Shunt dc Motor

Motor cutaway

- Lets start by studying the cut away of a dc machine. The parts are indicated on the figure.

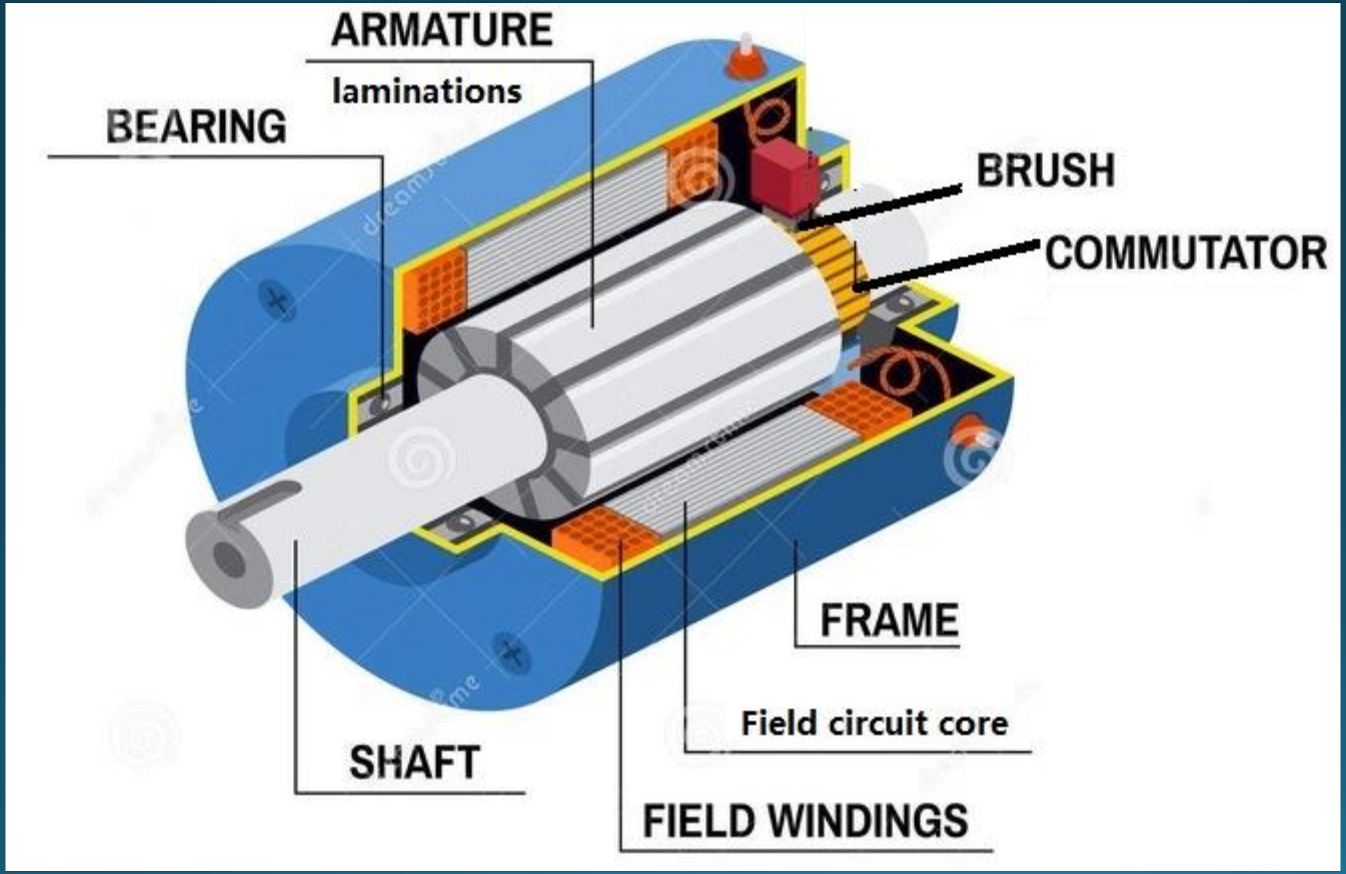


Figure 1

Shunt dc motor model

- As mechatronics engineers, we care a lot about the internal model of any device. The shunt dc motor is composed of two circuits in parallel. The armature circuit and the field circuit.

