



OPPORTUNITIES IN ALTERNATOR DESIGN AND MANUFACTURING

Dr. Greg Mowry

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School of Engineering, University of St Thomas

“

THOSE WHO CONTROL MAGNETICS,
CONTROL THE WORLD.

”

Anonymous quote while working at Ames Laboratory on the magnetic properties of Rare-Earth metals

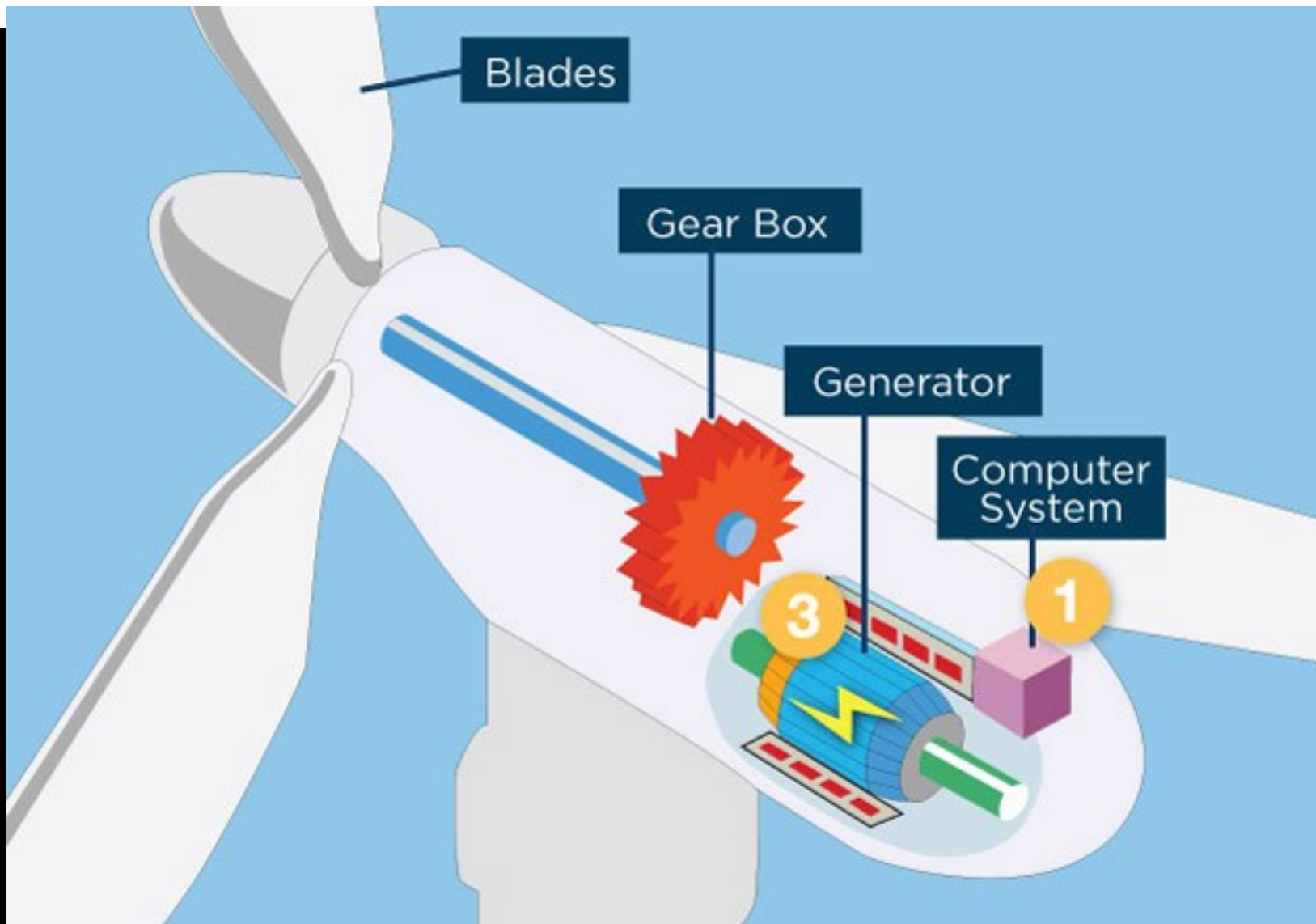
“ IN TOTAL, ABOUT 65% OF THE ELECTRICAL ENERGY
IN THE UNITED STATES IS CONSUMED BY ELECTRIC
MOTORS, AND OVER 99% OF THE ENERGY
PRODUCED BY UTILITIES WORLDWIDE IS PRODUCED
BY ELECTRIC GENERATORS. ”

