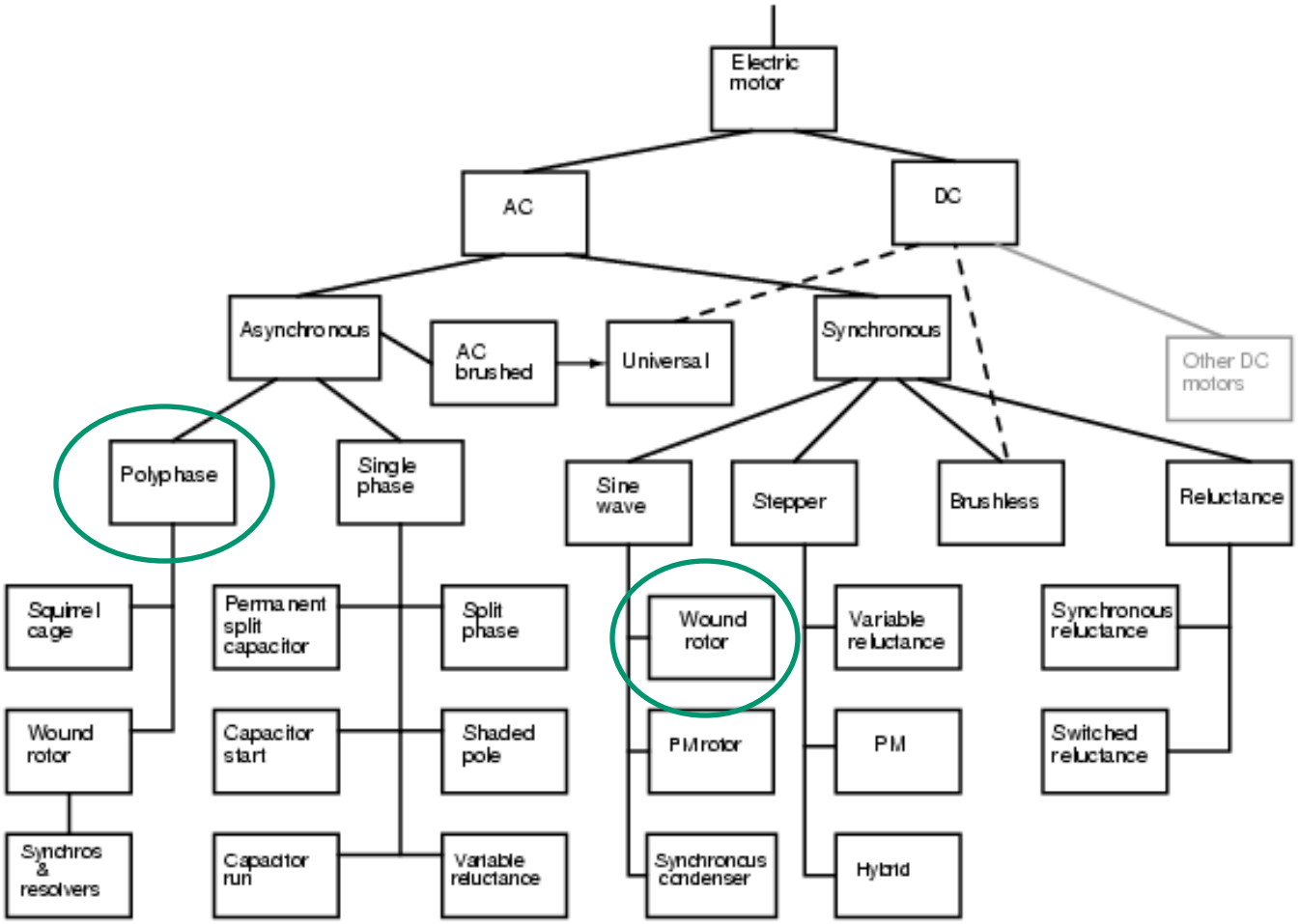
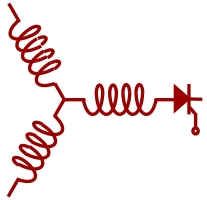
# Overview of Advanced HMW Motors

T.A. Lipo

# Electric Motor Family Tree





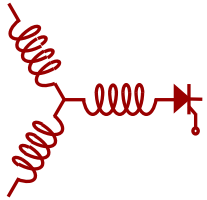
# Use of MegaWatt Size Motors in Industry

Constant Speed:

- Dominated by Induction Motors (90% in general)
  Synchronous Motors become Competitive beyond 3-5 MW

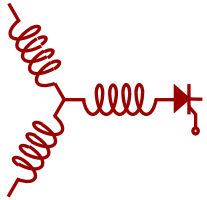
Variable Speed:

- Dominated by Induction Motors
- Significant Use of High MW Synchronous Motors
- PM Motor Use is Minimal (Using $Nd_2Fe_{14}B$)



# Questions to be Discussed

- Why Are Only Three Types of AC Motors Popular?



