ELEC0431 Electromagnetic Power Conversion Laboratories

Prof. C. Geuzaine
Teaching Assistant N. Davister

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Contents

WARNING

Switch-off before acting on the installation!

Keep your hands away from the rotating shafts and tie long hairs!

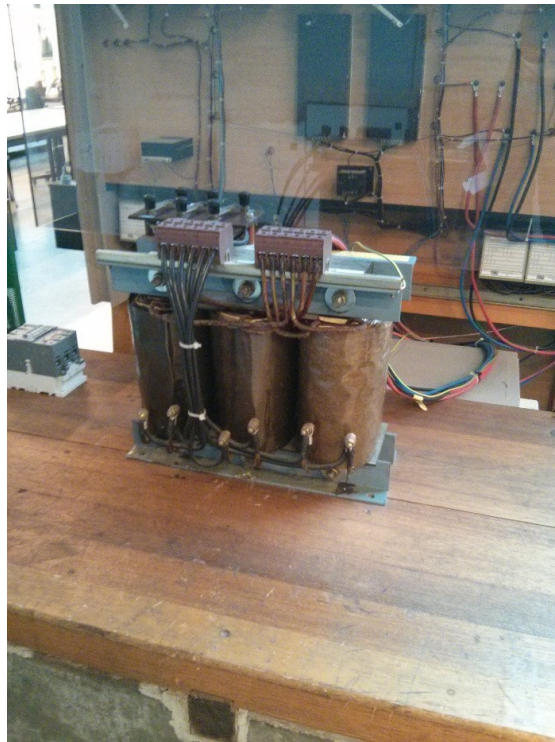# 1 Transformer Lab - Three-phase transformer

1.1 Components

The studied three-phase transformer:

The voltage is supplied through an autotransformer:

This allows to deliver an output voltage whose value depends on the angular position of the black indicator on top. This output voltage is the input voltage of the primary winding of the studied transformer. Load connected to the transformer's secondary winding:
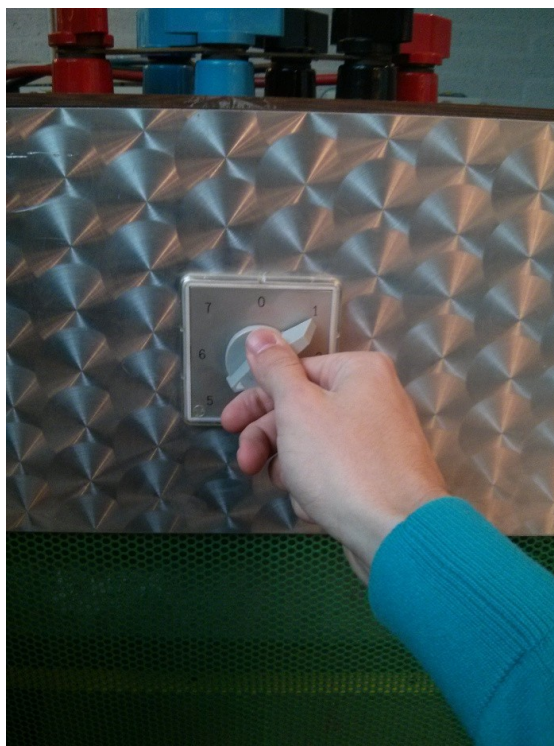
On the right side of the table. When on "0" the secondary winding is an open circuit. When on "1" it is $27\,\Omega$, "2" is $27/2\,\Omega$, "3" is $27/3\,\Omega$,... The secondary winding can not be shorted using this technique. A manual short-circuit on the back side of the table is required. All the power measurement are performed using a power quality analyzer (Fluke 434 or equivalent):
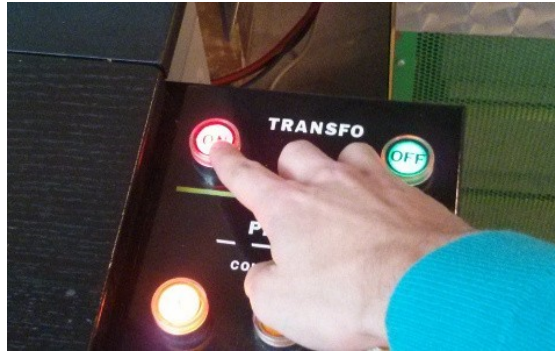
Do not forget to choose the phase coupling mode: "Y" or "Delta" configuration. Also, pay attention to the power flow direction when installing the clamps.

