High Level Automation to Achieve Improved Productivity, Energy Efficiency and Consistent Cement Quality

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***Abstract*--Cement industry worldwide, has now started realizing the importance of Process Control and Automation in achieving trouble free continuous operation leading to improved productivity and energy efficiency. Automation also takes care of optimal operation in mining and hence longer life of mines and consistent desired cement quality is assured.**

Instrumentation and control logic can also be used effectively for taking care of human and equipment safety and to monitor equipment health and implement preventive maintenance in the manufacturing facility. While first level automation deals with field instrumentation and the second level deals with control of subprocesses, higher level controls can be used for plant management and decision making. Needs of proper design of all three levels of automation may differ from plant to plant.

This paper will describe different instances where upgradation of automation has enable plants to achieve their continuous improvement targets and sustainability goals.

***Index Terms*—automation, cement process, improving energy efficiency, upgradation, Maintenance**

I. Nomenclature

CIS – Commonwealth of Independent States.
OPC – Ordinary Portland Cement.
KPI – Key Performance Indicators.
ERP – Enterprise resource Planning
MIS- Management Information Systems
PLC- Programmable Logic controller

II. Introduction

World cement production had reached around 4 billion metric tonnes in 2013. This value is projected to rise to 6 billion metric tons by 2025. Asia, Africa and CIS countries have seen almost 2.5 times increase over 2001 levels. The Americas and Europe have seen relatively low increase in production levels (around 0.25%). Cement consumption is a reflection of the development activities carried out in a nation. In countries like India where cement plants are currently operating at 75% of capacity, it is expected that demand generated from infrastructural projects will drive the cement consumption in the near future to complete utilization of available capacities and possibly even more.

The cost of cement production is governed by various factors - chief among them being the efficient use of raw material and fuel. The cement industry is highly energy intensive. The average energy requirement to produce one tonne of cement is equivalent to the combustion of approximately 120 kg of coal.While wet process cement kilns in the past have consumed over 5800 MJ/t (1400 kcal/ kg) in terms of thermal energy, the best performing plants of today with preheater/calciner kilns consume around 2950 MJ/t (690 kcal/kg clinker). Thermal energy is generally supplied by fuels like coal, pet coke, gas or fuel oil. The consumed electricity amounts on average to 90-100 kWh / t cement (OPC) using the same technology and can be supplied from the electricity grid or through captive power plants depending on the location of the cement plant.

Effective use of automation can achieve cement plant to reach their KPI’s in terms of raw material utilization, energy efficiency, emissions reduction, safety and use of alternate fuels while reducing the expenses of equipment replacement and maintenance. Significant incremental improvements can be made to industrial manufacturing usingadvanced process automation technology. These projects are much smaller in dollar costs, duration, andrisk compared to equipment modernization projects. They have quantifiable benefits and paybacks that are measured in months, if not weeks, as opposed to years. There are also indirect benefits associated with these projects that result fromincreased plant stability and consistent product quality. Stable operations are easier to maintain and require less operator involvement.

A. *Productivity*

In a cement plant as in other manufacturing processes the productivity depends on availability, quality production and capacity utilization.

Productivity or Overall Equipment Efficiency=f(Capacity Factor , Quality Production , Availability)

It is therefore essential to improve all the three elements mentioned above to improve productivity. The reduction of energy consumption and the optimal use of maintenance resources are additional productivity coals.

Downtime is a significant issue at aging plants. Lack of skilled operators, coupled with poor insights into the process, increase the likelihood of interruptions. Immediate improvements can be obtained with the implementation of relevant modern process automation techniques. By improving the level of automation and control within the process, staff can be alerted more quickly to the deviations in process parameters and take action before the situation becomes critical. Intelligent process instrumentation and gas analysis systems can play an important role by improving the quality of data coming from the process. This will have a better handle in dealing with fluctuations in raw material composition and fuel compositions. There is a need to improve maintenance cycles to deal with lower levels of maintenance and control expertize and reduce personal over heads. Signals from equipment health monitoring instruments can be used to detect abnormal behavior and take corrective action before the equipment breaks down. By reducing the amount of time taken to maintain the plant and ensuring that maintenance cycles around the plant reflect actual maintenance demands, plant operators can achieve considerable cost savings.

B. *Automation in Cement Plants*

The automation systems in a cement plant are usually at three levels as shown in Fig 1.

