Latest circumstances of electrostatic precipitator for coal-fired boiler plants in Japan and in several other countries

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1. Introduction

Mitsubishi Heavy Industries, Ltd. (MHI) and Hitachi, Ltd. (Hitachi) integrated their thermal power systems business, including air quality control system (AQCS), into Mitsubishi Hitachi Power Systems, Ltd. (MHPS) in 2014. However, among AQCS, dust collector was the only equipment which was procured from Mitsubishi Heavy Industries Mechatronics Systems, Ltd. (MHI-MS) or Hitachi Plant Construction, Ltd. (HPC), respectively a group company of MHI and Hitachi. In such situation, dust collector businesses, which were independently operated by MHI-MS and HPC, have also been integrated since October 2015, establishing Mitsubishi Hitachi Power Systems Environmental Solutions, Ltd. (MHPS-ES), one hundred percent owned by MHPS, so that MHPS has realized full AQCS line-up now in the group. MHPS-ES will play a part in MHPS's global AQCS business, and at the same time will integrate the strong technologies which were respectively owned by MHI-MS and HPC. In this paper, we introduce outline of electrostatic precipitator (ESP) projects for coal-fired boiler plants, which are proceeded by MHPS-ES in Japan and in several other countries, and technologies applied in those projects.

2. High Efficiency Flue Gas Treatment System (Low Low Temperature ESP)

2.1. Influence of Great East Japan Earthquake and Tsunami

Many power stations in Pacific coastal area of north-east region of Japan were seriously damaged by Great East Japan Earthquake and Tsunami (March 11, 2011). Several thermal power stations were also damaged but all have been recovered at present. Among them, Tohoku Electric Power's Haramachi coal-fired thermal power station (2 × 1000 MW) was most heavily damaged, and both ESPs of Units 1 & 2 were completely replaced (Fig. 1).

a) Aug. 31, 2011 (before replacing ESP dameged by Tsunami) b) Jan. 16, 2013 (after completion of replaced ESP)

Figure 1. ESP of Haramachi Power Station Unit 1

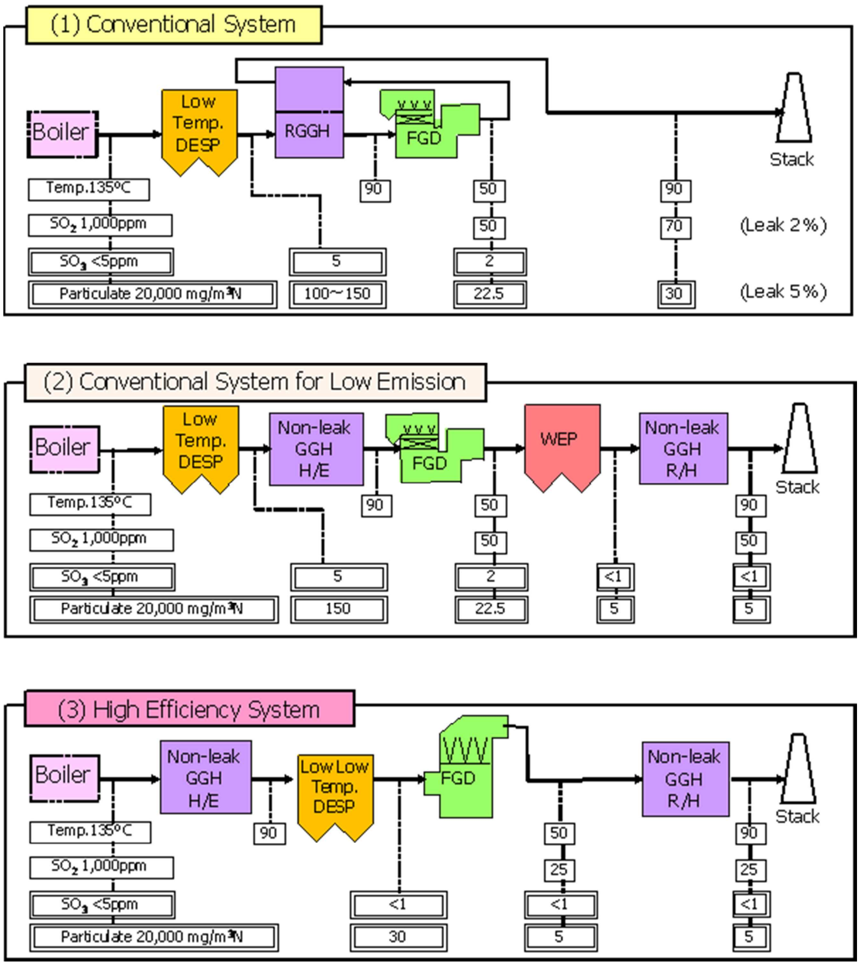
Haramachi coal-fired thermal power station had not been so much damaged by the earthquake, and Unit 1, including its ESP with earthquake-proof design, continued the operation until the arrival of the first tsunami attack, while Unit 2 was eventually stopped its operation during the disaster due to the scheduled shut-down, and the power station was fatally destructed at the time when the tsunami attacked. Especially, ESP of Unit 1 was located at the upstream side of the tsunami, so that it suffered directly and firstly the impact force, and as the result the ESP was floated and fallen down from the supporting structure. The bottom of hopper supported the ESP from the floor so that the ESP escaped from the complete collapse by a neck, however it considerably tilted and its internals were heavily damaged, so that when the utility company decided retrieval of the power station, the ESP was decided to be completely replaced to the new equipment with the original design. The damage of ESP of Unit 2 was slightly light compared with ESP of Unit 1 but since it was judged to be difficult to repair the existing equipment, ESP of Unit 2 was also decided to be completely replaced as Unit 1. Both ESPs of Unit 1 and Unit 2 were replaced with the original design by the original ESP suppliers, namely MHI-MS for Unit 1 and HPC for Unit 2. Both ESPs were completely replaced only in 10 months from the site construction start to the boiler ignition, without any incidents or injuries in spite of the rush job. At this moment, ESPs for both units are commonly maintained with the same after-sales service division of MHPS-ES, and they both are continuing operation in very well condition.

