PL 8_b – AC Motors and Variable Frequency Drives (VFDs) – Exercises resolution

Objectives: Selection and sizing AC induction motors with VFDs

Documents available

PL classes: 1) SEW_DV100M4.pdf;
2) i222e_j1_series_datasheet_en.pdf;
3) i176e_rx2-series_variable_frequency_drives_datasheet_en.pdf;

Web sites: https://industrial.omron.eu/en/products/variable-speed-drives www.weg.net; www.sew-eurodrive.com ; www.lenze.com ; www.ia.omron.com; www.marellimotori.com

Exercise PL8-1

Moving a vertical load using a four-pole induction motor with a VFD

(Adapted from *SEW-Practical Drive Engineering*)

Consider a lifting platform with a driving solution powered by a four-pole induction motor, controlled by a VFD, and the following moving requirements data:

- $m_{load} = 300\ kg$
- $m_{moving\ structure} = 200\ kg$
- $v_{max} = 0{,}3\ m/s$; range (1 – 10)
- $a = 0{,}3\ m/s^2$
- $t_{acel} = 1\ s$
- $cdf = 50\ \%$
- $\eta_{global} = 85\ \%$
- $f_{base} = 50\ Hz$
- $f_{max} = 70\ Hz$

- transmission ratio compatible with 4 poles motor.

Consider for motor selection the table (SEW_DV100M4.pdf) and for VFDs the catalogues available from OMRON (series J1 e RX2) mentioned above.

Select a motor from the table that best fits the specified requirements. Represent the characteristic curves (ω,T) corresponding to the specified base (50Hz) and maximum (70Hz) frequencies, indicating the values for the selected motor and working point at maximum load.

Synthesis of data and calculations, using the previously presented method to select a Variable Frequency Driver and induction motor:

- Application data analysis

- Variable frequency driver operating mode: V/f (scalar)
- f_{base}: 50 Hz - f_{max}: 70 Hz - speed range: 1-10
- Acceleration time: t_{accel}= 1 s Acceleration: a= 0.3 m/s^2 Velocity: v= 0.3 m/s
- Static power: P_{static}= 1,73 kW

- Motor selection: DV100M4 (SEW) (from P_{static} = 1,73 kW)

P_N = 2,2 kW $n_{N\text{-}50Hz}$ =1410 rpm $T_{N\text{-}f\text{-}50Hz}$ = 15 Nm $T_{Max\text{-}f\text{-}50Hz}$ = 35 Nm
J_{Motor}= 59x10^{-4} Kgm^2 $n_{f\text{-}70Hz}$ =1974 rpm $T_{N\text{-}f\text{-}70Hz}$ = **10.7 Nm** $T_{Max\text{-}f\text{-}70Hz}$ = **17.9 Nm**

I_N= 4.7 A
B_{brake_torque} = 40 Nm cosφ = 0.83

- Torques, load and motor (70Hz):

T_{static}= 8.37 Nm T_{accel_load} = 0.26 Nm T_{accel_motor} = 1.22 Nm
T_{total} = T_{static} + T_{accel_load} + T_{accel_motor} = 9.85 Nm < (**$T_{N\text{-}f\text{-}70Hz}$; $T_{Max\text{-}f\text{-}70Hz}$**)
T_{decel_motor} = 1,22 Nm T_{decel_load} = 0.19 Nm T_{decel_total} = 1,41 Nm

Note:

$$T_{decel\_total} = T_{decel\_motor} + T_{decel\_load}$$

$$T_{decel\_motor} = -J_{motor} \cdot \alpha_{motor} = -J_{motor} \cdot (\omega_{motor} / t_{decel})$$

$$T_{decel\_load} = -J_{load} \cdot \alpha_{motor} = -J_{load} \cdot (\omega_{motor} / t_{decel})$$

$$= -m(v_{load} / \omega_{motor})^2 \cdot \eta \cdot (\omega_{motor} / t_{decel})$$

- Power: P_{static}= 1.73 kW P_{accel}= 0.31 kW **P_{total}= 2,04 kW**

(lowering movement with full load) P_{static} = 1.25 kW P_{decel} = 0.29 kW
$P_{regenerative\_max}$ = 1.54 kW **$T_{braking\_regenerative\_max.}$ = 7.45 Nm**

- VFD selection: P_N = 2,2 kW (From P_N motor)

