NovaTorque

Beyond IE4:

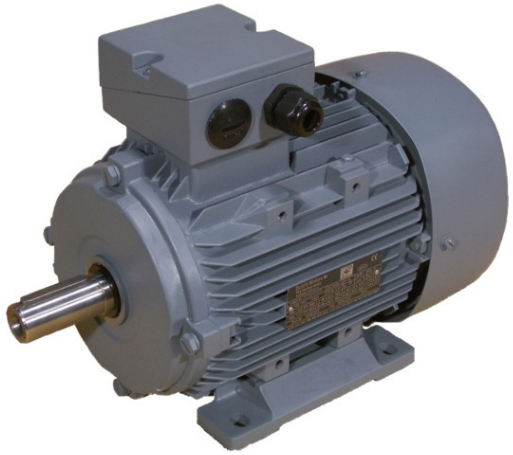
The Future of Motor Efficiency

Motor Summit 2012

Zurich December 4 - 6, 2012

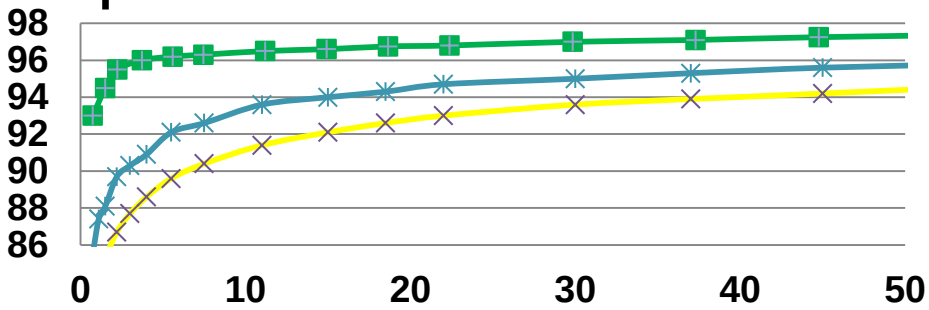
Outline

- Introduction
- Current status
- Improvements in motors
- Improvements for drives
- Conclusions



Introduction

- Both motor and drive improvements are addressed
- Motor efficiency is dependent on:
  - Motor Size
  - Motor type
  - Cost of motor



- Specifics presented focus on 1 to 10 kilowatt range, however, most of the improvements apply to all motor sizes
- Time frame for improvements to reach the marketplace is predicted

Efficiency Opportunities and Barriers

- The most significant way to improve efficiency is to move systems to variable speed and torque
- There is more opportunity to improve motor efficiency than drive efficiency
- System cost is the major limiting factor to the application of high efficiency solutions

