ISSN: 2414-1895 DOI: 10.6919/ICJE.202506_11(6).0012

Analysis of Capacity Expansion Schemes for the Water Treatment Plant of a Thermal Power Plant

Guohui Pan

Anhui Huadian Wuhu Power Co.,Ltd. , Wuhu 241000, China

Abstract

Due to the increase in industrial heat supply of a thermal power plant in Anhui Province, the capacity of its boiler make-up water system became insufficient. This paper analyzes two capacity expansion schemes. Scheme 1, employing ultrafiltration (UF), reverse osmosis (RO), and ion exchange (IX) system technology, involves a static investment of 21.43 million RMB. Scheme 2, directly adopting ion exchange system technology, has a static investment of 8.68 million RMB. However, Scheme 2 generates a large volume of high-salinity wastewater that cannot be reused within the plant. Therefore, Scheme 1 is considered more feasible.

Keywords

Thermal Power Plant; Boiler Make-up Water; Capacity Expansion; Ultrafiltration; Reverse Osmosis; Ion Exchange; Wastewater Reuse; Investment Analysis.

1. Introduction

Thermal power plants are major consumers of industrial water. According to the China Water Resources Bulletin, in 2023, once-through cooling water for thermal (and nuclear) power plants accounted for 16.4% of total industrial water consumption. With the promulgation of national laws and policies such as the "Energy Conservation Law," "Environmental Protection Law," "Action Plan for Prevention and Control of Water Pollution," and corresponding water use and discharge fee policies (water resource fees, discharge fees, excess discharge fees)[1-3], as well as the gradual implementation of regulations like the "11th Five-Year Plan for Water Conservation in the Power Industry," strict limits have been imposed on water consumption, wastewater discharge volumes, and water quality for thermal power plants.

A certain thermal power plant serves as a centralized heating point. From December 1 to December 23, 2024, the average heating load was 250 t/h, with a maximum heating load of 300 t/h. An additional heating load of 40 t/h will be added in 2025, and a further 95 t/h in 2026. By 2026, the average heating load is projected to reach 396.46 t/h. With this increasing heat demand, the existing boiler make-up water system can no longer meet the steam requirements of heating users and thus requires capacity expansion and retrofitting.

2. Current Situation

2.1 Raw Water Pretreatment System

Raw water is drawn from a river and enters the raw water basin of the water purification station. It is then pressurized by raw water pumps and fed into a distribution well, followed by mechanical accelerated clarifiers. A portion of the clarified water flows into industrial and firefighting water tanks, from where it is boosted by industrial and firefighting pumps into the respective networks for plant use. Another portion of the clarifier effluent directly supplies the circulating water system. The remaining clarified water passes through air-scrubbed filters and enters the chemical water tank, from

ISSN: 2414-1895 DOI: 10.6919/ICJE.202506_11(6).0012

which it is pressurized by chemical water pumps to supply boiler make-up water, among other uses. Based on the characteristics of comprehensive water consumption and the supply system's condition, the chemical water treatment at the purification station employs coagulation, clarification, and filtration processes, while industrial water uses coagulation and clarification. Domestic water for the entire plant is supplied by municipal tap water. A 100 m^3 domestic water tank is located within the purification station to buffer the municipal supply, which is then pressurized by domestic water pumps for various users in the project.

The treatment system is equipped with 2 × 1000 m^3/h mechanical accelerated clarifiers and 2 × 300 m^3/h gravity-type air-scrubbed filters. Coagulants are manually prepared and dosed continuously.

2.2 Overview of Boiler Make-up Water System

The boiler make-up water treatment system consists of high-efficiency fiber filtration and a two-stage demineralization process. There are four sets of high-efficiency fiber filters and primary demineralization systems, and three sets of mixed beds. The design treatment capacity is 4 × 100 t/h, which can meet the boiler water requirements. The system operates in a series unit configuration, with three trains normally in operation and one on standby. During unit start-up or in case of an accident, all four trains can be operated simultaneously. Backwashing and operation of the filters, as well as regeneration and operation of the primary demineralization and mixed bed systems, are remotely controlled. The cation and anion exchange equipment in the primary demineralization system employs top-pressure-free counter-current regeneration. The inlet device is a header-lateral system, and the outlet device uses a perforated plate with nozzle distributors. The intermediate drainage device for the cation exchanger is a header-lateral system, using 001×7 gel-type strong acid cation exchange resin, regenerated with HCl. The intermediate drainage device for the anion exchanger is a header-lateral system, using 213 acrylic strong base anion exchange resin, regenerated with NaOH. The inlet device for the decarbonator is a header-lateral system, with a packing height of 3 meters. The inlet device for the mixed-bed ion exchanger is a header-lateral system, the outlet device is a perforated plate with nozzle distributors, and the intermediate drainage and alkali inlet devices are header-lateral systems, using D001×MB type strong acid cation exchange resin and D201×MB type strong base anion exchange resin.

