ÉCOLE POLYTECHNIQUE
FÉDÉRALE DE LAUSANNE

SYSTÈMES TRIPHASÉS

SYSTÈMES TRIPHASÉS NON SYMÉTRIQUES

LEÇON 7

Électrotechnique II
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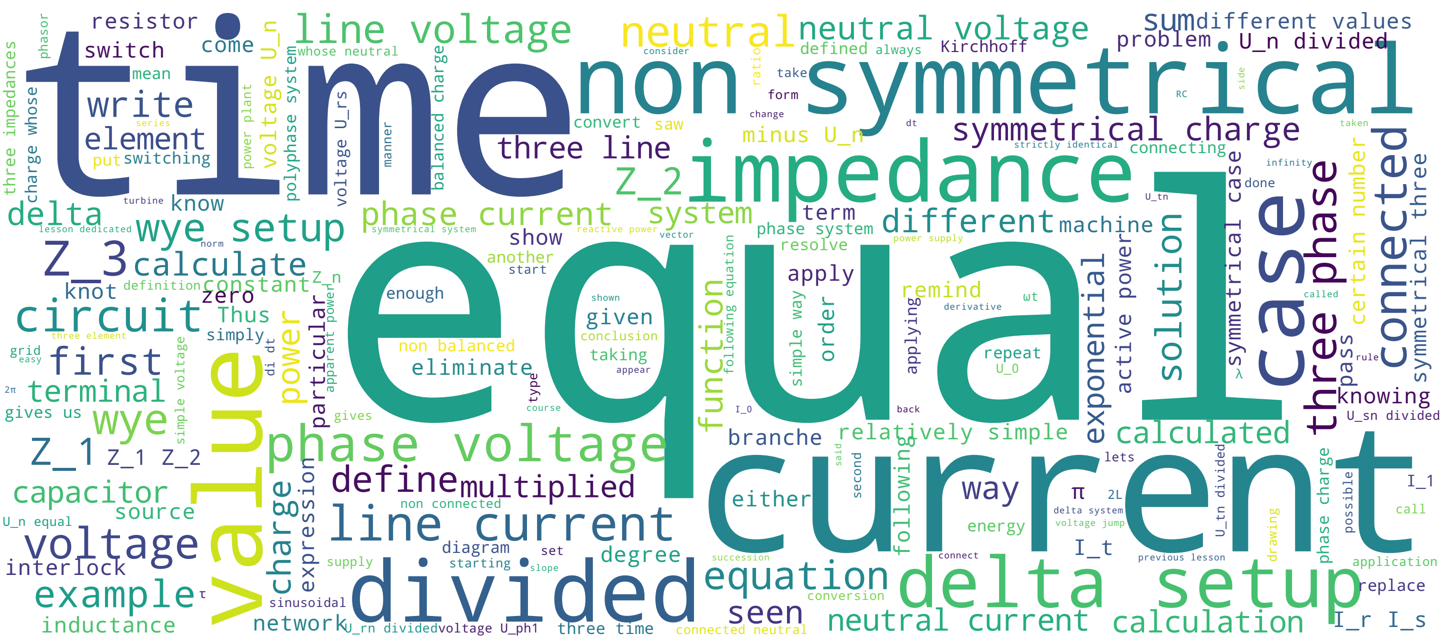
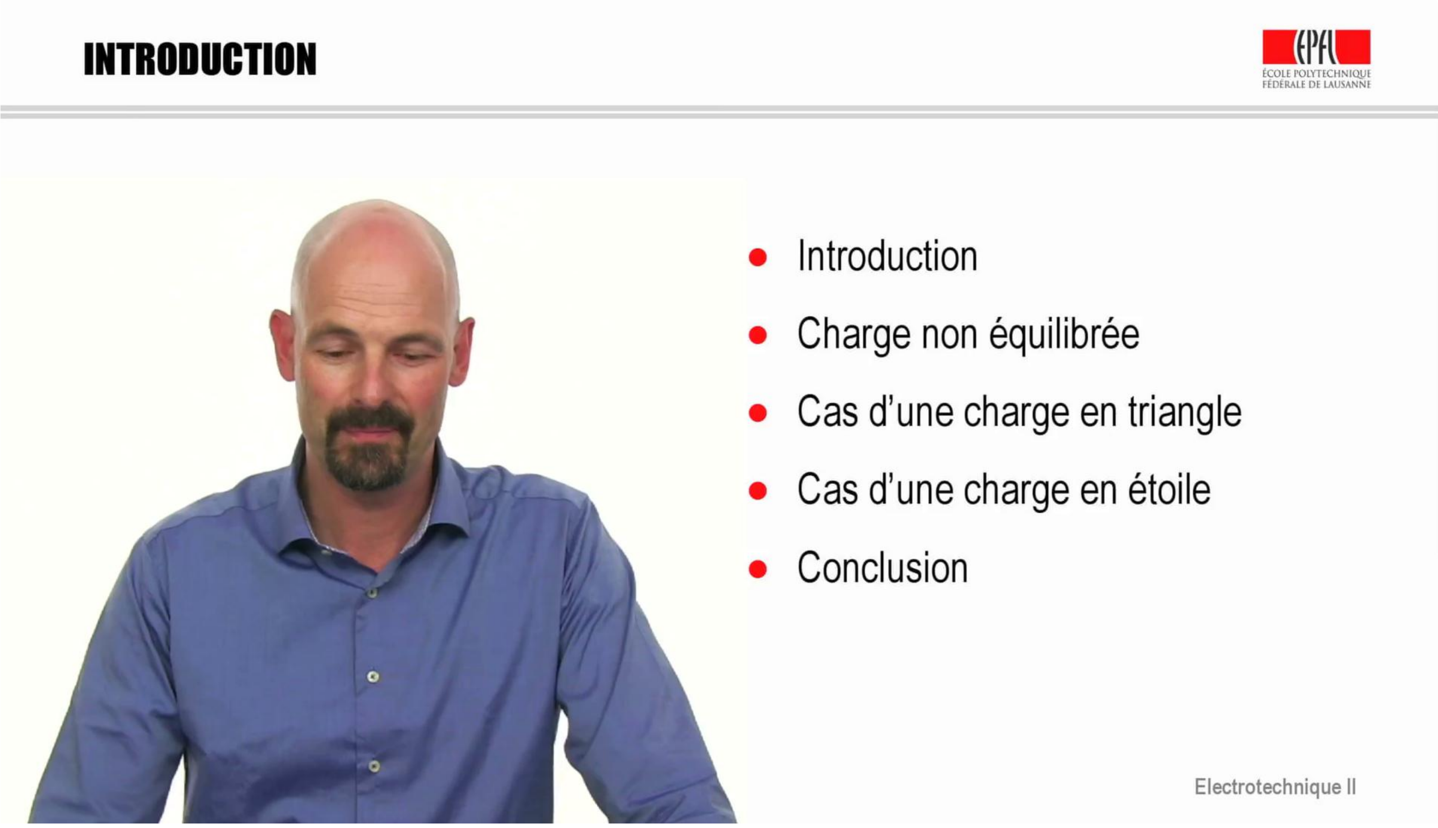


