

# HIGH OR PREMIUM EFFICIENCY MOTORS

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## INTRODUCTION

The purpose of this paper is to present an understanding of high efficiency motors. This will cover the relevant standards, technology, developments, practical application aspects and future developments.

Today, globally, electric motors account for as much as 60% of industrial energy usage. Industrial energy usage in turn is approximately 70% of national energy usage. Electric motors therefore account for approximately 40% of national energy consumption. In South Africa specifically, the percentage is higher, being approximately 60%. The exact percentages involved are impossible to determine but are certainly within 10% of the given values. It could then be said with certainty that electric motors account for  $\geq 40\%$  of national electrical energy consumption. Yet a huge amount of this energy is wasted, as organisations use solutions which are poorly designed or inappropriate for their application. By reducing this wastage, companies not only help the environment, but also cut their costs and improve profitability. For this reason, during the last few years high efficiency motors have very much become a focus in industry in the drive to reduce power consumption and their carbon footprints.

## EFFICIENCY STANDARDS DEFINED

Generically speaking, a high efficiency motor is defined as one that accomplishes more work per unit of electricity consumed than a standard motor. Standard motors comply only with the regulated minimum efficiency levels of each country.

In 1988, the European Committee of Manufacturers of Electrical Machines and Power Electronics (CEMEP) made a voluntary agreement defining efficiency levels. This covered motors from 1.1 to 90 kW, 2 and 4 poles, 50 Hz. The efficiency levels were defined as EFF3, EFF2 and EFF1. The efficiency levels were chosen by CEMEP and the method of testing efficiency was in accordance with the IEC60034-2:1996 standard. It is important to note that this was a voluntary guideline, not a defining standard. As of September 2008, the IEC 60034-30:2008 standard became effective. This defines efficiency standards for motors from 0.75 to 375 kW, 2, 4 and 6 poles, 50 Hz and 60 Hz. This is a regulatory standard. Locally it is published as SANS/IEC 60034-30:2008. In conjunction with this standard is IEC60034-2-1:2007 which defines the methods of testing efficiency. Efficiency levels in IEC60034-30:2008 are defined as follows:

IE1 – Standard Efficiency

IE2 – High Efficiency

IE3 – Premium Efficiency

IE4 – Super Premium Efficiency\*

IE5 – Ultra Premium Efficiency\*

\*under discussion

It is important to note that both CEMEP and IEC permit manufacturers to use their own terminology, for example: 'Top Premium Efficiency' or 'Enhanced Efficiency'. However, regardless of manufacturers' terminology, under the IEC standard, manufacturers have to stipulate the relevant IEC efficiency level and test method.

Furthermore, it is important to note that on December 22, 2009, CEMEP declared that from June 16, 2011, the 'EFF' trademark would no longer be permitted. These identifications were

registered on February 10, 2000 by the French Motors and Drives Association (Gimélec) on behalf of CEMEP and licensed to the participants of the 'voluntary agreement'.

The result is therefore that efficiency levels defined by IEC60034-30:2008 and tested according to IEC60034-2-1:2007 replace the voluntary efficiency standards defined by CEMEP and tested according to IEC60034-2:1996.

It is intended that the IEC efficiency levels be equivalent to the CEMEP efficiency levels: IE1 = EFF2 and IE2 = EFF1. It is important to note that under CEMEP, EFF3 was the lowest efficiency and EFF1 the highest efficiency. The IEC levels are the reverse of this, with IE1 being the lowest and IE3 the highest. There is provision for future development with yet higher efficiency levels of IE4 and IE5 that will come into force in due course.

Below is a table comparing the different levels. It is immediately obvious that the IE1/EFF2 and IE2/ FF1 efficiency levels are not the same. The reason for this is that the test methods as defined by IEC60034-2:1996 (old) and IEC60034-2-1:2007 (new) are different. The intent is that if the same motor, for example a 4 kW, was tested and defined according to CEMEP/IEC60034-2:1996 (old) it would give an efficiency of  $\geq 88.3\%$  (EFF1); while if it were tested according to IEC60034-30:2008/IEC60034-2-1:2007 (new), it would give an efficiency of  $\geq 86.6\%$  (IE2). This does not mean that the old CEMEP levels were higher or better. The old test methods allowed certain assumptions and tolerances that allowed manufacturers to legally declare an efficiency level that was higher. The test methods are explained in a later section of this paper.

<b>COMPARISON OF EFFECIENCY LEVELS</b>					
<b>4 Pole Motor</b>	<b>CEMEP EFF 2</b>	<b>CEMEP EFF 1</b>	<b>IEC IE1</b>	<b>IEC IE 2</b>	<b>IEC IE 3</b>
<b>kW Rating</b>	<b>Improved Efficiency</b>	<b>Premium Efficiency</b>	<b>Standard Efficiency</b>	<b>High Efficiency</b>	<b>Premium Efficiency</b>
0.75	74.40	82.20	72.10	79.60	82.50
1.1	76.20	83.80	75.00	81.40	84.10
1.5	78.50	85.00	77.20	82.80	85.30
2.2	81.00	86.40	79.70	84.30	86.70
3	82.60	87.40	81.50	85.50	87.70
4	84.20	88.30	83.10	86.60	88.60
5.5	85.70	89.20	84.70	87.70	89.60
7.5	87.00	90.10	86.00	88.70	90.40
11	88.40	91.00	87.60	89.80	91.40
15	89.40	91.80	88.70	90.60	92.10
18.5	90.00	92.20	89.30	91.20	92.60
22	90.50	92.60	89.90	91.60	93.00
30	91.40	93.20	90.70	92.30	93.60
37	92.00	93.60	91.20	92.70	93.90
45	92.50	93.90	91.70	93.10	94.20
55	93.00	94.20	92.10	93.50	94.60
75	93.60	94.70	92.70	94.00	95.00
90	93.90	95.00	93.00	94.20	95.20
110			93.30	94.30	95.20
132			93.50	94.60	95.40
160			93.80	94.80	95.60
200 - 375			94.00	95.00	95.80

