Special Technology Supplement

Indian market ripe for CFBs

Stricter emission laws in India could see the country re-assessing its choice of technology for base load coal fired plants. With large-scale units now possible, combined with supercritical and ultra-supercritical parameters for high efficiency, circulating fluidised bed technology is now being considered by the government as an alternative to pulverised coal fired boilers. **Junior Isles**

Despite sluggish global economic growth, India's economy is forecast to grow at 7.0 per cent in 2019, picking up to 7.2 per cent in 2020, according to the International Monetary Fund.

As is always the case with rapidly growing economies, this will drive demand for new base load power generating capacity in order to meet new demand and maintain reserve margins.

Market expert Ravi Krishnan, at Krishnan Associates, commented: "Following a few years of a downward trend in the economy due to structural reforms, the signs are for stronger economic growth starting from this year. The need for base load generation has therefore become imminent. When there is good, solid, economic growth, like we had between 2008 and 2014, on average India adds about 15 000-20 000 MW of new capacity per year."

India has very little gas or oil. Therefore it largely depends on coal for base load generation. According to the Central Electricity Authority, coal accounted for nearly 56 per cent of system capacity in 2018/19. Most of this was fuelled by domestic coal, with imported coal only serving about 20 per cent of the coal fired installed base.

Traditionally, India has predominantly used pulverised coal (PC) technology but fairly recent tightening of emission regulations could see things change. "The market favoured PC technology and more so because there were no environmental regulations whatsoever for NOx and SO_2, and there was a relaxed standard for particulates as well… The new emission laws promulgated in 2016 means that any new power plant commissioned in India has to meet a standard of 100 mg/Nm^3 for NOx and SOx and designed for as low as 30 mg/Nm^3 for particulates," said Krishnan.

The new legislation sets different limits for plants installed before 2004, those after 2004 but before December 31, 2016 and those after January 1, 2017.

In short, the legislation means that plants pre-2017 of less than 500 MW have to meet SO_2 standards of less than 600 mg/Nm^3, and less than 200 mg/Nm^3 for plants larger than 500 MW. For NOx, the level is 600 mg/Nm^3 for all sizes built before 2004. For plants built between 2004 and 2017, the SO_2 limits are the same as pre-2004 plants but the NOx limit is 300 mg/Nm^3. Notably, in some locations units that are smaller than 500 MW but are close to populated areas, also have to comply with the 200 mg/Nm^3 SO_2 standard. For plants of any size built from January 2017, both SO_2 and NOx must not exceed 100 mg/Nm^3.

The legislation means that many PC plants have to be retrofitted with selective catalytic reduction (SCR) equipment to cut NOx, and flue gas desulphurisation (FGD) to control sulphur. This presents an opportunity for circulating fluidised bed (CFB) technology. As CFB technology is inherently cleaner, it does not require the additional equipment. Krishnan says this now makes it a lot more competitive with PC fired technology.

"Additionally, there has also been a focus on lowering CO_2; that has led a lot of power plant owners to look at blending different types of fuels and co-firing with biomass. So CFB technology has become a much stronger and more compelling alternative to PC fired power plants," Krishnan added.

