Digi RTU Optimizer Case Study: New Technology to Maximum Energy Efficiency

Judy Sunde, Jinrong Wang, and Karisa Vlasek, Omaha Public Power District

ABSTRACT

The Digi RTU optimizer is a proven new technology for roof top unit (RTU) air conditioners. The Digi RTU Optimizer utilizes one variable frequency drive (VFD), to control both fan and compressor speed on the RTU to which it is installed. As an after factory addition it is a perfect fit for the multitude of existing inefficient RTU's that are currently in the market. The fact that it only takes one drive to control two components keeps the cost relatively low and minimizes the concern of having multiple drives on one RTU. The Omaha Public Power District (OPPD) reviewed the product and concurred that it performed as the manufacturer said it would and that it was unique to the industry. The utility then proceeded to initiate their pilot to test performance and public acceptance.

Customers were recruited to represent a variety of operations including offices and manufactures. Loggers were set to measure performance data before and after the installation. Outdoor air temperature, indoor air temperature, kWh of usage and kW of demand were all measured and compared.

The Digi-RTU optimizers reduced electricity consumption by up to 60%, kW of peak demand by up to 60%, compressor hunting (on/off short cycle) by up to 70% and held room temperature. Humidity was also better controlled. Based on these results OPPD is working to incorporate prescriptive incentives for this technology into their program in 2012. If this technology is widely adopted it truly has the potential to transform the market for RTU efficiency.

Background

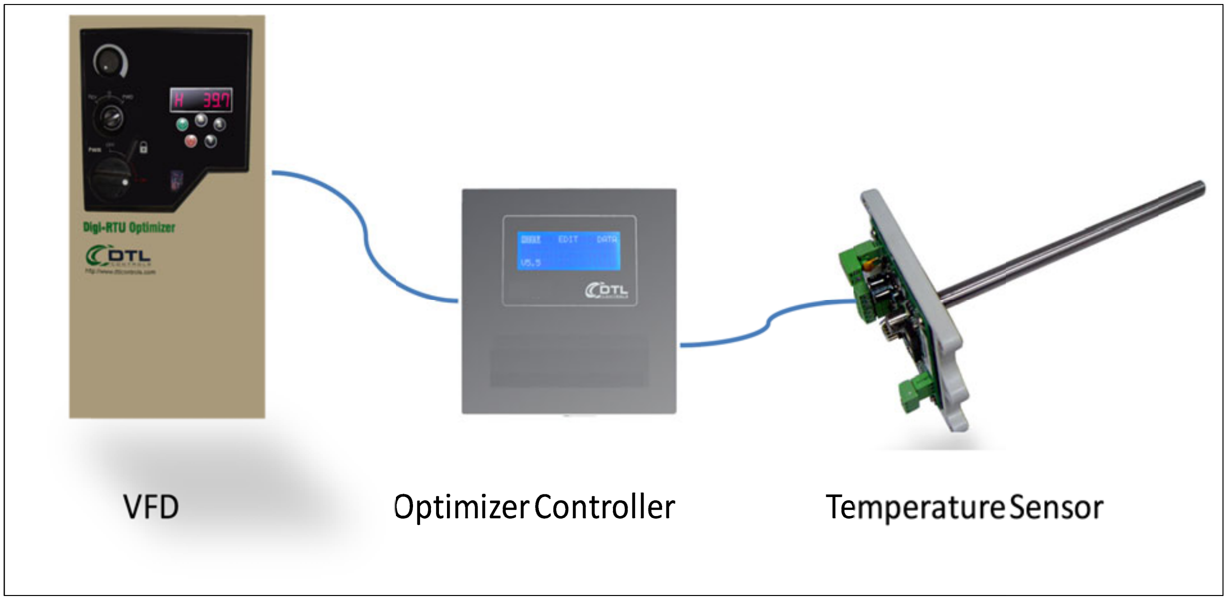
Rooftop Air Conditioners are ubiquitous and hold the greatest percentage of market share for heating and cooling of commercial and industrial space. These rooftop units are usually equipped with constant speed compressors and fans. The issues associated with using a constant speed rooftop unit include unregulated humidity control, fluctuating room temperature, compressor short cycling, noise, and high energy demand and consumption.

The Digi-RTU Optimizer technology, utilizes one VFD to modulate both the fan and compressor speed of the RTU. Figure 1 is a diagram of Digi-Optimizer hardware components. It consists of a VFD, an optimizer controller, and a temperature sensor. The speed of both compressor and fan is modulated based on actual cooling load to maintain the space temperature required. Utilizing only one drive to impact the functionality of two components results in a much lower cost compared to if two drives were required. Based on OPPD's extensive research, there is not a comparable product on the market.

