What Does Efficiency Really Mean for Your Power Consumption?

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Efficiency is an incredibly important topic in our age for end users, manufacturers, and others involved in the electric motor industry. From lifecycle cost implications to debates over human impact on climate change, conversations about energy efficiency are everywhere. Industry professionals often suggest that electric motors consume around half of the electricity generated worldwide; their power consumption is a critical topic to be considered. However, to accurately assess the amount of power induction motors consume, individuals in the electric motor field need to dive deeper than simply a motor efficiency rating.

Consider a situation where an end user issues a request for proposal (RFP) on a new induction motor. Their specification will cover items such as ambient environment details, required motor enclosure, bearing type, and very likely some requirement for motor performance including motor efficiency. This user specifies that the motor should be "premium efficient" and might even call out some cost penalties for the motor manufacturer associated with dollars per kilowatt (kW) loss when efficiency requirements aren't met. The motor manufacturer will consider these requirements during the sales cycle and provide either a previously designed or newly designed motor to meet the efficiency and other requirements set forth by the end user. Ultimately, the goal for the end user in specifying an efficiency level is to procure a motor that uses less energy for either environmental or cost reasons, or possibly both. With the conforming motor quotation in hand, the end user might believe they have found a machine that consumes as little electrical power as possible—but is that really the case? Unfortunately, all too often the customer has only found a motor that meets the federal efficiency minimum and not one that will actually consume less energy.

The question then becomes, what is overlooked when considering power consumption with induction motors? What many people fail to realize is that in addition to efficiency, power factor (PF) plays an equally vital role in determining power consumption. Unlike their synchronous (i.e. large wound field or smaller permanent magnet motors) or DC counterparts, induction motors exhibit lagging power factor. This, by definition, offsets the voltage and current waveforms producing increased power consumption. To illustrate this point further, consider that the most basic definition of total apparent electrical power in a three phase circuit is (More information on true vs apparent vs reactive power is readily available elsewhere and it is assumed the reader has prior knowledge about the subject.):

$$Equation\ 1: KVA = \frac{(\sqrt{3}\ x\ Volts\ x\ Amps)}{1000}$$

For active power (i.e. the real power used to perform useful mechanical work):

$$Equation\ 2: KW = \frac{(\sqrt{3}\ x\ Volts\ x\ Amps\ x\ PF)}{1000}$$

Or put another way:

$$KW = KVA\ x\ PF$$

For three phase induction motors, amperage at a given load point can be found via:

$$Equation\ 3: Amps = \frac{(HP\ x\ 746)}{(\sqrt{3}\ x\ Volts\ x\ Eff.\ x\ PF)}$$

As seen above, total power consumed by an electric motor is dependent on both the rated motor voltage and amperage with amperage being dependent on operating HP, rated voltage, efficiency and PF. As efficiency decreases, rated amperage for the motor increases and consequently more power is consumed. The point often overlooked here is that PF has an equal role in determining a motor's amperage. Demonstrated by equation three, as PF at a load point decreases, rated motor amperage increases and consequently so, the power consumed by the motor.

Knowing this, it is clear that a motor designed for the same HP, voltage, and efficiency can have amperages that vary considerably based purely on its PF. Consider three motors available in industry as standard catalogue products, all with the following rating:

100HP, 8 pole, 444/5T frame, 460V, 60Hz, TEFC enclosure, NEMA Design B, KVA Code G, Class F Insulated

The figure below shows the motors' rated HP, full load (FL) efficiency, FL PF, FL amps, and FL KVA:

	Nameplate HP	FL Efficiency	FL PF	FL Amps	FL KVA
Motor #1	100	.930	.667	151	120
Motor #2	100	.941	.790	127	101
Motor #3	100	.936	.740	135	108

Table 1 – Motor Performance Comparison from Three Different Manufacturers

As can be seen above, for the size of motor being considered here, the kilo-volt-ampere (kVA) rating varies considerably. Without proper compensation (in the form of PF correction capacitors, synchronous motors at the site, synchronous condensers, etc), this can result in wide differences in the amount of power consumed by the motor as well as the cost in utility bills borne by the end user.

