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# Feed-in Tariff Optimization of Nuclear Power under the Electricity System Reform Based on Price Linkage Policy

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***Abstract:***

Given in the phase of development and the cost element, Chinese nuclear power is not qualified temporarily for full participation in the market competition. The feed-in tariff (FIT) policies of nuclear power plants and portion of electricity in the market competition are the principal external factors determining. As the market reform deepens, the implementation of nuclear power FIT policies which have been carried out for 7-years tremendously differs from the expectation. And the policies of benchmark FIT for coal-fired plants have been changed to a market-based pricing mechanism of "base price + floating price". Based on the analysis of the pricing mechanism for nuclear power benchmark FIT and its implementation, this paper puts forward the overall idea of the regulation mechanism for electricity price. Besides, the paper discusses respective electricity price mechanisms for both guaranteed acquisition electricity and electricity for bidding. It describes a mechanism for construction investment and nuclear fuel price to be linked with FIT of nuclear power unit in detail. And it is suggested that the benchmark electricity price of nuclear power is no longer linked with that of coal-fired plants. This paper provides two methods to ensure the proportion of guaranteed acquisition electricity for performers' reference and suggests to establish a mechanism for construction investment and nuclear fuel price to be linked with FIT. The analysis results of this paper will provide a theoretical basis for perfecting the pricing mechanism for FIT of nuclear power.

***Keywords:*** *Electric power industry, Feed-in tariff, Linkage mechanism, Nuclear power plants.*

## I. INTRODUCTION

In 2013, the National Development and Reform Commission promulgated the Notification Concerning Related Problems of Perfecting Nuclear Power Feed-in Tariff Mechanism to

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formally implement the policy of nuclear power benchmark FIT. According to the average cost of Nuclear power plants, this policy determines the nuclear power benchmark price as 430 Yuan/MWh with appropriate rate of return. And it designs the pricing mechanism for opportunity cost stipulating that the nuclear power statement price finally approved by Nuclear power plants should be the lower one between the national nuclear power benchmark price and the local benchmark price of coal-fired unit[1]. The implementation of the policy of benchmark FIT for nuclear power ends the pricing mode which independently determines the FIT of different Nuclear power plants according to debt service and forms a mechanism for reversed interest pressure which plays a vital role for reasonably guiding investment and promoting the enterprises' cost cutting, thereby laying the foundation for the transition of nuclear power price from planned pricing to market pricing. In 2013, the benchmark price of coal-fired plant was generally higher than that of China due to relatively high coal price. So the nuclear power plants could get the expected return under the level of 430 Yuan/MWh for national benchmark price. However, as the coal price fell in recent years, the benchmark coal-fired power price in China witnessed a precipitous decline making the benchmark nuclear power price generally higher than the national benchmark coal-fired power price. The newly built nuclear power plants mostly follow the local benchmark coal-fired power price. However, in most regions, the benchmark coal-fired power price is significantly lower than 430 Yuan/MWh, so the nuclear power plants make decreased profits. In addition, with the improvement of power market, it is an inevitable trend for the nuclear power unit to participate in market competition. And how to enable the nuclear power plants with installed generation capacity accounting for around 2% to economically and efficiently participate in market competition has received much attention from the industry.

## II. LITERATURE REVIEW

Over the last few decades, governments around the world have been grappling with reforms and restructuring of the power sector. Tauqir [2] researched the influence of power structural reform by the Asian countries on the power price and proposed the Asian countries mainly reformed via two modes to reduce terminal consumption price: introducing competition into power market and adjusting the power price level in accordance with the actual cost of power. This research focuses on the special electricity system in China for exploring the reform and optimization mode for the electricity price of nuclear power units.

Globally, different scholars have discussed the policies on nuclear power price in different countries and regions [3-8]. In summary, the formation of power price of nuclear power units mainly comprises: power price formed by market competition, market competition plus subsidies, and government directly fixing the price, etc. The American market and Euro-market usually adopt market competition plus subsidies such as carbon tax, zero discharge subsidy, etc. to form the nuclear power FIT while Japanese nuclear power unit usually adopts government pricing [9]. Takizawa[10] expounded the promotion and inhibitory effect of government pricing

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for nuclear power on construction of nuclear power in Japan. The government calculated the project's net present value (NPV) to decide the regulated FIT so that the development rate of nuclear power industry can be macro-controlled. Traber [11] analyzed the influence of gradual decommissioning of German nuclear power units on European power market price, carbon emission price, investment in alternative power supply, and power transaction. In contrast, Chinese power market is in a special phase with coexistence of government pricing and market pricing, which is different from all other power markets in the world.

