HVAC OPTIMIZATION
DON'T LET THE SAVINGS SLIP

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EXECUTIVE SUMMARY

During routine preventative maintenance testing and measurement of efficiency on air handlers at Atlantis Paradise Island Resort, owned and operated by Kerzner International, it was discovered that operational efficiency and premature v-belt replacements in many air handler units (AHU) could be avoided. The corrections would not only provide operational and performance improvements, but also decrease energy consumption. A review of the systems revealed that the pulleys were also excessively worn, causing an increase in belt slip which creates additional heat which was damaging the belt casing. The above normal slip that was measured was calculated and measured to have been costing as much as 30% in additional energy consumption. Further evaluations of the units revealed that the grade of belt being used could be improved and had a short service life. Due to worn pulleys, improper v-belt tension, misalignment, and lower quality belts, the maintenance cost for belt replacement was higher than necessary. To solve these problems and correct this situation the resort's engineering group teamed up one of its Power Quality and Energy Service providers to customize a solution which addresses these challenges. Below are the steps that were taken to ensure that the best possible solution with positive results was achieved.

1) Pre Monitoring, Measurement and Verification
2) Replacement of low efficiency electric motors in each air handler to IEEE 841 high efficiency motors.
3) Measurement of Drive Efficiency
    a. Replacement of worn pulleys on fan and OEM Mechanical Adjustable Motor Pulleys on motors
    b. Replacement of v-belts to higher efficiency High Torque Drive.
4) Laser Alignment and Belt Tensioning of HTD Drive.
5) Installation of Intelligent Motor Control
6) Post Monitoring, Measurement and Verification

MONITORING, MEASUREMENT AND VERIFICATION

Like most energy projects, this project's success was determined by the team's ability to qualify and quantify the financial and operational benefit of the project. Accurate measurement and verification of the potential and actual energy savings was critical. Therefore, several methods of performance verification were used to support the full scale implementation of the project. The first was to analyze the results of the diagnostic Motor Current Signature Analysis testing on one unit. This test helped us to establish the health and condition of the old motor, establish the actual KW, current and voltage balance, RPM, actual motor efficiency and the evaluation of several power quality measurement parameters. The Motor Current Signature Analysis test provides a snapshot of the energy parameters of the motor. The motor that was used for the pretest and to establish the baseline was a 20 HP AHU unit servicing one of the resorts resort lobby areas. The initial Motor Current Signature Analysis Test revealed the following.

RPM = 1781
Load = 54.2 %

Table A

	RMS	Peak	CF
Current 1	22.944	33.207	1.447
Current 2	25.071	36.667	1.463
Current 3	26.134	39.322	1.505
Average	24.716	36.399	1.471
% dev	7.2	8.8	2.3

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Table B

	RMS	Peak	CF
Voltage 1	484.690	690.340	1.424
Voltage 2	483.470	693.180	1.434
Voltage 3	487.350	699.140	1.435
Average	485.170	694.220	1.431
% dev	0.5	0.7	0.5

Table C

	KVA	KW	kVARS
Phase 1	6.429	3.401	5.455
Phase 2	7.033	4.232	5.617
Phase 3	7.308	3.738	6.280
Average/Total	20.77	11.4	17.352

The Motor Current Signature Analysis Test results revealed a motor RPM of 1781 for the old standard motor which had a nameplate of 1740 RPM. The old motor pulley ratio was 3:1. Using this pulley ratio and RPM the old motor should provide a RPM of 594 on the fan. However, the measured fan speed using the Laser Tact was 505, which is a 17.5% loss of energy due to calculated belt slippage using slippage formula.

Diameter of drive pulley = x
Diameter of driven pulley = y
Rpm of driven pulley = R1
Rpm of driven pulley = R2

$$\left[\frac{\left\{\left[\left(\frac{x}{y}\right)\times R1\right]-R2\right\}}{R2}\right]\times 100 = \%\ \text{Belt Slip}$$

x = 1 R1 = 1781
y = 3 R2 = 505

% Slippage = 17.5

We will discuss the impact and opportunity to reduce the belt slippage thus improving the motor efficiency in the Belt and Pulley section, but let's focus on establishing the baseline first. The actual motor consumption based on the Motor Current Signature Analysis Test results was 11.4 kW or 8208 kWh in a 720 hour month. There was a measurable loss of energy due to the inefficiency of the proper transfer of energy because of the belt slippage.

