Key Enabling Technologies for Next Generation Electric Machines (NGEM)

Dr. Ziaur Rahman, Technology Advisor
Electric Machines & Drives Systems
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Rahman_MDZiaur@bah.com

Losses in Induction Machines

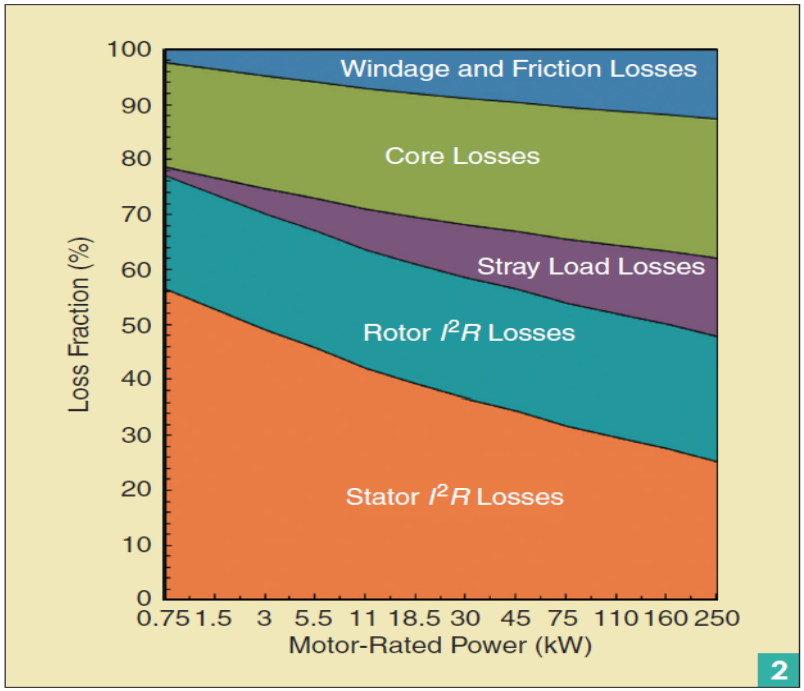


Fig. 1: Typical fraction of losses in 50-Hz, 4-pole IMs.[1]

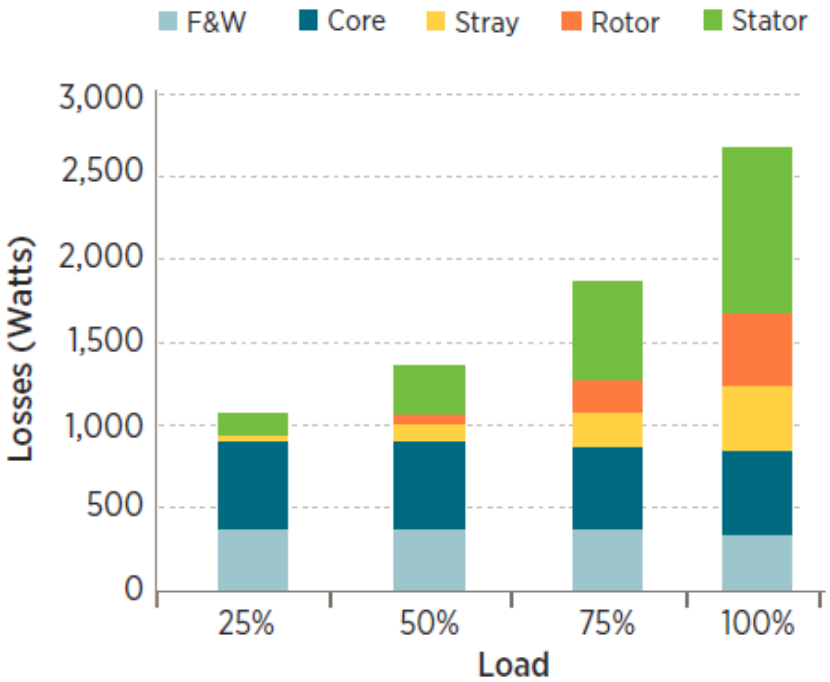
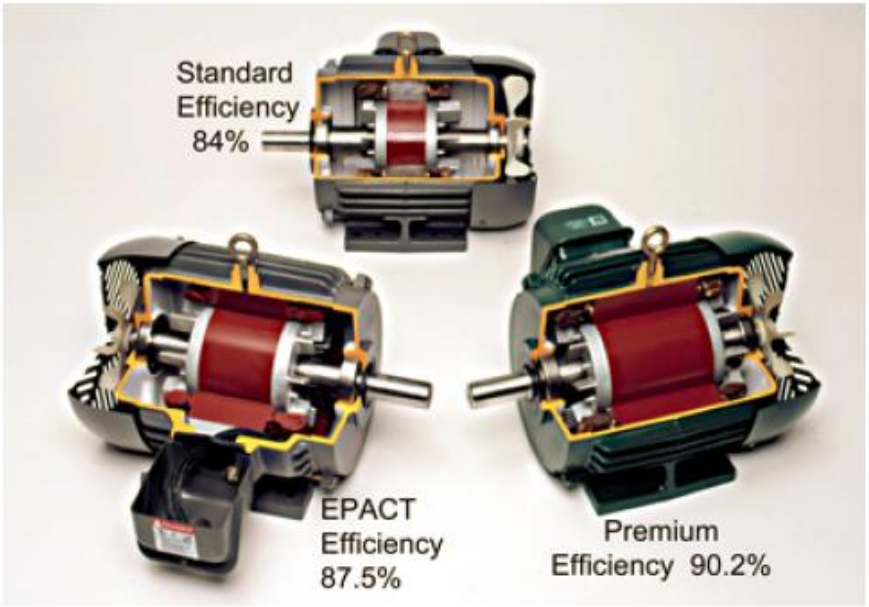