Table 1. Comparison of efficiency levels

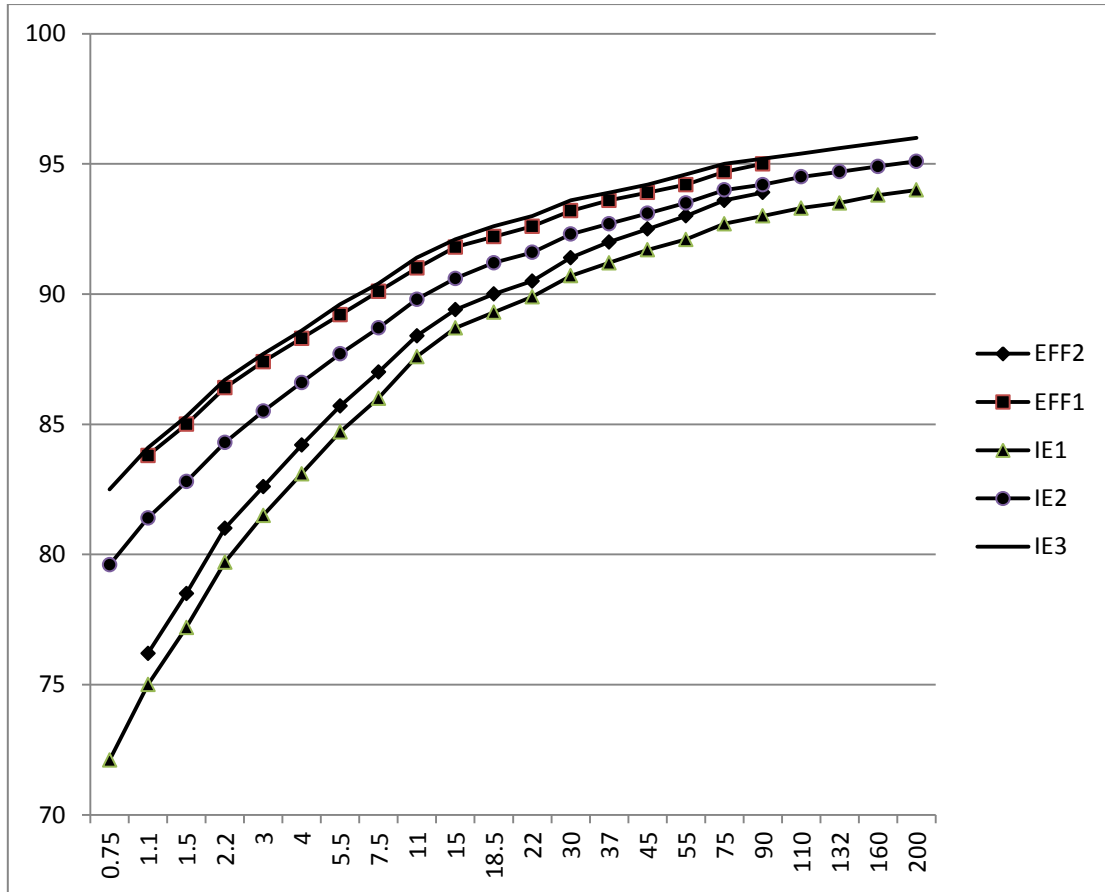


Figure 1. Graphic comparison of efficiency levels

### MAIN COMPONENTS OF MOTOR LOSSES

Motor efficiency is basically the ratio between the output power available at the motor shaft, and the electrical input power or absorbed power. The difference between P out and P in are the losses.

$$\eta\% = \frac{P_{out}}{P_{in}}$$

The main components of motor losses are:

#### Joule Losses

These losses are directly dependant on the resistivity of the material (copper/aluminium) and the current flowing in it, as per the formula below:

$$P_j = I^2 \times R$$

Where:

P<sub>j</sub> = joule losses (watts)

I = current (amps)

R = resistance of the material (ohms)

$$R = \frac{\rho \times l}{S}$$

Where:

ρ = resistivity of the material (ohms-meter)

l = length (metre)

S = area (square metre)

Therefore:

$$P_j = I^2 \times \frac{\rho \times l}{S}$$

### **Iron Losses**

Iron losses are losses due to the magnetic field in the rotor and stator laminations. These losses are dependent on the magnetic induction, frequency, and the quality of the magnetic properties of the material used. (Hysteresis is also part of iron losses but a very small component and is therefore ignored in the formula below)

$$P_f = K \times f^2 \times B_{max}^2$$

Where:

Pf = iron losses

K = constant depending on the material used

f = frequency in hertz

Bmax = maximum induction in tesla

### **Mechanical Losses**

Mechanical losses are produced by the cooling fan coupled on the motor shaft and also the bearing friction. These losses are directly affected by the motor speed. In addition, operating conditions such as ambient temperature, over-greasing or misalignment affect these losses.

### **Additional or Stray Load Losses**

These losses are caused by currents and magnetic flux in high frequency components. Design techniques are used to minimise additional load losses.

### **Loss Composition Summary**

There is no standard percentage that can be attributed to each component of the motor losses, however, joule losses are always the largest, followed by additional load losses, iron losses and mechanical losses. The values vary from motor to motor.

Joule losses, iron losses and mechanical losses can be reliably measured. Additional load losses are very difficult to determine. Previously manufacturers were permitted to assume additional load losses to be 0.5% of motor absorbed power. Sometimes the 0.5% value was much too low and allowed some manufacturers to quote efficiency values that were not accurate. This is no longer permitted.

### **How to Improve Motor Efficiency**

In order to improve motor efficiency, the losses on the motor must obviously be reduced by working on the main components listed above.

#### ***Joule losses***

The motor R (resistance) is reduced by using more copper in the windings by using winding wire or cables with a larger diameter. The motor must still have the same characteristics, therefore the core length, number of turns or slot design must be adjusted to accommodate the change in winding design. In practise, the increase of diameter is limited by the slot space available for the windings.

