Exercise: Synchronous machine alternator:
Study of the power supply of an Airbus A320

In flight, the electrical generation is ensured by two main alternators of **90 kVA** which deliver a three-phase system of voltages **115V / 200V, 400Hz**. The frequency **is kept constant** thanks to a hydraulic regulation of the rotation speed of the alternators.

We are interested in studying the **unsaturated alternator**.

The aircraft's electrical system is powered in **400 Hz**.

For the Airbus A320 the manufacturer gives:

Rated voltage V_N/U_N	**115 V / 200 V**
Number of phases	**3**
Rated apparent power S_N	**90 kVA**
Rated frequency f_N	**400 Hz**
Rated rotation speed n_N	**12.0×10^3 rpm**
Power factor	**$0.75 < \cos\varphi < 1$**
Armature resistance (per phase) R_S	**10 mΩ**

The armature is **star-coupled**.

Two tests were performed at constant rated speed: $\mathbf{n_N}$.

- Genrator at no-load test: no-load characteristic $E_o(I_e)$ where $\mathbf{E_o}$ is the value of induced electromotive force at no load in one winding and $\mathbf{I_e}$ the intensity of the inductive current. The characteristic is a **straight line** such that for $\mathbf{I_e=0}$ **corresponds** $\mathbf{E_o = 0}$ and for $\mathbf{I_e=92\ A}$ **corresponds** $\mathbf{E_o = 400\ V}$.

- Short-circuit test: in the useful range, the short-circuit characteristic is the line with equation $\mathbf{I_{SC} = 3.07 \times I_e}$ **,** where $\mathbf{I_{SC}}$ is the rms value of the short-circuit current in a stator winding.

1- We are interested **in nominal operation**:
a) Calculate the pulsation of the output voltages of the alternator.
b) Determine the number of pole pairs of the machine.
c) Calculate the rms value of the nominal armature current $\mathbf{I_N}$.

2- We assume the alternator unsaturated.

a) Drop its equivalent model by phase represented.

b) Calculate the synchronous impedance of the alternator Z_S.

c) Deduce the synchronous reactance $X_S = L_S\,\omega$.

3- **In the rest of the problem, the influence of stator resistance R_S is neglected.**

a) Determine the intensity of the inductive current I_{eo} for no-load operation at rated (nominal) voltage **V=115 V**.

b) We consider a balanced three-phase load. The alternator operates **in nominal conditions**; it delivers its rated current I_N, **behind** ("en retard") the voltage.

For **cosφ = 0.75**, represent the vector diagram of the voltages and deduce:

- the value of the e.m.f induced **Eo**.
- the new value of the excitation current **Ie** for maintaining **V = 115 V** at **cosφ = 0.75** when the alternator delivers its nominal current I_N.

Correction

1)

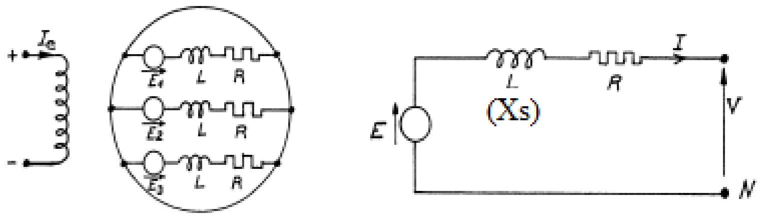
a) $\omega = 2\pi f = 25.1 \times 10^2\, rd/s$

b) $\Omega = \frac{\omega}{p} \rightarrow p = 2$

c) $S_n = 3\, V_n\, I_n = \sqrt{3} \times U_n \times I_N \;\rightarrow\; I_N = \frac{90\,.10^3}{3\times 115} = 260\; A$

2)

a)



Equivalent circuit of the synchronous machine

b) $\underline{V} = \underline{E_V} - \underline{Z_s}.\underline{I}$ et $\underline{Z_s} = \frac{E_{VCC}}{I_{CC}}$

The voltage E_V evolves linearly with I_e and its equation is : $E_V = \frac{400}{92} I_e$

And $I_{CC} = 3.07 \times I_e$

$$\underline{Z_s} = \frac{E_{VCC}}{I_{CC}} = \frac{\frac{400}{92}\, I_e}{3.07 \times I_e} = \frac{\frac{400}{92}}{3.07} = 1.4\; \Omega$$

c) $X_s = \sqrt{Z_s^2 - R_s^2} \approx 1.4\; \Omega$

3)

a) For no-load operation at rated (nominal) voltage V=115 V.

$V = E_v = 115\; V$

$E_v = \frac{400}{92} I_e$ so $I_e = \frac{92}{400}\, 115 = 26.5\; A$

b) $V_n = 115\; V$

$X_s I_N = 1.4 \times 260 = 364\; V$

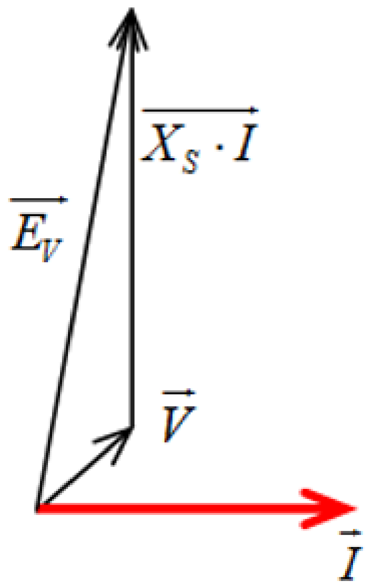
$\cos\varphi = 0.75 \;\rightarrow\; \varphi_{V/I} = 41.5°$

On the diagram we read: $E_V = 450\; V$

We can verify by calculation:

$$E_V = \sqrt{(V\;\cos\varphi)^2 + (V\;\sin\varphi\; + \; X_s I)^2}$$

$$E_V = \sqrt{(115\;\cos\;41{,}5)^2 + (115\;\sin 41.5\; + \;364)^2} = 448\; V$$



$E_V = 450\ V$

$E_V = \frac{400}{92} I_e$ so $I_e = \frac{92}{400}\ 450 = 102\text{A}$