Research on the selection of power distribution equipment in 220kV substation based on life cycle

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Abstract. Based on the concept of life cycle and the conditions of 220kV station, the technology and economy of GIS, HGIS and AIS of 220kV and 110kV sides are compared, the main cost of 30 years' construction from putting the equipment into operation to decommissioning are analyzed, and the cost from 2049 to 2019 according to the discount rate are calculated. Based on the life cycle cost objective function, the optimal solution is obtained, and the lowest cost distribution device selection scheme is obtained.

Key words: life cycle, power distribution equipment selection, substation, HGIS, GIS, AIS.

1. Overview of planned substation
The substation is divided into three areas according to its functions, namely, 220kV distribution area, main transformer and 10kV reactive power compensation device area and 110kV distribution device area. According to the general electrical layout, 220kV power distribution device, main transformer, 10kV reactive compensation device and 110kV power distribution device are arranged from south to North in the station area; 1#, 2# and 3# main transformers are located in the middle of the station area and arranged from west to East. The main control building is arranged at the east wall of the station area. The substation faces to the north, the gate is located at the east end of the North enclosure, and the access road is connected from Township Road Y009. The length is about 110 m from north to South and 150 m from east to west. The usable area of substation site is small.

According to the calculation results of short-circuit current, the short-circuit current level of 220kV equipment in the station is selected as 50kA, the short-circuit current level of 110kV equipment is selected as 40kA, and the short-circuit current level of 10kV equipment is selected as 31.5/40 kA.

Long term planning of outgoing line of the substation: 6 overhead outgoing lines. This phase: 2 overhead outgoing lines. Long term planning of 110kV outgoing line: 12 overhead outgoing lines. This phase: 4 overhead outgoing lines. Long term planning of 10kV outgoing line: 20 cable outgoing lines, 10 outgoing lines in this phase.

The following focuses on the analysis of the 220kV and 110kV power distribution equipment selection of the 220kV substation.
2. Scheme comparison of high voltage switchgear

According to the long-term construction scale and existing site conditions of commercial 220kV substation, considering the requirements of floor area and project cost, three possible schemes of high-voltage switchgear are compared and analyzed.

2.1. Comparison of floor area of distribution equipment

220kV electrical main wiring adopts double bus connection, with 2 outgoing lines in this phase and 6 outgoing lines in the final phase. The floor area of GIS, HGIS and AIS power distribution devices on 220kV side is compared.

110kV electrical main wiring adopts the form of single bus and three sections, with 4 outgoing lines in this phase and 12 outgoing lines in the final phase. The floor area of GIS, HGIS and AIS power distribution devices on 110kV side is compared.

(1) Layout plan of three design schemes

![Figure 1. Single row layout of air insulated switchgear (AIS) suspension tube bus](image1.png)

![Figure 2. Scheme of SF6 enclosed combined electrical appliance (GIS)](image2.png)
Fig. 3 mixed sulfur hexafluoride enclosed composite apparatus (HGIS)

(2) Scheme comparison of 220kV power distribution device
The land area of power distribution equipment in three schemes is as follows:
AIS: 150m × 51m = 7650 m² = 11.48mu
GIS: 83.5 × 24 = 2004 m² = 3.01 mu
HGIS: 75 × 33 = 2475 m² = 0.0015 * 2475 = 3.7125mu
GIS power distribution device and HGIS power distribution device can meet the requirements of land saving.

(3) Comparison of floor area of three schemes of 110kV power distribution device
AIS: 136m × 37.5m = 5100 m² = 7.65mu
GIS: 60 × 18 = 1080 m² = 1.62 mu
HGIS: 136 × 22 = 2992 m² = 4.49 mu
Air insulated switchgear (AIS) of the project increases the transverse dimension of the whole station, the remaining building area is too large and the land is wasted, so it is not considered to be used. GIS power distribution device and HGIS power distribution device can meet the requirements of land saving.

2.2. life cycle cost comparison
In this topic, the concept of life cycle is applied, and the technical and economic comparison of 220kV and 110kV GIS, HGIS and AIS is carried out based on the station site conditions. The main costs of the 30-year construction from putting the equipment into operation to decommissioning are analyzed. From 2048, the costs of decommissioning will be calculated from the discount rate to 2018 when the substation is put into operation. The formula is as follows:

\[ p = \frac{A_1}{1 + X} + \frac{A_2}{(1 + X)^2} + \frac{A_3}{(1 + X)^3} + \cdots + \frac{A_{30}}{(1 + X)^{30}} \]

Where, \( A_n \) is the cost value of the nth year, \( X \) is the discount rate, \( p_n = \frac{1}{(1 + X)^n} \) is the conversion coefficient of the expenses generated in the nth year discounted to the year of equipment put into operation.

