2.7 The National Grid

Name: _____ Class: _____ Date: _____ **Total: 25 marks**

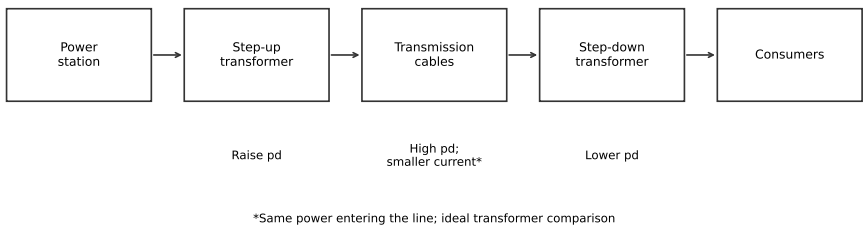
KEY WORDS National Grid • step-up transformer • step-down transformer

Objective

Describe the National Grid, the two transformer types, and explain – with $P = I^2R$ – why transmitting at very high potential difference is efficient. Original questions for spec statement 4.2.4.3.

1 Key knowledge and worked examples

The **National Grid** connects power stations to consumers through a system of cables and transformers.



Higher pd for transmission; lower pd for domestic appliances.

Transformer	What it does
step-up	raises the potential difference for the transmission cables
step-down	lowers the potential difference for domestic appliances

Explain the physical chain:

1. For the same power entering the transmission line, $P = VI$: a **higher potential difference** means a **lower current** in the cables.
2. The power wasted by heating the cables is $P = I^2R$ – the cables' resistance is fixed.
3. Halving the current wastes **a quarter** of the power. So very high potential difference keeps transmission losses small – the Grid is an efficient way to transfer energy.

(How transformers themselves work is Higher Tier, physics only – see topic 4.7. Here you only need the system-level explanation.)

Worked example – teacher-written model. A simplified line receives 500 kW at its sending end. Total cable resistance is 2.0 Ω. Compare sending-end pd 10 kV and 20 kV, keeping input power and resistance fixed and treating transformers as ideal. This is a simplified resistive-line calculation, not a real three-phase network model.

Convert: $P_{\text{in}} = 500\,000$ W; $V_1 = 10\,000$ V; $V_2 = 20\,000$ V.

Current follows from $P = VI$, and cable heating from $P_{\text{loss}} = I^2R$.

$$I_1 = \frac{P_{\text{in}}}{V_1} = \frac{500\,000\ \text{W}}{10\,000\ \text{V}} = 50\ \text{A}$$
$$P_{\text{loss},1} = I_1^2R = (50\ \text{A})^2 \times 2.0\ \Omega = 5000\ \text{W}$$
$$I_2 = \frac{P_{\text{in}}}{V_2} = \frac{500\,000\ \text{W}}{20\,000\ \text{V}} = 25\ \text{A}$$
$$P_{\text{loss},2} = I_2^2R = (25\ \text{A})^2 \times 2.0\ \Omega = 1250\ \text{W}$$

Double the sending pd → half the current → one quarter of the cable loss. Input power is fixed, but useful output increases because loss is smaller. If total input is not given, a loss calculation alone cannot establish a loss percentage or efficiency.

2 Practice

2.1 Name the system that connects power stations to consumers, and the two devices that change the potential difference along it. [3]

2.2 State what a step-up transformer does and where it is placed in the system. [2]

2.3 The current in a transmission cable is halved. State what happens to the power wasted in the cable, and the equation that shows it. [2]

3 Exam-style questions

3.1 A power station generates electricity at 25 000 V for the National Grid.

(a) Explain why a step-up transformer is used before the transmission cables. [4]

(b) Explain why a step-down transformer is needed before electricity enters homes. [2]

3.2 A transmission cable carries 2000 A and has resistance 40 Ω.

(a) Calculate the power wasted by heating in the cable. [2]

(b) The current is reduced to 500 A at a higher potential difference, with the same power entering the line in a simplified resistive model. Calculate the new wasted power. [2]

(c) Use your answers to explain why the National Grid is described as an efficient way to transfer energy. [2]

3.3 Two villages argue about a new transmission line.

Village A: "Build it at 400 000 V – less energy wasted." Village B: "Build it at 132 000 V – safer and cheaper pylons."

(a) Use physics to support Village A's claim, with the two equations involved. [4]

(b) Give one reason the planners still choose a lower potential difference near populated areas. [2]