7. Motor Selection

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Motor Selection

How to select an efficient motor for your application

Factors to be considered :

- The mechanical requirements of the driven load.
- Motor efficiency classification.
- The electrical distribution system.
- Physical and environmental considerations.

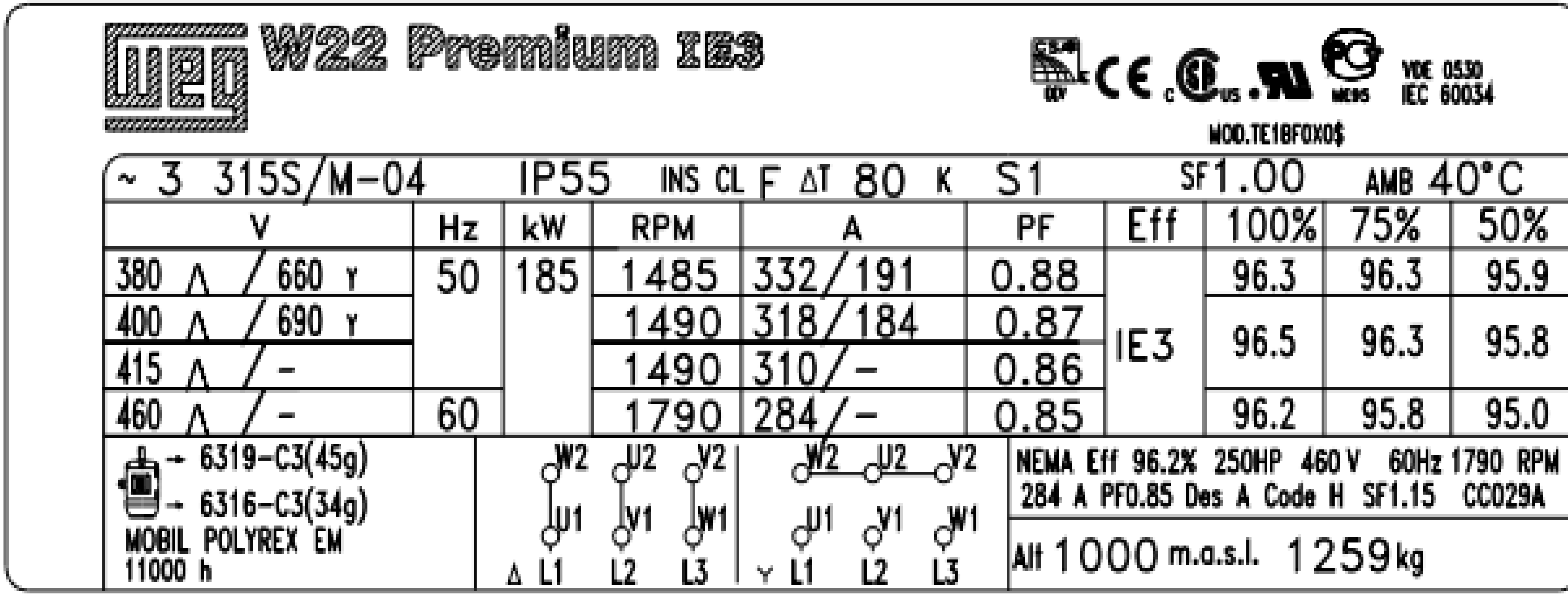
The evaluation of these characteristics should enable the user to select the most suitable type of motor for the application (AC or DC; single-phase; three-phase; power; mounting arrangement, etc)

Induction motor selection

NEMA Classification	Starting Torque (% Rated Load Torque)	Breakdown Torque (% Rated Load Torque)	Starting Current	Slip	Typical Application
IEC Design N — Design B normal starting torque & normal starting current	100-200%	200-250%	Normal	$< 5\%$	Fans, blowers and centrifugal pumps, where starting torque requirements are relatively low.
Design C high starting torque & normal starting current	200-250%	200-250%	Normal	$< 5\%$	Conveyors, stirring machines, crushers, agitators, reciprocating pumps & compressors, etc., where starting under load is required.
IEC Design H — Design D high starting torque & high slip	275%	275%	Low	$> 5\%$	High peak loads, loads with flywheels such as punch press, shears, elevators, extractors, winches, hoists, oil well pumping & wire drawing machines.

