Exercise: Study of an induction motor in a radio telescope

Figure 1 shows the overall infrastructure of a radio telescope which may be considered as a measuring instrument. Figure 2 shows its simplified kinematic diagram.
The rotational movement of the platform (R1) with respect to a fixed frame (Bâti S0) is provided by an asynchronous motor (M1) controlled in both directions of rotation. Two tests were performed on this motor:

- **No-load test ("à vide")** : **U=380 V** between phases, **50 Hz**, $I_0 = 3\ A$, $P_0 = 500\ W$
- **Rated load test ("à charge nominale"): U=380 V** between phases, **50Hz**, $I = 10\ A$, $P_a = 5Kw$ **, n=720 rpm (tr/min).**

The resistance of a stator winding is **R = 0.5 Ω.**

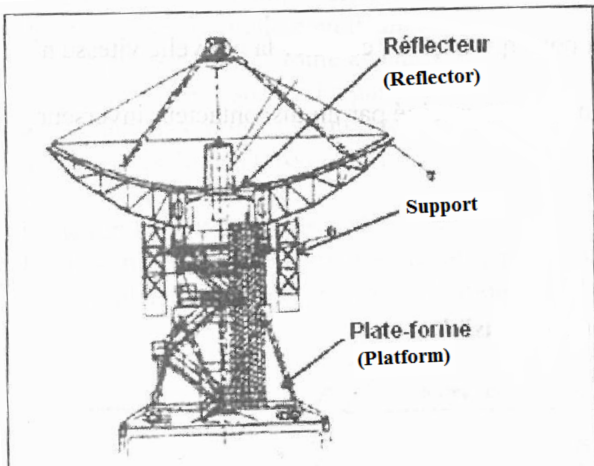


Figure 1

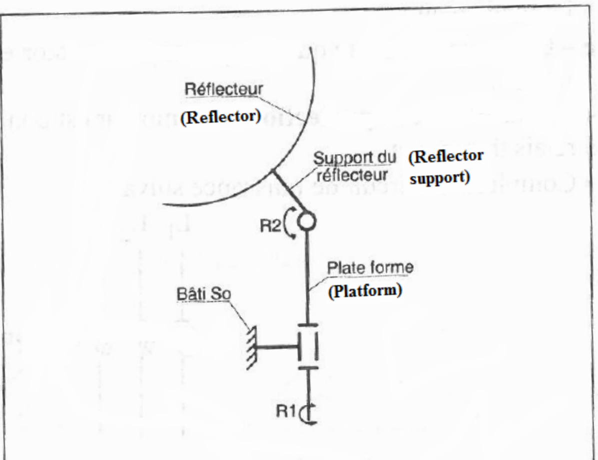
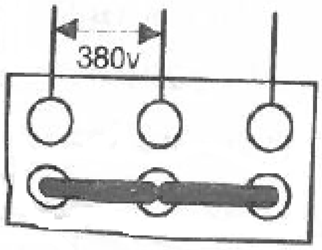


Figure 2

1- The following coupling is performed on the terminal plate :



What type of coupling is? Give the voltages indicated on motor descriptive plate ("sur la plaque signalétique").

2- Determine the stator iron losses P_{fs} and mechanical losses P_{mec} knowing that :

$$P_{fs} = \frac{2}{3} P_{mec}$$

3- Calculate the power factor $\cos\varphi_0$ at no-load and deduce the reactive power at no-load.

4- For operation **at rated load**, calculate :

a) Stator joule losses $\boldsymbol{P_{js}}$.

b) Transmitted power $\boldsymbol{P_{tr}}$.

c) Slip **g.**

d) Rotor joule losses $\boldsymbol{P_{jr}}$ **.**

e) Useful output power $\boldsymbol{P_{u}}$.

f) Efficiency **η** .

g) Power factor $\boldsymbol{\cos\varphi}$.

h) Impedance of each stator winding **Z**.

5- When the load torque applied to M1 is **Tr = 40 Nm**, is it (motor) capable of radio telescope rotational movement? Justify your answer.

Correction

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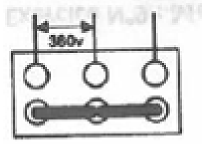
1) Is performed on the terminal plate the following coupling



The voltages indicated on the descriptive plate: 220v/380v.

2) The stator iron losses P_{fs} and mechanical losses P_{mec} with $P_{fs} = \frac{2}{3} P_{mec}$:

$$P_0 = P_{fs} + P_{mec} + Pjs_0 = P_{fs} + \frac{3}{2} P_{fs} + 3RI_0^2$$

$$\Rightarrow \frac{5}{2} P_{fs} = P_0 - 3RI_0^2 = 500 - 3 \times 0,5 \times 3^2 = 486,5\ W$$

Giving: $P_{fs} = \frac{2 \times 486,5}{5} = 194,6\ W$ *and* $P_{méc} = \frac{3}{2} P_{fs} = \frac{3}{2} \times 194,6 = 292W$

3) Power factor $\cos\varphi_0$ and reactive power at no-load.

$$\cos\varphi_0 = \frac{P_0}{\sqrt{3} \times U \times I_0} = \frac{500}{\sqrt{3} \times 380 \times 3} = 0,256$$

$$\Rightarrow \varphi_0 = 75°,33 \text{ and } \sin\varphi_0 = 0,967$$

$$Q_0 = \sqrt{3} \times U \times I_0 \times \sin\varphi_0 = \sqrt{3} \times 380 \times 3 \times 0,967 = 1910VAR$$

4) operation at rated load

a) Stator joule losses P_{js}.

$$P_{js} = 3 \times R \times I^2 = 3 \times 0,5 \times 10^2 = 150w$$

b) Transmitted power P_{tr} .

$$P_{tr} = P_a - P_{fs} - P_{js} = 5000 - 194,5 - 150 = 4655,5W$$

c) Slip g.

$$g = \frac{n_s - n}{n_s} = \frac{750 - 720}{750} = 0,04 \quad so\ \ g\% = 4\%$$

d) Rotor joule losses P_{jr} .

$$P_{jr} = gP_{tr} = 0,04 \times 4655,5 = 186,22\ W$$

e) Useful output power P_u.

$$P_u = P_{tr} - P_{jr} - P_{mec} = 4655,5 - 186,22 - 292 = 4177W$$

f) Efficiency η

$$\eta = \frac{P_u}{P_a} = \frac{4177}{5000} = 0,835 \quad so\ \eta\% = 83,5\%$$

g) Power factor $\cos\varphi$.

$\cos\varphi = \frac{P_a}{\sqrt{3}\times 380\times 10} = \frac{5000}{\sqrt{3}\times 380\times 10} = 0,76$

h) Impedance of each stator winding Z.

$$Z = \frac{U}{\sqrt{3}\times I} = \frac{380}{\sqrt{3}\ \times 10} = 22\ \Omega$$

5) Useful Torque : $T_u = \frac{P_u}{2\pi n}\times 60 = \frac{4177}{2\pi\times 720}\times 60 = 55,43Nm\ > T_r = 40Nm$

So motor M1 is capable of radio telescope rotational movement.