Energy Tips – Motor

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Industrial Technologies Program

Suggested Actions

- Contact your supplier to obtain drive efficiency as a function of motor operating speed or drive power output.
- Use this information to accurately determine the energy savings due to the use of ASD versus throttle or damper flow control. When ASD part-load performance values are not readily available, use the values given in Table 1.

Resources

U.S. Department of Energy—For additional information on motor and motor-driven system efficiency, and to download the MotorMaster+ software tool, visit the BestPractices Web site at www.eere.energy.gov/industry/bestpractices, or contact the EERE Information Center at (877) 337-3463.

National Electrical Manufacturers Association (NEMA)—Visit the NEMA Web site at www.nema.org for information on motor standards, application guides, and technical papers.

Adjustable Speed Drive Part-Load Efficiency

An adjustable speed drive (ASD) is a device that controls the rotational speed of motor-driven equipment. Variable frequency drives (VFDs), the most common type of ASDs, efficiently meet varying process requirements by adjusting the frequency and voltage of the power supplied to an AC motor to enable it to operate over a wide speed range. External sensors monitor flow, liquid levels, or pressure and then transmit a signal to a controller that adjusts the frequency and speed to match process requirements.

Pulse-width modulated (PWM) VFDs are most often used in variable torque applications in the 1 to 1,000 hp motor size range. For centrifugal fans or pumps with no static lift, the fluid or air flow provided varies directly with the pump or fan rotational speed. The input power requirement varies as the cube or third power of the speed ratio (see Figure 1). Small decreases in equipment rotating speed or fluid flow yield significant reductions in energy use. For example, reducing speed (flow) by 20% can reduce power requirements by approximately 50%.

$$hp_2 = hp_1 \times (RPM_2 / RPM_1)^3 = hp_1 \times (Flow_2 / Flow_1)^3$$

Where:

hp_1 = driven-equipment shaft horsepower requirement at original operating speed

hp_2 = driven-equipment shaft horsepower requirement at reduced speed

RPM_1 = original speed of driven equipment, in revolutions per minute (RPM)

RPM_2 = reduced speed of driven equipment, in RPM

$Flow_1$ = original flow provided by centrifugal fan or pump

$Flow_2$ = final flow provided by centrifugal fan or pump

Figure 1. Power requirement for centrifugal loads

Determining Energy Savings

To establish the energy savings that are possible when an ASD is applied to a variable torque load, you must determine the load duty cycle, or percentage of time that the fan or pump operates at each system operating point. You must also know the efficiency of the variable speed drive and the drive motor when the motor is operating partially loaded and at a reduced speed to satisfy variable flow requirements.

Variable and constant torque loads are expressed in terms of the shaft horsepower supplied by the motor. A motor "load factor" is the load imposed upon the motor by the driven equipment divided by the motor's full output rating. The load on the ASD is the actual power supplied by the device (shaft horsepower divided by the motor efficiency at its load point) divided by the rated output power. Manufacturers can provide efficiency values for ASDs as a function of operating speed or load for both variable torque loads (centrifugal fans and pumps) and constant torque loads (cranes, hoists, and conveyors).

When considering electronic PWM ASDs, you may use Table 1 to obtain efficiency values for drives of various ratings that supply power to motors connected to either variable or constant torque loads.

Table 1. PWM ASD Efficiency as a Function of Drive Power Rating[1]

Variable Speed Drive hp Rating	Efficiency,%						
	Load, Percent of Drive Rated Power Output						
	1.6	*12.5*	*25*	*42*	*50*	*75*	*100*
3	31	77	86	90	91	93	94
5	35	80	88	91	92	94	95
10	41	83	90	93	94	95	96
20	47	86	93	94	95	96	97
30	50	88	93	95	95	96	97
50	46	86	92	95	95	96	97
60	51	87	92	95	95	96	97
75	47	86	93	95	96	97	97
100	55	89	94	95	96	97	97
200	61	91	95	96	96	97	97
400	61	91	95	96	96	97	97

1. These efficiency values may be considered representative of "typical" PWM ASD performance. There is no widely accepted test protocol that allows for efficiency comparisons between different drive models or brands. In addition, there are many ways to set up an ASD that can affect the operating efficiency. *Source: Safronics, Inc.*

ASD efficiency decreases with decreasing motor load. The decline in efficiency is more pronounced with drives of smaller horsepower ratings. As shown in the following example, this reduction in efficiency is not as detrimental as it first seems.

Example

Consider an adjustable speed drive coupled to a motor that delivers 20 hp to an exhaust fan when operated at its full rated speed. At 1/4 of its rated operating speed, the fan delivers 25% of its rated airflow, but requires only 1/64 of full-load power. Even with the low drive efficiency of 47%, with adjustable speed operation the power required by the fan and the VFD is only 0.66 hp.

$$\mathbf{hp_{25\%} = (20\ hp\ x\ (1/4)^3 / (47/100)) = 0.66\ hp.}$$

Note: This example does not account for the efficiency at each load point for the fan drive motor.

Remember that the system efficiency is the product of the ASD efficiency, the motor efficiency at its load point, and the driven equipment efficiency ($E_{system} = E_{ASD}$ x E_{motor} x $E_{Equipment}$). Efficiencies for integral horsepower NEMA Design A and B motors at full and part-load can readily be obtained from the U.S. Department of Energy's MotorMaster+ 4.0 software tool. Efficiencies for driven equipment must be extracted from the appropriate pump or fan performance curves.

BestPractices is part of the Industrial Technologies Program Industries of the Future strategy, which helps the country's most energy-intensive industries improve their competitiveness. BestPractices brings together emerging technologies and best energy-management practices to help companies begin improving energy efficiency, environmental performance, and productivity right now.

BestPractices emphasizes plant systems, where significant efficiency improvements and savings can be achieved. Industry gains easy access to near-term and long-term solutions for improving the performance of motor, steam, compressed air, and process heating systems. In addition, the Industrial Assessment Centers provide comprehensive industrial energy evaluations to small- and medium-size manufacturers.

FOR ADDITIONAL INFORMATION, PLEASE CONTACT:

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