Highly Efficient Motors Are Available Today

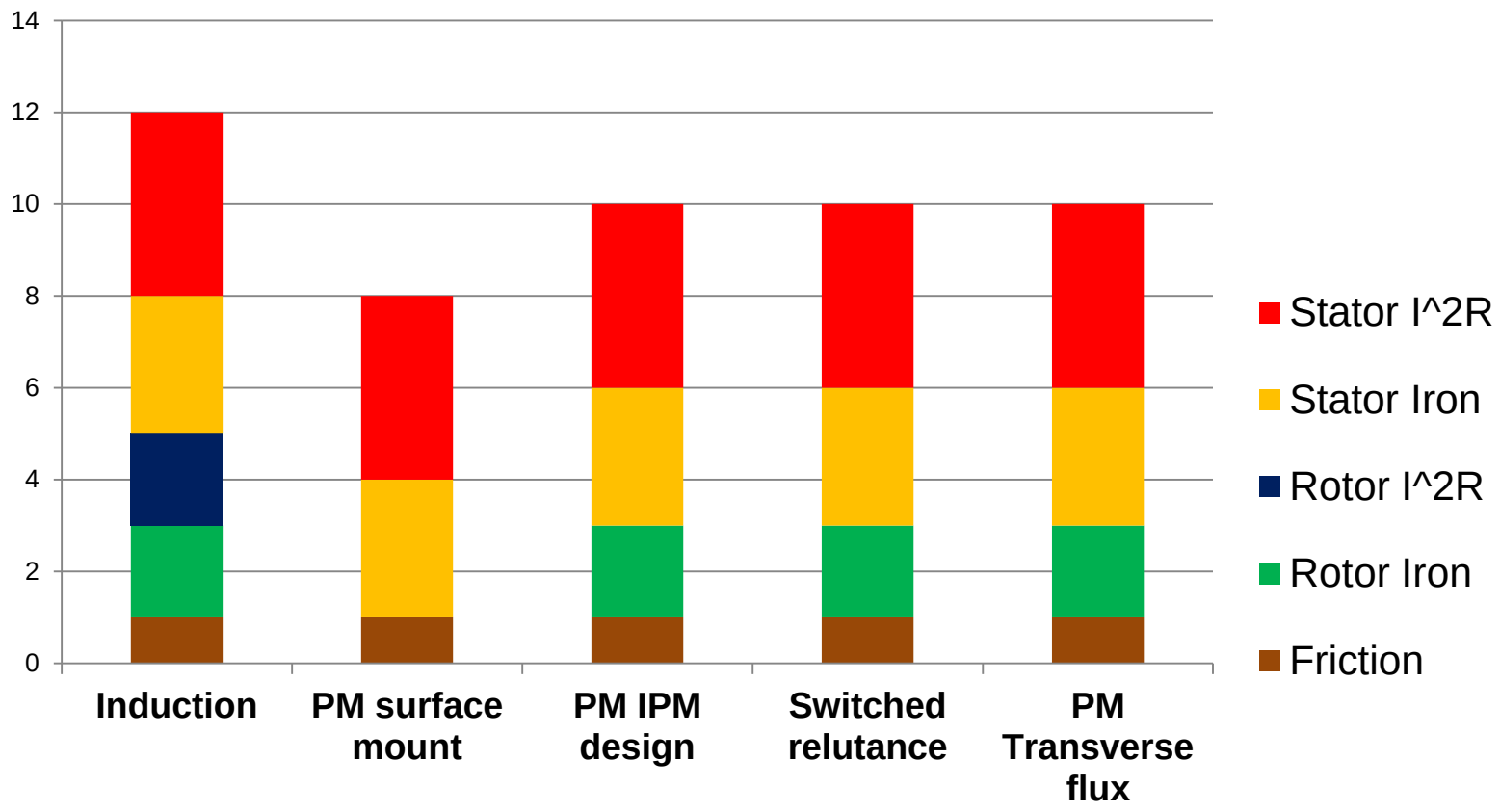
- 98% efficient motors and drives (96% system efficiency) can be built today, but the marketplace is reluctant to accept the cost
- Largest barrier to adoption is marketplace's payback expectation
  - Electricity is still relatively cheap
  - Even a carbon tax is unlikely to alter this much
- Second barrier is buyer / user separation

Sources of Loss in Motors

- Loss mechanisms for motors are well-known
  - Conduction losses – related to torque (motor current)
  - Speed losses – magnetic losses, friction and windage
  - Hysteresis and eddy currents related to both torque and speed combined

Motor Type	Induction	Permanent Magnet	Switched Reluctance
Loss with speed	Very Low	Medium	Very Low
Loss with torque	Medium	Low	Medium
Off rated speed efficiency	Good	Excellent	Good

Motor Loss Comparison



Potential Motor Material Improvements

	Years out	<3	3 to 6	>6
• Laminations / stator materials				
• Improved irons – laser processing		X		
• Amorphous metals – metglas and others			X	
• Exotic alloys and nano materials			X	------ X
• Soft magnetic composites			X	------ X
• Conductors				
• Improved shapes –rectangular		x	------ X	
• Better insulations – thin, high temp		X	------ X	
• Aluminum foils – low cost bobbin wind			X	
• Carbon nanotube wire				X
• High temperature super conductors			X	------ X