“Electric Energy: An Introduction”, 3e, M. A. El-Sharkawi; C12 ‘Electric Machines’



OUTLINE

- The wind turbine
- Wind Energy Conversion Systems (WECs)
- Power electronics
- Alternators
- Manufacturing
- Future



“

THE WIND TURBINE

THE REASON A WIND TURBINE EXISTS IS TO
PRODUCE ELECTRICITY

”

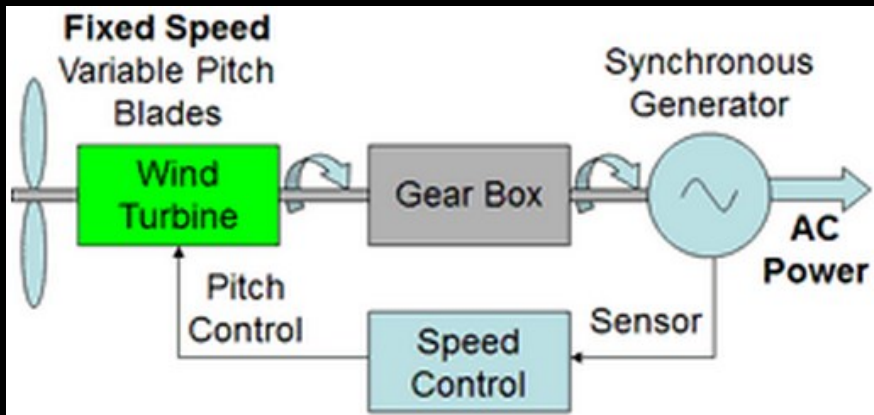
Mowry



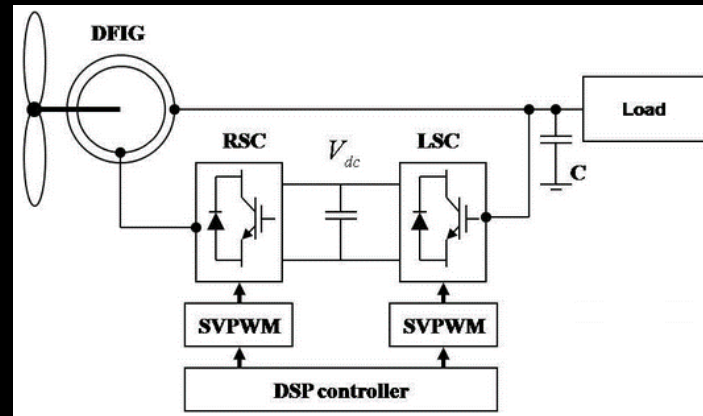
WIND ENERGY CONVERSION SYSTEMS

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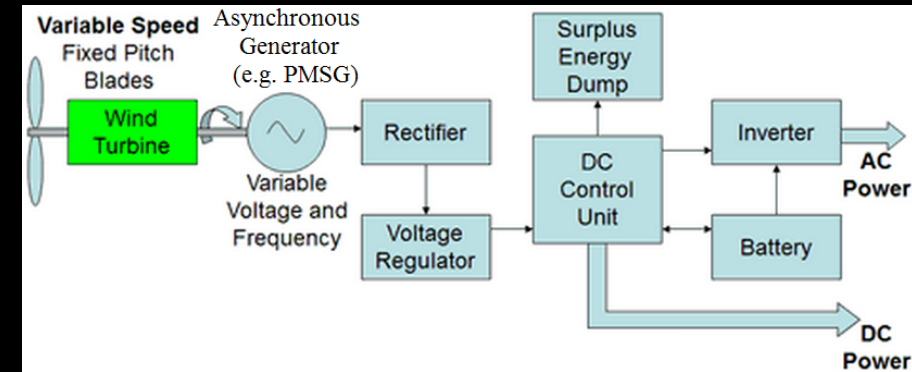
WIND



Large Scale Wind Power (Grid level)



Variable Speed WECs



Small Scale Wind Power (Domestic Scale)

