Ash conveying system upgrade from hydraulic to pneumatic system in a 550MW coal-fired power plant in Taiwan

Anshar Makhraja¹*, Thompson Tsai¹, Jimmy Lee¹, and Wendy Hsu¹,

¹Tai & Chyun Associates Industries, Inc., Taiwan

Abstract. The paper presents a comprehensive study on the ash handling system upgrade from a hydraulic conveying system to a pneumatic system in a 550 MW coal-fired power plant located in Taiwan. The ash pond used to dispose of ash from the economizer and air preheater is almost full due to having been in service for more than forty years. An alternative location to dispose of the ash is sought. The design process of finding the new location and the equipment to be used is explored. Some options for the new economizer and air preheater ash disposal site, including building a new silo or using an existing silo, are taken into consideration in terms of design, cost, and timing of execution. The project's execution procedure is reviewed, taking into account aspects of system integration, equipment installation, and commissioning. The primary objective of this paper is to detail the design, implementation, and outcomes of the ash handling system upgrade. This upgrade is accomplished in an effort to enhance operational efficiency, reduce maintenance requirements, and improve environmental compliance. The study explores the motivations behind adopting pneumatic conveying technology, focusing on its advantages over hydraulic systems, such as reduced maintenance needs and improved dust control. The case study provides insight into the lesson learned and recommendations for similar ash conveying system upgrades in other coal-fired power plants.

1 Introduction

The coal-fired power plants have long been pillars of providing a reliable source of electricity in Taiwan for over 40 years. With ten coal-fired units, each boasting a 550 MW capacity, this facility has been a steadfast contributor to the region’s energy grid, powering homes, businesses, and industrial operations. With environmental consciousness on the rise and stringent regulatory standards coming into effect, power plants have had to adapt to ensure both operational efficiency and compliance with evolving environmental norms.

Coal ash from coal burning is one thing that the plant needs to control in order to not pollute the environment. There are several ways to dispose of coal ash from the power plant: surface impoundments (ash ponds), landfills, mine and quarry fills, and ocean disposal [1]. Coal ashes from coal burning that need to be managed come from several sources of the

* Corresponding author: anshar.m@taichyun.com.tw

© The Authors, published by EDP Sciences. This is an open access article distributed under the terms of the Creative Commons Attribution License 4.0 (https://creativecommons.org/licenses/by/4.0/).
power plant process, including the boiler, economizer (ECO), air preheater (APH), and electrostatic precipitator (ESP), as shown in figure 1. Each has different characteristics that make it a different way to transport and dispose. Ash falling down from the boiler is called bottom ash. It has characteristics such as being coarse, ranging from about 0.1 mm to 50 mm in diameter, and having a high temperature [2]. Ash that is caught by ESP is called fly ash. It has the characteristic of a fine-grained particle with a small size ranging from 1 to 100 microns in diameter, with a median particle diameter of 20 to 25 microns [3]. Fly ash has a relatively low temperature compared to bottom ash. APH and ECO ash have characteristics in between bottom ash and fly ash in terms of fineness, size, and temperature. APH and ECO ash are often classified as fly ash, where ECO ash contains pebble and stone-like particles due to soot blowing from 6mm to 50mm size while APH ash has finer particles ranging from 100 to 800 microns [4].

The original design of the power plant dictated that the disposal of bottom ash uses a scraper chain conveyor (SCC), and later the ash goes into the bottom ash silo. Fly ash from the electrostatic precipitator (ESP) is disposed in the fly ash silo. Economizer (ECO) and air preheater (APH) ash is disposed via sea water in an ash pond—a solution that has served faithfully but now presents formidable challenges. The problem, succinctly stated, is as follows: After more than 40 years of operation, the ash pond is nearing full capacity, necessitating an urgent and effective solution for the disposal of ash residues. With the ash pond as a primary disposal method reaching its operational limits, the plant sought an alternative approach that would ensure not only continued operational efficiency but also compliance with evolving environmental regulations. The key conundrum faced by the power plant lay in identifying both the means and destination for the economizer (ECO) and air preheater (APH) ash, ensuring sustainable solutions that safeguard the environment while preserving reliability.

![Fig. 1. Ash from coal-fired power plant process](image)

This problem statement encapsulates the core issue that prompted the initiation of the project and serves as the catalyst for the subsequent exploration of the innovative transition from hydraulic to pneumatic ash conveying systems.
2 Method

The challenges to solving the problem are to find a suitable new disposal place and to find the best method for transporting the ECO and APH ash. Screening by comparing available disposal places and technology to transport the ash is performed.

