Philipp Fleiger and Dr. Stefan Schäfer, VDZ, and Jörg Bornemann, KHD Humboldt Wedag, Germany, teach the importance of simulator-based training.
The SIMULEX® cement plant simulator for training plant supervisors, foremen, and control room operators was developed by KHD Humboldt Wedag in cooperation with VDZ Research Institute of the Cement Industry. For over 10 years, VDZ used the simulator within the framework of training courses and constantly supported KHD’s development of the system with practical input from the industry. As a result, the simulator provides a very realistic reconstruction of the behaviour of a production plant combined with a state-of-the-art Supervisory Control and Data Acquisition system (SCADA). With over 200 applications worldwide, the simulator is well received among leading cement manufacturers.
In addition to new installations, an increasing number of recent customer projects are concerned with launching new technologies into existing facilities. The objective of such projects is to reduce energy consumption and emissions, while also supporting the substitution of fossil fuels for alternatives.

In order to satisfy the customer’s request for qualified training support for handling and monitoring plant upgrades and new installations, simulator-aided training classes are offered, which are guided by experienced process engineers. In 2010, VDZ conducted several training courses for process controllers, young engineers at existing plants, and new employees of greenfield plants in Namibia and Russia. The simulation was adjusted to meet customer requirements and fit local plant layouts, and was provided in German, English and Russian. The availability of customised simulation models has proven to be the key to focused training in step with current practice. All training courses have been regarded as highly successful. Customers confirmed a significant gain in trainee knowledge, as well as an increased understanding of the requirements of control room operation.

The cement plant simulator

Nowadays, to become a qualified pilot, experience with the ‘flight simulator’ is mandatory. In the cement industry, the idea of practical training prior to operating a complex production facility has likewise become an accepted part of education and examination. KHD’s SIMULEX® package, a flight simulator for cement plants, has emerged as a beneficial training tool with worldwide application.

As a part of its functionality, the simulator imitates the dynamic behaviour of a cement plant by incorporating real time calculations of entire mathematic and empirically derived models in order to display a huge scope of process variables. In combination with the state-of-the-art SCADA system, ‘SIMATIC WinCC Open Architecture (PYSS)’ from ETM professional control, fully equipped process control software (including high fidelity graphics, data acquisition, alarming and plant supervision), is available to the trainee.

Aside from the levels ‘visualisation and operation’ and ‘production’, described in Figure 2, the processing part, representing programmable logic controller functions (PLC) and electrical drive control, is also covered by the simulator. The model comprises security interlocks, a start/stop utility of drives, as well as feedback control loops. In front of the operator terminal the trainee can simulate grinding raw material, coal, and clinker. The trainee can handle and optimise kiln and cooling processes, without being connected to the real plant. The simulation is optional and intended to bring the simulated plant to excessive operating points and take measures for recovery.

The typical scope of process departments included in the simulator may be concluded from Figure 1. The material, upon being withdrawn from the feeding bins and ground and mixed by the raw mill, is stored and balanced in the raw meal silo. In a downstream direction, kiln meal, including all of its properties (e.g. the chemistry), is fed to the thermal processes, represented by the preheater/calciener/rotary kiln departments. At the kiln outlet, the material flow is transferred to the clinker cooler department, and finally to clinker storage silos with respect to physical and chemical properties. The subject of clinker grinding as well as coal grinding completes the scope of departments that are fully connected with the thermal part via mass, fuel and attribute transfer.

In addition to the downstream process of material throughout the production plant, including mass energy and chemical balances, it is essential to consider the gas flow model of the complete plant. Gas flows are directed conversely to mass flows, and in most cases it is necessary to run a separate gas flow model. The gas flow model determines the draught profile across the plant, gas analysis measurements, as well as interdependences with the mass flow model.

The arrangement of several SIMULEX® single units to a networking system (Figure 3) is an essential feature. This layout supports the sharing of an application among multiple screens (users). Each trainee may take responsibility for a plant detail, e.g. one to run the raw mill, another to run the thermal line, etc. However, the network arrangement also supports a classroom situation, where each participant may independently operate a separate application. The trainer unit may then remotely monitor and interfere with the trainee’s applications.