Wang Shixin [12] and Yan Lirong [13] presented an overview of the reform of pricing mechanism for Chinese nuclear power plants. The author believes that the current nuclear power construction and operating cost have changed a lot compared with those in 2013 when the policy of benchmark nuclear power FIT was established. In current stage of Chinese power structural reform, the polices of benchmark FIT and market competition price coexist. Zhang Lizi [14] believed that to determine the benchmark nuclear power price nationwide is premised on subtle differences among nuclear power cost.Wei Yuchao [15] analyzed the returns condition of investment in nuclear power projects under benchmark price and performed a sensitivity analysis.Some scholars also studied the economy of nuclear power. Paul [16] calculated electricity of nuclear power in accordance with levelized cost of electricity (LCOE) model and pointed out that the LCOE was between 97 dollars/MWh and 136 dollars/MWh for America, about 40 dollars/MWh for Korea, about 37 dollars/MWh for Britain and about 48 dollars/MWh for China.

China is at a critical stage of power market reform and promoting clean energy development. At this stage, the electricity price policies are implemented in parallel with the benchmark FIT and comprehensive market-oriented FIT. How to coordinate and optimize the FIT policy of nuclear power is the differences of this paper from previous studies.

## III. CHINESE BENCHMARK FIT PRICING MECHANISM FOR NUCLEAR POWER PLANTS

### 3.1Pricing Policy of Benchmark FIT for Nuclear Power in China

In 2004, the State Council's competent price department carried out the policy of benchmark FIT in the electricity industry. The transformation from competent price department determining the FIT of power stations one by one into determining benchmark price in accordance with the average cost plays a vital role for reasonably guiding investment and promoting enterprises' cost cutting.

As far as nuclear power plant is concerned, China's modified generation-II nuclear power station was constructed more independently and experience in construction and operation was accumulated. Thus, newly built power stations almost have stable and reasonable construction and operation costs. All of those above enable the nuclear power to have the basic conditions of introducing benchmark price. In 2013, National Development and Reform Commission promulgated the Notification Concerning Related Problems of Perfecting Nuclear Power Feed-

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in Tariff Mechanism (NDRC Price〔2013〕No. 1130), which decides to determine the FIT of newly built nuclear power plants by combining the two pricing methods of average cost method and opportunity cost method. China's current policy of benchmark nuclear power price finally takes the lower one between 430 Yuan/MWh and the benchmark coal-fired power price in accordance with the mechanisms of average cost pricing and opportunity cost pricing.

3.2 Execution Performance of Benchmark FIT Policy for Nuclear Power Plants

The effect has been obvious since the policy of benchmark nuclear power price was implemented in 2013, which has gradually reduced the FIT for subsequent new nuclear power projects. This effectively restricts the construction cost of nuclear power units.

However, some problems also appeared in the implementation of policies of benchmark nuclear power price coupled with development of Chinese nuclear power technologies. Firstly, China stopped construction of generation-II-plus nuclear power plants when the requirements on security of nuclear power became higher. A batch of generation-III AP series and Hualong nuclear power plants began to be constructed whose construction costs were different from those of the generation-II-plus plants, and the influence of the benchmark price level of nuclear power on the overall power price of electricity market is worth being researched. Secondly, the coal price was high in 2013 when the policy of benchmark nuclear power price was implemented. However during 2013 to 2018, the coal price fluctuated significantly, leading to regulation of benchmark coal-fired power price in accordance with the policy of linkage between coal price and electricity price.