1.2 Start-up

First

Then

1.3 Questions

1.3.1 Question 1

Locate all components that will be used in the lab and understand how they are connected. What are the current, voltage and power ratings of the transformer? Why are there 2 U-I ratings but only 1 power rating? **You should not exceed those ratings for the rest of the lab.**

Hint: You will find all info written on the nameplate on top of the transformer as on the picture below. All ratings as well as the voltage measurements shown on the board are indicated for the line voltage.

1.3.2 Question 2

What is the transformer ratio? How does it change when the primary or secondary winding is in a Y or Delta configuration? Use graphics to detail your explanations.

Hint: Switching configuration is easily done by pressing on the corresponding buttons ("H" is not used here) when the transformer is off. The picture shows the selection for the primary winding. All voltages shown on the board are line voltages.

1.3.3 Question 3

Perform 2 measurements to deduce the impedances of the transformer's electric model. Do your approximations make sense? Explain the electric model, the two tests and the underlying approximations/assumptions to your supervisor before measuring.

Hint: When the output load is on "0" you have an open circuit. The short-circuit has to be done manually on the back side of the table, as on the picture. When short-circuited the board will stop showing the measurements on the secondary side but you can still measure P and Q on the primary side.
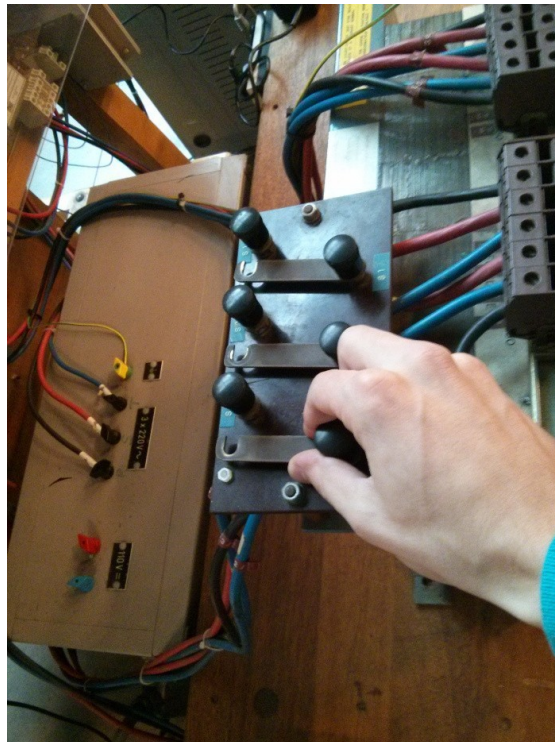
**Do not forget to start the short-circuit test with $0\,\%$ at the autotransformer and do not forget to take into account the Y and delta voltage ratio to guarantee to keep I_{out} lower than the rating.**

1.3.4 Question 4

Measure the U-I output characteristic for the connected resistive load. What would be the optimal curve? Are we close to it? Why don't we have the optimal curve? Link the voltage drop to the

measured impedances in the electrical model. What would you get for a capacitive and inductive load? Why? Be prepared to explain it to your supervisor.
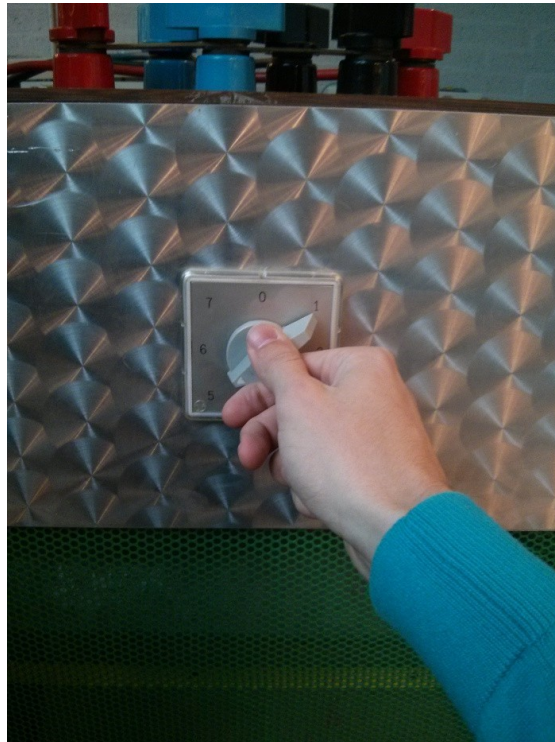
Hint: Put the autotransformer to 100 % and choose the right configuration (Y or Δ) for primary and secondary to maximize the output voltage. You do not have to perform the short circuit test, just interpolate graphically your results.