IEC 60034-12 (2002) and NEMA MG-1 (2011)

Induction Motor label



Induction motor selection

- Wound rotor induction motors are useful in some applications (above 250 kW) because the resistance of the rotor circuits can be altered to give the desired starting or running characteristics.
- More expensive and more maintenance

Synchronous motor selection

Speed:

- Synchronous motors operate at synchronous speed with no speed drop over the load range. They should be selected if exact speed is required.

Power Factor Correction:

- Synchronous motors can generate reactive power to correct poor supply system power factor while delivering mechanical power. When supplying reactive power they are said to be operating at a leading power factor.

Lower Operating Costs:

- Synchronous motors are often more energy efficient than induction motors, especially in the very large horsepower ranges (above 1000 hp).

Direct Current Motor Selection

- DC motors are often selected where precise speed control is required, as DC speed control is simpler, less costly and spans a greater range than AC speed control systems.
- Where very high starting torque and/or high over-torque capability is required, DC motors are often selected.
- They are also appropriate where equipment is battery powered.

Direct Current Motor Selection

Disadvantages of DC motors:

- High initial cost
- Increased operation and maintenance cost due to presence of commutator and brush gear
- Cannot operate in explosive and hazard conditions due to sparking occur at brush (risk in commutation failure

- AC motors with similar control capabilities are taking over

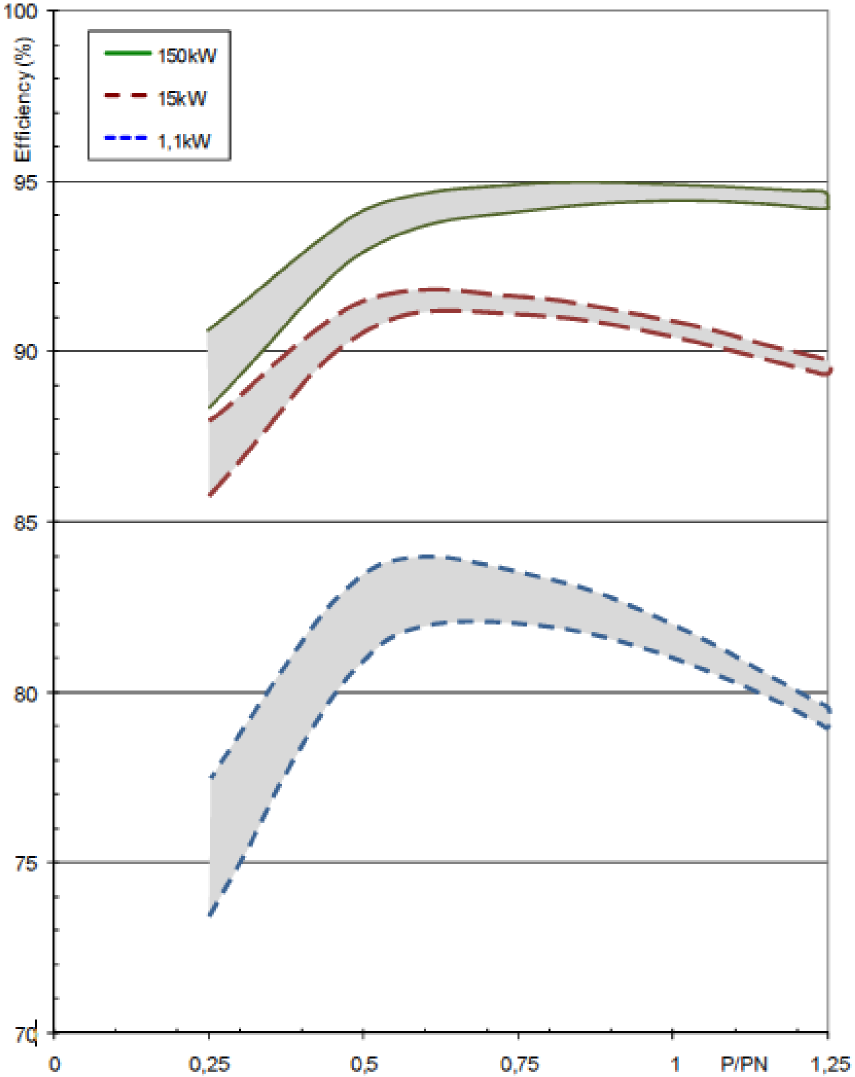
Single-phase motors selection

Type	Typical RPM	Starting Torque as Percent of Full-Load Torque	Comparative Efficiency	Typical Applications
Shaded Pole	1050, 1550, 3000	Very Low 50-100%	Low	Small direct-drive fans and blowers.
Permanent Split Capacitor (PSC)	825, 1075, 1625	Low 75-150%	Moderate	Direct-drive fans and blowers
Split-Phase	1140, 1725, 3450	Low to Moderate 130-170%	Moderate	Belt-drive and direct-drive fans and blowers, small tools, centrifugal pumps, and appliances
Capacitor-Start	1140, 1725, 3450	Moderate to High 200-400%	Moderate to High	Pumps, compressors, tools, conveyors, farm equipment, and industrial ventilators

Load

Motors must be sized to accommodate the running load's speed and torque requirements. Load types can be classified into different duty cycles describing operating time and load variations.

- *If replacing an existing motor is considered, monitoring the power input to the motor over a period of time will determine an optimum size. Inexpensive battery powered data loggers work well for load trending.*



Efficiency vs. Load

IEC 60034-31

Starting and Stopping

Frequency of starting and stopping.

- For frequent starts, ensure winding and core temperature do not exceed motor rating (Duty types as defined in IEC 60034-1)

Starting torque requirement.

- Pay special attention to high inertia loads to ensure motor starting torque is adequate.

Acceleration restrictions.

- Ensure the motor driving the load reaches full speed quickly enough to avoid tripping the overload protection. Conversely, some loads require time to accelerate to full speed, e.g. a conveyor belt – a variable speed drive may be justified to achieve this and keep current lower when starting up.

