Research on Pricing Model of Power Cable into the Pipe Gallery

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Abstract. The pipe gallery is an important content of future smart city construction. Scientific calculation of the paid service fee of power cable corridor can provide a basis for formulating the charging price of power cable corridor. This article studies the domestic commonly used comprehensive utility tunnel fees allocation method, comprehensive consideration of utility tunnel construction cost allocation method, the power pipeline laying alone cost method, the advantages of the comprehensive evaluation method, combining with the actual situation of electric power line, and then the power cable into the gallery fees calculation model is established, and the applicability of the model is verified by actual case calculation.

Keywords: Pricing model, power cable, case analysis.

1. Measuring Purpose

The pipe gallery is an important infrastructure for future urban development in China and an important part of smart city. In the urban infrastructure construction documents issued by China, it is clearly pointed out that the construction of comprehensive pipe corridor in old and old urban areas and the construction of comprehensive pipe corridor in new urban areas should be carried out[1]. At the same time, the urban pipe gallery in China adopts the management mechanism of paid use. The pipeline unit should pay the paid use fee of the pipe gallery to the pipe gallery construction and operation unit, negotiate and determine the underground pipe gallery charging standard, and form a reasonable charging mechanism[2].

The Power pipeline entrance gallery is an important content of pipeline corridor construction. It is of great significance to reduce the mutual interference between pipelines and promote the full and reasonable development and application of urban underground space resources[3]. However, the investment of power cable corridor is huge, especially when the existing power grid corridor transformation does not increase the power supply revenue, so it is very difficult to recover investment through the current electricity pricing mechanism[4]. At the same time, the state requires that power lines must be connected to the corridor and paid royalties will be paid, which will further aggravate the operating burden of power companies. How to reasonably and scientifically measure the paid cost of power cable access becomes the focus of common concern of power companies and the construction and operation units of comprehensive pipe corridor[5]. Therefore, by comparing various calculation methods at home and abroad, this paper establishes a more systematic and comprehensive model for calculating the paid user fee of power cables entering corridor, providing reference for the formulation of relevant charging standards, balancing the interest demands of power companies and the construction and operation units of comprehensive pipeline corridor, and improving the enthusiasm of power pipelines.

2. Calculation Ideas

The paid service fee of the pipe gallery includes the entrance fee and the operation and maintenance fee, which is mainly used to compensate the construction cost of the comprehensive pipe corridor. The operation and maintenance fee refers to the management and maintenance fee incurred after the pipe corridor is put into use. In general, the entry fee is calculated and apportioned according to the direct buried pipeline cost, and the operation and maintenance fee is apportioned according to the actual cost. The core issue of the two cost estimates is how to apportion. The method of direct cost ratio, space ratio, or direct cost as pipeline cost is used to apportion the cost of corridor. The allocation of operation and maintenance costs mainly adopts the space proportion method, space and income average proportion method. At present, the allocation method of pipe gallery in China is shown in Table 1.

The spatial proportion method and the direct-buried cost ratio method are more considered from the perspective of the recovery cost of the construction and operation unit of the pipe gallery. However, the pipe gallery’s investment is huge, and the simple proportional allocation is not lower than the cost of separate laying, or even higher than the cost of separate laying.

The government's "bottom line" margin law is based on the principle of "who benefits and who pays". As the representative of the ultimate beneficiaries, the government should also bear a certain proportion of the costs. Therefore, the cost recovery of the construction and operation units should be considered when considering the cost allocation of the comprehensive pipeline corridor, as well as the upper limit acceptable to all pipeline units, and the difference should be made up by the government.

This paper takes the calculation of power cable entrance fee as the research focus, combines the advantages of various methods, and combines the actual situation of power pipeline to formulate a comprehensive measurement model. Finally, the actual case calculation is used to verify the applicability of the model.

