Highly Efficient Conical Gap Motor Using Soft Magnetic Composites and Grain-Oriented Electrical Steel

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Regal Beloit / Texas A&M University
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Overview

Timeline

- Award issued September 2017
- Projected End date December 2019
- Project 20% complete

Budget

	FY 17 Costs	FY 18 Costs (planned)	FY 19 Costs (estimated)	Total Planned Funding (FY 17-Project End Date)
DOE Funded	18.4K	360K	400K	<$800K
Project Cost Share	4.6K	90K	100K	<$200K

Barriers

- Acquisition of internal commercial components from a production line still in start-up mode.
  - Not expected beyond BP1
- Drive linearity range narrower than expected.
  - Working with alternate drive manufacturer since June 1

Partners

- Regal Beloit
  - 6 regular engineers, technicians, project personnel
- Texas A&M University
  - 2 Faculty – Dr. Toliyat, Dr. Rahimian
  - 2 Graduate students

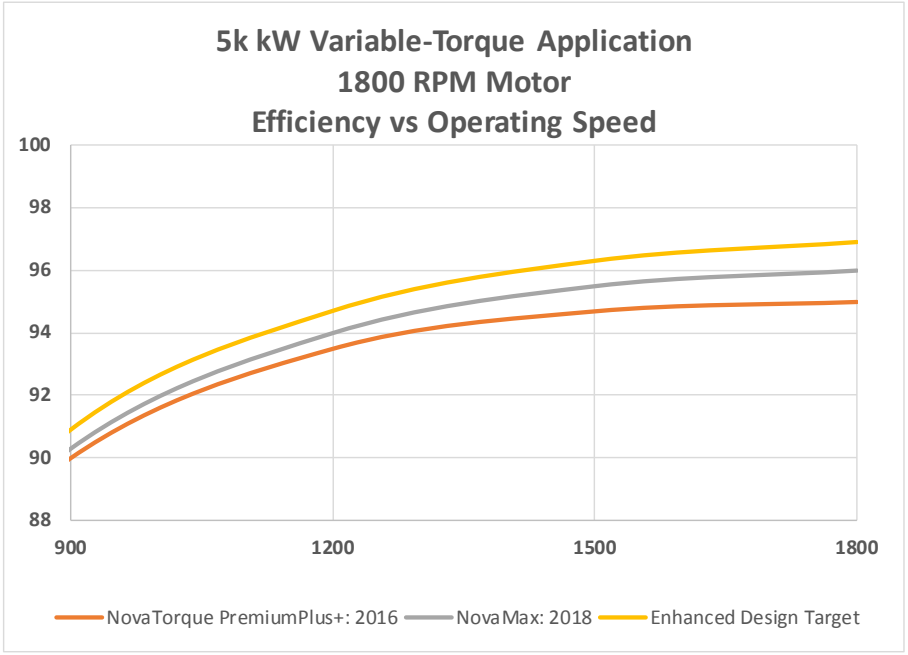
Objectives

The goal is to develop a cost-competitive 5 kW motor with 96.8% efficiency.

- Significant reduction in energy wasted (and heat produced) relative to standard motors
- Useful for a wide range of applications: fans and blowers, pumps, compressors, generators, etc.

This goal will be achieved by

- Leveraging proven design
- Use of Soft Magnetic Composites (SMCs) to augment the performance of Grain Oriented Electrical Steel (GOES) in the stator
- Extensive Modeling
- Experimental Testing