#### ***Iron losses***

The quality of the magnetic properties of the stator and rotor are improved in order to reduce iron losses. There are two approaches to this. Firstly, using thinner laminations reduces the losses due to eddy currents. There are limits as to how thin a lamination can be. Secondly, there are different grades of lamination steel. Each grade improvement has lower losses and higher costs.

**Mechanical losses**

The design of the motor cooling can be improved resulting in a smaller fan with lower losses. The cooling design can also improve bearing temperatures. Both these improvements result in a very small gain in efficiency because the mechanical losses on a motor are very low to begin with. A more efficient cooling system also reduces the noise of the motor.

**Additional or stray load losses**

Proprietary design techniques are used to reduce stray load losses. Developments in this area are mostly unique to each manufacturer’s engineering process.

**TESTING METHODS**

Both the old IEC60034-2:1996 and the new IEC60034-2-1:2007 test methods specify two methods of testing: direct and indirect. Under the old method, the additional load losses or stray load losses (SLL) were assumed as 0.5% of the motor absorbed power. The new IEC60034-2-1:2007 Standard continues to specify two methods for testing motors: direct and indirect. The main difference is that the indirect method has changed and no longer allows additional load losses to be accepted as 0.5% of motor absorbed power. The two are compared in the table below.

COMPARISON OF MOTOR EFFICIENCY TEST METHODS			
OLD IEC60034-2:1996		NEW IEC60034-2-1:2007	
Direct	Measure input electrical power and output mechanical power	Direct	Measure input electrical power and output mechanical power
Indirect	Sll assumed as 0.5% of motor rated power	Indirect	A. Measurement
			B. Regression analysis
			C. Assigned allowance
			D. Eh - start test

Table 2. Comparison of motor efficiency test methods

The direct method may seem the best but it does not yield the most accurate measurement. The results are a calculated efficiency based on measuring the input electrical power and output mechanical power. Several measurements must be made and the inherent instrumentation errors then make it difficult to achieve an acceptably accurate result.

The indirect method is the method most commonly used since it provides reliable figures and separation of losses. The joule, iron and mechanical losses are first measured. Additional load losses may then be determined by any one of four methods as given below:

- a. From measurement: the additional load losses are determined by measurement of all the other losses and subtracted from the absorbed power and output power.
- b. From a test with the rotor removed and reverse rotation: in this case, part of the test rotor is removed, a regression analysis to the log of power and currents is done to calculate the additional load losses.
- c. From assigned allowance: the value of the additional load losses at rated load is assumed as a percentage of input power, as per the figure below.
- d. From an Eh-start test: the additional load loss data is smoothed by using linear regression analysis and mathematic calculation.

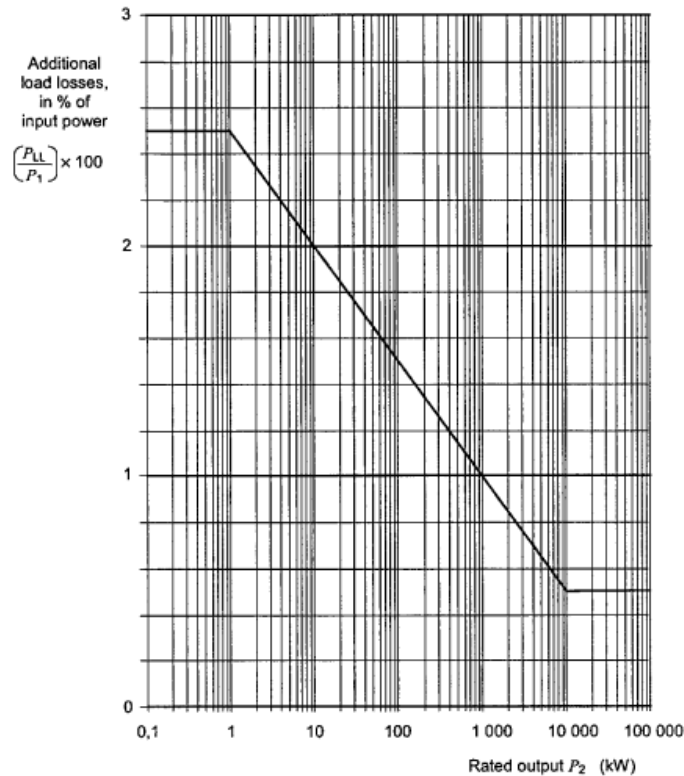


Figure 2. Assigned allowance for additional load losses

The most reliable way to determine the additional load losses is from measurement, where the actual value is found. Manufacturers are allowed to select the method they want to use to determine the additional load losses, but now the standard defines that they must state their option on the motor documentation since motors tested using different methods are **not comparable**.

For an end user to make a sensible comparison, motors of the same efficiency level and tested by the same standard method should be compared.

The efficiency comparison below is not valid:

Manufacturer A: IE2 92.8% Indirect measurement  
 Manufacturer B: IE2 93.2% Indirect assigned

The efficiency comparison below is valid:

Manufacturer A: IE2 93.4% Indirect measurement  
 Manufacturer B: IE2 92.9% Indirect measurement

It is not possible to predict the efficiency of the same motor based on different test methods. The efficiency can reduce, remain the same or even improve.

Below is an evaluation of one example for a 160 kW motor.

With the old testing methodology (IEC60034-2:1996), the additional load losses would be assumed as 0.5% of the motor absorbed power, leading to an efficiency value of 96.15%.

With the new testing methodology (IEC60034-2-1:2007), and the additional load losses measured using the indirect method, the efficiency would be 95.92%.

It is the same motor, using different testing methodologies to declare efficiency.

## DECLARING A MOTOR EFFICIENCY

Although manufacturers are allowed to specify their products using different terminology, such as 'Top Premium Efficiency', or 'Ultra Energy Saver Range' they must include the IE classification on the motor nameplate and the test method used must be stipulated on the motor datasheet. Examples of this are given below.