1.3.5 Question 5

What are two different ways to measure the efficiency of the transformer? Put the transformer in the question 4 configuration that you set to maximize the output voltage. Evaluate then the transformer efficiency by the output over input power ratio. Is it good? *Hint: Measure the efficiency at the nominal power and with the configuration (Y or Δ) that maximises the output voltage.* What does a high efficiency mean for the size of a transformer (or any electromagnetic energy conversion system)?

2   Transformer Lab - One-phase transformer
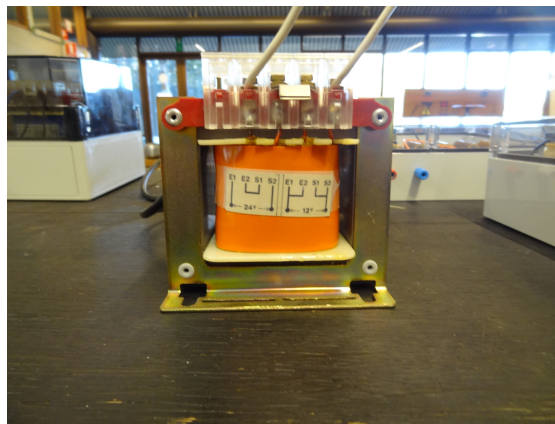
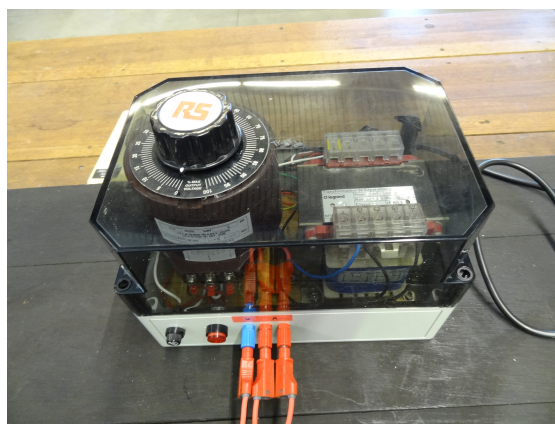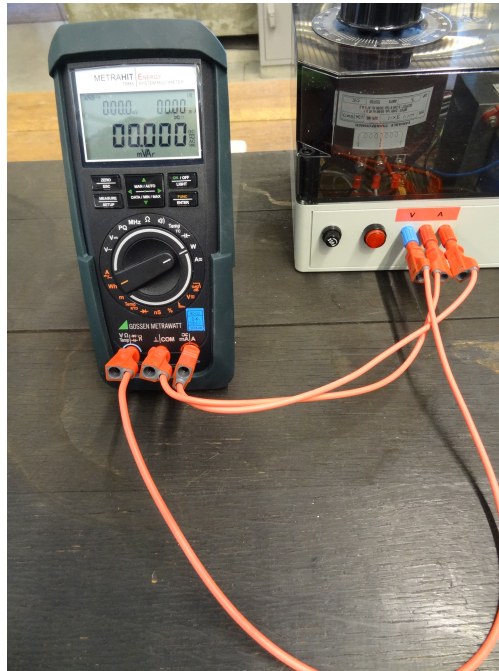### 2.1   Components

The studied transformer.

An autotransformer (left) and an isolation transformer (right), used to power the primary of the studied transformer.

A wattmeter connected to the primary of the transformer.

The different loads that will be used (R-L-C).
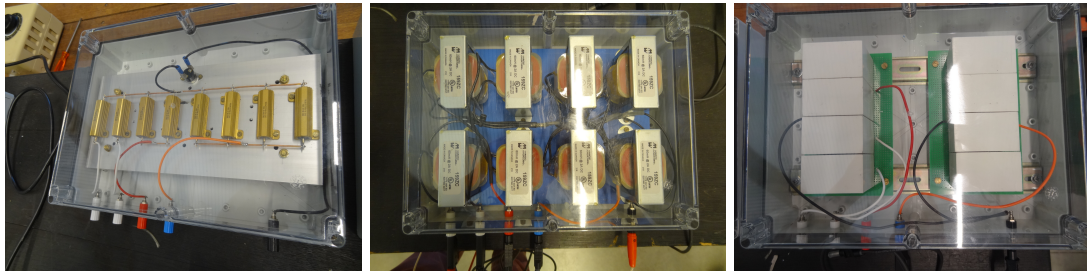
2.2 Start-up

1. Ensure that the autotransformer is set to "0"

2. Push the autotransformer button

3. Increase the voltage to 230 V

2.3 Questions

2.3.1 Question 1

Locate all components that will be used in the lab and understand how they are connected. What are the current, voltage and power ratings of the transformer? **You should not exceed those ratings for the rest of the lab.**

Hint: You will find all info written on the nameplate on top of the transformer.

