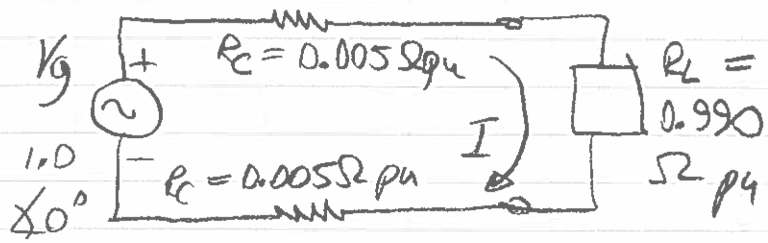
Case Study – 1φ, 3φ, & others, Cu required   C Abraham 18 Mar 2016   1/2



$$I = \frac{V_g}{2R_C + R_L} = \underline{1.00\ A\ pu\ \angle 0^\circ}$$

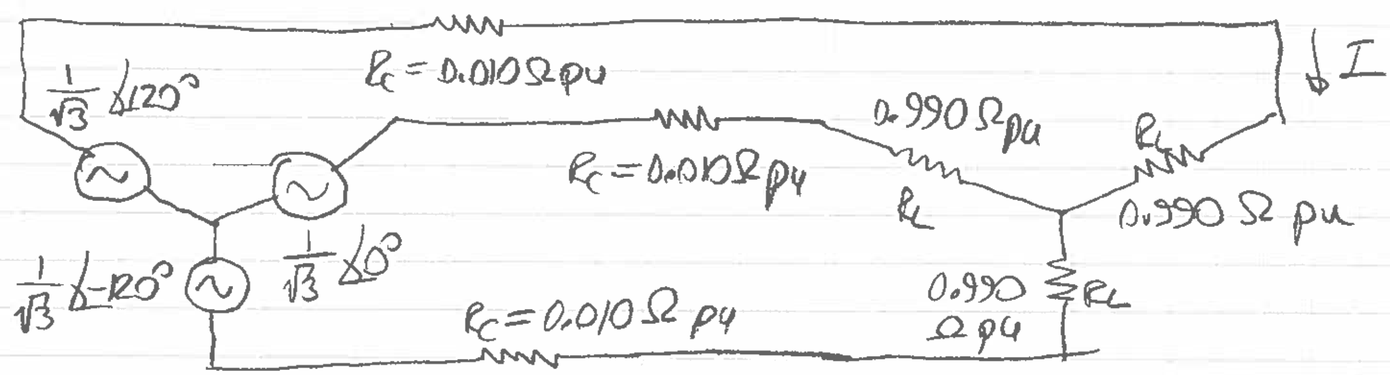
$$P_L = I^2 R_L = (1.0A)^2 (0.990\Omega)$$

$$= \underline{0.990\ W\ pu},$$

$$P_C = 2I^2R_C = 2(1.00A)^2(0.005\Omega)$$

$$= \underline{0.010\ W\ pu}$$

So we wish to transmit the same 0.990 W pu to load, losing only 0.010 W in cables, over same distance. Line-to-neutral voltage must be $\frac{1}{\sqrt{3}}$ since line-to-line must equal 1.0, for same insulation.

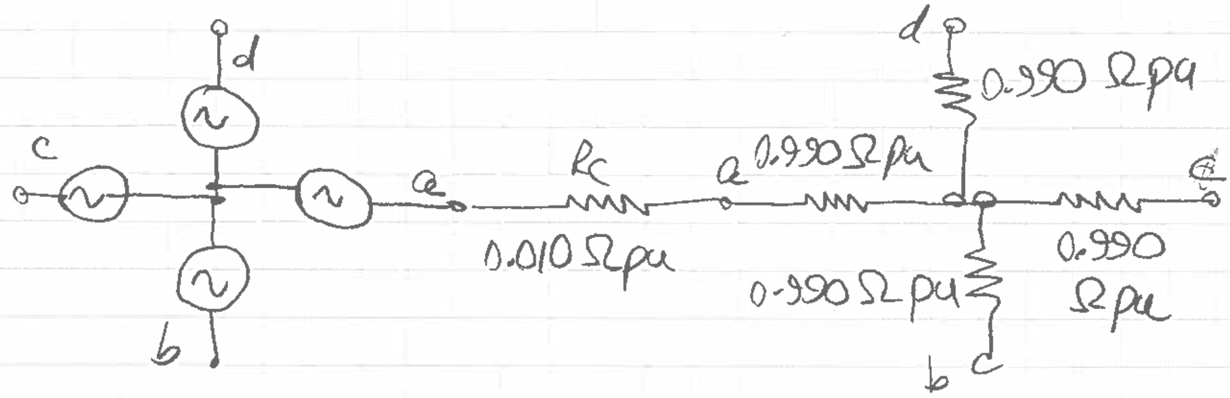


$$I\ (\text{per phase}) = \frac{V_{L-N}}{R_C + R_L} = \frac{(1/\sqrt{3})\ V}{(0.010 + 0.990)\ \Omega} = \frac{1}{\sqrt{3}}\ A\ pu \text{ per phase}$$

$P_L = I^2 R_L$ per phase $= \left(\frac{1}{\sqrt{3}} A\right)^2 (0.990\Omega) = 0.330$ W pu/phase $\Rightarrow P_L =$ 0.990 W pu total, like 1φ case. $P_C = I^2 R_C = \left(\frac{1}{\sqrt{3}} A\right)^2 (0.010\Omega)$ $= 0.003333$ W pu $\Rightarrow$ total $=$ <u>0.010 W pu</u> as was the case in 1φ.

Equal power lost in cables, equal power to load requires 5.0 mΩ cables in 1-phase, 10 mΩ cables in 3-phase. The 3-phase area can be half of 1-phase for 2X resistance, or 50%. But 3φ has 3 cables, 1φ has 2 cables; so 3-phase requires <u>75% the copper</u>.

For a 4-phase system, V_{L-N} must be 0.50 V_{pu} to keep V_{L-L} at 1.00 V_{pu}.



$$I(\text{per phase}) = \frac{V_{L-N}}{R_C + R_L} = \frac{(0.50\,V)}{(0.990 + 0.010)\,\Omega} = 0.50\,A\ pu \text{ per phase}$$

$$P_L = I^2 R_L = (0.50A)^2 (0.990\,\Omega) = 0.245\,W\ pu \text{ per phase}$$

$\Rightarrow \times$ 4 phases $\Rightarrow$ <u>0.990 W pu</u>, just as before.

$$P_C\ (\text{per phase}) = I^2 R_C = (0.50A)^2 (0.010\,\Omega) = \underline{0.0025\ W\ pu}$$

$\Rightarrow \times$ 4 phases $\Rightarrow$ <u>0.010 W pu</u>, just as before.

Equal power is lost in cables & equal power delived to load. With 1-phase 5.0 mΩ cables are needed, × 2 cables. With 4-phase 10 mΩ cables are needed, × 4 cables. With 4-phase, we can allow cables with 2 times the resistance of 1-phase, so we only need half, or 50% of the copper per cable. But 4 cables vs. 2 cables means that 4-phase requires <u>100%</u> the copper of 1-phase.

Claude