3. Measuring Model

3.1 Influencing Factors

According to the “National Development and Reform Commission and the Ministry of Housing and Urban-Rural Development to Guide Local Establishment and Improvement of the Urban Underground Pipe Gallery Paid Use System” (Price [2015] No. 2754), the factors that constitute the paid use fee of urban underground integrated

a) Reasonable construction investment of urban underground utility tunnel's main body and ancillary facilities.

b) Reasonable return on investment in the construction of urban underground utility tunnel's main body and ancillary facilities shall be determined in principle with reference to the long-term loan interest rate of financial institutions (the return on investment is not calculated for assets formed by government financial investment).

c) Proportion of pipe gallery space occupied by each corridor - entering pipeline.

d) The separate laying cost of each pipeline without entering the pipe gallery (including road occupation excavation cost, excluding pipe purchase and installation cost, the same as below).

e) The cost of repeated and separate installation of each pipeline in the absence of access to the pipe gallery during the design life cycle of the pipe gallery.

f) The cost of pipeline maintenance and production and operation saved due to the reduction of pipeline damage rate, water, heat and gas leakage rate during the design life cycle of pipe gallery compared with the situation of no pipe gallery.

g) Other influencing factors. For power pipelines, the value-added revenue of land transfer is mainly considered after overhead cable. According to the opinions of the ministry of housing and urban-rural development and the national energy administration on promoting the inclusion of electric power pipelines into the urban underground comprehensive pipe corridor (City-construction [2016] No. 98), various cities can consider the factors of value-added revenue from land transfer of electric overhead lines into and out, and give reasonable compensation to electric power pipelines into the corridor. In general, high voltage overhead wire cabling needs to take the value-added revenue of land transfer into account, but medium voltage overhead wire cabling is not considered.

Table 1. Apportionment method for paid use fee of utility tunnel

scholars	time of proposal	calculating method	The gallery fee	Operation and maintenance costs
Shoubiao Chen	The year 2005	Spatial proportional method	$Yi=Czi+Cpi+(Uc-Cz-Cp-Cs)\times C_{i1}$	D=Cmc×Wi1
Jian Wang	The year 2008	Spatial proportional method considering public space Direct buried cost ratio method	$Yi=Czi+Cpi+(Uc-Cz-Cp-Cs)\times W_{i2}$ $Yi=Czi+Cpi+(Uc-Cz-Cp-Cs)\times Ri$	Di=Cmc×Wi2 Di=Cmc×Ri
Ding Song	The year 2014	Government "bottom" difference method	The government subsidy is the difference between the annual rent expected by the investor and the acceptable annual rent of the pipeline unit. The investor calculates the annual rent with all the investment, and the pipeline unit calculates the annual rent with the direct burial cost.	Di=Cmc×Wi1

Note: Yi is the admission fee of pipeline I; Cz_i is the direct buried cost of pipeline I (direct buried cost of pipeline refers to the cost of pipeline laying alone); Cp_i is the compensation for pipeline I removal; Uc is the investment of comprehensive pipe gallery; Cz_i directly covers the cost of all pipelines; Cp is the compensation fee for all pipeline removal; Cs subsidizes all pipelines; Di is the operation and maintenance fee of pipeline I; C_{mc} is the operation and maintenance cost of the comprehensive pipe gallery in this year; Wi1 is the space share allocation factor, $W_{i1}=(V_i/\sum v_i+S_i/\sum S_i)/2$, where, V_i is the space occupied by pipeline I, V is the total space in pipe gallery, and Si is the annual income of pipeline I. W_{i2} is the allocation coefficient of the space proportion of public space, and $W_{i2}=[V_i+(V-V_i)\times V_i/\sum V_i]/V$; R_i is the allocation coefficient of direct buried cost.

3.2 Pipe Gallery Construction Cost Allocation Method

The construction cost allocation method of pipeline corridor mainly includes space proportion method and direct buried cost ratio method. $(C_T+C_NR_B)\ L_H-I_L$.

