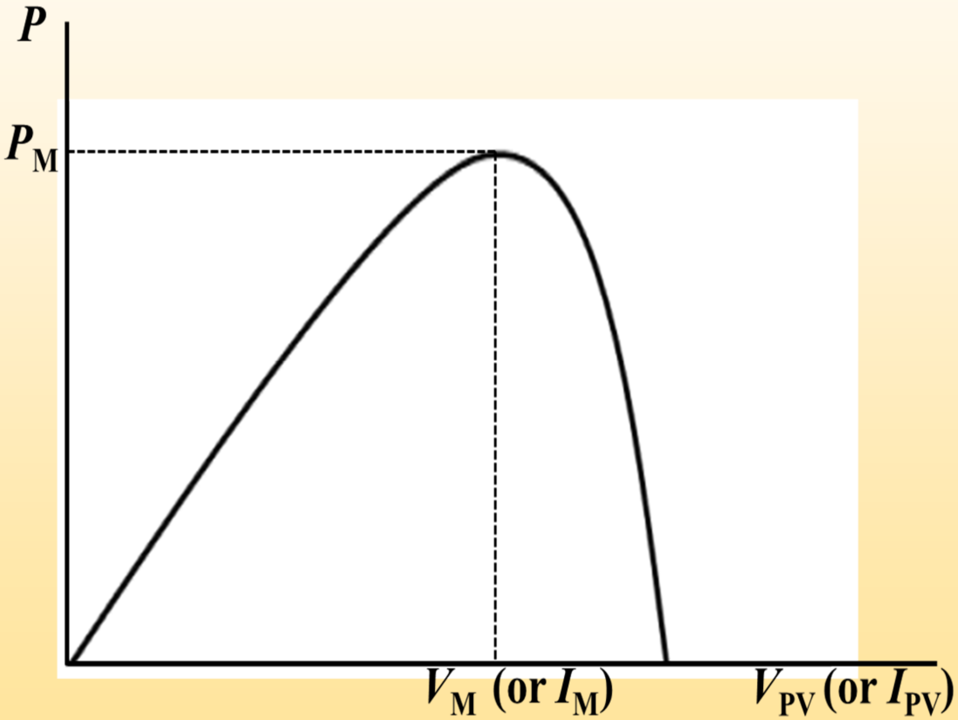
Raghav Khanna
HF Modeling for PV Systems



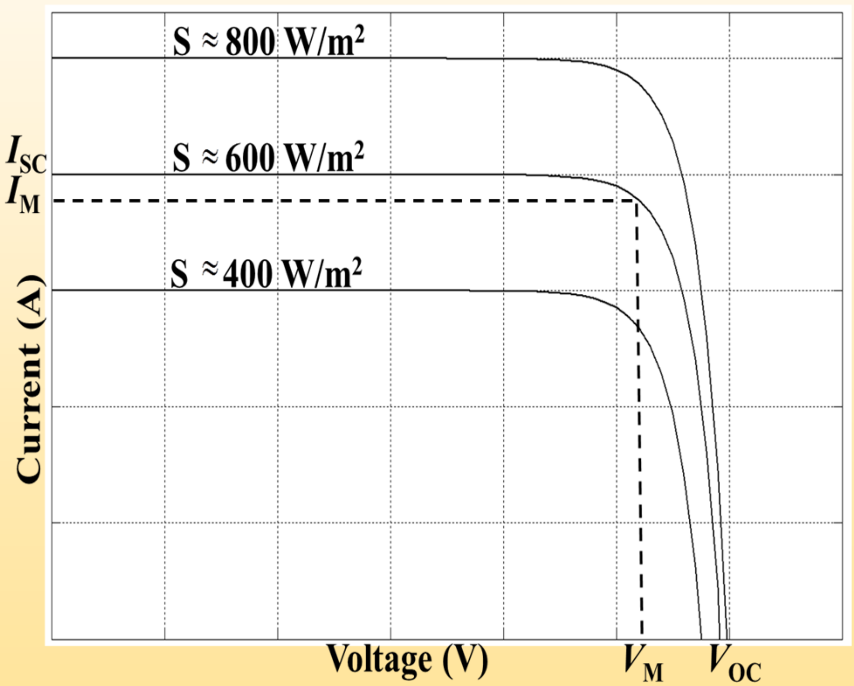
HF Modeling for PV Systems

Maximum Power Point Tracking:

- The objective is design a controller for PV system that converges to the theoretical MPP swiftly and precisely with minimal oscillation in the output voltage.