Video

EPFL



Hello, welcome to the 7th lesson, dedicated to non-symmetrical three-phase systems. In this lesson, we will define what a non-symmetrical three-phase charge is and we will see how, by connecting it in a wye or delta setup on a grid we will be able to calculate the current or the voltage in each of the charge's branches, letting us define the different values of a three-phase grid, such as the active power, the reactive power or the apparent power.

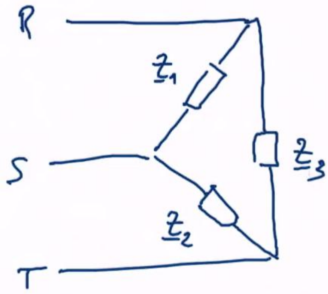
Notes

Summary

0m 00s

CHARGE NON ÉQUILIBRÉE

$\underline{Z}_1 \neq \underline{Z}_2 \neq \underline{Z}_3$



Electrotechnique II

The non-balanced charge, or non-symmetrical, is easy to define: it is actually a three-phase charge whose three impedances are not strictly identical. We will then have Z_1 different than maybe Z_2 which is different than Z_3 in a setup for example, in which, in delta, we have the three impedances, here with R, S and T, Z_1, Z_2 and Z_3. When can this happen ? This can firstly happen with a defect in a machine, a machine or a charge on which one of the impedances has been voluntarily changed or either a default, for example, when one of the charges has a defective connection and one of the impedances is suddenly disconnected. This implies that Z_2 and Z_3 should be identical, Z_1 is then disconnected and switches to 0. We then face the case of a non-symmetrical charge or non-balanced charge.