In 2009, OPPD completed two pilot projects utilizing Digi-HP (Heat Pump) Optimizer technology, which is vastly similar to Digi-RTU Optimizer technology. The heat pumps have been operating with Digi-Optimizers since they were installed almost two years ago. Both projects have proven that Digi-HP Optimizer technology is reliable and can significantly reduce peak demand (up to 60%) and reducing compressor short cycling (up to 70%), while improving occupant comfort.

In 2010, OPPD and DTL Controls, LLC teamed up to initiate a Digi-RTU pilot project. DTL Controls is also the manufacturer of the Digi-HP Optimizers. Through the pilot project, OPPD gained hands on experience with the technology, learned more about the installation process, determined peak kW reduction, determined kWh reductions and explored typical challenges from the customers' perspective.

Figure 1. Hardware Components



Project Information

The Digi-RTU pilot project recruited 40 rooftop units located at 18 buildings. There was much internal discussion around the recruitment process and whether or not the pilot should be a cost share scenario or should be fully funded by OPPD. Ultimately it was fully funded by OPPD in order to streamline the process and to ensure a quick customer response (no need for any customer budget approvals). The 18 buildings selected cover a variety of business types including manufacturing, restaurants, retail and offices. Based on the number of compressors in a roof top unit, Digi-RTU Optimizers are categorized into Digi-RTU-A that serves units with one or two compressors and Digi-RTU-B that serves units with 3 or more compressors. Typically, Digi-RTU-A covers unit sizing from 3- ton to 12.5-ton and Digi-RTU-B covers sizing from 15-ton to 20-ton.

The optimizer installation started at the beginning of July, 2010 and ultimately included 24 units for the 2010 portion of the pilot. The 2011 pilot included the addition of seven units utilizing Digi-RTU-B and an upgrade of Digi-RTU generation two on the 24 that were part of the 2010 pilot. The focus of this paper is the 2010 pilot however; information currently available regarding the 2011 pilot is also included. The remainder of the original 40 units were not retrofitted with the optimizers due to various reasons including the delay of the building owners' permission (scheduling related) and due to existing maintenance issues that need to be addressed by the building owners

As demonstrated later in this paper, the electricity demand of those 24 units operating with Digi-RTU optimizer technology has been greatly reduced while occupant comfort was maintained and compressor hunting (short cycling) was also greatly reduced. As reference compressor hunting or short cycling is when the compressor of the RTU turns on and off in a short amount of time. This contributes to wear and tear on the equipment and is also a factor in humidity issues. The pilot results achieved the goals of the project in regard to peak demand (kW) and energy (kWh) reduction. In addition, there have been some critical lessons, on both VFD selection and installation procedures. These lessons are paramount to address in order for a large scale roll out Digi-RTU Optimizer Incentive Program to be successful.

Specific lessons learned include:

- Initially three VFDs were undersized although the specification for the VFDs matched with the size of the motors. Following the specification resulted in OPPD overestimating the rooftop unit's performance although the same size VFD worked well for some other rooftop units with the same capacities. It made OPPD realize that a detailed specification manual for VFD selection and sizing, that considers more application scenarios such a RTU manufacturer and number of compressors, is essential to accurately size VFDs. After further discussion with DTL Controls about the findings related to VFD sizing, DTL was able to make modifications in the 2nd generation Digi-RTU Optimizer to allow for simpler VFD sizing than originally thought. Presently this installation manual which includes VFD sizing information is nearing completion.
- Currently, installation of a Digi-RTU Optimizer is not a plug and play process. While OPPD felt this might be the case in the beginning, the level of training that would be required was also underestimated. Special installation training will most definitely be required for contractors. Installation procedures were developed and implemented for a majority of the pilot project. Once trained, a contractor will be well equipped for a variety of RTU situations and configurations. A very specific training module is in the process of being developed.
- Roof top units for many businesses are lacking regular maintenance. Eight units (20%), out the 40 were identified as having mechanical/control issues. These issues were identified after the Digi-Optimizer hardware was installed and during the commissioning process. As a result, the Digi-RTU Optimizers were by passed until these issues are addressed by the building owners. This reactive process takes extra time and effort for both building owner and installation contractor. The fact that the installation identified maintenance problems can also be considered a benefit of the technology. OPPD learned that a pre-inspection of the roof top unit is necessary, during which the maintenance can be determined, before installing a Digi-RTU Optimizer. Inspection procedures in the form of a pre-installation check list have been developed and are to be utilized for the future RTU-B portion of the project and for the 2nd generation installations.

Digi-RTU Performance Data

OPPD set Elite loggers at each location prior to the Digi-RTU installation and trended the rooftop unit electrical data for at least 30 days in order to compare the electrical demand and kWh usage with optimizers and without optimizers. The electricity demand and kWh data of one day gathered "pre" Digi-RTU installation was then compared with one day when similar weather hot conditions occurred, "post" Digi-RTU installation. The two days compared had the same average outdoor air temperature and same operations within the building; this data provided convincing information for OPPD to determine peak demand (kW) reduction and kWh reduction attributed to the Digi-RTU. The figures below present the comparisons for two units from a manufacturing facility and a restaurant.