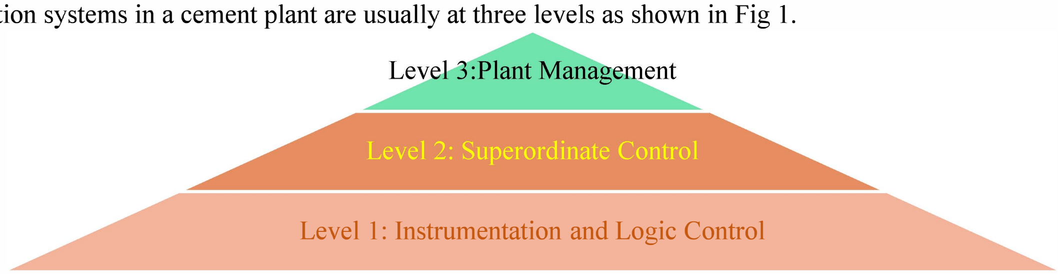

Fig 1. Automation levels

Level I deals with digital controllers and complete process controllers with control and logic functionality (PLC systems).

Level 2 includes control of sub processes for yield optimization by using advanced sensors (automation analyzers) directly in the processes like – raw material characterization, stockpile monitoring, grade control, raw mix control and optimization.

Level 3 is about automated systems for production coordination/ collaboration within entire process department or the entire manufacturing operation of the plant.

For example, in a distributed control system, control of individual plant sections is assigned to specific process controllers that store information relative to the process. The data base for a particular process section is stored in sections of standardized functional blocks and control blocks that are linked together to form control programs. These blocks can range from single logic connections to complete controllers with operator connections. Process controllers have both analog and digital inputs and outputs (I/O) for connections to sensors and actuators of various types. Communications with super ordinate process controllers can be accomplished via a field bus or profibus. These systems enable field instruments to deliver data directly into the control room and provides more accurate planning of maintenance activities.

C. *Process Optimization*

The process control for departments such as mills and pyro process is critical for operation of the cement plant. One method of control is using PLC with PID control loops. These take advantage of established norms of parametric behavior and accordingly control parameters are adjusted.

Advanced Process Control (APC) is also gaining popularity in the resent years. It should be noted that APC is not a substitute for the plant's normal instrumentation and control technology. APC is a software solution in the form of a higher-level control systemthat calculates improved operating points for the existing control loops. Neural networks and fuzzy logic and model predictive control (MPC) are some of the APC methods.

In MPC, a detailed dynamic model of the process is imbedded in the controller. This model takes the form of an "input-output" model, where it relates the effects of the inputs on the outputs. This model is usually determined from operational plant data. The plant is operated under different conditions in order to gather data reflecting those conditions. This data is then analyzed and the model is created based on that analyzed data. The MPC model allows the controller to take current and recent operational data and predict future behavior of the plant. This prediction is dynamic, it determines both the size and time lag of the response.

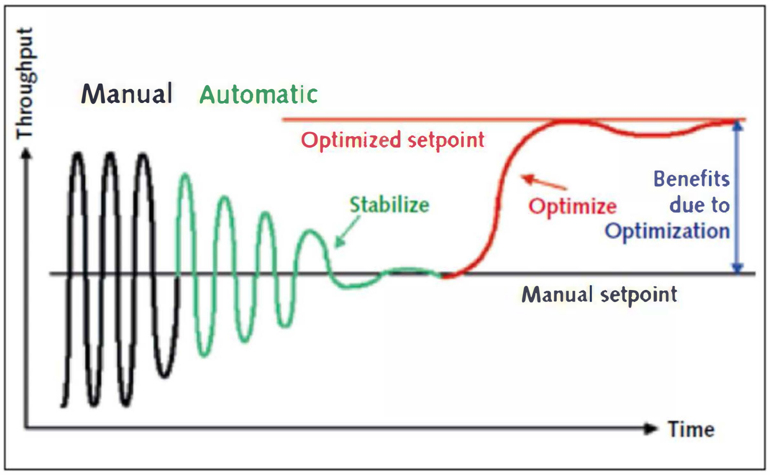

Fig 2. How Optimization works

As shown in Fig 2, the best possible control strategy is implemented and continuously applied on a computer linked with the instrumentation and control system. Faster response rates are achieved compared to human intervention. This leads to a sharp reduction in the variability of the process and means that the process can be operated at an optimum working point, e. g. at a maximum production rate, at the best operating temperature or under optimum combustion conditions.

For example, uniformity in kiln feed quality will lead to stable behavior of kiln, steady fuel consumption rate and consistent clinker quality. Kiln feed quality is in turn dependent on mining quality- statistical techniques like kriging is used for assigning quality to various blocks. Automation can be used to achieve the optimum quality of mined limestone. Further blending in stacker reclaimer and raw meal silo ensures this uniformity in kiln feed quality.

D. Optimization of Fuel Mix

The trend for using alternate fuels along with conventional fuels is increasing to reduce the carbon footprint of cement manufacture. The use of waste derived fuels has to me maximized while keeping the technological requirements of cement manufacture under control and avoiding undesirable environmental consequences. Automation can help balancing cost factors when changes in fuel type, raw materials and manufacturing limitations. The clinker quality had to be maintained while fuel mix varies and this is achieved by data interchange, reconciliation and integration using advanced computational methods.