The calculation formula of life cycle cost is as follows:
\[ C = \sum_{n=1}^{30} p_n \times (C_{\text{invest}} + C_{jz} + C_{az} + C_{zd} + C_{m} + C_{o}) \]

Including equipment purchase cost, construction engineering cost, installation engineering cost, land occupation cost, operation and maintenance and power failure loss.

The calculation time is based on the 30-year service cycle of the equipment. The current discount rate is 6.55%. From 2048 when the equipment is decommissioned, the annual cost is calculated according to the discount rate to the cost conversion value of the year when the substation is put into operation.

2.2.1. Life cycle cost analysis of 220kV power distribution equipment. The technical and economic comparison of 220kV GIS, HGIS and AIS is shown in Figure 4 with the concept of life cycle and the station site conditions. In Figure 4, the total cost is all the expenses incurred in the current year of the substation, and the life cycle cost is the converted value of the year when the substation is put into operation. As can be seen in Figure 4:

(1) In the construction of this phase, the cost of land occupation, construction engineering and installation engineering of HGIS scheme is significantly better than that of AIS scheme, and the cost of equipment purchase is significantly better than that of GIS scheme.

(2) In the long-term construction process, considering the equipment purchase cost, maintenance cost and power failure cost, the comprehensive cost of HGIS in each expansion period is slightly higher than that of AIS scheme, but significantly lower than that of GIS scheme.

(3) The 30-year life cycle cost of HGIS scheme equipment is reduced by 2.65 million yuan compared with AIS scheme; the 30-year life cycle cost of HGIS scheme equipment is reduced by 1.548 million yuan compared with GIS scheme.

(4) Considering the discount rate, the total cost is more affected by the recent outage loss cost, so HGIS equipment has more advantages in economy because of less outage loss compared with AIS equipment. Considering the rising trend of land price, HGIS equipment will have more advantages in the future.

2.2.2. Life cycle cost analysis of 110kV power distribution equipment. The technical and economic comparison of 110kV GIS, HGIS and AIS Based on the concept of life cycle and site conditions is shown in Figure 5.

(1) Due to the large number of 110kV outgoing lines, the difference between the equipment purchase cost of 110kV GIS and HGIS single bay is not significant, and the cost advantage of HGIS in equipment purchase cost is not obvious compared with 220kV.

(2) Due to the large number of 110kV outgoing lines, the advantage of GIS in the area occupied is enlarged, which makes the cost of land occupation of GIS scheme obviously better than that of HGIS scheme. At the same time, the construction cost and installation cost of GIS scheme are better than HGIS scheme.

(3) In the long-term construction process, considering the equipment purchase cost, maintenance cost and power failure cost, the comprehensive cost of GIS in each expansion period is slightly lower than that of HGIS scheme.

(4) The 30-year life cycle cost of equipment in GIS scheme is 1.17 million yuan lower than that in HGIS scheme.
Figure 4. Comparison column chart of annual cost and life cycle cost of three 220kV schemes

Figure 5. Column chart of annual cost and life cycle cost comparison of three schemes

2.3. Summary
(1) In terms of the floor area of the power distribution device,

| Floor area of power distribution device | AIS (m²) | GIS (m²) | HGIS (m²) |
|----------------------------------------|----------|----------|------------|
| 220kV                                  | 150×51=7650 | 83.5×24=2004 | 33×75=2475 |
| 110kV                                  | 136m×37.5m=5100 | 60×18=1080 | 22×136=2992 |
GIS power distribution device and HGIS power distribution device can meet the requirements of land saving.

(2) From the perspective of life cycle cost, the comprehensive cost of HGIS scheme in the early stage of 220kV is lower than that of GIS scheme and AIS scheme; within the 30-year life cycle of equipment, HGIS scheme saves 2.65 million yuan compared with AIS scheme and 1.54 million yuan compared with GIS scheme. HGIS scheme is the best.

The comprehensive cost of 110 kV GIS scheme is lower than that of HGIS scheme; in the 30-year life cycle of the equipment, the GIS scheme saves 1.17 million yuan compared with HGIS scheme. The GIS scheme is the best.

(3) The biggest advantage of HGIS scheme is the high degree of equipment integration. A single HGIS device integrates 5 electrical elements, including circuit breaker, disconnector (2 busbar disconnectors for the project), current transformer and voltage transformer, which is convenient to realize the intelligence of primary equipment, save land occupation and small amount of earth construction. At the same time, SF6 gas insulated equipment has high reliability, long service life and little environmental impact. And can use air insulated aluminum tube bus, equipment compatibility is high, expansion is simple and flexible. HGIS has the advantages of high integration and reliability of GIS equipment, high compatibility of AIS equipment and flexible expansion.

3. conclusion
To sum up, according to the characteristics of 220kV substation site planning, through the technical and economic comparison of the floor area, life cycle cost and advantages and disadvantages of AIS, GIS and HGIS three kinds of high-voltage switchgear, it is concluded that HGIS scheme is the most reasonable scheme for 220kV substation and GIS scheme for 110kV Substation.

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