Conceptual Clarifications in Electrical Power Engineering – Part 2

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Introduction

"It is important to simplify the explanation, not the subject"-
YouTube video on Physics – Henry Reich

As in Part 1, an attempt has been made in this part to unravel the underlying concepts in selected topics in power engineering. The topics covered are:

(a) Effect of phase shift introduced by transformer on angle stability

(b) Paralleling and synchronizing of transformer

(c) Ampere Turn Balance in Transformer

(d) Percentage impedance for three phase and equivalent three single phase transformers

(e) Voltage dip experienced at LV side of transformer for faults on HV side

(f) Effect of LV side Unbalance current on HV side reflected current

Phase Shift and Stability

We will prove that phase shift introduced by (Y-Δ) transformer can't influence power transfer magnitude.

In a power network, transformers that introduce phase shift are present. The most popular vector group in this category is (Y-Δ) transformer which creates 30^0 phase shift in voltage and current between two sides of transformer. When balanced power flow analysis is done for networks having transformers with different vector groups, it is advantageous to work in pu for following reasons:

a) Per unit impedance (or % impedance) is same whether referred to primary or secondary.

b) The current magnitude in pu is same on primary and secondary side. However a phase shift of 30^0 is introduced between primary and secondary currents.

c) The voltage in pu on primary and secondary side are same if the transformer is unloaded (current is zero). If the transformer is loaded, voltage on primary side is affected only to the extent of regulation (IX drop) compared to secondary side. A phase shift of 30^0 is further introduced between primary and secondary voltages.

For simplicity sake, assume that (Y-Δ) transformer is on nominal tap. This does not affect final conclusion even if tap is off-nominal. The hand calculations presented in sequel are easier to understand with nominal tap.

For illustration, consider the network shown in Fig.1

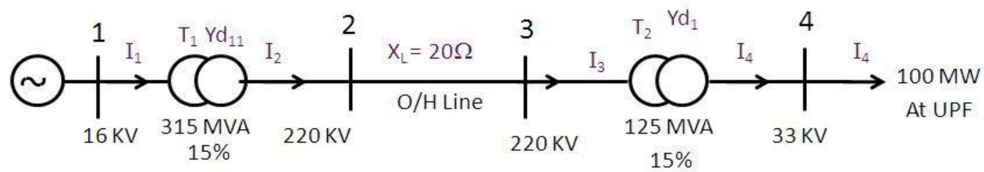

Fig 1

On 100 MVA base,

$$X_{T1} = \frac{100}{315} \times 0.15 = 0.0476 \text{ gu}$$

$$X_{T2} = \frac{100}{125} \times 0.15 = 0.12 \text{ gu}$$

$$X_{Base} = \frac{220^2}{100} = 484\Omega$$

$$X_L = \frac{20}{484} = 0.0413 \text{ gu}$$

First, power transfer is computed in per unit *without* considering phase shift across transformer. Choose V_4 as reference.

$V_4 = 1\angle 0$

Since load is 100 MW at UPF,

$I_4 = 1\angle 0$

Further it may be noted that in pu

$I_1 = I_2 = I_3 = I_4$

$V_3 = V_4 + I_4 \times jX_{T2}$

$= 1\angle 0 + 1\angle 0 \times 0.12\angle 90^0$

$= 1.0072 \angle 6.8428^0$