E. Optimization of Product Mix

In today's competitive market, one has to be flexible to meet the varying needs of the customers. These external factors influence the operation of product grinding departments. An optimum decision has to be taken regarding which product to grind, when to grind and how much to grind. Optimal scheduling of the operation of cement mills can be carried out by using mathematical methods to minimize the cost of power purchases and risk of filling silos with product that is not immediately saleable. Automation can help to simultaneously deal with shipment, storage and cost constraints to meet sales targets on a daily basis while remaining flexible to meet needs of a dynamic market.

F. Optimization of Power Consumption

Automation can be used to run equipment with heavy power consumption during low power tariff durations. This is applicable to the operations of clinker grinding mills and at times the raw mills. The power costs can be tracked in real time and operational modes can be made to adapt to the energy costs.

G. Automation in the Laboratory

Quality control in the cement industry is not only crucial but also complex given the variability in raw material and fuel compositions (especially in the case of solid fuels and alternate fuels). There is a trend of increasing automation in the laboratory ranging from individually automated analytical equipment to complex integrated on-line systems. The major advantages include consistency in sampling, reduction of human error, reduction of staff and labor costs, and assurance of quality in the final product. An integrated laboratory automation system provides improved accuracy of analysis, faster and frequent sample handing and analysis cycles and consistency of intermediate and finished products.

Samples taken at site specific predefined intervals and locations are dispatched in loaded closed containers via a network of pneumatic tubes to the laboratory for analysis. Robots in the laboratory can sort and arrange the sample for analysis. Sample are sequenced and analyzed in equipment such as XRF/ XRD/ Laser granulometers, Colorimeters, etc. The key to achieving success in automation is to ensure that the data generated is reliable and usable. Laboratory information management systems can then take over to make the information centrally accessible and applicable for process optimization and production quality planning as well as compliance with end-product specifications.

H. Condition Monitoring and Predictive Maintenance

The aim of maintenance is upkeep of the plant machinery and equipment, prevention of failure and breakdowns, increasing reliability, maintainability, reducing inventory, and lowering operating cost. The maintenance management system in the cement industry has matured from breakdown maintenance to preventive maintenance. The journey to predictive maintenance and further to reliability centered maintenance is now underway. Other industries such as refineries have already mastered such advanced maintenance techniques.

Reliability Centered Maintenance is a strategy that is employed when the actual condition of the machinery is to be assessed. In this method, the full integration of equipment inspection is warranted needed. Continuous on-line monitoring of the equipment is warranted including start-op and shut down times. Before the onset of automation field inspection with handheld instruments at predetermined frequencies were carried out to monitor the equipment. Equipment performance trends (Fig. 3) thus obtained are used to optimally schedule maintenance. A major advantage of this kind of maintenance is that maximum production and avoidance of catastrophic failures is achieved.

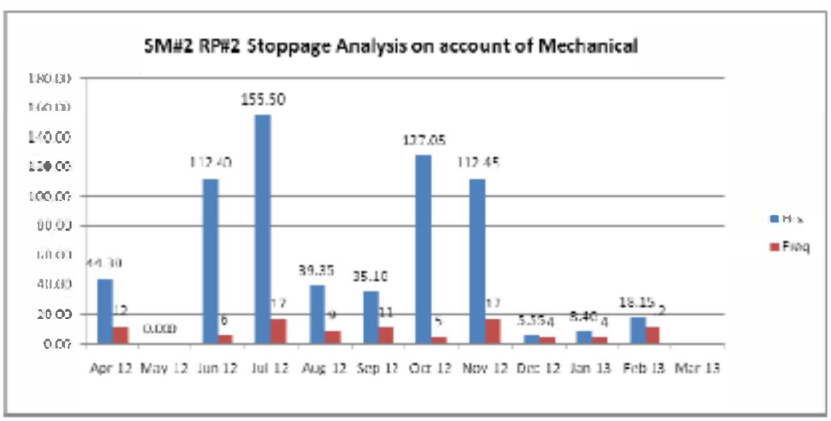

Fig 3. Equipment performance trend

With the implementation of automation, key equipment health parameters such as lubrication oil temperatures, vibrations, bearing temperatures, alignment sensors can continuously be monitored. The data can be stored and trended to predict the onset of breakdown. With application of networks, the data can also be stored on "cloud" based servers and accessed by remote monitoring stations where experts can monitor the trends. If an imminent problem is assessed, then plant maintenance staff or contracted maintenance staff can be deployed in time. Maintenance schedules can be implemented based on such triggers. This will optimize maintenance costs by avoiding over maintenance and reduction of excessive spares inventory. Computerized maintenance management services are now being offered for rotating equipment by many of the instrumentation and control vendors who are remotely able to assess the health of the assets of their customers and send in maintenance personnel as and when warranted. Moreover process upsets which lead to frequent equipment breakdowns (or replacement such as for refractory) can also be correlated and the optimum operating point that allows for smooth operation while maximizing production can be identified. These asset management systems help reduce the Mean Time between Failures (MTBF) as well as the Mean Time to repair (MTTR).