As shown in all the charts, after using Digi-RTU-A, the electricity demand was remarkably decreased. The reduction is up to 60%. Compressor cycling is also decreased, which can be clearly seen from the day to day electricity demand comparison.

Figures 2 to 4 present energy performance data of a RTU serving a manufacturing facility. The unit size is 20-ton (in this particular situation Digi-RTU-A was able to be utilized due to the fact the RTU had only two compressors). Figure 2 presents historical kW demand data. Demand has been significantly reduced since the Digi-RTU Optimizer was installed on July 31, including the hottest day of August 9.

Figure 2. Historical kW Demand Data of a RTU Serving a Manufacturing Facility

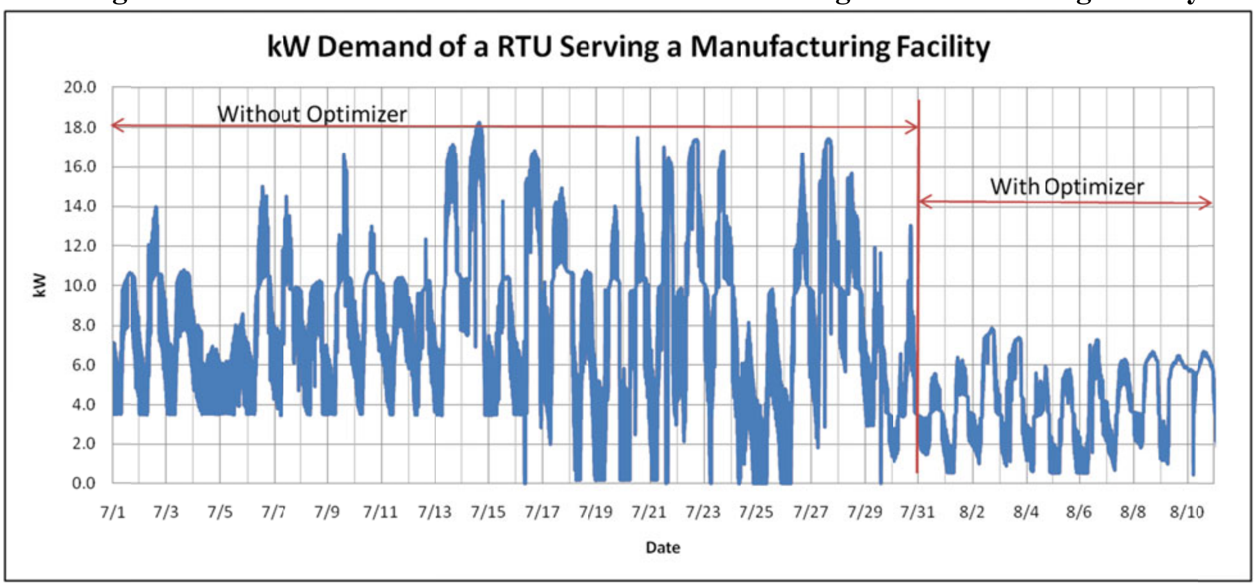


Figure 3 compares the electricity demand data on Thursday, July 22 (before the optimizer installation) and Monday, August 9 (after the optimization installation). The two days were the two hottest days of the year with similar weather data. The operation of the facility is the same Monday through Friday. The red line represents the data before and green line represents after. The electricity demand was reduced to 6.1 kW from 16.8 kW. This represents a 64% reduction.

Table 1. Outside Air Temperature Data of the Two Selected Days, July 22 and August 9

<table>
<tr><td colspan="3">Date</td><td>Average (°F)</td><td>Max (°F)</td><td colspan="3">Min (°F)</td></tr>
<tr><td colspan="3">July 22</td><td>84</td><td>95</td><td colspan="3">71</td></tr>
<tr><td>August 9</td><td>84</td><td>95</td><td colspan="5">73</td></tr>
</table>