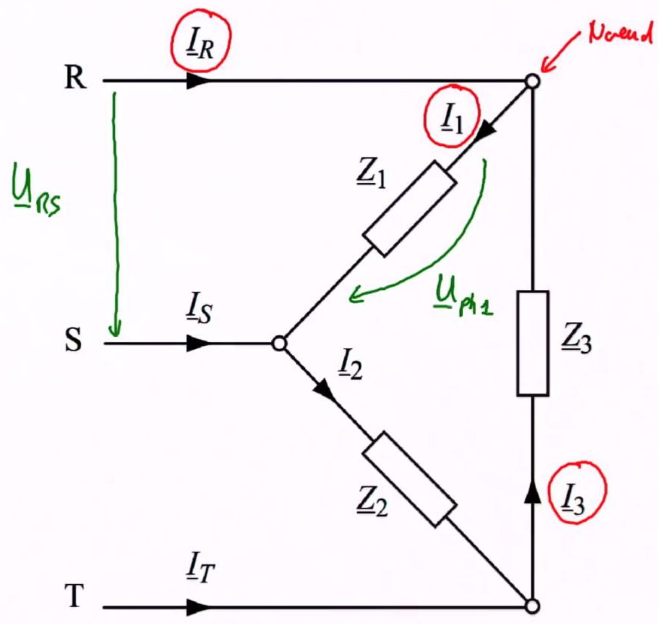
Notes

Summary

0m 31s

CAS D'UNE CHARGE EN TRIANGLE

$\underline{U}_{RS} = \sqrt{3}\, U\, e^{j\frac{\pi}{6}}$



Electrotechnique II

The first study case will be that of this non-symmetrical charge that will be connected using a delta setup. We will see that it is the easiest study that we can make, which can seem paradoxical, but we will see that this way of connecting in delta is actually quite easy to resolve, even for a non-symmetrical case. We remind the elementary values that we have seen previously, that is to say we have here the line voltage, the U_rs which will be equal to this phase voltage so I will write it U_ph1. However, as we have seen when studying the delta mode, the line current I_R will be equal, by Kirchhoff, to the subtraction between I_1 and I_3 since we have this knot here. So the Kirchhof equations will greatly help us to resolve such a problem of a non-symmetrical charge since, finally, knowing that Z_1, Z_2 and Z_3 are different, we just need to apply, in a relatively simple way, Kirchhoff. Then, we remind you what the three line voltage U_rs, U_st and U_tr are equal to in a symmetrical grid. Thus, U_rs is equal to √3*U*e^j(π/6). We then have a shift of 120 degrees for U_st with √3*U*e^j(-π/2) and the third U_tr √3*U*e^j(5π/6).