<https://tungvp.wordpress.com/2010/04/19/wind-energy-conversion-systems/>



POWER ELECTRONICS

WHAT MAKES ALTERNATIVE ENERGY CONVERSION POSSIBLE

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STATE-OF-ART SWITCHES

Manufacturer	Part Number	V _{DS}	R _{DS,on}	I _D 25°C	I _D 100°C	V _{GS} max	V _{GS} use	Q _g	t _{d,on}	t _r	t _{d,off}	t _f	f _{max}	
		(V)	(mW) max	(A)	(A)	(V)	(V)	(nC)	(nS)	(nS)	(nS)	(nS)	(MHz)	
ST Microelectronics	STW62N65M5	650	49	46	26	±25	10	142	101	11	101	8	5	FET
ST Microelectronics	STW69N65M5	650	45	58	36	±25	10	143	102	10	102	11.5	4	FET
IXYS Corp	IXYS 60N80P	800	150	40	26	±30	10	250	36	29	110	26	5	FET
IXYS Corp	IXFB50N80Q2	800	160	50	33	±30	10	260	26	25	60	13	8	FET
IXYS Corp	IXFH42N60P3	600	185	42	27	±30	10	78	32	23	60	17	8	FET
GeneSiC Semiconductor	GA50JT12-247	1200	20	100	80	3.85	3.42	239	16	21	33	45	9	SiC SJT
GeneSiC Semiconductor	GA50JT17-247	1700	20	100	80	3.85	3.42	288	17	23	44	47	8	SiC SJT
CREE - SiC	C2M0025120D	1200	34	90	60	-10/+25	20	161	14	32	29	28	10	FET
CREE - SiC	C2M0040120D	1200	52	60	40	-10/+25	20	115	15	52	26	34	8	FET
CREE - SiC	CAS300M12BM2	1200	5.7	404	260	-10/+25	20	1025	76	68	168	43	3	Module
Vishay	SiHG47N65E	650	72	47	30	±20	10	182	47	87	156	103	3	E-series
Vishay	SiHG64N65E	650	47	64	40	±20	10	239	66	122	213	103	2	E-series
Infineon	IPW65R019C7	650	17	75	62	±20	10	215	30	27	106	5	6	CoolMOS



POWER ELECTRONICS

- Board-level power efficiencies continue to increase; $> 95\%$
- Switching frequency continues to increase; $> 100\text{ kHz}$
- MOSFETs and SJTs beginning to dominate the market
- Low switch-count ZVS & ZCS topology advancements continue
- Coupled magnetics & interleaved topologies push power levels to $> 10\text{ kW/PCB}$
- Integrated high-level on-PCB computing continues to evolve



POWER ELECTRONICS TRENDS

- Concept: variable source power – controlled power out
- Utilize power electronics & controls to condition power for the application
- MISO: Multiple Input Single Output power electronics

