PER UNIT SYSTEM AND SINGLE LINE DIAGRAM

Basic Overview:

The per unit system simplifies power system analysis by expressing quantities as fractions of defined base values, while a single-line diagram provides a simplified, symbolic representation of a complex electrical power system using standard symbols and a single line to represent three-phase power.

Per Unit System:

The per unit (p.u.) system expresses electrical quantities—voltage, current, power, and impedance—as fractions of predefined base values. It's especially useful for analyzing power systems with different voltage levels and equipment sizes, as it avoids dealing with very large or small numbers.

To use the per unit system, base values for voltage, current, apparent power, and impedance must be defined. All system quantities can then be expressed as per unit values, simplifying calculations and comparisons.

For instance, a 100 MVA transformer with 10% impedance is represented as 1.0 p.u. and 0.1 p.u., regardless of voltage rating. This method reduces the system to simple normalized values, making it easier to analyse and compare component impedances.

Single-Line Diagram:

A single-line diagram (SLD) is a simplified graphical representation of an electrical power system. It uses a single line to represent all three phases and standard symbols for components like generators, transformers, breakers, and transmission lines.

SLDs simplify complex systems for power flow studies by showing the overall power path and configuration. They provide a high-level view of the system's topology, helping identify issues and understand connections.

Diagrams follow the physical layout (left-to-right/top-to-bottom) and may also show conduit runs for control systems, aiding both analysis and system design.

Let us dive deep into the topic to develop an in-depth understanding:

SECTION 1: INTRODUCTION TO PER UNIT SYSTEM

1. What is the per unit (p.u.) system in power systems?

Ans: The per unit system is a method of normalizing system quantities (like voltage, current, power, impedance) by expressing them as fractions of predefined base values. It simplifies calculations and comparisons across different voltage levels in power systems.

2. Why is the per unit system used in power systems?

Ans: The per unit system is used because:

- It eliminates the need for repeated unit conversions.
- It simplifies impedance calculations, especially in multi-voltage level systems.
- It helps standardize data and makes equipment ratings comparable.

3. What are the typical base quantities selected in the per unit system?

Ans:

1. **Base Power (S_{base})** – typically chosen as 100 MVA or 1 MVA.
2. **Base Voltage (V_{base})** – selected for each voltage level.
3. Derived base quantities:
    - **Base Current (I_{base})** = S_{base} / ($\sqrt{3} \times V_{base}$) for 3-phase
    - **Base Impedance (Z_{base})** = $(V_{base})^2$ / S_{base}

SECTION 2: PER UNIT CALCULATIONS AND FORMULAS

4. How is per unit value calculated for any quantity?

Ans:

Per Unit Value = Actual Value/Base Value

5. Give the formulas for base current and base impedance in a 3-phase system.

Ans:

- **Base Current (I_{base}):**

$I_{base} = S_{base}$ /sqrt3×V_{base}

- **Base Impedance (Zbase):**

$Z_{base} = (V_{base})^2/S_{base}$

6. How do you convert per unit impedance from one base to another?

Ans:

$$\%Z_{NEW} = \%Z_{OLD}\left(\frac{S_{BASE\ NEW}}{S_{BASE\ OLD}}\right)\left(\frac{V_{BASE\ OLD}}{V_{BASE\ NEW}}\right)^2$$

This is useful when all components are to be expressed on a common base.

7. What is the per unit value of a transformer’s impedance on its own rating?

Ans:
When expressed on its own MVA and voltage rating, the transformer's impedance (usually given in %) is the same as its per unit value:

Z_{pu} = Zactual/Zbase = % Z /100

SECTION 3: ADVANTAGES AND APPLICATIONS OF PER UNIT SYSTEM

8. What are the advantages of using per unit system?

Ans:

- Simplifies calculations by avoiding different units.
- Reduces numerical complexity in fault and load flow studies.
- Allows comparison of impedances across voltage levels.
- Normalizes machine parameters for easier analysis.