2.3.2 Question 2

Perform 2 measurements to deduce the impedances of the transformer's electric model. On which side of the transformer are the measurements performed? Do your approximations make sense? Explain the electric model, the two tests and the underlying approximations/assumptions to your

supervisor before measuring. **Do not forget to start the short-circuit test with $0\,\%$ at the autotransformer.**

2.3.3 Question 3

Measure the U-I output characteristic for the resistive load. What would be the theoretical curve? Are we close to it? Why don't we have the theoretical curve? Be prepared to explain it to your supervisor.

2.3.4 Question 4

Measure the U-I output characteristic for the inductive and capacitive loads. What would be the theoretical curve? Are we close to it? Why don't we have the theoretical curve? Be prepared to explain it to your supervisor.

3   Brushed DC Machine Lab

Warning:
This laboratory involves high currents and voltages, think before acting!
Important:
 • Never exceed rated current or voltage.

3.1   Components

DC motor on the left,   DC generator on the right.

The load is a resistor and is connected to the DC generator's output:

On the right side of the table. As shown on the resistors top and on the bottom picture one can see that the resistor can be adjusted from a short-circuit to an open circuit when rotating the wheel.

3.2 Start-up

First,

Second, make sure to start the motor with "I excitation" at maximum or it might not start.

Anf finally, after the motor is started, start the generator by pressing the "génératrice ON" button and connect the excitation circuit by pressing the button on the picture.
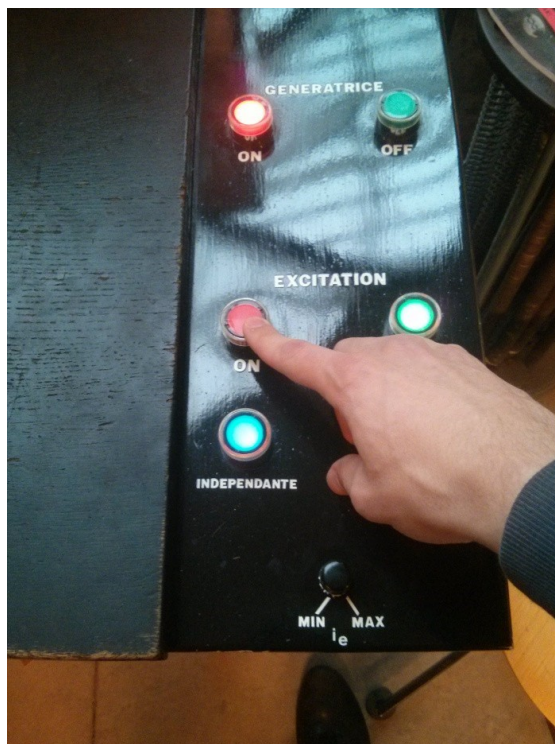
3.3   Questions

3.3.1   Question 1

Make sure you are aware of the current and voltage ratings for both the DC motor and generator. You will find this information on the nameplate of the machines.

Why does the motor start in 3 audible steps? How is the motor started? In which fixed configuration is the motor wired (have a look at the board drawings)? What is the only difference in the construction of the DC generator in front of you and the DC motor? Why?

Hint: Think about the position of the brushes.

3.3.2 Question 2

What is the effect of decreasing the generator's load? How does it change the rotating speed? What is the effect of increasing and decreasing the shunt motor's excitation current? Why?

Hint: You can easily increase the excitation currents by rotating the little buttons called "Ie" clockwise.

3.3.3 Question 3

Measure the speed with respect to the torque delivered by DC shunt wound motor. Compare your results with the theoretical curve below and justify that behavior.
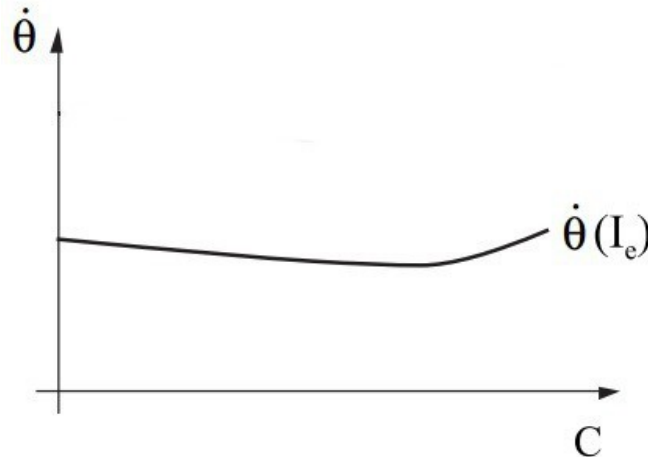
Hint: You do not have a torquemeter but there is however a simple way to increase the torque applied to the motor by using the generator. Do not forget to keep all currents and voltages below the values found in question 1.