Notes

Summary

1m 52s

CAS D'UNE CHARGE EN TRIANGLE

$$\underline{U}_{RS} = \sqrt{3}\, U\, e^{j\frac{\pi}{6}}$$

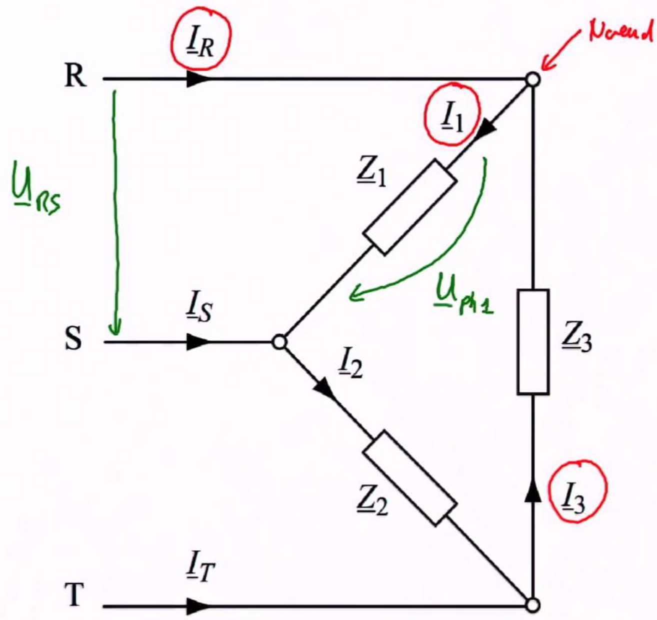
$$\underline{U}_{ST} = \sqrt{3}\, U\, e^{j(-\frac{\pi}{2})}$$

$$\underline{U}_{TR} = \sqrt{3}\, U\, e^{j\frac{5\pi}{6}}$$

$$\underline{I}_1 = \frac{\underline{U}_{ph1}}{\underline{Z}_1} = \frac{\underline{U}_{RS}}{\underline{Z}_1}$$

$$\underline{I}_2 = \frac{\underline{U}_{ST}}{\underline{Z}_2}$$

$$\underline{I}_3 = \frac{\underline{U}_{TR}}{\underline{Z}_3}$$



Electrotechnique II

This being said, and knowing that the phase voltage on the terminals of each impedance Z is equal to the line voltage, we can calculate, each time, for the three values, this time in an individual manner, since we have a non-symmetrical system, we can calculate I_1 which is equal to the phase voltage U_ph1 divided by Z_1 but this phase voltage U_ph1, as shown on the drawing, is also U_rs divided by Z_1. This gives me the phase current I_1 and in the same way, will be able to calculate I_2: U_st divided by Z_2, and I_3: U_tr divided by Z_3. Now that we have I_1, I_2, I_3, we can, on each knot, calculate the line currents I_r, I_s and I_t.

