Experimental Verification of Electrostatic Precipitator Stable Operation Under Oil and Co-fuel Firing Conditions of a Coal-fired Power Plant

Anh Hoang  
Power Engineering Consulting Joint Stock Company 2, 32 Ngo Thi Nhiem St., District 3, Ho Chi Minh City, Vietnam  
anh.ht2@pecc2.com

Tuyen Nguyen  
Ho Chi Minh City University of Technology, 268 Ly Thuong Kiet St., District 10, Ho Chi Minh City, Vietnam

Mao Nguyen  
Hanoi University of Science and Technology, 1 Dai Co Viet St., Hai Ba Trung District, Hanoi City, Vietnam

Abstract—Electrostatic Precipitators are usually put into service after a complete shut-off of oil supply to the boiler burners of the furnace of a coal-fired power plant. However, such practice may lead to enormous dust concentration in the flue gas (design value is 37.9 g/Nm³ at 50% RO load) and heavy black smoke appearing at the stack outlet during the oil and/or co-fuel firing condition of boiler. To minimize such problem, an experimental study on charging and electrostatic precipitator operation during unit start-up and shut-down was carried out to verify de-dusting performance. It requires the manual control of the secondary voltages to be lower than sparking voltage of 10–15kV in case of oil and/or co-fuel firing condition of boiler. The study results prove that the electrostatic precipitator runs normally with good de-dusting performance (about 56.4 mg/Nm³ at unit start-up and within 31 mg/Nm³ at unit shut-down) and meets the Vietnamese environmental emission requirements as per proposed specified rules. From the study results, it can be predicted that Electrostatic Precipitators (ESP) & Sea-Flue Gas Desulphurization System (FGD) may be kept running during house load operation and run-back modes. Also, with the ESP and FGD running, the coal-fired power plant may not be limited to the loading dispatch at stable loads under co-firing condition below the minimum load of anthracite coal firing as required from power system.

Index Terms—Coal-fired Power Plant, Collection Efficiency, Electrostatic Precipitator, Particle Matter, Unit Start-up and Shut-down.

I. INTRODUCTION

There have been numerous theoretical and experimental studies on the models of particle collection efficiency [1-9]. The studies showed that an Electrostatic Precipitator (ESP) in coal-fired power plant achieves high collection efficiency above 99.5% [10]. The research of a reduction in particulate matters emission to less than 5 mg/Nm³ from ultra-low emissions power plant [11-12] and increasing PM1,5 emission with Flue Gas Desulphurization System (FGD) & Selective Catalytic Reduction (SCR) installations [13] has also been examined. Otherwise, experimental studies on charging and electric field characteristics of biomass/coal co-combustion has also been carried out to verify ESP performance [14]. Dust concentration at outlet of the stack of a coal-fired power plants should meet the requirement of Vietnamese environmental standards at any output during operation [15-16]. In case of units fired with anthracite coal, the ESP are usually put into service for high load of boiler (≥70%RO) only. However, such practice may lead to enormous dust concentration in the flue gas and heavy black smoke appearing at the stack outlet during the low load condition of boiler in the absence of ESP operation. This study is conducted to prove that ESP can be operated and will perform well, even during oil and/or co-fuel firing conditions of a coal fired power plant, to meet the environmental emission requirements.

II. MODELING APROACH

The object of the study includes the 622.5 MW unit, which was built at Duyen Hai District – Tra Vinh Province - Viet Nam, (i) the unit was able to operate continuously and guaranteed at loads equal to 70% or above of RO when firing the specified design coal without fuel oil support under automatic control, (ii) the unit also was operated at loads between 70% and 30% of RO with support firing of HFO and under automatic control, (iii) the steam generator was designed to operate below 30% of RO with HFO heavy fuel oil only. The double-arch fired DG2028/17.35-II8 boiler made by DongFang Boiler Group CO. LTD for unit, which is designed as natural circulation drum, “W” fired using pulverized Viet Nam anthracite coal, balanced draft, single reheate, dry bottom, outdoor Π type. Domestic Anthracite coal (Cam 6A) from the mines in Hon Gai - Cam Pha area is provided as the design coal with the specification according to TCVN 1790 – 1999 [17]. Also, HFO No. 2B is used for boiler start-up and additional firing at low load with properties are given as TCVN 6239-2002 [18]. The ESP equipment was designed and manufactured by Fujian Longking Co., Ltd. The
advanced technology of top electromagnetic impact rapping was applied to D.E. and C.E. system. Digital micro-computer control was applied to high voltage rectifying equipment, and the ESP is centrally control by the IPC control system which is able to online monitoring and managing all high & low voltage equipment, which makes it easy to operate and maintain. The ESP main design data [19] are showed on table 1.

<table>
<thead>
<tr>
<th>Description</th>
<th>Unit</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>General flow rate of treated flue gas</td>
<td>m³/h</td>
<td>3176882</td>
</tr>
<tr>
<td>Flue gas temperature</td>
<td>°C</td>
<td>125.5±10</td>
</tr>
<tr>
<td>Inlet Dust Concentration</td>
<td>g/Nm³</td>
<td>42.2934</td>
</tr>
<tr>
<td>Precipitation efficiency</td>
<td>%</td>
<td>99.78</td>
</tr>
<tr>
<td>Drop pressure</td>
<td>Pa</td>
<td>&lt;245</td>
</tr>
<tr>
<td>Design pressure</td>
<td>Pa</td>
<td>± 7100</td>
</tr>
<tr>
<td>Short term max design pressure</td>
<td>Pa</td>
<td>± 8700</td>
</tr>
<tr>
<td>Casing air leakage rate</td>
<td>%</td>
<td>≤2</td>
</tr>
<tr>
<td>HV power supply for electric field</td>
<td>kV</td>
<td>72</td>
</tr>
</tbody>
</table>

According to design, the ESP will be put into service during high load of boiler (Boiler load ≥70%RO) with the secondary voltages at normal operation voltage and maintain under automatic control. However, such practice may lead to enormous dust concentration in the flue gas and heavy black smoke appearing at the stack outlet during the oil and/or co-fuel firing condition of boiler as illustrated in in Fig. 1.

