High voltage line (Demo) (Item No.: P1434305)

Curricular Relevance

Area of Expertise:	Education Level:	Topic:	Subtopic:	Experiment:
Physics	Age 16-19	Electricity	Electromagnetism	High voltage line (Demo)

Difficulty	Preparation Time	Execution Time	Recommended Group Size
Intermediate	10 Minutes	20 Minutes	1 Student

Additional Requirements:

- Power supply

Experiment Variations:

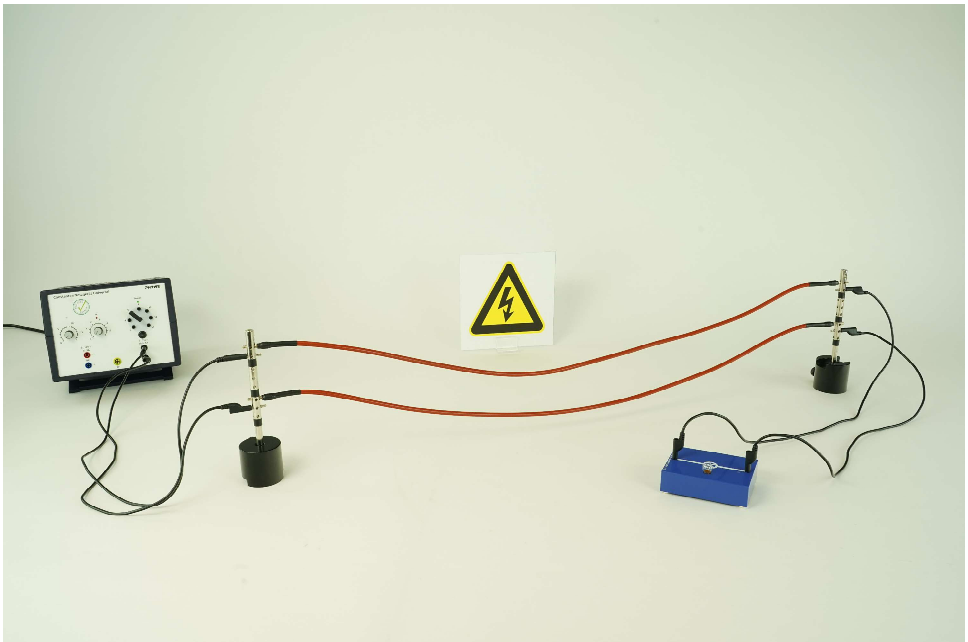
Keywords:

transmission line, power line, high voltage, overhead power line

Information for teachers

Introduction

Using two high voltage transformers the transmission losses between the power station and the consumer can be kept low despite high line resistance.



Equipment

Position No.	Material	Order No.	Quantity
1	PHYWE power supply, universal DC: 0...18 V, 0...5 A / AC: 2/4/6/8/10/12/15 V, 5 A	13504-93	1
2	Coil, 10000 turns	06519-01	2
3	Coil, 75 turns	06511-01	2
4	Barrel base expert	02004-55	2
5	Insulating support, l = 235 mm	07924-00	2
6	Long distance line - model , 2 pieces	07305-00	1
7	Lamp holder E10, on base plate	06170-00	1
8	Filament lamp 6 V/3 W, E10, 10 pcs.	35673-03	1
9	Iron core, U-shaped, laminated	06501-00	2
10	Iron core, I-shaped, laminated	06500-00	2
11	Pins for iron cores, U-shaped	06502-00	2
12	Clamping device for iron cores	06506-00	2
13	Caution Label - high voltage	06543-01	1
14	Holder for caution plate	06549-01	1
15	Connecting cord, 32 A, 500 mm, black	07361-05	4

Safety information

Voltages exceeding 25 V are hazardous if the current is greater than 0,5 mA. In the 2. experimental part, voltages that are **dangerous to touch** are delivered to the long distance cables.
The experiment is only to be operated by a specialist supervisor; never let students perform the experiment.

This experimental setup delivers high voltages that are dangerous to touch. The setup does not ensure a sufficient isolation against this high voltage. Therefore, the following advice is **strictly** to be followed!

- Put up a warning sign “high voltage” (e.g. 06543-01) before starting the experiment.
- The experiment is to be set up only when there is absolutely no voltage applied (disconnect power plug completely!); check every part once again before connecting the power supply to the mains.
- Changes in the experimental set-up are only to be made after disconnecting the power plug.
- **Important**: In order to prevent the danger of an electric shock, only perform the experiment with one hand (and the other hand in the trouser pocket).

Introduction

Application and task

In this experiment a transmission line is simulated.

It is shown why a high voltage is necessary for a long-distance transmission line.

Theory

There are energy losses due to the resistance in lines. In transmission lines the resistances are relatively large due to their length. The energy is released in the form of heat. Resistors become warm at high currents and longer loads. To keep the loss as low as possible, small currents should flow.

