# Research on Investment Economics of Hydrogen Production Project in Thermal Power Plant Under Auxiliary Service Market

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**Abstract.** On the basis of analyzing the characteristics of hydrogen energy, the application status and development trend of hydrogen energy storage technology, the feasibility and advantages of participating in auxiliary service of peak load balancing for hydrogen production projects invested in thermal power were studied and analyzed, and the investment economy of hydrogen production projects was demonstrated by using traditional engineering economic evaluation methods combined with examples. Finally, this paper argues that thermal power plants sell electricity to hydrogen production enterprises at a low price during peak regulation period, the thermal power plants can gain profits, the hydrogen market has a good prospect, and the hydrogen production project itself can achieve a better return on investment.

**Keywords:** New energy consumption · Auxiliary service · Hydrogen production · Economical efficiency

## 1 Introduction

Under the background of the rapid development of renewable energy power generation, it brings great challenges to the flexibility and depth of power system peak regulation. The low economic benefit of traditional thermal power plants participating in deep peak regulation restricts the consumption of new energy power generation. At present, the cost of electrolytic hydrogen production is high, among which the cost of electricity accounts for a large proportion. The use of low-price thermal power generation in peak regulation period can not only help thermal power units achieve deep peak regulation, promote the efficient consumption of new energy, ensure the safe and reliable operation of the power system, but also produce hydrogen which can be applied in many fields [1, 2].


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## 2 Principle Analysis of Thermal Power Hydrogen Production Project

In terms of the cost composition of hydrogen production by electrolytic water, the initial investment of electrolytic hydrogen production is basically fixed, and the cost of electricity in the operation process significantly affects the cost of electrolytic hydrogen production. The market selling price of hydrogen, the electricity price of hydrogen production and the transportation cost of hydrogen production have significant effects on the economic benefits of hydrogen production projects. On the one hand, the sales price of hydrogen determines the sales situation of hydrogen and the annual income of hydrogen production projects; on the other hand, the impact of transportation cost is also very significant. With the increase of transportation distance, the income of hydrogen production projects will decrease, which may lead to low return on investment [3, 4]; on the other hand, as electrolytic hydrogen production consumes a lot of electricity, the price of hydrogen production will greatly affect the feasibility of hydrogen production projects. Invest in the construction of a hydrogen production project near the thermal power plant, cooperate with the thermal power plant to achieve deep peak adjustment during the off-peak period of the power grid load, so as to obtain low-price electricity for hydrogen production, reduce the variable cost of hydrogen production, reduce the cost of hydrogen production to a certain extent, improve the market competitiveness of hydrogen generated by electrolysis, and believe that there is a market demand near the hydrogen production project. It can fully absorb the hydrogen produced as shown in Fig. 1.

Among them, the formulation of electricity price P for hydrogen production should ensure that the thermal power plant can obtain a certain income after adopting the hydrogen production scheme to achieve deep peak regulation, and the hydrogen production plant's selling price P1 should be ensured to be no higher than the lowest market price P2.

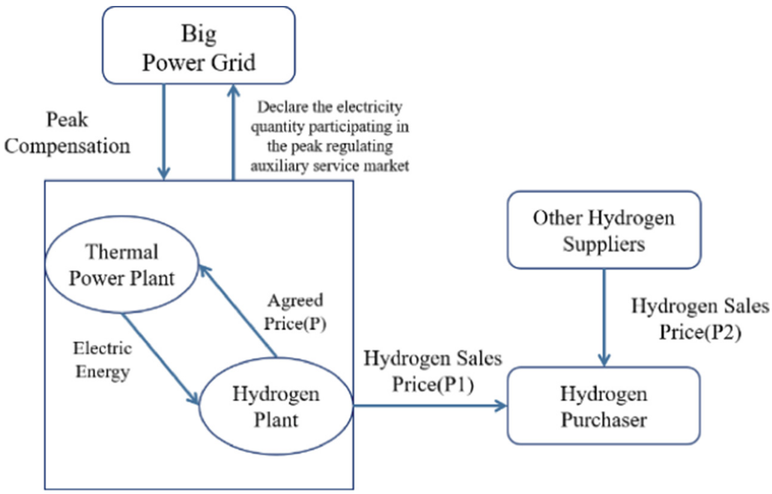


**Fig. 1.** Commercial model diagram of hydrogen production by thermal power investment.

On the premise of ensuring that the thermal power plant and hydrogen buyers can make profits, the self-economy of the investment hydrogen production project is analyzed.