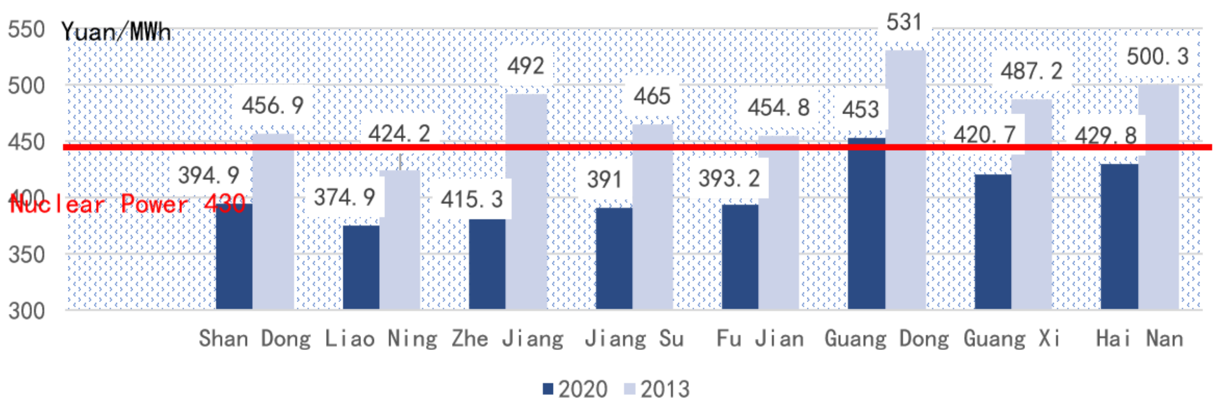


Fig 1: Benchmark coal-fired power FIT having nuclear plants from 2013 to 2020

The benchmark nuclear power FIT (430 Yuan/MWh) is compared with the benchmark coal-fired power FIT in provinces with nuclear power project (shown as the figure 1). The results show that except that Liaoning's benchmark coal-fired power price in 2013 was 424.2 Yuan/MWh, lower than 430 Yuan/MWh, the prices of other provinces (453 Yuan/MWh-531 Yuan/MWh) were all higher than 430 Yuan/MWh. In 2020, except that Guangdong's benchmark FIT was 453 Yuan/MWh, higher than 430 Yuan/MWh, the prices of other provinces (374.9 Yuan/MWh-531 Yuan/MWh) were all higher than 430 Yuan/MWh.

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## IV. POLICY OPTIMIZING OF ELECTRICITY AND CORRESPONDING PRICE FOR NUCLEAR POWER PLANTS

Against the background of the current reform on power system in China, the two mechanisms of power price formation including the benchmark price policy and the price rule in power market competition are carried out simultaneously. And the settlement for different types of power supplies is in accordance with various proportions of power by benchmark FIT and the market competition price. (shown as the figure 2) The generating capacity, proportion of power for market competition and price settlement, etc. influence the profits largely. This paper suggests designing a regulation mechanism of nuclear power FIT in which the power price is matched with the electricity.

4.1 Determination Method for Guaranteed Acquisition Nuclear Power Quantity

The guaranteed acquisition nuclear power electricity refers to the electricity produced by Nuclear power plants settled with the price which is determined by the National Development and Reform Commission. There are two methods for determining the guaranteed acquisition nuclear power electricity. The first method is based on Tentative Method of Guaranteeing Safe Consumption of Nuclear Power in accordance with technical features and national operation condition of Nuclear power plants. And the second method is based on economic factors to consider the guaranteed acquisition power electricity.

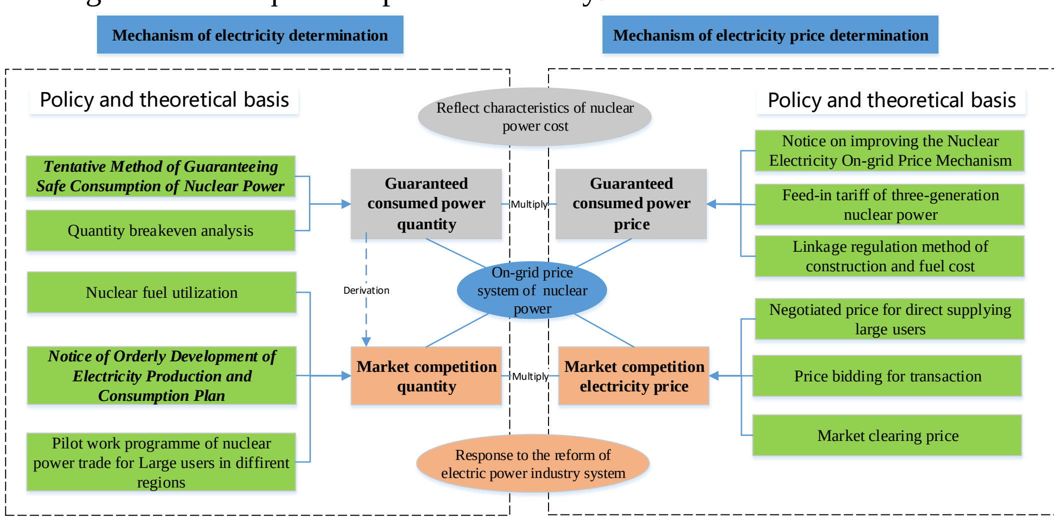


Fig 2: General thinking for optimizing formation mechanism of nuclear power FIT

4.1.1 Determination Method of Guaranteed Acquisition Power Quantity Based on Tentative Method of Guaranteeing Safe Acquisition of Nuclear Power

The nuclear power engineering and thermal power plants have quite different fuel uses. The latter can burn less fuel when the load rate is low, while the Nuclear power plants has a specific burn-up cycle. Refueling is required after the stipulated refueling cycle ends, no matter how much fuel has been burned. So running in low load cannot ensure to fully burn fuel of Nuclear

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power plants, forming a waste of nuclear fuel.

