INTELLIGENT MONITORING OF RESIN SEPARATION AND TRANSPORTATION FOR MIXED BED POLISHER

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Abstract

The effects of resin separation and transportation for mixed bed (MB) polisher are poor and unstable as lacking of effective monitoring, negatively impacting operational effects of MB polisher. Concerning about this issue, (Thermal Power Research Institute) TPRI developed an intelligent monitoring technology, which is able to not only accurately inspect the terminal point of resin separation and transportation, increasing separation percentage of exhausted resin, but also adjust a ratio of cation to anion resin depending on the requirement to increase periodic water production of MB polisher. In 2014, TPRI implemented optimization measures on condensate polishing system in 2×350-MW supercritical coal-fired units, applying the intelligent monitoring technology of resin separation and transportation. The operational effects of MB polisher are highly improved and more stable, with periodic water production increased from 26, 000 m^3 to 82, 000 m^3. Times of resin regeneration are highly decreased, saving 112 tons acid and base, 31, 000 m^3 demineralized water and 62, 000 m^3 fresh water. Annual supplemental resin decreases by 3%. In this way, the annual direct benefit is about 180,000 USD.

Introduction

The total installed capacity of power generation units in China reached about 1,360,190MW at the end of 2014, which is the largest in the world. Large capacities, high parameters, high efficiency and low emission thermal power units have been the main units. Mixed bed (MB) polisher in condensate polishing is of the great importance to guarantee the feedwater purity. Resin separation arrangements should be operated automatically as designed. However, Fullsep and Conesep[1-2], the most popular and effective resin separation arrangements, are not able to be program-controlled. The resin separation percentage do not reach the designed value to meet the requirement of both anion resin in cation and cation resin in anion less than 0.1% [3]. TPRI found that resin separation percentage of 80% separation arrangements are greater than 1%, even than 5%, which has a great impact to effluent quality of MB polisher and periodic water production. Low reliability of photoelectric detection and conductivity detection are the reason to not apply program-controlled operation. Resin separation and transportation have to be manually operated. Concerning about this issue, TPRI developed an intelligent monitoring equipment, named as "Instrument of image recognition and intelligent control of resin transportation (IRIC)", for the process of resin separation and transportation. IRIC is capable of monitoring resin interface, making resin separation equipment to be program-controlled. IRIC has won the Chinese invention patent (No.ZL 2012 1 0398598.5).It has been already successfully applied to 22 units in 10 power plants.

Technical Introduction of IRIC

Principle

In the process of resin separation and transportation, dynamic resin images are achieved through sight glasses of separation vessel. The cation and anion resin interface and resin superface are estimated by the intelligent image recognition technology. The volume of cation resin, anion resin and the total resin will be calculated. In this way, resin separation and transportation can be program-controlled. IRIC consists of three sections, including resin interface image acquisition, interface images intelligent recognition, control program of resin transportation. Resin interface image acquisition section is function of achieving the real time images of resin separation and transportation; interface images intelligent recognition section is function of analyzing the achieved images and sending control signals as response; control program of resin transportation acts as “signal bridge” between the two sections above, and is responsible for implementing control instructions. The core of IRIC is interface images intelligent recognition section, which is developed on the basis of “Self-adaption algorithm of resin separation and transportation images”, with the accuracy of estimating the resin transportation terminal point higher than 95%. It will result in that both anion resin in cation and cation resin in anion are less than 0.1%. Figure 1 is the system diagram of IRIC applied in Fullsep.

Function

Basic Function: Accurately estimate the terminal point of resin separation and transportation, precisely measure the volume of cation resin and anion resin in MB polisher, increasing resin separation percentage.

Expanding Function: Adjust cation/anion resin ratio and increase periodic water production without modify the internal structure of separation vessel, estimate resin transportation percentage to prevent incomplete resin transportation, monitor the total resin volume to estimate if leakage or not.

Application

TPRI developed IRIC in August, 2012.IRIC has been successfully applied to 22 units in 10 power plants so far, of which over 60% are (ultra) supercritical units. Among these 22 units, there are both air-cooled and water-cooled; both Fullsep and Conesep for separation. Specifically, the application effects are as following:

Improving resin separation percentage, both anion resin in caion and caion resin in anion are less than 0.1%, most are less than 0.05%.Improving MB polisher effluent quality, sodium and chloride decreases from 1~3μg/L to 0.2~0.5μg/L in the end of Hydrogen-type operation.Increase periodic water production, usually by 50%; periodic water production can be increased 200% by increasing the volume of cation resin.

Here is a case study in terms of IRIC installation, debugging and implementation effects.

