

## PER UNIT IDENTITIES

### DISCUSSION:

Per Unit (pu) systems are used by engineers to quantify equipment parameters in terms of their Nameplate Ratings. For example, a motor with a 100 Horsepower (HP) nameplate rating which delivers 90 HP to a dynamic load is said to be 90% loaded or 0.9 per unit. In this case, the per unit base is the nameplate horsepower rating of 100. When the motor delivers 90 HP, 90/100 equals 0.9 per unit. In general then,

$$\text{Per Unit} = \frac{\text{Present Value}}{\text{Base Value}}$$

Any piece of equipment can be per unitized using its nameplate ratings for Voltage, Current and Power (in Volt-Amperes). In a more generalized approach for power systems containing many pieces of equipment, there are standard base quantities for per unit calculations. These become useful when performing calculations across a power system where multiple voltage levels and different equipment sizes occur. In the most common usage for per unit calculation, the analysis of an entire power system, the nominal or nameplate voltage rating for each voltage level of the system is chosen as base voltage. In such analysis, the power base is often chosen as 100 MVA and bases for current and impedance are calculated using the power and voltage base. By the use of Ohm's law, selecting any two base values, such as voltage and power, allows the calculation of the other two bases.

### Calculation of Per Unit Base Values:

BASE Quantity	Single-Phase Systems	Three-Phase Systems
<b>POWER*</b>	$S_{\text{base } 1\phi} = V_{\text{base}} \times I_{\text{base}}$	$S_{\text{base } 3\phi} = \sqrt{3} V_{\text{base}} \times I_{\text{base}}$ (where $V_{\text{base}}$ is a Line-to-Line value)
<b>VOLTAGE</b>	Base Voltage is almost always known. Use the nameplate or nominal rating for the equipment or system. Otherwise, $V_{\text{base}} = \frac{S_{\text{base } 1\phi}}{I_{\text{base}}}$	Same comment as Single-Phase. Otherwise, $V_{\text{base L-L}} = \frac{S_{\text{base } 3\phi}}{\sqrt{3} I_{\text{base}}}$
<b>CURRENT</b>	$I_{\text{base}} = \frac{S_{\text{base } 1\phi}}{V_{\text{base}}}$	$I_{\text{base}} = \frac{S_{\text{base } 3\phi}}{\sqrt{3} V_{\text{base L-L}}}$
<b>IMPEDANCE</b>	$Z_{\text{base}} = \frac{V_{\text{base}}^2}{S_{\text{base } 1\phi}}$ <b>OR</b> $Z_{\text{base}} = \frac{V_{\text{base}}}{I_{\text{base}}}$	$Z_{\text{base}} = \frac{(V_{\text{base L-L}})^2}{S_{\text{base } 3\phi}}$

\* - Base Power is traditionally Apparent Power, S. Real Power, P, can also be used (with care).

### Per Unit Impedance:

$$Z_{\text{pu}} = \frac{Z \text{ (in Ohms)}}{Z_{\text{base}}}$$

### Converting from one base to another:

$$Z_{\text{pu}} \text{ (New)} = Z_{\text{pu}} \text{ (old)} \frac{[V_{\text{base (old)}}]^2 S_{\text{base (new)}}}{[V_{\text{base (new)}}]^2 S_{\text{base (old)}}}$$

