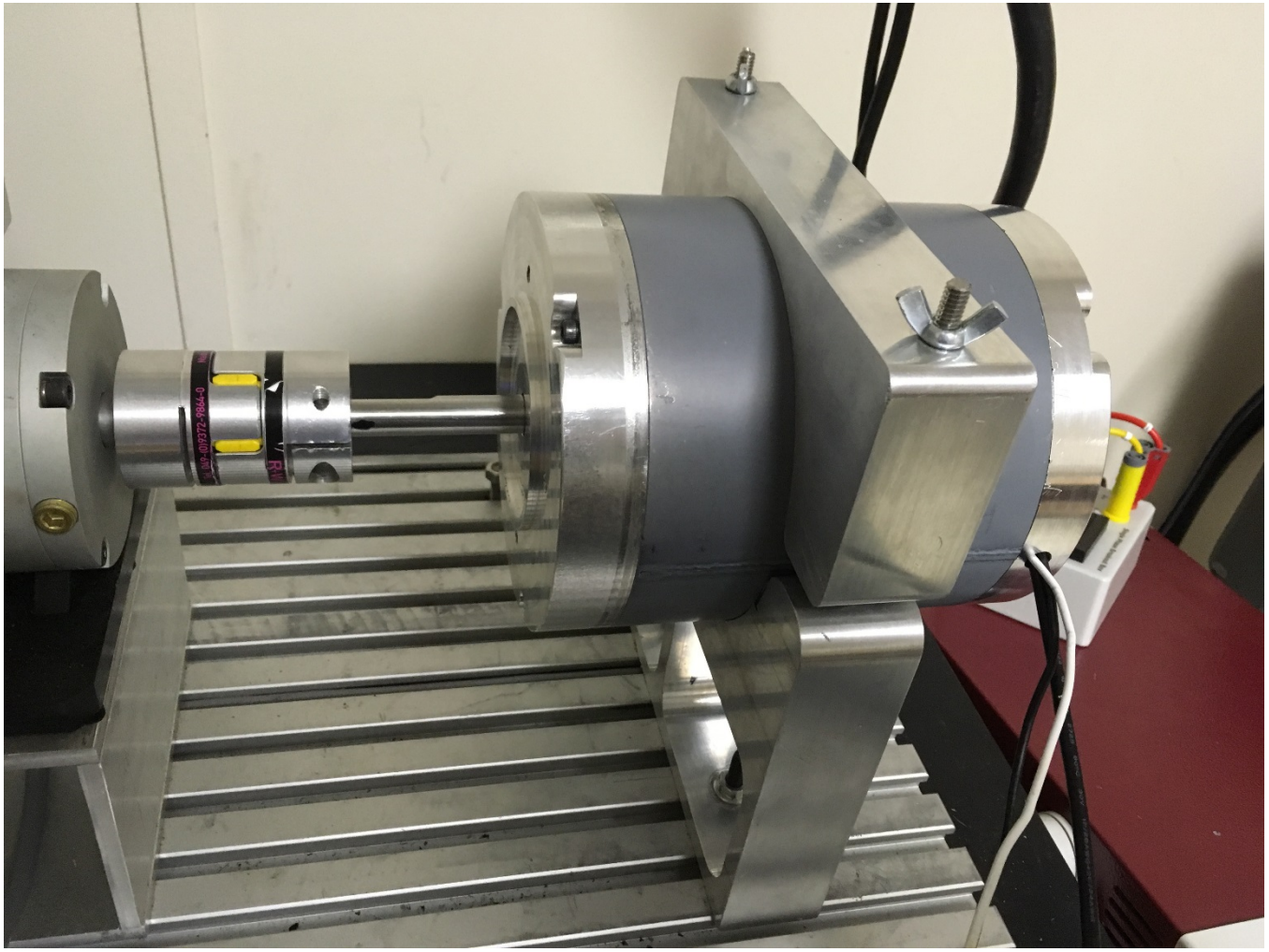
Higher Efficiency HVAC Motors

2017 Building Technologies Office Peer Review



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Project Summary

Timeline:

Start date: 10/1/14

Planned end date: 3/31/17

Key Milestones

1. Target Application and Machine Specs; 2/13/15
2. Motor Design; 9/30/15
3. Build prototype; 3/31/17
4. Performance validation; 8/31/17

Budget:

Total Project $ to Date:

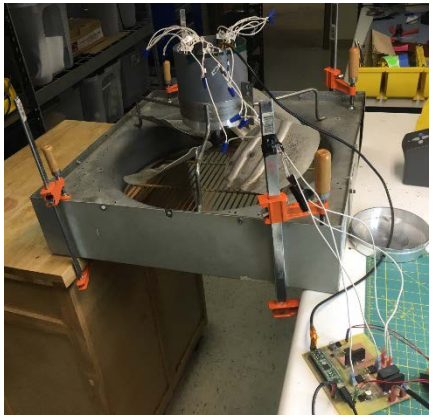
- DOE: $673,383
- Cost Share: $626,587

Total Project $:

- DOE: $750,000
- Cost Share: $635,756

Key Partners:

UTRC	Carrier



Project Outcomes:

Produce higher efficiency HVAC Motor

Validate motor performance

Reduce building energy consumption

Bring high efficiency cost effective motor to the market

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Purpose and Objectives

Problem Statement: Most of the hundreds of millions of residential and smaller commercial HVAC units in the U.S. contain low efficiency induction fan motors. Higher efficiency Electronically Controlled Motors (ECM) that have become available have low power factors and thus give up much of their efficiency advantage in the form of higher current draw. Moreover, ECM efficiency is limited due to the continual power conversions and electronic commutation required during operation.

Target Market and Audience: Residential and smaller commercial HVAC and commercial refrigeration equipment collectively use greater than 2 quads of primary energy according to DOE/BTO. QM Power will ultimately target HVAC OEMs, contractors, end users and utilities to commercialize its superior fan motors.

Impact of Project:

a. **Near-term:** Complete prototype assembly and testing, which will prove meaningful efficiency gains compared to incumbent induction and EC motors.
b. **Intermediate:** Expand the technology to additional sizes to address a broader set of HVACR applications, and adapt the technology to address the compressor and pump motor markets.
c. **Long-term**: When fully developed and commercialized, QMP's technologies have the potential to achieve over 1 quad of primary energy savings in HVACR fan systems alone, with significant additional savings available in other applications.

Approach

Approach:

- Develop, test, and commercialize advanced HVAC motors with higher efficiency and power factor than available Induction or Electronically Controlled Permanent Magnet motors.
  - Adapt Q-Sync Synchronous motor technology to higher power levels and to operate at multiple speeds.
  - Minimal electronic power conversion to achieve higher efficiency and power factor.
    - Avoid dual power conversion (no AC to DC to AC).
- Confirm superior performance through prototype characterization and performance validation by United Technologies Research Center (UTRC).

Approach

Key Issues:

- Minimal electronic power conversion requires innovative controls.
- No DC link capacitor to absorb inductive energy during switching.
- Operation at multiple speeds with a single (line) frequency source.

Distinctive Characteristics:

- The design combines an Internal Permanent Magnet Parallel Path Magnetic Technology (IPM-PPMT) topology with a Q-Sync based electronic controller, enabling higher efficiency and power factor than incumbents at multiple speeds.
- Elimination of the DC link capacitor improves cost and reliability.
- Simplified electronics.
- Single phase stator winding.

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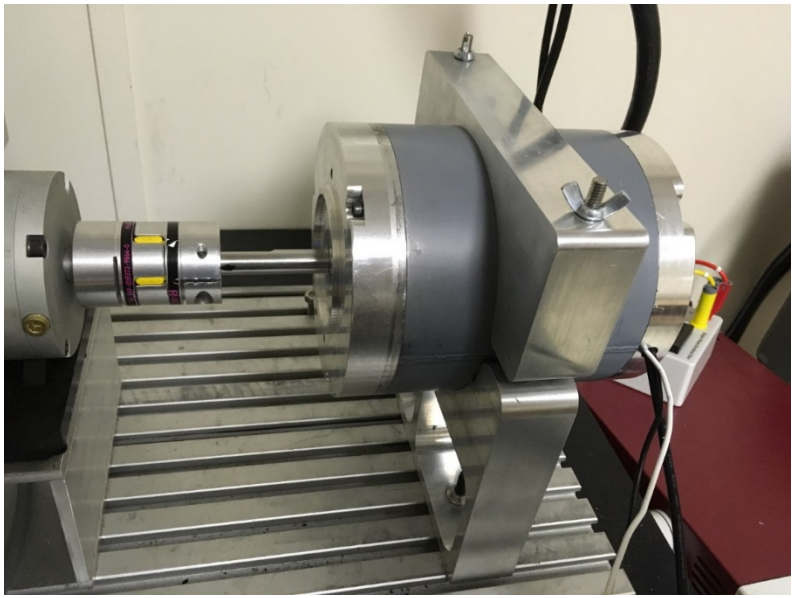
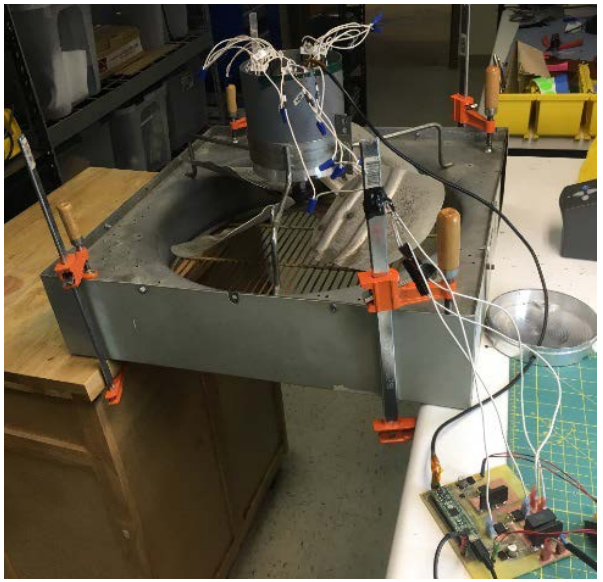
Progress and Accomplishments