Project Overview

From August to October, 2014, concerning about the issues of condensate polishing in a power plant in Hainan province, TPRI implemented a series of measures, applying IRIC as the core, to optimize the operation of condensate polishing. 2×350-MW supercritical coal-fired units were put into operation in this power plant at the end of 2012. The condensate polishing consists of 2 tubular pre-filters and 3 mixed beds, configured with external regeneration arrangements. Before optimization, the average periodic water production of MB polisher is 2.6 m^3, which is only 60% of the designed value, resulting in frequent resin regeneration and then it has to turn on partial-flow operation, negatively impacting safety operation of units.

After estimation and analysis, TPRI found out problems as following:

It is not able to monitor the process of resin separation and transportation, resulting in a wrong resin ratio, with deviation of 13% in maximum. And then lead to an unstable effect of resin separation. The anion resin in cation and cation resin in anion are relatively high, which are 1.4% and 1.5%, respectively. In this condition, the cation-exchange capacity is negatively impacted, resulting in a shorter run length.

The ratio of cation to anion resin in MB polisher (1:1) is inappropriate. Cation resin is not enough to have a long run length.

The expansion space for resin is 500mm in MB polisher, which is only 50% of the designed 1000mm. Moreover, the water distribution, which is back board and water distribution plates installed with strainers, is easy to be deformed or damaged. These two reasons easily result in uneven water distribution in mixed bed, and further to shorten the operation cycle.

Optimization

Installation of IRIC.

The components of IRIC are designed according to the size of external regeneration arrangements for each power plant, and will be processed and preinstalled in manufactory. The components, like intelligent host, will be tested. The installation of all components is performed outside of resin separation equipment, so IRIC can be installed during the operation of condensate system, without bringing any interruption. Installation information of each section is listed below.

Resin interface image acquisition section consists of high definition industrial digital camera, high definition camera, floodlight and special support. High definition industrial digital camera is the core of this section, with pixel of 1 M, resolution ratio of 720 P and delay time of image data transmission is just 0.5 s. It can work uninterruptedly. Separation vessel was installed with three resin interface image acquisition sections, at upper, middle and lower sight glass, respectively. Upper sight glass is used to observe the superface of resin; middle sight glass is used to observe the resin interface after backwashing and layering; lower sight glass is used to observe the location of resin interface at the end of cation resin transportation. Figure 2 is resin interface image acquisition section installed at lower sight glass.

Interface images intelligent recognition section consists of host computer and resin interface image intelligent recognition software, of which intelligent recognition software is the core. Figure 3 is the display interface of this software.

Control program of resin transportation section consists of four parts, which are intelligent control host, control signal circuit, transmission network of resin monitoring image and PLC. Intelligent control host is the core of this section, composed of industrial grade accessories, such as switchboard, remote I/O and LCD development board. The average failure-free operation time is over 2400 h. LCD development board supports embedded operating systems, including Windows CE, Linux and Android. The intelligent control host is installed by hanging on the wall, easy and convenient. Figure 4 is an intelligent control host installed at the field.

Debugging of IRIC.

First, debug each section of IRIC to make sure it can be operated normally. Then, analyze the whole process of resin separation and transportation and select appropriate parameters for software. Finally, debug the monitoring function back and forth, which is showed as following:

When exhausted resin transported to separation vessel, software conducts calculation to figure out the volume of total resin, cation resin and anion resin volume, respectively. On this basis, early warning is given to indicate the change of resin volume over $0.3m^3$.

When exhausted resin is backwashed and layer in separation vessel, software analyzes the images achieved from middle sight glass automatically. As the volume of cation resin is increased to adjust resin ratio, cation and anion resin interface is located above the anion resin exporting position, and what observed from middle sight glass is cation resin. Therefore, the analysis result is that “Cation resin is too much. In order to prevent transport cation resin into anion regeneration vessel, part of cation resin should be transported to cation regeneration vessel first, until cation and anion resin interface go down to reach the set location below anion resin exporting position.” When correct procedure of resin transportation is obtained, software will send the instruction of “Transporting cation resin”, begin to analyze dynamic images achieved from middle sight glass in real time, and estimate the terminal point of exporting cation resin. When reach the terminal point, “Go to next step automatically” will be sent by software. PLC system will receive and proceed the instruction. Anion resin will be transported to anion regeneration vessel as the procedure.

When anion resin transported to anion regeneration vessel, software will send “Second resin transportation” to PLC system, and analyze dynamic images achieved from lower sight glass in real time, until catch the cation and anion resin interface at the set location in lower sight glass, which means reach the terminal point of cation resin transportation. Then, software will send “Go to next step automatically”. PLC system will receive and proceed the instruction.

Adjust Cation/anion Resin Ratio.