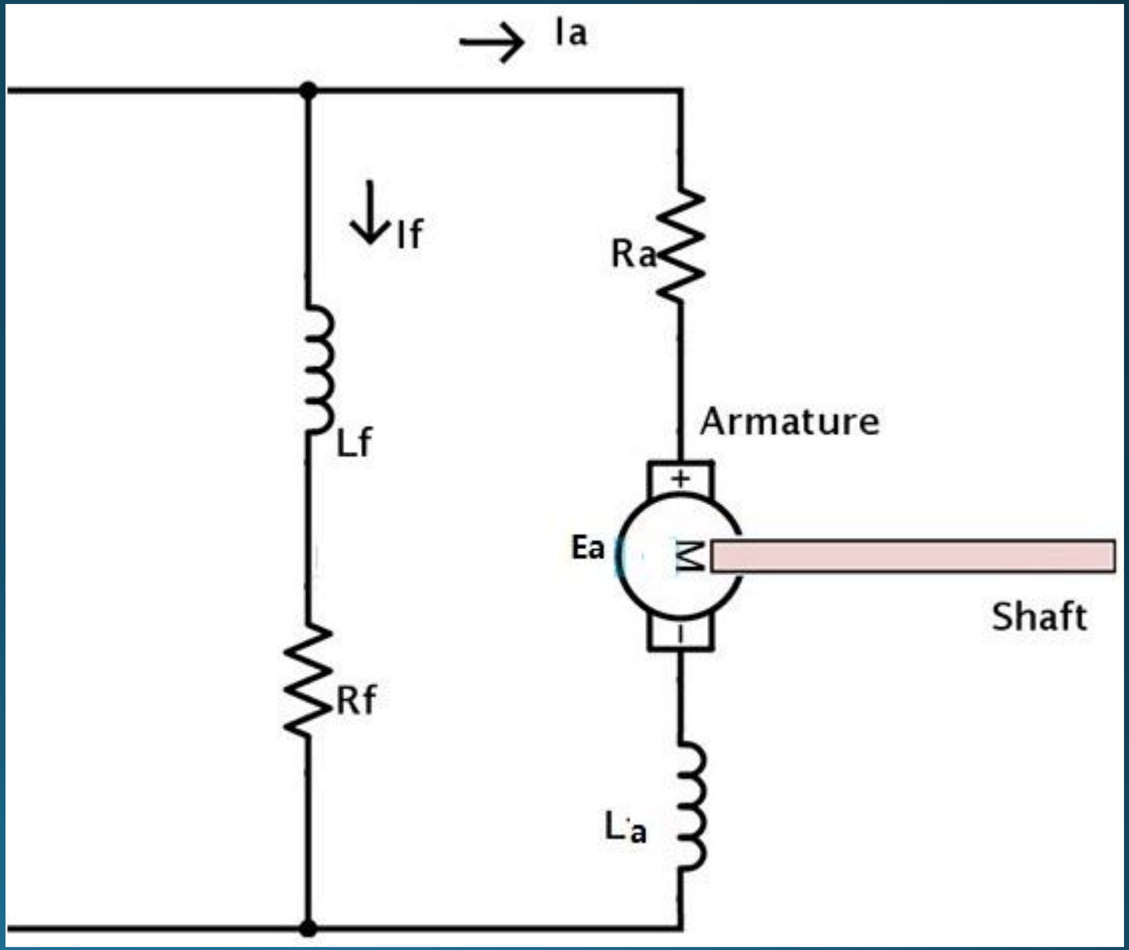


Figure 2

Shunt dc motor schematic circuit

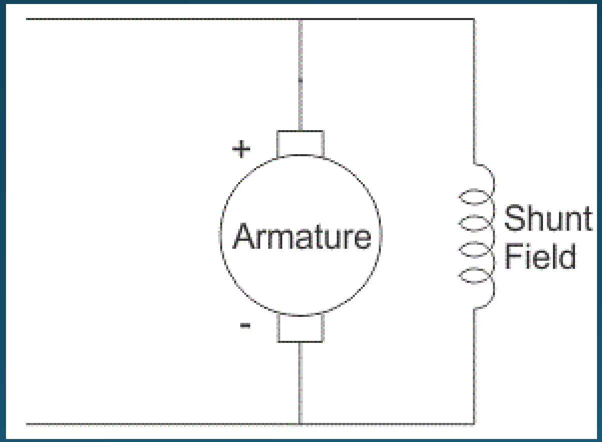


Figure 3

Shunt DC motor name plate

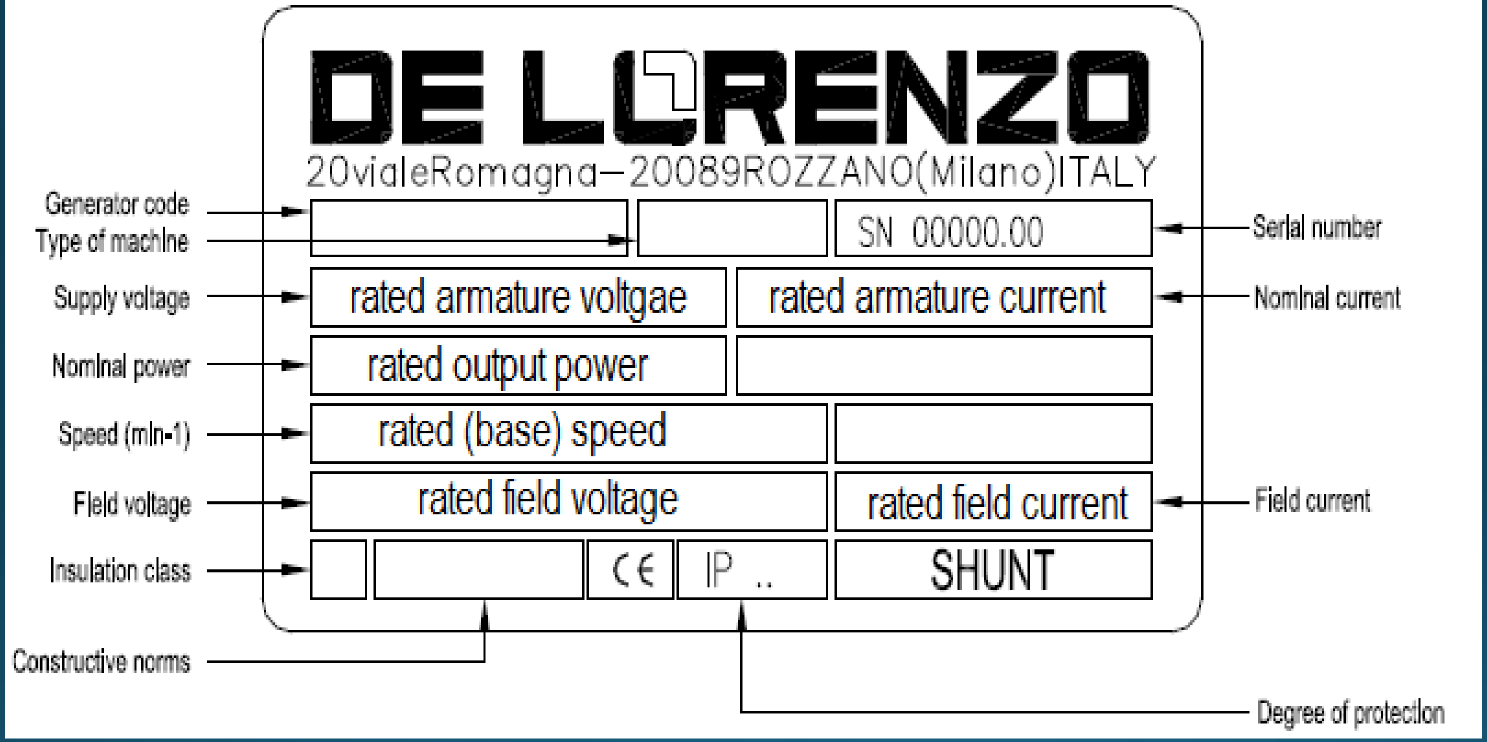


Figure 4

Experimental circuit

- The main circuit that will be used to operate and execute all the experiment parts is shown below

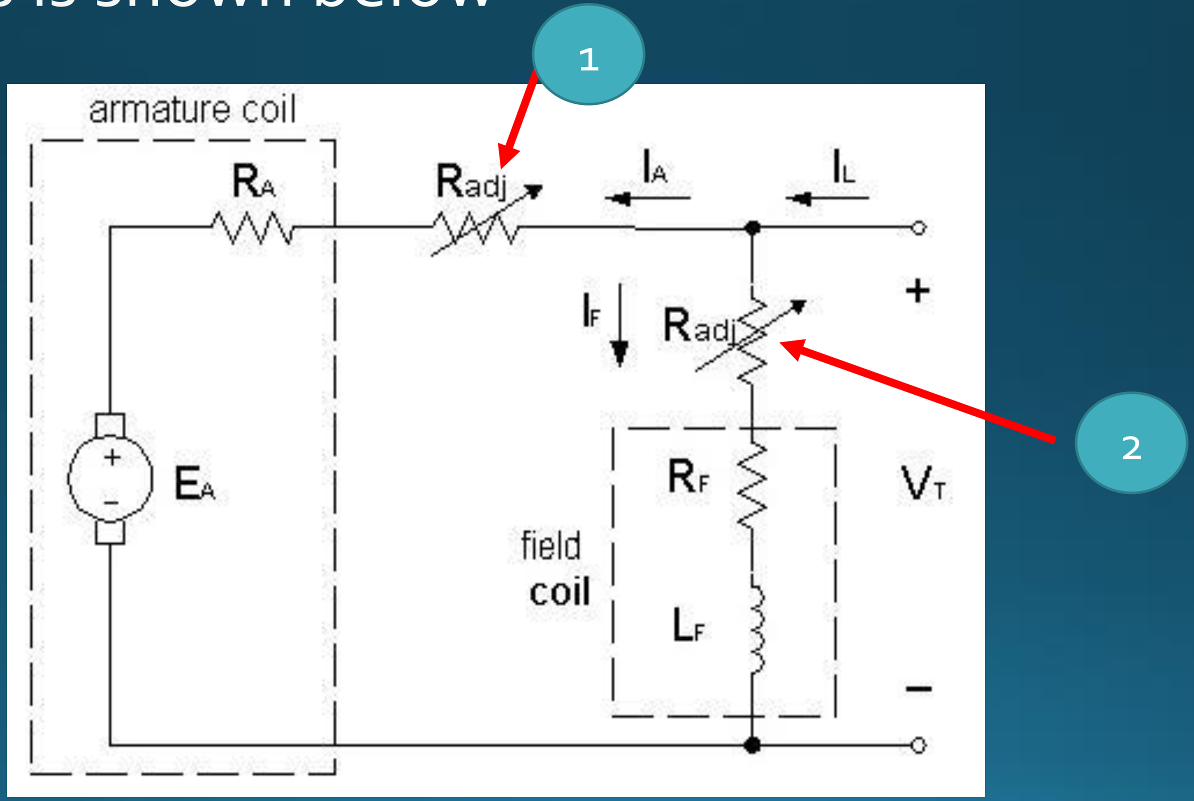


Figure 5

- Figure 5 in the previous slide represents the motor internal model plus two inserted adjustable resistors; 1 in the armature circuit and 2 in the field circuit.

- What is the purpose of 1?

- 1 is used for two purposes. The first purpose is to limit the starting current of the motor. Look at the following relationships

$E_a = k\phi\omega$

$I_a = (V_a - E_a)/R_a$

At the beginning of motion of motor shaft, the rotational speed is zero, thus Ea is zero and since Ra has small values the starting current will exceed the maximum current that can be sustained by the armature coils and this will damage the motor. Inserting this resistor will reduce the starting current, then when the motor gains enough speed, this resistor is taken out.

The second purpose is for speed control and will be discussed later.

- The adjustable resistor 2 is inserted for two purposes as well. The first one is related to the motor we specifically have in the lab. If we check the ratings on the name plate of the shunt dc motor in the lab we find that the rated armature voltage is 220V and its current is around 6A while the rated voltage of the field circuit is 130V and its current is 0.22.
- Since the terminal voltage in a shunt dc motor is applied to both circuits at the same time it only make since to apply the larger in order to get the best performance. But this wont work for the field circuit. Here comes the role of the inserted field resistor which will take the excess 90V (220-130=90V).

- The second role of this resistor is in speed control and this will be discussed later

Torque speed characteristics of shunt dc motor

- The torque and speed of a shunt dc motor are inversely but linearly proportional. Their characteristics is given by the following equation:

$$\omega = \frac{V_T}{K\phi} - \frac{R_A}{(K\phi)^2}\tau_{ind}$$

- Where:

-The base speed is the speed on the name plate of the motor

- The stall torque is the torque that will cause the motor shaft to stop rotating