After establishing this benchmark or baseline based on a snapshot of the energy profile using the Motor Current Signature Analysis software, the next step was to evaluate the actual energy consumption over time. This required the installation of a separate utility grade meter on an AHU unit for at least a month. The utility grade meter was consistent with the Motor Current Signature Analysis test at **11.4 KW** which is shown in **Table C** below

Table D

Date	Reading	Cum. KWH	Avg. KW
10/9/07	1156140	7150	11.4
10/10/07	1181258	7452	11.3
10/13/07	1231709	8057	9.3

This verified the accuracy of both testing approaches and validated with confidence the old motor performance.

Once this was done we could now begin to make changes and quantify measured savings using both approaches.

ELECTRIC MOTOR IEEE 841-2001(EFFICIENCY VERIFICATION)

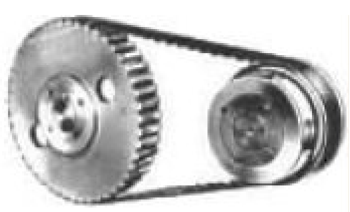
Standard high efficiency motors verses IEEE841 motors can mean huge costs when operating a motor 24/7. In fact, operating the motor is more than 95% of the cost of ownership. IEEE 841-2001 motors are cast-iron construction and are built with Class F insulation, Class B temperature rise and a 1.15 service factor. Motors thru 575 volts use ISR inverter spike-resistant wire. IEEE 841 motors add Impro/Seal bearing isolators on each end of the motor. IEEE 841 motors also guarantee a minimum efficiency which is shown on the motor nameplate of each motor. Higher power factor means lower kVa demand resulting in lower kVa demand charges from your utility as well.

Motor Master + Software provided by the US Department of Energy was used to qualify this savings. Determining in service motor efficiencies is important to industries concerned with energy conservation and cost savings. There are many methods to determine motor efficiency and the DOE software was just one tool used in this project.

MEASUREMENT OF DRIVE EFFICIENCY

Motor Current Signature Analysis (MMCSA) was also used in determining efficiency and load. This type of dynamic testing provides a reliable method for energy savings verification in addition to the integrity of the motors electrical and mechanical health.

Figure 1 eg. Synchronous Drive



To determine exactly how efficient the transmission of torque was by the existing v-belt drive a hand held laser tach was used to measure the exact speed of the fan. The motor speed was calculated by the MCSA dynamic test equipment. Measuring the pitch diameter of both the motor pulley and the fan pulley provided the ratio. Knowing that the fan speed should be 614 with no slip and measuring 505 rpm on the fan showed a slip of 17.8%. That shows that of the 11.44 kW consumed by the motor, 2.02 kW was lost in heat from slipping. That loss equates to $378.14 in wasted energy each month.

LASER ALIGNMENT AND BELT TENSIONING OF HTD DRIVES

In Today's industry, preventive and predictive maintenance can result in major savings. When aligning with a laser alignment tool you reduce the wear on sheaves/pulleys, belts, bearings and seals as well as reducing vibration. Proper alignment can result in less downtime, which of course means that you increase the available machine time. This is time that could guarantee your income. Increased efficiency also means large energy cost savings! The motor was vertically and horizontally laser aligned thus improving system performance. It is also very critical to have proper belt tension to assure long life. Using a Sonic Tensioner provides the proper tension for each load. Under or over tension can cause damage to the belt.

INTELLIGENT MOTOR CONTROL

Recognizing the sensitivity of the HTD drives, motor control via soft start and stop equipment with the added feature of energy efficiency optimization was also installed on the motors. Introducing this technology into the system design provided the safe ramp up starting procedure verses a cross the line hard start which could cause structural damage and which was necessary with the use of HTD drives.

The ramp time varied by the unit size and load but in general was between 10 – 20 seconds. This was necessary because the V-Belt drive provides slip at start up to prevent structural damage however, the positive high torque drive has no slip creating potential for structural damage at start up without an intelligent controller or soft start device.

Additionally, the Intelligent Motor Control has the option to optimize the efficiency of the motor. This is done by constantly monitoring the motor's load and calculating the exact amount of torque required. As a result the IMC is able to match the voltage needed for the load at that moment thus reducing the amount of electricity used. This also increases the life-span of motor by reducing heat within the motor which in turn reduces maintenance requirements and Carbon Dioxide emissions.