In order to extend run length of MB polisher and guarantee cation regeneration vessel normally operated, the ratio of cation and anion resin was adjusted from 1:1 to 1.2:1. Ratio adjustment is performed in the process of resin separation and regeneration after exhausted resin transported from MB polisher to separation vessel, which has no impact to MB polisher operation. The cation resin supplemented to adjust the cation/anion resin ratio, which was the same resin as old one, transported to cation regeneration vessel through resin addition funnel by means of hydraulic transportation. Double dose regeneration was conducted after adding cation resin.

Optimizing Procedure and Modifying PLC System.

IRIC can accurately catch the terminal point of resin transportation only on the basis of smooth moving of resin interface. Resin interface moves smoothly or not depends on if transportation flowrate is appropriate. Therefore, it is concerned to optimize flowrate parameters in transportation procedure by debugging.

In order to make resin separation and transportation program-controlled, the programmed logic of resin separation and transportation is modified in the following three aspects. Add warning signal of total resin volume. Modify the procedure of resin separation and transportation. “Export anion resin – Export cation resin” is changed to “Export cation resin 1– Export anion resin – Export cation resin 2”.Add control signal of cation resin exporting terminal point.

Modification of Water Distribution Device in MB Polisher.

TPRI developed the Enhanced Two-stage Water Distribution Device in 2014 (No. ZL 2014 2 0622942.9).Replace the original device with the Enhanced Two-stage Water Distribution Device in 6 Mixed Beds, at the greatest extent reducing the negative impact on water distribution effect resulted from insufficient resin expansion space, and weakening the problem of uneven water distribution. The water distribution device consists of first water distributor, second water distributor and connector. It can be easily and convenient installed in a short construction period, without normal operation of MB polisher. This device is solid, durable, and has a good water distribution effect.

Implementation Effects

It is much more reliable to monitor resin separation and transportation. The tracking record showed that 38 times of monitoring out of 40 can be operated automatically, except 2 times due to some other reasons in November and December of 2014.

Resin separation percentage is obviously increased. After exhausted resin separation in MB polisher, anion resin in cation and cation resin in anion decreased from 1.4% and 1.5% to lower than 0.05%.

In an operational cycle, sodium and chloride in MB effluent stay lower than 0.3μg/L

The cation resin volume increased and anion resin volume decreased as the result of cation/anion resin ratio adjusted to 1.2:1. Although resin interface cannot be observed in middle sight glass, resin can be effectively separated and transported by modifying resin separation procedure, with deviation lower than 1%.

Average periodic water production increases from 26, 000 m^3 to 82, 000 m^3, increasing more than 200%. Comparison of periodic water production is shown in Figure 5.

The times of resin regeneration decreased from 280 MB-time to 140 MB-time, saving 112 tons acid and base, 31, 000 m^3 demineralized water and 62, 000 m^3 fresh water. Annual supplemental resin is decreased by 3% and annual direct benefit is about 180,000 USD.

Conclusion

IRIC is capable of not only estimating the terminal point of resin separation and transportation, increasing resin separation percentage, but also increasing periodic water production by adjusting the resin ratio. This is a breakthrough of monitoring technology for MB polisher operation, which has been already successfully applied to 22 units in 10 power plants.

Apply optimization with IRIC as the core to 2×350-MW supercritical coal-fired unit in a power plant in Hainan province, increasing resin separation percentage and cation resin volume. Together with applying the Enhanced Two-stage Water Distribution Device, the MB effluent quality is obviously improved, and periodic water production is increased by 200%.

IRIC has an obvious effect on saving water and reducing emission. After applied to a power plant in Hainan province, it can save 112 tons acid and base, 31, 000 m^3 demineralized water and 62, 000 m^3 fresh water. Annual supplemental resin decreases by 3% and annual direct benefit is about 180,000 USD.

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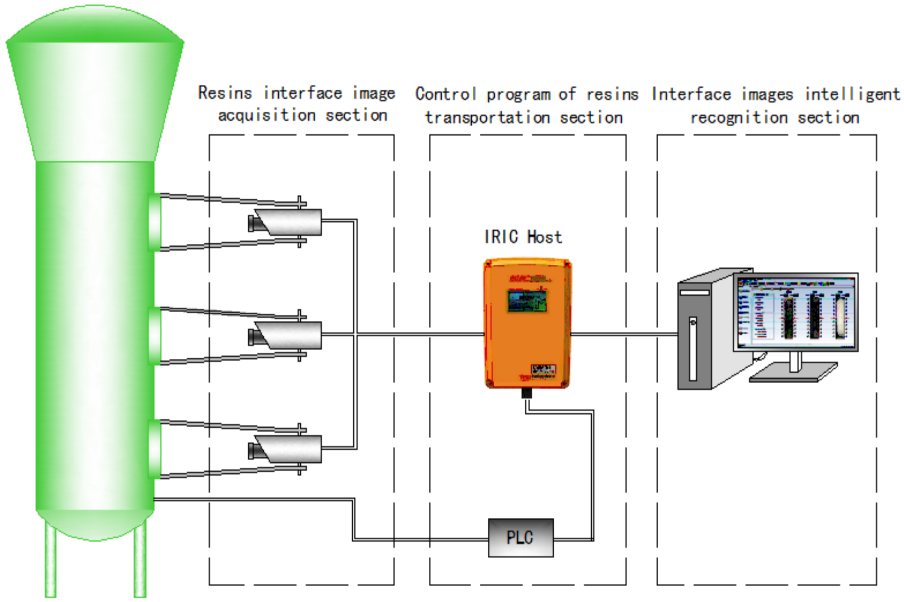