Accomplishments:

- Prototyped several ½ HP 1200 rpm motor and controller configurations to arrive at optimum balance of full speed (line frequency sync) performance and control at lower speeds.
- Demonstrated 89% peak efficiency & 0.88 power factor for ½ HP rated motor.
- Demonstrated multiple speed operation by adapting our production model 50W, 1800 rpm fixed speed fan motor to incorporate the new controls.
- Efficient switching at various speeds below line synchronous.





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Progress and Accomplishments

Market Impact: The potential to achieve over 0.5-1.0 or more quads of primary energy savings in residential and commercial building HVACR fan applications using Q-Sync fan motors up to 1 hp. Successful demonstrations of smaller versions of QM Power's novel designs are helping to spread awareness of Q-Sync's superiority and should make the market fertile for these better HVAC motors, especially given many of the largest OEMs have both HVAC and refrigeration divisions.

Awards/Recognition: N/A
Lessons Learned: N/A

Project Integration and Collaboration

Project Integration: Engaged UTRC/Carrier in the early design process to target specifications of the project, and to determine testing parameters and characteristics.

Partners, Subcontractors, and Collaborators:
QM Power is collaborating with the support of United Technologies Research Center (UTRC) and, by extension, Carrier to develop advanced HVAC fan motors.

Communications: N/A

Next Steps and Future Plans

Next Steps and Future Plans:

- Complete final ½ HP prototype hardware and software design iteration incorporating multiple speed control.
- Demonstrate and validate the improved performance vs. incumbents.
- Manufacturing plan and cost analysis.
- Expand the product range to address a broader market (1/4- 1 hp).
- Analyze potential energy savings for broader market.
- Apply the technology to the compressor and pump motor markets.

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REFERENCE SLIDES

Project Budget

Project Budget: The budget was revised upward as a result of QM Power changing from a single to multi-rate structure. This change, however, did not impact DOE's funding commitment; it did increase QM Power's cost share from 20% to 46%.
Variances: The original project design portion required fewer funds than budgeted for, however, additional prototyping iterations during controller development have nearly exhausted the projected budget. QM Power will contribute additional cost share to complete remaining prototyping and testing activities to meet project goals.
Cost to Date: $1,299,969.16 through January 2017, or 94% of the budgeted total.
Additional Funding: Series C venture capital financing closed in March of 2016.

Budget History

10/1/14 – FY 2016 (past, actual)		FY 2017 (current period, planned)		Project Totals (planned)	
DOE	Cost-share	DOE	Cost-share	DOE	Cost-share
$613,216	$566,030	$136,784	$69,724	$750,000	$635,755

