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Component Analysis and Calculation for Social Benefits of UHV Assessment

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Abstract

With the rapid development of the UHV power grid, evaluation of the economic and social benefits of the UHV power grid is conducive to guiding the planning and construction of UHV power grid. At present economic benefit evaluation system of the UHV power grid is driving to maturity stage on the whole at home and abroad, but it invariably tends to regard social benefits as part of economic benefits, without evaluating social benefit separately. The social benefit evaluation model of UHV power grid is built in case of sufficient investigation. The differentials between social benefit and social cost are calculated respectively by three kinds of solutions according to the constructed social cost evaluation index system and social benefits evaluation index system, conclusion that UHV power grid transmission has better social benefits can be reached by contrastively analyzing the social three kinds of solutions corresponding to benefits. At last, the evaluation model and method are verified and analyzed through the analysis of engineering projects.

Keywords

UHV Power Grid, Social Benefit Assessment Model, Contrastive Analysis, Social Cost, Social Income, Planning and Construction

1. Introduction

With the rapid development of UHV power grid, the analysis of the operational factors [1] and the economical assessment of UHV power grid are crucial in planning and constructing the UHV power grid. Currently, the main method for economical assessment is based on the discounted cash flow. The assessment is done by the Net Present Value (NPV) while the relevant economic indicators are obtained by the Internal Rate of Return (IRR) as well as the payback period method, and the benefits and costs are compared in Ref [2] [3]. The Ref [4] utilizes the optimal power flow calculation method to evaluate economic during the whole life cycle. In the Ref [5], the UHV transmission model is built and the economic analysis is done.

At present, the economic evaluation system is almost mature. However, either the current economic evaluation methods cover the economic benefits assessment and the social benefits assessment at the same time, or some social indicators and contents are part of indirect economic benefit, So the traditional methods have some obvious shortcomings: First, social benefits and influence cannot be completely measured because of the lack of related social benefits; Second, it is difficult to distinguishing the cost and the benefit, causing the inaccurate assessments; Third, considering some specific social benefits of UHV, evaluation indicators are not completely suitable for economic evaluation; Fourth, to develop the environmentally friendly society and promote the sustainable development, stricter requirements for controlling urban smog and PM2.5 have been put forward, thus simple economic evaluation cannot meet the demand. Therefore, reasonable social benefits evaluation system should be built for current UHV and provide scientific basis for the project feasibility studies.

It can be concluded that direct and indirect social benefit evaluation models should be established under the engineering practice of UHV. In this paper, social benefits and social costs evaluation indicators systems are built first. And then, under the situation of transferring the same amount of electricity energy, 3 cases are applied, namely the UHV, the 500 kv transmission and the 500 kv transmission with coal (the coal will be converted to electricity after transported to load centers). After that the direct social benefit of the 3 cases is calculated from the cost and benefit, the indirect social benefit is of the 3 cases obtained by the comparison and analysis, finally, the evaluation model and method are verified and analyzed respectively in the analysis of engineering projects.

The rest of this paper is organized as follows: In Section 2, social benefits evaluation model is built. Section 3 introduces social income evaluation index system. In Section 4, the social cost evaluation index system is introduced. And the assessment model and method is examined In Section 5.

2. Social Benefits Evaluation Model

The social benefits (SBs) assessment of UHV is different from others when taking the practical engineering of the UHV and the distinguished characteristics of the UHV into consideration. The social benefits (SE) of the UHV are evaluated thoroughly in this paper. To begin with, the direct social benefits are compared between the three possible transmission ways of the UHV from the vertical perspective regarding the social incomes and social costs. Moreover, the indirect social benefits are assessed thorough comparative analysis of the direct social benefits from horizontal angle. The vertical and horizontal methods are working in a complementary manner, among which the vertical assessment is supposed to emphasizing on the specificities of the social benefit assessment, while the horizontal assessment is capable of demonstrating the increment part is consistent with the principles of economics.