Fig. 2: Losses versus motor load for a standard efficiency motor.[2]

1. A.T. de Almeida, F. J. T. E. Ferreira, J. A. C. Fong, "Standards for efficiency of electric motors," IEEE Ind. App. Mag., vol. 17, no. 1, pp. 12–19, 2011. Available online: http://dx.doi.org/ 10.1109/MIAS.2010.939427
2. 2. Premium efficiency motor selection and application guide line – A handbook for industry, Advanced Manufacturing Office, DOE. http://energy.gov/sites/prod/files/2014/04/f15/amo_motors_handbook_web.pdf

Challenges in Increasing Efficiency

- The only way to improve motor efficiency is to reduce motor losses.
- To date, the largest possible gains in motor efficiency have already been tapped into using low loss electrical steels, PM materials and greater use of copper and aluminum in the highest-efficiency motors now commercially available, and further loss reductions have become extremely difficult and costly to achieve.



Source:(Copper Development Association Inc., 2009)

Fig. 3: Improving efficiency of a 10-hp electric motor via greater use of copper and electrical steel.[3]

3. U.S. adoption of high efficiency motors and drives: lessons learned, a historical and value chain perspective. Center on globalization governance & competitiveness, Duke University, Feb. 2010. http://cggc.duke.edu/pdfs/CGGC-Motor_and_Drives_Report_Feb_25_2010.pdf

Key Enabling Technologies

Key technologies that can enable further efficiency enhancements and weight reductions in a cost effective way while addressing the limitations of traditionally used conductive metals and electrical steels –

1. Rapid improvements in nanomaterial (carbon nanotubes) research has shown the potential of three fold improvement in the electrical and thermal properties of metallic conductors, thus, reducing stator and rotor I^2R losses significantly.
2. Affordable manufacturability of electrical steel with 6.5wt% Silicon provides the optimum condition of reducing core losses without sacrificing the saturation magnetization level.
3. Breakthrough advancements in the in-field performance of second generation high temperature superconductors makes possible to eliminate rotor resistance (I^2R) losses while also enabling considerably higher flux densities than those observed with traditional steel-core machines.

Potential Impact in Energy Savings

Key Technologies	Target Improvements	Potential Energy Savings in GWhr/Yr & % of Total US electricity		
		Industrial	Non-Industrial	Total
High performance conductors[4]	>33% reduction in stator I^2R losses.	2,861 & 0.09	22,772 & 0.58	25,633 & 0.67
Low loss soft magnetic materials[4]	>37.5% reduction in core losses.	2,143 & 0.07	9,721 & 0.25	11,864 & 0.32
Superconducting electric machines[5]	>1000A/cm-w at 2T & LN_2.	6,253 & 0.19	–	6,253 & 0.19

4. Internal calculation. Contact Rahman_MDZiaur@bah.com for details.
5. “Analysis of future prices and markets for high temperature superconductors”, J. Mulholland, T. Sheahen and B. McConnell, June 2003, ORNL, U.S. Department of Energy. See Table 3, page 15. http://web.ornl.gov/sci/htsc/documents/pdf/Mulholland%20Report%20063003.pdf

Potential Impact in Energy Savings

- When combined, the potential energy saving from these three enabling technologies is 43.75 TWhr/Yr, which is 1.18% of total U.S. electricity consumption.
- This is a fairly conservative estimate of energy saving as these calculations are done at 50/60 Hz operating frequency, and percent reduction in losses are expected to be much higher as operating frequency goes up with the inclusion of variable speed drives (VSD), thus paving the path for further loss reductions in VSD integrated applications.
- In addition, these enabling technologies will impact electric machines used in the growing green and alternative energy sectors, such as, wind, electric propulsion or grid storage applications.

Other Enabling Technologies

High Voltage Insulation for stator wires	Aggressive Thermal Management	Others
▪ Improvement in high-voltage high-frequency (dv/dt). ▪ Improvement in break down temperature. ▪ Improvement in thermal conductivity.	▪ Improvement in stator cooling. ▪ Improvement in rotor cooling. ▪ Reduction in overall cooling power. ▪ Low cost cryogenic solutions for superconductors.	▪ High speed, low loss bearings. ▪ Novel motor concepts. ▪ Analytic, firmware for accurate prediction of ‘stray’ losses.