Electrical Machinery Laboratory

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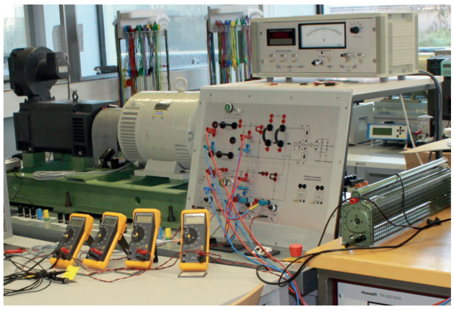

Complementary Lab

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Complementary Lab
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THWS, Stand SoSe 2024

Fundamentals of Electrical Machines

1 Objectives

Electrical machines are the basis of electric drives and also fundamental for the power generation. The course Actuators / Drives covers briefly the fundamental types of electrical machines. This Lab illustrates the same topics from the experimental point of view. At the end of this lab, you should be able to achieve the following objectives:

- Understand the principle of operation the three main types of electrical machine
  - Direct-Current motor
  - Synchronous machine
  - Induction motor
- Know the speed-control mechanism for each of these electrical motor types

2 Experiments

In this lab, UniTrain, a computer aided training and experimentation system, is used [1]. UniTrain courses on electrical machines consist of open, freely accessible stators. These are set up on the experiment cards and thus allow a deep insight into the internal structure of electrical machines. Several rotors are available for each card to demonstrate the operating principle of electrical machine. If not stated differently in this document, the connecting diagrams of the UniTrain software can be followed.

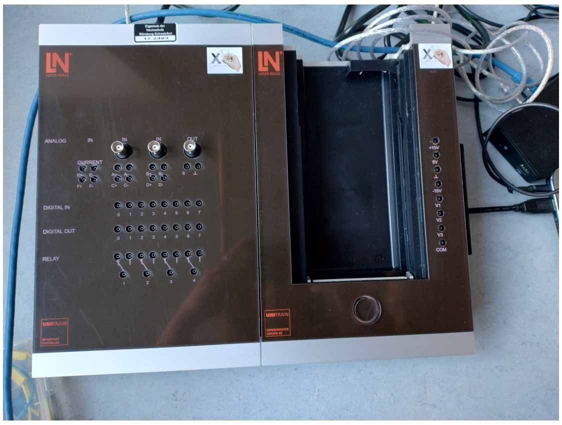
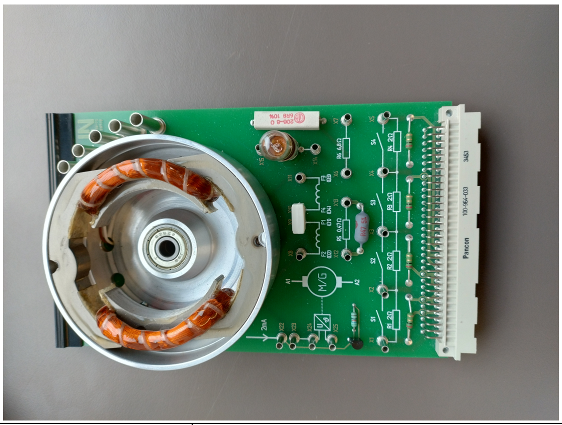


Figure 1: Main board of the UniTrain System

2.1 DC motor

Figure 2 shows the card and the key technical data for the stator of the DC machine. The armature (rotor) is shown in Figure 3.

[1] https://www.lucas-nuelle.de/219/apg/1425/Produkte/UniTrain.htm



Stator	two poles, 2 isolated excitation windings
Winding resistance ($20\,°\mathrm{C}$)	$22\,\Omega$
Nominal exciter voltage	$2 \times 7.5\,\mathrm{V}$
Max. speed (short-term)	$4500\,\mathrm{min}^{-1}$ ($5000\,\mathrm{min}^{-1}$)

Figure 2: Experimenting card SO42404-7S with the stator of the DC-motor

Commutator with 12 segments
12 windings, each with a cold resistance of $4.3\,\Omega$
Two adjustable carbon brushes (with fixations at: $-20°$, $-10°$, $0°$, $10°$ and $20°$)
Armature voltage: $15\,\mathrm{V}$ (short-time $20\,\mathrm{V}$)
Armature current: $0.4\,\mathrm{A}$ (short-time $1\,\mathrm{A}$)
Max. speed: $5000\,\mathrm{min}^{-1}$ (short-term $6000\,\mathrm{min}^{-1}$)

Figure 3: Armature for DC experiments - FIX ME left picture!