Combined with engineering practical of UHV, the social costs (SCs) are evaluated from longitudinal and horizontal two aspects, direct social costs (DSCs) index system is divided into four segments namely the environment cost (ENC), energy cost (EC), land cost (LC) and human resources cost (HRC), ENC includes carbon emission costs (CECs), carbon trading costs (CTCs) and emissions abatement costs (EACs), EC includes freshwater resources consumption costs (FRCCs) and generation resources costs (GRCs), LC includes Taki area of compensation costs (TACCs) and plant land acquisition costs (TACCs), HRC includes development and transmission of human resources costs (DTHRCs) and transmission line maintenance costs of human resources (TLMCHRs); Indirect social costs (ISCs) index system includes audible noise reduction cost (ANRC) and social power outages loss cost (SPOLC); At last, social income (SI) assessment index system consists of create industrial benefits (CIBs) and create employment benefits (CEBs). Social costs and social benefits evaluation index system of UHV are illustrated in Figure 1.

Social costs of UHV can be obtained as in Equation (1).

$$E_c = \sum_{i=1}^{4}\sum_{k=1}^{I_k} E_{ik} + \sum_{i=1}^{2} E_{1i} \tag{1}$$

I_k is the number of the *i*th direct costs, E_{ik} is the *k*th direct costs under the *i*th direct costs.

Social income of UHV power grid as in Equation (2).

$$E_s = E_{s1} + E_{s2} \tag{2}$$

E_{s1} denotes the CIBS and E_{s2} means CEBs.

Direct social benefits can be got as in Equation (3).

$$E = E_s - E_c \tag{3}$$

3. Social Income Evaluation Index System

3.1. Create Industrial Benefits

Create industrial benefits (CIBs) can be obtained through calculating create average value of 1 kwh in load center and the number of electrical power delivered to the load center, as in Equation (4).

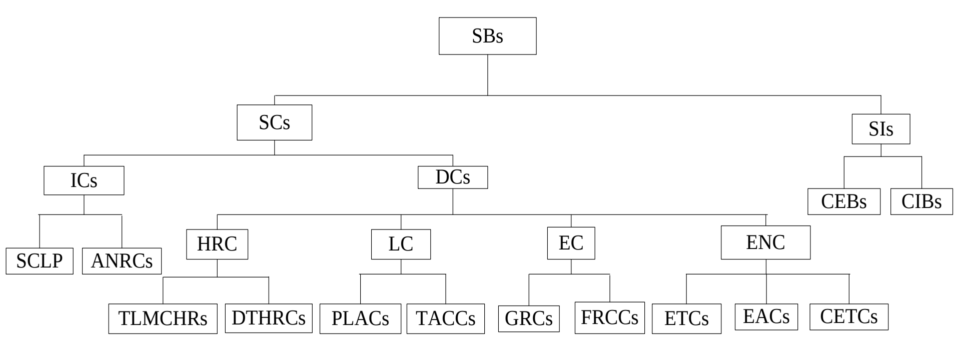

Figure 1. Social benefit estimation model for UHV grid.

$$E_{s1} = S_{we0} c_c \tag{4}$$

c_c refers to the created average industrial value of 1 kwh in load center, S_{we0} is the number of electrical power delivered to the load center.

3.2. Create Employment Benefits

CEBs include DEBs and IEBs. DEBs can be calculated through one trillion investment creating 11.59 million jobs and the wage of each worker is obtained from our country's per capita income under the current investment structure, as in Equation (5).

$$E_{s2z} = T_{tou} \times \overline{N_{tou}} \times \overline{c_r} \tag{5}$$

T_{tou} is the invest cost when the capacity of S_{we0} energy transported to load center, $\overline{N_{tou}}$ is employment number per invest, $\overline{c_r}$ is GNI per capita.

IEBs refer to the added employment number through resolving lack electricity problem when electricity is transported to load center, as in Equation (6).

$$E_{s2j} = S_{we0} \times c_c \times \eta \tag{6}$$

η is the ratio between China's per capita creation value and per capita income.

