IN^2 Final Report

TO: Wells Fargo Innovation Incubator (IN^2) Board of Directors

FROM: National Renewable Energy Laboratory (NREL)

DATE: April 2023

IN^2 Company Name: Turntide Technologies (demonstration project)

I Technology Description

It is estimated that 38.4% of the total U.S. electrical energy consumption is used to run motors.[1] Even a small increase in motor efficiency could greatly reduce energy consumption. Turntide has developed a patented High Rotor-Pole Switched Reluctance (HRSR) Motor system that can purportedly achieve up to 95% peak motor efficiency and maintain similarly high levels of performance over a wide range of operating speeds with its variable speed power drive. Figure 1 shows the Turntide high-rotor pole switched reluctance motor.

Figure 1. Turntide high-rotor pole switched reluctance motor

[1] J. Douglas and G. McCoy, 2014 *Premium Efficiency Motor Selection and Application Guide: A Handbook for Industry*. (Advanced Manufacturing Office: U.S. Department of Energy, 2014, DOE/G0-102014-4107).

Turntide has focused on retrofit applications for heating, ventilating, and air-conditioning (HVAC) systems including commercial rooftop units (RTUs) and air handling units. Its 1-15 horsepower (hp) product line is well-positioned to replace most commercial RTU supply fan motors. Turntide reports that its motor peak and part-load efficiencies are superior to induction motors and electronically commutated motors, which are the most common RTU supply fan motors. Turntide has developed a standard motor controller with inherent variable speed control that is required to control the HRSR motor. The company has begun to take advantage of its controller to provide additional energy savings for RTU retrofit applications. They now offer staged fan speeds that change based on whether the RTU is in ventilation, cooling or heating mode. The goal of this project, as shown in Table 1, was to evaluate both energy efficiency measures (EEMs), as listed below:

Table 1. Description of the energy efficiency measures evaluated during the Wells Fargo Beta project

Number	Energy Efficiency Measure (EEM)	Description	Application
EEM1	Higher efficiency motor	The High Rotor Pole Switched Reluctance Motor	Retrofit of the supply fan motor, operated at the same full speed as baseline
EEM2	Higher efficiency motor + Staged fan speeds	Reduce fan speed to 40% for ventilation mode and 90% for cooling and heating mode	Retrofit of the supply fan motor. Requires interception of thermostat wire or RTU control signals

According to a PNNL study2, EEM2 can provide significant savings simply by reducing the fan speed for ventilation mode from 100% down to 40%. Less significant savings were reported by reducing the fan speeds for cooling and heating mode.

II Project Description

The goal of this project was to evaluate the energy savings due to the improved efficiency of the HRSR motor (EEM1) and the energy savings due to the improved efficiency of the HRSR motor plus the reduced fan speeds (EEM2). Two Wells Fargo sites were selected in the Denver, Colorado, area (Englewood and Wheat Ridge branches) with baseline supply fan motors of 1 and 3 hp. NREL measured the speed and power of the baseline motors over an approximately two-week period. The Turntide system,

[2] Wang et. al. *Advanced Rooftop Control Retrofit: Field-Test Results*. July 2013. https://www.pnnl.gov/main/publications/external/technical_reports/PNNL-22656.pdf

which included the HRSR motor and the motor driver, was installed and the thermostat signal was routed to the motor driver in order to be able to stage fan speeds. The first EEM was evaluated by fixing the HRSR motor speed to match the baseline motor speed. The second EEM was evaluated by allowing Turntide to change fan speeds based on RTU mode. It was witnessed during this project that Turntide installs both EEM1 and EEM2 as a package for supply fan retrofits. NREL had to ask Turntide to fix its fan speed to match the baseline, but this is not normal procedure. The EEM1 evaluation occurred over a 10-week period. The EEM2 evaluation took place over two weeks.

III Project Outcomes

Table 2 summarizes the energy savings for the Englewood site with the 1 hp motor. The site with the 3 hp motor had too many issues with the data to provide reliable results. Both sites had to overcome several issues noted below:

1. Both sites had low run-times of the RTU; NREL asked Wells Fargo to expand operation hours to keep the supply fan on in order to capture baseline and EEM data.

2. Both motors were running at very low power consumption, likely due to oversizing, low airflow, or low torque. The 1 hp motor was consuming an average of 0.37hp and the 3 hp motor was consuming an average of 0.449 hp. This is an issue worth investigation to ensure proper operation of RTUs. Improper motor sizing can lead to increased power consumption, extreme supply air temperatures (both high and low temperatures are possible, the coil could freeze with extremely low supply airflow in cooling mode).