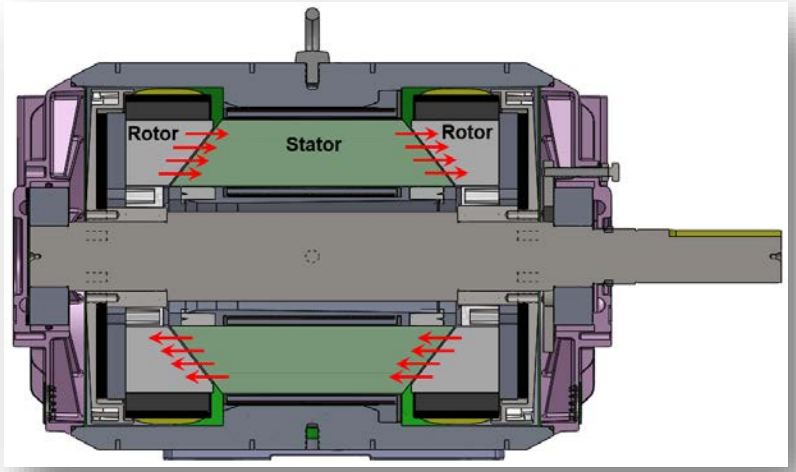


Technical Innovation

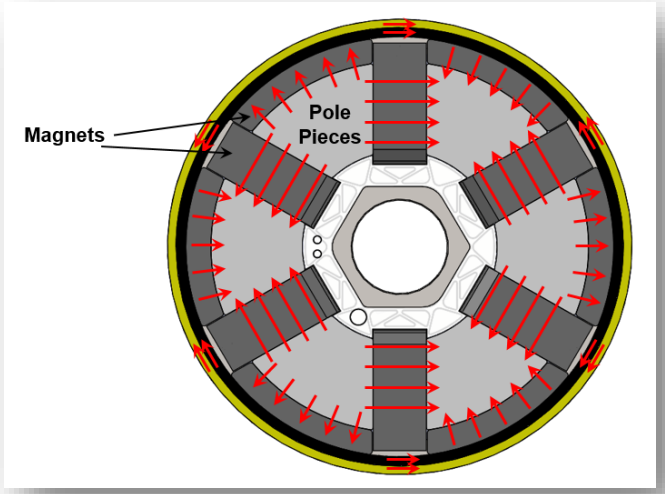
NovaMax motor at Regal Beloit:

- Dual-rotor, axial flux, interior permanent magnet motor using ferrite magnets.
- Conical air gaps enhance magnetic flux concentration by a factor of 1.2x to help take advantage of low cost ferrite magnets.
- Soft Magnetic Composite (SMC) in the rotors provides a path to further concentrate the flux to a factor of ~3.7x, in 3 dimensions with low losses.
- A straight axial flux path in the stator laminations allow use of Grain Oriented Electrical steel (GOES), commonly used in transformers to take advantage of high permeability and loss characteristics of GOES.

Air Gap Flux Paths



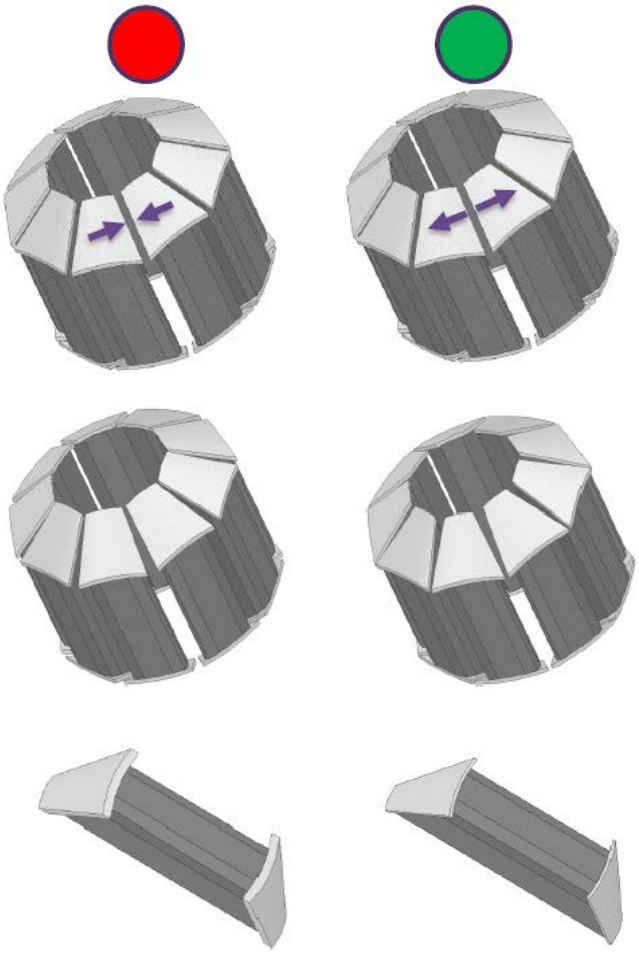
Rotor Flux Paths



Technical Innovation

New Approach for Significant Improvement:

