EE2029: Introduction to Electrical Energy System

Per Unit Analysis: Introduction

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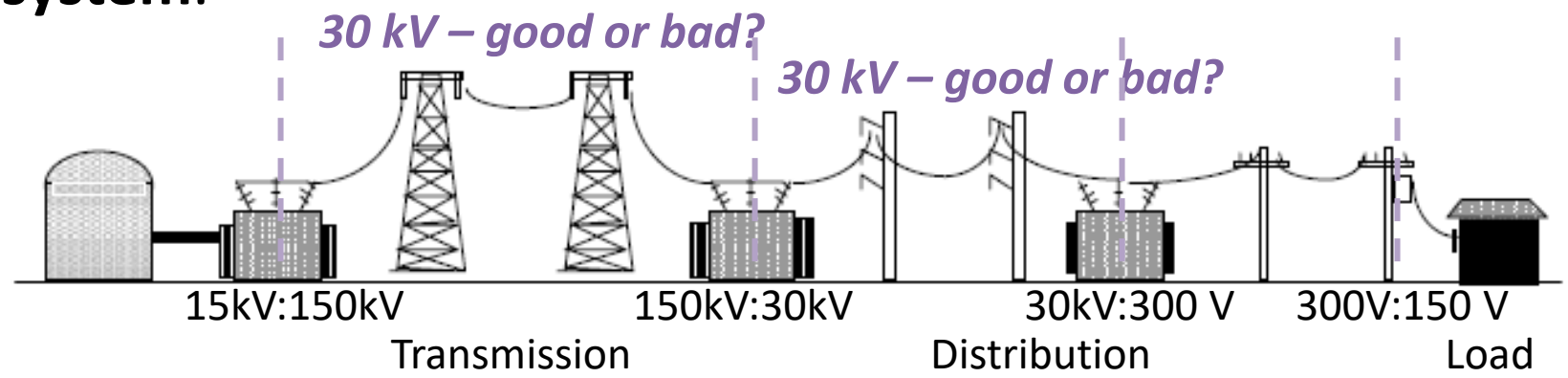
Learning Outcomes

- Motivations
- Per-Unit System
- Base Values

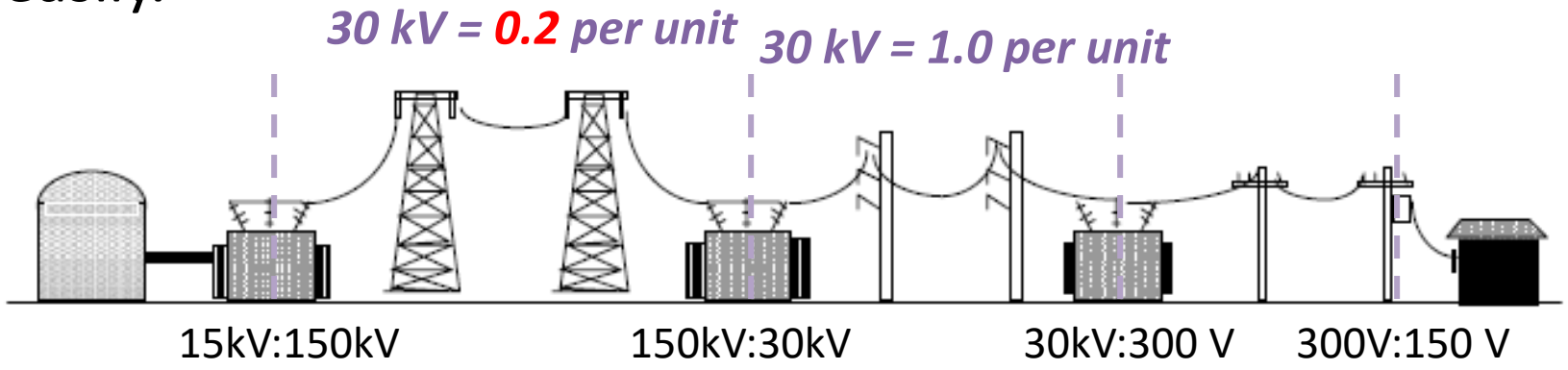
Motivations

- Transformer introduces various voltage levels.
- So far we can only reflect the load from one side of the transformer to another. Still we need to use turns ratio to find voltage and current at each side of the transformer.
- It is *difficult to calculate voltage and current* of the system at various points.
- It is **even more difficult** for system operators **to observe the current situation of the system**.



Per Unit System

- Per unit system is when we **normalize** the voltage and current at each location.
- The normalization typically follows transformer ratings.
- This usually makes the per unit value of both voltage and current to be around 1.0 per unit.
- Per unit system allows system operators to overlook abnormalities in the system easily.