Notes

Summary

4m 00s

CAS D'UNE CHARGE EN TRIANGLE

$$\underline{I}_R = \underline{I}_1 - \underline{I}_3$$

$$\underline{I}_S = \underline{I}_2 - \underline{I}_1$$

$$\underline{I}_T = \underline{I}_3 - \underline{I}_2$$

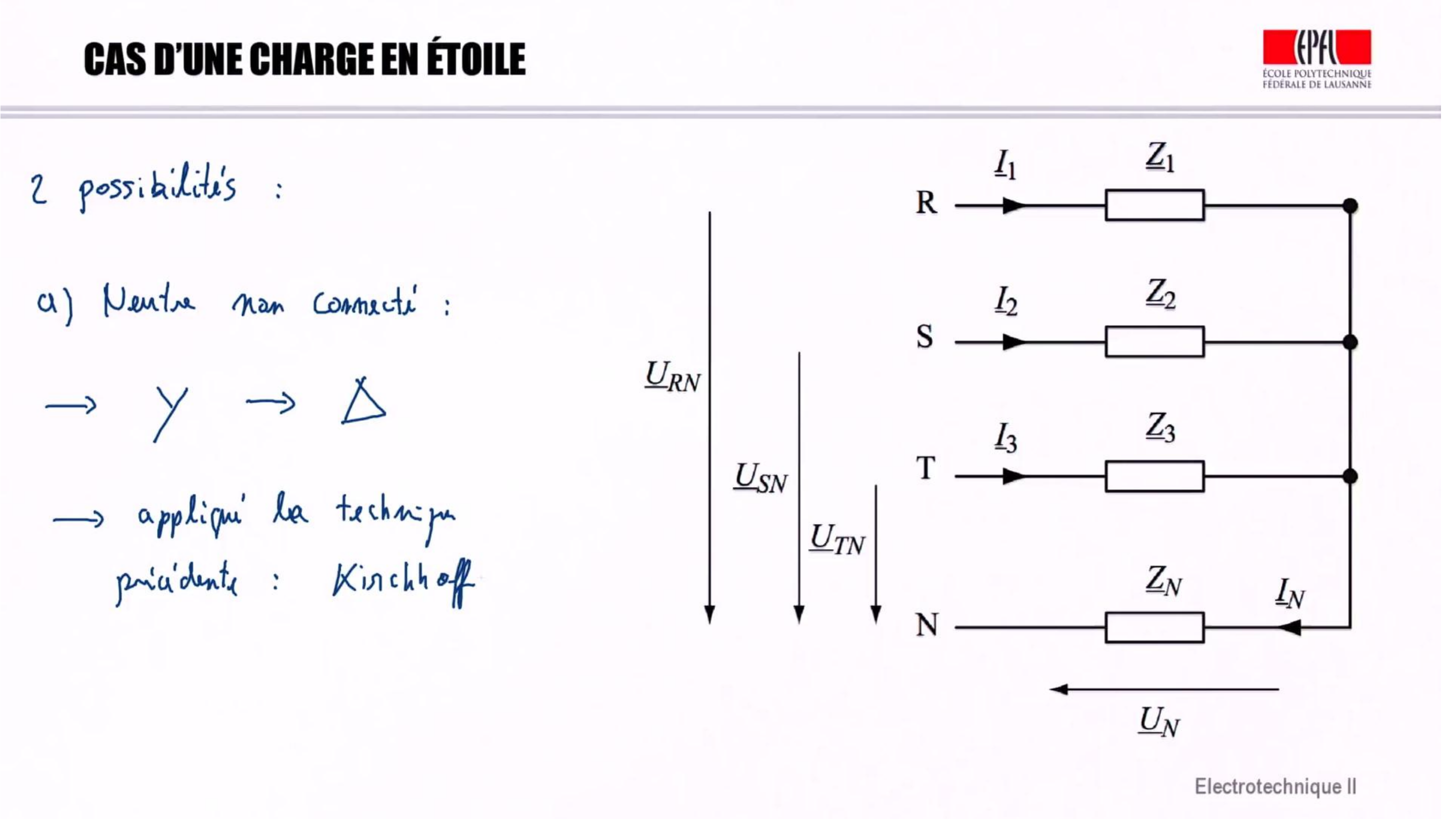
Electrotechnique II

The three line current are calculated by applying once again Kirchhoff on the knot, as shown previously and then I_r is equal to I_1 minus I_3. I remind you that it is a vectorial subtraction. I_s is equal to I_2 minus I_1 and I_t is equal to I_3 minus I_2. The calculations are then quite long, but relatively simple and need the calculation for each branch considered separately, since it is non-symmetrical. It is evident that, in a symmetrical case, we only look at one branche and all the other branches are simply shifted by 120 degrees. It is not the case here and each branch must be calculated individually.

Notes

Summary

5m 10s



Now in the case of a charge which is, this time, connected with a wye setup. In a wye setup, you have here the presented diagram, with shows a non-symmetrical impedance connected in a wye manner, with classically, a neutral point that appears and that be connected or not to the network's neutral. Thus, we will have two cases, two solutions, if you want to starting off with this diagram here and we need to define now which of these cases we are handling. So two possibilities. The first is that we have this wye charge whose neutral is not connected. Often, the neural is not connected to the network, so it is possible to have a case like ours if the neutral is not connected. This will be our case a) non-connected neutral, so the easiest way to resolve such a problem is to take the circuit that is in a wye setup, and convert the charge as for a delta setup. When it is for a delta setup, we can apply the previous technique, namely the application of Kirchhoff's rules on the circuit, this time, a delta system. Then, the conversion from wye to delta is done as seen in the previous lessons using the rules for the calculations of the impedances Z_1, Z_2 and Z_3 which pass in a wye setup, or a delta setup.