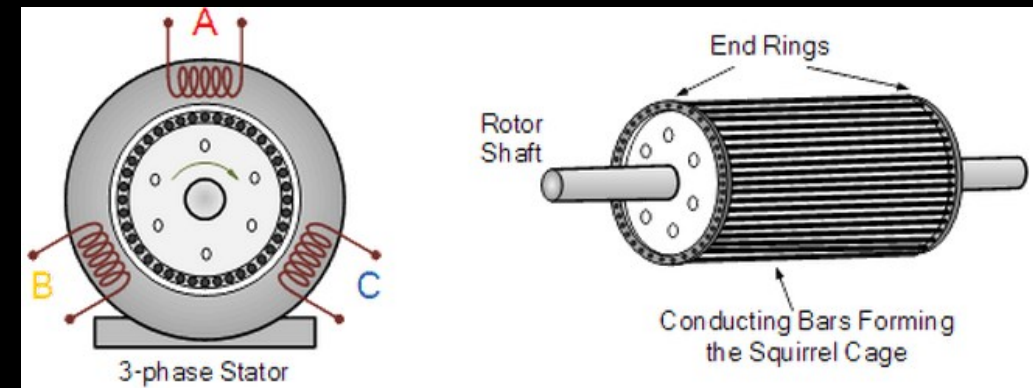


ALTERNATORS

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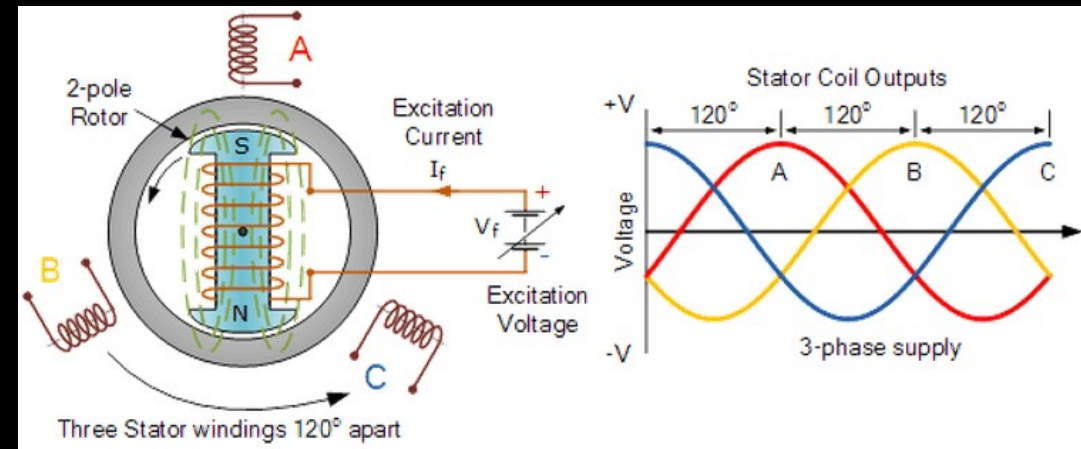
ALTERNATORS (GENERATORS)

- Asynchronous (induction) generators
 - Squirrel cage
 - Wound rotor
 - Dual-Fed Induction Generator



ALTERNATORS (GENERATORS)

- Synchronous generators (SGs)
 - Salient pole
 - Cylindrical rotor
- SGs used in wind turbines
 - Wound rotor (electrically excited SG)
 - Permanent magnet SGs
 - Axial
 - Radial
 - Surface mounted PMs
 - Inset PMs
 - interior