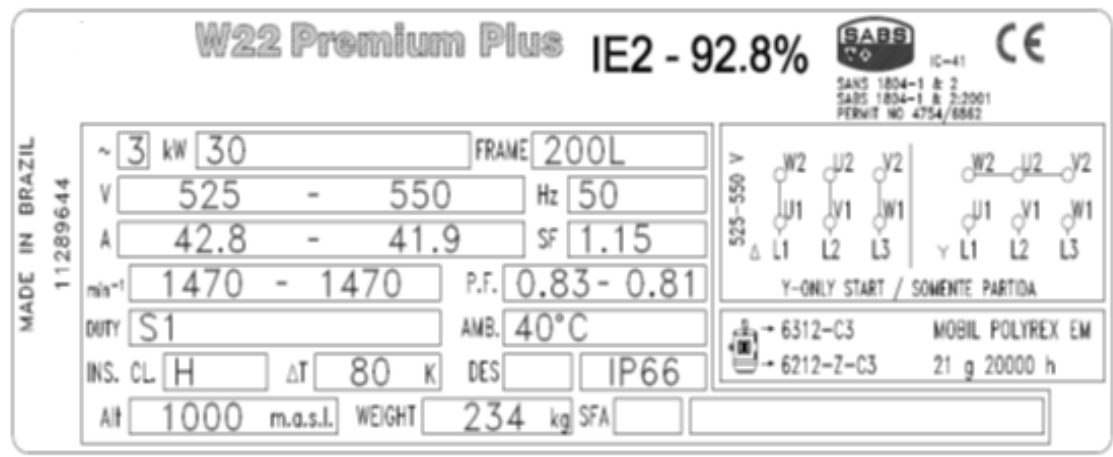


Figure 3. Nameplate showing the IE2 marking

	D.E.	N.D.E.	Load	Power factor	Efficiency (%)
Bearings	6312 C3	6212 Z-C3	100%	0.83	92.8
Regreasing interval	20000 h	20000 h	75%	0.78	93.0
Grease amount	21 g	13 g	50%	0.68	92.6

Notes:

Efficiencies according to the indirect method of IEC 60034-2-1:2007 with stray load losses determined from measurement.

Figure 4. Data sheet note informing how efficiency was determined.

### Tolerance on Efficiency

Besides the different test methods, manufacturers are permitted a tolerance in the figures they quote. This in accordance with IEC60034-1: 2010. The permissible efficiency tolerances are as follows:

- Motors up to and including 150 kW: — 15% of efficiency
- Motors above 150 kW: — 10% of efficiency

For example:

Motor of 75 kW with a nameplate efficiency of 94%

Tolerance:  $0.15 \times (1 - 0.94) = 0.009$

Efficiency on the test can reduce to 93.1%

Such a tolerance is intended to compensate for variances that are a reality. It does however, also allow manufacturers to possibly quote efficiency values above those which were obtained during testing.

## **THE EFFECT THAT EFFICIENCY INCREASE MAY HAVE ON OTHER MOTOR PARAMETERS**

### **Starting current**

The overall decrease in motor resistance to reduce joule losses and achieve a higher efficiency may result in the motor starting current increasing. The increase however, is not major. The increase in starting current is greater for small motors, where the effect on the user's system is less. The following values may be expected:

IE1 to IE2: +4% average  
IE2 to IE3: +15% average

### **Inrush Current**

Inrush current is a one-half cycle instantaneous peak value which may range from 1.5 to 3 times the starting current.

Thus, the slight increase in starting current leads to a proportionately slight increase in the inrush current. Inrush current is a sub-transient phenomenon which happens for a short period of time at starting and will only achieve its peak when the voltage is at 0 degrees at the moment the motor is switched on. The duration of inrush current is only a half cycle of a sine wave or 10 m/s.

### **Power Factor**

In some cases the changes made to the motor to improve efficiency does decrease the power factor, although this is not universally applicable. In some cases the power factor improves. Generally speaking, the power factor change is not detrimental because end users apply power factor control. The power factor of any installation is not only due to motors but also other capacitive or inductive equipment that impacts on the power factor of the installation. The power factor is something which can be corrected.

### **Torques**

In general, due to the higher magnetic flux used on higher efficiency motors, these present higher torque values which accelerate the load in a shorter period of time.

### **Slip**

As a result of the higher magnetic flux, high efficiency motors might present lower slip (higher speed), and depending on the type of load being driven, the motors can deliver more output (flow, pressure). This is not true on all high efficiency motors. If one considers power over a certain time then generally higher efficiency motors will absorb slightly more power. Taking into consideration power versus process production such as flow or tonnage, then a high efficiency motor absorbs less power.

### **External Items that Influence Motor Efficiency**

1. Supply voltage – a variance in voltage reduces the motor efficiency. In the case of a voltage increase, the magnetic flux increases, thus increasing the iron losses and reducing the efficiency. In the case of a voltage reduction, the stator current increases, thus increasing the joule losses and reducing the efficiency.
2. Constant or core losses in an electric motor vary with the voltage and frequency, as by changing one of these values, the magnetic flux on the motor changes, which changes the iron losses.
3. If a motor is required to operate at different speeds, the mechanical losses vary.
4. If bearings are over-greased, friction losses increase.

5. Misalignment can also increase bearing friction and therefore affect motor efficiency.
6. Rubber sealed bearings have higher friction losses than open bearings and should be avoided for optimum efficiency.
7. A poor fan design in a replacement fan can also decrease motor efficiency.
8. In a non-sinusoidal supply, the harmonic distortion causes an increase in iron losses due to the high frequency of the harmonics. These harmonics can also increase the winding losses, but in a smaller proportion since they depend on the square of the current.

### Incorrect Motor Selection

The efforts and extra capital spent when purchasing high efficiency motors may be lost if the motor selection is not properly done. Efficiency on motors decreases when operated below nominal operating point at 100% load. Some motors are designed to deliver equivalent efficiency down to 75% load. If one considers less than 75% load, there is a definite decrease in efficiency.