4. Social Cost Assessment Index Systems

4.1. Direct Social Cost Assessment Index System

Environmental pollution has become an important factor that restricts the development of today's economy, reducing CO_2 emissions is an effective way to protect environmental, constructing environment-friendly society is an important component to achieve the dream of China, UHV power grid can well reduce pollution gases emission, large number of ENs is saved. ENs includes CETCs and EACs. Wherein the CETCs include the process of electricity transport, transport tool in coal transport and coal is left behind during transport, EACs refer to nitrogen oxides and soot emissions sewage costs in the process of thermal power plants.

$$E_1 = \left(F_T + F_t + F_L + S_{we} m_0 k_1\right) c_t + S_{we}\left(m_0 k_2 c_2 + k_3 c_3 + m_0 k_4 c_4\right) \tag{7}$$

where F_T, F_t, F_L are carbon emission in the process of electricity transmission, coal transport, coal is left behind in [6], c_t is CO_2 trading price, S_{we} is generating capacity, k_1, k_2, k_3, k_4 is respectively conversion factor of carbon dioxide, nitrogen oxides, water and dust, c_2, c_3, c_4 is charges standard respectively in [7], m_0 is coal consumption per product 1 kwh electric energy.

China is a country that relatively lack in fossil energy and freshwater resources, coupled with inverse distribution between China's energy base and load center, not only add transport press, but also waste energy if energy is transported directly to the load center, which is not conducive to China building a resource-saving society. Thus reducing EC contribute to sustainable development of society, the construction of UHV power grid can solve these problems. EC of UHV includes ETCs, FRCCs and GRCs. Within ETCs include electricity and coal transmission cost, as in Equation (8).

$$E_2 = EP_{L1} + EP_{m1} = S_{we1} r p_{te} + \sum_{i \in I_N} \left(S_{we} - S_{we1}\right) m_T c_{I_{Ni}} \eta_i \tag{8}$$

EP_{L1}, EP_{m1} is transmission cost of electricity and coal respectively, S_{we1} is energy through transmission line from energy base to load center, r is the ration between thermal power transmission capacity and total transmission capacity, p_{te} is the life cycle cost for per transmission capacity, I_N is vehicle collection, is transport costs through using transport tool, $c_{I_{Ni}}$ is transport coal capacity ration between transport tool *i* and total tool, m_T is the average coal consumption of fossil fuel in power generation.

$$E_3 = S_{we} V_s c_s \tag{9}$$

Within V_s is water consumption per generation, c_s is per water price.

GRCs as in Equation (10) include transmission losses and power generation consumption cost.

$$E_4 = \sum_{i \in I_N} \mu_i L_i m c_L + \sum_{i=1}^{N_0} \lambda_i L_i S_{we} \Delta c_L + S_{we} m_0 c_{m0} \tag{10}$$

within μ_i is unit distance coal spill rate through using vehicle transportation *i*, λ_i is line loss rate per hundred km, Δc_L is loss price related to transmission distance in [8], c_{m0} is per coal price, c_L is coal price gap between energy base and load center, N_0 is transmission line number.

Lack of land resources in our country, land resources is of great significance to the economy sustainable development. LC of UHV includes TACCs and PLACs. TACCs in Equation (11) through using engineering experience and actual situation.

$$E_5 = L_L K_G S_G M_S \tag{11}$$

L_L is the construction feasibility study or preliminary design line length, K_G is Taki number per km, S_G is experimental design guidance covers area per Taki, M_S is land occupied compensation criteria. PLACs as in Equation (12).

$$E_6 = \sum_{i=1}^{N} c_{t_i} M_i R_i \tag{12}$$

c_{t_i} is land price in energy base, M_i is power plant unit capacity footprint, R_i is power plants install capacity, N is power plants number.

Our country lack skill human resources especially in adapting UHV development aspects, despite our country is large population country, so there is much point in reducing HRC. HRC include DTHRCs and TLMCHRs as in Equation (13).

$$E_7 = S_{we} n_0 \overline{c_f} + \sum_{i \in I_N} n_{i0} \eta_i m_0 S_{we} \overline{c_{yi}} \tag{13}$$

Within n_0 is the number of staff per produce 1 kwh, $\overline{c_f}$ is average wage of power plant worker, n_{i0} is per staff number engage in coal trans through using vehicle *i*, $\overline{c_{yi}}$ is staff average wage using vehicle *i*.