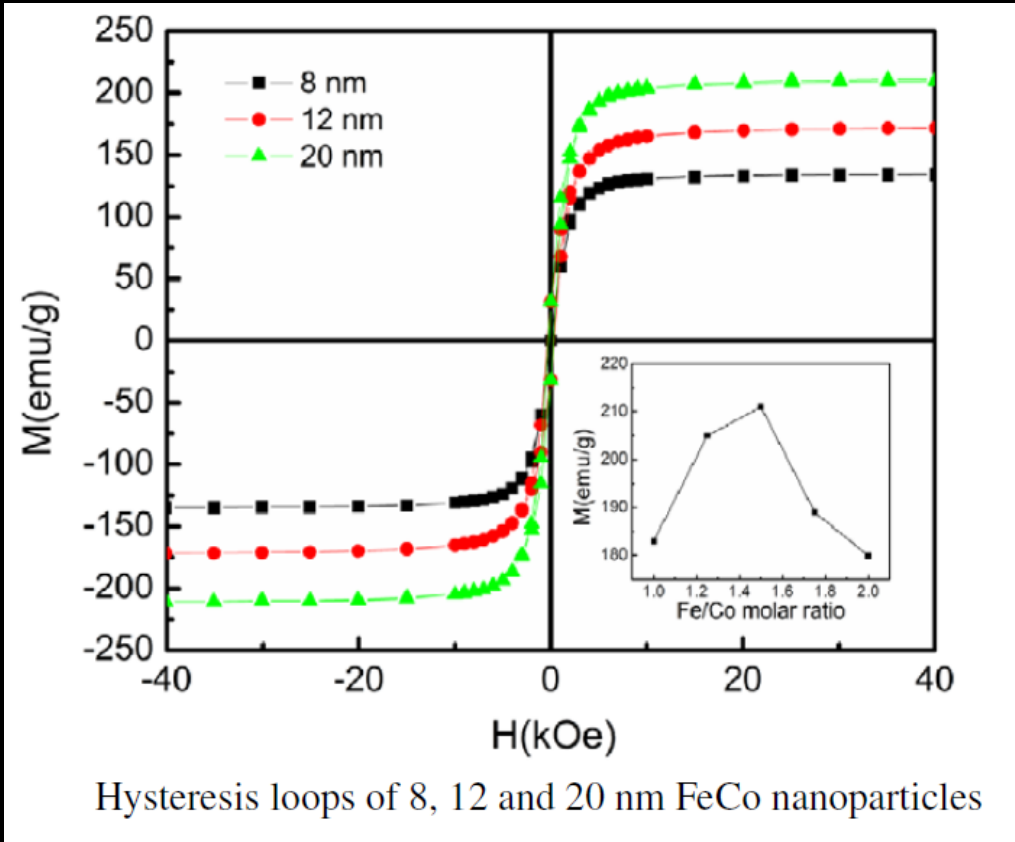




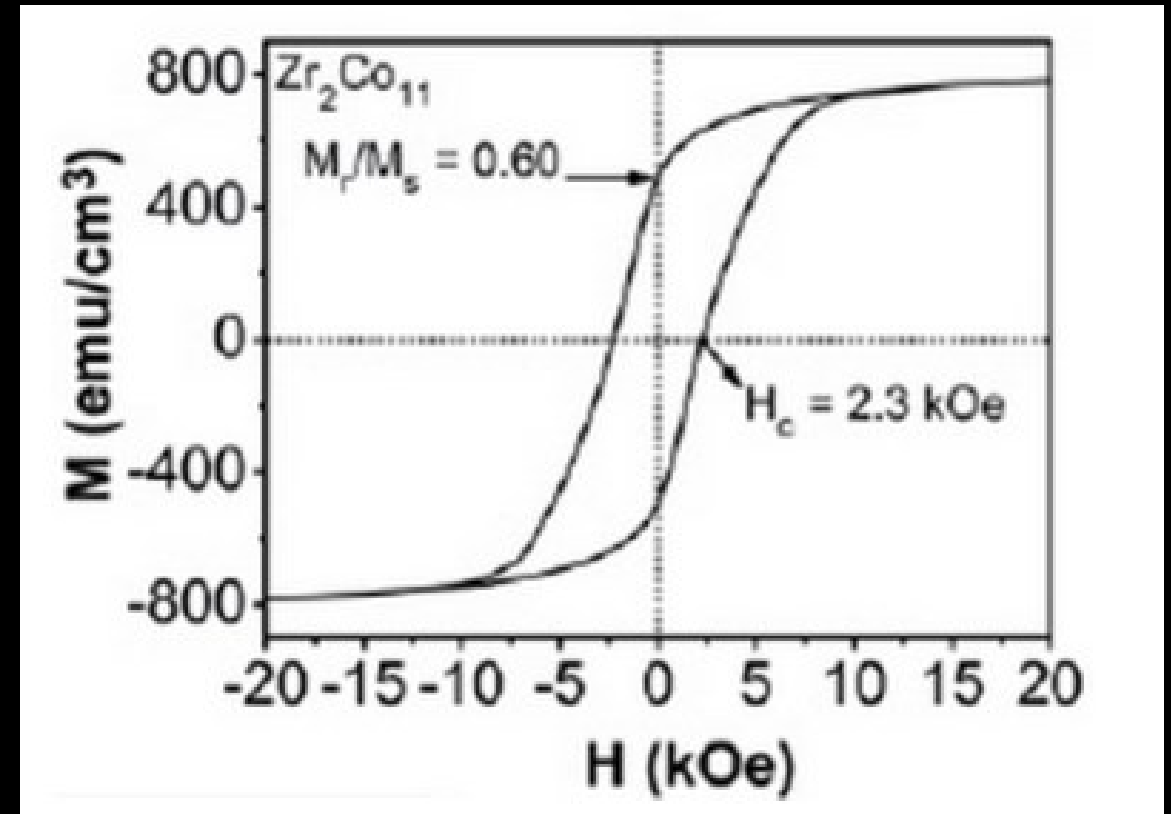
MAGNETIC MATERIALS DEVELOPMENT

- Soft and hard magnetic nanoparticles
 - Soft
 - Ideal BH loops – no hysteresis
 - High Bs materials; ~ 2.4 T
 - Hard
 - Replace RE PMs – e.g. NdFeB
 - High energy product: 25 – 50 MGOe (NdFeB ~ 64 MGOe)
- Film-based magnetic materials
 - Near-ideal hysteresis loops
 - High moment materials; ~ 2.4 T
 - Volume producible – outgrowth from HDD industry

NANO PARTICLES



Poudyal et al



Balamurugan et al

An abstract graphic at the top of the slide featuring a series of overlapping, wavy bands in shades of orange, red, yellow, and green, creating a sense of motion and energy.

