Documenting Results to Validate Energy Savings Projects: Case Study of Direct Drive Cooling Tower Installations: Before and After

Roman Wajda, Baldor Electric Company

ABSTRACT

Documenting the actual energy saving for green projects is often needed to validate expenditures and can be used to justify future energy savings projects. Often an energy savings project is started as a trial before it is scaled up across a plant or to other facilities in an organization. A Direct Drive Cooling Tower Motor and Drive package is a relatively new technology that can provide significant energy, environmental and reliability improvements. This presentation will be a case study that compares existing mechanical cooling tower drive system with a new Direct Drive Cooling Tower Solution.

At a time were energy efficiency / savings is of utmost importance, recent developments in motor technology have changed the playing field within cooling tower HVAC systems. This new permanent magnet / laminated frame motor technology allows for the removal of all the mechanical components such as gearboxes, drive shafts, disc couplings and existing motors and replaces them with one direct drive Cooling Tower Permanent Magnet (CTPM) motor. With the removal of these mechanical components, the mechanical energy losses are also removed decreasing your overall system energy demands. Plus the system also sees higher motor efficiency gains with PM technology over standard induction motor efficiencies.

To more fully understand the benefits of this technology, an understanding of the cooling tower application is important to clarify. There are typically two types of cooling towers found in the industry, cross flow towers and counter flow towers. These are defined by the direction of air passed over the waste water. A cooling tower is defined as a structure which extracts waste heat from a process and distributes it to the atmosphere. The most common method is to let heated water fall through a moving air stream created by a fan located at the top of the tower. This is an evaporative process which takes a large amount of heat from the process. The heated water is distributed over a "fill" material which increases surface area the water travels on and increases the cycle time within the tower. The water is cooled as it descends through the fill. The cooled water is then collected in a cold water basin below the fill from which it is pumped back through the process to absorb more heat. A typical tower arrangement is shown in Figure 1.

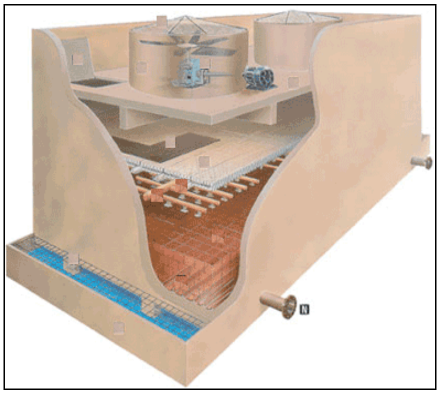

Figure 1. Typical Field Erect Cooling Tower

Commonly, the size of a tower is identified by the diameter of the fan. Fan sizes range from 6 to 40 feet, with the most common applications in the 10 to 26 foot range. The speed of the fan is typically limited by industry standards for stressing which are typically rated as a max fan tip speed of 12,000 fpm. This max tip speed generates a fan speed in the range of 147-382 rpm. As the fan diameters become smaller or larger than the 10-26 ft. sizes the fan speeds can differ. The most common solution for driving the fan in current cooling tower designs utilizes an induction motor, driveshaft, disc couplings, and gearbox arrangement, as shown in Figure 2.

Figure 2. Typical Fan Drive Arrangement

The motor used is normally a standard NEMA induction motor. Cooling tower applications follow fan affinity laws which state that HP varies by the cube of the fan speed. To put this in perspective if we had an application requiring a 40hp load at full speed if we were able to reduce the speed to 50% due to lower heat load requirements the application needs would only be 5hp or only 12.5% of rated full load requirements which reflects a great reduction of energy consumption. Sometimes a 2-speed variable torque motor is used and these motors are not regulated by the U.S. DOE for efficiency level.

The use of variable frequency drives (VFDs) has become much more commonplace in recent years within the industry on new construction due to the energy savings associated with the fan affinity laws. Additionally, most towers being upgraded or refurbished are also being equipped with VFDs. These drives have the advantage of a soft mechanical start, no large starting current draw, and the ability to run the fan at any desired speed from zero to the maximum design speed for the application. The energy savings realized by using a VFD are well recognized and documented and in case study evaluations can be shown to save 37-47% of energy use as compared to applications without VFD's

Historically, the mechanical components of the fan drive system, specifically the right angle gearbox, have been the largest maintenance issue for cooling tower installations. Gearbox failures, oil leaks, oil contamination, failed drive shafts, misaligned drive shafts and excessive vibration are all significant problems related to this type of fan drive system. And has been instrumental in the acceptance of this new technology into the industry.

The features and benefits of the Direct Drive Cooling Tower Permanent Magnet technology have been embraced by the industry and have shown to deliver performance reliability and energy savings over traditional solutions.