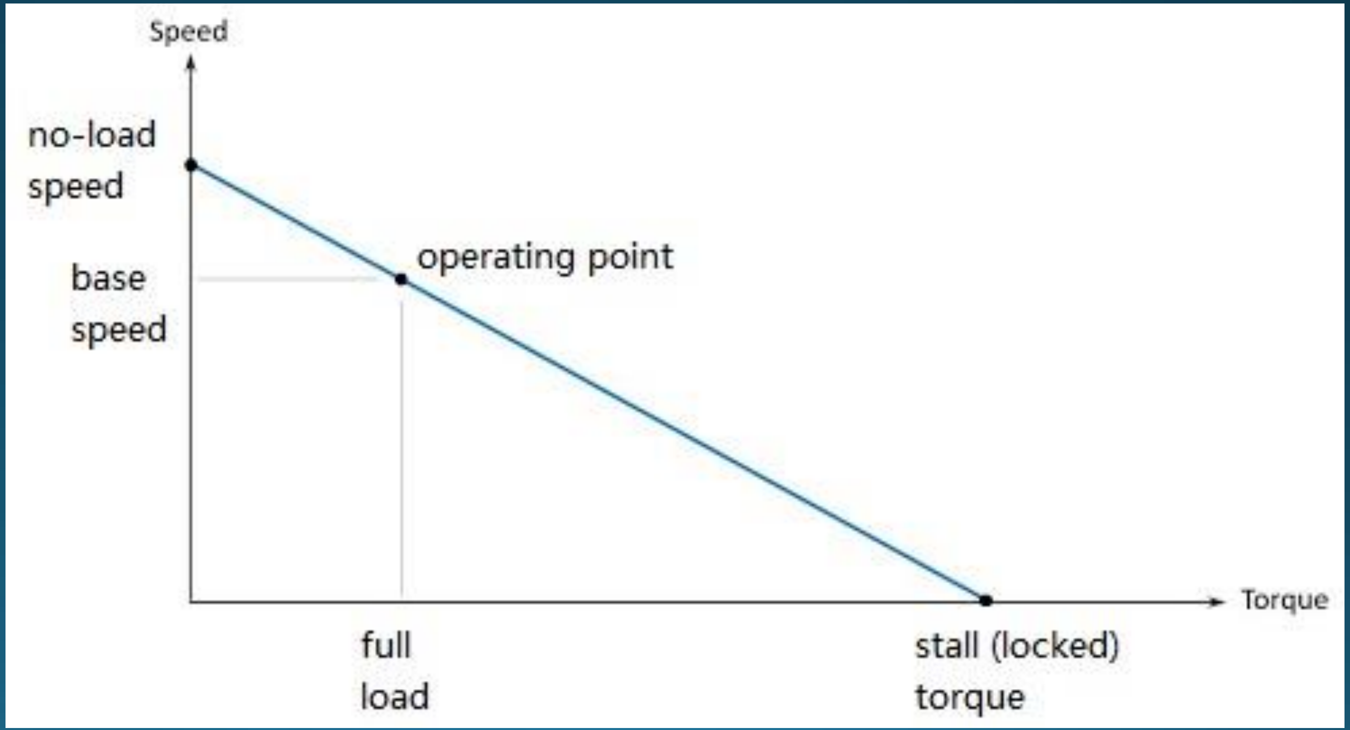


Figure 6

Speed control of shunt dc motor

- Since the characteristics of the motor is simple so is its speed control. The main two ranges for speed control are:

- Below the base speed (armature control), and this includes;

  a) adjusting armature (not terminal) voltage control

  b) inserting an adjustable armature resistor

- Above the base speed (field control)

  a) inserting an adjustable resistor in the field circuit.

Changing the armature voltage

- This method is used to control the speed of the motor below the base speed because at the rated 220V, the motor will have its rated speed and of course we cant increase the voltage above its rated value
- You can note that the curves are parallel because changing Va will only change the y-intercept of the curve but not its slope.
- This method can be used to control the motor speed efficiently from zero up to the base speed on the expanse of the load torque as shown by the figure.

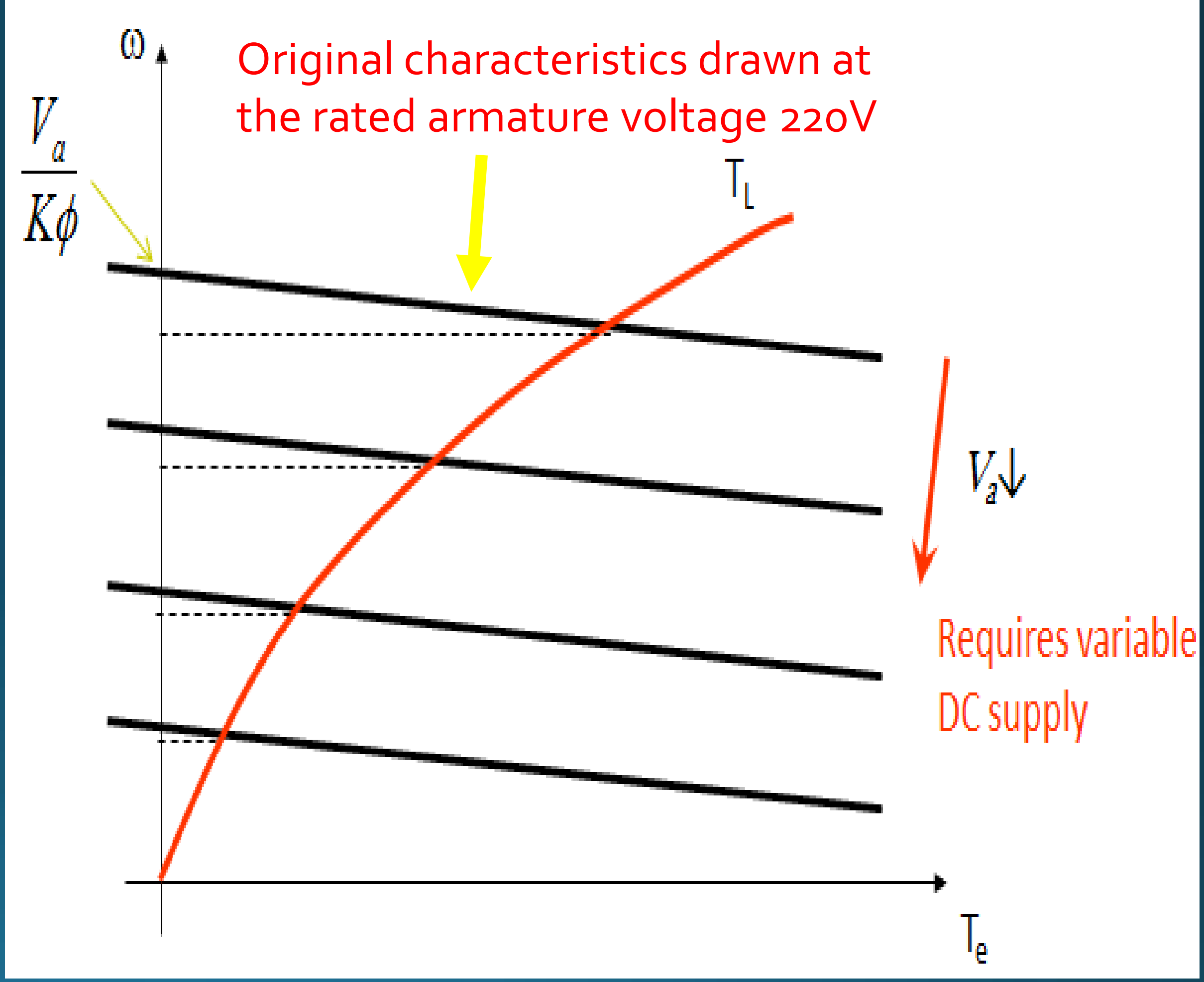


Figure 7

Inserting a resistor in series with the armature circuit

- Inserting a resistor in series with the armature circuit means increasing the equivalent resistance. we can explain the effect in many ways, the most simple one is to look at the equation describing the torque speed characteristics which shows that increasing the value of Ra will increase the slope of the curve but wont affect the y-intercept (no-load speed).

- Since the original Ra cant be decreased but only increased by inserting extra resistor, the speed can only be decreased using this method and will be below the base speed (which occurs at the original value of Ra).

- Resistors in general, tends to waste power and hence reduces efficiency tremendously as well as cause heating . This applies to this resistor specially since the armature current has high value.

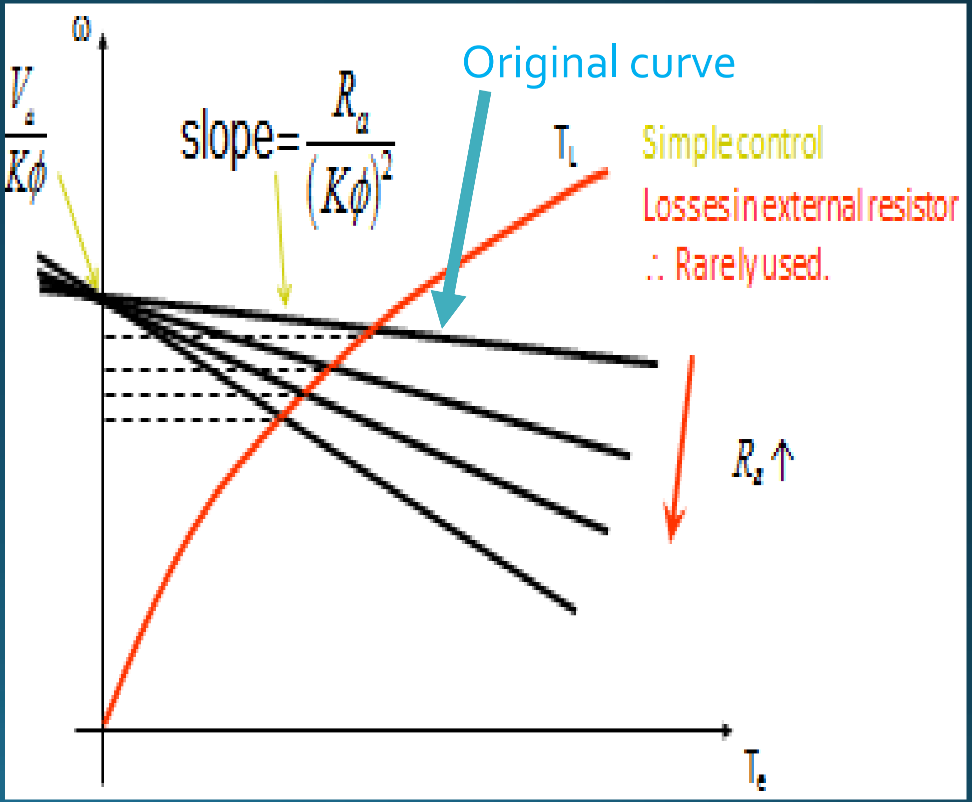


Figure 8

Inserting a resistor in series with the field circuit

- Inserting a resistor in series with the field circuit will increase the overall field resistance, consequently reducing the filed current and its flux. This will change both the slope and the y-intercept.

