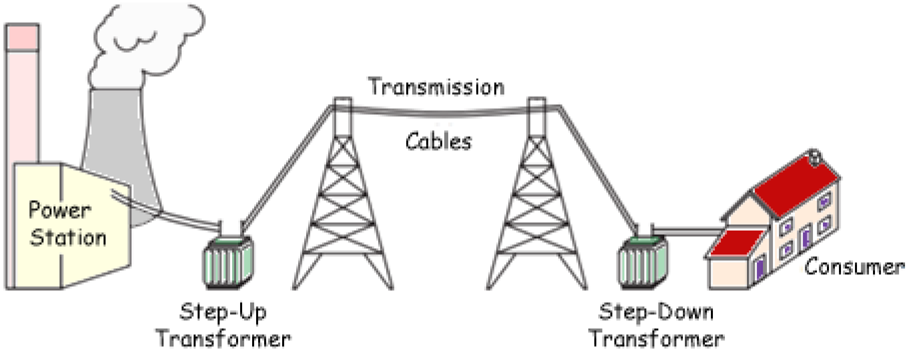
R07210 **National Grid Demonstration** **NFU172**

Introduction



Electricity is generated at a power station. The large generators produce an output voltage of 25,000V. The electricity is stepped-up in voltage using a transformer, to a very high voltage of 275,000V or even higher, 400,000V. The electrical energy is carried by “Transmission Lines” or “Power Lines” to a transformer sub-station which steps the voltage down to 230V for domestic use in the home.

Purpose

The National Grid Demonstration is an extremely safe way to demonstrate the advantages of distributing power at high voltages. The demonstration is made up of two step up/down transformers that are used to transform the 12V ac from a school power supply to 115V (nominal). The transmission line can be connected to either the low or High voltage connectors. The mounted bulb glows brightly when using the High Voltage connection and only dimly when the Low Voltage connection is used. Two sockets are provided to allow the high voltage to be measured safely using internal resistors to divide down the voltage to a safe level. The high voltage output is protected by an interlock that ensures that the high voltage is only enabled once the transmission line has been connected to the high voltage connector. Both ends of the transmission line are touch proof and use BS EN61010 compliant connectors. Two pylons are also included to support the transmission line.
The National Grid Demonstration has been designed to prevent any access to hazardous voltages and is safe for students to use under supervision.

Specification

Transformer

Power	20VA
Primary Voltage	12V a.c.
Secondary Voltage	115V a.c. (nominal)
Primary current	2.5A (Max)
Bulb	12V 18W

Equipment required

12V a.c. Bench power supply
4 x 4mm leads

Safety

The National Grid Demonstration has a number of safety features designed to allow students to safely use the equipment under supervision:

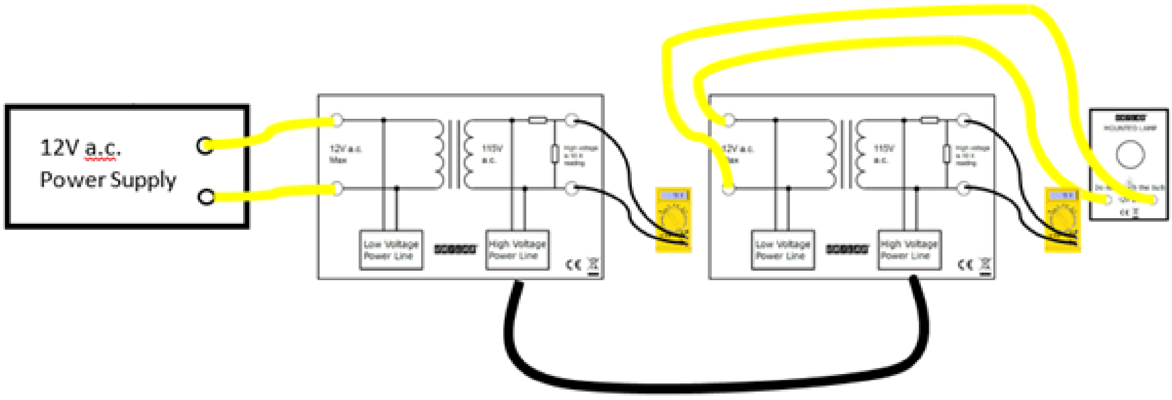
- The National Grid Demonstration can produce a secondary voltage of up to 115V when powered with 12V a.c.
- An inter-lock is used so that the high voltage secondary is only enabled when the transmission line is connected into the high voltage connector
- The transmission line cable is fitted with BSEN 61010 compliant touch proof connectors
- The High voltage monitor sockets are connected to an internal potential divider, reducing the voltage by a factor of 10
- Always check the equipment carefully before use. Ensure that there is no damage to the transformers or to the transmission line cable
- The equipment is protected against misconnecting the High and low voltage connections
- **Never exceed the 12V a.c. maximum operating voltage**