Haramachi was the first coal-fired boiler plant which adopted "High Efficiency System" in the world, and the ESP adopted in the system was also the world first Low Low Temperature ESP (LLT-ESP) [1]. Such the monumental products in ESP history have been revived after the heavy damage due to the tsunami disaster.

2.2. Outline of Low Low Temperature ESP

High Efficiency System is the flue gas treatment system for coal-fired power station, and it was developed by MHI (presently MHPS) in mid 1990s, through four-year R&D program. This system was firstly adopted in Tohoku Electric Power's Haramachi coal-fired thermal power station in 1997, as previously mentioned. Since then, this system has been applied in most of Japanese large scale utility or IPP coal-fired power stations.

Almost all coals used in Japanese coal-fired power station are imported from many countries, and properties of them are widely ranged. Environmental regulation in Japan has been very stringent, and in 1980s the flue gas treatment system shown in Figure 2 as "(1) Conventional System", which includes SCR (not shown in the figure), dry type ESP (DESP), wet type flue gas desulfurization equipment (FGD), was already applied in general.



Note: Gas conditions for typical case is shown in the figure for reference

Figure 2. Low Low Temperature Electrostatic Precipitator (LLT-ESP) – Comparison of Flue Gas Treatment System for Coal-fired Power Plant

In order to realize the system which is more simple but still keeps high efficiency in PM reduction, new system shown in Figure 2 as "(3) High Efficiency System" was developed. In this new system, DESP called as Low Low Temperature ESP (LLT-ESP), which is operated in the gas temperature of around 90°C, is installed at the downstream of heat extractor (H/E) of GGH. In this temperature range, electrical resistivity of coal ash is reduced as shown in Figure 3, since the electrical conductivity (surface conduction) increases because of the condensed water and sulfuric acid on the surface of the ash particles.