In an effort to guarantee operation security of nuclear power plant and economization of nuclear fuel, NDRC and National Energy Administration released Tentative Method of Guaranteeing Safe Acquisition of Nuclear Power in 2017 to provide guarantee measures for the on-grid nuclear power electricity. This tentative method stipulates that competent power department of provincial government shall determine the prioritizing generation schedule for local nuclear power plants for the regions where the electricity supply and demand are relatively balanced. For the regions where the electricity is oversupplied, the generation schedule by nuclear power plants shall be determined in accordance with a certain times of average utilization hours of electricity generation equipment from the local unit-installed plants with capacity of over 6000 kW. Different regions can appropriately regulate the times in accordance with the actuality. The calculation formula is shown as below.

$$k = \frac{h_n}{h_t}$$

Wherein, $k$ is the coefficient of guaranteed electricity for nuclear power plants;

$h_n$ is national average utilization hours of nuclear power in the last three years;

$h_t$ is national average utilization hours of generation equipment of power plants with capacity of 6000kW and more in the last three years.

According to the data, the guarantee coefficient and actual policy implementation since 2017 are calculated. In 2017, it was estimated to be 7294hof $h_t$, 4013hof $h_t$, and 1.82of $k$. In 2018, it was calculated as 7167hof $h_t$, 3847hof $h_t$, and 1.86of $k$ .This method can guarantee the national utilization hours of nuclear power units stabilize at a certain level, thereby improving the efficiency of nuclear power units. Nationally, the average utilization hours of nuclear power declined year by year during 2014 to 2016. After the guaranteed acquisition was carried out, the utilization hours of nuclear power slightly rose gradually during 2017 to 2018. And utilization hours in Liaoning and Fujian, etc. were guaranteed to a certain extent.

Although most provinces except Zhejiang, Guangdong and Guangxi that have met the nuclear power guarantee policy, are lower than the calculation according to nuclear power guarantee multiple. Shandong province is a special case, with no nuclear plants in service until 2018. In 2018 the province had less than a year's operation. The utilization hours of nuclear power units have increased since the policy was promulgated. It is beneficial to improve the project economy of nuclear power plants.

Tentative Method of Guaranteeing Safe Consumption of Nuclear Power highlights the trend of nuclear power utilization to make nuclear power operate in full load with base-load as far as possible. This method presents the advised calculation method for the guaranteed acquisition electricity, while the rest is for market competition. However, as Tentative Method of Guaranteeing Safe Consumption of Nuclear Power only stipulates the basic opinions about on-

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grid power of nuclear power plant yet does not highlight the matched mechanism of nuclear power price. The Nuclear power plants can get profits if Nuclear power plants can ensure that the electricity is settled in accordance with the benchmark nuclear power price.

Although the policy is not fully implemented, the method provides an idea for the determination of guaranteed electric quantity. If the government administration can implement the corresponding electricity price policy based on above policy, the economy of nuclear power plants can be better which may lower the electricity price of the whole society. The reduction of electricity price is consistent with the goal of electricity system reform.

4.1.2 Determination Method of Guaranteed Acquisition Quantity Based on Economy

(1) Breakeven point method

The determination method of guaranteed acquisition electricity based on breakeven point is to calculate output breakeven point of nuclear power plant. It can guarantee the recovery of nuclear power cost to calculate output breakeven point in accordance with average advanced cost and price parameters of nuclear power plants. The calculation method of output breakeven point is as follows:

$$BEP = \frac{C_f}{P - C_u - T_u}$$

Wherein, $BEP$ is the output breakeven point;

$C_f$ is project's fixed cost;

$C_u$ is product's variable cost;

$P$ is electricity price including tax;

$T_u$ is added-value tax, sales tax and surtax of unit product;

Based on the above formula, this paper takes the calculation of the boundary parameters of the national FIT of nuclear power at 430 Yuan /MWh as an example to analyze the break-even point. The calculated BEP is 72.24%, equivalent to 5057h of utilization hours.

Based on the above calculation, the output breakeven point of nuclear power can be calculated by regions given power prices vary from provinces. And the nationwide output breakeven point can be calculated based on national benchmark nuclear power price of 430Yuan/MWh. The benchmark nuclear power FIT even can be ratified by plant types because of different construction costs. The power within the breakeven point can be determined as the guaranteed acquisition power electricity while the rest can be confirmed and acquisition through marketized competition. The power plant has the motivation to actively surrender some profits to increase the utilization hours of plants so as to make full use of nuclear fuel.

(2) Calculation method of average power price for operative period

The breakeven-based calculation method only makes up the basic cost of power station and is relatively radical. The calculation method based on current benchmark nuclear power FIT can be adopted to calculate the average power price for the operative period according to the

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internal rate of return (IRR) of capital fund by a certain proportion (such as 9% IRR). This method can guarantee profitability of the nuclear power plant to some degree, and the government can regulate its basic profitability by adjusting the IRR.

