A HOLISTIC APPROACH

for the Cement Industry

Manish Maheshwari, Doug Clark and Dr Hans-Helmuth Jung, ABB, India, explain how taking a holistic view of plant performance can result in specific savings.

Abstract

ABB's Cement Performance Fingerprint is a new service approach to cement customers that aims to assess the status of a cement plant, from creating a stockpile to cement grinding, identifying process and energy efficiency improvement opportunities. Cement Performance Fingerprint is intended to analyse the total installed equipment base and relate these installations to the overall production process.

This article will explain the different steps of the Cement Performance Fingerprint concept, from data collection to plant modelling, and will discuss the results of one specific audit.

Cement Performance Fingerprint

What is it?

Cement Performance Fingerprint is a holistic approach that aims to assess the status of a cement plant, from stockpile making to cement grinding, finding process and energy efficiency improvement opportunities.

For this purpose, the historical plant data is collected to study operational practices and process variability. Plant sensitivity tests are then conducted to understand the dynamics of the different areas of the plant. This same data is used to build process models. Both historical data and process models are used to analyse the current plant performance and identify process and energy improvement opportunities (Figure 1).

What happens during a Fingerprint project?

The main tasks in the investigation of each designated area are as follows:

- Conduct process study and observe operation.
- Collect and analyse process data.
- Conduct plant sensitivity tests and develop process models.
- Analyse benefits.

To execute a Fingerprint analysis, the effort expected (per area!) is one of five days on site and five days in the office for one ABB Fingerprint engineer. Synergies can be realised if several areas are analysed simultaneously. Figure 2 represents a typical project execution plan.

Special attention is paid to the base automation. Indeed, base controllers such as material, pressure or flow controllers play an important role in the overall process stability; if the actuators do not obey closely then self-induced oscillations will propagate throughout the whole plant. These assets represent a constant challenge for the automation engineers not only due to their large number, but also for their tendency to performance degradation.

In a cement plant there are a number of critical PID loops whose performance is crucial for operational excellence (Figure 3). These are:

- Raw mill: limestone and additives feeders.
- Precalciner and kiln section: kiln feed, coal feeder.
- Cooler: under grate pressure controllers.
- Cement grinding: temperature controllers.

Activities in this area can be summarised as follows:

- Collect historical data for critical PID loops.
- Perform PID setpoint changes to generate data related to dynamic conditions.
- Analyse data with ABB's PID performance assessment tools.
- Make a diagnosis of generation and report writing.

How will it improve operations?

Depending on the plant situation the expected benefits are achieved by implementing (Figure 4):

- Variable-speed drives for specific applications.
- Additional measurements such as online gas analysers and feed and/or cement quality analysers.
- PID loops tuning services and continuous loop monitoring systems to preserve performance improvements into the feature.
- Multi-variable controllers using techniques such as Fuzzy Logic and/or Model Predictive Control.
- Energy management systems to monitor energy consumption, but also to manage the complexity inherent to power grid capacity constraints, own generation capacity and optimal production scheduling.
- Heat recovery power plants

The following section describes the audit where Cement Performance Fingerprint was conducted for a precalciner area. Furthermore, it points out where business excellence can be achieved, summarised as recommendations.

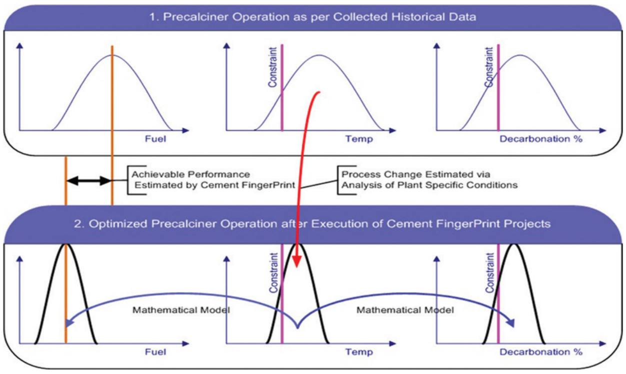

Figure 1. Cement Performance Fingerprint process.