According to the market rules of auxiliary peak regulating service, the auxiliary compensation of peak regulating can be obtained when the output level of thermal power units is lower than the basic depth limit of peak regulating. The settlement shall be made according to the paid peak power of each file and the corresponding market clearing price. The compensation cost obtained by thermal power plants is calculated according to the two levels of ladder electricity price corresponding to the peaking depth of the unit at different periods. The calculation method is as follows:

$$V = \sum_{\mathrm{i}=1}^{2} (Q_i \times P_{\mathrm{i}}) \tag{1}$$

where, V is the compensation cost for depth peaking of thermal power plant, $Q_{\mathrm{i}}$ is the paid-for peaking quantity of grade i, and $P_{\mathrm{i}}$ is the actual clearing price of grade i.

As shown in Fig. 2: Scenario 1 (Scenario without hydrogen production scheme in thermal power plant): It is assumed that in a certain operation period T (peak regulation period) of the unit, the peak regulation depth can reach $L_1$ according to the technical level of thermal power unit's peak regulation. Irregular figure $S_1$ is the on-grid electricity lost by the unit after providing peak regulation service. The loss of electricity multiplied by the compensation electricity price specified within the peak regulation depth can obtain the compensation of paid peak regulation cost of the unit during this period.

Scenario 2 (Hydrogen production scheme adopted in thermal power plant to achieve deep peak regulation): Suppose that in a certain operation period $T$ of the unit (peak regulation period), the output space of depth peak regulation of the thermal power unit is used for hydrogen production, then the peak regulation depth can reach $L_2$, and the irregular figure ($S_1 + S_2 + S_3$) is the on-grid power lost after the unit provides peak regulation service. The loss of electricity of each part can be multiplied by the compensation electricity price stipulated in the corresponding peak regulating depth to obtain the compensation of the unit's paid peak regulating cost during this period.

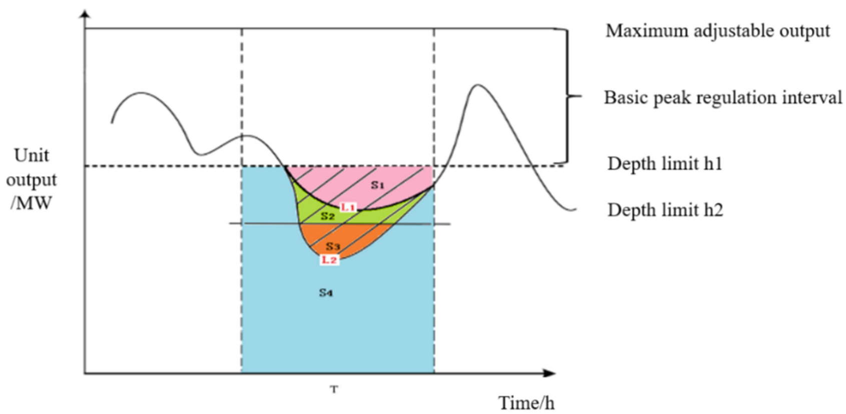


**Fig. 2.** Compensation diagram of auxiliary peak regulating service

The actual price of compensated peak regulation in the first gear is set as $P_1$ yuan/kW·h, the actual price of compensated peak regulation in the second gear is $P_2$ yuan/kW·h, the on-grid price of thermal power is $P_3$ yuan/kW·h, and the price of hydrogen production is $P$ yuan/kW·h. The normal power generation cost of thermal power unit is $C_1$ yuan/kW·h, and the power generation cost is $C_2$ yuan/kW·h when the depth peak regulation reaches $L_1$ (it is the output critical that the depth peak regulation technical level of thermal power unit can reach).

