HIGH EFFICIENCY MOTORS AND DRIVE SYSTEM

Gojko Joksimović[1]

ABSTRACT:
There are several electrical energy efficiency opportunities including lighting efficiency, motor and drive system improvements, power factor correction and automation/control. This paper focuses on high efficiency motors and drives. In industrial applications, motor driven systems represent about 60% of all the electrical energy used. That means that one of the first areas to look for energy savings is in adequate motor choice. Today, this means choice of modern, high efficiency motors. In addition, most motors turn at nearly constant speed.
However, much of the time the devices they drive may operate at less than maximum design speed. The speed reduction can be accommodated by a variable speed drive that varies shaft speed to the driven load, which can significantly reduce energy consumption.

1. HIGH EFFICIENCY MOTORS

Electrical motor turns electrical into mechanical energy. Motor efficiency is the ratio of mechanical power output to the electrical power input. In other words, motor efficiency represents the percent of input energy that is converted into useful work. However, motor efficiency varies with load. The efficiency of motors typically peaks at close to 75 percent of full load and is relatively flat down to a 50 percent load point.

A motor's nameplate rating is based on output power, which is fixed for continuous operation at full load. The amount of input power needed to produce the rated output power will vary from motor to motor, with more-efficient motors requiring less input wattage than less-efficient models to produce the same output. The energy consumption of a motor is inversely proportional to the motor effi-

[1] Dr Gojko Joksimović, Associate Professor, Department of Electrical Engineering, University of Montenegro

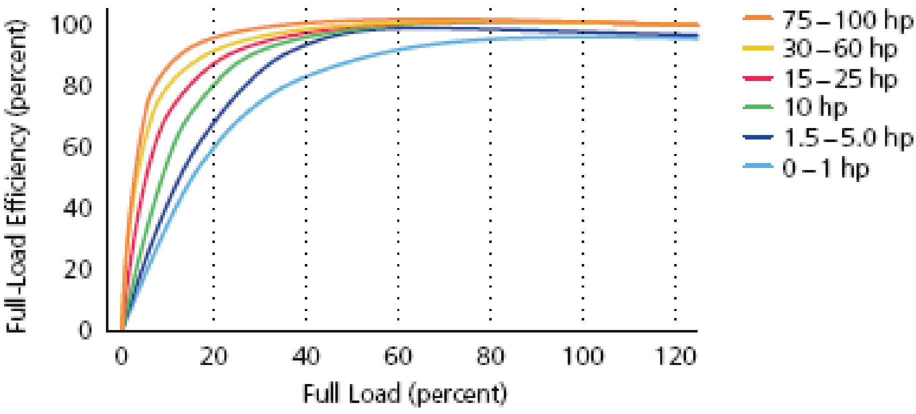

Fig 1. Motor efficiency versus motor loading

ciency, so, a higher level of efficiency results in an overall reduced level of consumption.

Most motors are operated at 60 to 75 percent of their rated capacity. Oversized motors have a lower rate of efficiency when they are in operation. A motor that is operating at a 35 percent load is less efficient than a smaller motor that is matched to the same load. Also, motor power factor depends of load. When motor operate near rated load, the power factor is high. For lightly loaded motors, the power factor drops significantly. In addition to increased electrical costs, a lower power factor will result in high internal electric losses and motor heating, which could reduce motor lifetime.

Since electric motor systems consume large amounts of electrical energy, they can provide an opportunity for significant energy savings. Energy represents more than 97% of total motor operating costs over the motor's lifetime. However, the purchase of a new motor often tends to be driven by the price, not the electricity it will consume. Even a small improvement in efficiency could result in significant energy and cost savings. Investing a little more money upfront for a more efficient motor is often paid back in energy savings. When a motor fails is often the best opportunity to install a more efficient motor, rather than repairing it.

What is high efficiency motor, or, how to classify a motor as a high or premium efficiency motor? In 1989, the National Electric Manufacturers Association (NEMA) developed a standard definition for high efficiency motors. The definition includes a table of threshold nominal full-load efficiency values. This table pass some revisions and any motor's performance, tested by IEEE 112 method B or

Table 1. Nominal full-load efficiency for
"High efficiency motors" – NEMA

HP	2 Poles	4 Poles	6 Poles	8 Poles
7.5	88.5	89.5	89.5	85.5
10	89.5	89.5	89.5	88.5
15	90.2	91.0	90.2	88.5
20	90.2	91.0	90.2	89.5
25	91.0	92.4	91.7	89.5
30	91.0	92.4	91.7	91.0
40	91.7	93.0	93.0	91.0
50	92.4	93.0	93.0	91.7
60	93.0	93.6	93.6	91.7
75	93.0	94.1	93.6	93.0
100	93.6	94.5	94.1	93.0
125	94.5	94.5	94.1	93.6
150	94.5	95.0	95.0	93.6
200	95.0	95.0	95.0	94.1
250	95.4	95.0	95.0	94.5
300	95.4	95.4	95.4	94.5
400	95.4	95.4	95.4	94.5
500	95.4	95.8	95.4	94.5

NEMA test method, must equal or exceed the efficiency levels given in the table below for it to be classified as "High efficiency motor"

In contrast to the American legislation on motor efficiency, the European agreement between the European Comission and the European Committee of Manufacturers of Electrical Machines and Power Electronics (CEMEP) does not establish mandatory efficiency levels for low voltage motors. It basically establishes three classes, Fig.2, giving motor manufacturers an incentive to qualify for a higher class. All efficiency levels are based on the IEC 34-2 and IEC 34-1 standards.

