**Exercises on High Voltage Engineering (May 29, 2025):**

**Exercise 9-1:** When lightning strikes the ground, what factors determine the potential of the hit point? Suppose that the lightning current amplitude is *I*=100kA, the surge impedance of the lightning channel is *Z*0=300Ω and the ground resistance of the hit point *A* is *R*=30Ω, please calculate the potential of point *A* (*UA*, kV).

Influencing factors: lightning current amplitude, ground resistance at the strike point, and wave impedance of the lightning channel.

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**Exercise 9-2:** A cylindrical oil storage tank with the diameter of 10m and the height of 10m is protected by a single lightning rod, which is 5m away from the wall of the oil tank. What is the minimum height of the lightning rod?

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**Exercise 9-5:** When lightning strikes an overhead transmission line, does the circuit breaker trip every time?

The circuit breaker does not trip every time. When a lightning strike causes a lightning overvoltage on the transmission line, if the lightning current exceeds the lightning withstand level under the given conditions, it will lead to insulation flashover. However, since the duration of the lightning overvoltage is extremely short-, the high-voltage circuit breaker does not have enough time to trip. A trip only occurs when the initial impulse flashover develops into a sustained power-frequency arc.

**Exercise 9-6:** When determining the lightning withstand level of an overhead transmission line, what polarity of the 50% impulse flashover voltage of the insulator string is used to calculate the amplitude of overvoltage when lightning strikes the phase conductor or the top of tower respectively?

(1) Lightning Overvoltage on Conductors: The negative-polarity 50% flashover voltage of the insulator string is used for calculation. This is because the polarity of direct lightning overvoltage is the same as that of the thundercloud charge, and in China, negative-polarity lightning is statistically more probable.

(2) Lightning Overvoltage on Tower Top: The positive-polarity 50% flashover voltage of the insulator string is used for calculation. The reason is that in China, most lightning strikes are of negative polarity. When lightning strikes the tower top, the tower-end potential of the insulator string becomes negative while the conductor-end potential becomes positive, which closely resembles the conditions of a positive-polarity impulse test on the insulator string.

**Exercise 9-8:** What are the parameters to evaluate the lightning withstand level of an overhead transmission line? For lightning strike the phase conductor or the top of tower, which case the value of this parameter will be greater than the other, and why?

(1) Parameter: In engineering, the lightning withstand level is primarily used as the key metric.

(2) Comparison: The lightning withstand level is higher for lightning strikes on the tower because the tower's grounding resistance is very low. For the same lightning current magnitude, the resulting backflashover voltage is lower than the overvoltage caused by a direct strike to the conductor, making insulation flashover less likely to occur.

**Supplementary Exercise 1:** The weight of the silicone rubber composite surge arrester is much lighter than that of the porcelain one, so it can be suspended on the transmission tower, see Page 49 of the document for May 29. Please analyze how the line arrester improves the lightning withstand level of the line when lightning strikes different part of transmission line (strike tower top or phase conductor).

(1) Surge arrester is essentially a discharge device installed in parallel close to the protected equipment. Under normal conditions, it remains non-conductive (with a series gap) or only allows microampere-level current to pass (without a series gap).

(2) When the applied overvoltage reaches the arrester operation voltage, the arrester conducts a large current, dissipates the overvoltage energy, and limits the overvoltage to a certain level.

(3) After discharging the overvoltage energy, the arrester recovers to its original state.

**Supplementary Exercise 2:** Describe the working principle of ZnO arrester briefly.

(1) During normal operation, ZnO exhibits a high-resistance state, allowing only a minimal current flow (a few microamperes).

(2) When an overvoltage occurs, ZnO switches to a low-resistance state, clamping the residual voltage of the surge current at a controlled level to prevent circuit tripping.

(3) Once the surge voltage subsides, the voltage decreases, and ZnO reverts to its high-resistance state, reducing the power-frequency follow current back to the microampere level.

**Supplementary Exercise 3:** What is the residual voltage of surge arrester? What is the reference voltage of surge arrester?

(1) Arrester residual voltage: Refers to the maximum voltage across the arrester terminals when discharge current flows through it.

(2) Reference voltage: The voltage across the arrester at the reference current, which is typically set at the knee point of the metal-oxide arrester's nonlinear voltage-current characteristic. This reference current is generally 1.25 times the maximum operating voltage.