Then, in the peak regulation period of scenario 1, thermal power income is:

$$K_1 = P_3 \times (S_2 + S_3 + S_4) + P_1 \times S_1 - C_2 \times (S_2 + S_3 + S_4) \quad (2)$$

Then, in the peak regulation period of scenario 2, thermal power income is:

$$K_2 = P_3 \times S_4 + P_1 \times (S_1 + S_2) + P_2 \times S_3 - C_1 \times (S_1 + S_2 + S_3 + S_4) + P \times (S_1 + S_2 + S_3) \quad (3)$$

$$\Delta K = K_2 - K_1 \quad (4)$$

In order to make the thermal power plant adopt the hydrogen production scheme, it should ensure that the income after the thermal power plant adopts the hydrogen production scheme is greater than that of the thermal power plant under the current situation, that is, $\Delta K \geq 0$.

# 3 Analysis on Cost and Benefit Composition of Thermal Power Hydrogen Production Project

## 3.1 Cost Composition

Expenses incurred during the full life cycle of hydrogen production project mainly include initial investment cost, equipment operation and maintenance cost, electricity cost, water cost, equipment repair cost, etc. The initial investment takes place in the early stage of construction of hydrogen production project, and mainly includes the purchase cost of equipment for hydrogen production by electrolytic water, equipment installation, civil engineering and other costs:

$$C_{Invest} = (\sum C_k + C_{land})(1 + \alpha) \quad (5)$$

where, $C_k$ is the purchase cost of each equipment for electrolytic hydrogen production; $C_{land}$ for civil works and other expenses; $\alpha$ is the proportion of installation cost of hydrogen production equipment to initial investment cost. Each equipment of the hydrogen production system needs to spend a certain amount of operation and maintenance fee when it runs normally every year. The present value of equipment operation and maintenance cost can be expressed as:

$$PC_{OM} = \sum_{t=1}^{n} C_{\text{OM-k}} \times (\frac{1+g}{1+I})^t \quad (6)$$

where, $C_{\text{OM-k}}$ is the annual operation and maintenance cost of equipment required for hydrogen production project; g is the inflation rate; n is the execution time of the project; i is the social discount rate.

The direct cost of electrolytic hydrogen production includes electricity cost (power consumption of hydrogen production device, power consumption of compressor, etc.) and water cost.

Electricity cost:

$$PC_{\text{e}} = \sum_{t=1}^{n} P_{et} \times q_{et} \times (\frac{1+g}{1+i})^{t} \tag{7}$$

where, $Q_{et}$ is the annual electricity consumed by electrolytic hydrogen production, and $P_{et}$ is the electricity price.

Water cost:

$$PC_{\text{w}} = \sum_{t=1}^{n} V_t \times q_{wt} \times \alpha_w \times (\frac{1+g}{1+i})^{t} \tag{8}$$

where, $V_t$ is the hydrogen output of hydrogen system in year t, $q_{wt}$ is the price of water in year t, and $\alpha_w$ is the water consumption of hydrogen production unit.

Present value of transportation and storage costs of hydrogen:

$$PC_{\text{h}} = \sum_{\text{t}=1}^{\text{n}} (C_{\text{h}} \times M_{\text{h}} + C_{\text{s}} \times V_{\text{t}}) \times (\frac{1+\text{g}}{1+\text{i}})^{\text{t}} \tag{9}$$

where, $C_{\text{h}}$ is the annual operating cost of each storage unit; $M_{\text{h}}$ is the number of storage units; $C_{\text{s}}$ is the transport cost per unit of hydrogen.

Hydrogen production equipment will gradually wear out in the process of use (only physical wear of equipment is considered here), and its performance will gradually decline. Therefore, hydrogen production equipment needs to be repaired after a period of use. The Dali fee is calculated as a percentage of the equipment acquisition cost.

$$PC_r = \sum_{\text{t}=1}^{\text{n}} C_{\text{t}} \times (\frac{1+\text{g}}{1+\text{i}})^{\text{t}} \tag{10}$$

where, A is the sum of major repair costs for all equipment in each year.

### 3.2 Income Composition

The income of thermal power hydrogen production project mainly includes hydrogen generated in the process of electrolytic hydrogen production and the income of recovery of equipment residual value at the end of life. Considering the factors of inflation rate and social discount rate, the electric quantity used for electrolytic hydrogen production can be calculated from the actual situation of deep peaking of thermal power plant, so as to obtain the output of hydrogen and thus the sales income of hydrogen.