3. Retrofit Schemes

The plant's raw water pretreatment system includes 2 × 1000 m^3/h mechanical accelerated clarifiers and 2 × 300 m^3/h gravity-type air-scrubbed filters. The existing four sets of 100 m^3/h boiler make-up water treatment systems, affected by the regeneration of cation and anion resins, have a maximum water production capacity of only 350 m^3/h. Therefore, the current surplus of clarified water from the raw water pretreatment system to the boiler make-up water system is 2 × 300 - 350 = 250 m^3/h. Due to site space limitations, there is no room for expanding the raw water pretreatment system in this retrofit. Consequently, this boiler make-up water system capacity expansion project is based on an incoming flow of 250 m^3/h from the raw water pretreatment system.

In this feasibility study, two schemes are designed. Scheme 1: Adopts a semi-membrane method, expanding with ultrafiltration (UF), reverse osmosis (RO), and an ion exchange (IX) system. Scheme 2: Maintains consistency with the original boiler make-up water system process, expanding with a primary demineralization + mixed bed process.

3.1 Scheme 1: Semi-Membrane Method

The existing boiler make-up water plant has no space for expansion. This retrofit proposes to locate the UF, RO units, outdoor water tanks, basins, etc., in an open area (20m × 20m) north of the water treatment plant's basin area. The control room, power distribution room, and plant building will be newly constructed. The process flow diagram is shown below.

This retrofit includes the new installation of two chemical water pumps, each with a rated capacity of 250 t/h, above the chemical water tank to supply water to the subsequent membrane equipment. Two

ISSN: 2414-1895 DOI: 10.6919/ICJE.202506_11(6).0012

new UF units, each with a rated capacity of 225 t/h (one operational, one standby), will be installed. The low-turbidity clarified water from UF treatment will be conveyed by UF water pumps to the RO system. Two new RO units, each with a rated capacity of 168 t/h (recovery rate 75%, one operational, one standby), will be installed. The permeate from RO will be sent to a permeate tank, and the RO concentrate will be sent to a chemical wastewater basin. Two permeate pumps, each with a rated capacity of 168 t/h, will be installed to convey the permeate to the ion exchange system. Due to limitations in expansion space, one new ion exchange system with a rated capacity of 168 t/h will be installed, serving as a mutual backup with the ion exchange system in the original water treatment plant. The regeneration system will utilize the existing regeneration units of the original water treatment plant.

3.2 Scheme 2: Ion Exchanger

The existing boiler make-up water plant has no space for expansion. This retrofit proposes to locate the new equipment in an open area (20m × 20m) north of the water treatment plant's basin area. The control room, power distribution room, and plant building will be newly constructed. The process flow diagram is shown below.

This scheme directly employs the ion exchange method, identical to the existing boiler make-up water system process, using high-efficiency fiber filters, cation exchangers, anion exchangers, and mixed-bed ion exchangers. Two new high-efficiency fiber filters, each with a rated capacity of 125 m^3/h, and two sets of cation exchangers, anion exchangers, and mixed-bed ion exchangers, each with a rated capacity of 125 m^3/h, will be installed. The backwash system for the high-efficiency fiber filters will utilize the existing backwash equipment of the original water treatment plant. The regeneration system for the ion exchange units will utilize the existing regeneration equipment of the original water treatment plant. The new ion exchange system will serve as a mutual backup with the original ion exchange system.

4. Investment Estimation Explanation

The base date for static investment is January 2025.

Bill of Quantities: Based on the construction content and bill of quantities provided by each design discipline. Deficiencies are accounted for by referencing similar projects.

Quotas and Standards:

Construction and installation engineering quotas: "Estimate Quota for Electric Power Construction Projects - Building Engineering (2018 Edition)," "Estimate Quota for Electric Power Construction Projects - Thermal Equipment Installation Engineering (2018 Edition)," "Estimate Quota for Electric Power Construction Projects - Electrical Equipment Installation Engineering (2018 Edition)," "Estimate Quota for Electric Power Construction Projects - Commissioning Engineering (2018 Edition)." "Notice on Publishing Comprehensive Information Prices for Installation Materials in Electric Power Construction Projects for 2023" (Ding E [2024] No. 19) by the Electric Power Engineering Cost and Quota Management General Station.

Project classification and calculation standards: "Budget Preparation and Calculation Standards for Thermal Power Plant Construction Projects" promulgated by the National Energy Administration in 2019.

Project classification and calculation standards: "Regulations on Budget Preparation and Calculation for Thermal Power Plant Construction Projects (2018 Edition)."

Pricing:

Unit price of labor cost: Labor adjustment coefficients are determined with reference to Ding E [2024] No. 1 document "Notice on Publishing Price Level Adjustments for the 2018 Edition of Electric Power Construction Engineering Budget Quotas for the Year 2023" by the Electric Power Engineering Cost and Quota Management General Station. The labor adjustment coefficient for

ISSN: 2414-1895 DOI: 10.6919/ICJE.202506_11(6).0012

building engineering in Fujian Province is set at 14.85%; the labor adjustment coefficient for installation engineering is set at 14.92%.

Material and machinery prices: For installation materials in installation engineering, the price difference is calculated based on the "Comprehensive Budget Price for Installation Materials in Electric Power Construction Projects (2018 Edition)" and the comprehensive information prices for installation materials in electric power construction projects for 2023 published in Ding E [2024] No. 19, or market prices. After accounting for taxes, this is listed as the price difference in the compilation year in the total estimate table.