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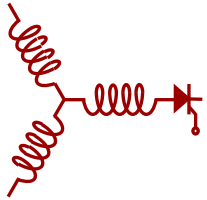
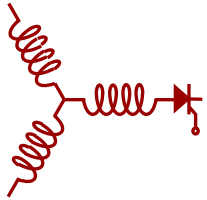
- How Can WBG Switching Devices Help?



# Motor Barriers

What Are Barriers to New Machine Topologies?



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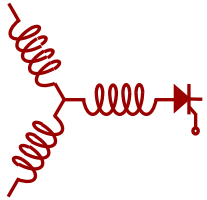


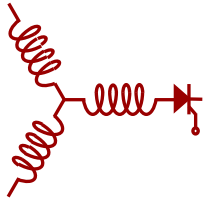
# Motor Barriers

What Are Barriers to New Machine Topologies?

#1 COST!! Of Course!
(Magnets, Assembly, etc.)

#2 Complexity

#3 Inductance(?)

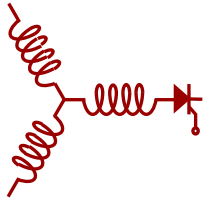


Electromechanical Energy Conversion Hinges Upon

$P = i*e$ (e = emf due to air gap flux)

Or

$P = i(d\lambda/dt)$ ($\lambda$ = air gap flux linkage)



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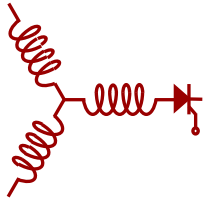
$d\lambda/dt = i(dL/dt) + L(di/dt) + e_{mag}$



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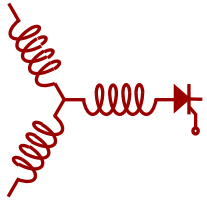
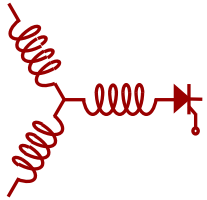
The friend! The enemy!



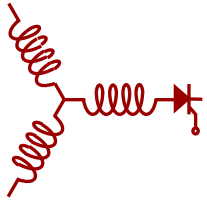
# Law of “Constant Sorrow” for AC Machines

i(dL/dt) The friend! Make dL/dt as large as possible!
Implies: High speed
Control of i (not v) is important.

L(di/dt) The enemy! Make L as small as possible!
Air Gap Armature Winding
Many Phases >3?



# How Can WBG Switching Devices Help?



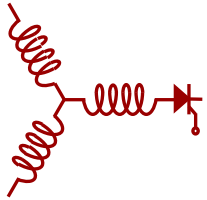
# Features of WBG Devices

## WBG Device Attributes

- High Voltage
- High Efficiency
- High Temperature
- High Switching Frequency
- High Fundamental Frequency

# Features of WBG Devices

| WBG Device Attributes | Benefit for Design of Electrical Machines |
| --- | --- |
| • High Voltage | Questionable |
| • High Efficiency | Questionable |
| • High Temperature | Questionable |
| • High Switching Frequency | Significant |
| • High Fundamental Frequency | Significant |

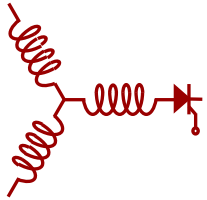


# Benefits of WBG Devices to the “Big Three”

- A New Motor Side Filter Could Result in Nearly Zero THD Motor Voltage Waveforms
- Negligible Stator Copper and Iron Loss Due to Impressed Harmonics
- Possibility of Reduced Magnetics
  Line Side Filter, Line Side Transformer

# WBG Devices – The Downside

- Increased Differential and Common Mode EMI
- Bearing Current Issues
- Insulation Degradation