- You can see that the no-load speed will be increased using this method because we can only reduce the flux but not increase it above its rated value. Other wise the field core will saturate. Thus, this method is used to increase speed above the base speed as long as it doesn't exceed the maximum speed the motor shaft can sustain (which is about 30% above the base speed for most motors).

- For this reason if we open the field circuit while the motor is running the flux will drop to zero and the motor will accelerate to infinite speed which is impossible mechanically and electrically and this will either break the shaft or destroy the insulation of the motor. Either way, the motor is damaged.

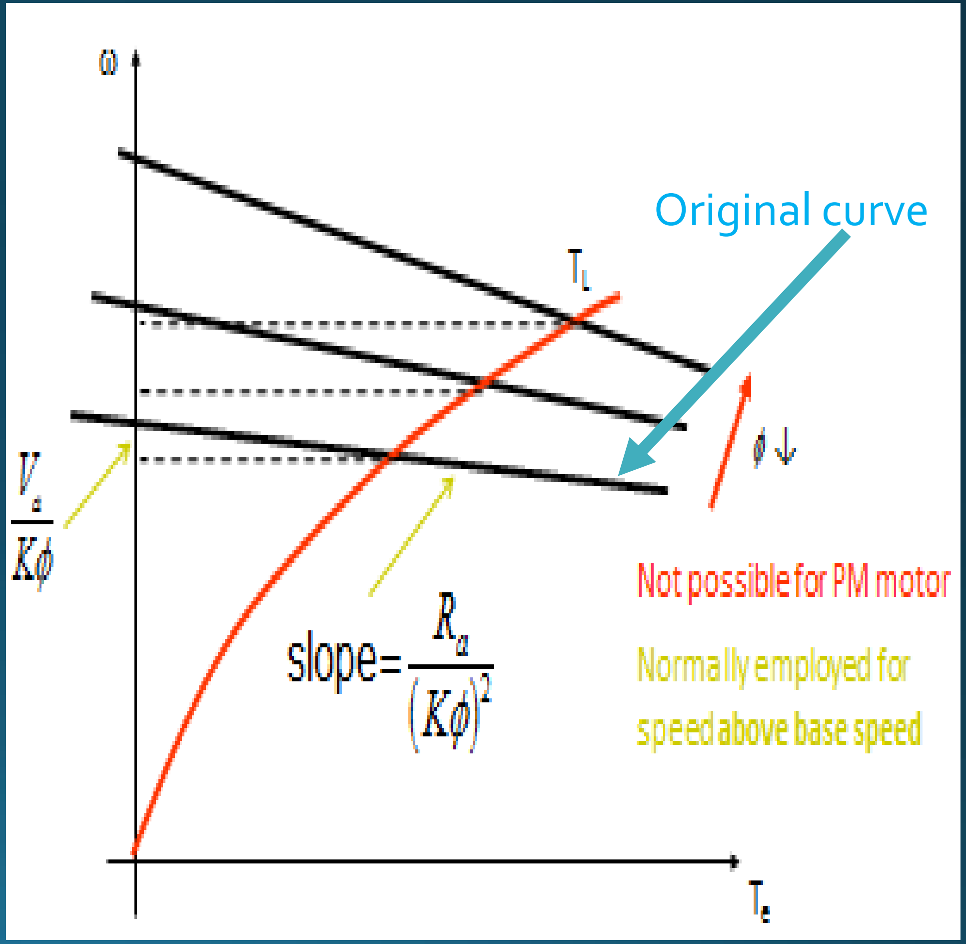


Figure 9

Reversal of direction of rotation of a shunt dc motor

- You can reverse the direction of rotation of a shunt dc motor by two ways:

1- reversing the armature current

2- reversing the field current

- Reversing both current will cause the motor to rotate in the original direction

Experimental setup

Shunt motor

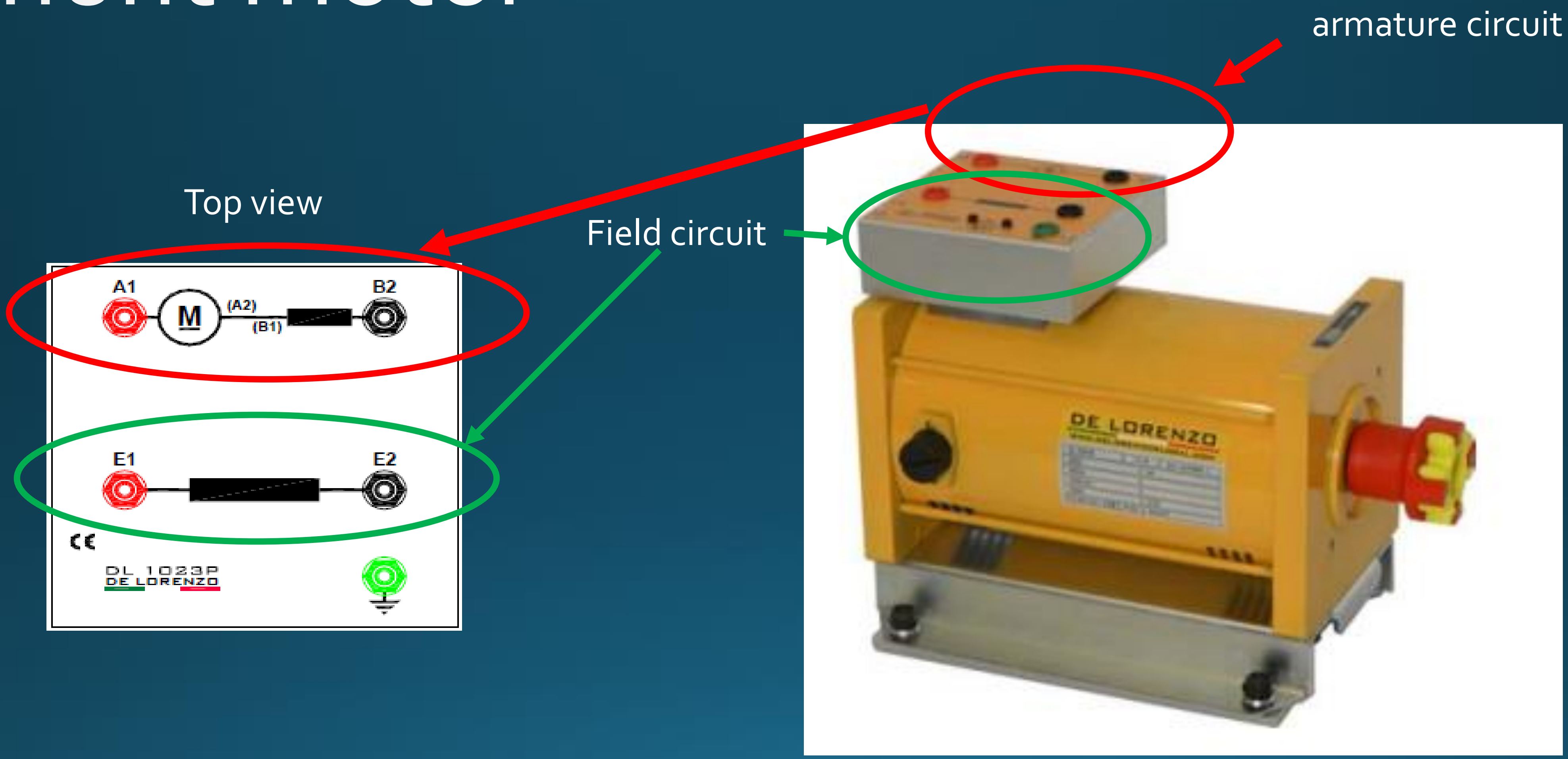


Figure 11

Power supply

- The dc motor requires a dc power supply to operate it. As you know well by know, we have two dc power supplies in the lab;
- The one circled by blue and has Vmax=240V, Imax=10A.
- The one circled by yellow and has Vmax=220V, Imax=1A.

- The motor terminal (line) current = armature current + field current
- = 6.3A+.22A= 6.5A
- Clearly the supply circled yellow is not suitable.