Notes

Summary

6m 13s

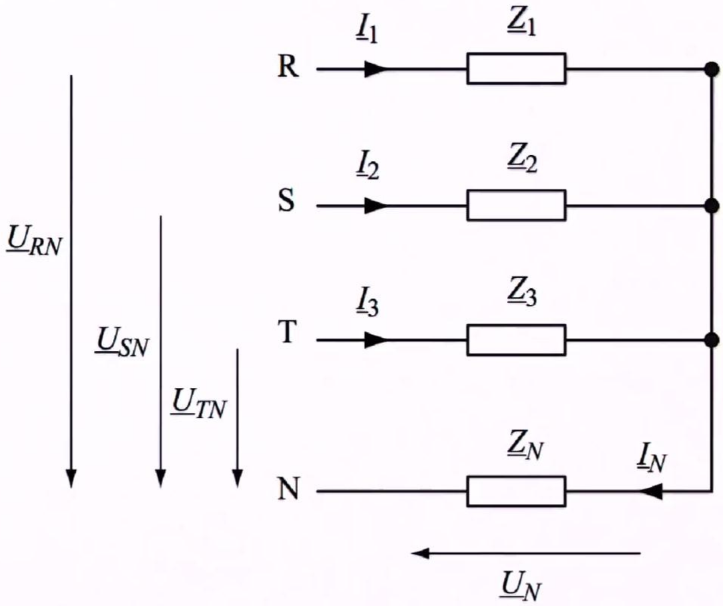
CAS D'UNE CHARGE EN ÉTOILE

2 possibilités :

a) Neutre non connecté :

→ Y → Δ

→ appliqué la technique précédente : Kirchhoff



Electrotechnique II

That is the easiest. Once we have a non-connected neutral, it is enough to convert this circuit or this charge for a wye setup, and to pass it in a delta setup, before applying Kirchhoff's technique.

Notes

Summary

8m 02s

CAS D'UNE CHARGE EN ÉTOILE

b) Neutre est connecté :

$$\underline{I}_R = \frac{\underline{U}_{RN} - \underline{U}_N}{\underline{Z}_1}$$

$$\underline{I}_S = \frac{\underline{U}_{SN} - \underline{U}_N}{\underline{Z}_2}$$

$$\underline{I}_T = \frac{\underline{U}_{TN} - \underline{U}_N}{\underline{Z}_3}$$

$$\underline{I}_N = \frac{\underline{U}_N}{\underline{Z}_N}$$

$$\longrightarrow \underline{I}_N = \underline{I}_R + \underline{I}_S + \underline{I}_T$$

Electrotechnique II

In the second case b), where the neutral is connected. Here things obviously change as we have an impedance Z_n, which is the impedance through which the neutral current will pass, to go back to the source, that needs to be taken into account. We then need to calculate a certain number of values that will depend on the neutral voltage. In particular, we have a line current that can be calculated, still using Kirchhoff, by taking the U_rn minus U_n and this divided by the impedance Z_1. We can say, in the same way, for I_s U_sn minus U_n divided by Z_2, and finally the third current in the branche t, or in the line t, is U_tn so the phase voltage, minus U_n divided by Z_3. We can also say that the neutral current, in the neutral which is normally zero in a symmetrical charge, but which will be non zero in the non-symmetrical case it is then equal to this voltage U_n divided by the impedance coming back from the neutral Z_n. We can also say that, and we know it, this neutral current, by Kirchhoff, is the sum of the three line current, that meet up. From there, we can then replace a certain number of elements that come from what we indicated previously, namely I_n = I_r + I_s + I_t and so, we replace with the three elements that we have calculated here I_r, I_s and I_t.

Notes

Summary

8m 18s

CAS D'UNE CHARGE EN ÉTOILE

b) Neutre est connecté :

$$\underline{I}_R = \frac{\underline{U}_{RN} - \underline{U}_N}{\underline{Z}_1}$$

$$\underline{I}_S = \frac{\underline{U}_{SN} - \underline{U}_N}{\underline{Z}_2}$$

$$\underline{I}_T = \frac{\underline{U}_{TN} - \underline{U}_N}{\underline{Z}_3}$$

$$\underline{I}_N = \frac{\underline{U}_N}{\underline{Z}_N}$$

$$\longrightarrow \underline{I}_N = \underline{I}_R + \underline{I}_S + \underline{I}_T$$