The agreement, initially, only applies to four-pole, three-phase squirrel cage induction motors, rated for 400V, 50Hz, with S1 duty class, ranging from 1.1 to 90kW output. These account for the largest volume on the market. Efficiency levels for various motor types are voluntarily agreed between the European Union's motor manufacturers in CEMEP and the European Commission. Manufacturers outside CEMEP are welcome to use the labeling, but there is no requirement for them to do so.

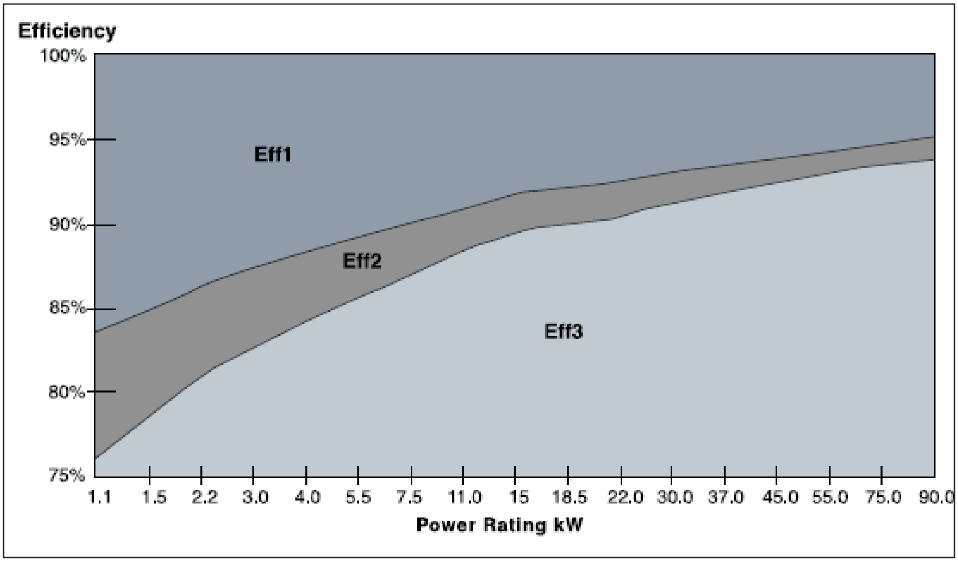

Fig 2. Motor efficiency versus motor power – CEMEP

Table 2. Borderlines between efficiency classes - CEMEP

Output kW	2-pole borderline Eff2/Eff3	Eff1/Eff2	4-pole Borderline Eff2/Eff3	Eff1/Eff2
1.1	76.2	82.8	76.2	83.8
1.5	78.5	84.1	78.5	85.0
2.2	81.0	85.6	81.0	86.4
3	82.6	86.7	82.6	87.4
4	84.2	87.6	84.2	88.3
5.5	85.7	88.6	85.7	89.2
7.5	87.0	89.5	87.0	90.1
11	88.4	90.5	88.4	91.0
15	89.4	91.3	89.4	91.8
18.5	90.0	91.8	90.0	92.2
22	90.5	92.2	90.5	92.6
30	91.4	92.9	91.4	93.2
37	92.0	93.3	92.0	93.6
45	92.5	93.7	92.5	93.9
55	93.0	94.0	93.0	94.2
75	93.6	94.6	93.6	94.7
90	93.9	95.0	93.9	95.0

When to buy Energy – Efficient motors?

Energy efficient motors should be considered in the following instances, [10]:
– For all new installations
– When major modifications are made to existing facilities or processes
– For all new purchases of equipment packages that contain electric motors, such as air conditioners, compressors and filtration systems
– When purchasing spares or replacing failed motors
– Instead of rewinding old, standard efficiency motors
– To replace grossly oversized and under loaded motors
– As part of an energy management or preventive maintenance program

2. VARIABLE SPEED DRIVES

Most motors turn at nearly constant speed. However, much of the time the devices they drive may operate at less than maximum design speed. Fans and pumps are the most common energy saving applications.

When a fix speed motor drives a fan, the air flow may sometimes be higher than it needs to be. Airflow can be regulated by using a damper to restrict the flow, but it is more efficient to control the airflow by regulating the speed of the motor.