Table 1 shows the comparison of the hydraulic system (wet) and the pneumatic system (dry). It is compared in terms of environmental impact, operational cost, and reliability.

<table>
<thead>
<tr>
<th>No</th>
<th>Point Consideration</th>
<th>Method to convey ECO/APH ash to mid-stage storage</th>
<th>Decision</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Hydraulic System (wet)</td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>Environmental</td>
<td>● Potential Slurry spillage</td>
<td>Not choosen</td>
</tr>
<tr>
<td></td>
<td></td>
<td>● Large amount of leachate</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>Operational Cost</td>
<td>High operational cost from slurry pump</td>
<td>Choose</td>
</tr>
<tr>
<td>3</td>
<td>Reliability</td>
<td>High corrosion potential from water use</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Low corrosion potential from corrosion</td>
<td></td>
</tr>
</tbody>
</table>

Existing ECO and APH ash transportation systems to the ash pond use hydraulic conveying systems, which are wet systems, as the ash is transported by the pump in a slurry form. This can lead to challenges related to water management, potential leakage, and water treatment. Moreover, the use of water in hydraulic systems raises concerns about water consumption and its potential environmental impact. The environmental impact comes from potential slurry spills and large quantities of leachate.

Upgrading the ash handling system from wet to dry has been a trend in the coal ash handling system. The dry system has the advantages of eliminating a huge amount of water, lower maintenance costs from corrosion and jamming along the piping line, and lessening power demands due to the elimination of the water circulation pump [5].

It is decided to utilize pneumatic conveying systems, which are dry systems, which can be advantageous due to some reasons below:
1. Eliminate ash pond usage.
2. Eliminates all water usage.
3. Flexible ash conveying route through the crowded plant buildings.
4. The new compressor consumes less power compared to the existing pump.
5. Reducing the potential for corrosion and slurry spillage.

The key design considerations for choosing the transportation system include APH and ECO ash characteristics, space for the equipment, project cost, and installation time.

Finding the new destination for the ECO/APH ash turned out to be the most challenging part of this project. The options are to build a new silo, to use an existing bottom ash silo, or to use an existing fly ash silo. The summary of the screening is shown in Table 2.

The existing fly ash silo is not considered because the characteristics of the ECO and APH ash do not qualify be sold to a cement plant. Characteristics is due to bigger and coarser particle size and also higher carbon content. Building a new silo option is not considered due
to high cost and long pre-outage installation. To put the ECO and APH ash into the existing bottom ash silo is the best option.

Existing bottom ash silo is wet type. The challenge comes because of the wetness and humidity present in the bottom ash silo. Since the method will use pneumatics, a bag filter is needed to collect the ash. Wet conditions are not suitable for bag filters. It will ruin the filter bags after sometimes being under operation. After a site survey and weighing up the few available options, it was finally concluded that the best solution was to convey the ECO/APH ash to the boiler hopper and have a bag filter installed on the nearby platform.

Table 2. New ECO/APH ash mid storage comparison

<table>
<thead>
<tr>
<th>No</th>
<th>Point Consideration</th>
<th>Existing Bottom Ash Silo</th>
<th>Existing Fly Ash Silo</th>
<th>Build new silo</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Ash Characteristic</td>
<td>Suitable</td>
<td>Not suitable. Fly ash has fine particle that sold to cement plant</td>
<td>Suitable</td>
</tr>
<tr>
<td>2</td>
<td>Space for Equipment</td>
<td>Available &amp; Reachable</td>
<td>Available &amp; Reachable</td>
<td>Available &amp; Reachable</td>
</tr>
<tr>
<td>3</td>
<td>Project Cost</td>
<td>Low</td>
<td>Low</td>
<td>High</td>
</tr>
<tr>
<td>4</td>
<td>Installation during outage time</td>
<td>45 days</td>
<td>45 days</td>
<td>45 days (not include pre-installation to build new silo)</td>
</tr>
<tr>
<td>Decision</td>
<td>Choose</td>
<td>Not chosen</td>
<td>Not chosen</td>
<td></td>
</tr>
</tbody>
</table>

The bottom ash and ECO/APH ash from the boiler hopper is delivered to the bottom ash silo through the submerged chain conveyor (SCC). A submerged chain conveyor is a double-stranded chain conveyor for handling high-temperature material that drops into water, which the conveyor is filled with. The chain strands are submerged in water, move at very low linear speed, and scrape out the material from the water. The wet condition of the environment due to SCC is a challenge because the bag filter is susceptible to moisture. Another step to avoid moisture getting out of SCC and into the bag filter is considered. It was decided to install a buffer tank in between the boiler and bag filter.