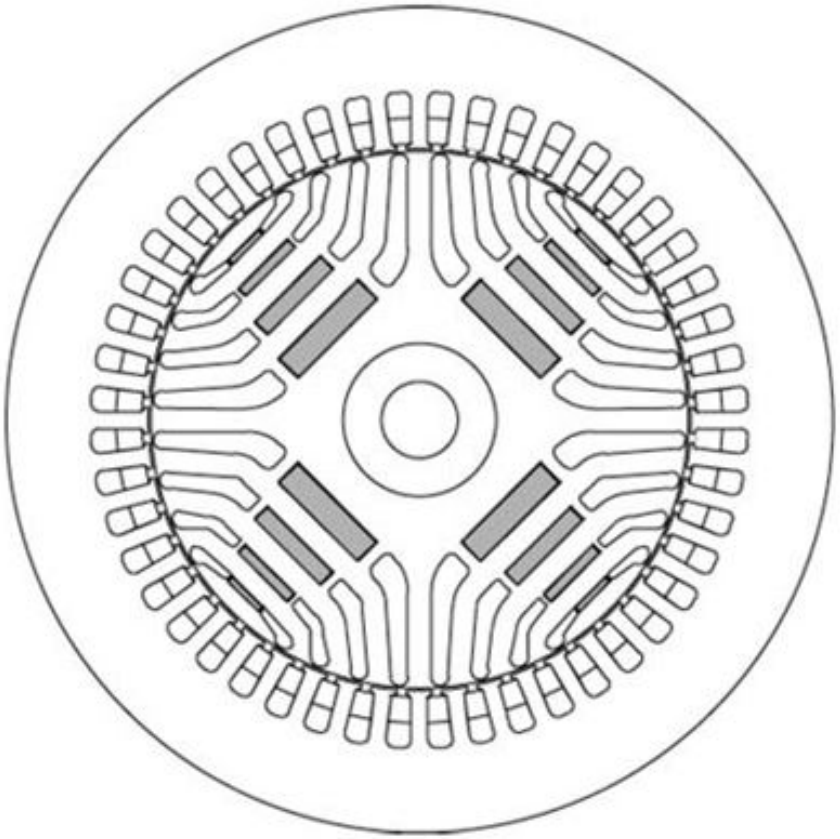


# “Poor Cousins” of the Machinery World

Other Machines Capable of Megawatt Ratings

- Switched (Variable) Reluctance Motor
- Synchronous Reluctance Motor
- PM Assisted Synchronous Reluctance Motor
- Spoke Type PM Motor
- Switched Flux Motor
- Transverse Flux Motor
- Vernier Motor

# PM Assisted Reluctance Motor



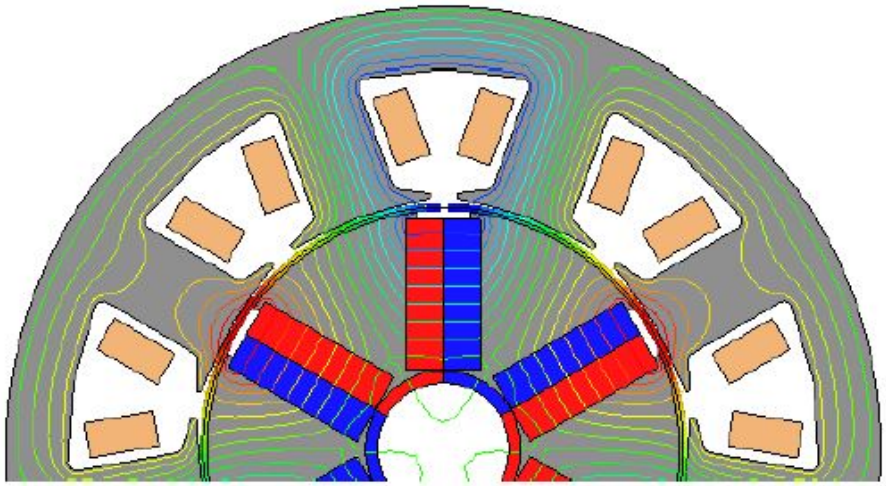
Characterized by:

- Good dL/dt
- High L
- Small $d\lambda_{mag}/dt$
- Good Power Factor
- Expensive Rotor