3. While installing the Turntide system, Turntide's contractor changed the sheave and belt. This changed the system and made the data for both EEMs not comparable to the baseline. Future field evaluations should include more measurements to check blower speed and supply and return air temperatures. Due to extensive previous laboratory and field evaluation with Turntide, NREL was able to predict the results with the HRSR motor. This only affected EEM1 as both predicted and actual field results for EEM2 yielded similar results.

Table 2 shows the power savings for each EEM. Predicted and actual field results are shown in Table 2 as absolute values (power in watts) and in relative values as well (percent compared to baseline). As mentioned previously the Turntide system actually increased power consumption with the same fan speed as the baseline. This was likely due to some unforeseen issues with the installation. Regardless, NREL was able to predict the performance of the Turntide system for EEM1 and EEM2 based on previous laboratory and field evaluations. Predicted savings ranged from 13-63% with EEM2 providing the most savings. Actual field results ranged from -36-83% savings. Looking at an average day with a mixture of ventilation and cooling/heating mode, the average predicted and actual field power consumption were 197 and 186 watts respectively. This shows the importance of leveraging both the high efficiency motor and the advanced rooftop controls for more robust energy savings. Even with poor performance in the field for EEM1, power was reduced almost the same in the field as predicted by NREL for EEM2.

Table 2. Predicted and actual field results for the Turntide System

Description	Fan Speed	Predicted Results		Actual Field Results	
		Power (W)	Savings (%)	Power (W)	Savings (%)
Baseline Induction Motor	100%	374	-	374	-
EEM1	100%	323	13.7	510	-36.4
EEM2	Cooling/Heating Mode, 90%	291	22.2	388	-3.6
	Ventilation, 40%	139	62.8	60.8	83.8
	Average Daily Run	197	47.4	186	50.3

Based on the results from the field evaluation NREL and Turntide created guidelines for Wells Fargo to use when considering where Turntide's system would provide the most savings:

Guidelines for site selection to maximize savings for Turntide installations for retrofit applications

1. Look for high supply fan motor run-times. During the project, one of the Wells Fargo buildings was using the RTU only 4% of the time: This reduces the total energy savings possible.
2. Look for 3-7.5 hp motors with high loading. Low-loaded, low-hp motors offer less savings potential.
3. No VFD on the baseline motor improves savings potential.
4. Consider locations with high rebates available for Turntide HRSR motors. There are rebates in Pennsylvania, Maryland, New Jersey, Illinois, California, and other states. Review this one-pager provided by Turntide for more information: https://turntide.com/wp-content/uploads/2023/03/Rebates-for-End-Customers.pdf
5. Use advanced rooftop control (ARC) strategies, which provide a majority of the savings, but check indoor air quality and outdoor air ventilation rates.
6. Measure blower speed to confirm it is the same before and after installation.
7. Check that the correct supply airflow is provided for the RTU and consider down-sizing motor if ductwork has low pressure.

Lessons Learned

1. It is possible that Wells Fargo is not using enough supply airflow for cooling. The manufacturer suggests 2,000 cfm for the five ton RTU at the Englewood site. Based on the power consumption witnessed during this field evaluation of 374W (0.5 hp), the output power could be roughly 224-254W or 0.3-0.4 hp. The

highlighted values in Figure 2 show that the majority of the possible airflows at this output power are lower than 2,000 cfm. Low airflow can reduce capacity in cooling or heating, can trip the low-pressure alarm during cooling, and can cause extreme supply air temperatures. Significantly low airflow can freeze the evaporator coil during cooling or cause high temperature trips during heating.

