PL 5 – AC Motors – Selection (1)

Objectives:	Selection and sizing AC induction motors
Documents available	
PL classes:	1) AseaM2BA.pdf 2) Sew-SDT100LS-82.pdf
Web sites:	https://new.abb.com/motors-generators/iec-low-voltage-motors https://www.sew-eurodrive.pt/inicio.html

Selection and sizing of electric motors

The choice and specification of a certain type of electric motor, for a given application, involves several considerations to be taken into account, from the characterization of the requirements imposed by the load to be driven, the power supply and control conditions of the defined driving system and the characteristics of the motor series available.

A- General principles

(1) Load requirements (constant, variable, …)

(2) Restrictions on maximum temperatures of motor frame and windings

(3) Existing standard motor series

(4) Motor technical specifications:

- power, duty cycle, velocity, torque, voltage, current, …;

- rated and maximum, or minimum, values;

- sizes and weight;

- …

B- Selection and specification of AC induction motors

(1) Load and motor torque ratios

Information available on motor catalogues and provides an initial general, overall indication regarding the capability to withstand load changes.

$$T_{max.motor}/T_{Nominal\ (rated)} \geq T_{max.load}/T_{Nominal\ (rated)}$$

(2) Limiting motor heating

In general, the selection is made based on the motor heating limits in an indirect way, since the complexity of the analysis of the electric/magnetic model of the motor and the need for parameters that are normally only known to the manufacturers, do not allow their direct calculation. Factors and considerations to consider include:

- motor start/stop frequency and duration
- operating modes or duty type (S1, S2, S3, S4, …) (EN60034)
- thermal classification (E, B, F, …) (EN60034-1)
- localization, environmental conditions and degrees (index IP) of protection (EN60529)
- …

(3) Comparative evaluation of load/motor ratios: mass or inertia, torque and power

Manufacturers often indicate their own procedures to account for several of these aspects in order to condition the use of the nominal, rated, values of the motors to effective values.

B1- Operating mode

a) Continuous running, operation at a constant load maintained for sufficient time to allow the machine to reach thermal equilibrium.

Motor nominal, rated power: $P_{Nmotor}=P^{motor}_{mec.load}/\eta_{transmission}$

b) Continuous running, operation under variable load cycle but allowing thermal equilibrium.

Calculate a constant value for power, which is equivalent to the variable load power

- Method of average energy losses

$$p_{average\ energy\ losses} \leq p_{average\ energy\ losses\ at\ nominal\ rates}$$

$$\frac{1}{\sum_j t_j}\cdot\sum_j (p_j\cdot t_j) \leq \left(\frac{1}{\eta_N}-1\right)\cdot P_N$$

- average energy losses should be approximately the same as the losses when the motor runs at nominal rates;
- efficiency of the motor changes with load changes;
-load diagrams calculations can be complex

$$\begin{cases} p_j = \left(\frac{1}{\eta_j}-1\right)\cdot P_j \\ p_{med} = \frac{1}{\sum_j t_j}\cdot \sum_j (p_j\cdot t_j) \end{cases}$$

- Method based on an equivalent current (torque, power)

***I**$_{eq}$* based on the concept of effective or rms (root-mean-square) current, assuming an approximation where energy losses have a constant term (p_0) and a term dependent on electric current (**k·I^2**):

$$\begin{cases} p_{average} \cong p_0 + k\cdot\frac{\sum_j (I_j^2\cdot t_j)}{\sum_j t_j} = p_0 + k\cdot I^2_{equivalent\ (effective,\ or\ rms)} \\ I_{eq} = \sqrt{\frac{1}{\sum_j t_j}\cdot\sum_j (I_j^2\cdot t_j)} \ \leftrightarrow\ I_{eq} = \sqrt{\int_0^{t_1}\frac{1}{t_1}\cdot I^2(t)dt} \end{cases}$$

***T**$_{eq}$* Considering torque as directly related to electric current:

$$\begin{cases} T_{equivalent} = \sqrt{\frac{1}{\sum_j t_j}\cdot\sum_j (T_j^2\cdot t_j)} \\ T \propto I \end{cases}$$

***P**$_{eq}$* Considering power as directly related to torque:

$$\begin{cases} P_{equivalent} = \sqrt{\frac{1}{\sum_j t_j}\cdot\sum_j (P_j^2\cdot t_j)} \\ P \propto T \end{cases}$$

Note: in strongly variable load regime the mechanical losses also vary and the variable losses are not proportional to the square of the electric current due to the existence in the overload regime or in the low speed regime of complex electromagnetic phenomena. Extensions of the method, in the case of the three-phase induction motor, become mere forced approximations.
[Ref. Manuel Vaz Guedes, "O motor de indução trifásico", 1994, FEUP].

c) Intermittent periodic running, or short duration operation

- It is necessary to accurately define the load diagram (load cycle) and use the previous methods, taking into account that they are only approximate methods.
- Consideration of parameters that make it possible to calculate (increase/decrease) permissible useful power in relation to the rated power of the motor (e.g. duty cycle factor).
- A more accurate dimensioning of the motor power requires an analysis of the motor heating during the load cycle, requiring information that only the motor manufacturer has.
- It is easier to check whether a certain motor can withstand a given intermittent load cycle than to determine the rated power for the motor subjected to a given load cycle.