Connection and operation

1. Open **LabSoft** on the computer. Select the module **electrical machine**.
2. Select **Commutator Machines > Types of DC machine > Circuit diagram of a shunt-wound machine > Connection and operation**.
3. Insert the experiment card on the UniTrain experimenter.
4. Place the rotor on the card. Make sure that the fixing pin is inserted into the socket labeled $0°$.
5. Wire the motor connections based on the circuit diagram. The wiring will also be shown as an animation in the course.
6. To operate the machine, select **Instruments > Motor Control > DC Motor Control** from the menu.

7. Set a voltage of 15V and switch on the power supply on the **POWER** button.

Which connection is used between stator (exciter) and rotor (armature) winding? **T-1**

Brush shifting

1. Select **Commutator Machines > Types of DC machine > Circuit diagram of a shunt-wound machine > Brush shifting.**
2. Change the position of the carbon brush by fixing the rotor pin at different angles.
3. Operate the machine with a 15V DC supply.
4. Repeat the experiment with different angles.

What can you observe? Why is there a difference between the different positions? **T-2**

Armature voltage

1. Select **Commutator Machines > Control of a DC machine > Experiment: Armature voltage.**
2. Select **Instruments > Motor Control > DC Motor Control** and set the voltage to an initial value of $20\,\mathrm{V}$.
3. Switch on the power supply on the POWER button.
4. Repeat the experiment with different reduced values of armature voltage.

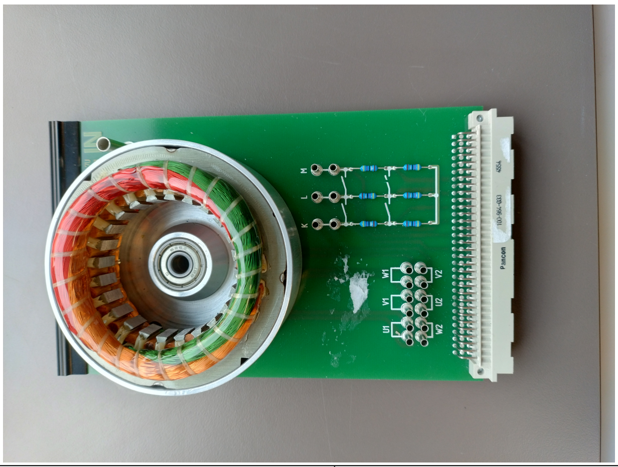
Does the speed of rotation change with the armature voltage? **T-3**

2.2 Synchronous machine

Figure 4 shows the card and the key technical data for the stator of the synchronous machine experiments. In Figure 5, two rotors with slip-ring can be found: a two-phase rotor, which will be used for the synchronous machine experiments and a three-phase rotor, which will be used for the induction motor experiments.