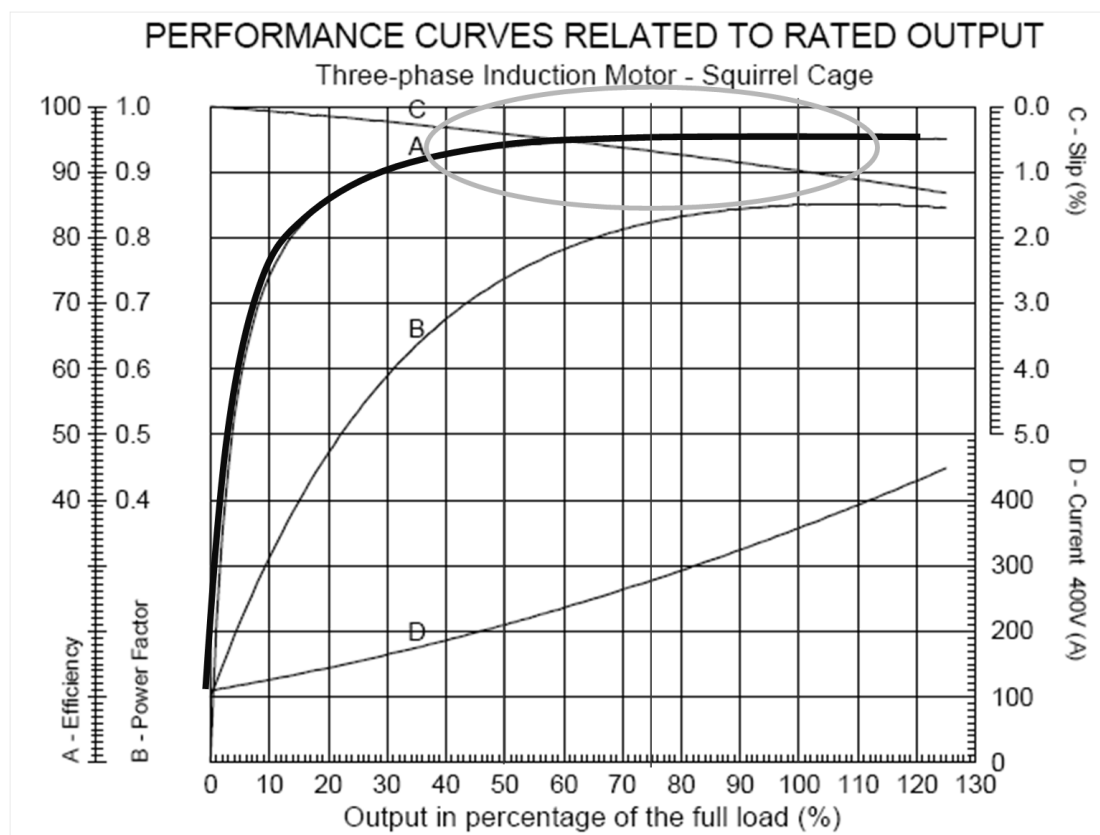


Figure 4. Performance curves related to rated output

### Efficiency on Large Motors

As stated in the introduction, approximately 40 - 60% of national electrical consumption is due to electrical motors. For purposes of illustration we will use 50% as a reasonable average. This in turn can be split between Small and Large motors as well as Low Voltage and High Voltage. The use of high efficiency motors does not address this entire spectrum. The reason for this is because the efficiency standards only cover from 0.75 Kw to 375 kW. For purposes of this paper, this would be considered as "Small Motors". Within this range, 0.75 kW to 160 kW is covered in detail, giving specific efficiencies for each standard motor rating. Thereafter from 200 kW to 375 kW a general minimum efficiency is given. Motors below 375 kW account for approximately 80% of motor electrical consumption, therefore, 30 - 50% of national energy consumption. The standards therefore address 80% of electrical motor power consumption. Secondly, the larger a motor the better it's efficiency is inherently. For

example, a standard efficiency (IE1) 7.5 kW motor has an efficiency of  $\geq 86\%$  while a high efficiency 7.5 kW has an efficiency of  $\geq 88.7\%$ . This represents a gain of 2.7%. Compared to this, a 630 kW motor would typically inherently have an efficiency of  $\geq 96\%$ . It is very difficult to get a significant improvement on an efficiency that is already at 96%. There is therefore very little to be gained by addressing large motor efficiency. Therefore, large motors only account for a small percentage of motor electrical power consumption and have relatively little possibility of gain. Large motors therefore are to be considered on a case by case basis by individual comparison rather than by applying a specification standard. One can expect an efficiency of  $>95\%$  for any large motor. For such motors it up to the end user to do a comparison or specify a required minimum efficiency.

## FUTURE DEVELOPMENTS AND NEW TECHNOLOGIES

New technologies which can provide higher efficiency levels on motors to the industry is a constant search of motor manufacturers, who are already looking forward to offering motors to comply with the upcoming IE4 and IE5 efficiency levels.

One of the recent technologies presented to the industry and currently available is the use of permanent magnets on the rotor.

By using magnets on the rotor, we eliminate joule losses on the rotor, as there will be no current circulating, and since joule losses on the rotor are part of the total losses, it is possible then to offer a higher efficiency.

These motors are presently available in two main ranges, one which has only magnets on the rotor with no cage, and requires a variable frequency drive to start, and another range, which besides the magnets, has a cage on the rotor, allowing a direct on-line starting.

### Line Start Permanent Magnet Motors

Line start permanent *magnet* motors are hybrid motors, including a cage on the rotor (like a normal induction motor) but also permanent magnets inside it, as shown on the figure below.