### 3.3.4 Question 4

Measure the unloaded E_v-I_e excitation graph for the separately excited DC generator. You should get something similar to the figure below. Increase I_e of the generator and then decrease it again. What do you observe? Why?
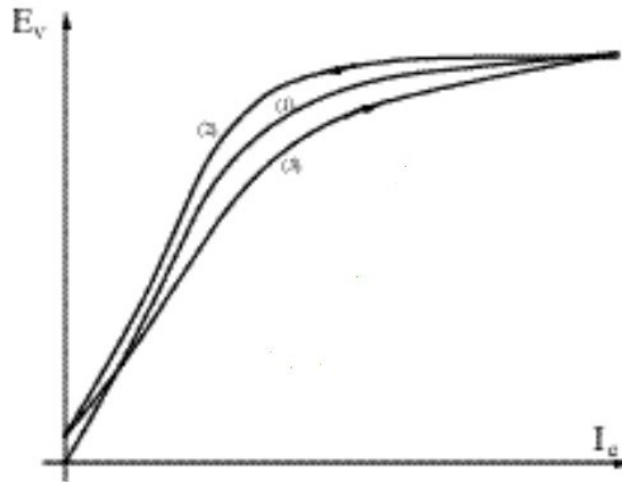
3.3.5 Question 5

Measure the U-I graph of the shunt wound DC generator at 1500 RPM. For this test to provide good results, set the generator's excitation current at a value that leads to $100\,\mathrm{V}$ of Root Mean Square (RMS) output voltage when unloaded at 1500 RPM. Explain the physical reasons for this curve to your supervisor.
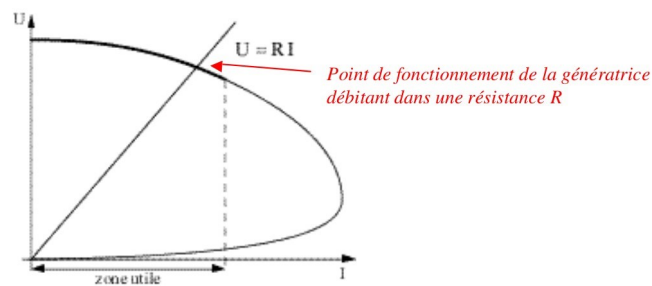
Hint: This test is to be done at constant speed. Use the motor side to keep the rotating speed constant.

4 Synchronous AC Machine Lab

4.1 Components

Synchronous machine on the left,   separately excited DC motor on the right.
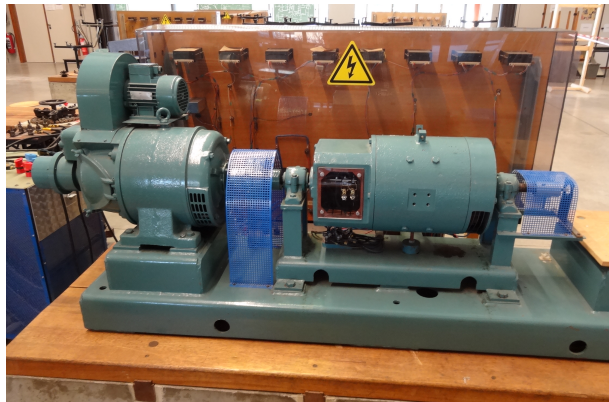
A voltage & frequency comparator (between grid and generator) is used to bring the generator output smoothly to the power network so that the generator can be connected to the network. V line has an arrow on the outer side of the circle which indicates the network voltage (divided by 2 via a transformer). It has also an inner arrow which shows the generator's output voltage. The two boxes below compare the network frequency with the generator frequency as well as the phase difference. To connect the generator to the network, the middle box should optimally have its arrow pointing to the top without moving : this means a frequency match, as well as a phase match. This in turn guarantees a smooth connection to the network without vibration or voltage spikes.