TLMCHRs refer to felling trees and line maintenance need human resource cost, as in Equation (14).

$$E_8 = \sum_{i=1}^{n} c_k L_i \lambda_k + n_w L_i c_w \tag{14}$$

c_k represent HRC per length due to fell trees, λ_k is the ration between need fell trees and total line, n_w is the maintenance number per transmission line length, c_w is the average wage of run and maintenance staff.

4.2. Indirect Social Cost Assessment Index System

According to some international researchers, residents living along the route is impacted by audible noise, no complaint when audible noise less than 52.5 dB (A), there is a small amount of complaints when audible noise exist between 52.5 dB (A) and 59 dB (A), there is large number of complaints when audible noise higher than 59 dB (A) in [9]. Therefore, transmission line need noise reduction when the transmission line noise higher than 52.5d BA. Related solve method is formulated through calculation and analysis power line audible noise. Audible noise on the transmission line is extensive researched at home and abroad, Ref [10] through the single-phase wire superposition to calculate entire line noise, and calculate it through different formulate is concluded from the analysis that BPA formula Equation (15) could better reflect actual situation.

$$\text{SLA} = \begin{cases} 120\lg g + 26.4\lg n + 55\lg d - 11.4\lg D - 128.4 & n \geq 3 \\ 120\lg g + 55\lg d - 11.4\lg D - 115.4 & n < 3 \end{cases} \tag{15}$$

where g is the maximum potential gradient averages, n is the number of bundled conductors, d is split wire diameter, D is distance from observation point to the corona point. In order to reduce transmission lines audible noise, usually by increasing the diameter of the wire split, the number of bundled conductors, the division split conductor spacing and the average height of the wires on the ground, but the increase in tower height costs too much often rarely used. Thereby lower 1 dB (A) expenses as in Equation (16) can be obtained.

$$E_9' = \min\left\{\sum_{i=1}^{N_0} L_i(\varepsilon_2 - \varepsilon_1)n_1, \sum_{i=1}^{N_0} L_i \varepsilon_1 (n_2 - n_1), \sum_{i=1}^{N_0} L_i(\varepsilon_2 - \varepsilon_1)(n_2 - n_1)\right\} \tag{16}$$

e_1, e_2, e_3 is increased wire diameter, number and fee split pitch. ε_1, ε_2 is cost per length before and after transmission line being transformed, n_1, n_2 is the number of bundled conductors before and after transmission line being transformed. So ANRCs can be got, as in Equation (17).

$$E_9 = \begin{cases} (SLA - [52.5] + 1) \times E_9' & \text{SLA} > 52.5 \\ 0 & \text{SLA} \leq 52.5 \end{cases} \tag{17}$$

The sustained development of economy, security of energy supply is an important guarantee, if the power supply is interrupted in power grid transmission process will cause users a great loss, Ref [11] from the power system generation and electricity transmission reliability point of view, electricity accident losses is assessed rely on reliable cost. According to power outages and blackouts every time combine with historical data in social loss costs due to power cut in [12], SCLP when power supply interruption time is T_i can be obtained, as in Equation (18).

$$E_{10} = \sum_{i=1}^{p_{lj} \times L'_k} E_{t0} T_i \beta_{i'} \tag{18}$$

where p_{lj} is transmission line trip frequency per 100 km/a, L'_k is hundredth of the transmission line length, E_{to} is per unit time social loss caused by power outages in historical data, T_i is per power outages time, β'_i is similarity between power outages area and historical data collection area.

5. Case Study

The 1000 kV UHV transmission project is taken as an example, 7.06 billion electricity can be transported to load centers annually after project has been completed, conductor use, line length is 640 km, from A (energy base) to B line length is 360 km, from B to C (load center) segment line length is 280 km, static investment is 5.7 billion RMB.