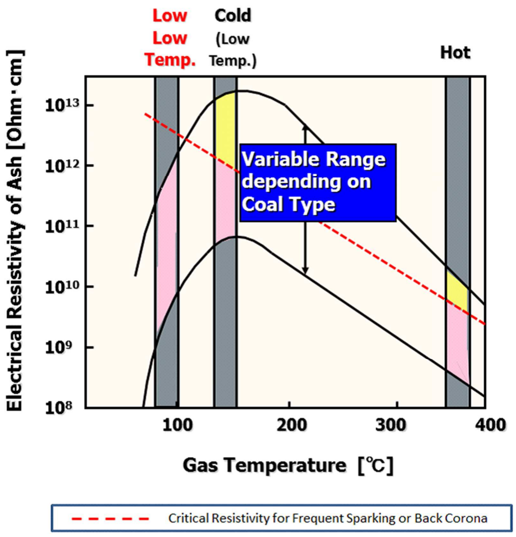


Figure 3. Low Low Temperature Electrostatic Precipitator (LLT-ESP) – Gas Temperature vs. Electrical Resistivity of Ash

In this situation, back corona phenomenon, which may severely reduce the performance of DESP, is supressed, so that stable and high performance can be achieved for various kinds of coals. In the conventional system whose H/E is installed at downstream of DESP, PM concentration at ESP outlet (namely at H/E inlet) shall be maintained more than the certain level (for example, more than around 150 mg/Nm^3-dry) in order to avoid corrosion of H/E, however in High Efficiency System, PM concentration at LLT-ESP outlet can be reduced, for example, below 30 mg/Nm^3-dry, and as the result the PM concentration at stack (at FGD outlet) can be reduced to less than 5 mg/Nm^3-dry, and the same low level of stack emission can be achieved without WESP.

2.3. Off-Flow Power-Off Rapping System

In LLT-ESP, the electrical resistivity of ash is reduced and the precipitability of PM is increased, while particles attracted once on the collecting electrode easily lose its electrical charge due to their low electrical resistivity. As a result, re-entrainment of particles at electrode rapping sometimes reduces the ESP performance. It was confirmed in the pilot test executed during the R&D program of High Efficiency System as shown in Figure 4a.

In order to avoid the performance deterioration due to the rapping re-entrainment, MHI developed Off-Flow Power-Off Rapping System [1], shown in Figure 4b, and it has been adopted since the first installation in Haramachi Unit 1. LLT-ESP is divided into several streams by partition wall, and the damper is installed in each stream. The dampers are closed one by one in series, and the stream whose damper is closed is isolated from the main gas flow, and at the same time energization of the bus sections is switched off to execute power-off rapping at the stream. Other streams whose dampers are opened, ESP is operated without electrode rapping. Using this system, rapping re-entrainment to the downstream can be significantly reduced. Power-off rapping realizes very efficient cleaning of all electrodes, and high ESP performance can be maintained for the wide range of operation conditions.

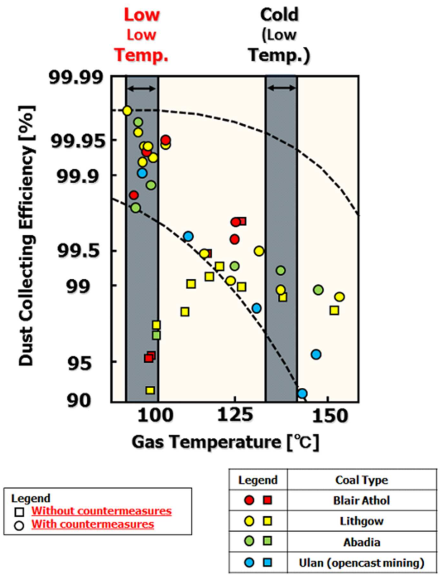
2.4. Moving Electrode ESP (MEEP)

On the other hand, Hitachi had the technology of Moving Electrode ESP (MEEP) [2], and its first adoption to LLT-ESP was in Haramachi Unit 2. MEEP has many references applied to DESP in conventional system, as the countermeasure of high resistivity PM. As shown in Figure 5, it is usually equipped in the last field of DESP.

Upstream fields with fixed electrode system reduces the PM concentration to the certain level, and then the reduced PM is introduced to the field with moving electrode system, and the PM is attracted on the chain-driven segmented collecting electrodes, rotating in the MEEP field. The collected PM on the moving electrode is scraped and removed by brush at outside of the main gas flow, so that this system can reduce the PM re-entrainment significantly, compared with usual rapping system.