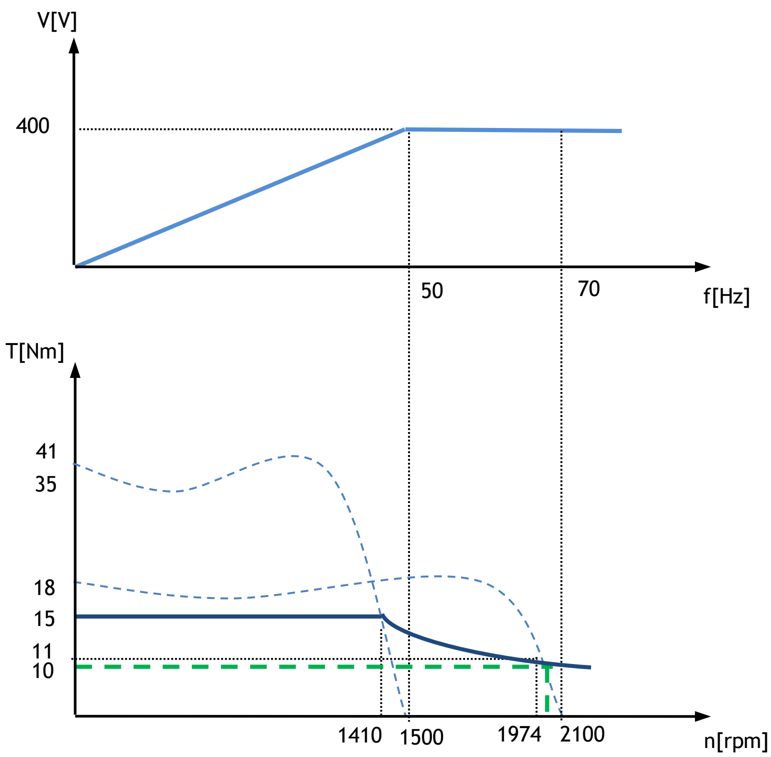
Verification of torque ratio, load and total, and permissible torque obtained considering the inverter (i.e. VFD) power at maximum speed:

$$T_{total} < 1.3 \cdot \frac{P_N^{INVERTER}}{\omega_{70Hz}} \quad , \qquad \mathbf{9.85\ Nm < 13.8\ Nm}$$

a) Analysis of **J1** series drives
- Main characteristics: ____
- Programming/parametrization characteristics: ____________________________
- Installation and main components: _____________________________________
- Model selected: ___________

b) Analysis of **RX2** series drives
- Main characteristics: ____
- Programming/parametrization characteristics: ____________________________
- Installation and main components: _____________________________________
- Model selected: ___________

- Representation of characteristics curves (ω, T) e (f, V) corresponding to the specified frequencies, base (50Hz) and maximum (70Hz), considering the selected motor data and the values for the working point at maximum load during elevating movement.



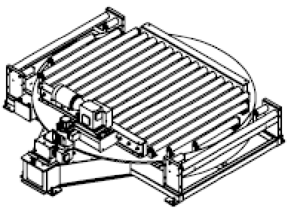
Exercise PL8-2

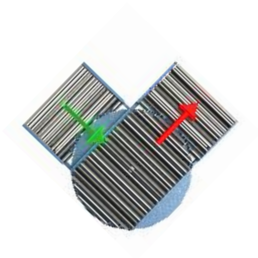
Rotating table for transfer and material flow orientation powered by an AC induction motor (4 poles) controlled by a Variable Frequency Driver

(Adapted from Exam of SE-13/07/2016)

Automatic systems for material handling involving conveyor belts and turntables can be considered good examples of application of three-phase induction motors. One of these turntables, illustrated in the figure shown below, is used to reorient containers (0.6 x 0.6 x 0.6 m^3) that arrive from a roller conveyor to another that is at 90°, both arranged horizontally at the same level. The table has two independent motors, one for the activation of the table rollers and the other for the rotation of the table. Data of this application:

- $m_{containers} = 350\ kg$
- $m_{moving\ platform} = 113\ kg$
- $\phi_{table} = 1\ m$
- $\phi_{supporting\_bearings} = 0{,}50\ m$
- $\mu_{friction\ coef\ \ supporting\_bearings} = 0{,}01$
- $J^{table\ axis}_{total\ moving\ masses} = 33{,}6\ kgm^2$
- $n_{table} = 20\ rpm = 2{,}09\ rad/s$
- $t_{accel} = 0{,}4\ s$
- $\eta_{transmission} = 0{,}71$
- $f_{base} = 50\ Hz$
- $f_{max} = 70\ Hz$





(i: transmission ratio not directly specified, but it can be assumed as being available and compatible with 1500 rpm motor.)

Consider for motor selection the table (*SEW_DV100M4_Aula Tp10.pdf*) and for VFDs the catalogues available from OMRON (series J1 e RX2) mentioned above.

Select a motor from the table that better fits the specified requirements. Represent the characteristic curves (ω,T) corresponding to the specified base (50Hz) and maximum (70Hz) frequencies, indicating the values for the selected motor and working point at maximum load.