Per Unit Quantity

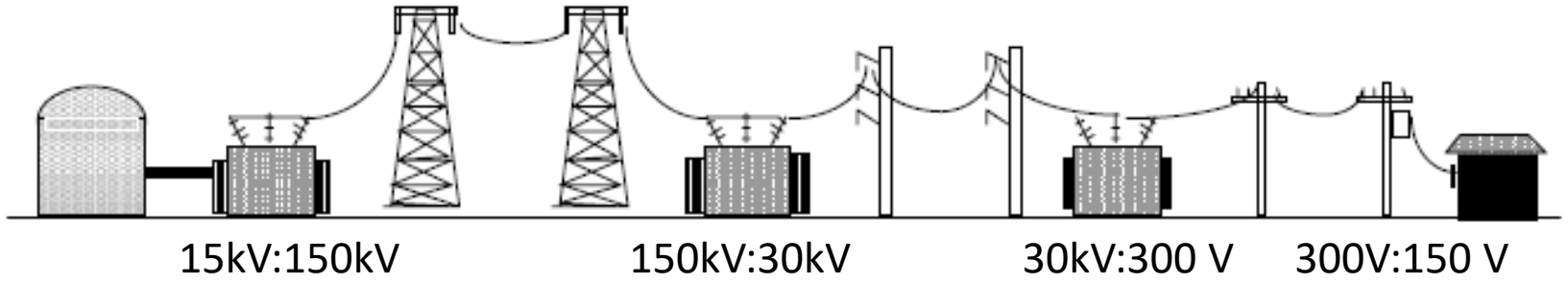
- The per unit quantity of voltage, current, power and impedance is found from dividing the actual quantity by a base value of that quantity

$$\text{per} - \text{unit quantity} = \frac{\text{actual quantity}}{\text{base value of quantity}}$$

- Per unit value is denoted by 'p.u.'
- All base values are **real numbers**, denoted by subscript '*B*'
- The base value is *used only to normalize the quantity*

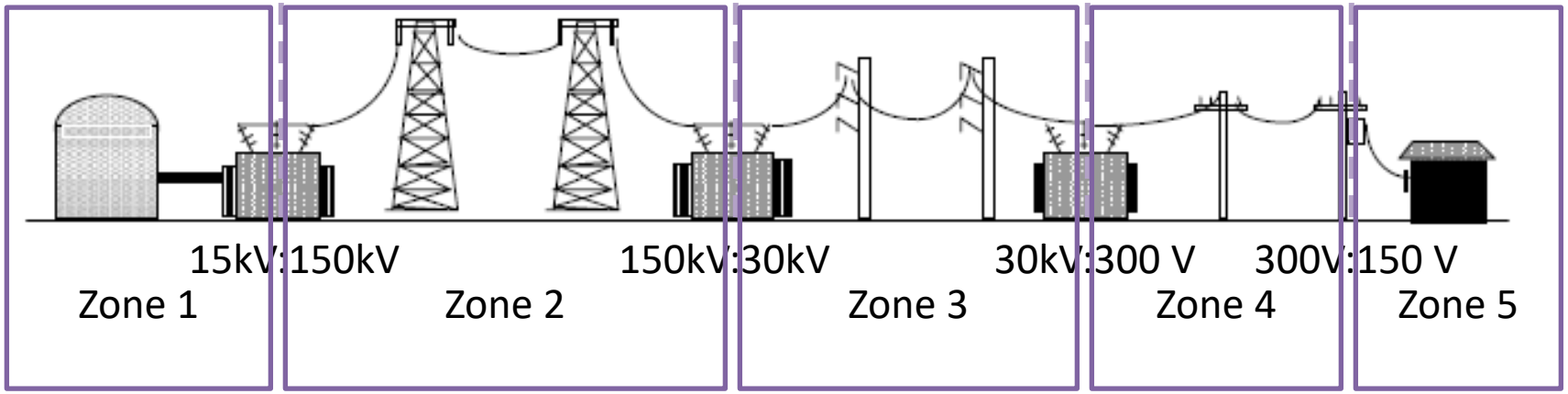
Base Value for Voltage

- Transformers separate overall circuit to different zones with different voltage levels.
- We typically set the base value quantity for voltage following transformers' voltage ratio.



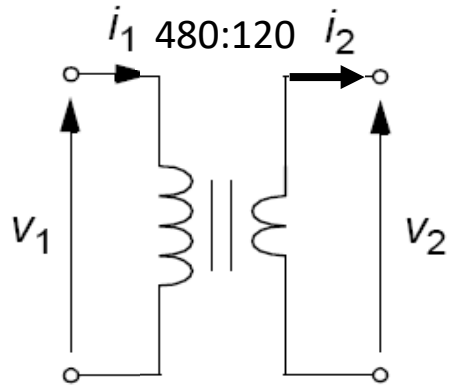
Example 1

- Consider the following electrical energy system.
  - How many zones (with different voltage level) does the system has?
  - Find the base value of the voltage at each zone.



Example 2

- Consider a single phase 480/120 V transformer.
  - Choose the base value of voltage on the primary side to be 480 and that of the secondary side to be 120.
  - If the voltage at primary is measured to be 432 V, which is 0.9 per unit, the voltage at secondary side is 108 V.
  - What is the per unit quantity on the primary and secondary side?



Base Value for Complex Power

- First, choose voltage base values following transformer voltage ratings.
- Select only **single base complex power** $S_B^{1\Phi}$ in the system.
- The base value of power is *used to* ***normalize*** *the quantity*. Thus, the base values of real power, reactive power, and complex power are all the same real number.

$$P_B^{1\Phi} = Q_B^{1\Phi} = S_B^{1\Phi}$$

Base Value for Current and Impedance

- Current base values are calculated from the base power and base voltage.

- Impedance base values (same value for impedance, resistance, or reactance) are calculated from voltage and current.

Summary