Potential Motor Material Improvements

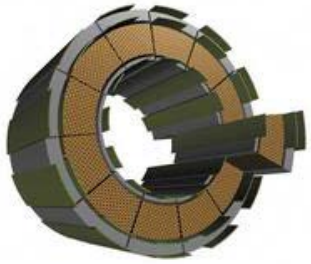
	Years out	<3	3 to 6	>6
• Permanent magnets (PM)				
• FeN – Iron Nitride formulations				X
• Cerium compounds				X
• Nano-composites magnetic compounds				X
• Minimized rare earth formulations		X	------	X
• Bearings				
• Ceramic bearings				X
• Better lubrications		X	------	X
• Casing Materials				
• Higher thermal conductivity potting				X

Potential Motor Design Improvements

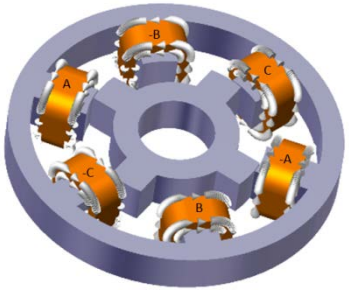
Years out <3 3 to 6 >6

- Induction
  - Copper rotor X

- PM Radial
  - Segmented Core X ----- X

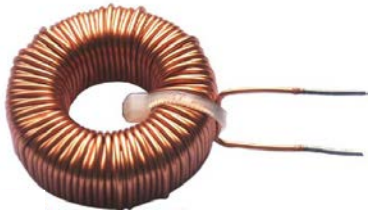


- PM Axial
  - Optimized dual rotor X ----- X



- Switched Reluctance
  - Pole counts and drives X ----- X
- PM – Transverse Flux X ----- X

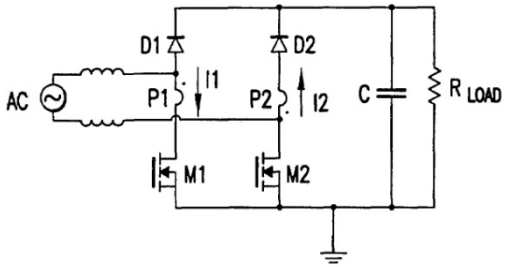
Potential Drive Component Improvements

	Years out	<3	3 to 6	>6
• Power semiconductors				
• IGBTs and MosFets		X	------	X
• GaN – Gallium Nitride			X	------ X
• SiC – Silicon Carbide			X	------ X
• Passive components				
• Inductors – lower loss		X	------	X
• Capacitors – high power capability			X	------ X
• Control components				
• Low power processors		X	------	X
• Efficient internal supplies		X	------	X

Potential Drive Design Improvements

Years out <3 3 to 6 >6

- Bridgeless designs
  - Reduce line rectifier losses X
- Capacitive coupled designs
  - Minimize loss in inductors X ----- X
- Integral power factor correction
  - Reduce loss in feed lines X ----- X
- Improved control schemes
  - Variable DC link voltage X ----- X
  - Regeneration back to AC line X ----- X



Conclusions

- Most improvements apply to all motor types
  - Magnets apply only to PM types
  - Foil windings only to bobbin windings
  - High temperature superconductors apply only to very large motors
- Largest gains are in
  - PM and switched reluctance motors
  - Permanent magnet materials
  - Improved laminations
  - Reduced bearing friction
  - Drive topology changes