5.1. Social Benefits Assessment

Suppose that each unit of electricity can create 3.943 RMB social benefits, 7.06 billion energy is transported from energy base to load center, 24,660,580,000 RMB industry benefits can be got; Based on CASS calculate data combine with China's per capita income, can get direct employment benefits about 2.80724 billion RMB, according to China's per capita social value and create social benefits per 1 kwh can get indirect employment benefits about 22.2701 trillion RMB, social benefits is shown in Table 1.

5.2. Social Cost Assessment

It is known that the line loss rate of 1000 kV and 500 kV were 0.277% and 0.7%, the electric field intensity of transmission lines were 7.171 kV/m and 1.457 kV/m, the tower height is respectively 25 m and 14 m in the residential zone, distance between sub conductors is respectively 400 mm and 375 mm, transmission corridor distance is respectively 20 m and 13 m, integrated circuit fault trip rate is respectively 0.15 bout/(100 km/a) and 0.2 bout/(100 km/a), coal consumption is need 310 g per produce 1 kwh energy, 500 kV of 1000 kV is 4.5 times and above in the transmission line transmission capacity aspect, this paper take 4.5 times, according to the American institute for statistics global insight that 100 to 116 people are need per produce 10 kwh, this paper take 116. Suppose coal is transported from A to C, road transport line is 40 km, railway transport line is 600 km, and combine with China's actual, 60% of coal volume is transported by rail transport, 40% of coal volume is transported by road transport, per fresh water cost is calculated 1.5 RMB/cubic meter. Direct cost can be got when transport same power as shown in Table 2.

Table 1. Social income (unit: RMB ten thousand).

CIBs	DEBs	IEBs
2,466,058	280,724	222,701

Table 2. Direct social costs (unit: RMB ten thousand).

DSCs	ENs		EC		LC			HRC	
	CETCs	EACs	ETCs	FRCCs	GRCs	TACCs	PLACs	DTHRCs	TLMCHRs
Option one	46,745	7817	35,791	4312	78,041	4758	18,148	5505	1565
Option two	48,072	8039	36,807	4435	80,597	19,726	18,662	5653	4579
Option three	46,494	7759	65,463	4280	78,623	4383	23,549	5443	1018

Case two needs noise reduction to avoid being complained because its audible noise over 52.5 dB (A), the minimum noise reduction costs is 2.05 million RMB through comparative analysis several options; And suppose power is recovered need 1 hour per power cut, based on historical data and load center actual situation, fuzzy theory is used to assess the similarity between load center and historical blackout area, social power cut loss cost can be got, this paper take similarity is 0.4. Indirect costs as shown in Table 3.

A conclusion can be got from Table 3, ANRCs can be reduced effectively through option one and three, and SCLP is lower compare option three to one. Therefore, the option three has the lowest ISCs and best indirect social benefits.

5.3. Figures and Tables

Social benefits can be obtained through comparative analysis social costs and social income, as shown Table 4.

Huge social benefits can be obtained through option one from Table 4, and about over 461.73 million RMB can be got option one much more compared to option two, 254.85 million RMB can be got option one much more option three, we can conclude that much

6. Conclusions

Based on the UHV engineering practice, social costs and social income assessment index system are built, and social benefits assessment model is introduced according to the gap between costs and income, indirect social benefits can be got through comparative analyzing the gap between option one and the other two options. Conclusions can be inferred as follow.

Direct social costs evaluation index system of UHV can be introduced from environmental protection, energy, land and human resources four aspects, indirect social costs evaluation index system of UHV can be introduced from audible noise reduction and social cost of lost power two aspects, social costs assessment model is systematic and comprehensive introduced; social income assessment index system is introduced from production and employment two aspects. Social benefits assessment model can be systematic and comprehensive introduced. Social benefits of UHV can be systematicly and comprehensively assessed through its model from cases operators.

Table 3. Indirect social costs (unit: RMB ten thousand).

ISCs	ANRCs	SCLP
Option one	0	17,684
Option two	205	39,774
Option three	0	8839

Table 4. Social benefits (unit: RMB ten thousand).

SBs	SC	SE
Option one	220,366	3,247,859
Option two	266,539	3,247,859
Option three	248,496	3,247,859

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