Figure 3. kW Demand Comparison of a RTU Serving a Manufacturing Facility

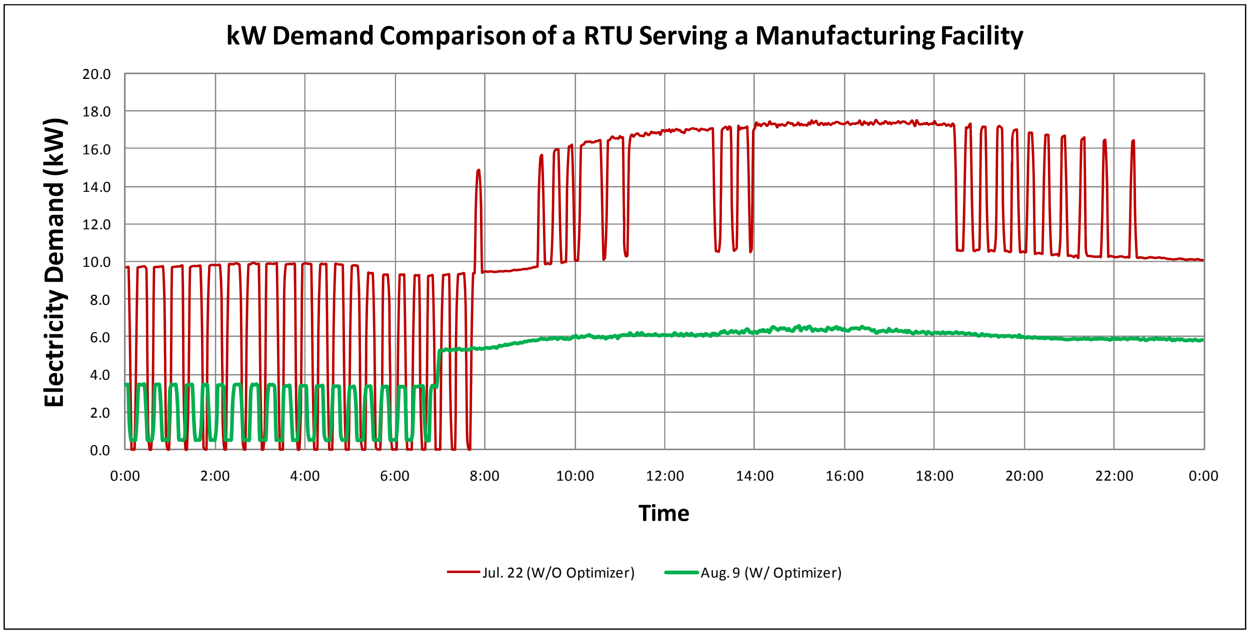
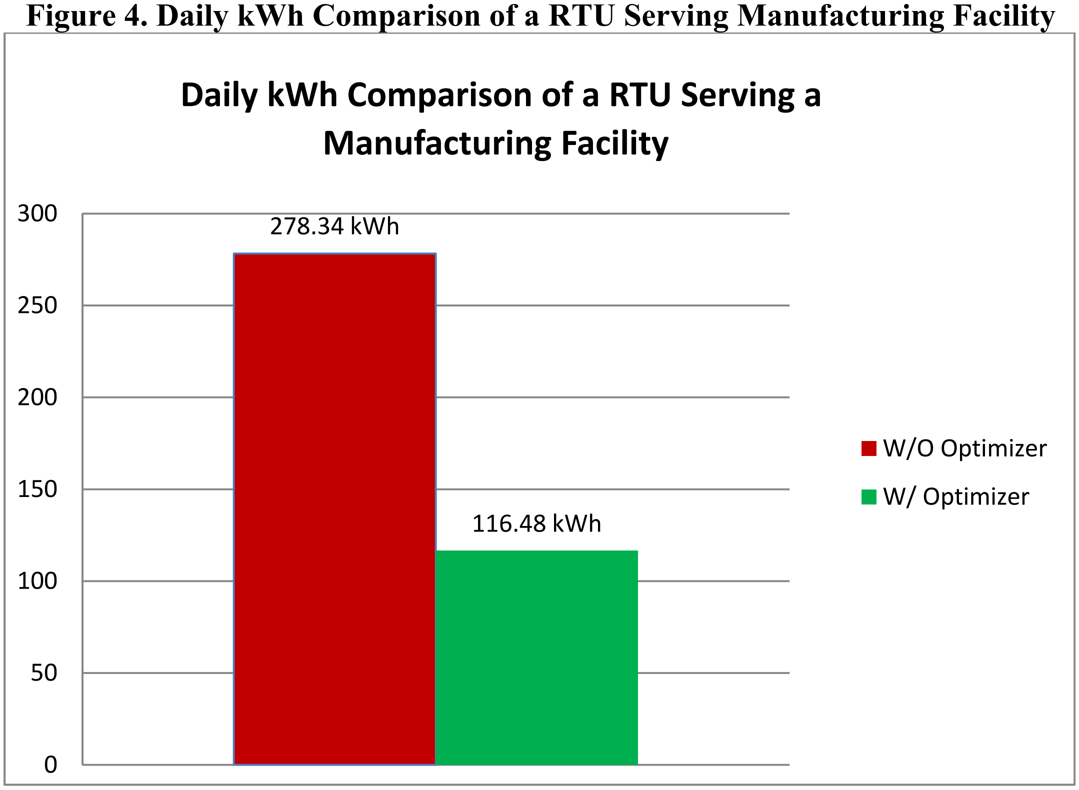


Figure 4 compares the daily kWh consumption of the two hottest days before and after the optimizer installation. The daily electricity consumption was reduced to 116.48 kWh from the before electricity consumption of 278.34 kWh. This represents a 58% reduction.