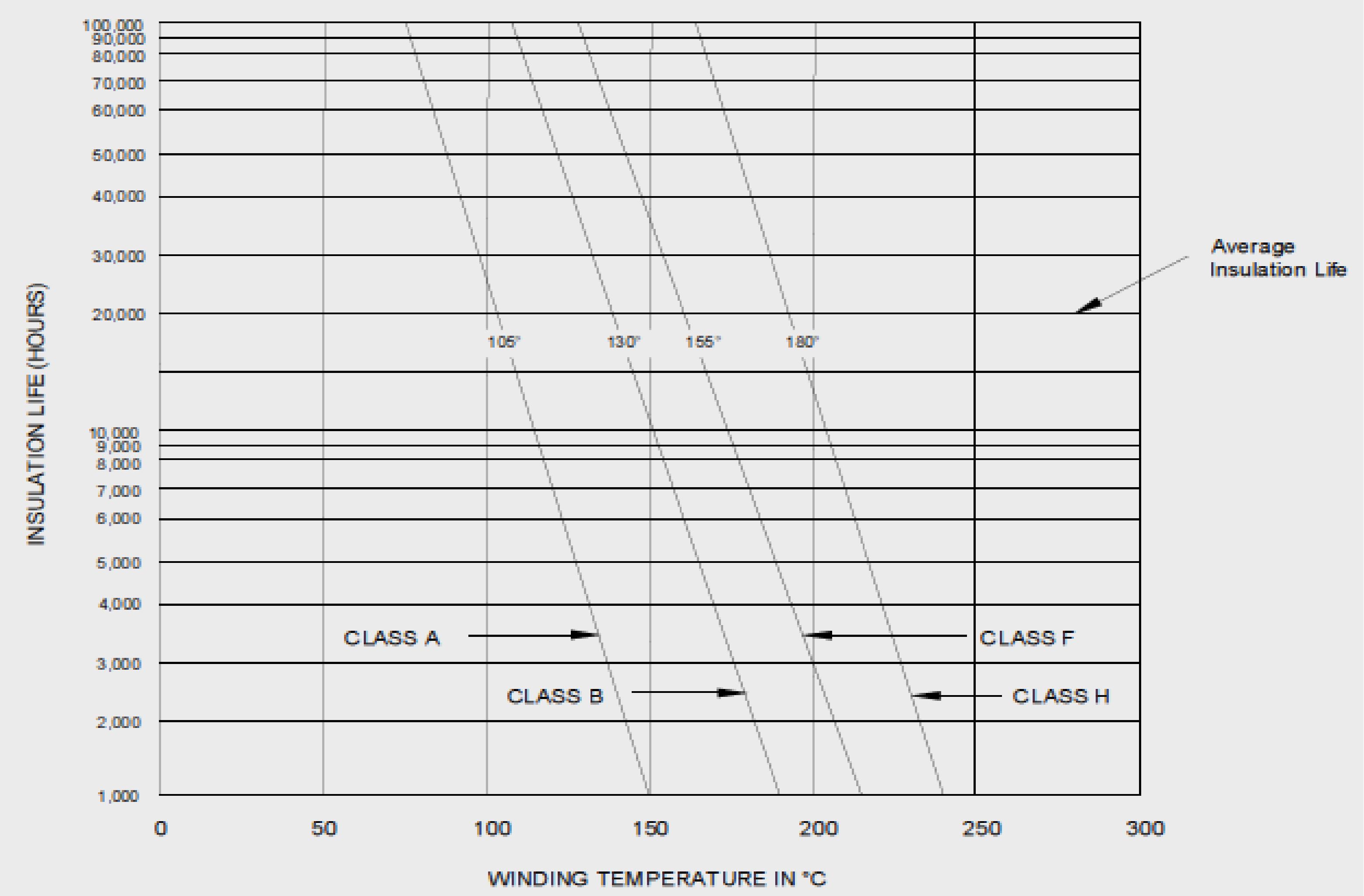
Operating Temperature

The standard IEC 60085 gives the maximum operation temperature for each thermal class

Thermal classes for insulation systems	A	E	B	F	H
Maximum operation temperature (ºC)	105	120	130	155	180

Ambient temperature is the temperature of the air surrounding the motor.
Maximum operation temperature is the maximum permissible hot spot temperature of a winding (rated temperature of the insulation system)