I. Ensuring Safety

Automations role in maintenance is closely related to Safety Management. While unsafe conditions such as possibility of fires are monitored by emissions measuring instruments, dangerous situations with respect to rotating machinery can also be monitored. Adequate alarms can be installed so that worker safety is ensured at all times.

J. Cement Production Accounting

Along with manufacturing process optimization, business process optimization is necessary to administer the cement business. Once automation is adapted for process optimization and control, there is full integration of the system for the data collection, storage, and analysis. The seamless integration of all data types from the different data source enables the system to convert data to useful information with a larger context value.

Cement Production Accounting, as an application in Information Management, helps in balancing production figures. Production figures inevitably need balancing and reconciliation due to errors in sensors and instrument malfunctions.

The collected figures need to be match with reality and consistent among various systems such as inventory management, sales administration and ERP systems, The administration of data regarding received, consumed, produced, and shipped materials is facilitated by the use of Management information systems which communicate with the production information systems. Through advanced stock tracking mechanisms, it is possible to pass on accurate and Real-time data across various systems and reduce errors in reported data and the manpower needed to manage the business.

K. Case Study: Stabilizing Operations

At one of the cement plants, there was a typical configuration of the 2nd stage cyclone exhaust gas being passed to the raw mill for drying of the raw material. As this gas bypassed the 1st stage twin cyclone, every time the raw mill started or stopped the kiln system was getting destabilized. The manual control system depended on the skill of the operator to control the PH exhaust pressure by varying the fan flow. The solution to achieve stable operation was to introduce an automatic loop which depends keeps the PH outlet pressure constant (relative to a particular kin throughput) whenever the Raw mill operating mode changes.

In one cement plant, it was found that the calciner exit gas temperature was controlled manually and erroneously kept at different levels based on the kiln throughput. By taking material samples from the various stages a calcination curve was established for the raw meal Fig (4). This indicated the temperature which was to be maintained for calciner exit gas for achieving desired calcination (~95%). Once the operating parameter was determined, it was possible to incorporate an automatic control loop to stabilize the calciner operation.

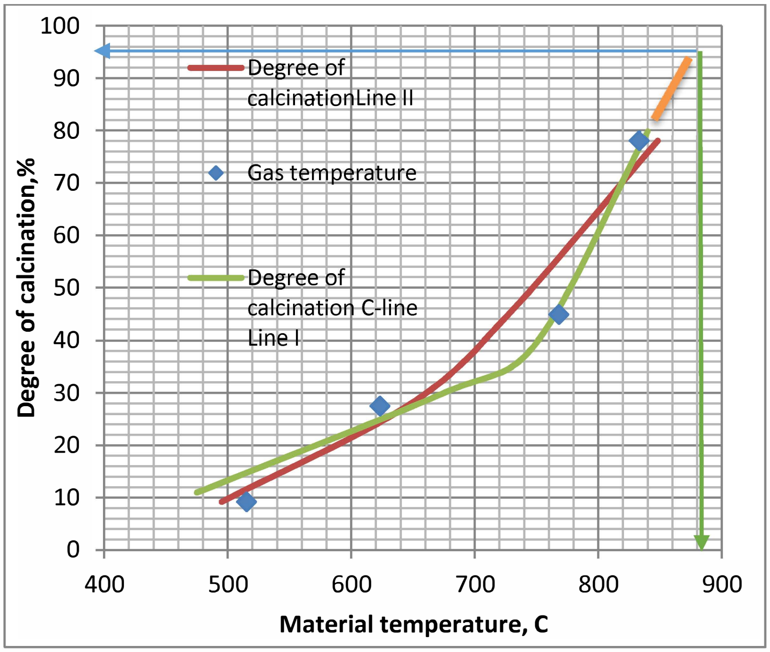

Fig. 4. Determining Calciner control setpoint

III. Conclusion

Higher level control systems thus help in various ways. They can bring about cost saving based on improvement in process efficiency to the tune of 2.5 to 5%. Capturing the best knowledge in plant operations helps to operate the plant consistently in the level of the best operator instead of average levels. Valuable knowledge is retained and not lost with employee turnover.

Equipment health monitoring and predictive maintenance increase the life of key equipment and reduce maintenance cost (inventory control and spares management) by 10-15%. Experts can carry out remote monitoring of equipment, and/or processes thus solving the problem of lack of skilled manpower.

Of course the tangible benefits of increased plant capacity, improved product quality, plant availability and decreased consumption of utilities and consumables all warrant the need for automation in cement manufacturing.

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