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Power Systems Interview Questions

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Transmission & distribution

1. What is the Ferranti effect?

The receiving-end voltage of a long, lightly loaded or open-circuited line rises above the sending-end voltage. The line's charging current flows through the series inductance, and the voltage across that inductance adds to the receiving-end voltage instead of subtracting from it. The rise grows with the square of the line length.

2. What is the difference between series and shunt compensation of a transmission line?

Series compensation puts capacitors in the line to cancel part of its series reactance, which raises the power transfer limit and helps stability. Shunt compensation connects reactors or capacitors across the line to control voltage: reactors absorb excess charging reactive power at light load, and capacitors supply reactive power at heavy load.

3. Why are bundled conductors used on extra high voltage lines?

Bundling raises the effective radius of each phase conductor, which lowers the electric field at the conductor surface. Corona loss and radio interference then fall. It also lowers the line inductance and raises its capacitance, which lowers the surge impedance and raises the power the line can carry.

4. In a string of three suspension insulator discs, the voltage across the disc nearest the conductor is 17.5 kV and the voltage across the whole string is 45 kV. Find the string efficiency.

String efficiency is the voltage across the whole string divided by the number of discs times the voltage across the disc nearest the conductor. Here that is 45 kV divided by $3 \times 17.5 = 52.5$ kV, so the string efficiency is 85.7 %.

WORKING

1. $\eta = \dfrac{V_{string}}{n \times V_{max}}$
2. $n \times V_{max} = 3 \times 17.5 = 52.5$ kV
3. $\eta = 45/52.5 = 0.857$
4. $\eta = 85.7\,\%$

5. What is surge impedance loading of a transmission line?

Surge impedance loading is the power a line delivers when the load impedance equals its surge impedance $\sqrt{L/C}$. For a lossless line at this loading, the reactive power absorbed by the series inductance equals that supplied by the shunt capacitance, so the voltage is flat along the line.

Per-unit system, bus admittance matrix and load flow

6. What is the per-unit system and why is it used in power system studies?

Each quantity is written as the ratio of its actual value to a chosen base value of the same kind. When the base voltages on the two sides of each transformer are in its turns ratio, ideal transformers disappear, so a network with several voltage levels can be solved as one circuit. Equipment impedances on their own ratings also stay in a narrow range whatever their size.

7. What is the difference between a PQ bus, a PV bus and the slack bus in a load flow study?

At a PQ bus the real and reactive power are specified, and the voltage magnitude and angle are found. At a PV bus the real power and voltage magnitude are specified, and the reactive power and angle are found. The slack bus has its voltage magnitude and angle specified, and its generator supplies whatever real and reactive power balances the system, including the losses, which are not known in advance.

8. Why does each iteration of the fast decoupled load flow cost less than one of Newton-Raphson?

Fast decoupled load flow uses the strong coupling of real power with voltage angle and of reactive power with voltage magnitude, and neglects the weak cross-coupling. This holds when line resistance is small compared with reactance and angle differences are small. The Jacobian splits into two constant matrices factorised once, so it is never rebuilt, though more iterations are needed.

9. A generator rated 50 MVA, 11 kV has a reactance of 0.2 per unit on its own ratings. Find its reactance on a base of 100 MVA and 10.5 kV.

Per-unit reactance scales directly with the base MVA and inversely with the square of the base voltage. So the new value is $0.2 \times (100/50) \times (11/10.5)^2 = 0.4 \times 1.0975$, and the reactance on the new base is 0.439 per unit.

WORKING

1. $X_{new} = X_{old} \dfrac{S_{new}}{S_{old}} \left(\dfrac{V_{old}}{V_{new}} \right)^2$
2. $X_{new} = 0.2 \times \dfrac{100}{50} \times \left(\dfrac{11}{10.5} \right)^2$
3. $X_{new} = 0.4 \times 1.0975$
4. $X_{new} = 0.439$ pu

Dispatch & control

10. What is the condition for economic dispatch of generators when transmission losses are neglected?

All units that are not at a limit run at the same incremental cost, $dF_i/dP_i = \lambda$, while the outputs add up to the load. If one unit had a higher incremental cost, moving load to a cheaper unit would lower the total cost. Units at their limits are held there.

11. Why do generators with the same percentage droop share a load change in proportion to their ratings?

Droop makes each unit's output change by $\Delta P = -\Delta f / R$, with both in per unit on its own rating, so output rises as frequency falls. In steady state all units see the same frequency change, so with equal percentage droop every unit moves by the same fraction of its rating. So a larger unit takes a proportionally larger share of the change.

12. Two generators have incremental costs of $20 + 0.2P_1$ and $25 + 0.1P_2$ in Rs/MWh, with P in MW. They must supply 200 MW, neglecting losses and ignoring limits. Find the output of unit 1.

For least cost both units run at the same incremental cost while their outputs add up to 200 MW. Setting $20 + 0.2P_1 = 25 + 0.1(200 - P_1)$ gives $0.3P_1 = 25$, so unit 1 supplies 83.3 MW and unit 2 supplies 116.7 MW.