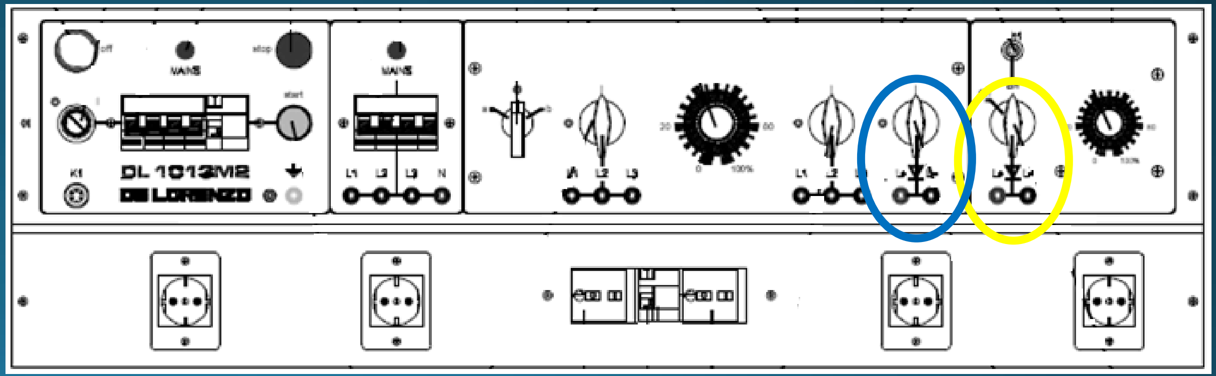


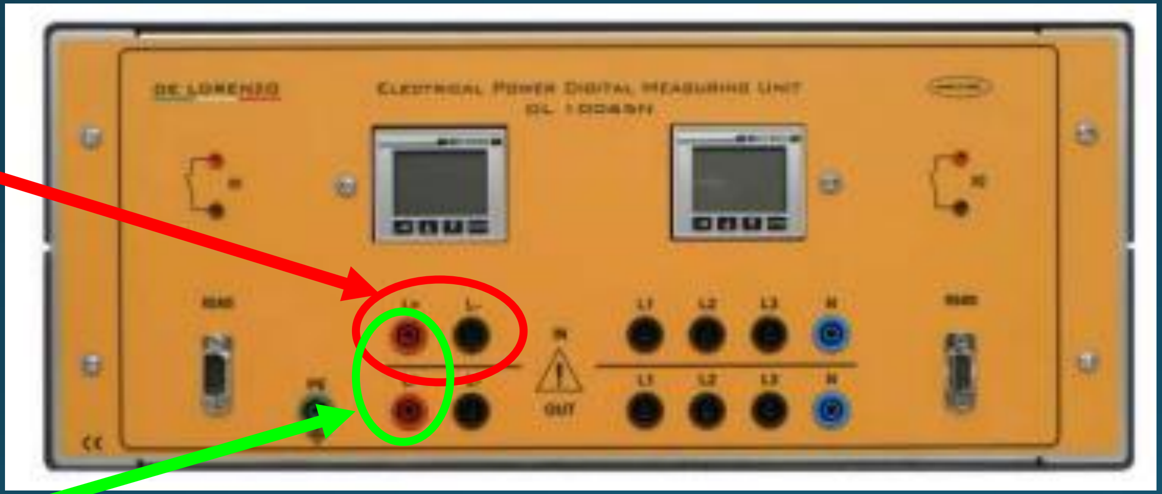
Figure 12

Digital multimeter

Dc voltmeter (horizontally)

Don't forget about the common node

Dc ammeter (vertically)



Using this unit you can measure one voltage and one current as long as there is a common point

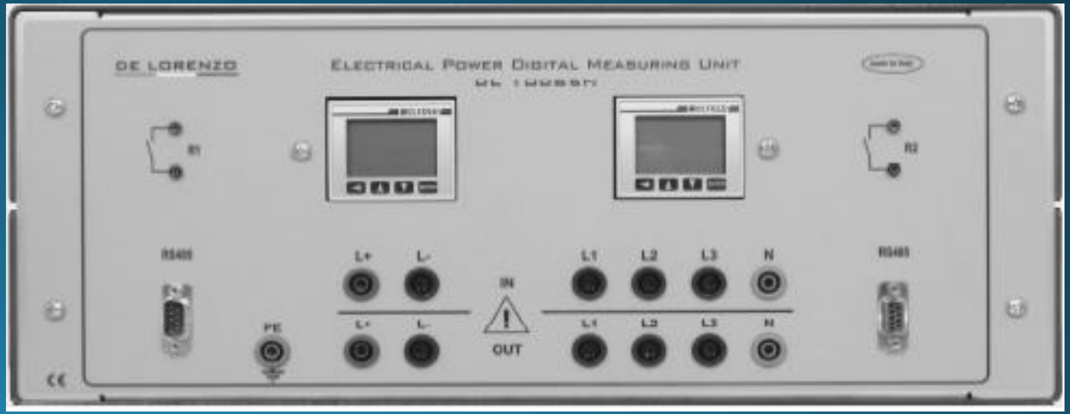


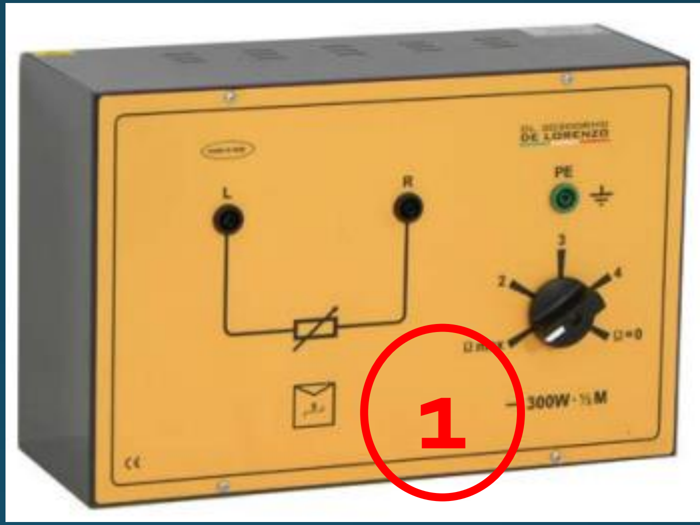
Figure 13

Resistors

- Resistor 1 has high power rating (1.1KW) and small ohmic value (about 30 ohm) which makes it suitable for the armature circuit which has high armature current

- Resistor 2, is basically a potentiometer, thus we will use one of the fixed ends and the wiper in the middle. The third terminal should be shorted to the wiper in the middle to ensure there is no floating terminals.

This resistor has relatively high ohmic value (which will register compared to the original field resistor value) at the same time it can sustain 0.6A max which is fine because the rated filed current is 0.22A.



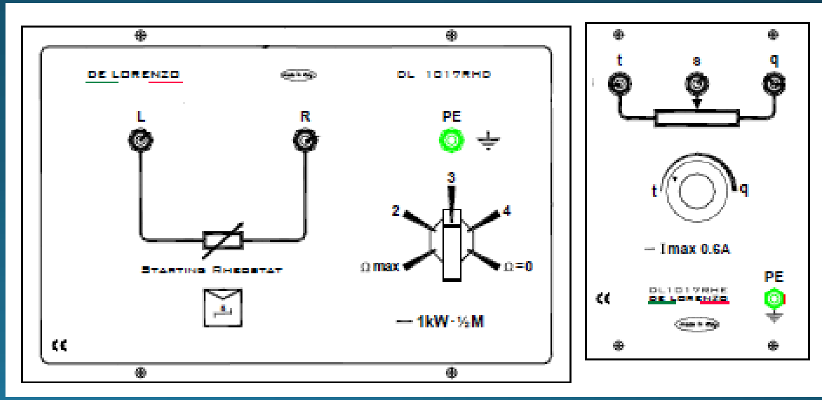
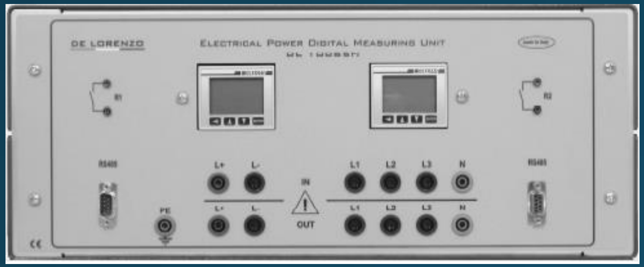
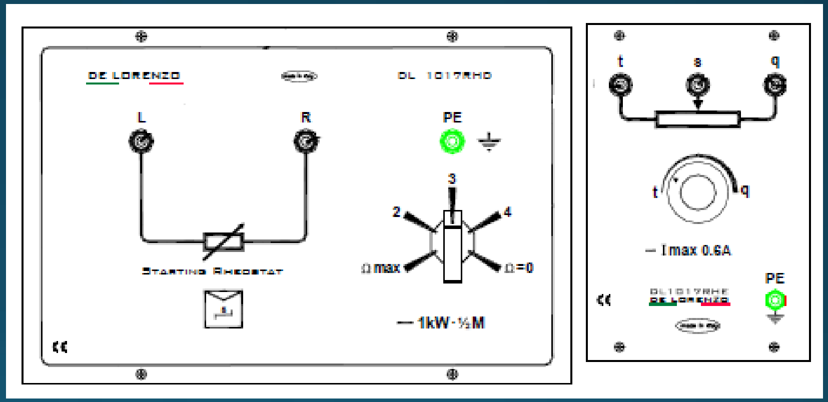