Figure 4. Daily kWh Comparison of a RTU Serving Manufacturing Facility



Similarly, Figures 5 to 7 present energy performance data of a RTU serving a restaurant. The unit size is 12.5 ton. Figure 5 presents historical kW demand data. As shown by the figure, peak demand has been significant reduced since the Digi-RTU Optimizer was installed on June 29, although the weather was hotter than before.

Figure 5. Historical kW Demand Data of a RTU-Serving a Restaurant

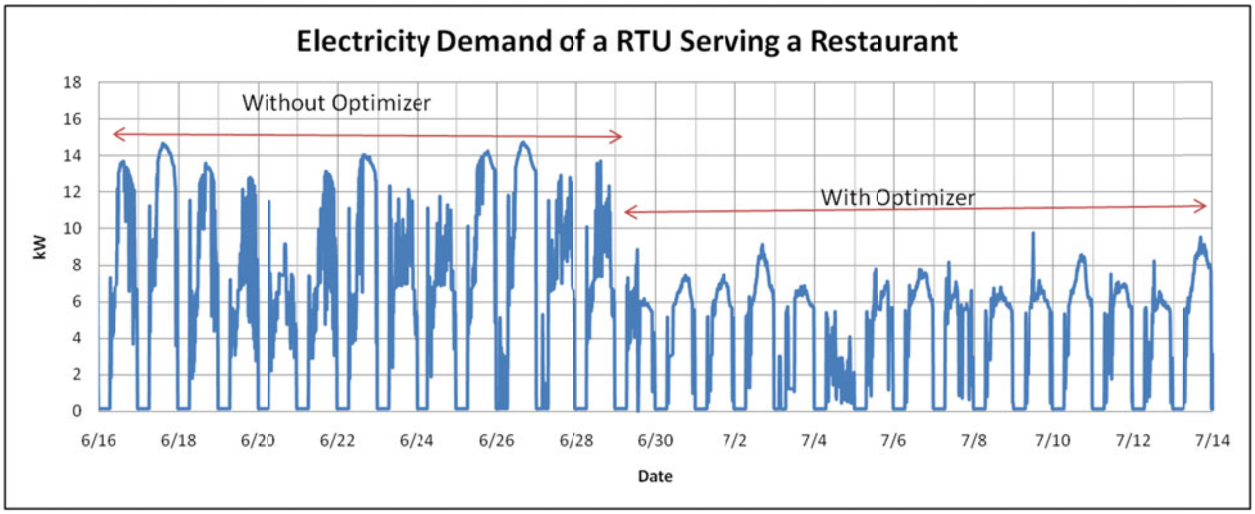


Figure 6 compares the electricity demand data on Tuesday, July 13 (before the optimizer installation) and Sunday, July 18 (after the optimization installation). The two days were the two hottest days of available measured data and with similar weather data. The red line represents the data before and green line represents after. The electricity demand was reduced to 8.8 kW from 16.1 kW. This represents a 45% reduction.