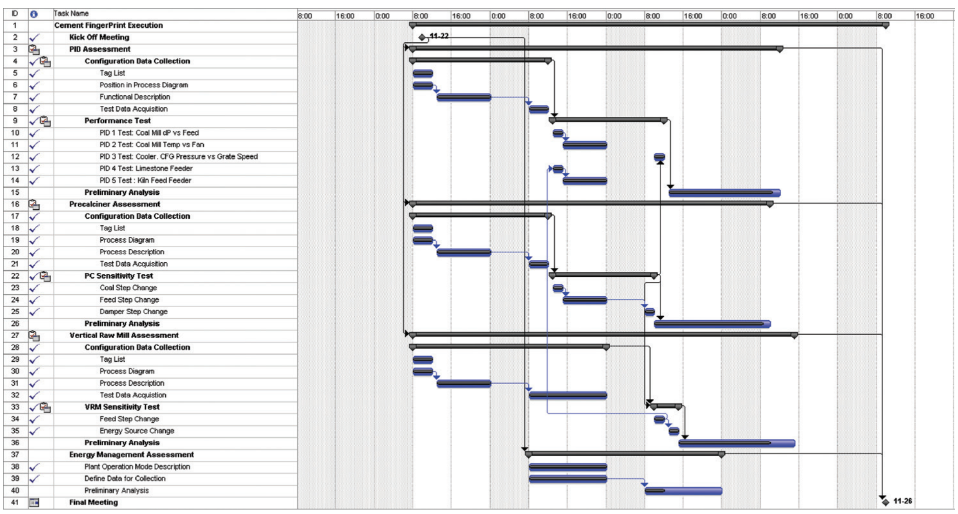

Figure 2. Cement Performance Fingerprint project plan.

Process area: precalciner

Process description

The pyroprocessing system at the plant investigated consists of a five stage preheater with Low NOx in-line precalciner equipped for staged combustion, kiln and cross bar cooler. The design rating of the system is 3200 tpd of clinker, but it is currently working at 3750 tpd. At the moment, specific energy consumption

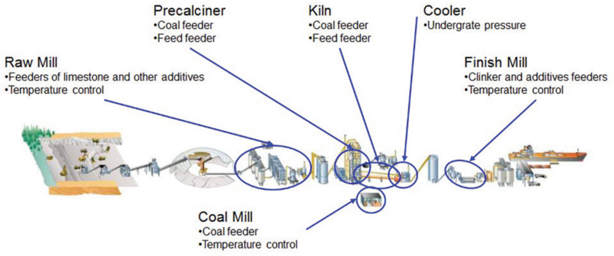

Figure 3. Critical PID Controllers in a cement plant.

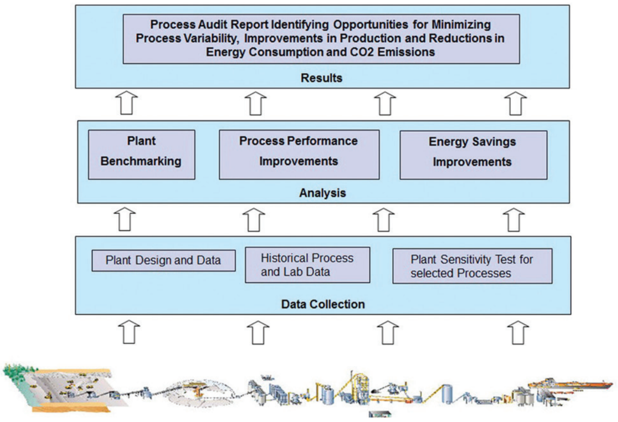

Figure 4. Cement Performance Fingerprint value proposition.