9. Where is the per unit system typically applied in power system studies?

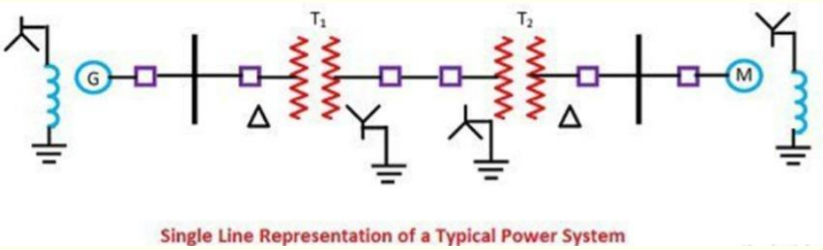
Ans:

- Load flow analysis
- Short circuit analysis
- Stability studies
- Transformer parameter simplification
- Generator and motor data representation

SECTION 4: SINGLE LINE DIAGRAM (SLD) – BASICS AND COMPONENTS

10. What is a Single Line Diagram (SLD)?

Ans:
An SLD is a simplified representation of a three-phase power system using a single line to depict all three phases. It shows the arrangement and connection of components like generators, transformers, buses, circuit breakers, and loads.



Single Line Representation of a Typical Power System

11. Why is a single line diagram used in power systems?

Ans:
Because:

- It simplifies complex 3-phase systems.
- It's easier to visualize system configuration.
- Useful for design, protection, and operation planning.

12. What components are usually shown in an SLD?

Ans:

- Generators
- Transformers
- Circuit breakers
- Bus bars
- Loads (industrial, residential, etc.)
- Transmission/distribution lines
- Protection devices (CTs, relays)

13. How are different components represented in an SLD?

Ans:
Each component has standard symbols:

- **Transformer**: Two coils with a core
- **Generator**: Circle with G
- **Bus**: Straight horizontal line
- **Circuit breaker**: Rectangular box with break line
- **Line**: Straight connection lines
- **Load**: Arrow with “Load” or resistive/inductive symbols

SECTION 5: INTERPRETATION AND USE OF SINGLE LINE DIAGRAMS

14. How do you read a single line diagram?

Ans:
To read an SLD:

- Follow the power flow from source (generator) to load.
- Identify busbars as junction points.
- Trace transformer connections to understand voltage levels.

- Note ratings and per unit values mentioned on components.

15. What information can be obtained from a single line diagram?

Ans:

- Voltage levels of each bus
- Location of generators, transformers, and loads
- Connectivity of system components
- Protection and isolation devices
- System configuration (radial, ring, or mesh)

16. Can per unit values be directly used in single line diagrams?

Ans:
Yes, per unit values (like impedance or voltage) are often marked on SLDs to simplify analysis and avoid confusion due to changing units.

SECTION 6: COMBINED USE IN POWER SYSTEM ANALYSIS

17. How are per unit systems and single line diagrams used together in power system studies?

Ans:
In SLDs, all component ratings (impedance, voltage, etc.) are often converted into per unit on a common base. This allows system-wide analysis, like fault current calculation or load flow studies, to be done uniformly.

18. How does the per unit system aid in fault analysis using SLD?

Ans:

- Impedances are normalized, making fault current calculations easier.
- Reactances of different machines and lines can be directly added.
- Helps simplify multi-bus fault current paths.

SECTION 7: APPLICATION-BASED AND CONCEPTUAL QUESTIONS

19. If a transformer has 10% impedance, what is its per unit impedance?

Ans:
Per unit impedance = 10% / 100 = 0.1 p.u.

20. How does a per unit system help in detecting abnormal conditions?

Ans:
Any value significantly deviating from the normal 1.0 p.u. (like voltage below 0.9 p.u. or above 1.1 p.u.) can indicate undervoltage or overvoltage problems.

21. Can two systems with different voltage levels be analysed together in the per unit system?

Ans:
Yes. By selecting a common base, all values can be converted to the same per unit system, regardless of actual voltage levels, enabling unified analysis.

22. How does a single line diagram help during power system operation?

Ans:

- Helps in visualizing breaker status during switching
- Shows load distribution and voltage levels
- Assists in identifying fault locations and isolating them