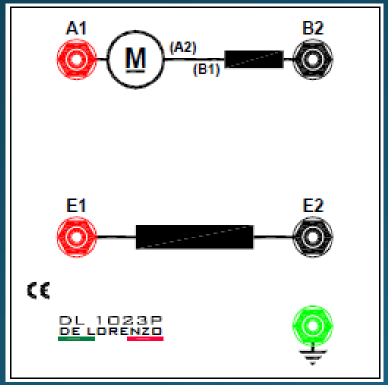
Figure 14

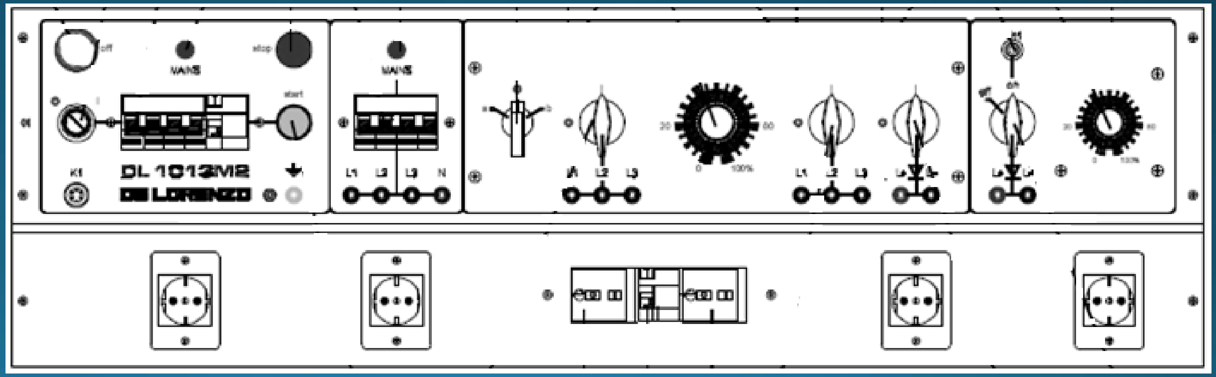
Circuit Connection

- Now we will connect the circuit in Figure 5 using the components illustrated in the previous slides.

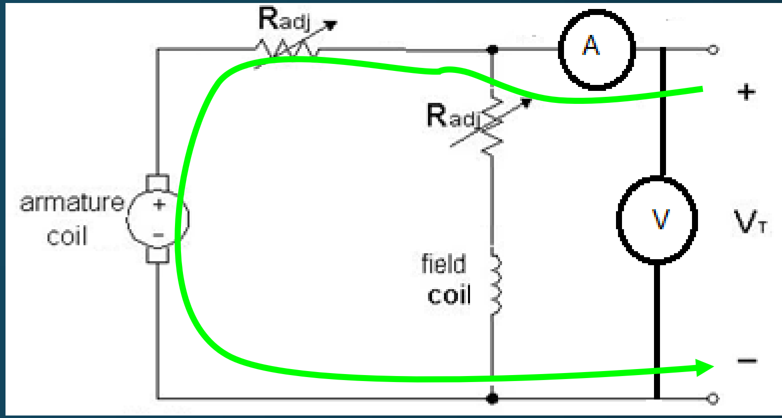


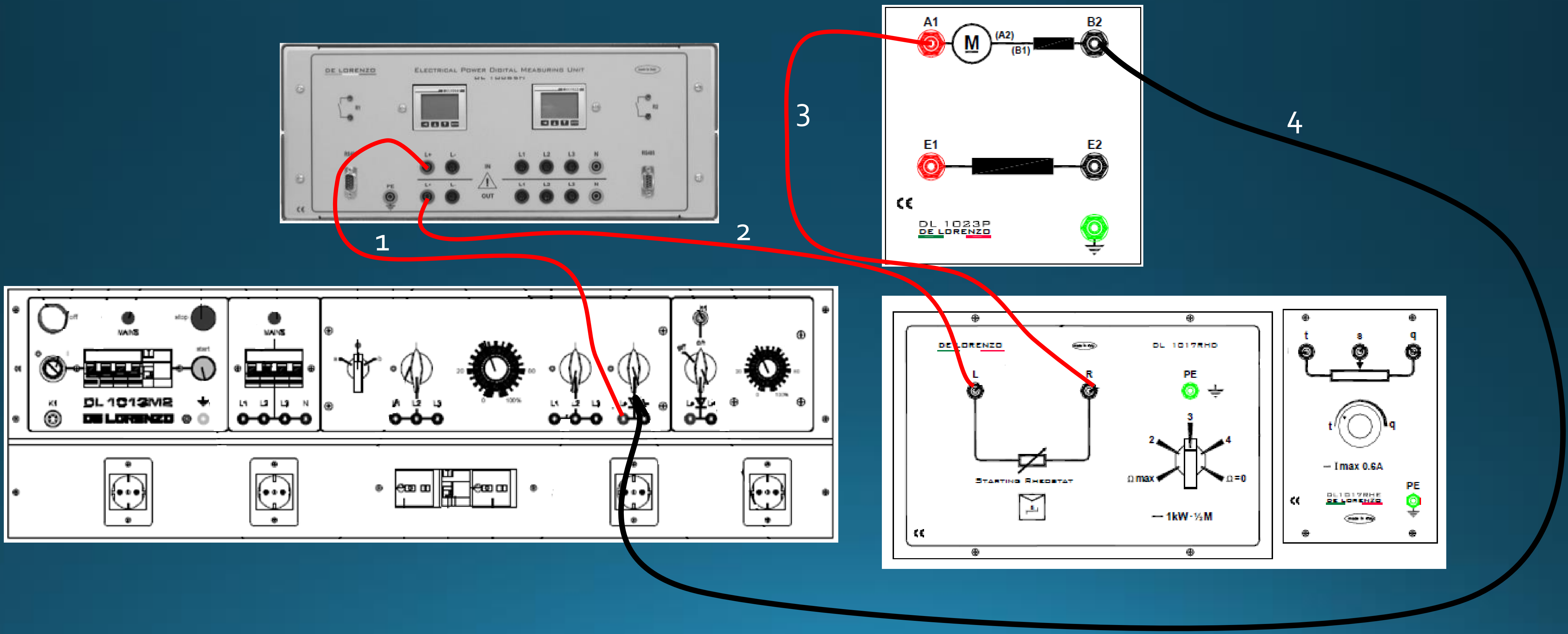




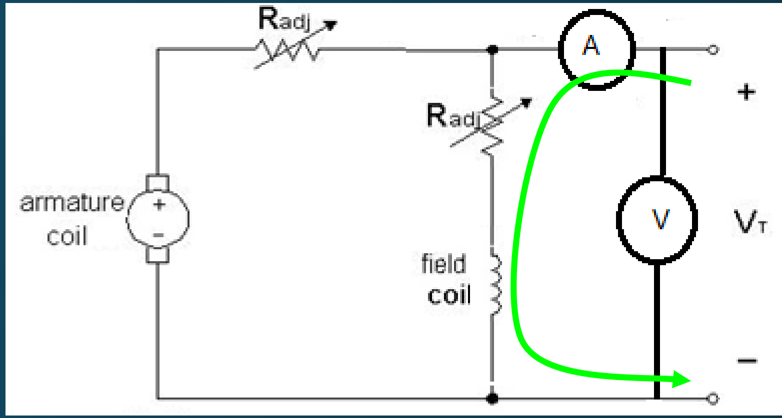


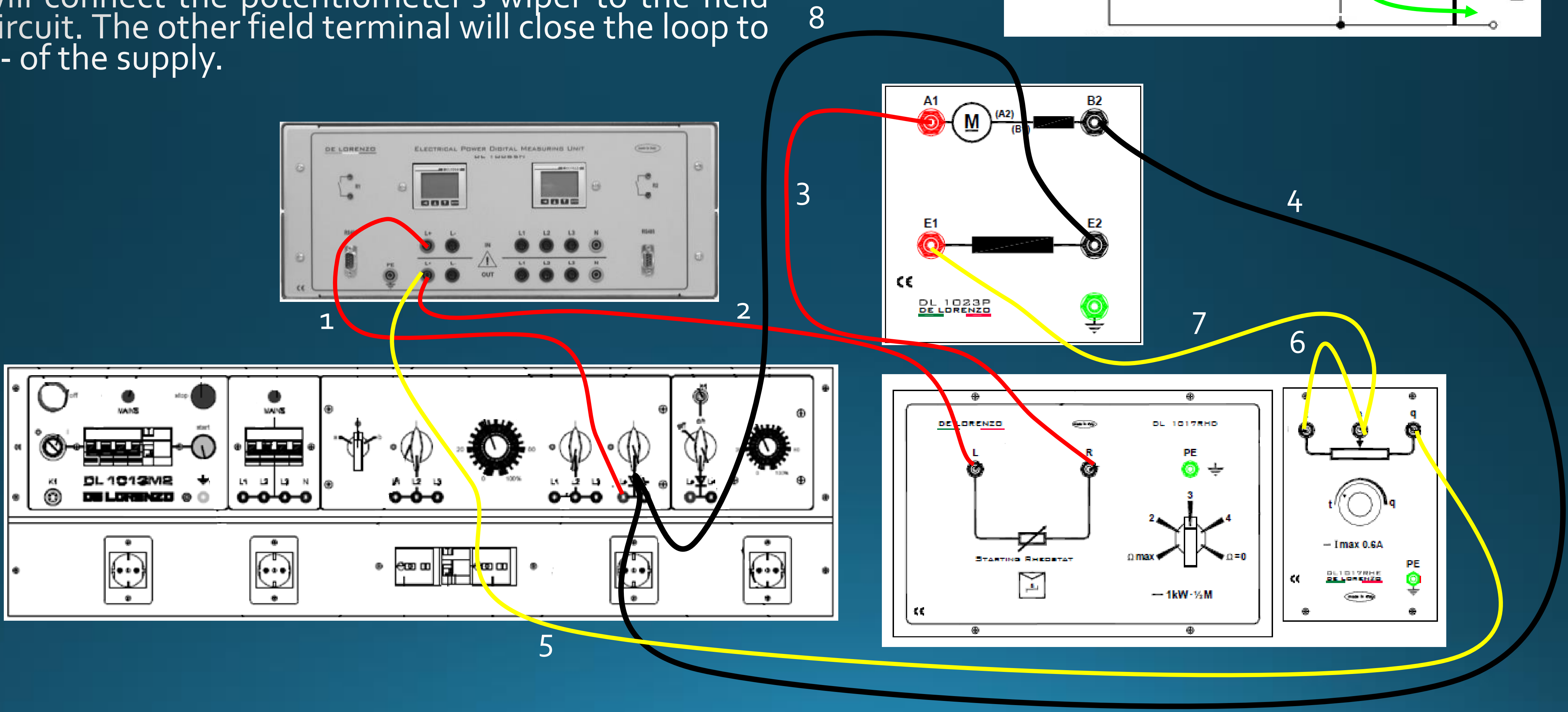
- Lets start with the armature circuit (indicated by the green loop to the right). We will start with wire 1 connecting L+ from the dc power supply to the upper terminal of the ammeter. Exiting the ammeter using wire 2 we will head to a terminal in the adjustable armature resistor. Wire 3 will connect the resistor to the armature circuit. The other terminal of the armature is connected to L- of the supply to close the loop.