Power versus voltage for PV systems.

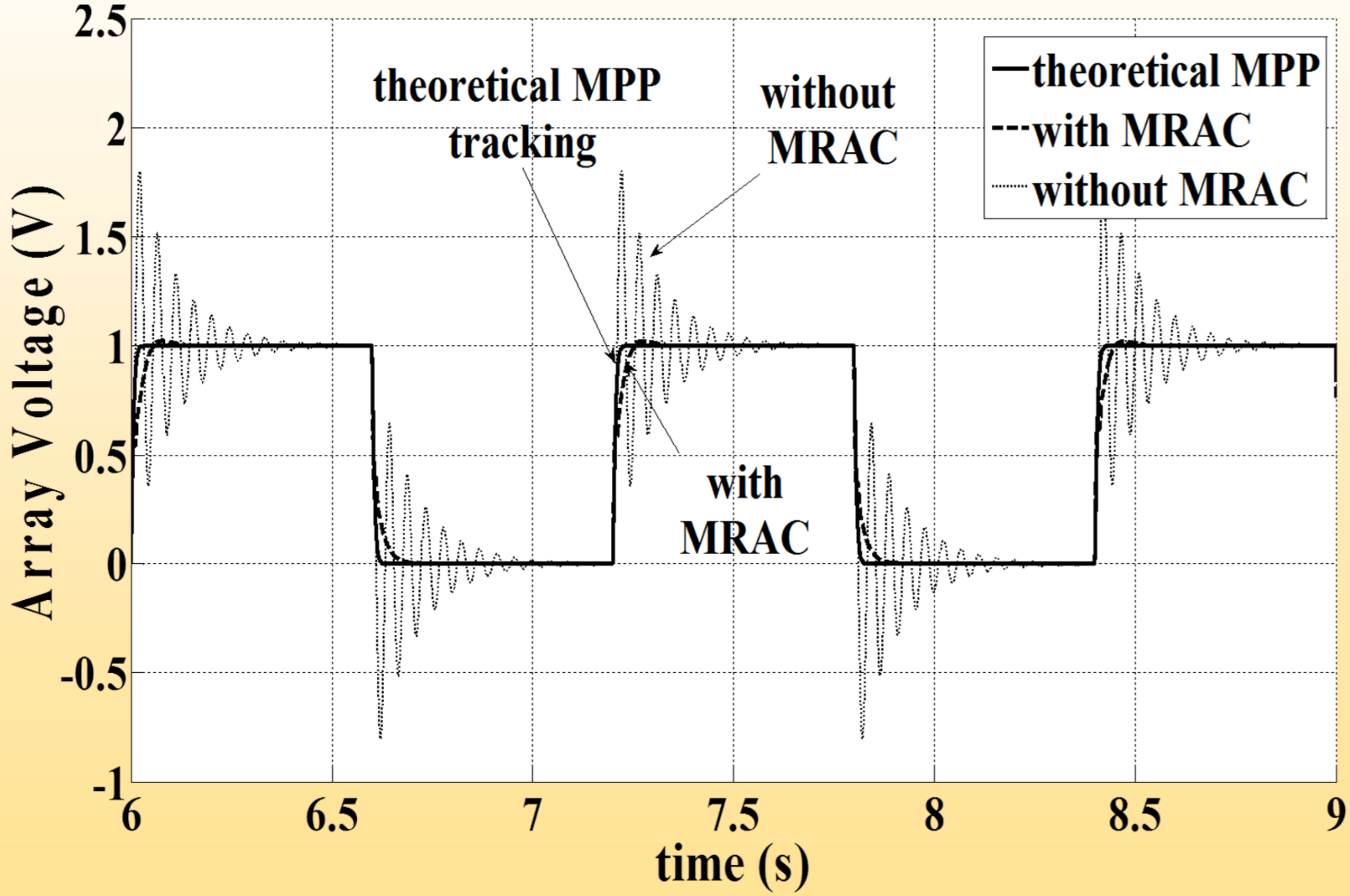


Current versus voltage for PV systems.