- Add Soft Magnetic Composite (SMC) to the stator pole ends to increase flux collection area in the air gap. Increased flux results in higher torque output for same Ampere turns input.
- Balance and optimize the loss distribution to reduce the core loss and minimize overall loss.
- All potential design changes are focused on improved manufacturability.
- All tools are combined to reduce the losses 21% from the current design



Adding SMC to the Stator

Technical Approach

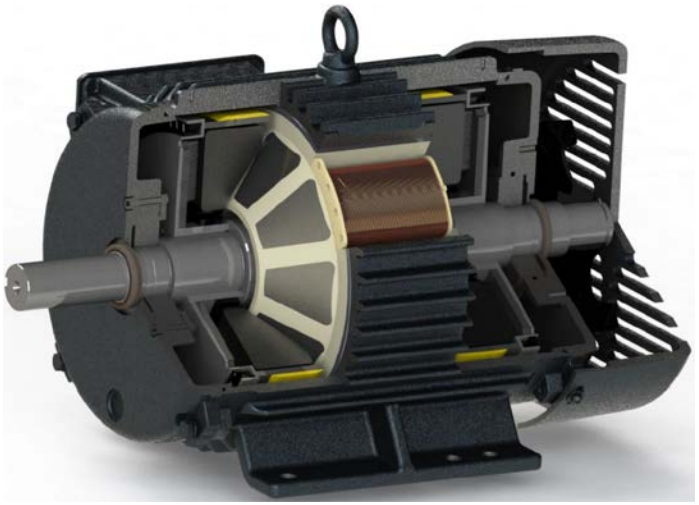
- Motor losses of the original design are calculated with FEA modeling to get an expected breakdown of losses.
- The motor is tested over a wide speed and torque range to determine the various components of loss. Analytical loss distribution is correlated with measured loss distribution to form an accurate model to investigate future design changes.
- Stator SMC flux cap performance is evaluated for various design options to determine which options provide the best reduction of losses.
- Motors will be designed, built and modified at Regal Beloit.
- Motor testing will be done at both Regal Beloit and Texas A&M.
- Magnetic FEA modeling will be done at Texas A&M.
- Evaluating designs and tradeoffs of design choices for optimum performance will be done by both Regal Beloit and Texas A&M.

Technical Approach

- Risk: Achieving an additional 21% reduction in losses from a motor that already has very high efficiency
  - Optimizing systems, not just components through multiple variable analysis in FEA and a validated physical model
  - Validating significant trends with physical testing
- Challenge: Cost must be held in check because we are in a competitive market
  - Identify material cost per watt saved and trends for optimization
  - Adding material only if the gains show a significant value in terms of a 12-18 month payback on energy savings
  - Reduce material where possible.
- This motor topology has been in limited production , and is presently going through volume production ramp.

Results and Accomplishments

- **Accomplishments:** Currently in Budget period 1 working on Tasks 1, 2 and 3 until October 2018. **Milestones not complete yet:**
  - Milestone 2.7.1: Report motor loss breakdown and identify areas for improvement to meet project objectives of 21% reduction in losses
  - Milestone 3.5.1: Model to predict motor losses within +/- 10% of experimental losses.
  - Milestone 3.5.2: Improved model to show 21% reduction in overall losses.



- **Original Efficiency Improvement goal:** Reduce overall losses by 21 % to increase motor efficiency from 95% to 96% (June 2016)
  - New ownership of technology: Design improvements for manufacturability
  - Recent test results of newly built motors have efficiency of 96.0% at project operating point of 5 kW at 1800 RPM.
- **Revised Efficiency Improvement goal:** Reduce overall losses by 21 % to increase motor efficiency from 96% to 96.8%

Transition

- Initial markets for this technology
  - OEM air handling
  - Retrofit air handling
  - OEM equipment - generators, industrial, pumps
  - High duty cycle variable speed application
- Commercialization
  - Regal is making significant investments in marketing and manufacturing to promote and enable the use of the technology developed in this program.
  - Potential extension of the technology to larger and smaller motor frame sizes.
- Market Drivers
  - The motor has value due to the dominant cost being in lifetime consumed power as opposed to purchase (Consider total cost of ownership)

Questions?