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Integrated energy optimisation for the cement industry: A case study perspective

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ABSTRACT

Energy costs play a major role in the cement production process. As much as 60% of total cost is allocated to energy and 18% to the consumption of electrical energy. Historically, energy cost savings were achieved by large infrastructure upgrades. These upgrades are often costly and lead to interruptions in production. In this paper the operation of all the energy intensive components of the cement production process are identified, modelled, integrated and optimised for minimum operational costs while meeting production targets. This integrated approach allows for simulation of the collective effect of individual production components. The system incorporates constraints such as maintenance, production and dynamic energy costs. No published research could be found where these constraints are incorporated into a single operational solution. The system was implemented on four cement plants and a total energy cost saving of 7% was achieved. This highlights the practical significance of an integrated approach to energy cost savings.

1. Introduction

A large portion of the total financial expenditure in the production of cement is allocated to cost of energy [1,2] which is increasing in some instances at a more rapid rate than inflation [3–8]. Resultingly, the proportion of cost allocated to energy in cement production is increasing. This highlights the importance of decreasing cost in a competitive market that is under pressure due to increasing energy costs [9,10].

The layout of a typical cement plant is shown in Fig. 1, whilst the major energy consuming components in the production of cement are shown in Fig. 2.

Fig. 2 shows that approximately 60% of the energy is consumed by the grinding circuits. These circuits consume both thermal energy, provided by coal fired kilns, and electrical energy to power the drive motors, conveyor transport systems and fans. Modern cement plants consume an average of 100–120 kW h per ton in the grinding circuits [12,13].

Electrical auxiliary systems of the grinding circuits include air compressors, conveyor transport, water- and oil pumps, and various large fans. The combined electrical energy consumption of grinding systems can constitute up to 75% of all energy used in the cement industry [2,12]. This corresponds to a total production cost component of 50–60% for energy of which 17.8–42.6% is allocated to electricity alone [2]. The fairly large variation is attributed to different pricing structures and electricity costs in different areas in the world.

In addition to energy costs, environmental conservation in terms of reducing carbon dioxide (CO_2) and nitrogen oxides (NO_x) emissions is a global concern [14]. 33% of global emissions are directly linked to the use of energy of which the cement industry contributes up to 7% of global CO_2 emissions [15,16].

South Africa's primary electricity utility, Eskom, produces 95% of the electricity consumed in the country. 93% of this electricity is generated in coal-fired power plants and the remaining 7% produced by hydro-, nuclear- and gas turbine power generation [17-19]. Reducing electricity demand of cement plants in South Africa will therefore serve to reduce CO_2 emissions. Managing the demand of the cement industry will also assist in creating a more uniform daily demand distribution and eliminating peaks and valleys in the electricity demand profile.

Various new technologies are available that allow the cement manufacturing industry to operate more efficiently [2]. These technologies are available for various components including mills, kilns, and conveyor transport [2,21]. Most of these technologies require the installation of new equipment and offer average electrical energy savings of between 1 kW h and 5 kW h per ton [22–24]. In a life-cycle assessment, Valderrama et al. [20] reported that the implementation of best available technologies (BAT) reduced the electricity consumption of clinker production from 76 kW h to 69 kW h per ton. These installations are however costly

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Nomenclature

Abbreviations

APC	All Purpose Cement
BAT	best available technologies
DMP	Demand Market Participation
ENMS	energy management system
FEMP	Federal Energy Management Projects
FM	Finishing Mill
GHG	greenhouse gas
HSC	High-Strength Cement
IPMVP	International Performance Measurement and Verification Protocol
M&V	Measurement and Verification
OPC	OLE process control for object linking and embedding process control
PDCA	Plan, Do, Check, Act
PLC	Programmable Logic Controller
PTB	Process Toolbox
RHC	Rapid Hardening Cement
RM	Raw Mill
RTN	Resource Task Network
SCADA	Supervisory, Control and Data Acquisition
TOU	time-of-use
VRM	vertical roller mill

Symbols

EL	electricity supply
M_k	processing machine or component
P_{ij}	process flow/product outflow from component
S_{ij}	process flow/product inflow to component