A load is connected to the synchronous generator's output, consisting of resistor in series with a variable inductor. The three loads for the three phases are balanced and connected in a delta configuration. For the resistor : when on "0" the resistance is infinity. When on "1" it is $36\,\Omega$, "2"" is $36/2\,\Omega$, 3 is $36/3\,\Omega$,... To vary the inductance, turn the wheel from the bottom picture. Only one every two contacts is connected to the inductive load so that as you turn the wheel you will go through an open circuit connection before being again connected to an inductive load with a different value than before. To connect a "purely" inductive load to the generator's output, the resistors should be short-circuited, pay attention: **The current in the cables should stay below** $10\,\text{A}$**.**
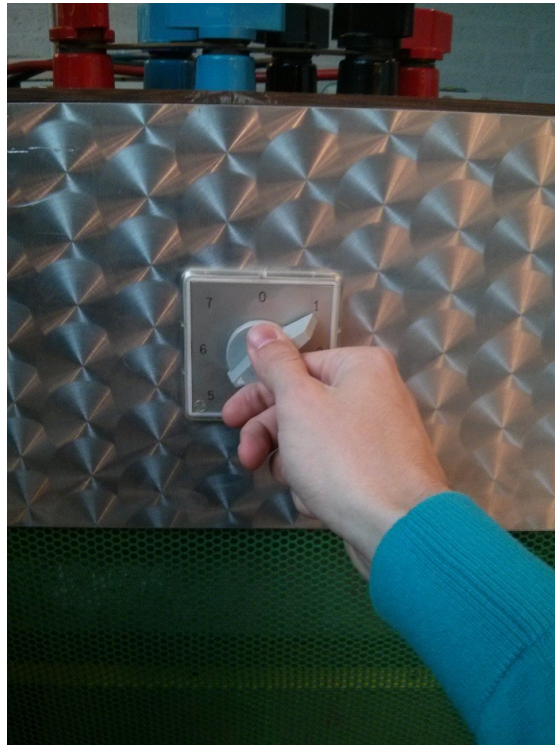
4.2   Start-up

First, press the 2 "marche" buttons

Then, start the DC motor. It will start in 3 audible steps by progressively increasing the motor's input voltage. Please set the excitation current I_e to the maximum before starting to limit the in-rush current.

Finally, press on "charge", this will connect the load to the synchronous generator's output, then press "on". **DO NOT** press "reseau" as the generator's output is not close to the networks voltage and frequency yet.

4.3 Questions

4.3.1 Question 1

Make sure you are aware of the current and voltage ratings so you know what you should not exceed.

Hint: You will find all information written on the nameplate of the machines.

4.3.2 Question 2

Measure the U-I output curve of the synchronous generator for a purely inductive charge as well as for a resistive charge. "U unloaded" should be chosen to 70 V (measuring "I short-circuit" is not required). Do your measurements follow the theoretical curve, as displayed below? Explain to your supervisor why for a purely inductive charge U decreases faster than for a resistive charge and why the decrease is linear. What is the U-I curve for a resistive load with a perfect generator? Make a link to the U-I curves of the transformer.
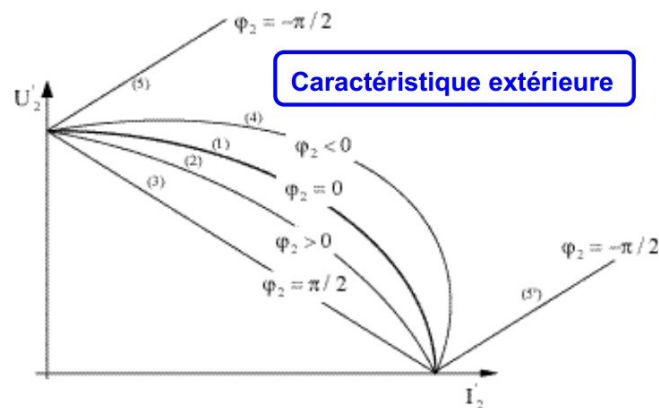
For a purely inductive charge, how many watts are transferred to the load? Explain in your case how reactive power transfer leads to power losses. *Hint: This test requires a constant rotor speed.*

You can adjust the rotor speed by changing the excitation current of the DC motor as explained in the DC machines lab.