4.2 Determination Method of Guaranteed Acquisition Electricity FIT

As the economy of Nuclear power plants is co-determined by on-grid power quantity and corresponding FIT, this paper suggests the policy of nuclear power price should combine power amount and price to make united research and calculation. The above content describes two determination methods to determine guaranteed acquisition nuclear power, and the power beyond the guaranteed acquisition can be considered as the part for market competition. The corresponding price of the guaranteed acquisition power should be ensured in accordance with the determination methods of the power amount. Currently, the universally applicable method is to determine the guaranteed acquisition power price based on average cost. As the benchmark coal-fired power price influenced by coal price is hard to reflect the actual cost of nuclear power plant, this paper suggests tying to separate the nuclear power price from those of benchmark coal-fired power price. There are following thoughts to determine the power price based on average cost:

4.2.1 Calculation Based on Current Policy of Benchmark FIT

The benchmark FIT policy of nuclear power makes calculation based on the cost parameters of China's generation-II modified nuclear power plant in 2013. Currently, the generation-III nuclear power plants are being constructed in a large scale and put into production successfully in China. Its settlement price for the guaranteed acquisition power can adopt the already ratified national benchmark nuclear power price of 430Yuan/MWh. Also, differentiated benchmark FIT corresponding to various types of plants can also be explored, if they have various of construction costs.

4.2.2 Recalculation Generation-III Nuclear Power FIT

The above has analyzed the historical background and implementation situation of the policy of benchmark FIT. The current policy makes calculation based on the parameters of generation-II-plus nuclear power plants. However, after the Fukushima nuclear accident, China didn’t build any new generation-II-plus nuclear power plants. And three projects of generation-III nuclear plants were put into commercial operation in China in 2019. These plants are remarkably different from the generation-II-plus ones both in construction cost and operation cost. So in combination with the determination method of guaranteed acquisition power, it is also feasible to perfect the benchmark power price for generation-III nuclear power plants based on average cost of standard designing. The calculation method for the power price during operative period is financial evaluation model. The detail calculation method refers to Economic evaluation method for nuclear power plant construction projects.

$$\sum_{i=1}^{n}(C_i - C_o)_i(1+FIRR)^{-i} = 0$$

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Wherein, $FIRR$ is the capital fund's financial internalrate of return, $n$ is operative period, $i$ is the year ordinal of operative period. $C_i$ is the cash inflow, and $C_o$ is the cash outflow.

The settlement price corresponding to guaranteed acquisition power can be determined via the above two modes.

## V. LINKAGE MECHANISM DESIGNING OF BENCHMARK FIT FOR NUCLEAR POWER PLANTS

The fundamental schemes are economical evaluation parameters advised in Economic evaluation method for nuclear power plant construction projectsand part of mastered cost data for generation-III nuclear power (as shown in the TABLE I.). The fundamental schemes calculate the overall cost composition and proportion of typical generation-III nuclear power plants. Based on the calculation results, this paper analyzes the major factors influencing nuclear power price so as to decide the regulation factors for nuclear power price.

**TABLE I.Calculation parameters for basic scheme**

| S.N. | Item | Unit | Unit parameters |
|---|---|---|---|
| | I. Basic information of power supply | | |
| 1 | Unit quantity | | 2 |
| 2 | Total installed capacity | MW | 2,500 |
| 3 | Annual utilization hours of unit | Hour | 7,000 |
| 4 | Construction period | Month | 62 |
| 5 | Evaluation period for economical running | Year | 20 |
| | II. Cost of running and maintenance | | |
| 1 | Variable operation and maintenance costs | | |
| | Water expenses | Yuan/t | 0.5 |
| | Material expenses | Yuan/MWh | 5 |
| | Post-treatment expense of spent fuel | Yuan/MWh | 26 |
| | Treatment and disposition expenses for low-and-intermediate level radioactive waste | Yuan/MWh | 0.5 |
| | Nuclear emergency expenses | Yuan/MWh | 0.2 |
| 2 | Fixed running and maintenance costs | | |
| | Repair expense rate | % | 1.5 |
| | Quota of establishment | People | 800 |
| | Per capital annual salary | Ten hundred Yuan/year | 12.5 |
| | Welfare expenses coefficient | % | 60% |
| | Retirement fund | % | 10 |
| | Insurance expenses | % | 0.15 |

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| S.N. | Item | Unit | Unit parameters |
|---|---|---|---|
| | Other expenses | Ten hundred Yuan/people | 13 |