Figure 1
IRIC System Diagram in Fullsep

Figure 2
Resin Interface Image Acquisition Section

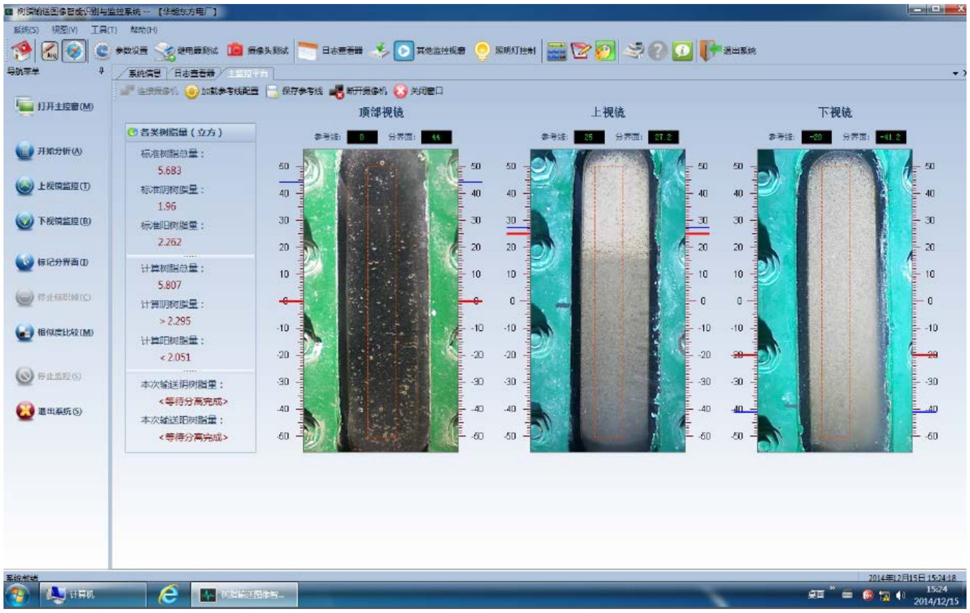

Figure 3
Display Interface of Interface Images Intelligent Recognition Software

Figure 4
Intelligent Control Host

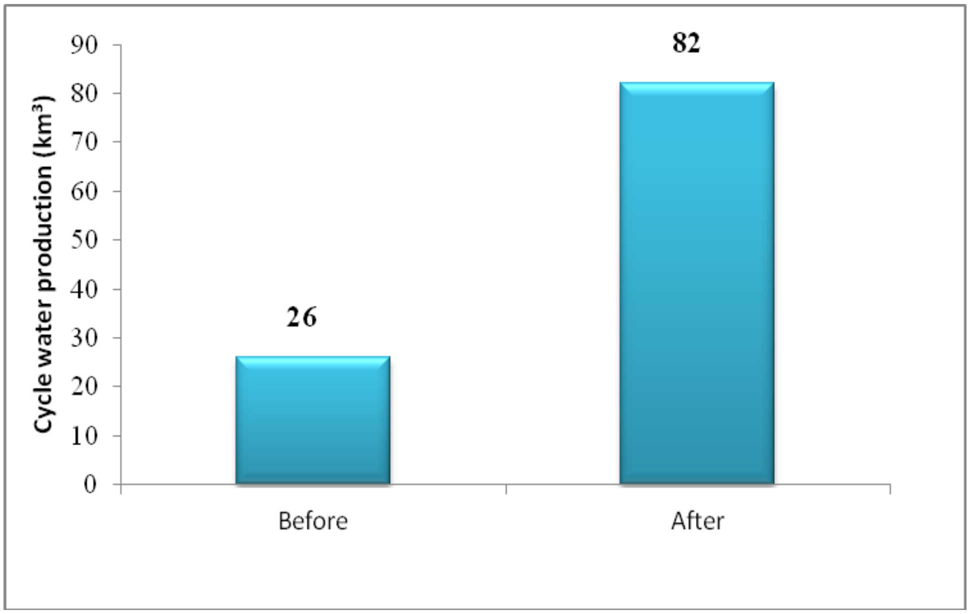

Figure 5
Comparison of periodic water production