Using the National Grid Demonstration

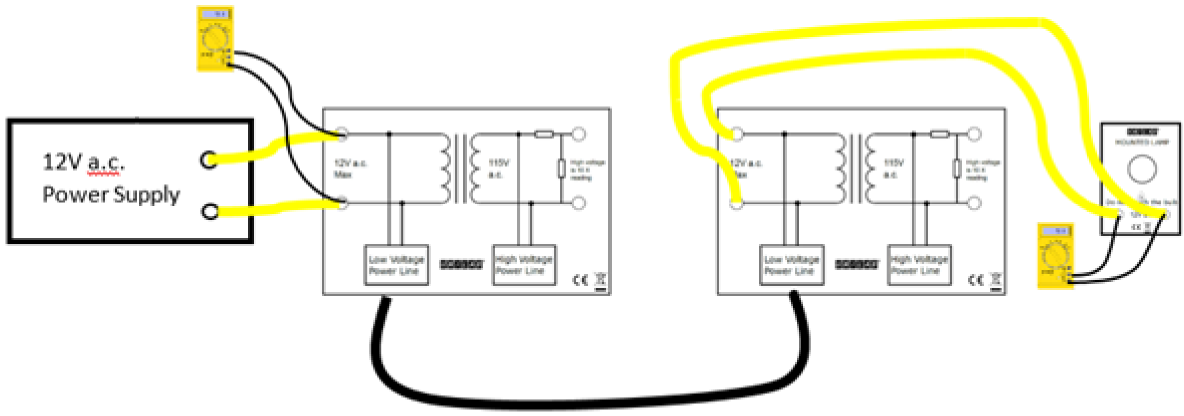
Both the transformers are identical, so they can be used either as the step-up or step-down transformer. Two pylons are included that can be used to support the transmission line. The pylons consist of two parts that are simply slotted together.

Connect the 12V primary of one of the transformers to a 12V a.c. bench power supply capable of delivering at least 2 amps. Now connect the mounted 12V lamp to the 12V secondary of the second transformer.

An identical resistor is fitted in series with both the low voltage and high voltage outputs to simulate the line impedance of a real transmission line. When power is transmitted through the transmission line, this causes a volt drop proportional to the current passing through the transmission line. This is the equivalent of the power loss experienced in real transmission lines.



Plug the transmission line into the high voltage connectors. Note that the lamp glows brightly. Two 4mm sockets are provided so that students can monitor the high voltage. The sockets are connected to an internal potential divider that limits the voltage at the terminals to a safe level. Just multiply the voltmeter reading by 10 to get the true value.



Disconnect the transmission line and re-connect using the low voltage connection. The lamp now glows dimly, showing that the losses in the low voltage transmission line are much higher.