The calculation model for power price of operative period is constructed in accordance with the parameters in the table, and proportions and components of cost electricity are figured out of overall cost for the model shown asTABLE II. The unequal costs of that year are converted into annual value. The proportions of overall cost are shown as the figure 3. Wherein, the construction investment is represented by depreciation expenses, amortization expenses and financial expenses, with depreciation and amortization expenses accounting for 39.8%, financial expenses for operative period accounting for 15.2%, fuel expense accounting for about 14.7%, overhauling expenses accounting for about 11%, post-treatment expenses for spent fuel accounting for 8.3%. It is observed that the construction investment, fuel expenses, overhaul expenses, post-treatment expenses for spent fuel in the inner cost produce a large influence on cost price of power. Wherein, as the load factor is ever changing under the influence of market demands and scheduling policy, etc., the guaranteed acquisition power price is inadvisable to be regulated too frequently. Thus, the load factor is not considered in the regulation method of guaranteed acquisition power price. The construction period is relatively stable for the maturely constructed unit, so this paper does not consider linking this factor with guaranteed acquisition power price either. Based on the above considerations, this paper designs the regulation method of guaranteed acquisition nuclear power price from two factors of construction investment and nuclear fuel price.

**TABLE II. Simulation result for scheme of triggering point of power price change**

| | Change rate (%) | Absolute value of changes in investment of construction completion cost (100Million Yuan) | Change rate of construction completion cost (%) | Sensitivity coefficient |
|---|---|---|---|---|
| Power price | -20.00 | -115.38 | -25.61 | 1.28 |
| Power price | -15.00 | -86.53 | -19.21 | 1.28 |
| Power price | -10.00 | -57.69 | -12.80 | 1.28 |
| Power price | -5.00 | -28.84 | -6.40 | 1.28 |
| Basic scheme | 0.00 | 0.00 | 0.00 | 0.00 |
| Power price | 5.00 | 28.84 | 6.40 | 1.28 |
| Power price | 10.00 | 57.69 | 12.80 | 1.28 |
| Power price | 15.00 | 86.53 | 19.21 | 1.28 |
| Power price | 20.00 | 115.38 | 25.61 | 1.28 |

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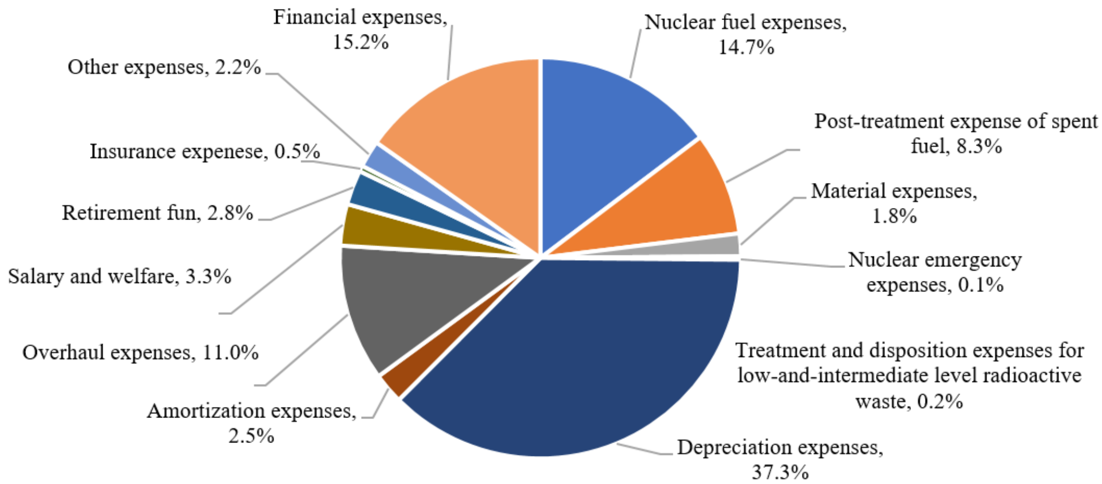


Fig3: Proportions of components in overall cost for typical generation-III nuclear power plant

5.1 Linkage Mechanism of Construction Investment with FIT

The current policies of benchmark nuclear power price in China is the FIT calculated using the method of power price for operative period. These policies take 8% of capital fund internal rate of return into consideration in accordance with the cost data of generation-II modified units called M310 and 80% of load factors. The publicized data shows that the average construction completion cost of China's last batch of M310 units is between 12,000 and 13,000 Yuan/KW, while the industrial expectation about unit investment of construction completion cost for mass construction of generation-III nuclear power is between 15,000 and 16,000 Yuan/KW. Through calculation, with other parameters unchanged, when the construction completion cost increases by between 1000 and 3000 Yuan/kW, the power price will change between 5% and 15% after the construction investment transferred to calculated power price via depreciation and amortization costs. This shows that it is necessary to analyze the reasonableness of benchmark nuclear FIT due to fluctuation of construction cost caused by changes in technical line or other factors