HF Modeling for PV Systems

Maximum Power Point Tracking:

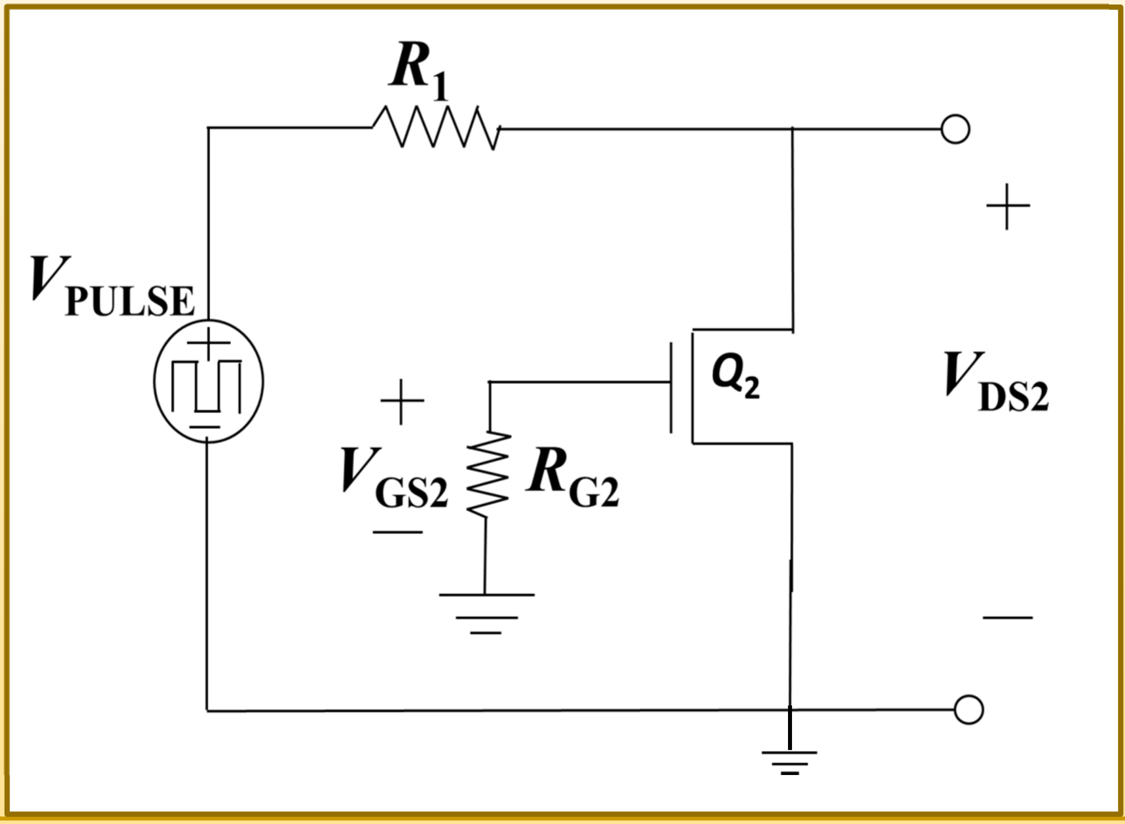
- Preliminary analytical results to date. Experimental results pending.



HF Modeling for PV Systems

SiC MOSFET Modeling:

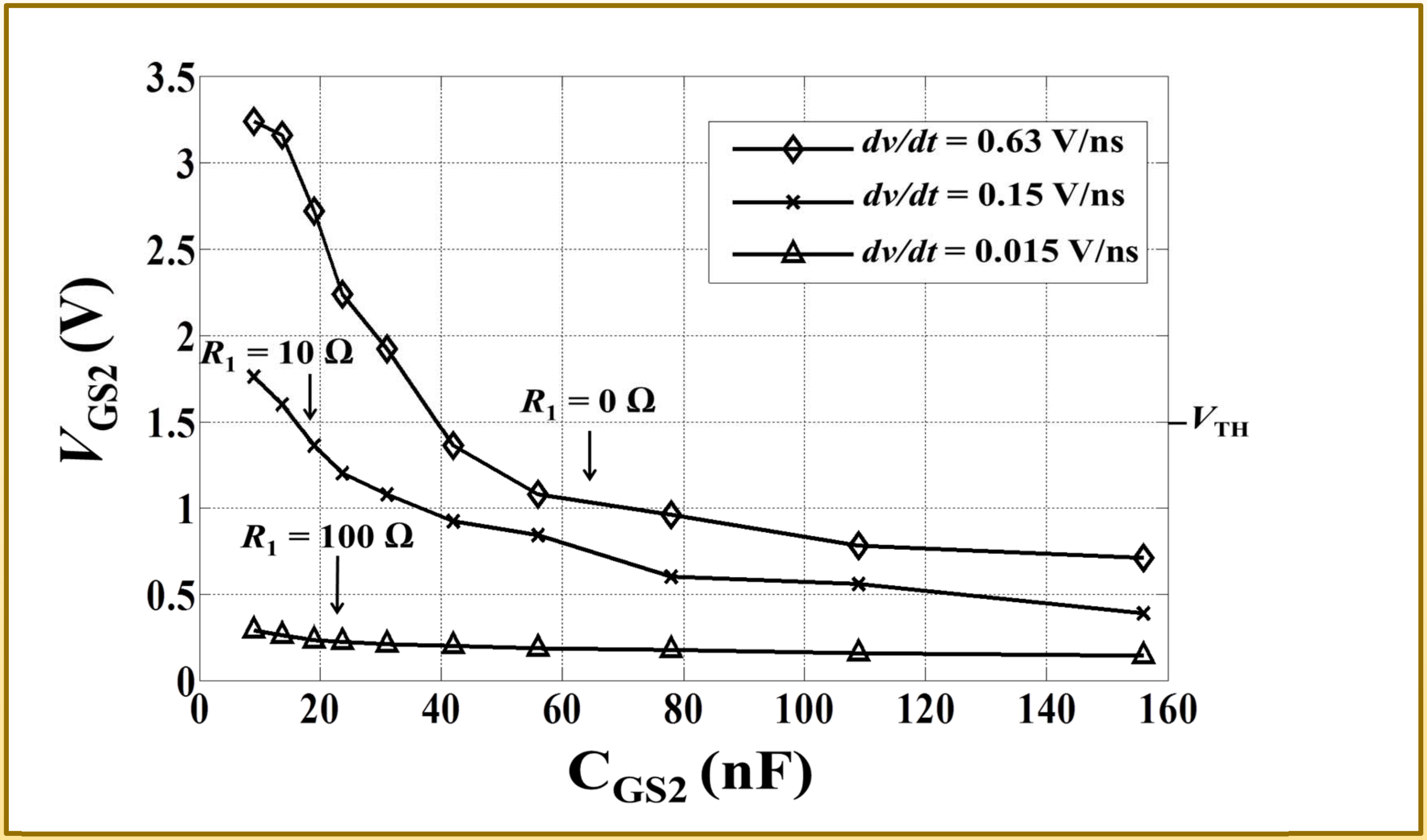
- *Cdv/dt* Test Circuit
  - R_1 varied to change *dv/dt* seen at drain-terminal
  - Objective was to determine maximum allowable *dv/dt* and what value of C_{GS} can prevent false conduction.



HF Modeling for PV Systems

SiC MOSFET Modeling:

- Results from *Cdv/dt* Test Circuit



- Stop by our poster for more on GaN modeling using SaberRD (Synopsys)