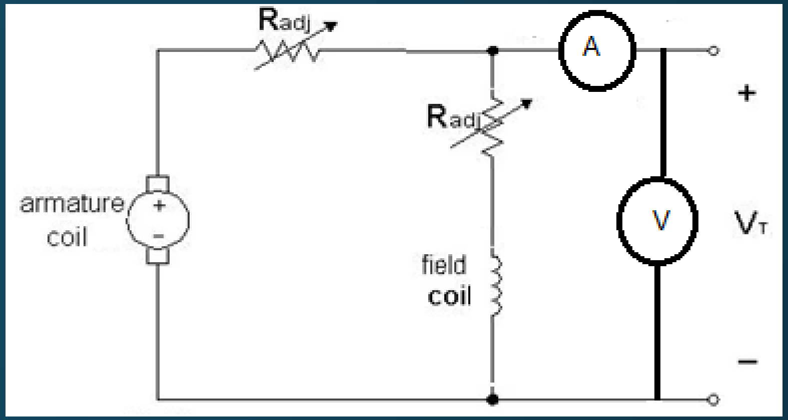


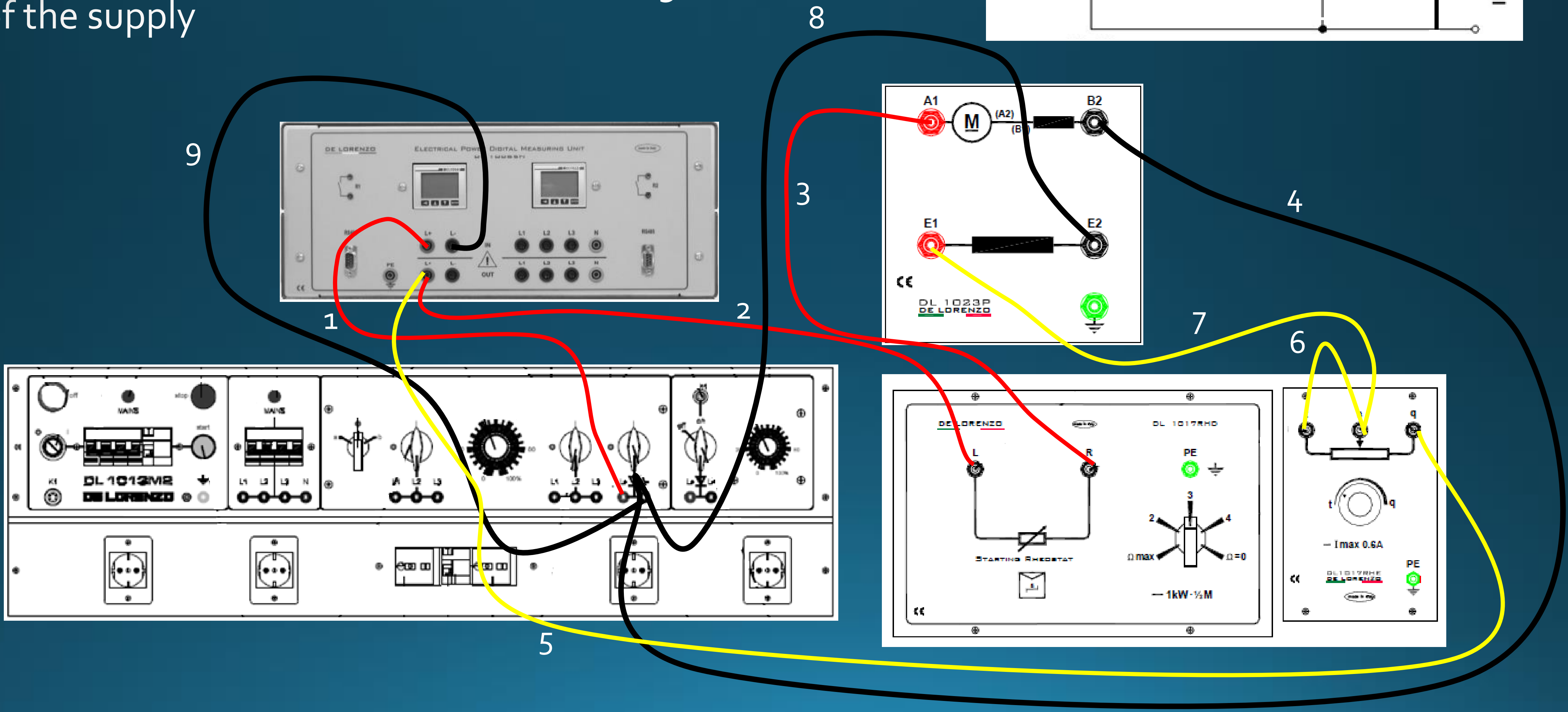
- Lets move to the field circuit (indicated by the green loop to the right). The ammeter is already connected so wire 5 will connect the exit of the ammeter to the one of the outer terminals of the potentiometer. Wire 6 will short the wiper to the other outer terminal of the potentiometer. Wire 7 will connect the potentiometer's wiper to the field circuit. The other field terminal will close the loop to L- of the supply.





- Now the final step is to connect the voltmeter. As you know the voltmeter and the ammeter has a common terminal. Which is already connected to L+ of the supply. So to complete the voltage measurements we will connect the other terminal of the voltmeter via wire 9 to L- of the supply
-