5.1.1 Coordinated Modes between Construction Investment and FIT

1) Mode of regularly re-ratifying nuclear power FIT

The construction of nuclear power unit in China lasts about five years, without many constructions being built in the same period. In the same construction cycle, there are not large changes in the construction cost whose reduction needs some time via technical progress. To facilitate implementation of power price regulation policy by Chinese competent price department, the regulation method of regularly collecting nuclear power's construction cost and re-ratifying power price is highly operable and feasible. It is advised to set three years or five years as a cycle to re-ratify the guaranteed acquisition power price. In the case of significant changes in construction price of nuclear power caused by the factors beyond the construction

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unit, it can be reported to related price department to regulate the price level of newly built power station in the next power price cycle.

2) Mode of re-ratifying nuclear power FIT in accordance with degree of impact

Beside the mode of regularly re-ratifying power price, the degree of FIT fluctuation caused by construction cost's change can work as coordinated triggering point for power price. When the fluctuation extent exceeds the triggering point, the guaranteed acquisition power price should be re-ratified, while the investment risk within the scope of fluctuation should be assumed by the enterprises themselves. The current national benchmark nuclear power price of China is 430 Yuan/MWh. If the triggering point is set as 10% or 20%, that is, the regulation mechanism will be triggered when the guaranteed acquisition nuclear power price fluctuates by 43 Yuan/MWh or 86 Yuan/MWh. According to the triggering point, how many hours that the dependent variables change given investment cost can be calculated. Such calculation mode can enable the competent price department to flexibly master the triggering point, yet without fixing regulation time, so this method needs to continuously supervise the investment cost by the management department.

5.1.2 Simulation Calculation for Linkage Scheme of Construction Investment and FIT

In accordance with the above linkage mechanisms of power price, this paper selects the basic parameters of economical evaluation on generation-III nuclear power to make simulation calculation. The scheme based on triggering point of power price is fixing the change amplitude of power price to back-calculate the investment change. The calculation result shows that the power price fluctuates by 5% when the construction completion cost changes by 6.4%, and fluctuates by 10% when the construction completion cost changes by 12.8%, implying a sensitivity coefficient of 1.28 between construction completion cost and power price. This method can set the change amplitude of construction completion cost for the completed project as the triggering point. When this value is exceeded by the settlement price of finished nuclear power project built in the same batch, the regulation mechanism of FIT can be started.

5.2 Linkage Mechanism of Nuclear Fuel Price with FIT

The price of nuclear fuels will be regulated somewhat under the influence of fluctuation of market price of natural uranium and the changes in costs of conversion, enrichment, and components costs. For the coal-fired power unit which accounts for the largest proportion in China, the linkage mechanism of coal and electricity prices was introduced to guarantee stable profiting of unit. The benchmark FIT changes with fluctuation of fuel price, to reasonably dissolve the sharp effect of coal price swing on the rate of return of coal-fired unit. Similarly, the nuclear power price is also influenced by nuclear fuel, so it is advised to establish the linkage mechanism of nuclear fuel price with the policy of coal and power prices linkage as reference.

5.2.1 Coordinated Modes between Nuclear Fuel Price and Guaranteed Acquisition Power Price

Two modes can be adopted for nuclear fuel price linkage: re-ratify and regulate power price within a fixed cycle, and make regulation in accordance with the influence of change amplitude of nuclear fuel price on power price.

1) Re-ratify and regulate price within a fixed cycle: take average change amplitude of nuclear fuel price within a fixed cycle (such as three or five years) as the basis for whether and to what extent benchmark price will be regulated.

2) Make regulation in accordance with the influence of change amplitude of nuclear fuel price on power price. The calculation flow of nuclear FIT is started when the average change amplitude of nuclear fuel (such as 5% or 10%) is beyond the reference threshold of amplitude.

5.2.2 Simulation Calculation for Linkage Scheme of Nuclear Fuel Price and FIT

For the sake of better understanding the triggering method of linkage between fuel cost and FIT, this paper will adopt the basic parameters of generation-III of nuclear power to calculate the influence degree of fuel cost change on FIT and the change proportion of fuel cost corresponding to FIT change. The case calculation shows the influence of fuel price fluctuation on FIT is smaller compared with the influence of fixed investment. A change of 20% in fuel price produces an influence of about 3.37% on power price. The FIT changes by only 10% when the fuel cost that year changes by over 50%. To realize a change of 5% in power price requires the annual fuel cost to change by about 30% (shown as TABLE III and TABLE IV).

