Induction Machine Negative Sequence Example

$pu := 1 \qquad MVA := MW$

Suppose that phaes "a" of the supply an induction motor is opened. Find sequence voltages and currents if Vbc = 1.0pu on a line to line basis.

Machine parameters:

$V_b := 4kV \qquad Efficiency := 0.93$

$P_{out} := 1000hp$ or in W $P_{out} = 745.7 \cdot kW$

$P_{in} := \dfrac{P_{out}}{Efficiency} \qquad P_{in} = 801.828 \cdot kW$

$power\_factor := 0.90$

$S_{in} := \dfrac{P_{in}}{power\_factor}$

$Sbase1 := S_{in} \qquad Sbase1 = 0.891 \cdot MVA$

$slip\_rated := 0.02$

$R_s := 0.02pu \qquad X_s := 0.08pu \qquad X_m := 3.0pu$

$R_r := 0.02pu \qquad X_r := 0.08pu$ referred to stator

$I_a = 0 \qquad V_{bc} = V_b - V_c$

$I_b = -I_c$

Moving to sequence domain:

$$I_1 = -I_2 = j \cdot \frac{I_b}{\sqrt{3}}$$

$$V_{bc} = -j \cdot \sqrt{3} \cdot (V_1 - V_2)$$

or $$V_1 - V_2 = j \cdot \frac{V_{bc}}{\sqrt{3}}$$

Therefore we connect the positive and negative sequence circuits in series and impose the voltage V1 - V2 across them (derived from the value of Vbc)

Original voltage:

$V_{ap} := 1pu\, e^{j\cdot 0deg}$ $V_{bp} := 1pu\, e^{-j\cdot 120deg}$ $V_{cp} := 1pu\, e^{j\cdot 120deg}$

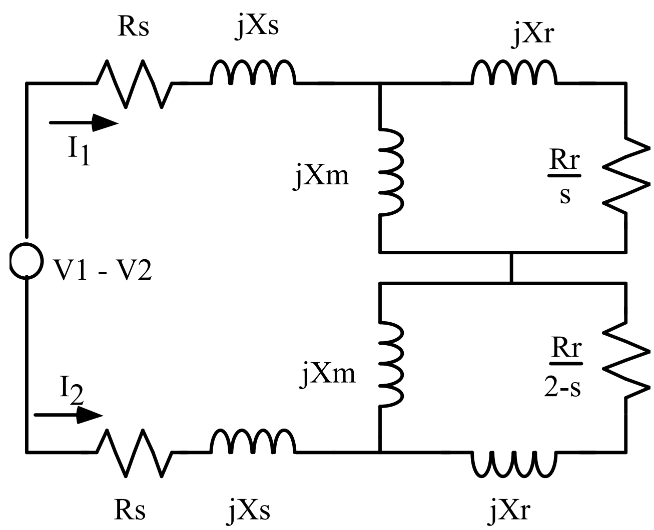
$V_{bc} := V_{bp} - V_{cp}$ $\left|V_{bc}\right| = 1.732\cdot pu$ $\arg\left(V_{bc}\right) = -90\cdot deg$

- ***This is 1.0 per unit in the line to line voltage......***

Then V1 - V2 is:

$V_{1\_2} := j\cdot\frac{V_{bc}}{\sqrt{3}}$ $V_{1\_2} = 1\cdot pu$ the problem was set up to use nice numbers

Now we can solve the circuit below, where the positive and negative sequence circuits are connected in



- First come up with the equivalent circuit for the parallel combination in the two rotor circuits...

$$z_{pos\_rot} := \left(\frac{1}{j\cdot X_m} + \frac{1}{j\cdot X_r + \frac{R_r}{slip\_rated}}\right)^{-1} \qquad z_{pos\_rot} = (0.858 + 0.357i)\cdot pu$$

$$z_{neg\_rot} := \left(\frac{1}{jX_m} + \frac{1}{j\cdot X_r + \frac{R_r}{2 - slip\_rated}}\right)^{-1} \qquad z_{neg\_rot} = \left(9.583\times 10^{-3} + 0.078i\right)\cdot pu$$

- Note how much smaller the real part of this expression is than for the positive sequence part.

$I_{1\_stator} = -I_{2\_stator}$

$$I_{1\_stator} := \frac{V_{1\_2}}{2(R_s + j \cdot X_s) + z_{pos\_rot} + z_{neg\_rot}}$$

$I_{1\_stator} = 0.771 - 0.505i$ $\left|I_{1\_stator}\right| = 0.921 \cdot pu$ $\arg(I_{1\_stator}) = -33.22 \cdot deg$

$I_{2\_stator} := -I_{1\_stator}$ $\left|I_{2\_stator}\right| = 0.921 \cdot pu$ $\arg(I_{2\_stator}) = 146.78 \cdot deg$

$V_1 := I_{1\_stator} \cdot (R_s + j \cdot X_s + z_{pos\_rot})$ $V_1 = (0.897 - 0.107i) \cdot pu$

$\left|V_1\right| = 0.904 \cdot pu$ $\arg(V_1) = -6.788 \cdot deg$

$V_2 := I_{2\_stator} \cdot (R_s + j \cdot X_s + z_{neg\_rot})$ $V_2 = (-0.103 - 0.107i) \cdot pu$

$\left|V_2\right| = 0.148 \cdot pu$ $\arg(V_2) = -133.828 \cdot deg$

$V_1 - V_2 = 1 \cdot pu$ as expected.....