Table 95. Belt drive evaporator fan performance - 5 tons high efficiency - THC060E3,E4,EW,F3,F4,FW downflow airflow

	External Static Pressure (Inches of Water)																			
	0.10		0.20		0.30		0.40		0.50		0.60		0.70		0.80		0.90		1.00	
cfm	rpm	bhp	rpm	bhp	rpm	bhp	rpm	bhp	rpm	bhp	rpm	bhp	rpm	bhp	rpm	bhp	rpm	bhp	rpm	bhp
	1-hp Standard Motor & Low Static Drive Accessory Kit(a)														1-hp Standard Motor & Drive					
1000*	379	0.06	469	0.09	546	0.12	614	0.16	676	0.20	732	0.24	784	0.28	833	0.33	879	0.37	922	0.42
1200*	416	0.09	498	0.12	571	0.158	635	0.20	694	0.24	749	0.28	800	0.33	849	0.38	894	0.43	938	0.48
1400*	456	0.12	531	0.16	599	0.20	662	0.25	717	0.29	769	0.34	820	0.39	867	0.44	911	0.50	955	0.56
1600	499	0.16	570	0.21	631	0.25	691	0.31	745	0.36	794	0.41	842	0.46	887	0.52	930	0.57	972	0.63
1800	544	0.22	609	0.27	667	0.32	721	0.37	773	0.43	823	0.49	868	0.55	911	0.61	953	0.67	992	0.73
2000	589	0.29	650	0.35	706	0.40	755	0.46	804	0.52	851	0.58	897	0.65	938	0.71	978	0.77	1017	0.84
2200	636	0.37	692	0.43	745	0.50	793	0.56	838	0.62	882	0.68	925	0.75	967	0.83	1007	0.90	1044	0.97
2400	683	0.47	736	0.54	785	0.61	833	0.68	875	0.74	916	0.81	956	0.88	996	0.95	1036	1.03	1073	1.11

Continued

	External Static Pressure (Inches of Water)									
	1.10		1.20		1.30		1.40		1.50	
cfm	rpm	bhp	rpm	bhp	rpm	bhp	rpm	bhp	rpm	bhp
	1-hp Standard Motor & Drive									
1000*	962	0.46	1002	0.51	1040	0.56	1076	0.61	1111	0.66
1200*	979	0.54	1018	0.50	1055	0.64	1091	0.70	1126	0.75
1400*	996	0.61	1035	0.67	1072	0.73	1107	0.79	1143	0.85
1600	1013	0.70	1051	0.76	1088	0.82	1124	0.89	1160	0.96
1800	1031	0.79	1070	0.86	1106	0.93	1142	1.00	1176	1.07
2000	1054	0.91	1091	0.98	1126	1.04	1161	1.12	1195	1.19
2200	1080	1.04	1115	1.11	1148	1.18	1183	1.26	1215	1.33
2400	1108	1.19	1142	1.27	1176	1.34	1207	1.42	1238	1.49
	1-hp Standard Motor & Field Supplied High Static Drive(b)									

Notes:

Figure 2. Baseline fan performance form the manufacturer[3]

2. Due to cost limitations, NREL opted to only put a speed measurement on the motor and asked Turntide to be careful to use the same belt, sheave, and pulley as the baseline. Unfortunately, Turntide needed to change the sheave and belt during installation. This likely caused part of the increased power consumption of the Turntide motor in the field. NREL's laboratory experiments showed that simply changing the belt tightness could change the blower speed by 10 rpm, equivalent to a ~4% change in power. Furthermore, the smallest diameter changes of the sheave resulted in an ~25 rpm change to the blower speed or ~10% change in power.

[3]Trane Product Catalog. https://www.trane.com/content/dam/Trane/Commercial/lar/Peru/Manuales/Precedent/RT-PRC023AJ-EN_Catalog_Cooling%20and%20Gas-Electric.pdf

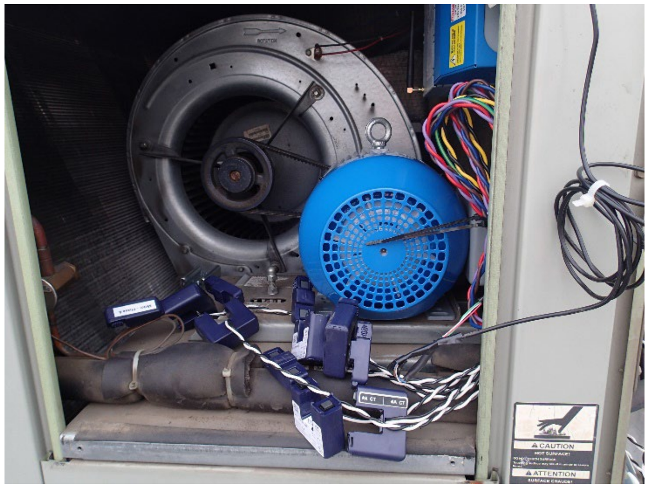

Figure 3. Turntide motor installed with a new belt and different sheave