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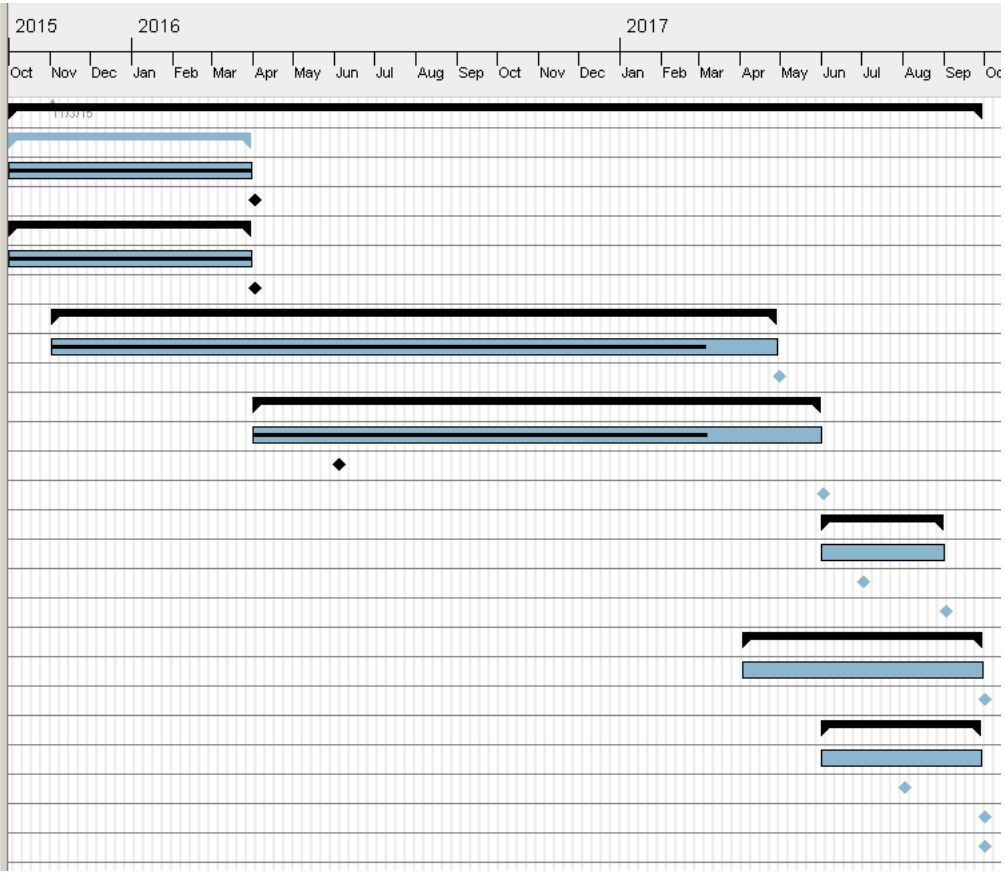
Project Plan and Schedule

- Project began 10/1/14 & is scheduled to end 9/30/17.
- Original end date was 9/30/16, a no-cost extension to 3/31/17 was granted, and an additional, no cost to the government, extension to 9/30/17 has been requested. The Gantt chart below assumes that extension will be granted.
- Current Work: Third prototype iteration exceeding efficiency goal at part load with new control strategy. Final hardware and software design iteration will be completed next month followed by thorough performance evaluation.

Name	Begin d...	End d...	Completion
Phase II Motor & Controls Fabrication and Testing	10/1/15	9/29/17	68
Task 6	10/1/15	3/30/16	100
Motor Fabrication	10/1/15	3/30/16	100
6.1 Fab and assembly of test motors	3/31/16	3/31/16	100
Task 7	10/1/15	3/30/16	100
Motor Controller Fabrication	10/1/15	3/30/16	100
7.1 Fab and assembly of controller	3/31/16	3/31/16	100
Task 8	11/2/15	4/28/17	89
Controller Tuning and Testing	11/2/15	4/28/17	90
8.1 Complete tuning and test report	4/28/17	4/28/17	0
Task 9	4/1/16	5/31/17	79
Dynamometer Testing	4/1/16	5/31/17	80
9.1 Verify test setup	6/2/16	6/2/16	100
9.2 Dynamometer testing results	5/31/17	5/31/17	0
Task 10	6/1/17	8/31/17	0
Characterization and Validation	6/1/17	8/31/17	0
10.1 Experimental Setup	6/30/17	6/30/17	0
10.2 Experimental Validation	8/31/17	8/31/17	0
Task 11	4/3/17	9/29/17	0
T2M Strategy & Commercialization Plan	4/3/17	9/29/17	0
11.1 Manufacturing Analysis	9/29/17	9/29/17	0
Task 12	6/1/17	9/28/17	0
Additional HVAC Applicaitons	6/1/17	9/28/17	0
12.1 Prelim Analysis - Energy Savings	7/31/17	7/31/17	0
12.2 Refined Analysis - Energy Savings	9/29/17	9/29/17	0
Final Report	9/29/17	9/29/17	0



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