Figure 6: kW Demand Comparison of a RTU-Serving a Restaurant

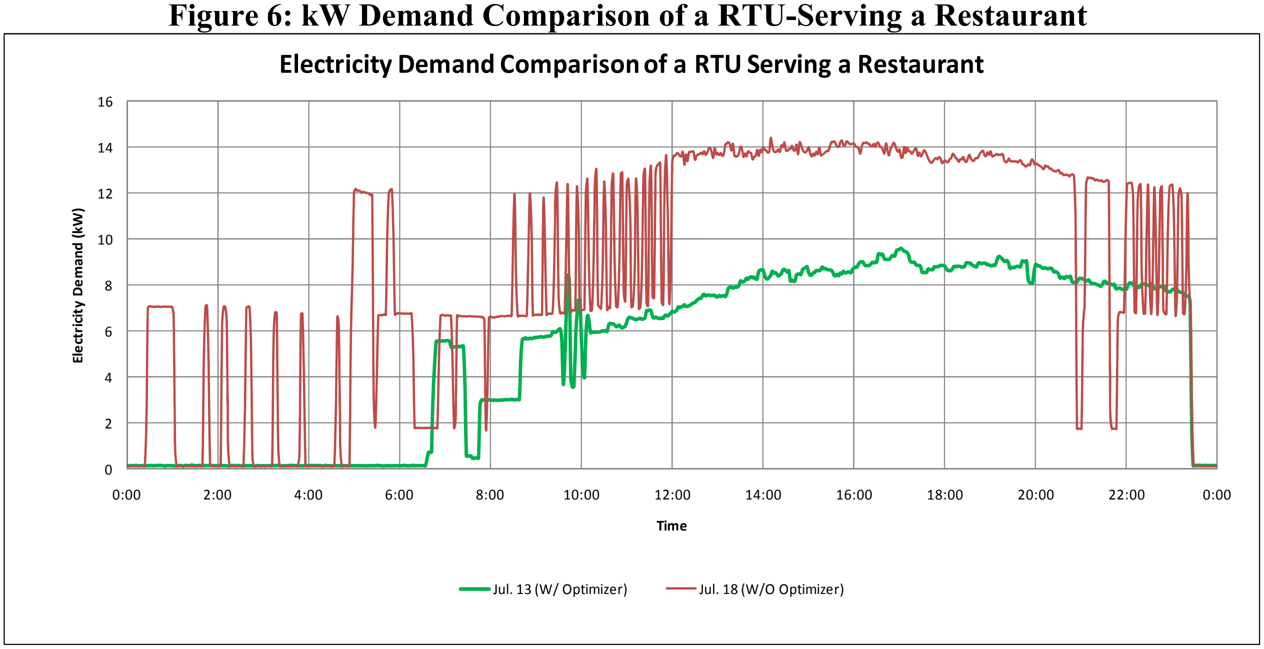
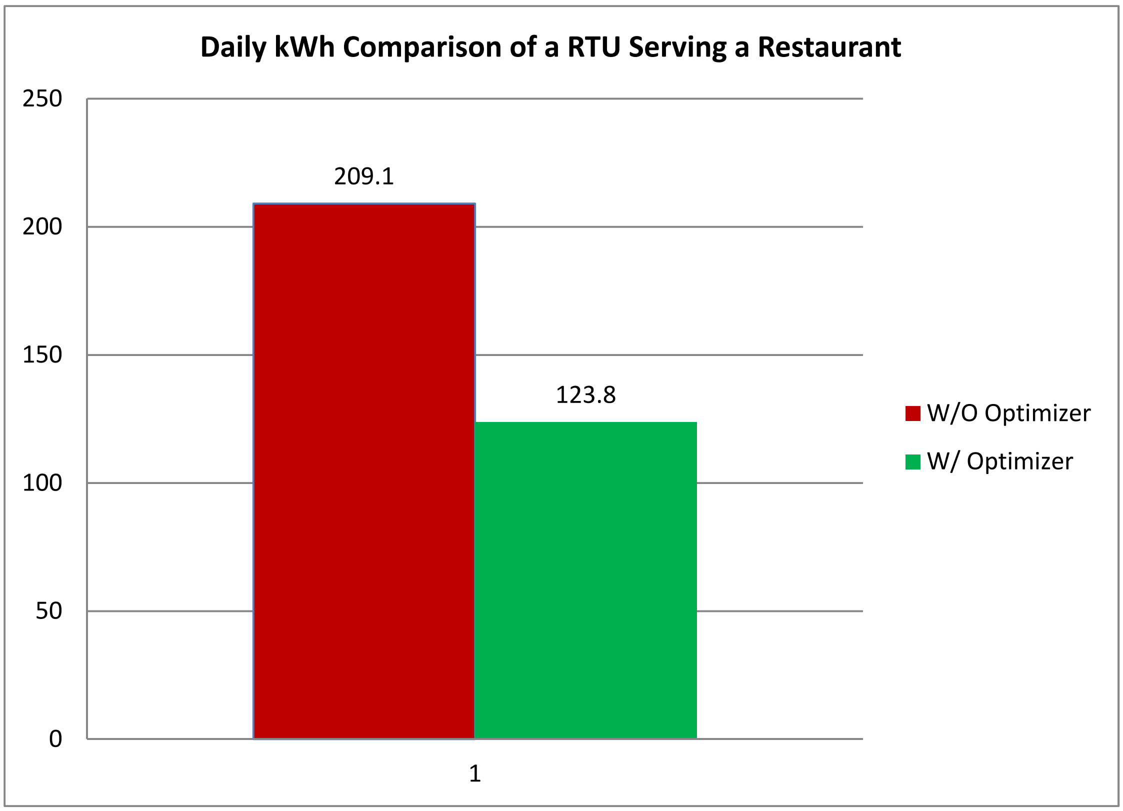


Table 2. Outside Air Temperature Data of the Two Selected Days, July 22 and August 9

Date	Average (°F)	Max (°F)	Min (°F)
July 13	80	91	68
July 18	83	91	74

Figure 7 compares daily kWh consumption of the two hottest days of before and after the Optimizer installation. The daily electricity consumption was reduced to 123.8 kWh from the before electricity consumption of 209.1 kWh. This is 41% reduction although the average outside temperature of July 18 was higher than July 13.

Figure 7. Daily kWh Comparison of a RTU Serving a Restaurant



It should also be pointed out that the temperature within each building remained consistent on the two days compared and that humidity levels were also maintained or improved.

Figure 8 shows measured results and is an example of the calculation for an individual unit.