Insulation Life vs. Temperature



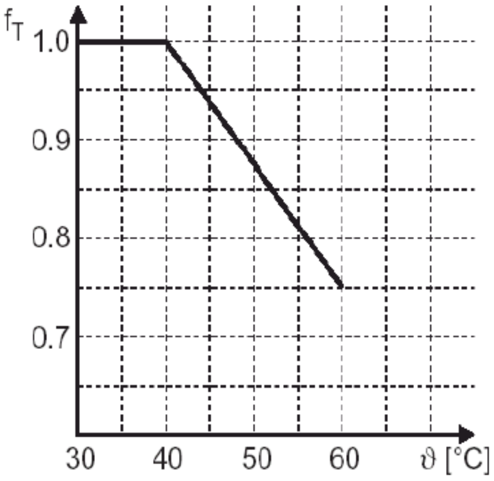
Service Factor

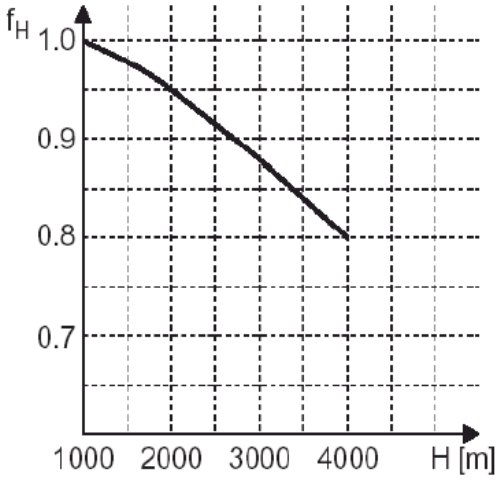
- Motor service factor is an indication of the ability to exceed the mechanical power output rating on a sustained basis. A service factor greater than 1.0 allows a margin for peak power demand without selecting the next larger motor size.
- A motor operating continuously at a service factor greater than 1 will have a reduced life expectancy (insulation and bearings).
- Motor efficiency is usually reduced during operation at the service factor rating.

Motor Derating

For temperatures above 40° C and below 60° C

For altitudes above 1000m





$$P_{Nred} = P_N \bullet f_T \bullet f_H$$

Energy Saving Strategies

Choose a Replacement Before a Motor Fails

Sometimes in trying to get a motor back into service as quickly as possible, decisions are made that satisfy the short-term goal but negatively impact long-term efficiency and motor life. When conducting this evaluation it may determined that it is beneficial to replace working motors with properly sized more efficient ones.