Conclusions

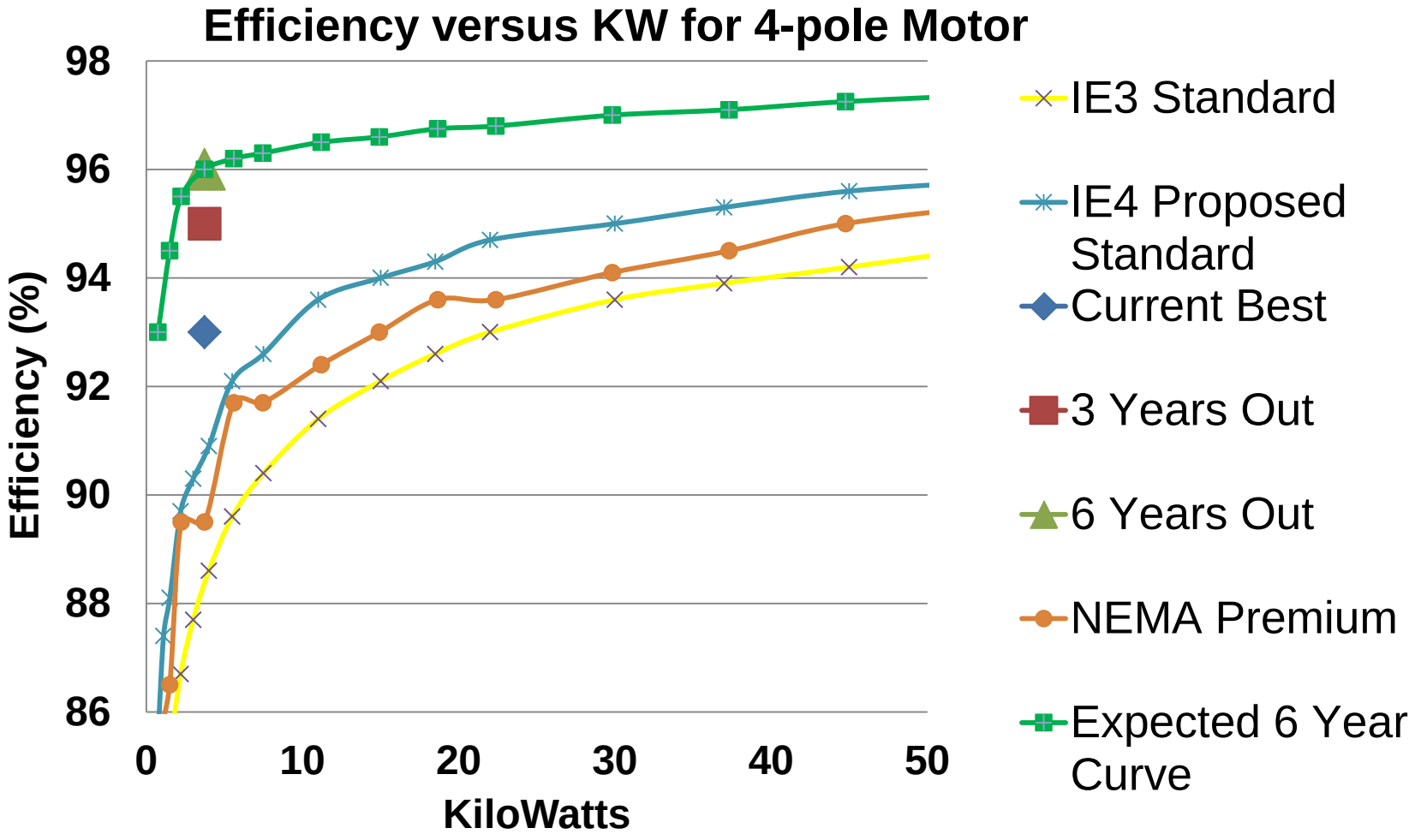
- Many opportunities for efficiency improvement
- Almost every component is being improved

- My best guess prediction (3.75 KW designs)

	Motor	Drive	System
• Today (standard)	90	95	85.5
• Today (best practice)	93	96	89.3
• 3 Years estimate	95	97	92.1
• 6 Years estimate	96	98	94.1

Significant efficiency improvements are coming !!!

Potential Increases in Efficiency Standards



The End

Thank You !

Questions ?

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