Equipment prices: Most engineering facility equipment is domestically sourced. Prices for major equipment are obtained through inquiries from manufacturers. Prices for some equipment are referenced from recent similar project contracts and bidding prices. Transportation and miscellaneous expenses rate: 0.7%.

Composition and Standards for Construction and Installation Engineering Costs: Based on the "Regulations on Budget Preparation and Calculation for Thermal Power Plant Construction Projects" promulgated by the National Energy Administration in 2013. The fee rate table is shown in Table 1.

Table 1. Fee Rate Table

No.	Fee Name	Construction Engineering		Installation Engineering	
		Fee Base	**Rate**	**Fee Base**	**Rate**
I	**Measure Fees**				
1	Winter & Rainy Season Construction Surcharge	Direct Engineering Cost	0.55%	Labor Cost	5.20%
2	Night Construction Surcharge	Direct Engineering Cost	0.36%	Labor Cost	1.54%
3	Construction Tools & Equipment Usage Fee	Direct Engineering Cost	0.40%	Labor Cost	6.92%
4	Temporary Facilities Fee	Direct Engineering Cost	2.28%	Quota Direct Cost	14.45%
5	Construction Organization Relocation Fee	Direct Engineering Cost	0.37%	Labor Cost	4.65%
6	Safety & Civilized Construction Fee	Direct Engineering Cost	3.19%	Direct Engineering Cost	3.19%
II	**Indirect Fees**				
1	Regulatory Fees				
1.1	Social Insurance Premiums	Direct Engineering Cost	5.35%	Labor Cost	38.61%
1.2	Housing Provident Fund	Direct Engineering Cost	2.16%	Labor Cost	15.60%
2	Enterprise Management Fee	Direct Engineering Cost	6.62%	Labor Cost	61.94%
3	Construction Enterprise Cooperation & Commissioning Fee			Quota Direct Cost	3.75%
III	**Profit**	Direct + Indirect	5.13%	Direct + Indirect	6.75%
IV	**Taxes**	Direct + Indirect + Profit	9.00%	Direct + Indirect + Profit	9.00%

ISSN: 2414-1895
DOI: 10.6919/ICJE.202506_11(6).0012

Other Expenses: Based on the "Regulations on Budget Preparation and Calculation for Thermal Power Plant Construction Projects (2018 Edition)" promulgated by the National Energy Administration. Survey and design fees refer to the "Guiding Opinions on Implementing NDRC Price [2015] No. 299 - Basis for Design Fee Collection."

Price Escalation Reserve: According to the former State Planning Commission document Ji Touzi [1999] No. 1340, the investment price index is calculated as zero.

Basic Contingency: The basic contingency rate is calculated at 3%.

5. Investment Estimation Results

The preliminary estimate of the investment for this retrofit project, with a static investment base date of January 2025, is summarized in the table below.

Table 2. Major Data on Project Investment

No.	Item	Scheme 1 (Million RMB)	Scheme 2 (Million RMB)
I	Main and Auxiliary Production Engineering	1882	677
1	Boiler Make-up Water System	1489	481
2	Electrical System	194	93
3	Thermal Control System	171	77
4	Commissioning Engineering	28	26
II	Price Difference in Base Period	37	32
III	Other Expenses	162	133
IV	Basic Contingency	62	25
V	Static Investment of Project	2143	868
VI	Interest on Loans During Construction	32	13
VII	Dynamic Investment of Project	2176	881

6. Conclusion

The proposed retrofit schemes for the water treatment plant, incorporating membrane equipment and wastewater reuse, are technically feasible and economically reasonable. The recommended process flow offers advantages such as good adaptability to water quality, stable operation, and reliable performance, yielding significant economic, environmental, and social benefits.

Scheme 1: Static investment of 21.43 million RMB, total operating cost of 3.24 million RMB, resulting in an increase in the on-grid electricity tariff of 1.16 RMB/MWh.

Scheme 2: Static investment of 8.68 million RMB, total operating cost of 2.22 million RMB, resulting in an increase in the on-grid electricity tariff of 0.86 RMB/MWh.

Both Scheme 1 and Scheme 2 can meet the plant's water demand. However, the acid-alkali wastewater generated by Scheme 2 cannot be reused. Therefore, this feasibility study recommends Scheme 1.

ISSN: 2414-1895 DOI: 10.6919/ICJE.202506_11(6).0012

References

[1] Yu, J., & Wang, S. Q. . Economic comparative analysis of pretreatment process routes for high-salinity wastewater in coal-fired power plants. Cleaning World, 2021, 37(12), 1–3.

[2] Wang, R. L., Heng, S. Q., et al.. Experimental study on the performance of a zero-liquid-discharge system for desulfurization wastewater in a 1000 MW unit. Industrial Water & Wastewater, 2020, 46(9), 78–81.

[3] Xu, Z., Yang, B. H., Wang, Z. J., et al. . Water balance optimization and water consumption index analysis in thermal power plants. Thermal Power Generation,2007, 36(5), 1–4.