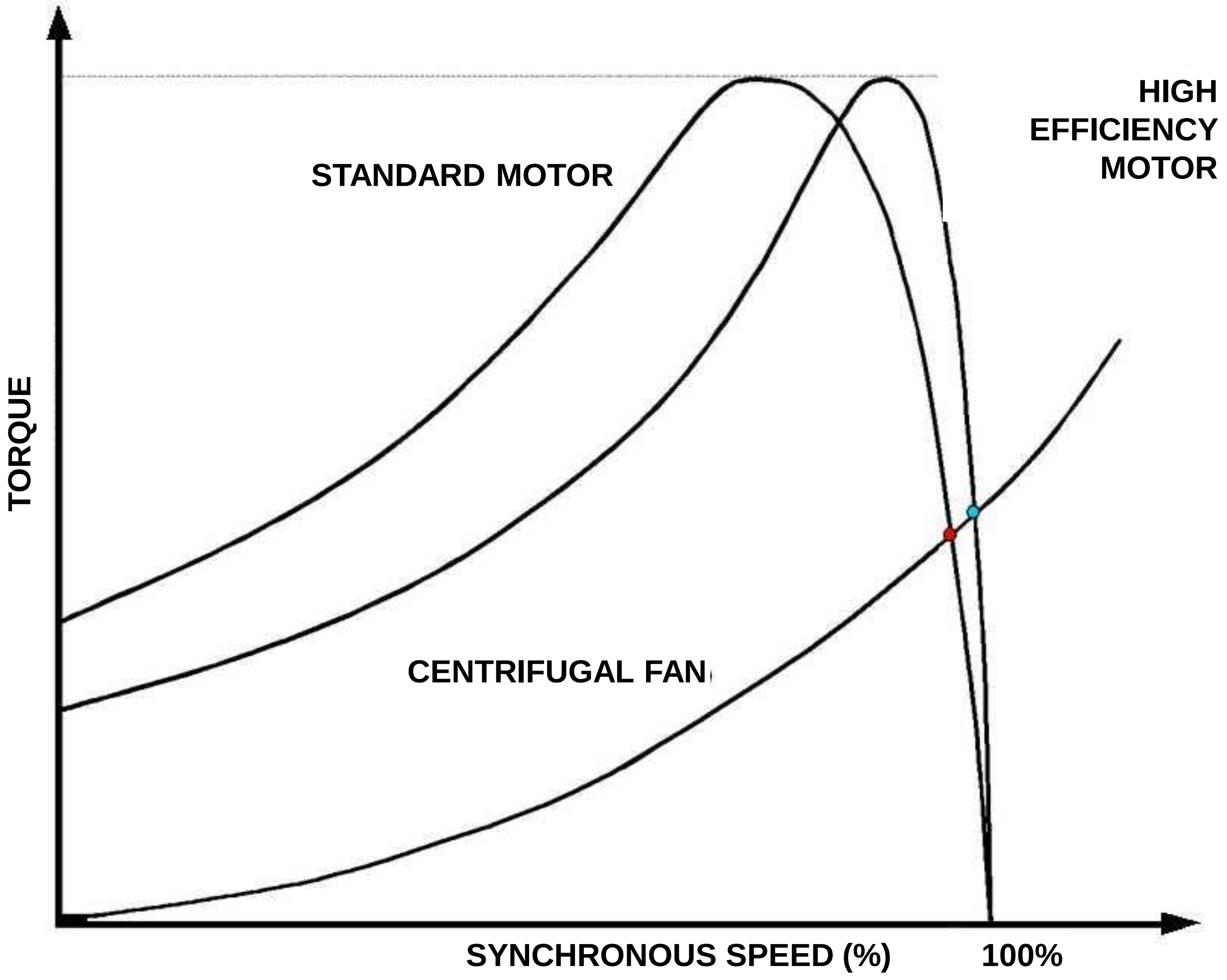
Energy Saving Strategies

Match Motor Operating Speeds

In general, motors with higher efficiency have a higher operating speed i.e. a reduced slip compared to motors of lower efficiency. On average, the slip is reduced by some 20 to 30% per next higher efficiency class for motors of the same rated output power.

For most rotating machinery, power consumption is proportional to the cube of the rotational speed. For example, increasing operating speed by 2% can increase the power required to drive the system by 8%. This can easily offset the savings expected by the replacement of a motor with a more efficient one.