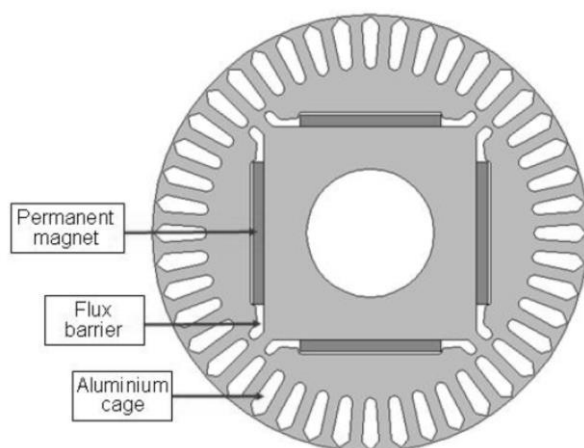


Figure 5. Line start permanent magnet motor

Due to the cage on the rotor, they work like an induction motor during starting to accelerate the motor, and when it gets to a speed close to synchronous speed, the motor is pulled into synchronism by the permanent magnets.

When the motor is at synchronism, there are no significant currents in the rotor, thus the joule losses on rotor are zero and the motor will then present a higher efficiency. Providing that the motor does not lose synchronism, i.e., that its pull-out torque is not exceeded, the motor will keep constant speed for any given load with no losses on the rotor. These motors are designed to offer a pull-out torque up to two times rate torque.

Care must be taken with regards to the load to be started by these motors, as the motor must be able to reach synchronism after starting. If the load torque is too high then synchronism may not be reached and the motor thermal capability exceeded. The lower the torque, the higher the inertia that can be started, as per the picture below, and vice-versa.

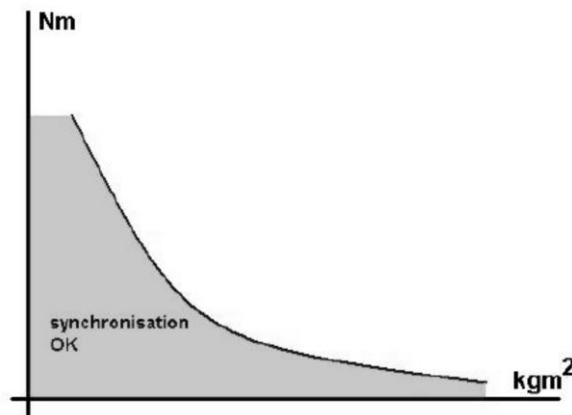


Figure 6. Torque vs. inertia characteristic

The rotor cage on these motors is smaller than that for a standard squirrel cage motor. This results in a lower thermal capability during starting. For this reason, these motors are not suitable for all applications and loads with high inertia cannot be started. Secondly, if the load torque is too great then synchronism is not reached and the motor cannot operate correctly. Thus each application must be carefully analysed.

Currently this range is available from frame size 80 up to 132, 0.37 kW to 7.5k W in 380 V and 525 V, 4 pole and 6 pole.

They are fully interchangeable with existing standard induction motors (same dimensions and same output x frame ratio) and are also suitable for VSD operation.

Below is an efficiency comparison.

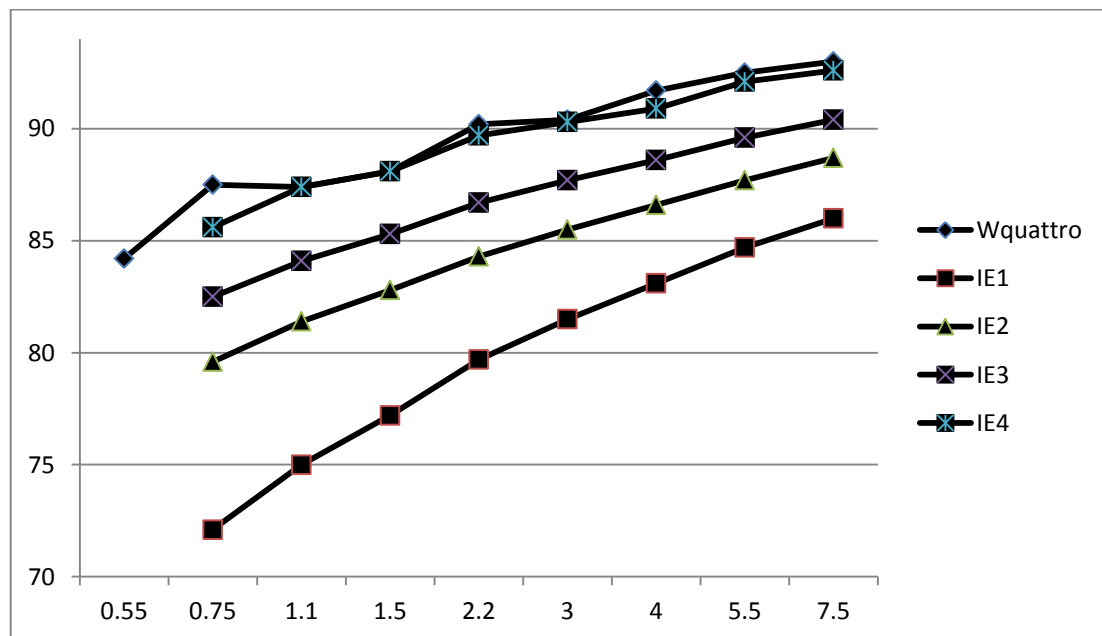


Figure 7. Graphic permanent magnet efficiency comparison

## Permanent Magnet Motors

The permanent magnet motor is a motor with magnets only on the rotor (no cage). This provides a motor with no losses on the rotor, thus increasing the motor efficiency. Due to the fact that this motor has no cage in the rotor, it provides no starting torque and requires a VSD to be started. A standard VSD is not necessarily suitable as special software is required.

Below is a picture of the rotor lamination.