- Reduces Energy Use
- Soft start capability reduces overall tower stress
- Removes alignment issues
- Removes mechanical rotating equipment
- Increase reliability
- Decreases noise levels
- Decreases yearly maintenance
- Decreases vibration levels
- Decrease ingress of contamination due to trickle current during idle periods
- Incorporates anti-wind mill option during idle periods
- Increases safety by enclosing all rotating equipment inside the tower

Many of the problems associated with cooling tower maintenance and reliability are solved with the CTPM motor design. The relatively high speed gear input shaft which typically runs at 1750rpm has been eliminated. The CTPM Direct Drive motor runs at the fan operating speed which are typically slow in the range of 147–382rpm. Vibration and noise concerns have been minimized. The driveshaft and associated disc couplings have been removed, thus eliminating problems associated with misalignment, natural frequencies, or delaminating of the driveshaft itself. The right angle spiral-beveled gearbox has been removed. Difficult maintenance associated with changing the oil, proper oil fill levels, contamination of the oil, oil leaks, and gearbox failures is no longer a concern.

New motor technology now provides an alternative solution, the direct drive of cooling tower fans. PM motor technology combined with the finned, laminated frame design now allows the construction of low speed, compact motor for use in place of the existing gearbox. Data obtained to date indicates this solution will eliminate the problems associated with the right angle gearbox and drive shaft design. By eliminating the gearbox, which is a significant source of loss in the system, improved system efficiencies can be realized.

Case Study

- **Dates Performed:** The study was performed on August 5th and 6th, 2014.
- **Location:** This study occurred in Fort Worth, Texas
- **Temperature:** The high temperatures for August 5th and 6th, 2014 were approximately 96° to 98° Fahrenheit.

Background Information

The study was performed on a bank of cooling towers at a major manufacturer in the Dallas/Fort Worth area. The cells studied were physically located side by side from each other. The cells were original installed in the early 1980s (exact date unknown) and are assumed to be approximately 20 to 25 years old. The fiberglass towers were manufactured by the Ceramic Cooling Tower Company. The fans were each 16' feet in diameter with 24' X 24' bases (measured at bundles). Each fan had 10 blades. It was observed at the beginning of the study that the pitch and blade type of each fan were different (the new Cooling Tower Direct Drive (CTDD) solution having been upgraded fully at the time of the drive conversion).
This study focused exclusively on energy usage differences between the Mechanical and Direct Drive (CTDD) Solutions. Sound levels were not considered for the purpose of this study.

Specifics of Applications Studied

1) New Direct Drive Solution – T-1A

Motor - Cooling Tower Direct Drive (CTDD) Motor

- Duty - Continuous
- HP - 100
- RPM - 219
- Amps - 128
- Volts - 460
- Hertz - 14.6
- Framesize – FL4421Y

Fan Blades -

- **Bai. Moment – 3397 Inch Lbs.**
- **Weight – 64.99 Lbs**

Blade Pitches – **All** blades on this fan were pitched at 15.6° as measured by the M-D Building Products Digital Level.

2) Mechanical (Geared) Solution – T-1B

Motor –Premium Efficiency

- Duty - Continuous
- HP - 125
- RPM - 1785
- Amps - 145
- Volts - 460
- Hertz - 60
- Framesize – 444T

Gear Box –Right Angle Gear Box

- Ratio – 8:1

Blade Pitches – Blades pitches were measured by the M-D Building Products Digital Level.

Blade Number	Pitch (°)
1	6.9
2	7.4
3	7.0
4	7.4
5	7.0
6	7.5
7	7.5
8	7.0
9	7.0
10	7.4

Equivalency Ratio between Fans

Since both the blade types and blade pitches between the 2 fans were different it was difficult to perform an "apples to apples" study without a conversion factor between the 2 units.

Using available site parameters and Fan Design software, it was determined that an equivalency ratio of 1.983 would effectively scale the measured power of the mechanical drive

Applying the equivalency ratio to this example allows us to consider this an "apples to apples" study and we find that the:

- Old Mechanical Drive Solution consumes an average of 87.25 KW
- New CTDD Solution consumes an average of 80 KW

Findings

Two samples were collected from each unit. A 36 minute sample was taken with a sampling period of 0.5 seconds. A 15 day sample was also taken with a sampling period of 5 minutes.

Data was collected during the sampling period for the following parameters.

- Voltage
- Current
- Frequency
- Active Power
- Reactive Power
- Apparent Power
- Power Factor
- Distortion Power
- Cos PHI
- Total Harmonic Distortion Volts
- Total Harmonic Distortion Amps
- Active Energy
- Reactive Energy

15 Day Study – Average KW consumption over a 15 Day period (KW vs. Time)

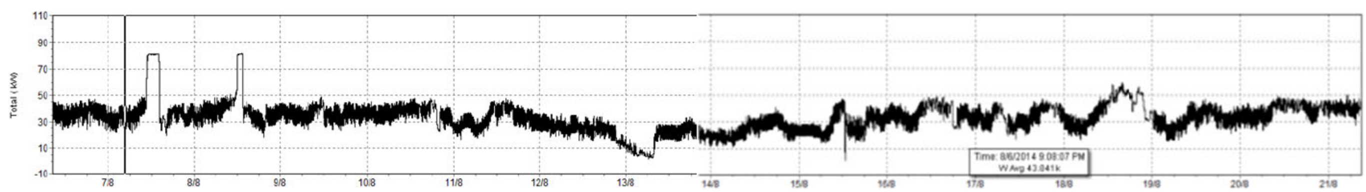

Figure 3: Average KW Consumption over a 15 Day Sample Period – T-1A

36 minute Study – Peak KW consumption over a 36 minute period (KW vs. Time)