Setup and Procedure

Setup

Experiment 1

- Set up the experiment according to Fig. 1.
- Stick the ends of the long distance cable each in two insulated areas of the insulating support.
- Connect the power supply (AC voltage output) and the lamp holder with inserted filament lamp each to one side of the long distance cable.

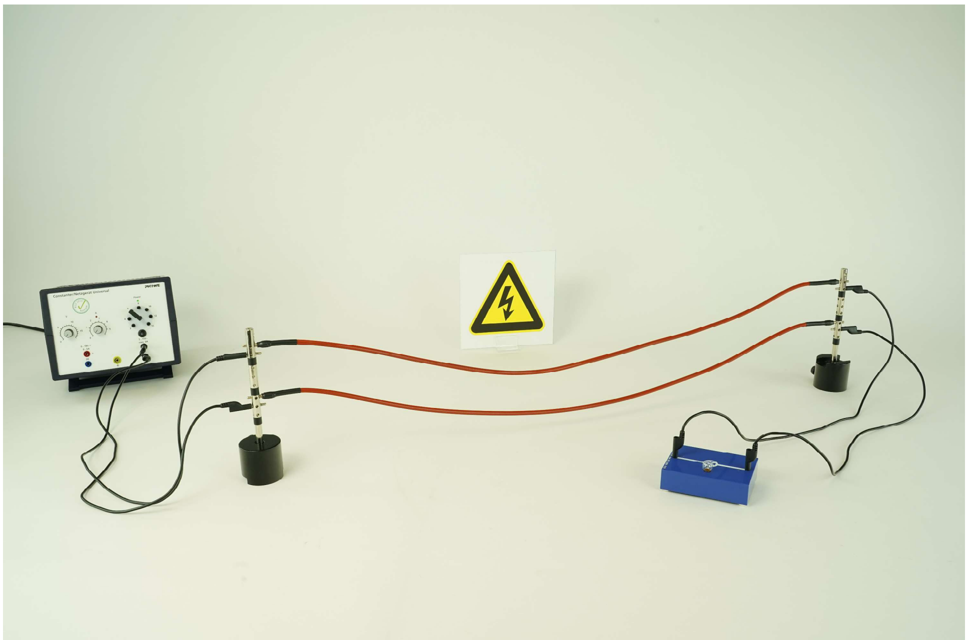


Fig. 1

Experiment 2

Safety information: The power supply must be switched off while setting up the experiment or rearranging the setup!

- To set up the transformers place a coil with 75 turns and a high voltage coil with 10,000 turns on each of the U-shaped cores.
- Stick iron core pins in both branches of the U-shaped cores and place the yokes ontop.
- Press the transformers tightly together using the clamping devices.
- Setup the experiment according to Fig. 2:
- Connect both coils with 10,000 turns (high voltage coils) of the transformers with the high voltage transmission lines.
- Connect the low voltage coil of the secondary transformer with the filament lamp in the lamp holder.
- Connect the low voltage coil of the primary transformer to the AC output of the power supply.

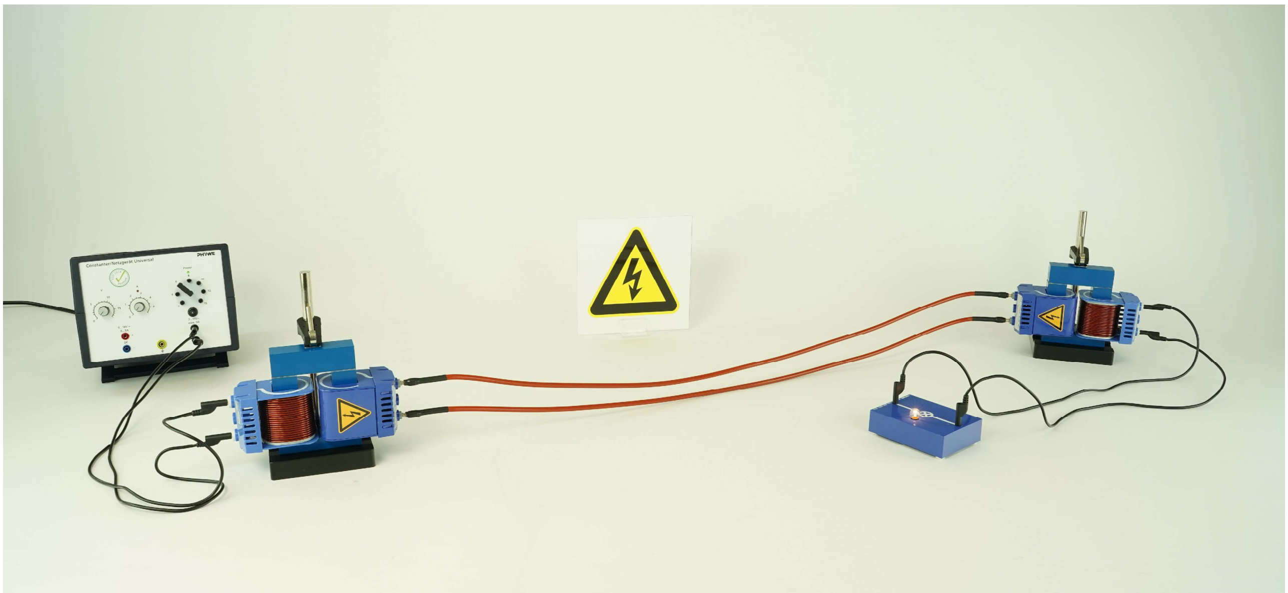


Fig. 2

Procedure

Experiment 1 / 2

- Adjust the voltage of the power supply in both experiments to 6 V~.
- Switch on the power supply and observe the lamp in both cases.