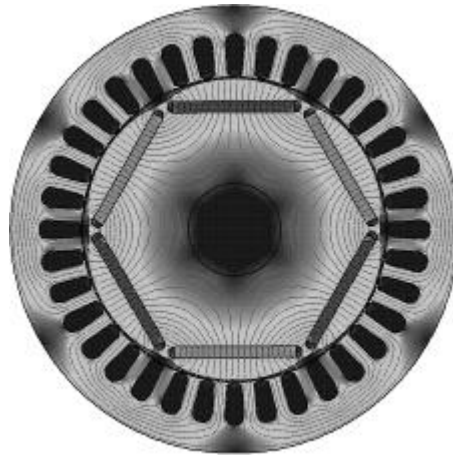


Figure 8. Permanent magnet motor (non-line start)

Due to the magnetic properties of the permanent magnets, it is not necessary to induce currents in the rotor so joule losses are eliminated.

Since most of the rotor heat is transferred to be dissipated via the bearings and in this case we have eliminated the rotor heat, we can reduce the operating temperature of the bearings, thus increasing bearing life time and re-greasing intervals.

Also, since rotor losses are eliminated, it is possible to increase the current in the stator. This increases torque while keeping the same motor temperature. Therefore, comparing with standard induction motor, it is possible to deliver the same kW in smaller frames, when permanent magnets are used on the rotor.

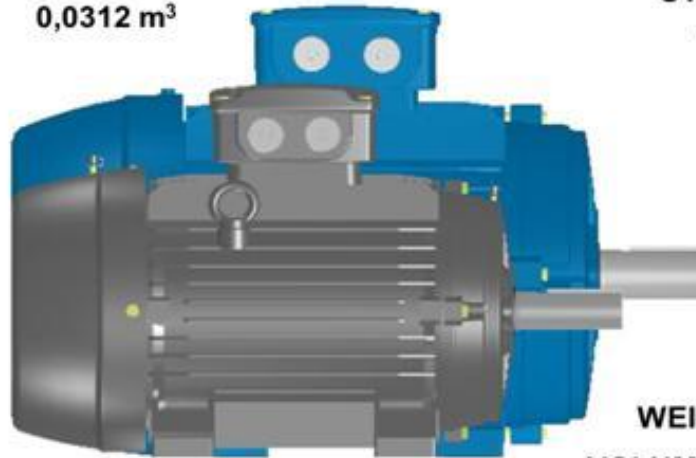
See below a comparison.

## INDUCTION MOTOR

15kW – Frame 160M

108,1 kg

0,0312 m<sup>3</sup>



## PERMANENT MAGNET SYNCHRONOUS MOTOR

15kW – Frame 132S

70,3 kg

0,0178 m<sup>3</sup>

## REDUCTION

WEIGHT: 37,8kg = - 35,0%

VOLUME: 0,0134 m<sup>3</sup> = - 42,9%

Figure 8. Permanent magnet vs. standard motor frame size comparison

Being in a reduced frame, these motors will also provide lower noise and vibration levels.

Currently this range is available from frame size 160 up to 315, 15kW to 160kW in 380V and 525V, 2 pole and 4 pole.

## CONCLUSION

When one considers that electric motors are already very efficient by comparison to various mechanical loads, one may well ask:

1. Can the use of High Efficiency motors realistically and significantly contribute towards national electrical energy saving?
2. Are the potential savings worth the cost for the end user?

In conjunction with question 1, the next question that may be asked is: 'How much electrical power may realistically be saved by using high or premium efficiency motors'? This question has been asked and answered many times. During the last few years several studies have been conducted that project potential savings. These various studies quantify this at anywhere between 2 – 7% of national power. Below is a table prepared for the purpose of Beltcon 16 detailing a possible savings projection. The calculation uses a very realistic, practical approach. The reader may well reason that not all motors in South Africa are IE1. Many large end users have been installing IE2 or IE3 motors for some time now. This is true, however, to counter this one should also consider that the vast majority of installed motors are more than five years old, therefore most are at efficiency levels well below IE1.

It is obvious from this table that the net gain is significant.

COMPARISON OF POWER CONSUMPTION						
Motor Power Rating	IEC IE1	IEC IE 2	IEC IE 3	IEC IE1	IEC IE 2	IEC IE 3
	Average Efficiency - %	Average Efficiency - %	Average Efficiency - %	Power Consumption - GWh	Power Consumption - GWh	Power Consumption - GWh
<0.75	68.00	73.00	76.00	5,793.60	5,396.78	5183.75
0.75 - 3	77.10	82.72	85.26	31,864.80	29,699.90	28815.11
4 - 7.5	84.60	87.67	89.53	17,380.80	16,772.16	16423.72
11 - 22	88.88	90.80	92.28	16,415.20	16,068.09	15810.39
30 - 55	91.43	92.90	94.08	10,621.60	10,453.53	10322.42
75 - 110	93.00	94.17	95.13	3,862.40	3,814.41	3775.92
132 - 375	93.77	94.80	95.60	6,759.20	6,685.76	6629.81
44 - 500	94.00	95.00	95.80	3,862.40	3,821.74	3789.83
<b>Total</b>				<b>96,560.00</b>	<b>92,712.39</b>	<b>90,750.95</b>
<b>Difference in GWh</b>					<b>-3,847.61</b>	<b>-5,809.05</b>
<b>Difference as a percentage</b>					<b>-3.98%</b>	<b>-6.02%</b>
<b>Savings as a percentage of national energy consumption</b>					<b>-1.59%</b>	<b>-2.41%</b>
<b>Electrical Power Consumption South Africa (GWh)</b>						<b>241,400</b>
<b>Total Electrical Motor Power Consumption</b>						<b>120,700</b>
<b>Small Motor Electrical Motor Power Consumption @ IE1 Efficiency levels</b>						<b>96,560</b>
<b>Small Motor Electrical Motor Power Consumption @ IE2 Efficiency levels</b>						<b>92,712</b>
<b>Small Motor Electrical Motor Power Consumption @ IE3 Efficiency levels</b>						<b>90,751</b>
The above calculations are based on the following assumptions: Electric motors are 50% of national power consumption, Electric motors ≤ 375kW account for 80% of motor power consumption & the majority of motors installed presently are IE1						

Table 3. Comparison of power consumption

The answer to question 1 above is therefore definitely 'Yes'. There is a clear quantifiable gain to be made if IE2 or IE3 motors are used as opposed to Standard Efficiency IE1 motors. For each motor there is an efficiency improvement that can be quantified according to the IEC60034-30 standard. Besides the above, an International Energy Agency (IEA) study endorsed by the International Electrotechnical Commission (IEC) gave very similar results.