MANUFACTURING

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ELECTRIC MACHINE COMPANIES



Windings

<http://www.windings.com/>

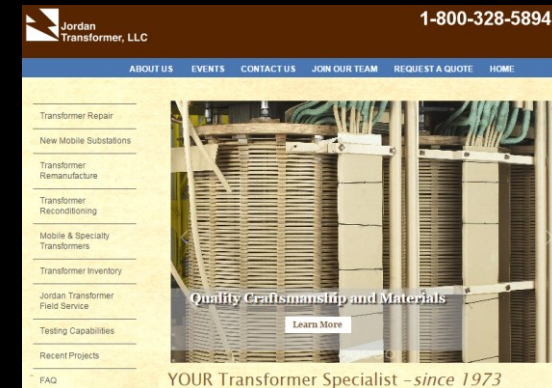
Generators & motors: custom, commodity



EMC/WEG

<http://www.electricmachinery.com>

Designing, Manufacturing, and Servicing Electric Motors and Generators



Jordan Transformer

<http://www.jordantransformer.com/>

YOUR Transformer Specialists
All types

ELECTRIC MACHINE COMPANIES



Precision
Incorporated

<http://www.precision-inc.com/>

High Frequency Power
Magnetics

- < 100 kW alternator sizes – all types; not much success in supplying the US market for this power range
- Intense cost pressures from Asian generator manufacturers
 - Quality suspect
 - Reverse engineering approach – avoids R&D investments
- Most WT companies tend to focus on blades first and then electronics – the generator is often an after-thought with a restricted budget allowance.
- WT companies tend to want custom generators with commodity pricing

- Skilled labor: hourly. Not directed into these areas by high-school councilors
 - Machinists
 - Too & die makers
- Skilled labor: Professional
 - Not as much emphasis on engineering as needed: magnetics & electric machines
 - Aging engineering work force
 - Technical sales talent lacking
- Location – rural locations competing poorly against ‘city’ lifestyles even though quality-of-life, education, and activity options are exceptional



MANUFACTURING

- Development and custom capabilities of most of the electric machine facilities are modern and competitive
- Cost pressures have forced overseas production with the known consequences of work-force depletion loss of manufacturing skills
- Need for re-visiting electric-machine manufacturing with modern methods
 - Metrology and automation
 - Magnetic materials
 - Positive processes

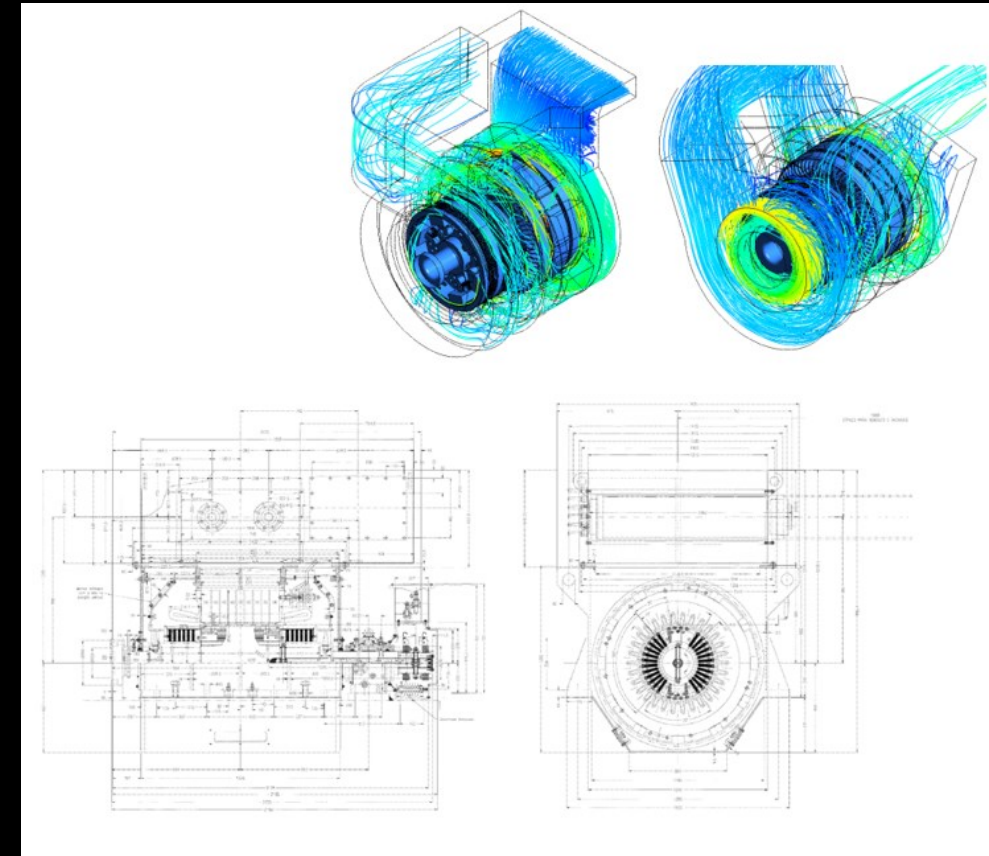
MANUFACTURING

- **Design**

- Cost-effective designs needed to stay competitive
- Focus increasingly on manufacturability
- Robust designs must meet performance requirements without premium price