Benefits from high switching frequency of WBG devices

- Reduced torque ripple by current control

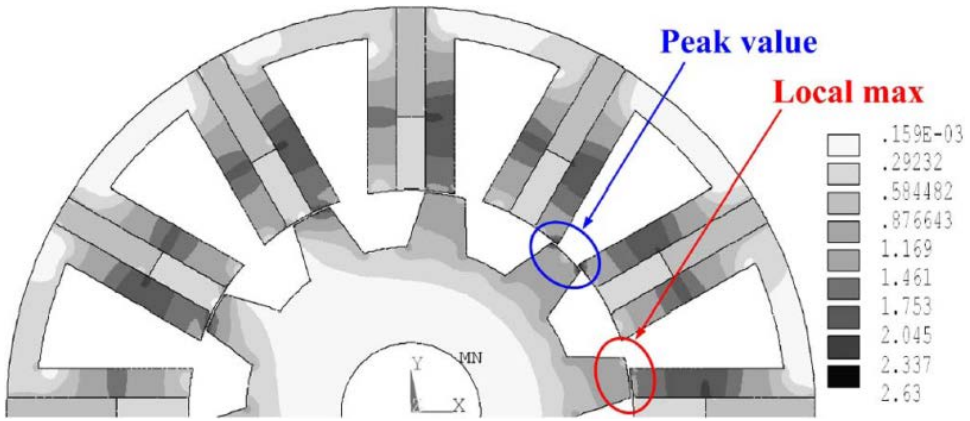
# Spoke Type PM Motor



Characterized by:

- Low dL/dt
- Moderate L
- High $d\lambda_{mag}/dt$
- Good Power Factor
- Expensive Rotor

# Switched Flux Motors



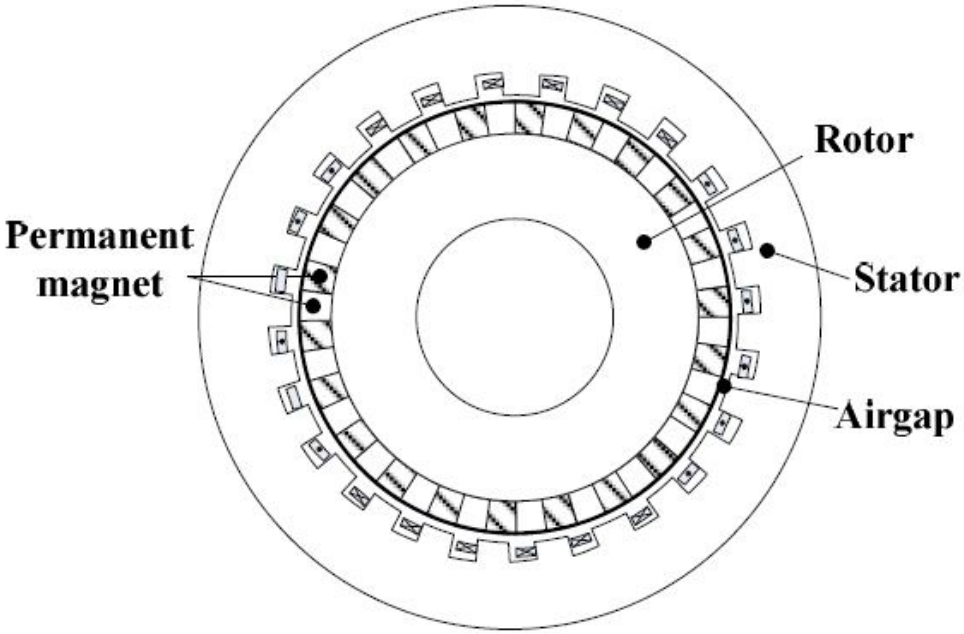

Characterized by:

- Low dL/dt
- High $d\lambda_{mag}/dt$
- High L
- Expensive Stator
  Many magnets

Benefit from high switching frequency of WBG devices

- Improved torque precision
- Higher speed (frequency)

# PM Vernier Motor

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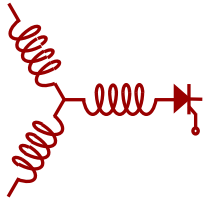

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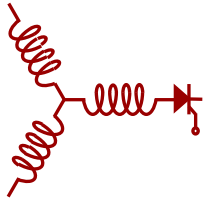
# Where will the boundaries of machines be extended?

High Speed Machines
- Compact Turbine Driven Power Source
- Energy Storage Systems

Low Speed Machines
- Directly Driven Wind Turbines
- Ocean and Tidal Wave Machines

High Temperature Machines (and Drives)
- Compact Mechanical Power Sources
- Switching Devices in the Motor Frame

HT Superconducting Machines



Time for questions?