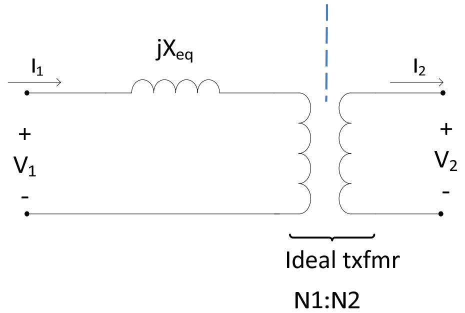
ENEL 487

Non-ideal transformers in Per Unit

Let's start with the simplest non-ideal transformer model.



Zone 1

Suppose we selected $V_{base\ 1}$

$$Z_{base\ 1} = \frac{(V_{base\ 1})^2}{S_{base}}$$

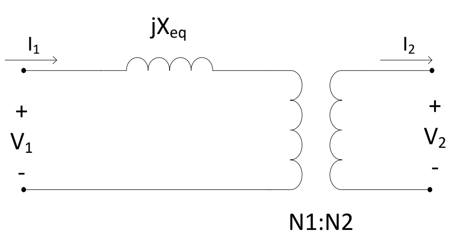
Zone 2

$$V_{base\ 2} = V_{base\ 1}\frac{N_2}{N_1}$$

$$Z_{base\ 2} = \frac{(V_{base\ 2})^2}{S_{base}} = \frac{\left(V_{base\ 1}\frac{N_2}{N_1}\right)^2}{S_{base}} = \left(\frac{N_2}{N_1}\right)^2 Z_{base\ 1}$$

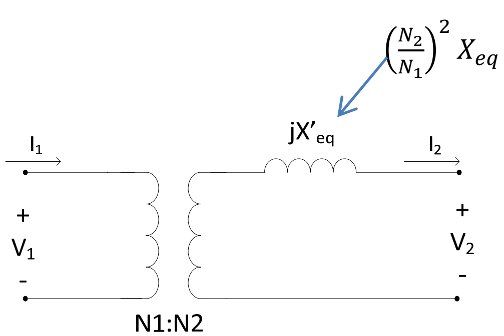
We already stablished that the ideal transformer portion can be removed in per unit analysis. The transformer impedance is the only thing left! The impedance should be divided by the correct Z_{base} in the per unit analysis.

1) With transformer impedance referred to winding 1 side:



$$X_{eq,pu} = \frac{X_{eq}}{Z_{base\ 1}}$$

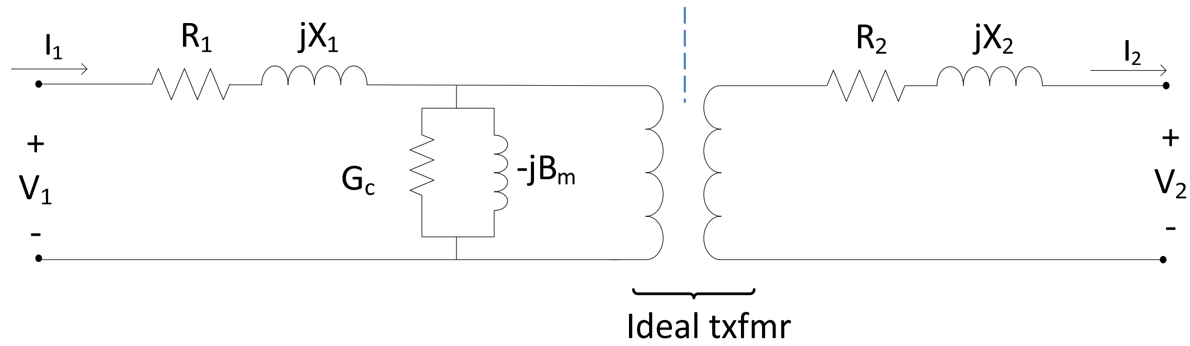
2) With transformer impedance referred to winding 2 side:



$$X'_{eq,pu} = \frac{X'_{eq}}{Z_{base\ 2}} = \frac{\left(\frac{N_2}{N_1}\right)^2 X_{eq}}{\left(\frac{N_2}{N_1}\right)^2 Z_{base\ 1}} = \frac{X_{eq}}{Z_{base\ 1}} = X_{eq,pu}$$

Conclusion: Transformer impedance in PU is the same regardless of which side it is referred to.

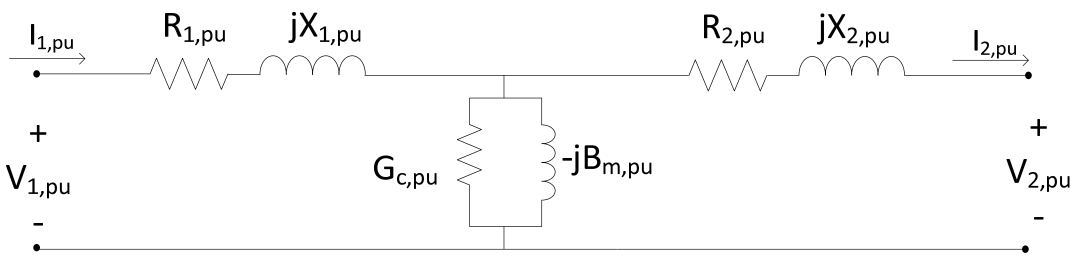
We can extend this out to the complete non-ideal transformer model:



Zone 1 with $V_{base\ 1}$ and $Z_{base\ 1}$ as defined before

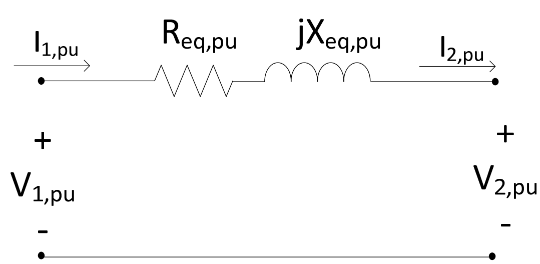
Zone 2 with $V_{base\ 2}$ and $Z_{base\ 2}$ as defined before

In per Unit, this transformer model becomes:



$$X_{1,pu} = \frac{X_1}{Z_{base\ 1}} \qquad R_{1,pu} = \frac{R_1}{Z_{base\ 1}} \qquad G_{c,pu} = \frac{G_c}{Y_{base\ 1}} \qquad B_{m,pu} = \frac{B_m}{Y_{base\ 1}} \qquad X_{2,pu} = \frac{X_2}{Z_{base\ 2}} \qquad R_{2,pu} = \frac{R_2}{Z_{base\ 2}}$$

With the excitation branch omitted, the per unit representation of a non-ideal transformer becomes:



This is just the model from the previous page with winding resistance added.

The other conclusion: In PU analysis, non-ideal transformer becomes just another impedance in the circuit.