Figure 8. Measured Results 6 Ton Unit

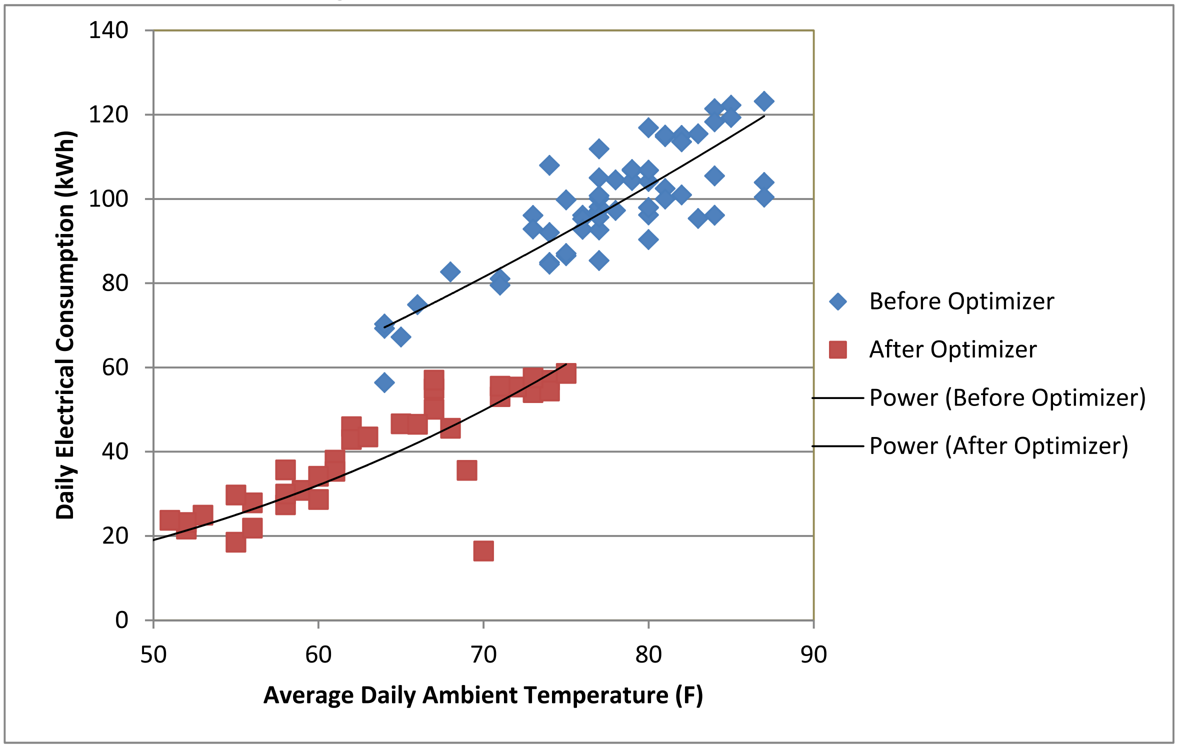


Table 3 presents the pilot results of 20 individual units. The two units with the most savings and the two units with the least savings were removed to more accurately represent the average. Measurements were made over the early winter months in order to project annual savings on a unit by unit basis. These measurements utilized American Society of Heating Refrigeration Air-conditioning Engineers (ASHRAE) bin weather data for Omaha, NE applied to the consumption curves.

Table 3. Projected Savings from 20 Units Included in Pilot

						Peak Demand Savings			Annual Savings				Summer Savings		Winter Savings	
Unit #	Unit Make	Tonnage	Fan Power (HP)	Usage	Schedule	Before	After	%	Before	After	kWh	%	kWh	%	kWh	%
1	Trane	12.5	5	Office Area	5 days	25.0	20.0	20%	43,916	15,026	28,890	66%	19,548	45%	9,341	21%
2	Carrier	7.5	3	Office Area		6.0	4.1	32%	7,866	3,563	4,303	55%	3,496	44%	807	10%
3	Trane	12.5	3	Restaurant Dining Area	7 days	14.7	12.3	16%	27,096	14,576	12,520	46%	9,052	33%	3,456	13%
4	Carrier	7.5	3	Office Area		5.8	3.7	36%	17,813	7,504	10,309	58%	6,123	34%	4,186	23%
5	Carrier	7.5	3	Daycare		10.1	9.0	11%	10,837	7,493	3,344	31%	2,704	25%	670	6%
6	Carrier	7.5	3	Daycare		10.8	9.8	9%	21,489	11,068	10,421	48%	8,236	38%	2,186	10%
7	Trane	10	3	Call Center		8.6	3.0	65%	24,612	11,986	12,626	51%	7,718	31%	4,907	20%
8	Trane	6	1	Call Center		7.2	3.0	58%	14,485	8,079	6,406	44%	5,009	35%	1,397	10%
9	Armstrong	10	3	Office Area		9.8	6.1	38%	28,683	17,563	11,120	39%	8,604	30%	2,516	9%
10	Carrier	7.5	3	Office Area		8.0	4.6	43%	8,009	4,412	3,597	45%	2,973	37%	624	8%
11	Carrier	5	2	Doctor's Office	5 days	5.6	3.4	39%	14,286	10,077	4,209	29%	3,095	22%	1,114	8%
12	Carrier	5	2	Restaurant Lobby	7 days	6.3	3.0	52%	12,430	6,885	5,545	45%	3,928	32%	1,617	13%
13	Trane	3		Restaurant Dining Area	7 days	3.9	2.8	28%	9,686	4,675	5,011	52%	3,850	40%	1,162	12%
14	York	7.5	2	Office Area		9.1	4.7	48%	7,673	2,659	5,014	65%	4,082	53%	932	12%
15	Trane	6	2			4.6	2.7	41%	22,693	12,079	10,614	47%	6,073	27%	4,214	19%
16	Trane	5	1			7.2	3.2	56%	18,561	10,930	7,631	41%	6,496	35%	1,135	6%
17	Lennox	5	0.75	Fitness Center	7 days	6.7	3.1	54%	11,442	4,695	6,747	59%	4,202	37%	2,545	22%
18	Lennox	5	0.75	Fitness Center	7 days	7.0	2.9	59%	11,819	3,298	8,521	72%	6,111	52%	2,410	20%
19	Carrier	12.5		Motorcycle show room		14.6	3.0	79%	47,915	21,638	26,277	55%	17,231	36%	9,082	19%
20	Carrier	10		Motorcycle show room		20.0	11.5	43%	64,125	9,914	54,211	85%	33,387	52%	20,824	32%