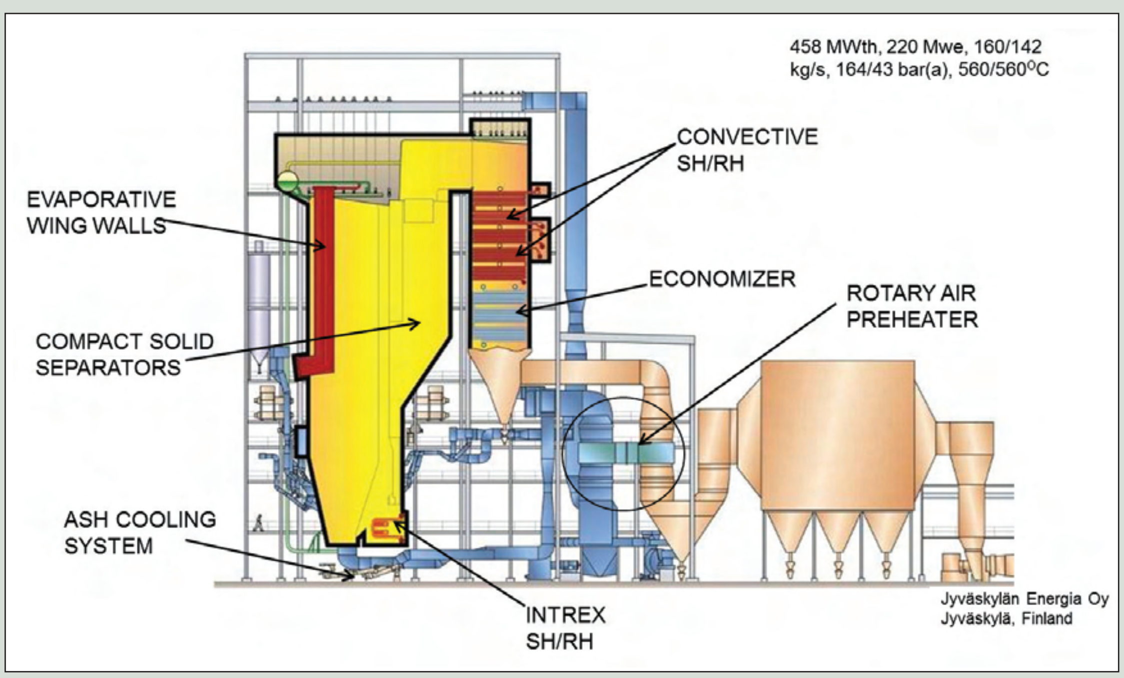
This thinking was highlighted in a Ministry of Power expert committee report published last year. The report notes that CFB has "several benefits" over PC boilers. "CFB boilers are extremely flexible, allowing a wide range of fuel qualities and sizes to be burned. Emissions of SOx and NOx are significantly reduced without the addition of expensive flue gas emissions control systems," it stated.

Over the last 25 years or so, Sumitomo SHI FW (SFW) has broadened both fuel flexibility and unit size so much that a growing number of power companies have taken notice. Many now see CFBs as a way to produce low cost power from low quality fuels such as brown coals, lignite, and waste coals, as well as, high-energy, hard-to-burn fuels like anthracite and petroleum coke.

They can also burn an almost "limitless number" of other types of solid fuels, separately or mixed with coal. "The limitations, if any, are only in the feeding system and other mechanical equipment," stated the report. Other solid fuels include bagasse in sugar plants, bark in pulp and paper mills, biomass products as well as, municipal solid waste. Mixing with coal when other fuels are not available gives uninterrupted steam and energy supply.

The CFB's ability to burn high ash, low calorific value coal is a big plus for the Indian market where coal typically has 30-40 per cent ash content. Robert Giglio, Senior Vice President of Strategic Business Development for SFW, noted that its technology can handle coals with up

SFW's circulating fluidised bed steam generating technology



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to 60 per cent ash. He said: "India's domestic coal is ideal for CFBs. It's amazing that they have been firing that coal in PCs for as long as they have been, but it's much easier for the CFB because you don't have to deal with slagging ash, etc., and you can meet the new emission control standards without the expensive back-end equipment in what is a cost-sensitive market."

A CFB's ability to burn a broad range of fuels is due to its flameless, low-temperature combustion process at the heart of the technology. Unlike conventional PC or oil/gas boilers, instead of an open flame, circulating solids are used to achieve high combustion and heat transfer efficiency to burn a wide range of fuels. The fuel's ash does not melt or soften, which allows the CFB to avoid the fouling and corrosion problems encountered in conventional boilers.

"In a normal boiler the ash gets so hot it turns into a fouling material or slag and coats everything," noted Giglio. "The CFB uses the ash to support the process. It uses it to circulate and distribute the heat in the boiler evenly. It also keeps the surfaces clean. So instead of causing fouling, resulting in maintenance issues and frequent outages, etc., you can choose a different technology and solve a lot of these issues."

From an environmental aspect, the low temperature CFB combustion process – typically 800-900°C, which is significantly lower than in a PC boiler – minimises NOx formation and allows limestone to be fed directly into the furnace to capture SOx as the fuel burns. In most cases, a SCR and FGD are not needed for NOx and SOx control, dramatically reducing plant construction and operating cost and water consumption, while improving plant reliability and efficiency.

