

# SMART Wind Consortium

## Subgroup Leads





## **Electrical Subgroup**

### **Lead**

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# My Background

- D.E. from Dartmouth College
- P.E. in electrical, mechanical & HVAC
- Involved in PV for 32 years and wind for 15 years
- Designed inverters from 250W to 250 kW.
- Co-designer of the inverter for the Skystream turbine.
- Wind rep, National Electrical Code (NEC - Article 694)
- Member of related UL and IEEE standards committees.

# Distributed Wind Activities

- Rep - US National Electrical Code
  - Proposals due Nov 7
- Certification of Battery Energy Storage
  - Aqueous, Li-Ion, PbA
- Electrical lead for a VAWT startup
  - Induction vs PM Generators
  - VF Motor Drives as Rectifiers
- Working with Electrical Inspectors

# The Big Picture

- Lack of Off The Shelf (OTS) Equipment
  - Generators
  - Rectifiers & Diversion Load Controllers
  - Inverters (esp. 20 - 38 kW, single-phase)
- Certification
  - Solar inverters may require re-certification
- Future Directions
  - 1000 V generators, Matrix VF Drives (Yaskawa)

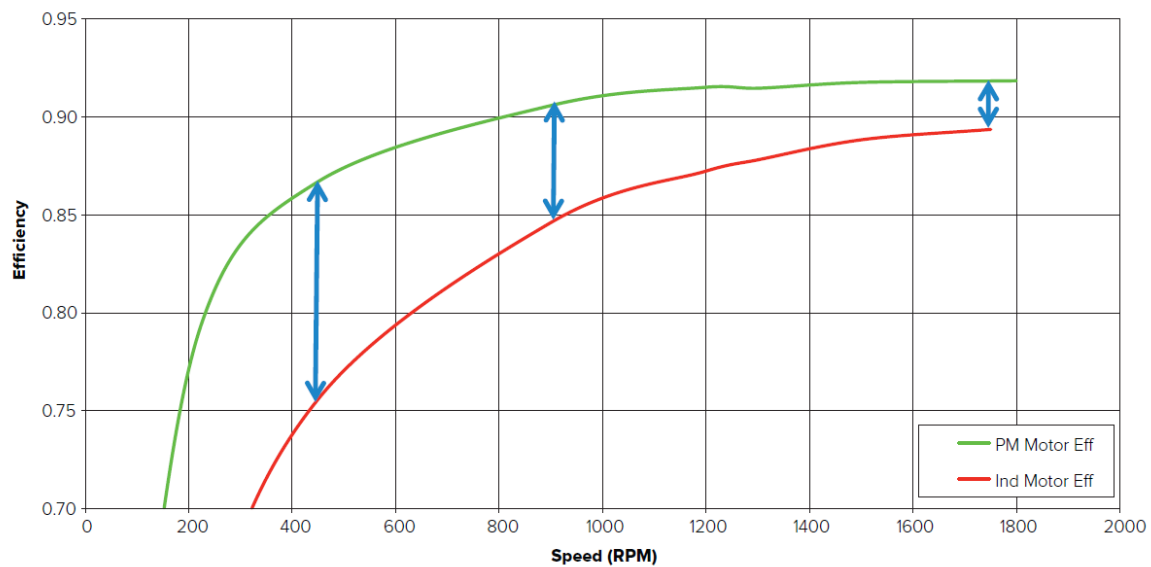
# Generators

- EPM vs. IPM vs. Induction vs. SR ??

## Typical Motor Performance

Efficiency vs Speed

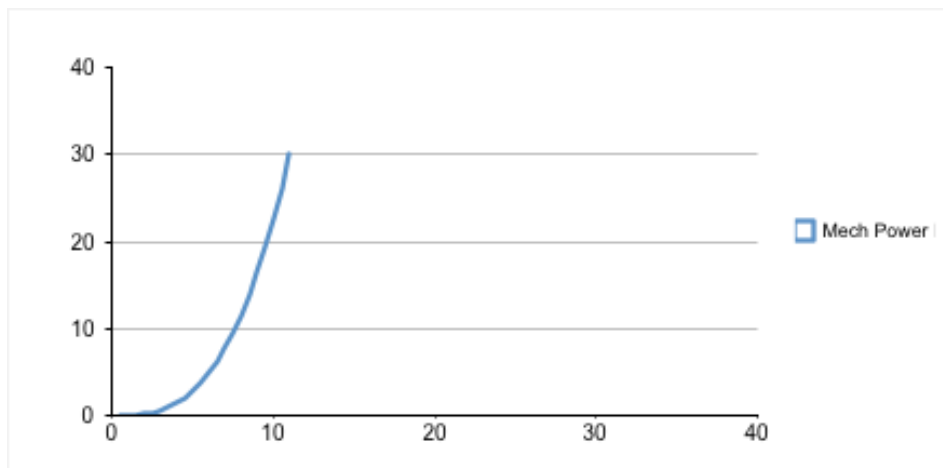
Permanent Magnet AC vs NEMA Premium Induction