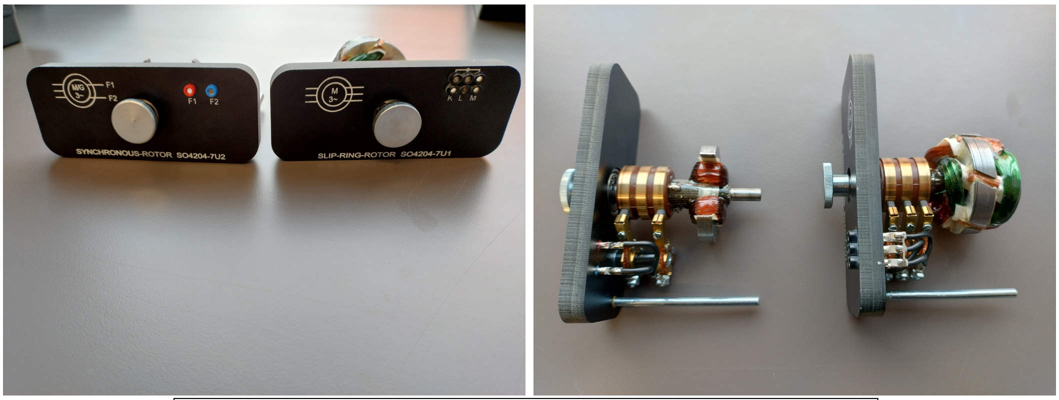
Connection and operation

1. Open the **LabSoft** on the computer. Select the module of electrical machine.
2. Select **Synchronous and Slip ring machines > Synchronous machine > Measurements and Experiments > Connection and operation.**
3. Insert the experiment card on the UniTrain experimenter and place the synchronous rotor in the card.



Stator	two poles
Winding resistance (20 °C)	$3 \times 20\,\Omega$
Nominal voltage delta / wye	$3 \times 13\,\mathrm{V}/22\,\mathrm{V}$
Nominal frequency	$50\,\mathrm{Hz}$
Nominal current delta / wye	$3 \times 0.9\,\mathrm{A}/0.5\,\mathrm{A}$
Power factor ($cos\varphi$)	0.95
Max. speed (short-term)	$3000\,\mathrm{min}^{-1}$ ($4500\,\mathrm{min}^{-1}$)

Figure 4: Experimenting card SO42404-7U with the stator for the synchonous machine



2-phase rotor with slip rings - synchronous rotor
2 poles, winding resistance $20\,\Omega$
Nominal voltage: $15\,\mathrm{V}$ (DC)
3-phase rotor with slip rings
2 poles, winding resistance $3 \times 20\,\Omega$

Figure 5: Slip ring rotors

4. Delta connect the stator. Leave the rotor winding open.
5. Select in the menu **Instruments > Power Supplies > 3-phase supply.**
6. Use the values U=11V und f=50Hz and switch on the supply with the **POWER** button.
7. Now connect the rotor winding to the fixed 15V DC-supply and switch on the power supply.
8. Switch the three-phase power supply off and change to **Instruments > Mo-**

torsteuerung > U/f-Motor control.

9. Use the following settings:
   - Frequency F : 50Hz
   - Ramp : 30s
   - Start voltage : 10V
   - Corner frequency : 75Hz [2]

   Hint: Click on the U/f-Button to change the values.

10. Switch on the supply with the POWER button.

How does the rotor behave in each case? And why? **T-4**

Repeat points 9 and 10 at a frequency of 25 Hz. How does the speed of rotation change with the frequency? **T-5**

2.3 Induction motor

Hint: The squirrel-cage rotor is widely used in practice, but because of its lack of connections it is not suitable for experiments to understand the operating principle of induction motors. Therefore, the slip-ring 3-phase rotor from the synchronous machine kit (Figure 5 right) is used here to start with. This means that it is not possible to follow the steps of the LabSoft software 1 to 1. Instead, use these instructions as a guide.

Figure 6 shows the card and the key technical data for the stator of the induction machine experiments. The squirrel cage rotor, which will be used in the last experiment, is shown in Figure 7.

Open and shorted rotor winding

1. Select the course **Synchronous and slip-ring rotor machines > Slip-ring rotor machines > Measurements and experiments > Slip-ring machine with unconnected rotor winding and > Slip-ring machine with shorted rotor winding.**

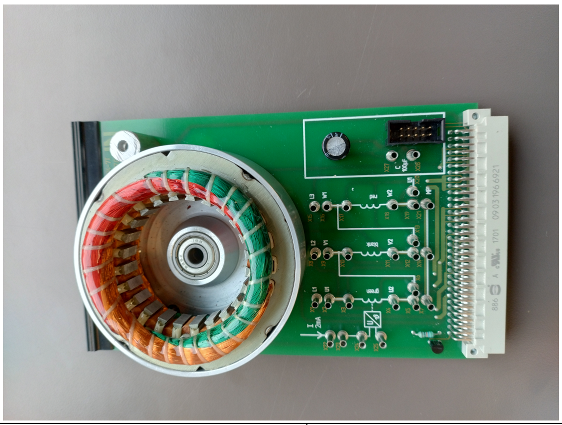
2. Place the three-phase slip-ring rotor in the card.