Since the fuel ash does not soften or melt in a CFB, the size of the furnace does not increase as much as PC boilers when firing lower quality fuels. In order to control fouling, slagging and corrosion, a PC furnace height typically increases by 45 per cent and its footprint by more than 60 per cent when firing low quality fuels such as high sodium lignite. With a CFB, boiler height increases by only 8 per cent and its footprint by only 20 per cent. This results in a smaller and lower cost CFB boiler as compared to the PC boiler for lower quality fuels.

Further, unlike a PC boiler, a CFB boiler does not need soot blowers to control the build-up of deposits and slag in the furnace since the circulating solids keep the furnace walls, panels and steam coils clean for the most efficient heat transfer.

Another important advantage of CFB boilers is their ability to withstand the corrosion that can occur when certain fuels are burned. In a boiler, final superheat and reheat steam coils operate at the highest metal temperatures, making them the most vulnerable to corrosion and fouling attack.

In a PC or oil/gas boiler, these coils are hung from the furnace ceiling and are directly exposed to the slagging ash and corrosive gases (sodium and potassium chlorides) in the hot furnace flue gas. To cope with this undesirable situation, boiler designers use expensive high-grade alloys and recommend a high level of cleaning and maintenance for these coils.

This is avoided in SFW's CFBs by submerging these coils in hot solids, fluidised by clean air in heat exchanger compartments called INTREXs, protecting them from the corrosive flue gas. The bubbling hot solids efficiently conduct their heat to the steam contained in the coils and since the solids never melt or soften, fouling and corrosion of these coils are minimal.

Further, due to the high heat transfer rate of the solids (via conduction heat transfer), the final superheat and reheat coil sizes are many times smaller than the pendent and convective coils in PCs saving more capital and operating cost.

In addition to recognising the fuel flexibility and new economic case for CFBs, the Indian government has also acknowledged that their much increased power output and efficiency makes them much more suitable for utility scale application than in the past.

The report stated: "Almost all of the existing CFBC power generating units are small in size (330 MWe compared to > 1000 MWe for a PC boiler), and use subcritical steam conditions that make CFBC systems less efficient than supercritical/ultra-supercritical PCC plants. The poorer economy of scale and lower efficiency of the CFBC plants result in higher plant costs and has limited deployment. However, over the last decade, significant advances have been made in scaling up CFBC units and in the adoption of supercritical (SC) steam cycles."

Giglio noted: "It's always a case of the incumbent wanting to stay with what they know. So it's a case of educating, and getting the message out that there is another option. And while it has not been demonstrated in India on these 500+ MW coal plants, it has been demonstrated in other parts of the world."

SFW's CFB technology has been proven at increasing sizes for a number of years, achieving the 200 MW utility size in the 1990s. Today, SFW has single unit CFB designs up to 800 MWe capacities with advanced vertical tube supercritical steam technology.

Supercritical steam conditions represent a physical point just above the vapour/liquid equilibrium phase of water. When the steam pressure reaches above the critical pressure of 221.2 bar two-phase mixtures of water and steam cease to exist, and as the temperature of the water rises above 374°C the water behaves as a single supercritical fluid, allowing the fluid to absorb much more heat resulting in significantly improved overall power plant efficiency.

The technology advance to once-through supercritical (OTSC) units was first demonstrated at the 460 MWe Łagisza plant in Poland, which entered commercial operation in 2009. Since its startup, the plant has operated on a range of Polish bituminous coals and has demonstrated a

Giglio says India's domestic coal is ideal for CFBs

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Samcheok design steam parameters at 100 % load

SH steam flow (kg/s)	437.7
SH steam pressure (bar[g])	257
SH steam temperature (°C)	603
RH steam flow (kg/s)	356.4
RH steam pressure (bar[g])	53
RH steam temperature (°C)	603
Feed water temperature (°C)	297

LHV net plant electrical efficiency of 43.3 per cent. Then in 2016 SFW completed the Novocherkasskaya GRES No. 9 supercritical CFB project in Russia. This 330 MWe CFB unit, which is the first of its kind in the country, is capable of combusting a wide selection of fuels including anthracite, bituminous coal and coal slurry.