Revenue from selling hydrogen:

$$R_{H_2t} = P_{1t} \times V_{\mathrm{t}} \times (1+g)^t \tag{11}$$

$$R_{H_2} = \sum_{i=1}^{n} R_{H_2t} \tag{12}$$

Assuming that all high-purity hydrogen produced by water electrolysis by the electrolytic device can be sold and the price of H2 increases in accordance with the inflation rate in each year, $R_{H_2t}$ represents the income brought by hydrogen sales in year t. $P_{1t}$ is the price of hydrogen in year t; $V_{\mathrm{t}}$ is the amount of hydrogen produced in year t.

Make a brief estimate of the equipment salvage value according to the total amount of initial investment, and make a rough estimate of the equipment salvage value according to a certain proportion of the total amount of initial investment to recover the cost. Its calculation formula is as follows:

$$NB_{\mathrm{r}} = (\sum C_{\mathrm{k}} \times \lambda)(\frac{1}{1+i})^n \tag{13}$$

where, $C_k$ is the purchase cost of each equipment for electrolytic hydrogen production, λ is the salvage value rate, and n is the total operation years of the project.

### 3.3 Project Investment Decision Evaluation Model

In the financial evaluation index system, investors are most concerned about the financial net present value of the project to evaluate the thermal power hydrogen production project economy. The net present value of thermal power hydrogen production project refers to the net cash flow of each year of hydrogen production project, discounted to the initial stage of hydrogen production project construction according to a certain discount rate, and the net present value is the sum of all discounted present values.

Judging criteria: when $NPV \geq 0$, it indicates that the investment hydrogen production project has relatively good economy; If $NPV \leq 0$ indicates that the investment in thermal power hydrogen production project is economically poor, the investment should not be carried out. Is calculated as follows:

$$NPV = R_{H_2} + NB_{\mathrm{r}} - C_{Invest} - PC_{OM} - PC_e - PC_w - PC_h - PC_r \tag{14}$$

## 4 Case

In this paper, the fake customized hydrogen project has been running for 20 years with a corporate income tax rate of 25%. The benchmark discount rate for the society was set at 8% and the benchmark inflation rate at 4% [5, 6]. Let's say the price of water is 10 yuan per t. Since the power source of the thermal power hydrogen production system is the unconnected power of the thermal power plant under the condition that the hydrogen production enterprise collaborates with the thermal power plant to achieve deep peak regulation, the thermal power price can be determined through negotiation under the condition that the hydrogen production scheme of the thermal power plant has a certain return rate. When the installed capacity of hydrogen production system is 120MW, the electricity price of hydrogen production can be set between 0.115 yuan/KWH and 0.228 yuan/KWH. Therefore, the tentative electricity price of hydrogen production is 0.2 yuan/KWH. The annual electricity available for hydrogen production in thermal power plants is about $1.333408 \times 10^8$ kWh, and the transportation cost is 0.15 yuan/$Nm^3$. The sale price of high-purity hydrogen on the market is about 3.0 yuan/$Nm^3$, and the price of hydrogen is set as 2.5 yuan/$Nm^3$ in this paper. According to the above data, the net present value at this time is about 6,069,600 yuan, indicating that the thermal power investment in hydrogen production project is economical.

## 5 Conclusion

According to the current situation of low economic benefit of deep peak regulation achieved by thermal power and high electricity cost of electrolytic hydrogen production project, this paper proposes to use the surplus electricity in peak regulation period of thermal power electrolytic hydrogen production to assist thermal power to achieve deep peak regulation and obtain low electricity cost at the same time. The cost-benefit analysis model is established to analyze the investment economy of thermal power hydrogen production project, and the simulation analysis results show that: Hydrogen production project can not only ensure its own economy, but also bring benefits to thermal power plants and hydrogen users, indicating that thermal power hydrogen production project has strong feasibility and operability, can assist thermal power units to achieve deep peak regulation, and promote the efficient consumption of renewable energy power generation.

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