Match Higher Efficiency Motor Operating Speed



Motor sizing

Properly Size the Motor for your Application

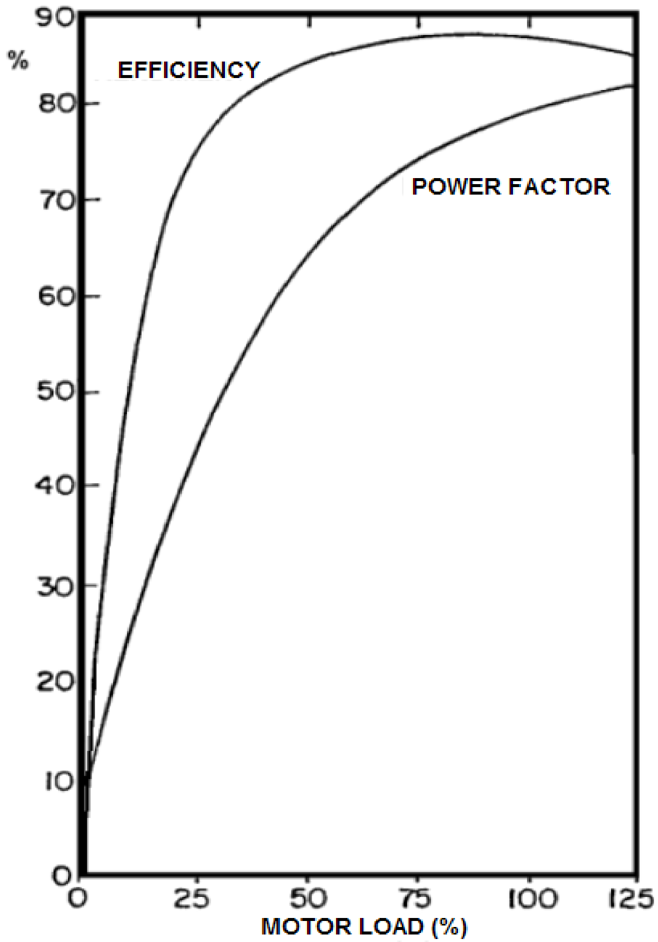
Motor efficiency is fairly constant down to approximately 50% of rated load, below which it drops off quickly. Care should be exercised in leaving an adequate but not excessive safety margin. The motor should be sized for the peak load expected. Oversized motors can significantly increase costs since all electrical components must be sized to the motor rating.