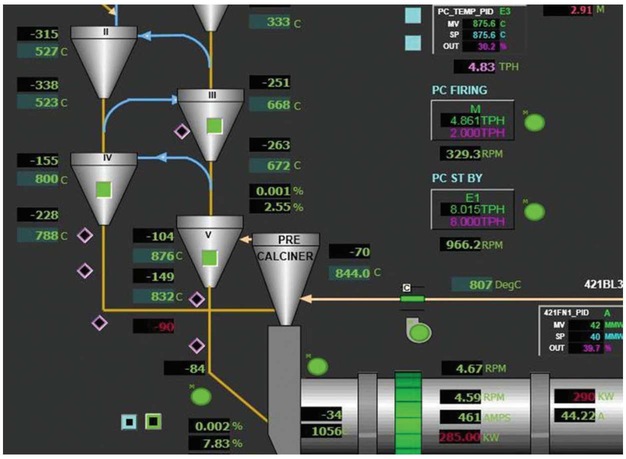

Figure 5. Precalciner process diagram.

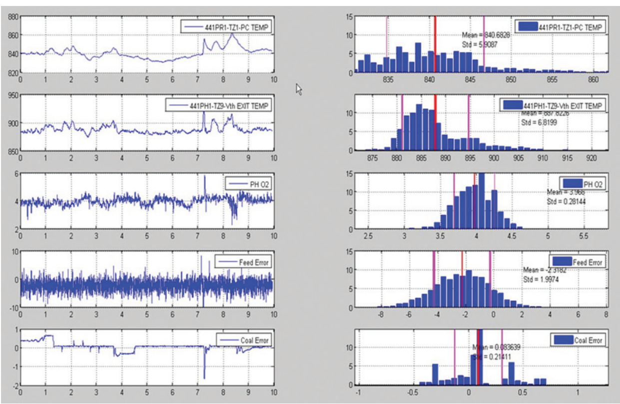

Figure 6. Precalciner historical data.

appears to be in the order of 800 kcal/kg of clinker, which seems high for the plant layout. Coal is introduced through an indirect firing system on both the kiln and the precalciner with 55 – 60% of the fuel being introduced in the precalciner.

The signals available appear to be sufficient to control, monitor and optimise the process. The combustion conditions are assessed using an oxygen probe that is reliable. There is no CO meter in the precalciner area, which is possibly an area for improvement of the combustion efficiency. Measurements of the precalciner outlet temperature and the cyclones are in place. An overview of this area can be found in Figure 5.

Process analysis

Historical data analysis

Raw data was gathered during these activities and Figure 6 gives a representative sample of this. The graphics on the left column represent a time series. The horizontal axis is the time, while the vertical axis depicts the value of the magnitude in question at the given time. The graphics on the right column represent so called histograms. This means that in the horizontal axis lies the natural scale of the magnitude (e.g. ˚C), while in the vertical axis is an indication of how often the particular value of the magnitude was measured. These graphs give a visual clue as to how variable the process magnitude is. Additionally, the average and standard deviations are represented by the red and pink vertical lines, respectively.

Methodology for benefit estimation

For the precalciner the calculation of benefits is conducted according to the following scheme:

- Use historical data to calculate average and standard deviations of the critical magnitudes.
- Assess as to which extent kiln feeding could be made more accurate.
- Use models generated from the sensitivity analysis. This enables the effect of this change on the precalciner temperature variability to be calculated.
- Calculate the effect on the fuel consumption of a change in precalciner temperature setpoint.
- Estimate financial benefits.
- Realise further savings by reducing the excess oxygen setpoint.

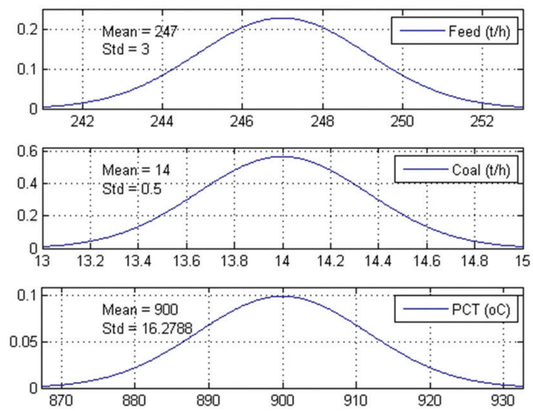

Figure 7. Precalciner starting conditions.