3 Results and discussions

The new system layout is shown in figure 2. The Pneumatic conveying system is composed of four major portions, as below:
1. Air mover
2. Feeding/mixing device,
3. Pipe
4. Gas/dust separation device (bag filter)
Ash that falls from the ECO and APH is fed into a feeding/mixing mechanism before entering a bag filter. As the feeding or mixing apparatus, blow tanks with an effective volume of 100 liters were used. Ash entering and leaving the blow tank is controlled by inlet and outflow valves with the aid of a timer and pressure transducer. There are a total of 14 blow tanks, including 2 for ECO ash and 12 for APH ash.

Pressurized air is used in the pneumatic system to move the ash. Using pressured air, the ash at the blow tank was then conveyed through ash piping. The air compressor, dryer, and air tank make up the bulk of the air mover's equipment. The greatest working pressure used to transport the dust is 7 kg/cm². Two new air compressors are available, one for use and the other as a backup.

Ash from the blow tank is collected using bag filters. Ash is both separated from air and cached by the bag filter. The ash then moved from the bag filter to the buffer tank below and then into the boiler hopper.

The pneumatic system consists of two types in terms of ash discharge location at the blow tank. Top discharge or bottom discharge. Bottom discharge is chosen due to the coarse and poor permeability of the ECO and APH ash. It is more suitable to apply bottom-discharge blow tanks instead of the top-discharge blow tanks commonly seen in the ESP fly ash handling system.

The challenge with the pneumatic conveying system is to provide reliable valves and piping since the dry ash is able to cause abrasion. The inlet and discharge valves use rotating disc valves with tungsten plates. A tungsten seal is applied to the disc, and the top and bottom portions of the valves that contact the disc are also made of tungsten seal. It can sustain constant abrasion from ash. A spring is used to support the disc. When the valve opens or closes, the disc can spin freely to allow even abrasion of the seal ring.
Pipe abrasion for pneumatic systems often happens where the pipe direction changes in degree, such as at the elbow pipe. The elbow pipes are installed with a ceramic sleeve and a large bend radius. By increasing the bend radius, the bend to pipe diameter ratio (D/d) is increased and the particle impact angle is decreased, and thus the abrasion is kept to a minimum. The hardness of ceramic liner is 9 MOHS, which also allows for a longer lifetime of the bend pipe.

There is a buffer tank with fluidization after the bag filter outlet and before the SCC to reduce the risk of moisture from the SCC traveling up to the bag filter and leading to bag clogging. A buffer tank is utilized between the boiler and bag filter. The buffer tank plays a vital role in ensuring a smooth and controlled transition of ash material from the bag filter to the SCC. It can also assist in managing moisture levels if the ash collected at the bag filter is damp. It prevents the bag from being ruined by moisture.

The installation takes around 45 days’ outage time in 2021. The installation process consists of the removal of the existing hydraulic system below the APH and ECO hopper, the installation of a new blow tank and piping under the APH and ECO hopper, the installation of new air mover equipment, the installation of a bag filter, and the installation of a buffer tank. Picture of existing and new equipment are shown in figure 5-10. Existing SCADA was modified to control new pneumatic ash handling system.
Fig. 5. Existing APH tank before retrofit

Fig. 6. Existing ECO tank before retrofit

Fig. 7. New APH tank after retrofit
4 Conclusions

The ECO/APH ash can now be handled alongside the bottom ash by switching from a hydraulic system to a pneumatic conveying system. The bottom ash, APH ash, and ECO ash gathered on the bottom ash silo are sold and transformed into controlled low-strength material (CLSM) after additional drying, screening, and mixing procedures to produce the necessary mixture of particle sizes.
The enclosed ash pipeline utilized by the pneumatic ECO and APH ash conveying system keeps the site clean and does away with the requirement for water, which was previously required for hydraulic systems. The amount of water required for the SCC process beneath the boiler hopper is unaffected by the addition of ECO and APH ash to the hopper silo. Reduced maintenance costs and a longer lifespan are made possible by the sturdy design of the valves and ceramic elbow pipe. Since the project's outcome was successful, the concept was eventually adapted to other units during the ensuing shutdowns, which took place over the course of three years.

References