Now, MHPS-ES has two technologies, Off-Flow Power-Off Rapping System and MEEP, to remove PM from electrode of LLT-ESP. MEEP requires no damper system and there is no stream with damper closed, so that it can realize smaller size ESP, and it has advantage especially when the installation area is limited. On the other hand, Off-Flow Power-Off Rapping System can clean all electrodes including upstream fields by power-off rapping, so that it has advantage in the case when the performance of upstream fields is critical. MHPS-ES selects the technology properly according to the conditions, project by project.

a) Gas Temperature vs. Collecting Efficiency at Pilot Facilities



b) Concept of Off-Flow Power-Off Rapping System

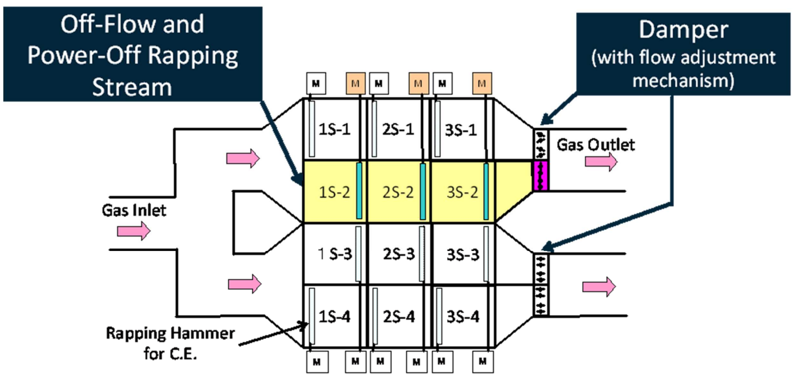


Figure 4. Off-Flow Power-Off Rapping System

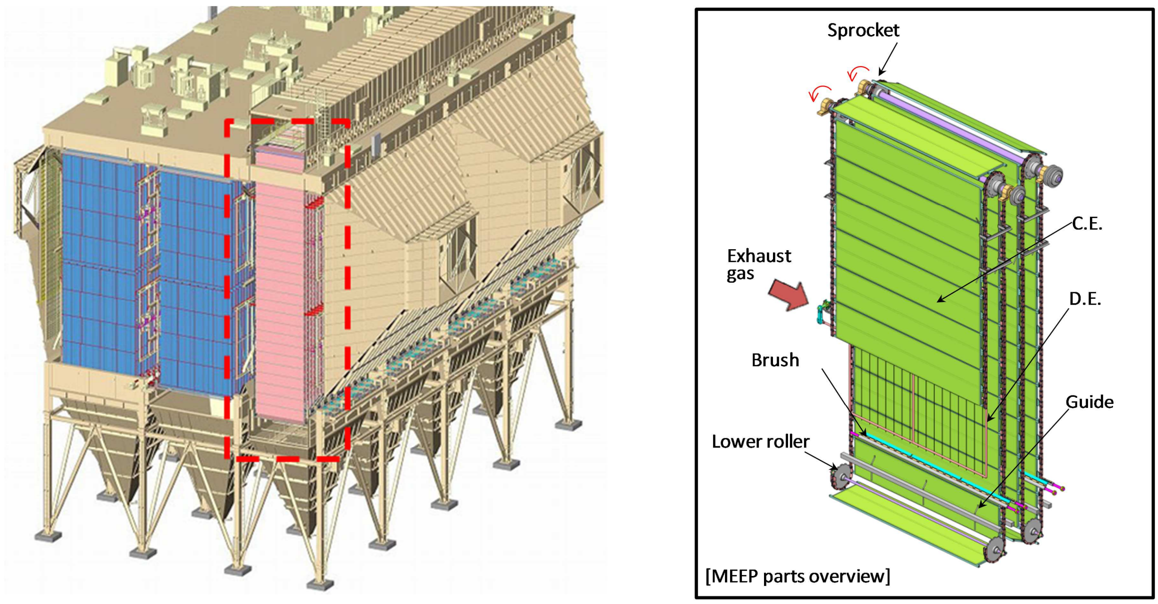


Figure 5. Moving Electrode ESP (MEEP)