$$\underline{I}_N = \frac{\underline{U}_{RN}}{\underline{Z}_1} + \frac{\underline{U}_{SN}}{\underline{Z}_2} + \frac{\underline{U}_{TN}}{\underline{Z}_3} - \underline{U}_N\left[\frac{1}{\underline{Z}_1} + \frac{1}{\underline{Z}_2} + \frac{1}{\underline{Z}_3}\right]$$

$$\underline{U}_N = \left[\frac{1}{\underline{Z}_1} + \frac{1}{\underline{Z}_2} + \frac{1}{\underline{Z}_3} + \frac{1}{\underline{Z}_N}\right]^{-1}\left[\frac{\underline{U}_{RN}}{\underline{Z}_1} + \frac{\underline{U}_{SN}}{\underline{Z}_2} + \frac{\underline{U}_{TN}}{\underline{Z}_3}\right]$$

Electrotechnique II

What does this give us? This gives us the following equation. I_n I put on one side the phase voltages and on the other the neutral voltages, so we have U_rn divided by Z_1 plus U_sn divided by Z_2 plus U_tn divided by Z_3 minus and we have the neutral voltage that come here, evidently, and that multiplies 1 divided by Z_1 plus 1 divided by Z_2 plus 1 divided by Z_3. This is equal to, I repeat it, the neutral voltage divided by Z_n. We will then eliminate the current I_n in this equation and make the top equation, here and the bottom equation equal. In this way, we eliminate the neutral current and we can set down the equation by writing U_n equal and then, by extracting the neutral voltage. We find U_n equal firstly to 1 divided by Z_1, plus 1 divided by Z_2 plus 1 divided by Z_3 plus 1 divided by Z_n and all this at the power -1 that multiplies U_rn divided by Z_1 plus U_sn divided by Z_2, plus U_tn divided by Z_3. To be clearer, I eliminate what I put here to get the whole equation and then what do we still need to do? The whole work is now to calculate U_rn by taking, each time, the voltage U_rs that we have here and by subtracting this voltage U_n of the neutral that we have just calculated, of course in a vectorial way.

Notes

Summary

10m 20s

CAS D'UNE CHARGE EN ÉTOILE

b) Neutre est connecté :

$$\underline{I}_R = \frac{\underline{U}_{RN} - \underline{U}_N}{\underline{Z}_1}$$

$$\underline{I}_S = \frac{\underline{U}_{SN} - \underline{U}_N}{\underline{Z}_2}$$

$$\underline{I}_T = \frac{\underline{U}_{TN} - \underline{U}_N}{\underline{Z}_3}$$

$$\underline{I}_N = \frac{\underline{U}_N}{\underline{Z}_N}$$

$$\longrightarrow \underline{I}_N = \underline{I}_R + \underline{I}_S + \underline{I}_T$$

$$\underline{I}_N = \frac{\underline{U}_{RN}}{\underline{Z}_1} + \frac{\underline{U}_{SN}}{\underline{Z}_2} + \frac{\underline{U}_{TN}}{\underline{Z}_3} - \underline{U}_N\left[\frac{1}{\underline{Z}_1} + \frac{1}{\underline{Z}_2} + \frac{1}{\underline{Z}_3}\right]$$

$$\underline{U}_N = \left[\frac{1}{\underline{Z}_1} + \frac{1}{\underline{Z}_2} + \frac{1}{\underline{Z}_3} + \frac{1}{\underline{Z}_N}\right]^{-1} \left[\frac{\underline{U}_{RN}}{\underline{Z}_1} + \frac{\underline{U}_{SN}}{\underline{Z}_2} + \frac{\underline{U}_{TN}}{\underline{Z}_3}\right]$$