Figure 7 shows the starting conditions in the precalciner. Note the large variability of the feed as root cause for the variability of the temperature.

The variability of the temperature decreases after improving the accuracy of the kiln feeder (Figure 8). The improvement can be accurately and systematically quantified using ABB's methodology based on process model identification.

Figure 9 depicts the final status after having selected a new setpoint for the precalciner temperature. Note how fuel consumption could be reduced. The financial value of this chain of improvements is estimated to be a five-digit US dollar sum per year.

However, if the feed rate cannot be increased due to bottlenecks in the systems outside the precalciner, the reachable benefits would be based only on fuel consumption reductions, in this case of about 2%. The final precalciner status would be as depicted in Figure 10.

The benefits of these recommendations have been calculated using the following simple formula and data (Figure 11 and Table 1).

Path to operational excellence

Recommendation 1

The kiln feeder is a major source of disturbance for precalciner operation; deviations of up to 5% are commonly observed. The feeder has a negative bias, which produces high PC temperatures.

Estimations with ABB's models suggest that correcting this feeder will lead to either 1% production increase or alternatively, if that is not possible, to an equivalent reduction of coal consumption. The company recommends:

- Retune underlying PID loop.

Recommendation 2

Precalciner temperature sensor produces erratic results. From the data it is also seen that precalciner temperature is better assessed via Cyclone 5 sensor, and ABB therefore recommends:

- Change PCT sensor location.
- Consider installation of two more sensors for more robust results.
- Use the median as temperature indicator, as opposed to average.

Recommendation 3

Preheater O_2 is at a relatively high level of 4%. This means relatively high specific energy consumption, in this case of about 780 – 800 kcal/kg.

It is further noted that no CO measurement exists. This is considered a disadvantage as, in order to increase the efficiency, it will be necessary to reduce the excess oxygen level. In a 'scarce oxygen' situation it is important to have a CO measurement for better assessment of the combustion conditions. The recommendations are:

- Reduce oxygen setpoint from 4% to 3%, and achieve it via reduction of fan rate.
- Consider CO online analysers in the preheater outlet and/or the precalciner for better monitoring of the combustion conditions.

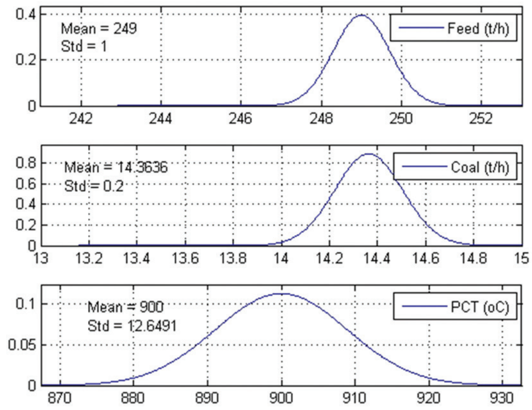

Figure 8. Precalciner conditions after improvement of kiln feeder accuracy.

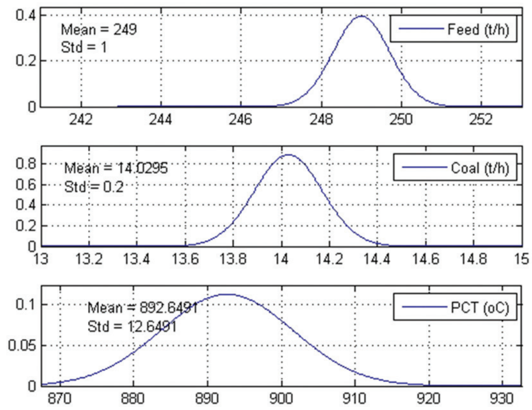

Figure 9. Final status in the precalciner.