It is also wise to remember that for induction motors, both efficiency and power factor decrease as the motor load lessens. As can be seen in Figure 1 below, power factor drops off especially quickly as shaft load on a motor is decreased, making the aforementioned issues even more costly for a lightly loaded motor.

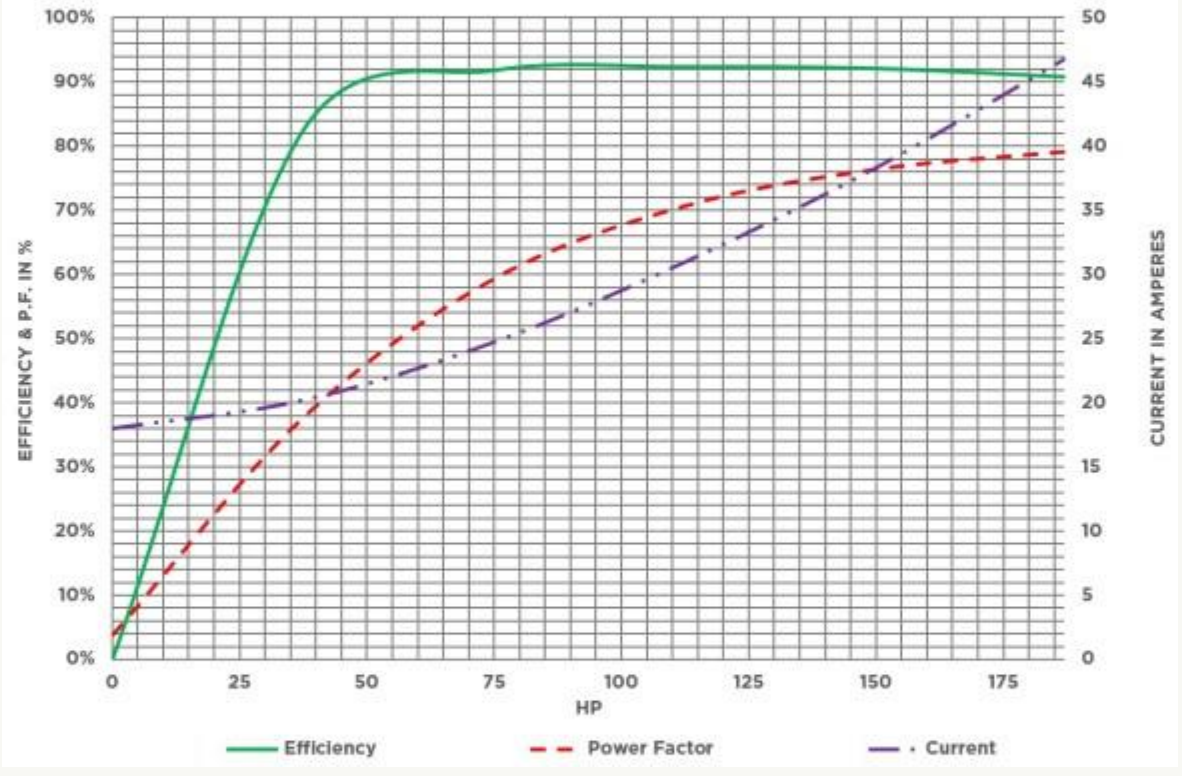

Figure 1 – Typical Eff/PF/Amps vs HP Curves for an Induction Motor (credit designmotors)

In summary, unless induction motor users have some method to correct a system wide lagging power factor, it is critical to consider a motor's rated PF in addition to its rated efficiency. If industrial users intend to be good stewards of both the resources consumed to provide electrical power and the costs associated with this power, a more thorough view of power consumption is necessary. With an expanded view, our field can bolster its efforts to use our available power resources effectively as we continue to provide vital work to society.