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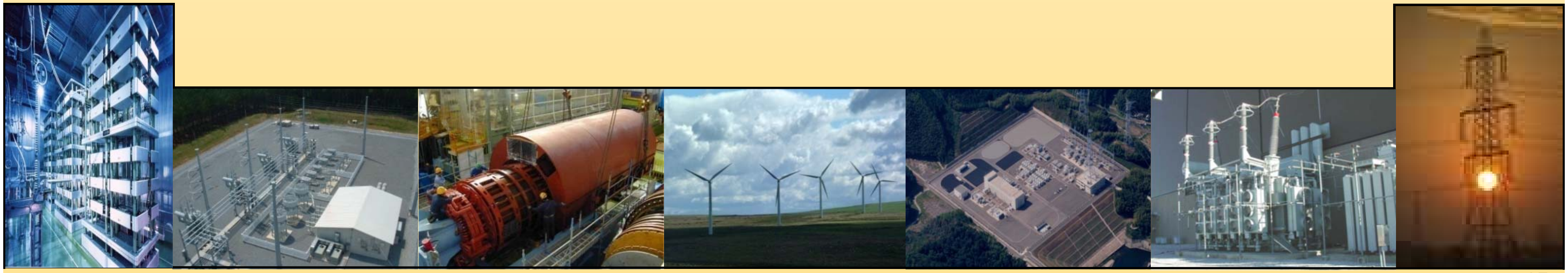
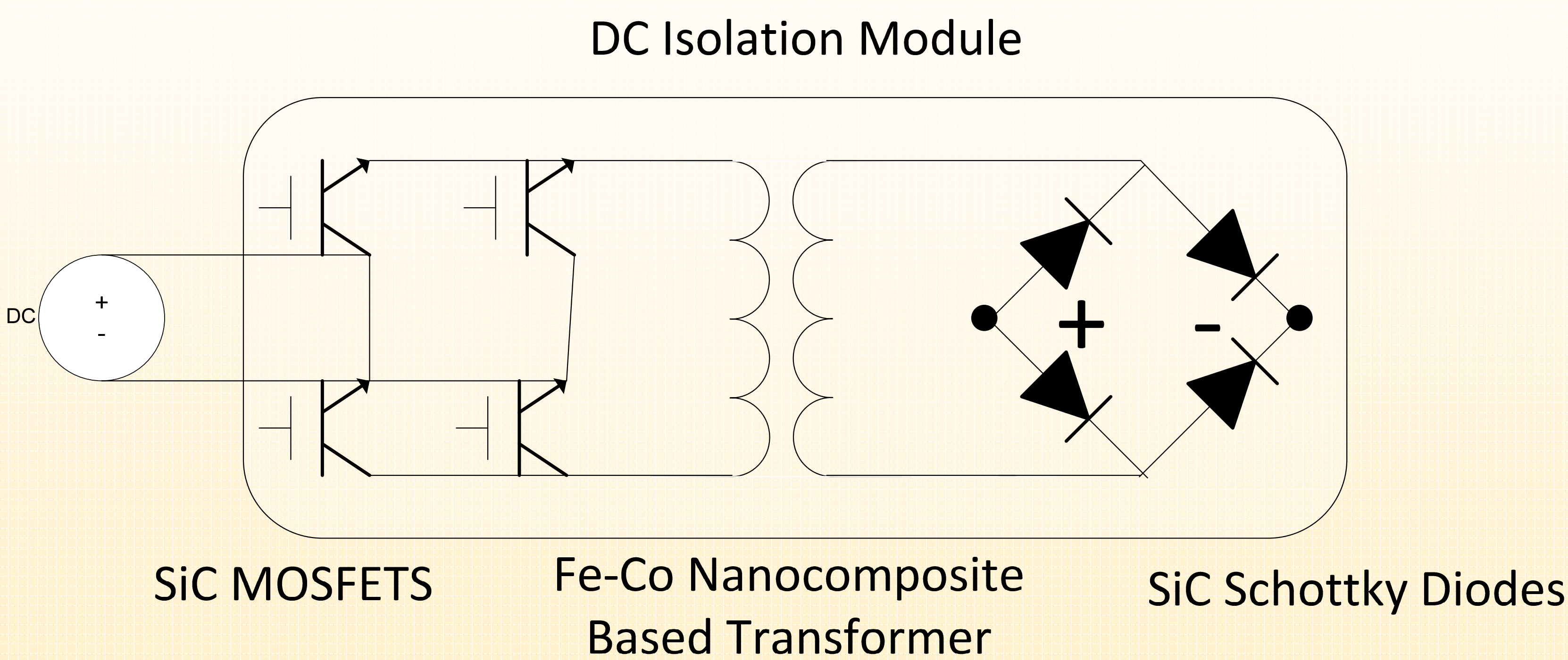
Emmanuel Taylor
HF Materials for DC Isolation