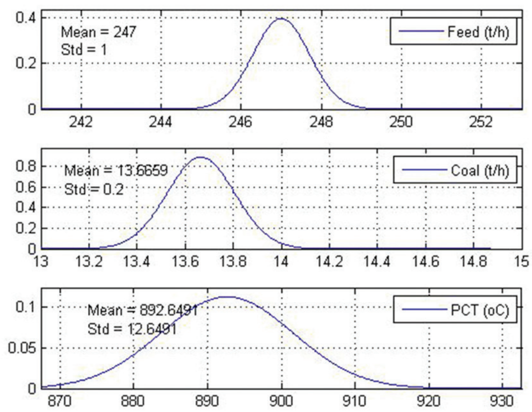

Figure 10. Final status of precalciner if the feed rate cannot be increased.

Benefit = 24 x Number Days x (Product Margin x Δ Feed/Clinker Factor + Fuel Cost x Δ Fuel)

Figure 11. Benefit formula.

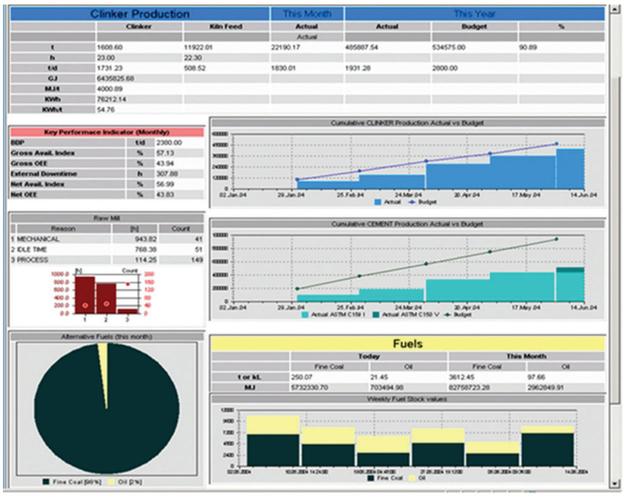

Figure 12. Knowledge Manager.

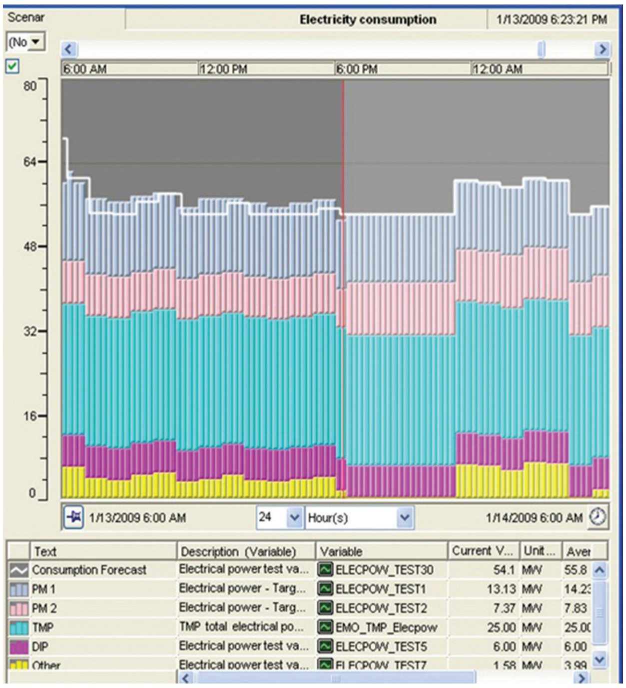

Figure 13. ABB's Energy Manager.