**TABLE III. Correspondence of fuel cost change to FIT change**

| Factor | Change rate of fuel price (%) | Change rate of power price (%) | Sensitivity coefficient |
|---|---|---|---|
| Fuel cost | -20.00 | -3.37 | 0.169 |
| | -10.00 | -1.69 | 0.169 |
| | 0.00 | ---- | ---- |
| | 10.00 | 1.69 | 0.169 |
| | 20.00 | 3.37 | 0.169 |

**TABLEIV. Correspondence of FIT change to fuel cost change**

| Factor | Change rate of electricity price (%) | Annual change rate of fuel cost | Sensitivity coefficient |
|---|---|---|---|
| FIT | -10.00 | -56.46 | 5.646 |
| | -5.00 | -30.30 | 6.059 |
| | 0.00 | ---- | ---- |
| | 5.00 | 28.92 | 5.784 |
| | 10.00 | 61.97 | 6.197 |

## VI. CONCLUSION AND POLICY PROPOSALS

Based on an analysis of the implementation situation of current policy of benchmark nuclear power price, this paper fully considers the reform progress for power system in current stage and studies the regulation factors and mechanism for the guaranteed acquisition nuclear power price. Besides, this paper analyzes the current implementation actuality of benchmark FIT in China and the significant changes of market environment compared with when the policy was established in 2013. The policy that nuclear power benchmark FIT hooks with coal-fired power benchmark FIT based on pricing method of opportunity cost needs to be delved into. Then this paper proposes the general planning thinking for nuclear power price system, in which the competent price department determines the guaranteed acquisition nuclear power price and the power price for market competition is formed by the market. It is suggested that the research on policy should also consider that whether the power is matched with the price policy. The largest correlation factor influencing the nuclear power price is analyzed, and a regulation mechanism of linking fixed assets investment and nuclear fuel price with the guaranteed acquisition power price is proposed, whose feasibility is expounded via case calculation.

The policy mechanism design in this paper can make China's nuclear power FIT policy more reasonable. This kind of mechanism design can reduce the nuclear power FIT on the whole society, which is in line with the reform trend of government electricity system. In addition, it can promote the stable and orderly development of the nuclear power industry and optimize China's energy structure. Based on the above conclusions, following major core suggestions about policies are proposed as below.

6.1 Nuclear Power Benchmark FIT No Longer In Linkage with Coal-Fired Power FIT

The benchmark coal-fired power price fluctuates quickly when Chinese power market is not mature enough, and the fixed investments in different types of power supply are largely different, so does the composition of cost price. Thus, the pricing mode using opportunity cost is hard to truly reflect the real cost of different types of power supply. It is advised to no longer link nuclear power benchmark FIT with the coal-fired power benchmark FIT, which is also equal to reducing the market risks of nuclear power unit. In order to guarantee a reasonable power supply structure nationwide, competent department should put more efforts into establishment of medium and long-term planning of nuclear power project, and the country should control the rhythm of nuclear power construction to prevent severe overcapacity of power incurred by blind investment in nuclear power.

6.2 Determining the Proportion of Guaranteed Acquisition Power Reasonably

In accordance with the technical features of nuclear power running and utilization of nuclear fuel, it is suggested that nuclear power unit should run with base load in full load to guarantee efficient utilization of national strategic resource. It is also advised to reasonably determine the proportion of guaranteed acquisition power quantity, design a reasonable benefit sharing mechanism matching the proportion, and value the policy objective of nuclear power unit generating power in full load and charging preferential price. This paper provides two

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determination methods of guaranteed power quantity: one is determining guaranteed acquisition power quantity based on Tentative Method of Guaranteeing Safe Consumption of Nuclear Power and in accordance with the technical features and national running performance of nuclear power unit, while another is to calculate the guaranteed acquisition power quantity based on economic factors of plants. The power outside the guaranteed acquisition part is for market competition. The design of competitive mechanism of nuclear power is advised to mainly consider the price competition, and guaranteeing nuclear power unit can run in full load can realize the best social benefit.

6.3 Analyzing Construction and Operation Cost of Various Types of Nuclear Power Plants

The generation-III nuclear power plants in China under construction and operation include Hualong, AP series, EPR, VVER, etc. have richer types than those of generation-II modified plants. Hence the construction, operation and fuel costs may be different from the generation-II-plus plants. So it is advised to calculate reasonable power price correspondingly by analyzing the cost of various types of nuclear power plants. And a linkage mechanism shall be designed for the guaranteed acquisition power price in accordance with the important factors influencing the nuclear power price. The mechanism shall properly design the triggering point of linkage with power price and regulate the benchmark FIT at proper time.

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