3. Present Japanese Situation of Coal-fired Power Station

Great East Japan Earthquake and Tsunami caused a big accident in Tokyo Electric Power's Fukushima No. 1 Nuclear Power Plant, which has been decided to be permanently closed. After the accident, Japanese government ordered all nuclear power stations to receive new safety assessment before their re-start. All nuclear power stations were shut-down for a while, and even at present most of them are still suspending their re-start. In this situation, Japan has to reconsider the baseload electricity source to be other than nuclear, and utility companies are planning many coal-fired power plants, whose fuel can be secured stably. All of them adopt ultra-super-critical (USC) system, and most of them adopt LLT-ESP (High Efficiency System) to meet the stringent environmental regulation. MHPS-ES's LLT-ESP projects for Japanese large scale utility and IPP coal-fired power plants are summarized with required ESP outlet dust concentration in Table 1. (Projects which will be on-line from now on are shown in yellow columns).

Table 1. Utility and IPP Coal-fired Power Stations in Japan Equipped with MHPS-ES's LLT-ESP

Plant Identification	Capacity (MW)	Online Schedule	ESP Outlet Dust Concentration (mg/Nm^3-dry)
1	1,000	Jul. 1997	50
2	1,000	Jul. 1998	50
3	1,000	Jun. 1998	50
4	700	Jun. 2000	30
5	1,050	Jul. 2000	30
6	700	Sep. 2000	70
7	1,000	Nov. 2001	30
8	700	Apr. 2002	21 (Depends on Coals)
9	700	Jun. 2002	39
10	1,000	Nov. 2002	30
11	250	Mar. 2003	50 (Average of One All Day)
12	700	Jun. 2003	100
13	700	Apr. 2004	21 (Depends on Coals)
14	600	Jul. 2004	30
15	500	May 2007	30 (Average of One All Day)
16	900	Aug. 2010	30
17	600	Dec. 2013	27
18	1,000	Dec. 2013	30
19	650	Jan. 2020	30
20	600	Nov. 2020	40 (May change in future)
21	600	Sep. 2021	40 (May change in future)
22	1,000	Dec. 2019	45
23	600	Nov. 2019	30
24	1,000	Apr. 2023	30
25	1,000	Mar. 2022	30
26	1,000	Nov. 2022	30
27	500	Mar. 2023	30 (Average of One All Day)
28	650	Sept. 2021	30
29	650	Sept. 2022	30

Furthermore, retail electricity sales for general consumers will be liberalized in Japan from April 2016, and in order to secure cost-reasonable electricity source, many power retailers are planning new 110 MW class coal-fired power plants, which requires only the simplified procedure for setting up. In many cases, MEEP is adopted to achieve the compact installation.

4. Overseas operations

MEEP, which is the unique technology of MHPS-ES, is noticed not only in Japan but also in overseas countries. Especially for the upgrading project with improving performance of existing ESP due to the enforcement of environmental regulation, replacing the last field of existing ESP to MEEP is very effective. Such upgrading projects have already proceeded in Turkey (already operating) (Fig. 6), India (commissioning stage), and Taiwan (design stage), to contribute to their environmental improvement, under the global trend of enforcing environmental regulations.

In China, environmental regulations are becoming more stringent, and MHPS-ES is providing technical licenses of Wet type ESP (WESP) to 8 companies, of LLT-ESP to 1 company, and of MEEP to 1 company. These technologies provided in China contribute to meet the new regulations in that country.

Figure 6. Outside View of MEEP installed at Coal-fired Thermal Power Station in Turkey

5. Conclusion

In October 2015, new company MHPS-ES was established as a division of MHPS group, integrating dust collector business of MHI group and Hitachi group. As the result, MHPS group achieved the full line-up products of AQCS, and hereafter MHPS group will provide total solutions of AQCS to contribute to the environmental improvement in the world.

And MHPS-ES will integrate the technologies independently cultivated by MHI and Hitachi, to develop more value-added dust collectors, and will expand the business in Japan whose coal-fired power becomes more important as the baseload electricity source after the accident of nuclear power station, and also in other countries, including developing countries, where environmental regulations are becoming more stringent.

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