4.3.3 Question 3

Cite the 4 requirements needed to safely and smoothly connect the synchronous generator to the electrical grid. **To turn on the comparator, press the "reseau" button**. Once, the 4 required conditions are fulfilled, press the "on" button to connect the generator to the electrical grid (**ask your supervisor to check all parameters before connecting the generator to the network**). Now that the generator is connected, see what happens when you change the DC motor's and the generator's excitation current. Explain why. What would happen if the generator's output voltage was lower than the network voltage? Explain it. Increase the DC motor's "I_e" until the synchronous generator's output power gets negative. Why is it negative? How does the synchronous machine now act like? How about the DC motor? What would happen if the generator's output frequency was lower than the network frequency?

4.3.4 Question 4

Make sure you understand the meaning of the "V" curves. Explain to your supervisor what it represents, in which conditions it is to be measured, why it looks like a "V". Since all points in a same "V" curve have the same active power transfer under the same network voltage, why does the stator current still change? What consequence does this have on the efficiency? Deduce where the efficiency is maximized. Based on the "V" curves, explain how one could stabilize the network using an unloaded synchronous motor. Why do we want the synchronous motor to be unloaded?

V curves for a synchronous motor with variable excitation.
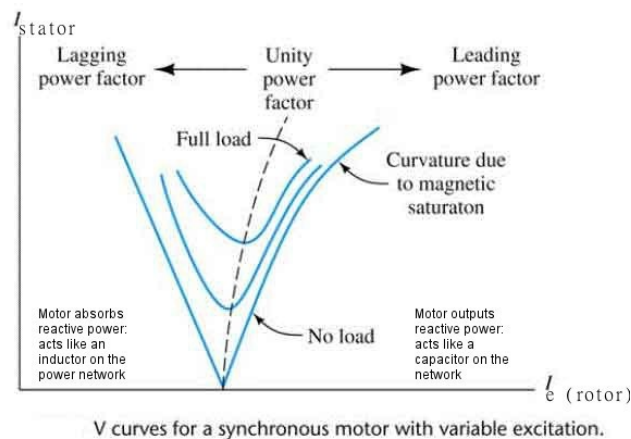
Measure the "V curve" at no-load. Do you get the theoretic curve ?
    Hint: couple back the generator to the network if you powered off the machine in the meantime
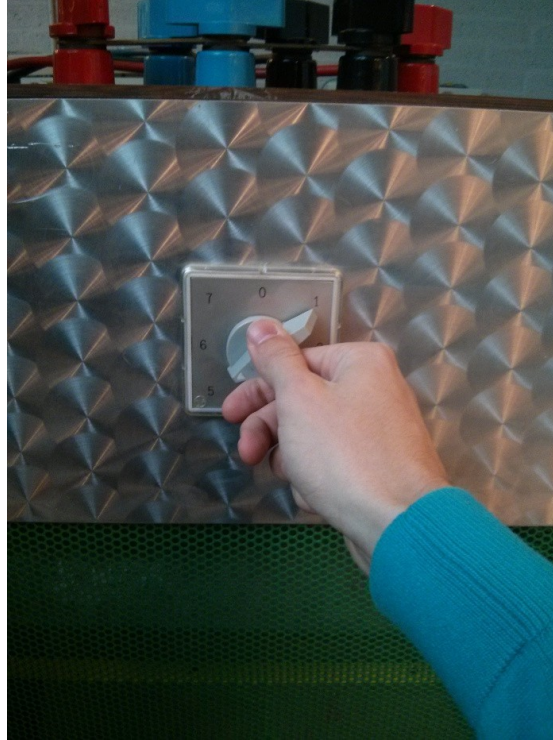
5 Asynchronous AC Motor Lab

5.1 Components

DC generator used as a variable mechanical load on the left, three-phased asynchronous motor on the right.

The voltage is supplied through an autotransformer:

This allows to deliver an output voltage whose value depends on the angular position of the black indicator on top. This output voltage is the input voltage of the primary winding of the studied transformer. The load is connected to the DC generator's output. It allows to electrically change the asynchronous motor's load torque:

On the right side of the table. When on "0" the DC motor output is an open circuit. When on "1" it is $36\,\Omega$, "2" is $36/2\,\Omega$, "3" is $36/3\,\Omega$,... When the load decreases the DC generator generates more electric power and thus the torque applied on the asynchronous motor by the DC generator increases. Changing the excitation current of the DC generator's stator is another way to change the torque applied to the asynchronous motor (moving the wheel clockwise increases the excitation current):

A current transformer is used to convert a current from the $50\,\text{A}$ range to a $5\,\text{A}$ range. The ammeter part of the wattmeter should be plugged as indicated on the picture.

Three-phase power will be measured using the 2 wattmeters method. Use the current transformer as explained before to reduce the current range. Plug the ammeter connections in the current transformer and the voltage connections at the right place in the table. Do not forget to multiply your readings by the transformer ratio!