Evaluation

Observation

Experiment 1

If the lamp is directly connected via the long distance cables to the power supply, it does not light up. With a voltage of 6 V the current through the transmission lines is not high enough to operate the lamp.

Experiment 2

If high voltage is generated by a transformer, which is then applied to the transmission lines and stepped down again with the second transformer to 6 V, then the lamp lights up.

Results

Experiment 1

The long distance model has two lines each with a resistance of $\frac{R_{LD}}{2} = 50\ \Omega$ each.

The total resistance of the model is:

$$R_{LD} = \frac{R_{LD}}{2} + \frac{R_{LD}}{2} = 50\ \Omega + 50\ \Omega = 100\ \Omega.$$

Fig. 3 shows that both lines of the long distance line model and the lamp are connected in series and therefore both resistances R_{LD} and R_L add up.

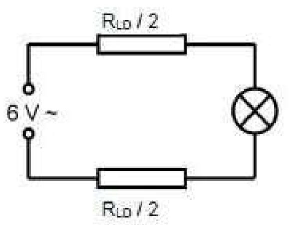


Fig.3

The maximum value for the current of the lamp can be estimated if the calculation only takes the resistance of the long distance line model into consideration.

$$R_{LD} = \frac{U}{I} \qquad (1)$$

$$I = \frac{U}{R_{LD}} = \frac{6\ V}{100\ \Omega} = 60\ mA$$

The nominal value for the current of the lamp is:

$$I_L = 0.5\ A = 500\ mA$$

It does not light up at a current of only 60 mA.

Experiment 2

Fig. 4 shows the circuit diagram of the second experimental part:

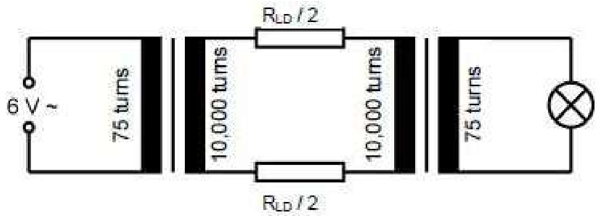


Fig.4

The first transformer transforms the AC voltage U_1 at the primary side into a AC voltage U_2 to the secondary side in ratio of the number of turns of the primary coil N_1 and secondary coil N_2:

$$\frac{U_1}{U_2} = \frac{N_1}{N_2} \qquad (2)$$

The voltage of the power supply is 6 V, which results in a voltage on the secondary side of:

$$U_2 = \frac{N_2}{N_1} \cdot U_1 = \frac{10000}{75} \cdot 6\ V = 800\ V$$

In order to transport the power of $P_L = 6\ V \cdot 0.5\ A = 3\ W$ necessary for the lamp at $800\ V$, only a relatively small current I_2 is necessary in the high voltage circuit:

$$P_L = U_2 \cdot I_2 \Rightarrow I_2 = \frac{P_L}{U_2} = \frac{3\ W}{800\ V} = 3.75\ mA$$

At this current the voltage drop at the line resistor $R_{LD} = 100\ \Omega$ is

$$U_{LD} = R_{LD} \cdot I_2 = 100\ \Omega \cdot 0.00375\ A = 0.375\ V$$

The voltage drop is negligible. On the secondary coil of the second transformer the voltage is again 6 V. In the lamp circuit there is no additional resistance anymore and the filament lamp shines brightly.

The power P_{LD}, which is used on the long distance lines as power loss is

$$P_{LD} = U_{LD} \cdot I_2 = 0.375\ V \cdot 3.75\ mA \approx 1.4\ mW$$

The power loss on the long distance cables has become very small due to high voltage transformation, because less current flows with the same power at a higher voltage.

Remarks:

The level of efficiency of the transmission is:

$$\eta = \frac{P_L}{P_{Total}}$$

which was only calculated in the second experiment and is therefore nearly 100%. Subsequent measuring of the power would however result in a smaller level of efficiency. The transformers do not ideally transform.

During the technical energy transmission a total loss of 10% is still accepted. Typical values for a high voltage transmission line are:

Setup:	4 cables with 30 mm² steel on the inside and 340 mm² aluminum on the outside
Length:	250 km
Resistance:	5 Ω
Operating voltage:	380 kV
Operating current:	4200 A