# Generators

Torque is not constant (actually  $\sim \text{RPM}^2$ )

Compare to EV, Material Handling

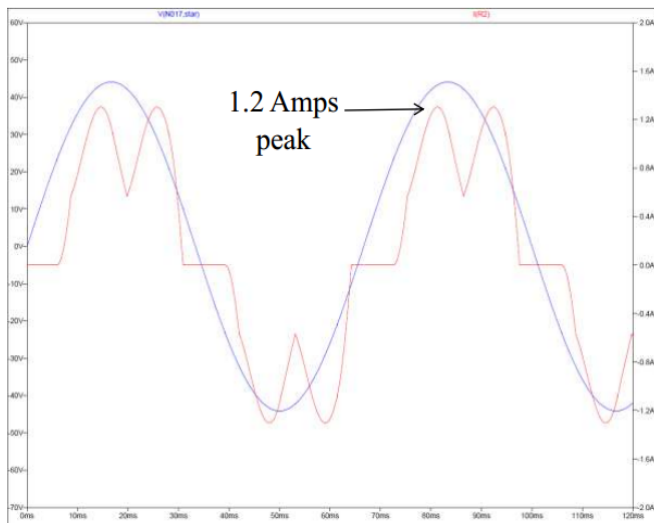


- Induction machines have lower iron losses
  - Double-fed Induction machines can use much smaller inverters

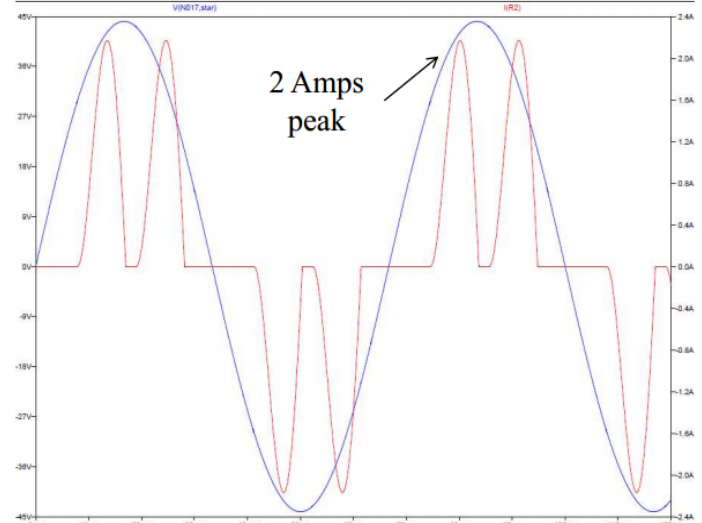
# Rectifiers & Torque Ripple

2014 SWC Presentation

Ferrite alternator



...the heartbeat of a NEO



Diode Bridge Rectifiers cause Torque  
Ripple

# Rectifiers & Torque Ripple

An OTS Solution



VF Drives can Regenerate

# OTS Diversion Load Controllers



Off the shelf VFD Braking Modules

# Inverters

ABB string inverters  
TRIO-20.0/27.6-TL-OUTD  
20kW to 27.6kW

There are no OTS 20 –  
38.4\* kW  
Single Phase Inverters



\* 38.4 kW is the largest inverter that can be  
connected to a 200A single-phase service

# Codes & Standards

- NEC 2014 Changes

- From SMALL to ALL
- From 600 V to 1000 V

## **VIII. Systems over 1000 Volts**

### **694.80 General**

Wind electric systems with a maximum system voltage exceeding 1000 volts ac or dc shall comply with Article 490 and other requirements applicable to installations rated over 1000 V.



- NEC Proposals Due Nov 7
  - Contact Robert Wills or Robert Preus
- Storage and Microgrids
  - New Interest due to Hurricane Sandy