WORKING

1. Equal incremental cost: $20 + 0.2P_1 = 25 + 0.1P_2$
2. With $P_2 = 200 - P_1$: $20 + 0.2P_1 = 45 - 0.1P_1$
3. $0.3P_1 = 25$
4. $P_1 = 83.3$ MW, so $P_2 = 116.7$ MW

13. A load of 500 kW works at 0.8 power factor lagging. Find the shunt capacitor rating needed to raise the power factor to 0.95 lagging.

The capacitor supplies the difference in reactive power between the two power factors at the same 500 kW of real power: $Q_c = P(\tan\phi_1 - \tan\phi_2) = 500 \times (0.75 - 0.3287)$. The capacitor rating needed is 210.7 kVAr.

WORKING

1. $\tan\phi_1 = \tan(\cos^{-1} 0.8) = 0.75$
2. $\tan\phi_2 = \tan(\cos^{-1} 0.95) = 0.3287$
3. $Q_c = P(\tan\phi_1 - \tan\phi_2)$
4. $Q_c = 500 \times 0.4213 = 210.7$ kVAr

Symmetrical components and fault analysis

14. Why are symmetrical components used to analyse unbalanced faults?

Any unbalanced set of three phasors can be resolved into balanced positive, negative and zero sequence sets. In a balanced network, each set sees only its own sequence network, which behaves like a single-phase circuit. An unsymmetrical fault then becomes an interconnection of three single-phase networks, which is much easier to solve than the three-phase problem.

15. What is the difference between positive, negative and zero sequence components?

Positive sequence phasors are equal in magnitude, 120 degrees apart, and have the same phase order as the system. Negative sequence phasors are also 120 degrees apart but in the opposite order. Zero sequence phasors are equal and in phase, so their currents need a return path through the neutral or ground.

16. Why does a delta winding block zero sequence current from passing through a transformer?

Zero sequence currents are equal and in phase in all three phases, so they need a neutral path to flow to or from the line. A delta winding has no neutral, so the current can only circulate inside the delta. Seen from the line side of the delta, the zero sequence path is open.

17. A bus has a Thevenin equivalent impedance of 0.25 per unit on a 100 MVA base. Find the three-phase fault level at the bus, taking the prefault voltage as 1 per unit and the fault impedance as zero.

With zero fault impedance, the fault current is the prefault voltage divided by the Thevenin impedance: $1/0.25 = 4$ per unit. At 1 per unit voltage the fault MVA in per unit equals this current, so the fault level is $4 \times 100 = 400$ MVA.

WORKING

1. $I_f = V_f / Z_{th} = 1 / 0.25 = 4$ pu
2. Fault MVA $= I_f \times S_{base}$
3. Fault MVA $= 4 \times 100 = 400$ MVA

Protection and circuit breakers

18. Why must the secondary of a current transformer never be left open while its primary carries current?

With the secondary open there is no opposing ampere-turns, so the whole primary current acts as magnetising current. The core saturates deeply and the flux changes very fast near each current zero, inducing a very high voltage in the secondary. This can break down the insulation and endanger anyone nearby.

19. What is the difference between overcurrent protection and differential protection?

Overcurrent protection operates when the current exceeds a setting, and its time delays are graded with neighbouring relays, so it also gives backup. Differential protection compares the currents entering and leaving a protected element and operates only for faults inside it, so it is fast and does not need grading.

20. An overcurrent relay with a 5 A rating is fed from a 400/5 A current transformer. The plug setting is 125 percent and the primary fault current is 4000 A. Find the plug setting multiplier.

The relay current is the primary fault current divided by the CT ratio: $4000 \times 5/400 = 50$ A. The pickup current is 125 percent of 5 A, which is 6.25 A. The plug setting multiplier is $50/6.25 = 8$.

WORKING

1. Fault current in the relay: $4000 \times 5/400 = 50$ A
2. Pickup current: $1.25 \times 5 = 6.25$ A
3. $\text{PSM} = 50/6.25 = 8$

21. Why is it easier to interrupt an AC arc than a DC arc in a circuit breaker?

AC current passes through a natural zero twice every cycle, so the arc can be extinguished at a current zero. The breaker then has to withstand the recovery voltage, so its dielectric strength must rise faster than that voltage. A DC current has no zero, so the breaker must force the current down.

Power system stability and the equal area criterion

22. What does the swing equation describe?

It describes how the rotor angle of a synchronous machine accelerates when mechanical input and electrical output differ: $\frac{H}{\pi f}\frac{d^2\delta}{dt^2} = P_m - P_e$, in per unit, with H in MJ/MVA and δ in electrical radians. A larger inertia constant makes the angle change more slowly.

23. What is the difference between steady-state stability and transient stability?

Steady-state stability is the ability to stay in synchronism after small, gradual changes, and its limit is at a power angle of 90 degrees for $P = P_{max} \sin \delta$. Transient stability is the ability to stay in synchronism after a large, sudden disturbance such as a fault; in the classical model it is judged on the first swing.

24. Why does clearing a fault faster improve transient stability?

During the fault the electrical output falls below the mechanical input, so the rotor accelerates and gains kinetic energy. A shorter clearing time means a smaller accelerating area on the power-angle curve and a larger decelerating area left after clearing. The machine stays in step if the decelerating area matches the accelerating area before the angle reaches the point where the post-fault output falls back below the mechanical input.

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