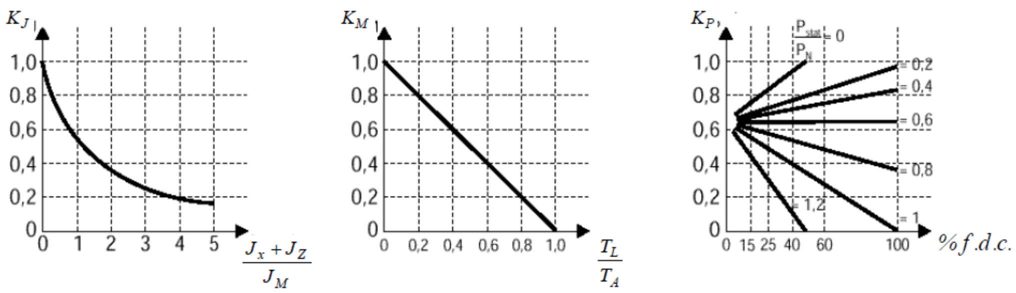
B2- Parameter factors: load, torque, starting frequency (ex. SEW-EURODRIVE)

Taken into account when the motor is operating in the following conditions:
- frequent start/stop
- high accelerating masses, or inertias, ratio of load and motor: (J_L/J_M: <10 …)
- low resistant torque.

In these cases, the choice of motor is not only determined by the power required but mainly by the number of starts, also implying the consideration of the motor insulation class due to the abnormal heating of the motor. In the case of some manufacturers (e.g. Sew-Eurodrive):

- start/stop allowed frequency: $Z_{admissible} = Z_0 \cdot K_J \cdot K_M \cdot K_P \quad [{cycles}/{h}]$
- inertias factor: $K_J = f(J_x, J_Z, J_M) = \frac{1}{1+\frac{J_x+J_Z}{J_M}}$
- torque factor: $K_M = f(T_L, T_A) = 1 - \frac{T_L}{T_A}$
- power factor: $K_P = f(P_{static}, P_N, fdc)$
- duty cycle factor: $dcf = \frac{\sum time\ motor\ running\ with\ load}{Total\ cycle\ time\ (máx=10min)}\%$

- Z_0: freq. of starts unloaded and *dcf* = 50%
- J_x: all load inertias represented at the motor shaft
- J_Z: fan inertia
- J_M: motor inertia
- T_L: load torque during start phase
- T_A: motor starting torque
- P_N: motor nominal power
- P_{static}: power required at constant speed (static power)



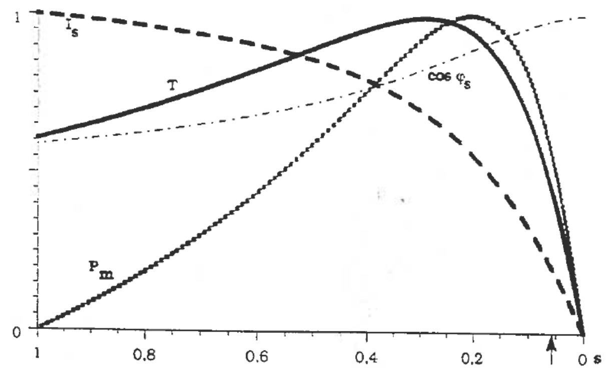
B3- General characteristics of AC induction motors

- brushless (robustness, reliability, easy or low maintenance, low price, …)
- constant base speed (3000/1500/1000/750 … [rpm])
- available in a wide power range (0.25 a 186 [KW] …)
- automatically adjust to load variations
- available with gear unit
- control possible with simple electromechanical devices
- high starting torque
- characteristics curves and analytical models complex
- …

B4- Characteristics curves

From the graph on the right, indicate the motor speed, expressed in synchronous speed n_s, corresponding to:

- P_maximum:________________________
- T_maximum:________________________
- I_maximum:________________________
- PF_minimum:________________________



- Characteristic curves (T-ω) of a 2 speed motor. Considering the technical data from motor SDT100LS8/2 (document *sew-SDT100LS-82.pdf*), identify, or signalize in the graph below the following characteristics and operating modes:

-Zone *a*:________________
-Zone *b*:________________

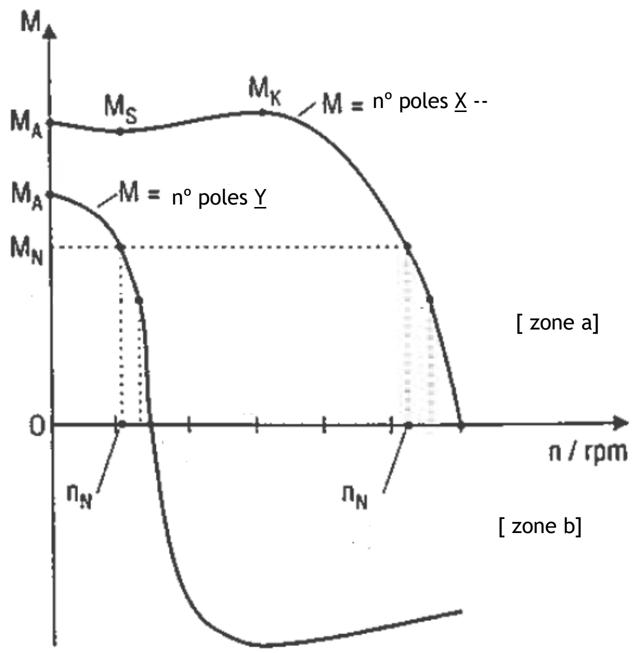
- nº $_{poles\_X}$ =________________
- nº $_{poles\_Y}$ =________________

- P_{N1} = ________________
- P_{N2} = ________________

- n_{N1} = ________________
- n_{N2} = ________________

- M_{N1} = ________________
- M_{N2} = ________________
- M_{A1} = ________________
- M_{A2} = ________________

- I_{N1} = ________________
- I_{N2} = ________________
- I_{A1} = ________________
- I_{A2} = ________________



B5- Procedure for choosing an induction AC motor, under constant load

Step 1: Specify power and speed required, under uniform movement conditions (i.e. at constant speed):

$$P_{static\_load},\ \omega_{load\_uniform\_movement}$$

- determination of the load static power, that is, driving the load in a uniform regime;
- determination of the motor speed to drive the load at the desired speed, taking into account specified transmission ratios if eventually used.

It is yet common to distinguish the cases of driving vertical and horizontal loads, considering:

- the weight in the drive of vertical loads (without counterweights) is the main contribution to the required **static power** and reference to the rated power of the motor;
- in horizontal loads, the nominal power reference value for choosing the motor results from the sum of the **static power and the dynamic power** (mass acceleration).

Step 2: Selecting a motor from a motor manufacturer's catalogue

- motor power: $\boldsymbol{P}_{nominal\_Motor} > \boldsymbol{P}^{Motor}_{static\_load}$

or $\boldsymbol{P}_{nominal\ Motor} > \boldsymbol{P}^{Motor}_{total} = \boldsymbol{P}^{Motor}_{static\_load} + \boldsymbol{P}^{Motor}_{dynamic}$

- motor speed: $\boldsymbol{n}_{syncronism} \geq \boldsymbol{n}^{Motor}_{load}$

- environmental conditions of the installation (location, ambient temperature, protection index)
- motor efficiency (IEC/EN 60034-30: e.g. super premium (IE4), premium (IE3), high efficiency, (IE2), standard efficiency (IE1))

Step 3: Identify for the selected motor the relevant data and associated characteristic curves

- nominal values of power, torque, velocity, current: P_N, T_N, n_N, I_N
- inertia: J
- efficiency: η
- starting torque and current: $\frac{T_{start}}{T_N}$ $\frac{I_{start}}{I_N}$
- maximum torque (overload capacity): $\frac{T_{max}}{T_N}$
- power factor $\cos\varphi$

Step 4: Verify the compatibility of the selected motor with the load requirements

- overload coefficient (with variable loads) $T_{max.motor}/T_N \geq T_{max.load}/T_N$
- velocity profile requirements (i.e. acceleration limits);
- start-up phase (considering al loads during start running, including the motor inertia and calculated at the motor shaft);
- working conditions (ex. continuous, intermittent, periodic, …)

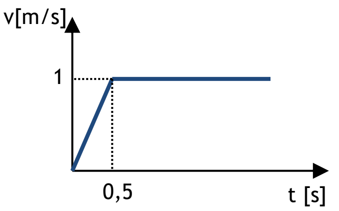
  - method of average energy losses
  - method of effective electric current, torque, power
  - inertia ratio (motor and load)
  - torque ratio (motor and load)
  - power ratio (motor and load).

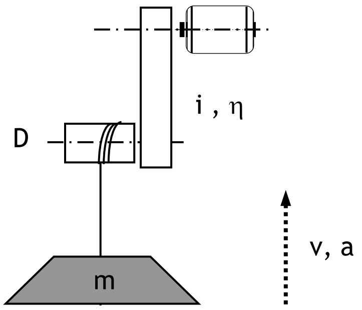
Example – load lifting system

Select an appropriate electric motor for a load lifting application with the following data:

Data

m = 1000 kg
v = 1 m/s
a = 2 m/s^2
i = 10
D = 198 mm
η = 75%





Note:

See online sizing software
from SEW:
https://www.seweurodrive.com/os/ds/#welcomeDialog
from ABB
https://selector.drivesmotors.abb.com/country