**Exercises on High Voltage Engineering (Mar 13, 2025):**

**Exercise 2-5:** Under the impulse voltage, why is the electrical strength of the gap expressed not only by the 50% breakdown voltage, but also by the voltage-time characteristic? Please use the curve in Figure 2-27(a) of this textbook to draw the voltage-time characteristic curve of 4m air gap within 10μs with voltage as the vertical axis and time as the horizontal axis.

由于放电时延的存在，气隙的击穿过程需要一定的时间才能完成。因此，峰值较低但持续时间较长的冲击电压可能导致击穿，而峰值较高但持续时间较短的冲击电压则可能无法引发击穿。

一張含有 行, 繪圖, 圖表 的圖片

AI 產生的內容可能不正確。

**Exercise 2-6:** How are the voltage-time characteristics of the air gap obtained in laboratory?

逐步增加冲击电压的峰值，同时保持波形不变。当电压较低时，击穿现象出现在波形的尾部。尽管在击穿发生前的瞬间，电压已从峰值降至某一数值，但该峰值仍是导致气隙击穿的关键因素。因此，以该电压峰值为纵轴，击穿发生的时刻为横轴，可以确定一个坐标点。随着电压的进一步提升，击穿可能恰巧发生在波形的峰值处，这一点自然成为伏秒特性曲线上的一个标记。当电压继续升高，气隙可能在电压达到波形峰值之前就被击穿，此时又可确定另一个坐标点。

**Exercise 2-7:** What is the relation between the electric field distribution and voltage-time characteristics of a gas gap?

间隙的伏秒特性曲线的形态受电极间电场分布的影响。

在极不均匀的电场中，由于平均击穿场强较低且放电时延较长，其伏秒特性曲线随着放电时间的减少而显著向上翘起。

在均匀或稍不均匀的电场中，由于平均击穿场强较高且放电时间相对较短，因此其伏秒特性曲线显得较为平缓。

**Exercise 2-9:** When actually measuring the electrical strength of an air gap under impulse voltage, how to determine its 50% discharge voltage *U*50? With *U*50, how to determine the withstand voltage of this air gap for a certain withstand probability?

确定50%放电电压：在保持标准波形不变的前提下，逐步提高电压幅值，每一级电压施加10次，直到在每10次施加中有4至6次发生击穿，此时的电压可视为该间隙的大致50%放电电压。

确定耐受电压：通常认为放电电压的放电概率遵循高斯分布，若分散性取相对标准偏差𝜎 = 3%。对于放电能够自恢复的外绝缘，可以采用𝑈50(1 − 1.3𝜎)作为耐受电压；对于安全要求更高的场合，则可以采用𝑈50(1 − 3𝜎)作为耐受电压。

**Exercise 2-12:** It is known that the maximum surface field stress of the ground wire is 13.9kV/cm, the radius of the ground wire is *r*=0.53cm, the maximum field stress of the split conductor is 23.3 kV/cm in phase A, 25.2 kV/cm in phase B, and the radius of the conductor is *r*=1.18cm. Please estimate whether the corona occurs under the following atmospheric conditions (the field stress given in the question is the peak value, surface roughness coefficient is *m*=0.82)?

(1) Standard reference atmospheric conditions; (2) *t*=35℃, *p*=99.9kPa.

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AI 產生的內容可能不正確。

**Supplementary Exercise 1:** According to the experimental curve in Figure 2-41 of the textbook, please draw the relationship between the gap breakdown field strength and the air pressure when the electrode distance *d*=2.0cm and *d*=0.5cm respectively.

正极性直流击穿电压约为 330kV，负极性直流击穿电压约为 780kV。

工频击穿电压约为 270kV。

**Supplementary Exercise 2:** According to the experimental curve in Figure 2-42 of the textbook, please calculate the gap breakdown voltage and the corresponding breakdown strength when the gap distance is 2mm, 5mm, 10mm and 30mm respectively.

𝑑/mm 𝑈𝑏/kV 𝐸𝑏/(MV ∙ cm−1)

2 150 0.75

5 220 0.45

10 280 0.30

30 450 0.20

**Supplementary Exercise 3:** As a commonly used internal dielectric gas for high voltage equipment, what are the advantages and disadvantages of SF6? Why are countries trying to develop alternative gases of SF6 in recent years? What are the measures for reducing the total amount of SF6?

优点：

绝缘性能优异，灭弧能力强。

化学稳定，热传导性好。

缺点：

强效温室气体，GWP是CO₂的23,500倍。

成本高，泄漏后难回收，高温下可能产生有毒物质。

各国开发SF6替代气体的原因：

环保压力大，需减少温室气体排放。

政策法规限制SF6使用。

技术进步，替代气体性能接近或优于SF6。

减少SF6总量的措施：

推广环保替代气体（如干燥空气、氟化酮）。

改进设备设计，减少SF6依赖。

加强SF6回收与泄漏检测。

**Supplementary Exercise 4:** In the selected topic document on OHLs-1, some photos of the self-supporting tower, tension tower and guyed tower of overhead transmission line are given.

(1) What is the main role of the tension tower? What are the main advantages and disadvantages of a guyed tower?

(2) What is the main function of insulators in the overhead line?

张力塔主要用于承受架空输电线路中导线的张力，特别是在线路转角、跨越障碍物或线路分段处。它能够固定导线，防止导线因张力过大而松动或断裂，同时确保线路的机械稳定性。

优点：

成本低：拉线塔结构简单，使用的材料较少，建造和维护成本较低。

重量轻：由于采用拉线支撑，塔身可以设计得更轻便，适合在偏远或难以到达的地区安装。

适应性强：拉线塔可以灵活调整高度和跨度，适应复杂地形。

缺点：

占地面积大：拉线需要较大的地面空间来固定，可能受限于土地使用。

维护复杂：拉线容易受到环境影响（如腐蚀、松动），需要定期检查和维护。

美观性差：拉线塔的外观不如自立塔简洁，可能影响景观。

绝缘子的主要功能：

电气绝缘：绝缘子的主要作用是防止导线与塔身之间发生电气接触，确保电流沿导线传输而不泄漏到地面。

机械支撑：绝缘子需要承受导线的重量、风荷载和其他机械应力，确保导线稳定悬挂。

耐环境性能：绝缘子需耐受恶劣环境条件（如雨、雪、污染、紫外线等），保持长期稳定的电气和机械性能。

**Supplementary Exercise 5:** A ±500kV HVDC project with a transmission distance of 1000km and the rated power of 3 GW. 4-split conductor is used. The aluminum cross section for each split conductor is 685mm2 on pages 25-26 of the selected topic document on OHLs-1, and the HVDC project runs 5000h per year at rated power with the conductor temperature of 20℃, please calculate how many kWh is lost per year by the resistance of this OHL. For each split conductor, if the aluminum cross-section of 806mm2 is adopted, please calculate again the annual resistance loss of the OHL under the same operating conditions.