Synthesis of data and calculations, using the previously presented method to select a Variable Frequency Driver and induction motor:

- Application data analysis

- Variable frequency driver operating mode: V/f (scalar)

- f_{base}: 50 Hz   - f_{max}: 70 Hz

- Acceleration time: t_{accel}= 0.4 s   Acceleration: α= 5.24 rad/s² ω= 2.094 rad/s

-Power: P_{static}= 33.5 W P_{accel}= 519.3 W P_{total}= 0,55 kW

Note:

Motor selection, horizontal loads: using the total power as a reference for motor nominal power (i.e. P_{static} and P_{accel}),

$$\begin{cases} P_{total} = P_{static} + P_{accel} \\ P_{static} = \dfrac{T_{static} \cdot \omega}{\eta} \\ T_{static} = m_{total} \cdot g \cdot \mu \cdot \dfrac{\phi_{support\_bearings}}{2} \\ P_{accel} = \dfrac{T_{accel} \cdot \omega}{\eta} \\ T_{accel} = J_{total\_moving\_masses}^{table\ axis} \cdot \alpha \\ \alpha = \dfrac{\Delta\omega}{t_{accel}} \end{cases} \Leftrightarrow \begin{cases} \boldsymbol{P_{total} = 550,2\ W} \\ P_{static} = 33,4\ W \\ T_{static} = 11,34\ Nm \\ P_{accel} = 516,8\ W \\ T_{accel} = 175,56\ Nm \\ \alpha = 5,23\ rad/s^2 \end{cases}$$

- Motor selection: DT80K4 (SEW) (from P_{total} = **0.55 kW**)

P_N = 0.55 KW $n_{N\text{-}50Hz}$ = 1360 rpm $T_{N\text{-}f\text{-}50Hz}$ = 3.9 Nm $T_{Max\text{-}f\text{-}50Hz}$ = 7.0 Nm
J_{Motor} = 7.5x10⁻⁴ Kgm²   **$n_{f\text{-}70Hz}$ = 1904 rpm**   **$T_{N\text{-}f\text{-}70Hz}$ = 2.79 Nm**   **$T_{Max\text{-}f\text{-}70Hz}$ = 3.58 Nm**
$I_{N\text{-}50Hz}$ = 1.75 A
B_{brake} = 10 Nm   cosφ = 0.72

- Torques, load and motor (70Hz), referred to the motor shaft:

T_{static}= 0.168 Nm T_{accel_load}= 2.604 Nm T_{accel_motor}= 0.374 Nm **T_{total}= 3.15 Nm > ($T_{N\text{-}f\text{-}70Hz}$)= 2.79 Nm**

The first selected motor does not satisfy the requirements, so a larger motor was selected

- 2nd motor selection   **DT80N4 (SEW)**   (from P_N > **0.55 kW**)

P_N = 0.75 KW $n_{N\text{-}50Hz}$ = 1380 rpm $T_{N\text{-}f\text{-}50Hz}$ = 5.2 Nm $T_{Max\text{-}f\text{-}50Hz}$ = 10.4 Nm
J_{Motor}= 9.6x10⁻⁴ Kgm²   **$n_{f\text{-}70Hz}$ = 1932 rpm**   **$T_{N\text{-}f\text{-}70Hz}$ = 3.71 Nm**   **$T_{Max\text{-}f\text{-}70Hz}$ = 5.31 Nm**

$I_{N\text{-}50Hz}$ = 2.1 A
B_{brake} = 10 Nm   cosφ = 0.73

- **Torques**, load and motor (70Hz), referred to the motor shaft:

T_{static}= 0.166 Nm T_{accel_load}= 2.567 Nm T_{accel_motor}= 0.486 Nm **T_{total}= 3.219 Nm < ($T_{N-f-70Hz}$;$T_{Max-f-70Hz}$)**

T_{decel_motor}= 0.49 Nm T_{decel_load}= 1.29 Nm T_{decel_total}= 1.78 Nm

- **Power:** P_{static}= 0.334 kW $P_{acel.total}$= 0.618 kW **P_{total}= 0.651 kW**

(deceleration with load) P_{decel} = 0.36 kW **$T_{regenerative\_braking}$= 1.77 Nm**

- **Selection of VFD:** P_N = 0.75 kW (from motor nominal power, P_N)

Verification of torque ratio, load and total, and permissible torque obtained considering the inverter (i.e. VFD) power at maximum speed:

$$T_{total} < 1.3 \cdot \frac{P_N^{INVERTER}}{\omega_{70Hz}} ,$$ **3.22 Nm < 4.82 Nm**

- **Representation of characteristics curves (ω,T) e (f, V)**, corresponding to the specified base and maximum frequencies (50Hz, 70Hz), considering the selected motor data and the values for the working point at maximum load (raising).