The speed reduction can be realized using variable speed drive that varies shaft speed to the driven load.

The most common type of variable speed drives are variable frequency drives or inverters. An inverter is static converter that is able to generate alternating voltage of variable frequency and magnitude, Fig 3. The motor speed varies propor-

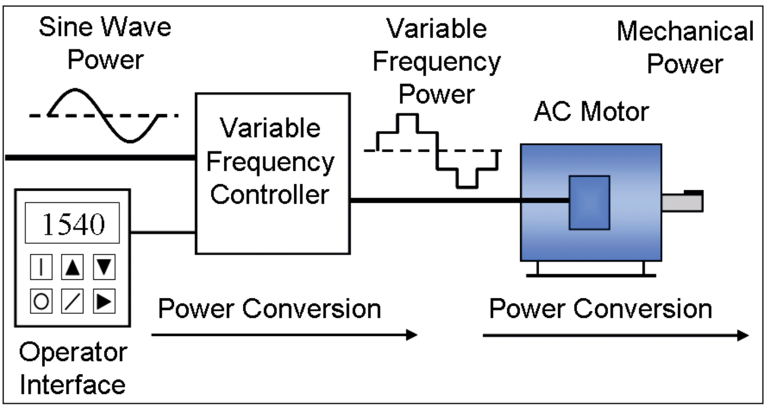

Fig.3. Variable speed drive scheme

tionally to frequency of the applied voltage. Variable speed drives often uses less energy than an alternative fixed speed mode of operation.

Saving energy with the adjustable speed pump operation is similar to saving energy with adjustable speed fan operation. It is more efficient to regulate the flow of fluid by regulating the speed of the motor rather than by restricting the flow using a control valve.

Savings from variable speed drives in these applications come from reduced load of fans and pumps. Namely, both devices, fans and pumps, are described with so called cube characteristics. Consumed power of devices depends of cube of shaft speed,

$$P \propto \omega^3$$

So, reducing of shaft speed for 10% means reducing consumed power of 27%

$$P \propto (0.9\omega)^3 = 0.73\omega^3 = 0.73P$$

or, reducing of shaft speed for 20% means reducing consumed power of almost 50%.

$$P \propto (0.8\omega)^3 = 0.51\omega^3 = 0.51P$$

Variable speed drives also allows for soft starting. This means that motor starts slowly, at lower frequency and voltage and than speeds up. This reduces starting current, voltage dips and mechanical stress of the motor and driven devices.

Basic variable speed drive cost about the same as the motors they drive. Cost for basic drive start at around 300 euro per kW for one kW drive and drop sharply to around 90 euro per kW for a 15 kW drive. Other costs such as installation, electrical filters and special features for constant torque, special controls or diagnostics can easily more than double the costs.

CONCLUSION

High efficiency motors and variable speed drives obviously offers great opportunity for big amount of electrical energy savings, especially when high energy efficiency motors are part of variable speed drives. Initial investments in these devices will pay back in a few years with big savings for electricity bills during the remaining life of the equipment.

4. LITERATURE

http://www.energy.wsu.edu/documents/engineering/motors/MotorDrvs.pdf
http://www1.eere.energy.gov/industry/bestpractices/pdfs/whentopurchase_nema_motor_systemts1.pdf
http://www.controleng.com/article/CA6427957.html?rssid=123
http://www.alliantenergy.com/docs/groups/public/documents/pub/p012399.hcsp
http://www.copper.org.sg/pdf/HEM-Chapter2-Part2.pdf
[10]Energy efficient motor selection handbook, Bonneville power administration, http://www.wbdg.org/ccb/DOE/TECH/ce0384.pdf

SAŽETAK:
Jedna od značajnih mogućnosti efikasnije upotrebe električne energije, pored povećanja efikasnosti izvora svjetlosti, korekcije faktora snage i automatizacije i kontrole procesa, jeste korišćenje visoko efikasnih električnih motora i električnih pogona čiji su oni sastavni dio. U industrijskim primjenama, električni motori i električni pogoni u čijem su oni sklopu, troše oko 60% ukupno preuzete električne energije. Ovaj procenat nije zanemariv i u komercijalnim i rezidencijalnim objektima. Iz ovoga prirodno slijedi da je jedan od prvih koraka koji treba napraviti u cilju uštede tj. efikasnije upotrebe električne energije, adekvatan izbor motora. Danas, pored pažljivo i adekvatno odabrane snage motora, to znači prije svega izbor tzv. high efficiency motora, tj. motora sa visokim stepenom koeficijenta korisnog dejstva. Pored toga, oprema pokretana električnim motorom, u najvećem dijelu vremena ne zahtijeva maksimalnu projektovanu brzinu. Ukoliko se redukcija brzine ostvaruje korišćenjem električnih pogona varijabilne brzine, može biti ostvarena dodatna značajna ušteda električne energije.