Note that KW is cycling up and down over a three minute period from ~ 0 KW to ~ 80 KW. This corresponds with a change in speed from ~24 RPMs to 217 RPMs. The average value of 44 KW seen in the fifteen day study is the average of these high and low values. For the purposes of this study, the full load full speed value of 80 KW as seen below in the 36 minute study was used for the comparison since the geared solution is operating at full load full speed.

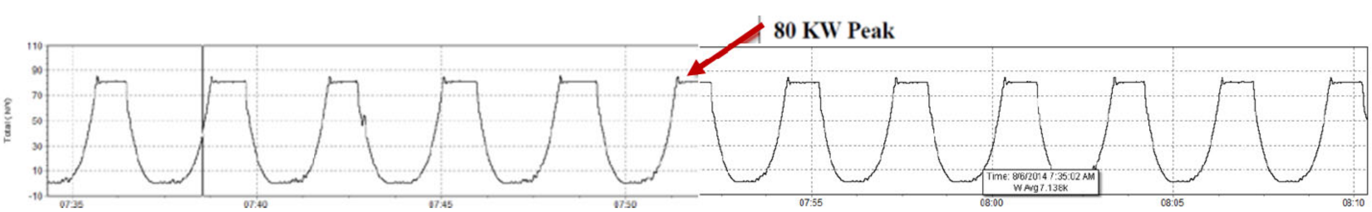

Figure 4: Peak KW Consumption over a 36 Minute Sample Period – T-1A

15 Day Study – KW usage over a 15 Day period (KW vs. Time)

Scaled per the methodology discussed in section V, we can assume an average KW value of approximately 87.25 KW.

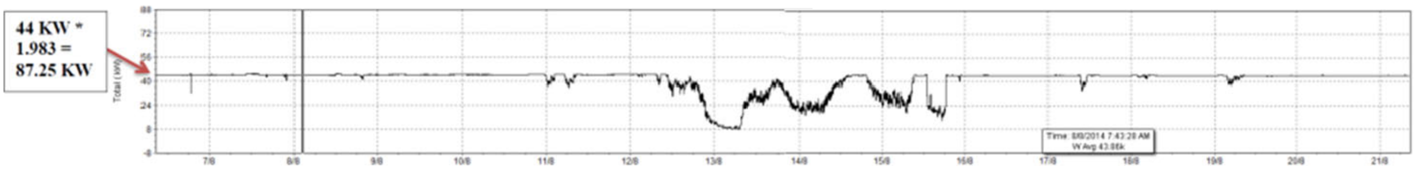

Figure 5: kW Consumption over a 15 Day Sample Period – T-1B

36 minute Study – kW usage over a 36 Minute period (kW vs. Time)

Scaled per the methodology discussed in section V, we can assume an average kW value of approximately 87.25 kW.

II. Summary

Arrangement	Fan Design	Fan Speed	Fan Pitch (Average)	Present Motor HP	Measured Power Full Load Full Speed	Equivalency Ratio	Full Load Estimated Power Usage	Energy Savings
Direct Drive	16KW10	217	15.6	100	80 kW	1X	80kW	8.31%
Geared	16H10	223	7.2	125	87.25 kW	1.983X	87.25 kW	

Existing Gearbox, drive shaft Solution

Avg. Operating hours		Fan Speed	Motor Hp	Motor Rating kW	Power Usage kWh	Energy cost Per cust 6 c/kWh
6570	Full Speed	223	117	87.3	573443	$ 34,407
2190	Off	0	0	0	0	0
8760 Total				**Totals**	**573443**	**$ 34,407**

(Assumed) 9 months at full speed
(Assumed) 3 months of idle operation
Energy cost per customer 6 c/kwh

New Direct Drive CT Motor Solution

Avg. Operating hours		Fan Speed	Motor Hp	Motor Rating kW	Power Usage kWh	Energy cost Per cust 6 c/kWh
6570	Full	217	107.3	80.0	525901	$ 31,554
2190	Off	0	0	0	0	0
8760 Total				**Totals**	**525901**	**$ 31,554**

Total Yearly Savings $ 2,853 Per Fan
We have not added maintenance costs savings associated with the Baldor Solution
Total Yearly % Savings 8.3% Per Fan

Conclusion
As well as the features and benefits of the Direct Drive Cooling Tower Permanent Magnet technology which delivered performance reliability and energy savings over traditional solutions.

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