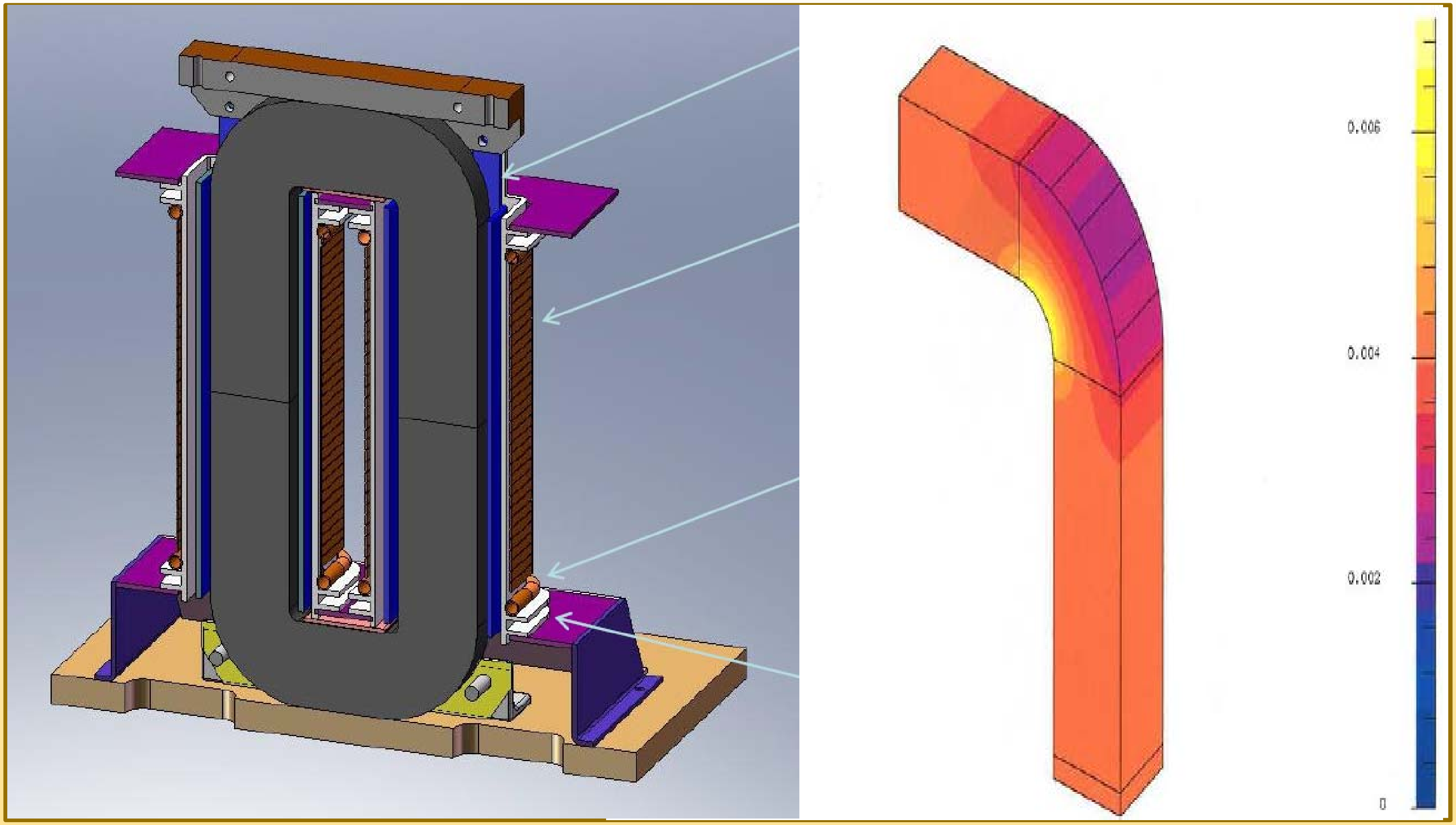
HF Materials for DC Isolation

DC Isolation Module Schematic:



HF Materials for DC Isolation

Transformer Modeling Using Maxwell, PExprt, Simplorer:



UNIVERSITY OF PITTSBURGH
SWANSON school of engineering
Power & Energy Initiative

HF Materials for DC Isolation

Transformer Modeling:

Typical H.V. Transformer

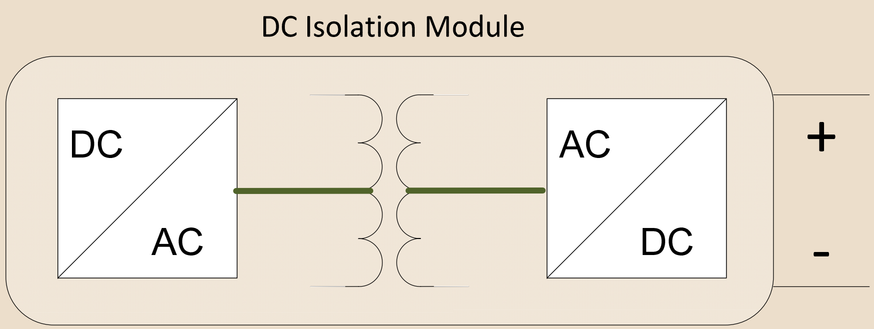
- 100 kV, 60 Hz
- 20 Amp RMS
- 2 MW Average
- 35 Tons
- ~30 KW Loss

HVCM Transformer

- 140 kV, 20 KHz
- 20 Amp RMS
- 1 MW Average (3) present use
- 450 LBS for 3
- 3 KW Loss At 2 MW

HF Materials for DC Isolation

Transformer Modeling:

Isolation	Shipboard
	
HVDC	**PV**