More advanced work

Low Voltage Power Line

Using an a.c. Voltmeter and Ammeter, it is possible to make some quantitative measurements. With the transmission line connected to the low voltage power line, measure the Voltage at both low voltage terminals to determine the volt drop across the transmission line. Now measure the current flowing through the bulb. Using Ohm's law ($R = \frac{V}{I}$), calculate the resistance of the transmission line. You should find that the resistance is about 10 Ohms.

Measure the input current to the step-up transformer and calculate the power ($P = IV$). Now calculate the output power using the measurements made at the step-down transformer output to the lamp. You will find that only 25% of the power is being delivered to the lamp. What has happened to the missing 75%?

The power loss is due to the electrical energy being converted to heat energy because of the power line resistance. Calculate the power lost as heat in the power line. Using Ohm's law $V = IR$
Substituting for V in the power equation $P = IV$, we can see that $P = I^2R$
Calculate the power loss using the input current and the calculated value of the power line resistance, is it the expected value?
Because the power loss is proportional to I^2, halving the current will reduce the power loss by a factor of four. This is why the national grid transmits power at such high voltages so that the current flowing in the powerline is as small as possible to reduce power loss to a minimum.

High Voltage Power Line

Connect the transmission line to the High Voltage Power Line connectors. Measure the high voltage output to the power line. The output terminals use a potential divider to keep the voltage to a safe level, so you need to multiply the reading of the voltmeter by 10 to get the real value. Repeat the measurement at the other end of the power line. Subtract this voltage to determine the volt drop. How does this compare to the Low Voltage Power Line?

Rearranging Ohm's law we have $I = \frac{V}{R}$
Substituting for I in the power equation $P = IV$, we can see that $P = \frac{V^2}{R}$
We know that the power line has an impedance of about 10 Ohms, so the power loss in the high voltage power line can be calculated, which is less than 0.5W

Other power losses

If you measure the input and output power for the High Voltage Power Line, you will see that although the lamp shines brightly, less than 50% of the input power is being delivered to the lamp. You will also note that when the High Voltage power line voltage is measured, it is much lower than the theoretical 115V. We have already calculated that the power loss in the transmission line is just 0.5W which is less than 3% of the input power, so where is the rest of the power loss?

The other losses are due to the step-up and step-down transformers. Even the best transformers have significant losses. Transformers are usually around 70% efficient due to losses caused mainly by the resistance of the windings ($P = I^2R$) but there are additional losses due to the magnetising current needed to energize the core of the transformer. There are also hysteresis losses and eddy current losses in the core laminations of the transformer. Unplug the mounted lamp from the step-down transformer and measure the input current. You will note that it is over 0.5A with no load connected.

Periodic testing

Check the transmission Line lead and transformer enclosures for any damage.

Disposal of Waste Electrical and Electronic Equipment (WEEE)

Do not dispose of this product with household waste

- For the proper treatment, recovery and recycling please take this product to an appropriate collection point.
- If you are unsure where this is, contact your Local Authority
- By disposing of this product correctly you will be providing positive help to the environment.

Warranty, repairs and spare parts

The National Grid Demonstration is guaranteed for a period of one year from the date of delivery to the customer. This warranty does not apply to defects resulting from the action of a user such as misuse, improper wiring, any operations outside of its specification, improper maintenance or repair, or unauthorized modification.

Our liability is limited to repair or replacement of the product. Any failure during the warranty period should be referred to Customer Services or techsupport@philipharris.co.uk

Instructions for authorized service technicians

Please refer to the detailed service procedures, safe servicing and continued safety – contact techsupport@philipharris.co.uk for advice.

Please refer to product specific risks that may affect service personnel, the protective measures and verification of the safe state after repair.

Supplier details

Unilab, 2 Gregory Street, Hyde, Cheshire, SK14 4RH

Orders and Information:

Tel: 0845 120 4521

Fax: 0800 138 8881

Repairs:

Tel: 0845 120 3211

Technical Support:

E-mail: techsupport@unilab.co.uk

www.unilab.co.uk