Figure 1. Heavy black smoke and enormous dust concentration appearing at the stack outlet.

Unit start-up and shut-down without ESP operation during the oil and/or co-fuel firing condition of boiler is indicated on Fig. 2&3, dust concentration is over maximum scale value of 220 mg/Nm³ of opacity sensor under co-fuel firing condition (design value at 50%RO load is 37.9 g/Nm³ and at 75%RO load is 40.2 g/Nm³). These dust concentration values do not meet the requirement of Vietnamese environmental standards, which are associated with significant adverse human health effects.

According to design, the ESP will be put into service during high load of boiler (Boiler load ≥70%RO) with the secondary voltages at normal operation voltage and maintain under automatic control. However, such practice may lead to enormous dust concentration in the flue gas and heavy black smoke appearing at the stack outlet during the oil and/or co-fuel firing condition of boiler in the absence of ESP operation as illustrated in in Fig. 1.

According to design, the ESP will be put into service during high load of boiler (Boiler load ≥70%RO) with the secondary voltages at normal operation voltage and maintain under automatic control. However, such practice may lead to enormous dust concentration in the flue gas and heavy black smoke appearing at the stack outlet during the oil and/or co-fuel firing condition of boiler in the absence of ESP operation as illustrated in in Fig. 1.

III. METHODOLOGY OF RESEARCH

To minimize such problem concerning about enormous dust concentration and heavy black smoke appearing at the stack outlet, a testing of the electrostatic precipitator operated during start-up and shut-down was carried out to verify dusting performance under the oil and/or co-fuel firing condition as per the following proposed specified rules.

At the start of the unit (Boiler load≤40%RO), put the high voltage of field number one (1st) and/or field number two (2nd) of ESP into operation before ignition the boiler and manually control the secondary voltages lower than sparking voltage 10~15kV, keep this operation until the load reaching about 40%RO. When the boiler load reaching from 40%RO to 70%RO, put the other fields of ESP into operation (3rd, 4th and 5th sequentially) according to the emission at the outlet of stack, and manually control the secondary voltages lower than sparking voltage 10~15kV. Properly adjust the secondary voltage according to the actual situation and Particle Matter (PM) emission at the outlet of stack.

To bring the furnace/boiler off line, the unit load is reduced slowly. Under the low load conditions of the unit, the oil guns are also used to slowly increase the fuel oil and reduce the coal supply volume. When the unit load is at 40%~70%RO, run the electrostatic precipitator by manually controlling the secondary voltage of the electrostatic precipitator less than the sparking voltage of 10~15kV of the 1st ~5th electric fields. From <40%RO of boiler load to the
shutdown of steam turbine valve and the stop of boiler, stop the running of 5th, 4th and 3rd electric fields sequentially and manually control the secondary voltage of 1st and 2nd electric fields less than the sparking voltage of 10–15 kV.

IV. RESULTS AND DISCUSSION

During the ignition stage of the boiler, start the 1st electric field of electrostatic precipitator as per standard procedure, control the voltage at approximately 25 kV and PM concentration at about 33.5 mg/Nm$^3$. The secondary voltage is increased within 40 kV in order to guarantee de-dusting performance until 250 MW is reached. From 250 to 435 MW load, the processing volume of the dusts is further enhanced by additionally starting the 2nd–5th electric fields in turn. The secondary voltage of the control cabinet can be appropriately adjusted depending on the site situation, with the increased variation range controlled at 3–5 kV, in order to run the electrostatic precipitator under the optimal mode while guaranteeing the de-dusting performance about 56.4 mg/Nm$^3$. At 435 MW load, the electrostatic precipitator can be restored to the normal running mode. The site test results are presented on Fig. 4 and 5.

![Volt-ampere characteristic curves for unit start-up under proposed specified rules](image1)

![Volt-ampere characteristic curves for unit shut-down under proposed specified rules](image2)

The site test results of unit shut-down with ESP operation is indicated on Fig. 6 & 7. When the unit load is at 435–250 MW, decrease secondary voltage of electric fields at 3–5 kV in parallel with load till at approximately 40 kV. From 250 MW of boiler stop the running of 5th, 4th and 3rd electric fields and decrease the secondary voltage of 1st and 2nd electric fields till about 25 kV, maintained until oil gun stop. Dust concentration is controlled within 31 mg/Nm$^3$. 

![Figure 5. Unit start-up with ESP operation](image3)

![Figure 6. Volt-ampere characteristic curves for unit shut-down under proposed specified rules](image4)
energization control of secondary voltage based on the feed back signal of opacity sensor, the ability to put Sea-FGD into service during start-up and shut-down, and keep ESP & Sea-FGD during house load operation and run-back modes as well as loading dispatch of stable loads under co-firing condition below minimum anthracite load including 40%, 50% and 60% rate output as required form power grid.

ACKNOWLEDGMENT

This work is a part of a research program, of Power Engineering Consulting Joint Stock Company 2 – PECC2, to become a power plant project main EPC contractor after 2020.

OMENCLATURE

RO Rate Output
SCR Selective Catalytic Reduction
ESP Electrostatic Precipitator
FGD Flue Gas Desulphurization System
D.E Discharge electrode
C.E Collector electrode
IPC Industrial Personal Computer
PM Particulate matters
HFO Heavy Fuel Oil

REFERENCES