Motor sizing

Properly Size the Motor for your Application

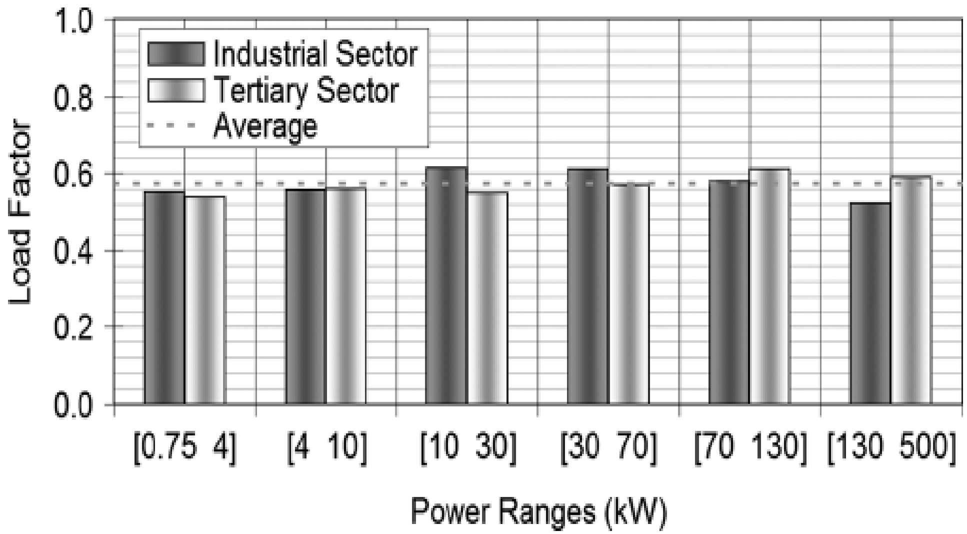
Due to the low temperature utilization of more efficient motors their overload capacity is typically higher when compared to standard motors. Therefore, oversizing the motor for occasional peak-power demands is seldom required and certainly not cost effective.

Oversizing



DISADVANTAGES:

- HIGHER CAPITAL COST (MOTOR AND COMMAND AND PROTECTION EQUIPMENT);
- LOWER MOTOR EFFICIENCY AND POWER FACTOR;



AVERAGE LOAD FACTOR BY POWER RANGE, IN INDUSTRY AND TERTIARY SECTOR, EUROPEAN UNION, 2000.

Exercise – Estimation of Mechanical Motor Load

Estimation of approximate load based on of motor speed and voltage

Name plate data:

Rated kW of Motor = 30 kW

Rated Amps = 55 A

Rated voltage = 400 V

Name plate efficiency = 92%

Name plate speed = 1440 rpm

Measured Data

Measured speed = 1460 rpm

Input load current = 33 A

Operating voltage = 415 V

Input power = 20 kW

Exercise – Estimation of Motor Load

Based on Input Power Method Measurement:

Nominal input power = 30/0,92 = 32,6

Load = 20 /32,6 = 0,61

Note: the accuracy of method drops when load is below 40% since efficiency drops sharply below that value

Exercise – Rough Estimation of Motor Load

Based on the Speed Measurement:

Synchronous speed = 60 x 50/2= 1500 rpm

Slip = Synchronous Speed – Measured speed in rpm,

= 1500 – 1460 = 40 rpm

$$Load\ (\%) = \frac{Slip}{(S_{synch} - S_{nameplate}) \times \left(\frac{V_n}{V_{measured}}\right)^2} \times 100$$

$$Load\ (\%) = \frac{40}{(1500 - 1440) \times \left(\frac{415}{400}\right)^2} \times 100 = 61{,}9\%$$

Note:This method has larger errors for big motors because of their smaller slip

Exercise – Rough Estimation of Motor Load

Based on the Current Measurement:

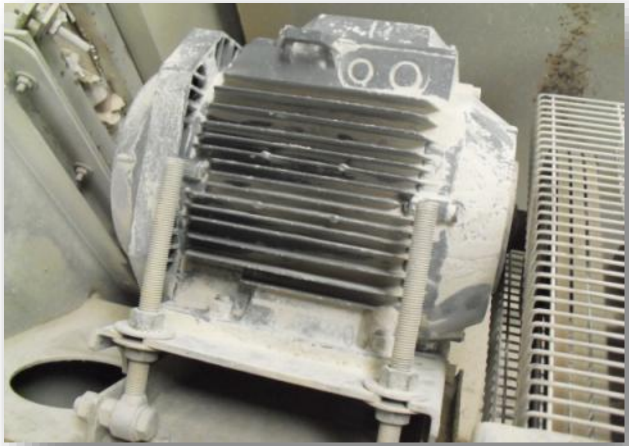
$$Load\ (\%) = \frac{V_{measured} \times I_{measured}}{V_{rated} \times I_{rated}}$$

$$Load\ (\%) = \frac{415 \times 33}{400 \times 55} = 0{,}623$$

Note:This method has larger errors for loads below 50% because of decreasing PF

Case Study- Super-Premium Retrofitting

As an example of retrofitting, an IE0-Class Equivalent, 5.5-kW, 4-pole, Induction Motor driving a fan in an industrial facility, has been replaced by an IE4-Class LSPM.



(a) IE0 SCIM

(b) IE4 LSPMSM

Photos of the replaced and replacing motors: (a) Brand A, 132S, IP55, Cl. F, 5.5 kW, 380-420V, 11.5 A, 1450 r/min, PF=0.83, Eff.=83.2% (IE0/EFF3 Class); (b) Brand B, 132S, IP55, Cl. F, 5.5 kW, 380-420V, 9.34 A, 1500 r/min, PF=0.93, Eff.=92.5% (IE4 Class).

Summary of the Motor Performance for the SCIM and LSPM

	Before Replacement	After Replacement
Motor Type	SCIM	LSPM
Efficiency Class	IE0/EFF3	IE4
Rated Efficiency	**83.2%**	**92.5%**
Rated Power	5.5 kW	5.5 kW
Rated Voltage	400 V, 50 Hz	400 V, 50 Hz
Rated Current	11.5 A	9.34 A
Rated Power Factor	0.83	0.93
Rated Speed	**1450 r/min**	**1500 r/min**
Actual Voltage	≈ 400 V	≈ 400 V
Actual Current	≈ 7,5 A	≈ 5,5 A
Actual Power Factor	0,75	0,90
Actual Input Real Power	3750 W	3500 W
Actual Input App. Power	5100 VA	4000 VA
Actual Speed	1472 r/min	1500 r/min
Estimated Load	< 57%	< 59%

The original motor was oversized (load lower than 57%) and, therefore, a 4-kW LSPM would be enough for this application, but the user decided to maintain the rated power. Moreover, since the new 5.5-kW LSPM has a load lower than 60%, it can benefit in terms of efficiency and power factor from voltage regulation.

Savings & Payback

$$Electricity\ Savings\left[kWh/year\right] = Hr \times LF \times \left(\frac{P}{\eta_1} - \frac{P}{\eta_2}\right)$$

$$Simple\ Payback = \frac{Cost\ difference\ of\ \ new\ motor\ (US\$)}{Energy\ Savings(kWh/year) \times Electricity\ Cost(US\$/kWh)}$$

Hr – *Number of Operating Hours per year*
LF – *Load Factor*
P – *Motor mechanical output power*
η – *Motor Efficiency*

Savings & Payback

$$Electricity\ Savings\left[kWh/year\right] = 4000 \times 0.59 \times \left(\frac{5.5}{0.832} - \frac{5.5}{0.925}\right)$$

$$= 1557.6\ \text{kWh/year}$$

Hr – 4000 hours
LF – 0,59
P – 5.5 kW
η_1 – 83.2%
η_2 – 92.5%

$$Simple\ Payback = \frac{\$300}{1557.6 \times \$0{,}10}$$

$$= 1.92\ years$$