Further utilization of ASHREA's bin weather data from Omaha was used to project kWh savings based on tonnage of the RTU. A selected few of those projections are shown in Table 4.

Table 4. kWh Reduction For Omaha On A Tonnage Basis and Based On ASHREA Bin Weather Data

Omaha, NE		
Tonnage	kWh	%
3	4055	46%
4	4711	47%
5	5472	47%
6	6356	48%
7	7383	48%
8	8576	49%
10	11572	50%
12	15615	51%
14	21069	53%
15	24474	53%
Average:		49%

The chief variable which is projected to have the most effect on overall savings that needs to be addressed in both training and in prescriptive incentive development is the initial sizing of the RTU. If an RTU was initially undersized for the actual load then the optimizer would have little or no benefit in regard to demand reduction but would still have benefit in kWh reduction, hunting reduction and humidity improvement. Since OPPD's programs are based on demand reduction we are developing criteria to qualify whether the existing RTU has been sized in a fashion that does not allow for demand reduction possibilities. However programs based on kWh reduction criteria would not have this concern.

Summary of Results

The compelling data has proven the benefits of Digi-RTU Optimizers in improving RTU energy performance. As shown in the charts, after using optimizers, the electricity demand and daily energy consumptions from both facilities were significantly reduced and the results of the complete group mirrored those results. The electricity demand was decreased by up to 60%. The daily energy savings are also as high as 60%. A summation of the results of the units included in the 2010 Pilot shows an average annual projected demand reduction of 39% and an annual kWh reduction of 56%. Installation of Digi RTU Optimizers potentially prolongs the life span of compressors, and saves dollars on maintenance costs due to the number of compressor cycles being greatly reduced. This savings was accomplished while maintaining occupant comfort within the building and maintaining or improving humidity control. Results of the pilot are being further scrutinized to determine how much kW reduction can be attributed to each Digi-RTU installation according to the RTU's tonnage (kW/ton). The projected kWh reduction has already been determined by utilizing ASHRAE's bin weather data from cities around the US. An incentive amount can be attributed to each kWh or on a kW per ton basis.

Recommendations

In order to proceed with the installation of Digi-RTU optimizers it will be necessary to complete a comprehensive pre-inspection of the existing RTU and to establish installation training for HVAC contractors or electricians. The initial training of existing trade allies is recommended provided there is already an established trade ally group. If not, then it is recommended to train a small group of contractors initially in order to maintain quality control. Incorporation into an existing prescriptive program is also recommended. If that proves too difficult based on existing program criteria, then a custom incentive approach could be adopted. In most cases a utility with an existing prescriptive program could utilize existing applications, term and conditions and other associated paperwork and processes to include Digi RTU technology.

Conclusions

The Digi-RTU Optimizer greatly reduces kWh consumption, demand and RTU short cycling. Installation of the optimizer can be done with the proper training. The price point at the time of the pilot does require that an incentive would be required to quickly infiltrate the market with this technology. Finalized pricing (non-pilot pricing) is anticipated to be available from DTL very soon however, it is expected that price will also require a utility incentive in the short term. Marketing can be done via the already established channels for commercial and industrial customers. Expected results will have a great impact on reaching DSM and energy efficiency goals. This technology also addresses the underserved market segment of small commercial and industrial customers, which should make it a welcome addition to many existing programs.

Acknowledgements

The authors would like to acknowledge the technical support from DTL Controls, LLC. This project was supported by funding from a grant from the American Public Power Association's Demonstration of Energy-Efficient Developments (DEED) Grant Program.