3. Delta connect the stator winding as shown in Figure 8. Leave unconnected (open-circuit) the rotor winding (see Figure 9).

4. Select in the menu **Instruments > Power Supplies > 3-phase supply**.

5. Use the values U=11V und f=50Hz and switch on the supply with the POWER button.

6. Repeat steps 4 and 5 with the rotor winding shorted (see Figure 10).



Stator	two poles
Winding resistance (20 °C)	$3 \times 20\,\Omega$
Nominal frequency	50 Hz
Nominal current delta / wye	$3 \times 0.73\,\mathrm{A}/0.42\,\mathrm{A}$
Power factor ($cos\varphi$)	0.8
Max. speed (short-term)	$3000\,\mathrm{min}^{-1}$ ($4500\,\mathrm{min}^{-1}$)

Figure 6: Experimenting card SO42404-7T with the stator for the induction-machine experiments

Figure 7: Squirrel cage rotor for the last induction-machine experiment

Why does the rotor behave differently in both cases? **T-6**

Open circuit voltage in the rotor winding

1. Select in the same course **Measurements and Experiments > Voltage for an unconnected rotor winding.**
2. Connect the virtual measurement device to measure the rotor and the stator voltage in channel A and B. For the measurement of the stator voltage use Figure 12 instead of the description in the software.
3. Select in the menu **Instruments > Measurement devices > Oscilloscope.**

[2]Corner frequency is a literal (and unfortunate) translation in the software of the German term. Better is base frequency or even cut-off frequency.

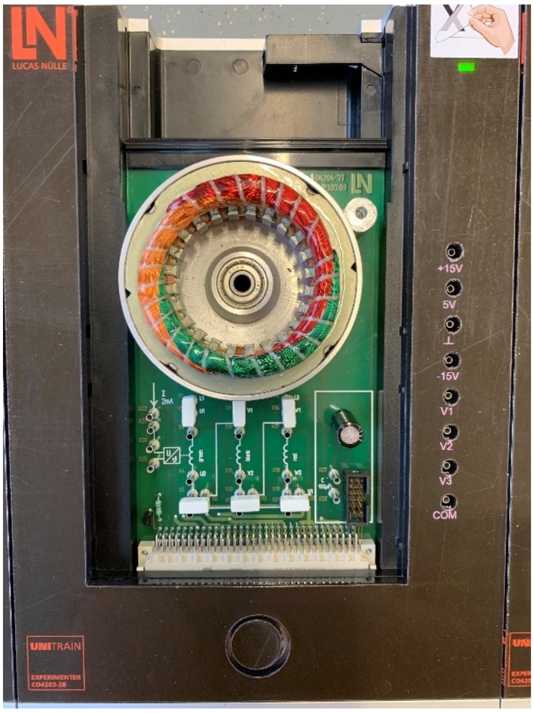


Figure 8: Delta stator connection for the induction motor experiments

Figure 9: Delta stator connection and open rotor winding

4. Select in the menu **Instruments > Power Supplies > 3-phase supply.**
5. Use the values U=11V und f=50Hz and switch on the supply with the **POWER** button.
6. Rotate the rotor slowly with the disc at the end of the shaft.