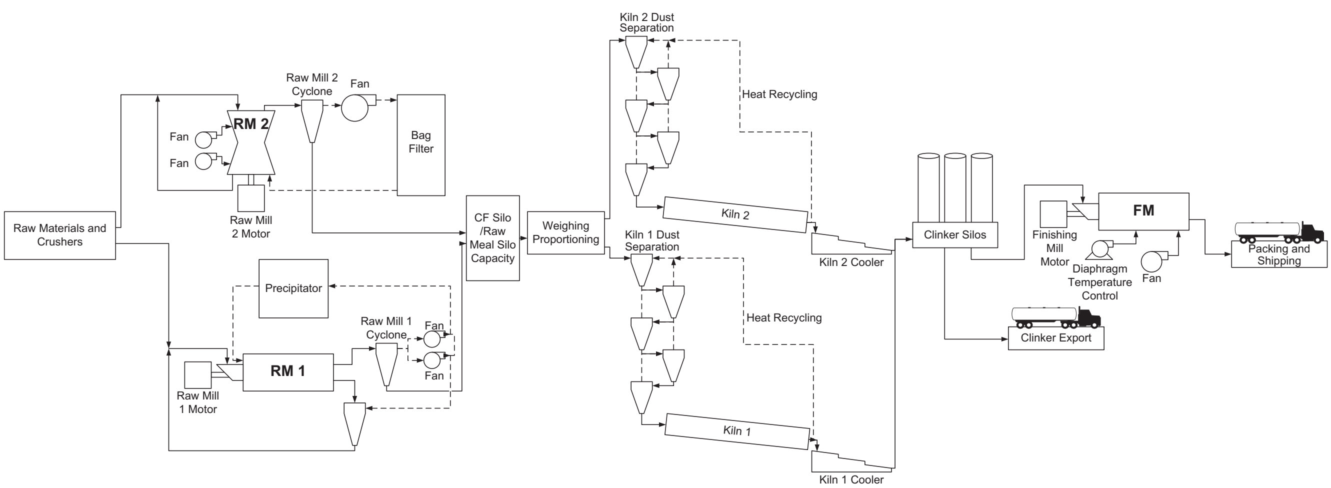

Fig. 1. Physical layout of a typical cement plant: Adapted from site audit and plant layouts drawings RM – Raw Mill; FM – Finishing Mill. (Adapted from [11]).

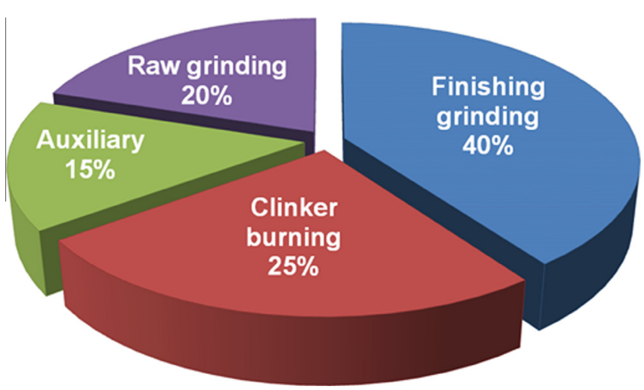

Fig. 2. Energy distribution of cement manufacturing equipment [12].

and require extended production down time [12,13]. The payback period for these installations is often longer than 10 years [23]. Considering emissions, Valderrama et al. [20] reported a 4% reduction in CO_2 emissions by implementing BAT. Reduction in NO_x, SO_2 and dust emissions of 20.5%, 54% and 84% respectively are also possible.

Another technique for achieving energy savings is improved control systems. These systems optimise specific component operation, thus ensuring stable, optimal operation [25]. Savings of between 1.4 kW h and 6 kW h per ton can be realised [22–25]. Even larger energy savings can be obtained when considering more than one component. While the individual components function optimally, the combined analysis of the system will provide interlinked savings. An example is presented by Chae et al. [26]. Doing a plant wide analysis identifies the possibilities for these savings [27].

No published literature could be found on the application of management and computerised modelling systems that simultaneously integrate the numerous production components. A new energy management system was therefore developed and implemented that provides a solution for reducing energy consumption and emissions. The new energy management system not only integrates, optimises and controls specific subsystems according to energy cost saving strategies, but can also predict future electricity costs. Results from *in situ* experiments at four existing South African cement plants are reported, including financial savings.