Notably, SFW took the next evolutionary step in the design and scale-up of its CFB boilers at the Samcheok Green Power Plant in South Korea, owned by Korea Southern Power Company (KOSPO). These are the most advanced supercritical circulating fluidised bed boilers in the world, capable of co-firing a wide range of coals with biomass.

Each boiler at Samcheok is designed to produce main steam at a temperature of 603°C and reheat steam at 603°C. Superheat steam pressure is 257 bar [g]. The once-through ultra-supercritical (OTUSC) CFB boilers utilise advanced vertical tube low mass flux Benson evaporator technology, which is more efficient and easier to build and maintain than conventional spiral-wound supercritical boiler technology.

The vertical tube design has several advantages over a spiral tube design. It has a lower pressure drop across the boiler, resulting in higher efficiency. Samcheok has a net electrical efficiency of more than 42 per cent (LHV) compared to the 38-39 per cent typically achieved with traditional boilers.

SFW says that out of the hundreds of boilers sold in the market, only a few use this relatively unique technology.

Under a contract awarded in 2011, SFW designed and supplied four 550 MWe (gross) ultra-supercritical boilers producing steam at 600°C for the first phase of the project. The first phase (Units 1 and 2) are configured as two blocks with each block having two boilers feeding into a single 1100 MW steam turbine.

An important aspect of the project is its ability to burn low quality international coal that is 20-30 per cent cheaper than premium quality coal. For a plant as large as Samcheok's phase I, this fuel discount works out to be a considerable amount in plant operating cost savings, considering that the fuel cost is around 70 per cent of a power plant's total running cost.

The boilers are expected to burn about 5 per cent biomass in terms of heat input, depending on availability. This is likely to be in the form of recycled wood waste from the local lumber industry and imported wood pellets. The plant's environmental performance will be further improved as more biomass is introduced to the mix.

In the first years of operation, the Samcheok CFB plant has been firing mainly Indonesian coals and domestic biomass. KOSPO has begun exploring other fuel sources by test firing US and Russian coals. SFW says the plant's full fuel flexibility potential will be realised over time

According to SFW, environmental performance on these low rank coals has also been "excellent", meeting the design limits. NOx and SOx emissions are each guaranteed at 50 ppm (at 6 per cent O_2). Dust emissions are controlled by an electrostatic precipitator, so that particulates do not exceed 20 mg/Nm^3. Carbon dioxide emissions are around 800 g/kWh, which is about 25 per cent below a typical coal fired plant in Korea.

Unit 1 has been operating successfully since late 2016 and Unit 2 since June 2017. Samcheok is a good reference for India, as such units are in the right size range and efficiency for the Indian market.

"Most of the plants that come online are increasingly supercritical units," said Krishnan. "And if you look at the projects that are on the drawing board at this point, many of them are in the 500-660 MW range."

The size of the opportunity in India, however, is a function of how fast the economy grows. As Krishnan notes: "If it grows at 9-10 per cent, the need for new capacity becomes more critical. And if it grows at 7 or 8 per cent, it is essential but not as much. Another factor is the ageing of India's coal fired fleet as a number of plants approach their end of life requiring new capacity additions. So we are looking at between 10 000-20 000 MW per year in additional capacity, and a lot of that is going to be coal fired. Perhaps 20-30 per cent will be renewables and hydro and 70-80 per cent will be coal fired.

"Renewables, especially solar, are making inroads into the Indian market but the country needs base load power, and renewables in India are still unreliable and expensive in many parts of the country. With the abundance of local coal that is available in India, it is very much at the forefront of all the fuels. And SFW is the only one with supercritical CFB units in the size range that India is demanding."

There is no doubt that CFB technology is now at the point where it matches the demands of the Indian market much better than in the past. As Giglio summarised: "In the past it was not about the fact that the CFBs could meet the emission limits without the backend equipment, because the emission limits didn't exist before. So the default choice was PC. Now that's been disrupted because they now have to control the emissions from these plants. The Indian market is now at the point where it sees the value of the CFB."

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