3.2.1 Spatial Proportional Method

Items a, b, c and g considering the influencing factors are based on the reasonable investment cost of urban underground pipe gallery construction, and the calculation formulas of high pressure and medium pressure are as follows:

$$Y_{H1}=\begin{cases}\frac{(C_T+C_NR_B)V_H-I_L}{L_H}, I_L<(C_T+C_NR_B)V_H\\ 0, I_L\geq(C_T+C_NR_B)V_H\end{cases} \tag{1}$$

$$Y_{M1}=\frac{(C_T+C_NR_B)V_M}{L_M} \tag{2}$$

Where: Y_{H1} and Y_{M1} respectively refer to the corridor fee per unit length of high-voltage and medium-voltage cables calculated by the spatial proportion method, yuan/ (hole ·m); C_T is the total investment of the pipeline gallery, which is the sum of government financial input and non-government financial funds, ten thousand yuan; C_N is a non-government financial fund of ten thousand yuan; R_B is the reasonable investment rate of return for construction investment; V_H is the proportion of pipe gallery space occupied by V_H cable cabin space; V_M is the proportion of pipe gallery space occupied by medium pressure cable cabin space; L_H is the total length of the pipe hole of the high-voltage cable cabin, m; L_M is the total length of the pipe hole of the neutral pressure cable cabin, m; I_L is the value-added revenue of land transfer after overhead cabling, RMB 10,000 yuan.

3.2.2 Direct Buried Cost Ratio Method

When using the proportion of the separate laying cost of each pipeline to the separate laying cost of all pipelines to apportion the construction investment of pipe gallery, the calculation formula is as follows:

$$Y_{H1}=\begin{cases} \dfrac{(C_T+C_NR_B)C_H-I_L}{L_H} \\ I_L<(C_T+C_NR_B)V_H \\ 0,\ \ I_L\geq\ (C_T+C_NR_B)V_H \end{cases} \tag{3}$$

$$Y_{M2}=\frac{(C_T+C_NR_B)C_M}{L_M} \tag{4}$$

Where: Y_{H2} and Y_{M2} respectively refer to the corridor fee per unit length of high-voltage and medium-voltage cables calculated by the direct buried cost ratio method, yuan/ (hole ·m); C_H is the ratio of the cost of laying the high-voltage cable alone to the sum of the cost of laying all the pipelines separately; C_M is the ratio of the separate laying cost of medium voltage cable to the sum of the separate laying cost of all pipelines.

3.3 Separate Cost Method for Power Pipelines

Items d, e and f considering the influencing factors are based on the separate laying cost of power pipelines, and the calculation formula is as follows:

$$Y_{H3}=C_{H,U}N+C_R \tag{5}$$

$$Y_{M3}=C_{M,U}N+C_R \tag{6}$$

Where: Y_{H3} and Y_{M3} are respectively the corridor entrance fee per unit length of high-voltage and medium-voltage cables calculated by the cost method of laying power pipelines separately, yuan / (hole· m); C_H , U are the unit cost of laying high voltage cables separately without entering the pipe gallery, yuan / (hole· m); C_M, U is the unit cost of laying medium voltage cables separately without entering the pipe gallery, yuan / (hole· m); N is the number of times that power pipelines are laid separately without entering the pipe gallery during the design life cycle of utility tunnel, generally 4 times. C_R is the pipeline maintenance, production and operation cost saved by the reduction of pipeline damage rate in the design life cycle of the corridor, compared with the situation where the power pipeline entering the corridor does not enter the corridor. It is difficult to obtain relevant data at this stage, so it is generally not considered in the actual calculation.

3.4 Comprehensive Evaluation Method

The core idea of the comprehensive evaluation method is the calculation results of the comprehensive space proportion method, the direct buried cost ratio method and the independent cost method for laying electric pipelines, balancing the interest demands of the electric power company and the construction and operation unit of the comprehensive pipeline corridor, reflecting the government's "bottom line" function as the ultimate beneficiary of the comprehensive pipeline corridor. The construction and operation unit of the comprehensive pipeline corridor hopes to recover the cost and ensure reasonable profit. The upper limit of the corridor fee accepted by the power company as one of the corridor pipeline units is "the cost of the separate installation of the power pipeline". Therefore, when the two are expected to be different, the government should make up the difference by means of subsidies, allowing cost transfer, etc. As the "underwriter", so as to mobilize the enthusiasm of the construction and entrance of the comprehensive pipeline corridor. The calculation formula is as follows:

$$Y_H = MIN\left(\frac{Y_{H1}+Y_{H2}}{2}, Y_{H3}\right) \tag{7}$$

$$Y_M = MIN\left(\frac{Y_{M1}+Y_{M2}}{2}, Y_{M3}\right) \tag{8}$$

Where: Y_H and Y_M are the unit length entrance fees for high-voltage and medium-voltage cables measured by the comprehensive evaluation method, yuan/ (hole· m). When $Y_H = Y_{H3}$ or $Y_M = Y_{M3}$, it indicates that the entrance fee expected by the pipe gallery construction and operation unit has exceeded the upper limit which is acceptable to the power company, and the government needs to make up the difference through direct subsidy or other forms.

$$S_H = \frac{Y_{H1}+Y_{H2}}{2} - Y_H \tag{9}$$

$$S_M = \frac{Y_{M1}+Y_{M2}}{2} - Y_M \tag{10}$$

Where: S_H, S_M are the subsidies for the unit length of the high-voltage and medium-voltage cables that the government should give, yuan/(hole· m).

4. Case Analysis

A pipe gallery in an eastern coastal city has a length of 5.9km, with a total investment of 500 million yuan, of which the government's financial input accounts for 30%. The pipe gallery is composed of comprehensive cabin and power cabin, in which the comprehensive cabin is 1.8m x 2.4m (width x height) and contains three kinds of pipelines such as medium-voltage cable, communication and water supply, and the medium-voltage cable channel is 15 holes. The specification of power cabin is 3m x 2.4m (width x height), all used to accommodate 220kV and 110kV cables, which can accommodate 8 times, a total of 24 holes. By calculation, the proportion of pipe gallery space occupied by high-voltage and medium-voltage cabins was 62.5% and 18.3% respectively.

Other known conditions: the reasonable rate of return on investment of construction investment is 4.9% of the benchmark interest rate of bank loans over 5 years; Currently, the value-added revenue from land transfer after high voltage overhead cabling is 187 million yuan. The average cost per unit of high-voltage cable laying alone is 972 yuan/ (hole ·m); The average cost per unit of medium voltage cable laying alone is 250 yuan/ (hole ·m); The cost of laying high voltage cable alone accounts for 65% of the cost of laying all the pipelines alone. The cost of laying medium voltage cable alone accounts for 10% of the cost of laying all the pipelines alone.

The above known data is substituted into the calculation formula in the calculation model, and the results are shown in Table 2.

Table 2. measurement and calculation results

	calculating methods	High-voltage cable entrance fee / [yuan· (hole· m)$^{-1}$]	Medium-voltage cable entrance fee/ [yuan· (hole· m)$^{-1}$]
Pipeline construction cost sharing method	Spatial proportional method	960	1069
	Direct buried cost ratio method	1051	584
	average value	1005	827
Power line separate laying cost method		972	250
Comprehensive assessment	The entrance fee for the power company	972	250
	Government subsidies	33	577

From the final result, the high-voltage cable entrance fee and the medium-voltage cable entrance fee have all selected the calculation results of the power line separate laying cost method, but relying solely on the entrance fee paid by the power company, the pipe gallery construction and operation unit is difficult to recover. Cost, in which case the government needs to make up the difference through direct subsidies or other forms. The government subsidies for high-voltage cable entrance fees are less than the medium-voltage cable entrance fees. This is due to the fact that the value-added income of land transfer after the high-voltage overhead cable is large, which offsets a large amount of expenses, making the calculation result of the cost-sharing method of the pipe gallery construction slightly It is higher than the calculation result of the separate costing method of the power pipelines.

5. Model Evaluation

Based on the study of the cost allocation method of pipeline corridor construction, the separate costing method and the comprehensive evaluation method of the power pipeline, the model for calculating the paid user fee of power cables entering corridor is established. The actual case is used to calculate the corridor fee for high-voltage and medium-voltage cables, the results show that the model has strong applicability and can provide reference for the power cable entrance fee charging standard, which is helpful to improve the enthusiasm of power companies for power pipelines. With the accumulation of relevant experience and data in the operation of the pipe gallery in the future, the calculation model can be further optimized to improve its applicability and practicability.

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