Solutions

Marking: **M1** a correct method, **A1** the correct answer, **B1** an independent mark.

Each answer shows the steps, then the **result**.

2.1

$Z_b = \dfrac{13.8^2}{50} = \mathbf{3.81}\ \Omega$; $\dfrac{8}{3.81} = \mathbf{2.10\ pu}$; $0.5 \times 3.81 = \mathbf{1.90}\ \Omega$

2.2

$I_b = \dfrac{100 \times 10^6}{\sqrt{3} \times 132\,000} = \mathbf{437\ A}$; at 33 kV: **1750 A**; $\dfrac{1750}{437} = 4 = \dfrac{132}{33}$

2.3

transformer: $0.08 \times \dfrac{100}{50} = \mathbf{0.16\ pu}$; generator: $0.20 \times \dfrac{100}{80} \times \left(\dfrac{13.8}{13.2}\right)^2 = \mathbf{0.273\ pu}$

2.4

33 kV: $Z_b = 54.45\ \Omega$, $0.05 \times 54.45 = \mathbf{2.72}\ \Omega$; 11 kV: $Z_b = 6.05\ \Omega$, $\mathbf{0.303}\ \Omega$; $\dfrac{2.72}{0.303} = 9 = \left(\dfrac{33}{11}\right)^2$

3.1

generator $0.2 \times \dfrac{100}{60} = 0.333$; transformer $0.10 \times \dfrac{100}{50} = 0.200$ pu

line: $Z_b = 43.56\ \Omega$, $\dfrac{20}{43.56} = \mathbf{0.459\ pu}$

$I_f = \dfrac{1}{0.992} = \mathbf{1.01\ pu}$

line: $1.01 \times 875 = \mathbf{881\ A}$; generator: $1.01 \times 5249 = \mathbf{5290\ A}$

3.2

T1 0.05 pu; T2 $0.04 \times \dfrac{1}{0.5} = \mathbf{0.08\ pu}$

T1 carries $1.2 \times \dfrac{0.08}{0.13} = \mathbf{0.738\ MVA}$; T2 carries **0.462 MVA**

T1 at 74%, T2 at 92% of rating: the smaller unit works harder

T2 reaches 0.5 MVA when the total is $\dfrac{0.5}{0.385} = \mathbf{1.30\ MVA}$

3.3

(a) $X_T = 0.12 \times \dfrac{100}{30} = 0.4$ pu, total 0.5 pu: $I_f = 2.0$ pu $\times 5249$ A $= \mathbf{10.5\ kA}$; fault level $\dfrac{100}{0.5} = \mathbf{200\ MVA}$

(b) $0.1 + 0.2 = 0.3$ pu: **17.5 kA**, 333 MVA; above 16 kA, so the breakers are not safe

(c) $16\,000/5249 = 3.05$ pu needs $X \geq 0.328$ pu; reactor $\geq \mathbf{0.028\ pu} = 0.028 \times 1.21 = \mathbf{0.034}\ \Omega$

(d) the reactor is cheaper and quick to fit, but it causes a voltage drop and losses at every hour of load; new breakers cost more once but keep the stiff, low-impedance supply; choose the breakers if the voltage drop matters for the motors, otherwise the reactor, and say the trade

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