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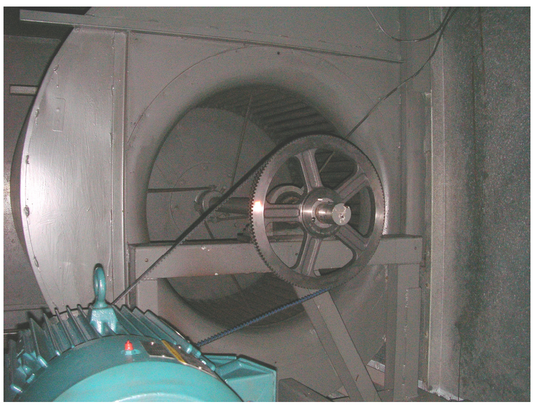
POST MONITORING, MEASUREMENT AND VERIFICATION

As mentioned earlier, the motor RPM on old motor was 1781. The pulley ratio was 3:1. This would provide a RPM of 594 on the fan. However, the measured fan speed was 505, which is a 17.5% loss of energy due to belt slippage. The motor consumption was 11.4 kW or 8208 kWh in a 720 hour month. This would be a cost of $2,134.08 per month based on $0.26 cents per kWh or approximately $25,608.96 (**NOTE:** Cost per KWH has increased in resent months to $0.37/KWH). The annual project cost could be as much as $36,443.52 for this particular unit.



Motor RPM on new IEEE841 motor is 1791. The pulley/sprocket ratio on the new poly chain drive is 2.9:1. The measured fan speed is 613. This is an increase of 20% more airflow than before. The motor consumption is 9.31 kW based on utility grade meter and approximately 9.334 from the post Motor Current Signature Analysis test or 6552 kWh in a 720 hour month. This will be a cost of $1,703.52 per month based on .26 cents per kWh. (NOTE: Cost per KWH has increased in resent months to $0.37/KWH) The kVa for this motor is 12.7. This cost per month is $131.19 per month based on $10.33 per kVa demand. The total monthly expense to operate this air handler was $1,834.71 after the corrections.

Table E

	RMS	Peak	CF
Current 1	14.225	22.754	1.600
Current 2	15.447	23.821	1.542
Current 3	16.393	25.090	1.531
Average	15.355	23.889	1.557
% dev	7.4	5.0	2.7

Table F

	RMS	Peak	CF
Voltage 1	478.54	678.69	1.418
Voltage 2	482.53	686.08	1.422
Voltage 3	483.87	692.14	1.430
Average	481.65	685.64	1.423
% dev	0.6	1.0	0.5

Table G

	KVA	KW	KVARS
Phase 1	3.935	2.710	2.853
Phase 2	4.302	3.375	2.667
Phase 3	4.576	3.25	3.222
Average/Total	12.813	9.334	8.742

Table H

Measured Performance	Before	After
Motor KW	11.4	9.3
Motor KVA	20.77	12.8
Motor Measured Efficiency	89.9%	93%
Fan RPM	505	614
Motor Operating Temp.(F)	122	95.7
Monthly Run Cost	$2,134	1741

Additionally, it was found that the motor ran cooler, which should extends the motor life, but also reduce heat load which will improve the air temp in the air being supplied for cooling.

The monthly savings was, $393.04 for an annual savings of $4,716.48 at the conservative $0.26 for a payback of approximately 1 year.

While the increased RPM provided additional air movement now that you have a consistent and efficient transfer of energy of 17.3%, there could be additional savings by reducing the RPM back to the original 505 RPM by approximately $0.9 kW. This would reduce the load from 9.1 kW down to 8.2 kW which would produce another 648 kWh in savings each month. That equates to $168.48 in additional monthly savings. This can be easily produced if desired.

It should also be noted that the old motor was operating at 122 degrees F and the new motor is operating at 95.7 degrees F. The cooler operating temperature will extend motor life, but also reduce heat load which will improve the air temp in the air being supplied for cooling.

As you can see there was a tremendous loss of energy due to the inefficiency of the motor, belt slippage and poor alignment.

CONCLUSION

The results of the test unit were used to justify the conversion of 24 units for the first phase of this project. The expected payback is less than 18 months. The Phase I results of this project are shown below in ***Table I.***

Table I

	MONTHLY KW SAVINGS	MONTHLY ACTUAL SAVINGS (Based on $0.26)
COMBINED AHU UNITS	48.52	$8,764.56

Analyses of other units throughout the facility are being analyzed and the proper solutions are being evaluated on case by case bases.

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