- **International manufacturing**

- Manufacture in low-cost countries increasingly used
- “Kit” concepts often utilized, where globally-manufactured components assembled and tested domestically
- Lean manufacturing has become the norm



MANUFACTURING

- **Quality**

- Customers increasingly demand the highest quality with no premium on price
- Consistent production needed to minimize field problems

- **Competition**

- Low cost manufacturers becoming increasingly acceptable to customers
- Innovation and lean manufacturing is driving down costs (and thus price) worldwide
- Constant development needed to stay competitive





FUTURE

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- Scarcity and location of critical materials for PMs; e.g. Nd
- Talent pool decreasing due to age combined with reduced emphasis on magnetism at universities; e.g. ABET no longer requires E&M for EEs and magnetic materials are not generally considered in ME curriculum
- The US is no longer a leader in manufacturing due to overseas manufacturing



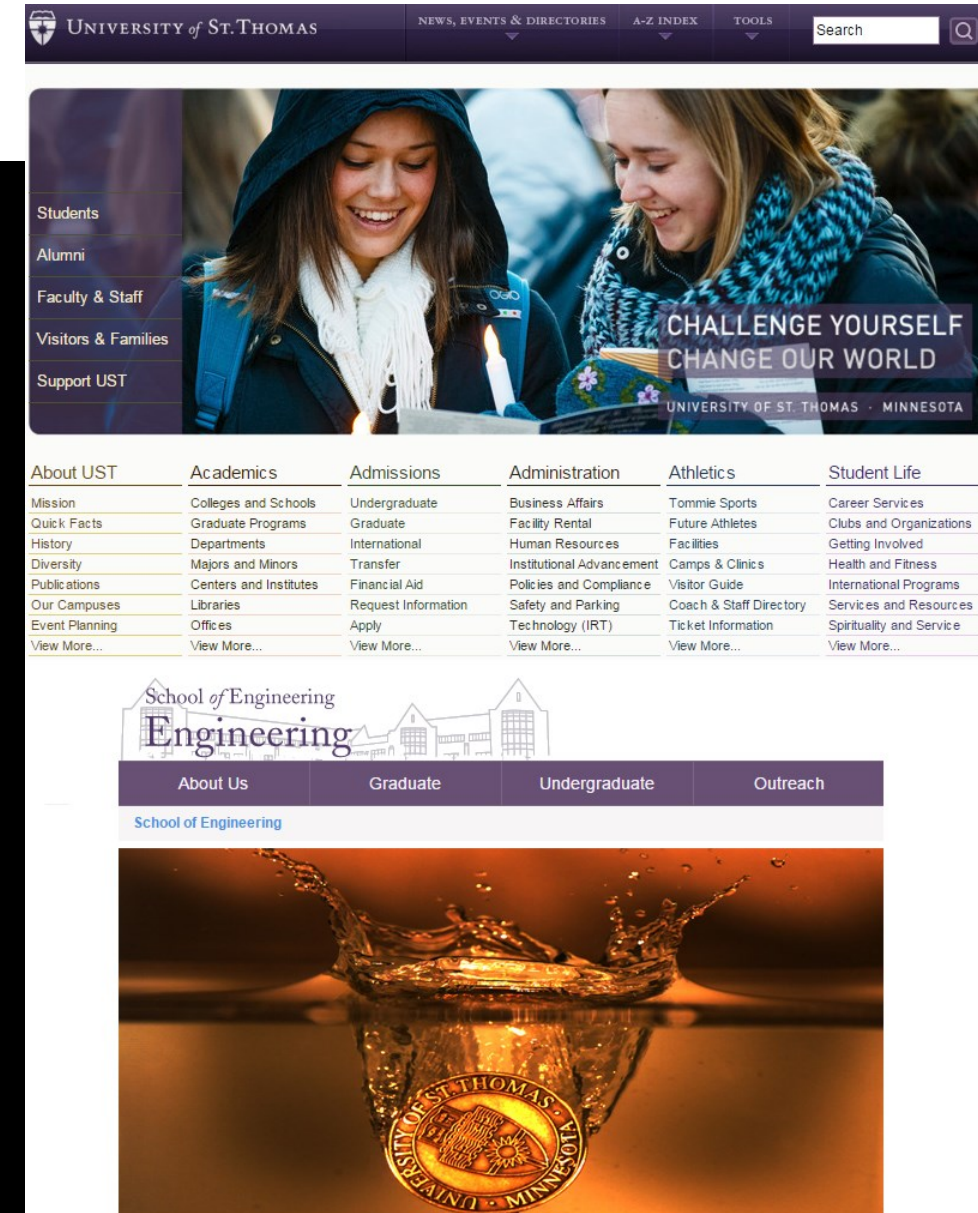
ADDRESSING THE ISSUES AT UST

- MSEE thesis/project based graduate program at the University of St Thomas with power emphasis
 - Magnetics and magnetic materials
 - Electric machines
 - Power electronics
 - Power systems
- BSEE degree with a power emphasis – systems, electronics, electric machines
- REAL – the Renewable Energy and Alternatives Laboratory

THE UNIVERSITY OF ST. THOMAS ST. PAUL, MN (NOT THE BAHAMAS)

WWW.STHOMAS.EDU

- ~ 12,000 UG & G students
- UG & G Engineering is > 10% of entire university; the single largest entity at UST
- Fully accredited (ABET) in EE and ME
- IP owned by sponsoring entity – not the University



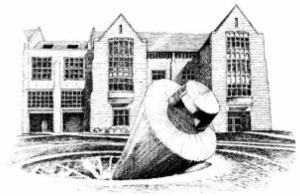
The screenshot displays the University of St. Thomas website. At the top, the navigation bar includes the university's name, links for 'NEWS, EVENTS & DIRECTORIES', 'A-Z INDEX', 'TOOLS', and a search bar. A large banner image shows two students in winter attire looking at a book, with the text 'CHALLENGE YOURSELF CHANGE OUR WORLD' and 'UNIVERSITY OF ST. THOMAS · MINNESOTA'. A