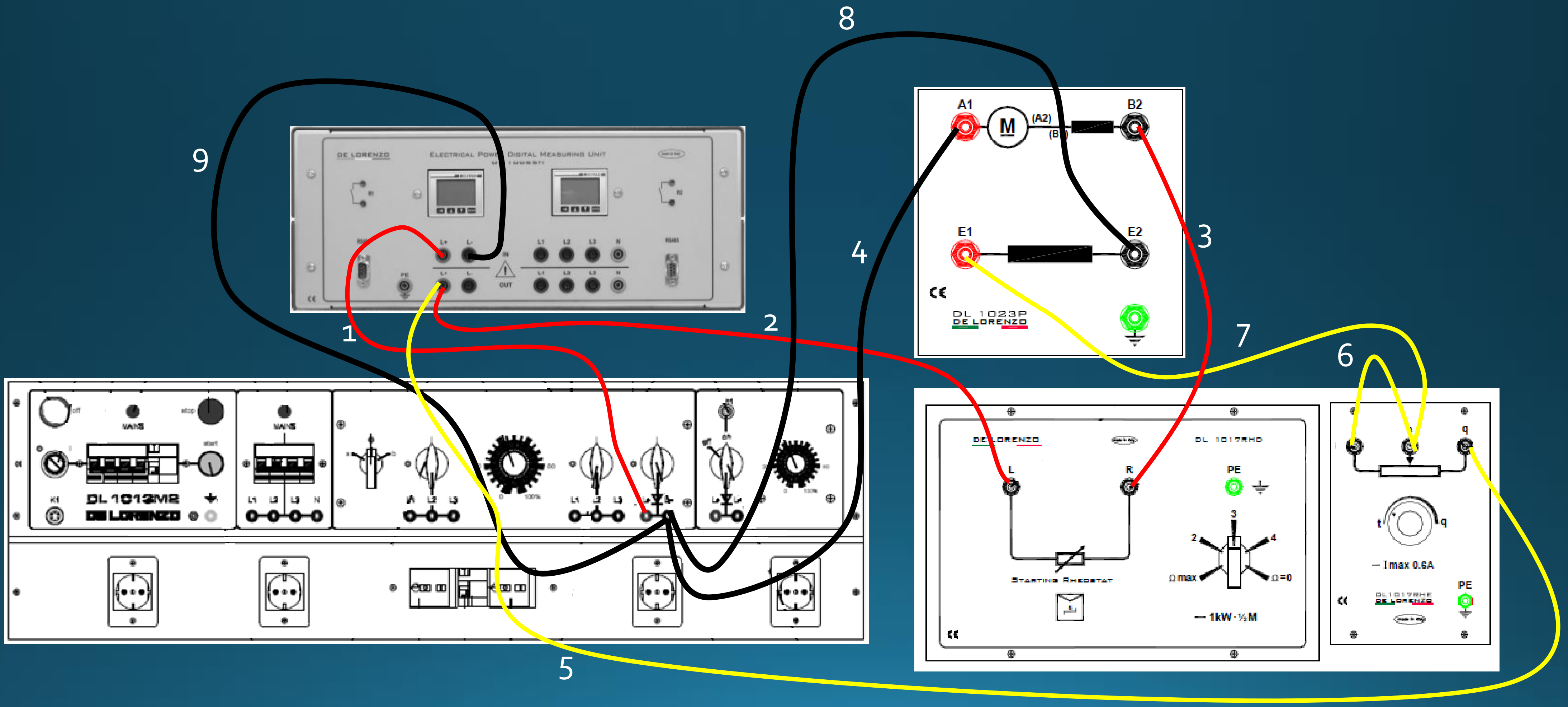




Reversal of direction of rotation

Method 1

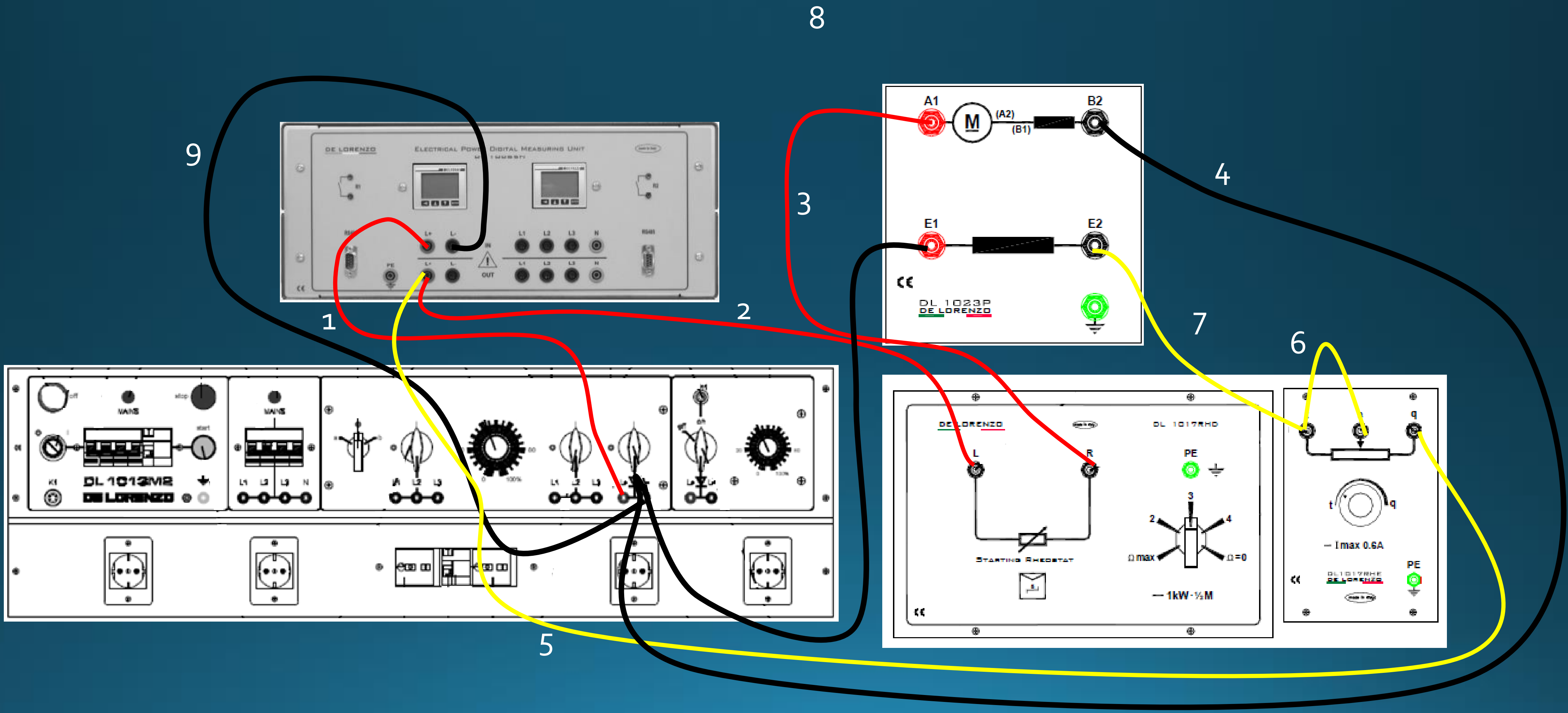
By reversing the armature current. You can achieve this by switching the red (3) and black (4) wires entering the armature circuit, as follows



Reversal of direction of rotation

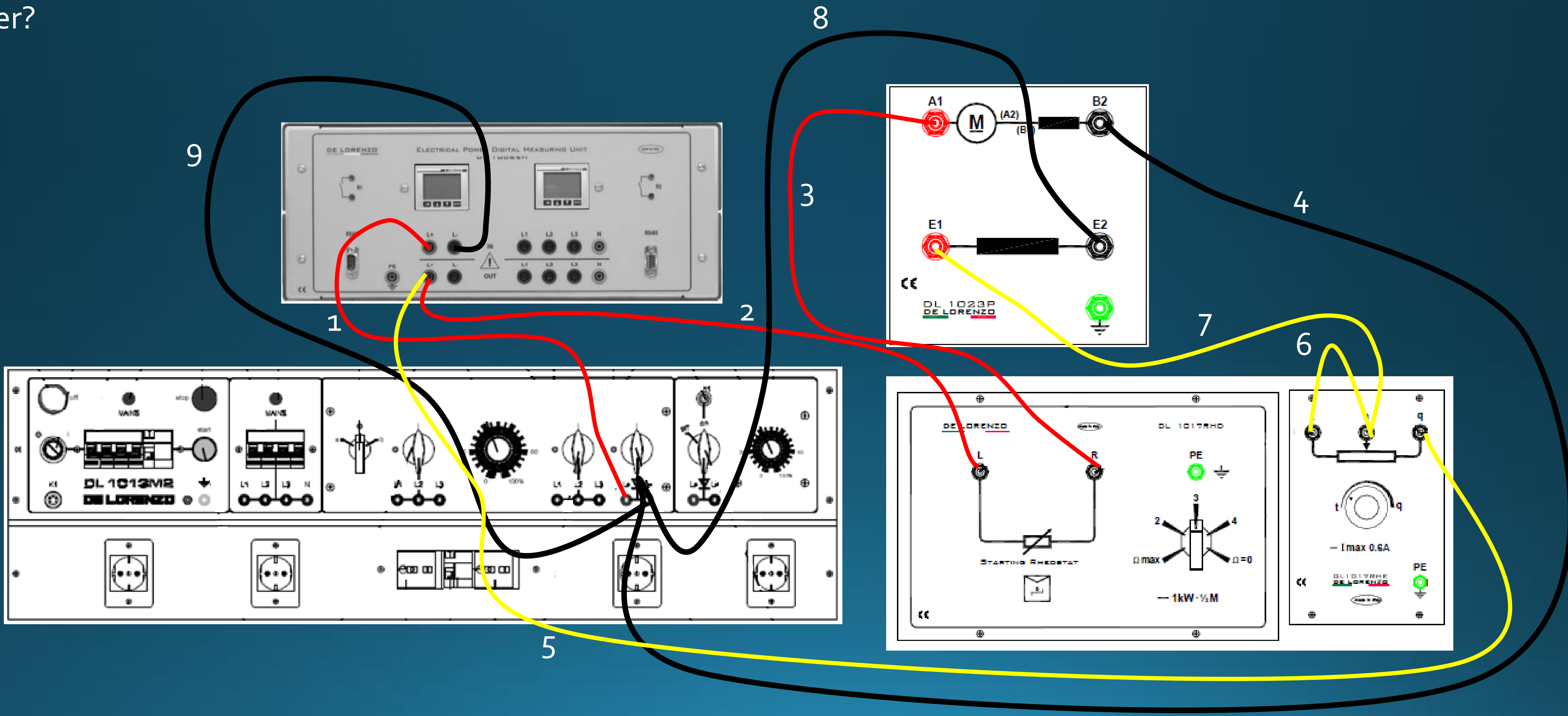
Method 2

By reversing the filed current. You can achieve this by switching the yellow (7) and black (8) wires entering the armature circuit, as follows



Brain teasers

Which current is being measured?
Which voltage is being measured?
Which current will be measured if we move the start of wire 5 from the exit f the ammeter to the upper point of the ammeter?



Good luck everyone
Stay home .. Stay safe

Prepared by:
Eng.Shatha Al-Qadomi