5.2 Start-up

Short-circuit the current transformer input to deviate the "in- rush" current from the current transformer when starting-up.
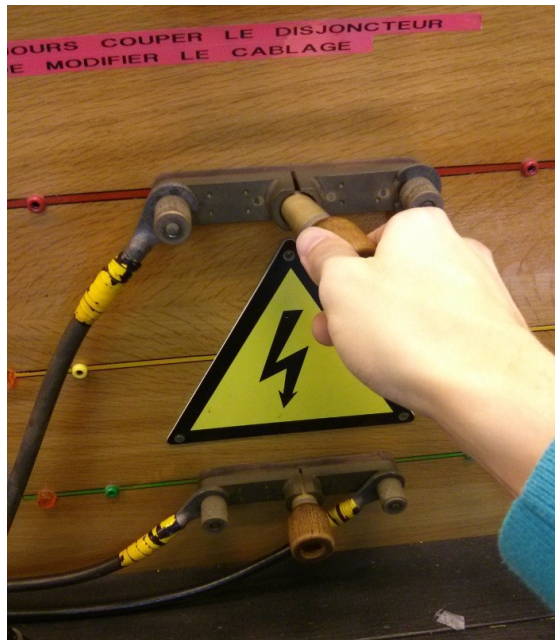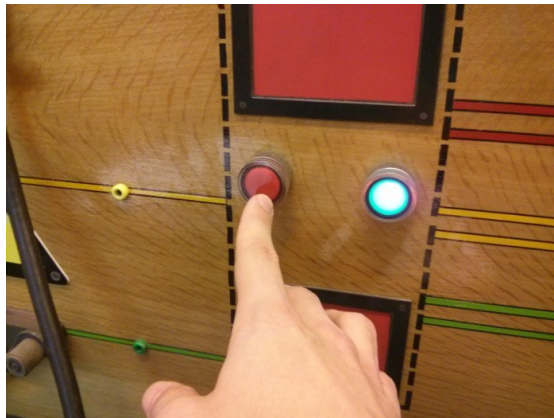
Make sure those two switches are up:

Then, press those two buttons:

Finally, start the asynchronous motor and remove the short-circuits at the current transformer input.

5.3 Questions

5.3.1 Question 1

Why does the asynchronous motor have 2 current ratings but only one power rating?

Proof that the considered motor is an asynchronous motor. What is the motor's synchronous speed ? What is the slip value at the rated speed? What about the torque? Why is the motor input connected in a "Y" configuration when starting?

Hint: You will find all information written on the nameplate of the asynchronous motor. The motor is a motor with 2 pole pairs.

5.3.2 Question 2

Explain the asynchronous motor's electric model and the link to the transformer model. Measure its impedances. Which two tests do you need to perform? Explain it to your supervisor. Why is the magnetic coupling worse than for the transformer? **You need to block the rotor so that it does not spin. Make sure to put the autotransformer to 0% and increase it slowly during the test while making sure you stay within the current limits.**

5.3.3 Question 3

Measure the torque C with respect to the slip g to capture the stable zone of the theoretic graph from the picture. Based on the motor power factor, explain why the torque increases as the rotor starts to spin. What is the effect of putting a series resistor on the rotor at $g = 1$ and $g = 0$? Explain it to your supervisor.
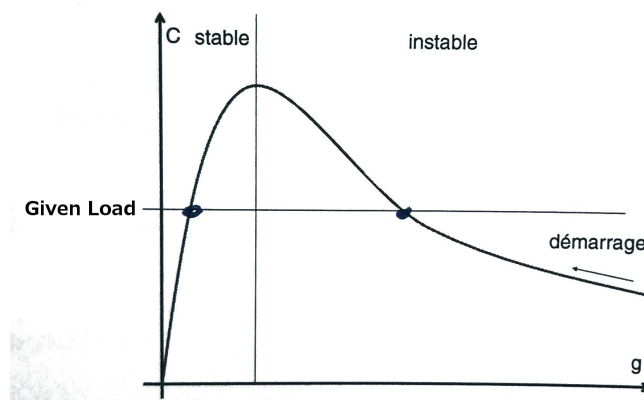
Show that the asynchronous motor's efficiency increases when g gets closer to 0. In our case what is the best efficiency you can measure? What is the effect of increasing the autotransformer output voltage?

Hint: You can easily measure the efficiency of the asynchronous motor by dividing the mechanical power by the input electric power. To change g you just have to play around with the DC motor load, with its excitation current.