What happens in the oscilloscope picture? Why? **T-7**

Figure 10: Delta stator connection and shorted rotor winding

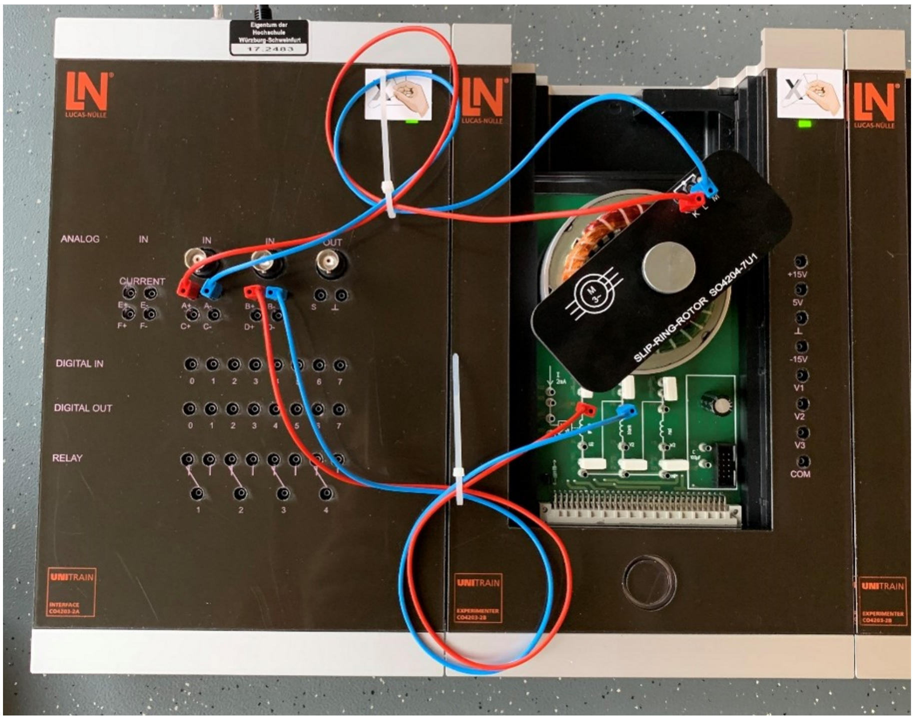


Figure 11: Connection to measure the stator and the open-circuit rotor voltage

Rotor current and frequency

1. Select in the same course **Measurements and Experiments > Rotor winding with starting resistor**.

2. The 3 rotor windings are short-circuited for this experiment. Windings K and L are shorted directly. Winding M is short-circuited via a 1 Ω resistor to enable current measurement.
3. Connect the virtual measurement device to measure the rotor current and the stator voltage in channel A and B. Use Figure 12 instead of the description in the software.
4. Select in the menu **Instruments > Measurement devices > Oscilloscope.**
5. Select in the menu **Instruments > Power Supplies > 3-phase supply.**
6. Use the values U=11V und f=50Hz and switch on the supply with the **POWER** button.

Why are the periods of the rotor current (channel A) and the stator voltage (channel B) different? **T-8**

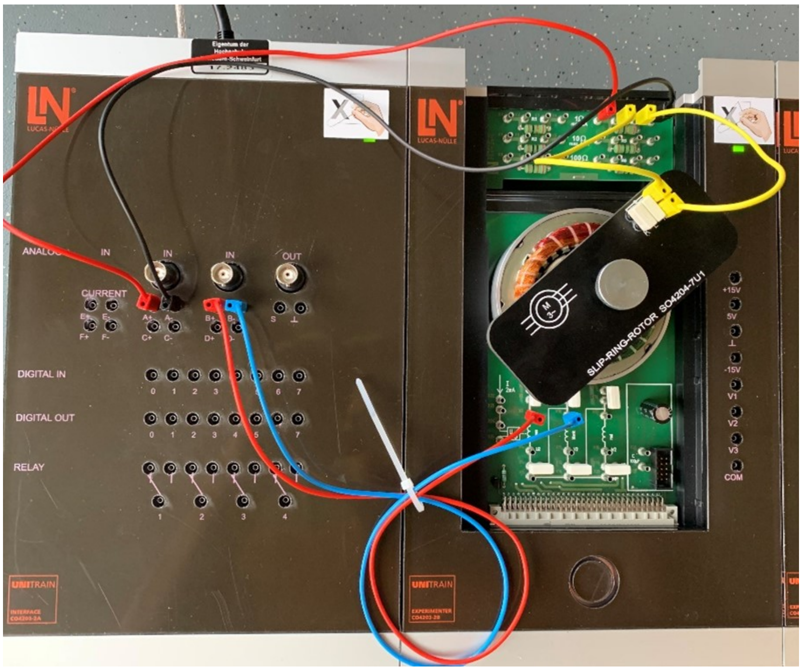


Figure 12: Connection to measure the stator voltage and the rotor current

Operation with squirrel cage rotor

1. Now disconnect the voltage and current measurement and use the squirrel cage rotor instead of the slip-ring rotor
2. Use the values U=11V und f=50Hz and switch on the supply with the **POWER** button.

What happens? Is there a current in the rotor? How is this possible? **T-9**
