Efficient Refrigeration Condenser Fan Motors

CASE STUDY: DENVER SUPERMARKET

Background

Supermarkets are among the most energy intensive building types in the U.S. Commercial refrigeration systems must run 24/7 to keep perishable food products fresh or frozen. An average supermarket spends about $4 per square foot on electricity, with 40% consumed by the refrigeration system[1]. Since supermarkets and grocery stores operate on extremely thin profit margins[2], they are always looking for refrigeration technologies that can reduce energy spending. This fact sheet highlights a new technology called a high rotor pole switched reluctance (HRSR) motor that can help grocers improve the efficiency of their refrigeration systems.

Refrigeration Basics

When liquid refrigerant absorbs heat from inside commercial refrigeration display cases, it evaporates. It is then compressed and must release this heat and condense back into a liquid to complete the refrigeration cycle. In a typical supermarket, this release of heat happens in a piece of equipment called a condenser. Most condensers are air cooled, meaning that they use a bank of fans to pass air over them to take the heat away.

The High Rotor Pole Switched Reluctance (HRSR) Motor

While switched reluctance motors have existed for several decades, the new HRSR design has improved controllability and efficiency. It has a nameplate efficiency of 93% for 1+ hp motors, is inherently variable speed, and is more efficient across a wide range of speeds when compared to induction motors paired with variable frequency drives. The National Renewable Energy Lab (NREL) researchers hypothesized that HRSR motors should outperform induction motors in condensers whether using CFS or VHP controls. In collaboration with Walmart they put their hypothesis to the test.

The Field Test Setup

Technicians replaced half of the induction motors in two condensers at a Walmart supermarket in the Denver area with HRSR motors (Figure 1). The field experiments involved carefully measuring the power consumption of the legacy induction and HRSR motors (the energy efficiency measure or “EEM”) at different fan speeds. These measurements allowed the researchers to compare the estimated annual electricity consumption of induction or HRSR motors operating under CFS or VHP control, as shown in Table 1.

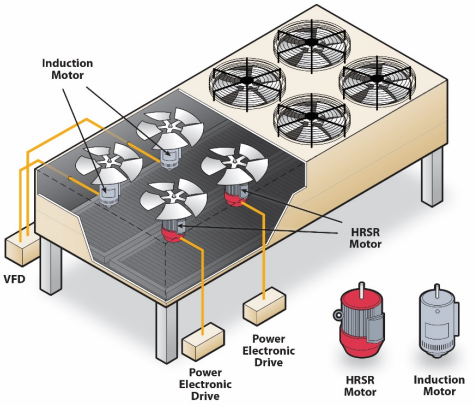

Figure 1: Installation of HRSR motors

KEY CONDENSER FACTS

Condensers are not all created equal in terms of their energy efficiency; their overall energy use can vary depending on how they are controlled.

- **Most condensers can improve their motor efficiency:**

  The nameplate efficiency of the legacy 1.5 horsepower induction motors used in this case study to drive condenser fans was 74%. This level of efficiency is common in basic induction motors at the lower power ranges from 1-5 hp[3].

- **Condensers benefit from advanced motor controls:**

  Using a variable head pressure (VHP) strategy instead of constant fan speed (CFS) can produce dramatic energy savings, since fan speeds are reduced when the outside air temperature is low and the refrigeration load is less.

Table 1. Baseline and Energy Efficiency Measures

Scenario	Baseline Control	EEM Control	Baseline Motor	EEM Motor
1	CFS	CFS	Induction	HRSR
2	VHP*	VHP	Induction	HRSR
3	CFS	VHP	Induction	Induction
4	CFS	VHP	Induction	HRSR

Quantitative Results

Estimated energy savings ranged from 29% to 71% depending on the combination of control strategy and which motors were being compared (Table 2).

Even when using CFS control, where fans remain at a constant rpm, annual energy use is cut by almost a third with the HRSR motors. When comparing induction and HRSR motors under VHP control, savings improve by an additional 4%. The results underline the savings to be gained by switching from CFS to VHP condenser controls regardless of the motor type – savings can exceed 50% for induction motors and 70% for HRSR motors.

- **What's the impact on the bottom line?**

  Going from induction motors using CFS control to HRSR motors using VHP control could save about 4,400 kWh/year per motor in Colorado. At 10 cents per kWh, savings for a 10-motor condenser could total $4,400 per year.

- **Where would a retrofit make sense?**

  Sites with constant speed legacy induction fan motors ranging from 1-10hp in areas with high electricity prices would be most likely to recoup their investment in HRSR motors with VHP controls in less than three years.

Qualitative Results

The HRSR motors used in the field testing include real-time operational monitoring for speed, torque, and power. This monitoring allowed the manufacturer to identify a locked rotor problem caused by a piece of foam and to remotely shut down the motor. With a traditional motor system, serious motor damage could have resulted.

Other HRSR Applications

HRSR has the potential to contribute in commercial buildings beyond supermarkets, in particular retrofitting supply fan motors in packaged rooftop HVAC systems:

- Laboratory and field testing of this application suggested annual savings in Southern California of 50-57% versus a single-speed induction motor and 11% versus variable speed induction motor[4].

Table 2. Annual Energy Savings

Scenario	Baseline Energy (kWh/motor)	EEM Energy (kWh/motor)	Savings (kWh/motor)	Savings (%)
1	6,186	4,369	1,817	29%
2	2,641	1,775	866	33%
3	6,186	2,641	3,545	57%
4	6,186	1,775	4,411	71%

NREL would like to acknowledge the contributions of their partners in the field study including VaCom Technologies, the legacy data acquisition manager; SMC Motors, the HRSR motor manufacturer; and Walmart Corporation, who hosted the field evaluation.

The full technical report for the field study can be found here.

[1] EPA 2008. Energy Star Building Manual, Facility Type: Supermarkets and Grocery Stores
[2] Ibid.
[3] DOE. 2014. Premium Efficiency Motor Selection and Application Guideline. Advanced Manufacturing Office, Washington, DC: U.S. Department of Energy.
[4] Southern California Edison Emerging Products (2018). Software-Controlled Switch Reluctance Motors.