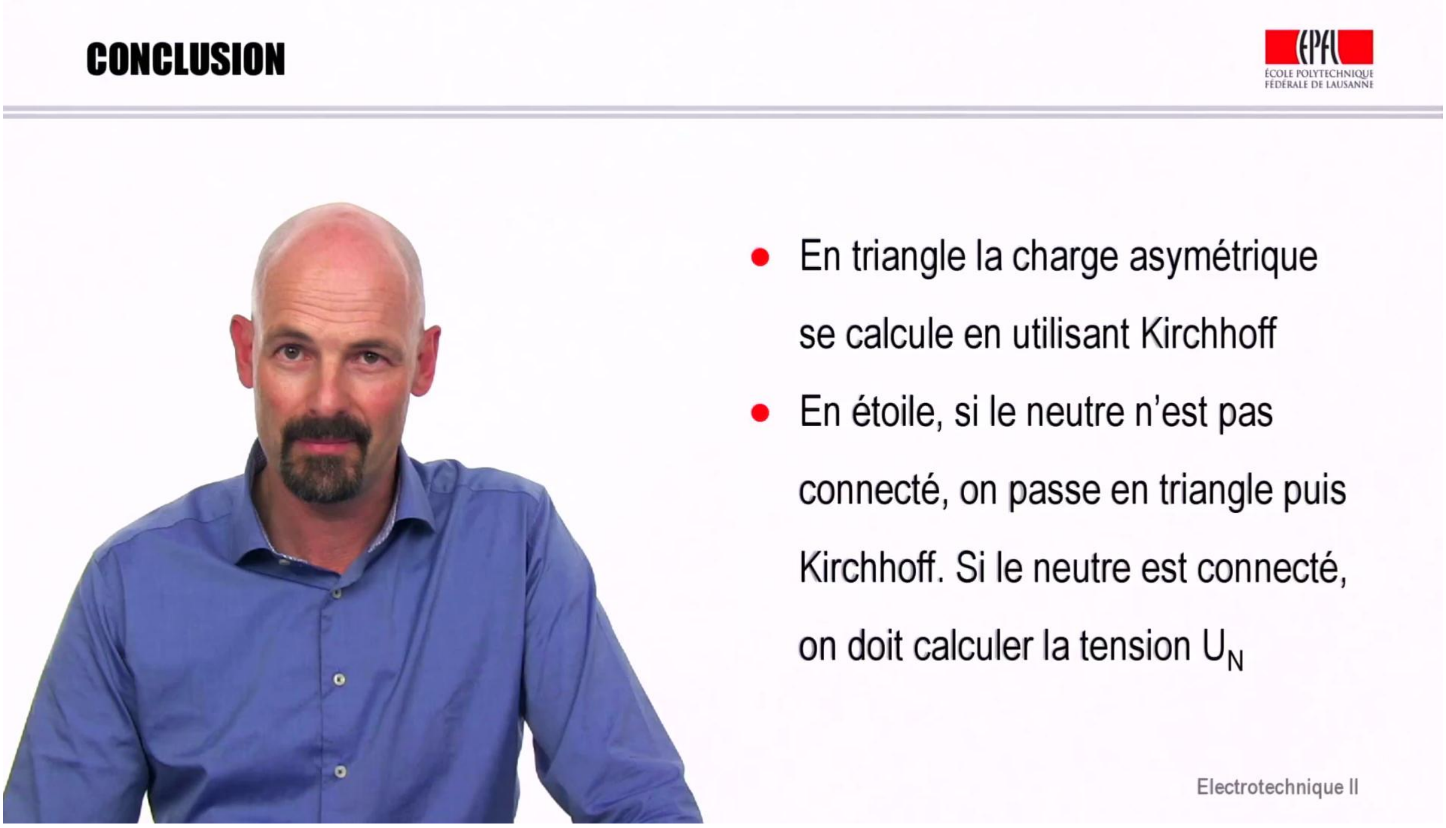
Electrotechnique II

But this lets us calculate the voltage U_n, so on the neutral impedance, to determine completely the different values of a non-symmetrical charge that was connected in wye, and whose neutral is connected.

Notes

Summary

12m 37s



In conclusion, we saw the non-symmetrical charge, we saw how, in a delta setup, we can in a relatively simple way determine these different values and by applying the Kirchhoff equations for the wye setup two cases presented themselves, either the neutral is connected and then we need to calculate everything, in particulat the neutral voltage and to a relatively complex vectorial calculation on each of these values. Or else, the neutral is not connected and it is enough to switch from a wye to a delta setup and to repeat what we have seen for the delta setup.

Notes

Summary

12m 56s