left sidebar lists links for 'Students', 'Alumni', 'Faculty & Staff', 'Visitors & Families', and 'Support UST'. The main content area features a grid of links categorized by 'About UST', 'Academics', 'Admissions', 'Administration', 'Athletics', and 'Student Life'. Below this is a section for the 'School of Engineering' with a logo and a navigation bar for 'About Us', 'Graduate', 'Undergraduate', and 'Outreach'. The bottom of the page features a large image of a water splash with the university's seal.

About UST	Academics	Admissions	Administration	Athletics	Student Life
Mission	Colleges and Schools	Undergraduate	Business Affairs	Tommie Sports	Career Services
Quick Facts	Graduate Programs	Graduate	Facility Rental	Future Athletes	Clubs and Organizations
History	Departments	International	Human Resources	Facilities	Getting Involved
Diversity	Majors and Minors	Transfer	Institutional Advancement	Camps & Clinics	Health and Fitness
Publications	Centers and Institutes	Financial Aid	Policies and Compliance	Visitor Guide	International Programs
Our Campuses	Libraries	Request Information	Safety and Parking	Coach & Staff Directory	Services and Resources
Event Planning	Offices	Apply	Technology (IRT)	Ticket Information	Spirituality and Service
View More...	View More...	View More...	View More...	View More...	View More...

School of Engineering
Engineering

About Us	Graduate	Undergraduate	Outreach
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School of Engineering



REAL

Renewable Energy & Alternatives Laboratory

Dr.

Director

Director MSEE – Power Emphasis

- Resurgence of magnetics and manufacturing in the USA
- Integration of advanced/modern magnetic materials into mainstream manufacturing
- Transition to asynchronous generation up to intermediate power levels with power electronics totally managing the power conversion



THE END

FOR MORE INFO ON REAL AND RELATED RESEARCH
CONTACT:

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[HTTP://WWW.STTHOMAS.EDU/ENGINEERING/FACULTY/GREG-S-MOWRY-.HTML](http://WWW.STTHOMAS.EDU/ENGINEERING/FACULTY/GREG-S-MOWRY-.HTML)

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