Secondly then, are the potential savings worth the cost? When one considers the effects of carbon emissions and the global reduction in the gap between available energy and energy demand, the answer should be self-evident. However, to be pragmatic and put a value to it, let us consider one or two examples. Let us compare energy and capital costs on two motor sizes and efficiencies. We will consider 7.5kW IE1, IE2 and IE3 motors as well as a 75kW IE1, IE2 and IE3 motors.

7.5kW Motor			
	IE1	IE2	Difference
Motor kW rating	7.5	7.5	
Capital cost	R 4,500.00	R 5,220.00	R 720.00
Efficiency according to IEC60034-30	86.0%	88.7%	2.7%
Cost of Electricity	R 0.50	R 0.50	
Operating hours per day	22	22	
Operating days per year	350	350	
Percentage load	75.0%	75.0%	
Electrical Power consumption (kWh)	50,363	48,830	-1,533
Electrical Power operating cost	R 25,181.69	R 24,415.16	R -766.52
Realistic payback period			11

Table 5. 7,5 kW IE1 to IE2 comparison

7.5kW Motor			
	IE1	IE3	Difference
Motor kW rating	7.5	7.5	
Capital cost	R 4,500.00	R 5,850.00	R 1,350.00
Efficiency according to IEC60034-30	86.0%	90.4%	4.4%
Cost of Electricity	R 0.50	R 0.50	
Operating hours per day	22	22	
Operating days per year	350	350	
Percentage load	75.0%	75.0%	
Electrical Power consumption (kWh)	50,363	47,912	-2,451
Electrical Power operating cost	R 25,181.69	R 23,956.03	R -1,225.66
Realistic payback period			13

Table 6. 7,5 kW Ie1 to IE3 comparison

75kW Motor			
	IE1	IE2	Difference
Motor kW rating	75.0	75.0	
Capital cost	R 40,600.00	R 47,096.00	R 6,496.00
Efficiency according to IEC60034-30	92.7%	94.0%	1.3%
Cost of Electricity	R 0.50	R 0.50	
Operating hours per day	22	22	
Operating days per year	350	350	
Percentage load	75.0%	75.0%	
Electrical Power consumption (kWh)	467,233	460,771	-6,462
Electrical Power operating cost	R 233,616.50	R 230,385.64	R -3,230.87
Realistic payback period			24

Table 7. 7,5 kW IE1 to IE2 comparison

75kW Motor			
	IE1	IE3	Difference
Motor kW rating	75.0	75.0	
Capital cost	R 40,600.00	R 52,780.00	R 12,180.00
Efficiency according to IEC60034-30	92.7%	95.0%	2.3%
Cost of Electricity	R 0.50	R 0.50	
Operating hours per day	22	22	
Operating days per year	350	350	
Percentage load	75.0%	75.0%	
Electrical Power consumption (kWh)	467,233	455,921	-11,312
Electrical Power operating cost	R 233,616.50	R 227,960.53	R -5,655.98
Realistic payback period			26

Table 8. 7,5 kW to IE3 comparison

The foregoing comparison is a very realistic scenario. The number of operating days, percentage of load and cost of electricity are realistic. Based on this it can be seen that even though the initial capital costs are certainly higher, the medium to long term costs are much lower. Based on R0.50 per kW/hr. the payback period for using IE3 motors versus IE1 motors is 26 months or less. If the projected electricity price increases are considered then the payback period becomes lower. Based on this one can project that almost any IE2 or IE3 motor capital outlay can be recovered in less than three years. This is considering present

day electricity costs, if future costs are considered the period will be much less than 3 years. An electric motor's operating cost is far greater than its purchase cost. As can be seen from the foregoing values, purchase price varies from 15 – 25% of electrical power consumption cost in the first year of operation. Electric motors have an expected lifetime of >20 years. If one even considers only a ten year operating life and an annual inflation in electrical costs of 5% then the purchase price accounts for less than 2% of total motor costs.

Table 9. 7,5 kW IE2 to IE3 ten year comparison

<b>75kW Motor - 10 Year Estimate</b>			
	<b>IE1</b>	<b>IE3</b>	<b>Difference</b>
<b>Motor kW rating</b>	<b>75.0</b>	<b>75.0</b>	
<b>Capital cost</b>	<b>R 40,600.00</b>	<b>R 52,780.00</b>	<b>R 12,180.00</b>
<b>Efficiency according to IEC60034-30</b>	<b>92.7%</b>	<b>95.0%</b>	<b>2.3%</b>
<b>Cost of Electricity</b>	<b>R 0.50</b>	<b>R 0.50</b>	
<b>Operating hours per day</b>	<b>22</b>	<b>22</b>	
<b>Operating days per year</b>	<b>350</b>	<b>350</b>	
<b>Percentage load</b>	<b>75.0%</b>	<b>75.0%</b>	
<b>Electrical Power consumption (kWh) per annum</b>	<b>467,233</b>	<b>455,921</b>	<b>-11,312</b>
<b>10 Year Electrical Power consumption (kWh)</b>	<b>4,672,330</b>	<b>4,559,211</b>	<b>-113,120</b>
<b>10 Year Electrical Power operating cost</b>	<b>R 2,704,578.28</b>	<b>R 2,639,099.01</b>	<b>R -65,479.26</b>

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Johan van Niekerk has worked in the drives industry for 20 years. First gaining practical experience as a technician involved hands-on with installations and applications. Thereafter as a project engineer, business development manager, and drives manager. He is currently drives and automation manager for Zest Electric Motors and Drives.

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