Table 1. Benefit calculation				
Item #	**Name**	**Unit**	**Value**	**Description**
1	Number of days	1/year	330	Number of operating days per year
2	Product margin	US$/t	20	"EBIT margin" per tonne of cement
3	Δ Feed	tph	2 / 0	Production increase
4	Clinker factor	t/t	1.6	Feed to produce 1 unit of clinker
5	Fuel cost	US$/t	40	Cost per tonne of fuel
6	Δ Fuel	tph	-0.02 / 0.33	Reduction in fuel consumption
7	Benefit	US$ pa	n.a	Financial impact

In addition to audits and assessments in specific process areas, it is also important to take a plant-wide view. In the next section the use of an information management system and an energy management system are described.

Plant-wide topics

Information management system

It is evident that, to make a long-term analysis of plant performance, the plant records process data. Such a system is an important item of plant optimisation initiatives as it facilitates tracking their success. One such plant information management system is ABB's Knowledge Manager (Figure 13).

Energy management system

Electrical power cost accounts for a substantial share of the total cement production cost. Moreover, in the presence of constraints given by the power grid and/or variable electrical power prices, power management becomes a matter that needs serious attention from management. This is even more the case when the cement plant has captive power generation, as it increases the degree of freedom to respond to the variability of the external conditions.

In such conditions, the plant manager must take decisions on a daily basis, such as which parts of the plant may be disconnected from the grid and in which order. Optimally these decisions are based on:

- The plant conditions (e.g. which equipment is online or on maintenance; which mills are more or less efficient).
- The cement market condition (need for a particular cement type, and existence of it in storage).
- Power market (power prices, grid constraints, possibility to buy and sell power).

In order to make optimal decisions, all aspects of the problem need to be considered.

A modern cement plant needs a plant-wide energy management system due to the following reasons:

- Liberalised power market.
- Plant captive generation.
- Power grid constraints.

As an example, a plant needs 20 MW in normal operation, while having captive power of 14 MW. At the same time, there are time-dependent constraints on the amount of power that can be drawn from the grid: at peak hours, maximum 1 MW can be taken from the grid, which means that the cement plant needs to reduce consumption by 5 MW during those parts of the day. It follows that the cement plant needs a dynamic and flexible strategy in place to deal with the power constraints at all times.

It is clear from this that some consumers can be used to reduce power consumption by about 5 MW at peak times. For instance, the crushers, the conveyor belt ('cross country') and the cement mills are large consumers that can be stopped basically at any time without compromising plant integrity.

However, for several reasons, stopping some of the equipments (e.g. cement mills) should be avoided if possible. Further, it is also clear that, depending on the plant conditions, it may not be necessary to disconnect all these large consumers. It follows that the cement plant

Table 2. Power consumption details	
Average load (kW)	
Crusher	750
LS stacker	150
Cross country conveyor	250
Raw mill	3850
Kiln	3700
Coal mill	650
Cement mill 1	4700
Cement mill 2	3050
Packing plant	350
Colony	100
Services	750
Mines	800
Lighting	150
Line-2	300
Total load	**19 550**

needs a system that allows for consistent decision-making, based on the real conditions in the plant and in the market on the particular date.

The functionality of such a system is tailored to meet the needs of the cement industry.

ABB recommends the installation of an Energy Management system in two phases:

First phase

- Monitoring of main consumers (Table 2).
- Short-term (15 minutes to several hours) forecast of power consumption over these consumers.

Second phase

- Increase granularity of energy monitoring system.
- Create closed loop strategy for optimal decision making at peak times or at times of grid restrictions.

ABB has created an energy management system with the following functionality:

- Monitoring of equipment efficiency.
- Establishment of targets and monitoring of actual energy efficiency to improve real-time decision making.
- Prediction of accurate energy demand schedules.
- Allocation of energy consumption to off-peak hours and energy production to peak hours.
- Utilisation of several optional energy sources.
- Use of the most cost-effective sources and the best combination of fuel types.
- Cost accounting for company's internal energy distribution.

Conclusion

With the rising energy prices it is very important for the cement manufacturers to operate the plants in an optimal manner to remain cost competitive. ABB has the capability to carry out comprehensive study and analysis of the current process performance, identify the potential improvement opportunities and provide solutions to help plants to work towards operational excellence and run businesses more profitably.