<u>Exercise: </u> Three phase alternator

In this exercise, we propose to study a three-phase alternator with smooth poles and a wound rotor. The three phases are **star-connected**.

We measured its electromotive force **E** as a function of the excitation current **Ie** at the speed of **3000 rpm**. The measurement of **E (Ie)** is shown in Table 1:

I_e (A)	0	2	4	6	8	10	12	14	16	18	20	22	24
$E(I_e)$ (V)	0	50	100	148	190	227	260	283	300	305	310	312	314

Table 1.

The alternator has a nominal **apparent rated power** of **250 kVA** and a nominal **phase-neutral** voltage **230 V**.

1- Represent the connection scheme of the three phases corresponding to the star coupling of the alternator.

In addition, draw the equivalent circuit of the synchronous machine (for one phase) according to Behn-Eschenburg.

2- The frequency of the phase voltages is **50 Hz**. Specify the number of poles of the alternator.

3- Calculate the nominal current value: **In**.

4- **At short-circuit**, the current of the alternator reaches the calculated nominal value **In** for a value of the excitation current: **Ie = 6 A**. Calculate the value of the synchronous reactance **Xs** if we neglect the resistance of the windings that constitute the phases.

5- The alternator is now connected to a set of **unit power factor** loads. These loads are three-phase balanced and star wired to the alternator.

What is the value of the excitation current **Ie** allowing supplying **150 kW** to all the loads under a voltage between two phases of **400 V**?

(Make a **Fresnel diagram** of the magnitudes of the equivalent single-phase circuit before starting any calculation.)

Correction

1) FIG. 1 shows the star coupling of the alternator and the equivalent single-phase diagram of the machine according to Behn-Eschenburg.

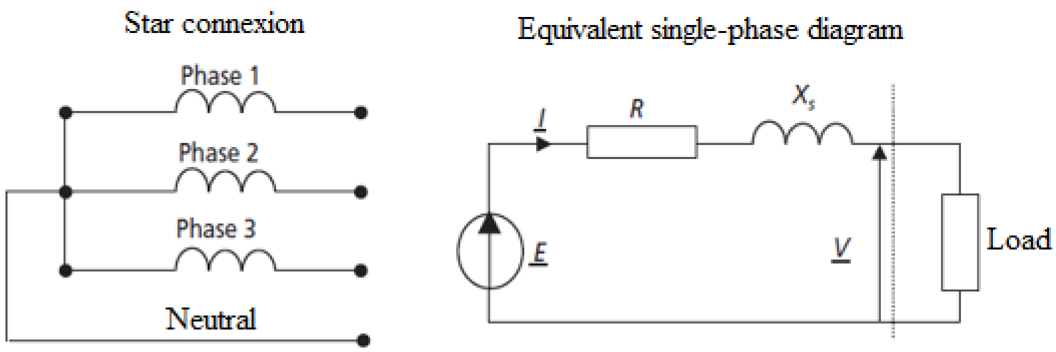

Figure 1

2) $N = \frac{60\, f}{p}$

$p = \frac{60 \times 50}{3000} = 1$ pair of poles means 2 poles.

3) $I_n = \frac{S_n}{3.V_n} = \frac{250.10^3}{3 \times 230} = 362\ A$

4) If we neglect the resistance of the windings that constitute the phases, the short circuit current Isc is just limited by Xs. Thus, for Ie = 6 A, we read : E = 148 V. Hence:

$$X_s = \frac{E}{I_{sc}(= I_n)} = \frac{148}{362} = 0.4\ \Omega$$

5) If we consider a set of unit power factor loads, that are three-phase balanced and star wired to the alternator, the Fresnel diagram of the magnitudes of the equivalent single-phase circuit is as shown in figure 2:

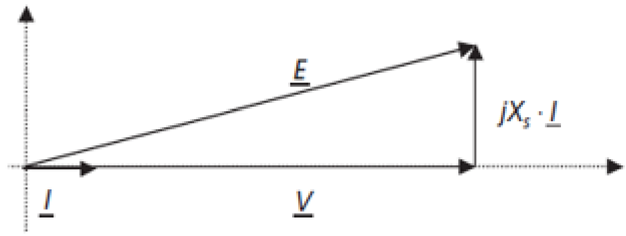

Figure 2

Moreover, the current called by the load of 250 kW is in this case:

$$I = \frac{P}{3.V_n.I_n} = \frac{150.10^3}{3 \times 230} = 217A$$

We deduce the value of the electromotive force E by writing:

$$V^2 + (X_s.I)^2 = E^2$$

So: $E = \sqrt{V^2 + (X_s.I)^2} = 245.8\ V$

By linear regression of the values of table 1, we obtain: $I_e = 7.2\ A$