The networking feasibility over long distances via internet is also possible (Figure 4). In that case, the functionality is divided into server-client relationship. The application resides on the server, while the client maintains a reduced package for quick installation on regular office PCs. Remote client-server sessions run with full functional scope.

Advantages of simulator-aided training

The scope of the program, including software, functionality, and hardware layout, puts a wide range of options at the trainee’s disposal, and thus greatly improves training performance. One key function is simply to start and stop the dynamic calculations. The option to save a snapshot of an arbitrary state condition into a file and to reload the same or another condition set is used most commonly. It enables the trainer to prepare kick-off scenarios for individual purposes, in order to draw the trainee’s attention to certain aspects.

The trainee loads the kick-off state, for example a grinding plant in ‘stop condition’, to perform a start-up procedure. During the session the trainee may stop calculation and freeze operating points of interest. Furthermore, it is possible to save the state condition for backup reasons or for later continuation.

The network facility enables the trainer to share a trainee session, running on a remote unit, for monitoring reasons as well as for interventions. The trainer also has the ability to initiate process disturbances, such as changing the grindingability of materials or even to superimpose random fluctuations to heat values. The trainee is forced to use the according system response to recognise, solve, and rectify the problem.

To satisfy the evaluation and review aspect, which affiliates a training session, the simulator optionally provides operator event logging, a recorder for the trainee’s session trajectories, as well as a trainer configurable performance evaluation module. This add-on framework supports the trainer in preparing training lessons, dedicating auto-running lessons to the trainees, as well as generating and comparing results afterwards.

The simulator has proven to contribute to a purposeful education of plant operators, to accomplish high production efficiency, to shorten failure downtimes, lower emissions, and finally to reduce costs.

Production controllers and foremen

Over 10 years ago, the education for production controllers and foremen in the German, Austrian and Swiss cement industries began to integrate training. Annual courses for both of these groups consist of basic lectures on math, physics and chemistry, as well as cement-specific subjects ranging from raw materials and process technology, to concrete products. SIMULEX® training courses last one week.

After a detailed introduction to the user interface, training starts with the heat-up of a cold kiln. Normally, temperature gradients that are significantly higher than in reality can be allowed in the simulation to limit the heat-up period. During the start-up, trainees are given the opportunity to slowly familiarise themselves with the user interface before complexity arises. Step-by-step the mills are put into operation, beginning with the cement grinding plant and followed by the coal and raw mill, which are interlinked with the kiln by the hot gases. Once all systems are running, optimisation in terms of energy efficiency, maximum alternative fuel rate or capacity starts. Depending on the experience of the groups, this takes 3 – 4 days. Concluding the course, trainees will have to handle process disturbances activated by the trainers, ranging from cyclone blockages to failures of motors and fans.

During the training, the theoretical knowledge obtained during the lectures is utilised by practical application, and new specialised questions arise that can be discussed in group. The simulator has also proven to be a great tool for explaining complex physical, chemical, or technical inter-relationships, such as the impact factors on the formation of NOx, control loops for kiln hood pressure (Figure 5), or the appearance of vibrations in vertical roller mills. VDZ’s experienced trainers have optimised didactic concepts to fully utilise the complete potential of the system, and to provide highly efficient training (Figure 6).

International training

In addition to these courses, a wide range of simulator trainings for everything from the education of new employees to specialised expert training, are also offered. These can be enhanced by theoretical lectures and plant inspections.

In 2010, VDZ Research Institute conducted two training courses for new employees at greenfield plants in Namibia and Russia. Ohorongo Cement’s Sargberg plant commenced

production at the end of 2010. Nearly the entire staff was recruited from the local community in Namibia, most of whom did not have any previous experience in cement manufacturing. The majority of the new control room operators and foremen were sent to Germany for a 5-month training course organised by Ohorongo’s mother company Schwenk. A basic cement course gave a first introduction to the staff’s new work environment and provided basic knowledge before trainees began intensive simulator training. For the most effective training, VDZ, in cooperation with KHD, amended the simulator in terms of plant equipment, process layout and capacities to match nearly 100% with the real equipment at the Sargberg plant. This way, the trainees were able to familiarise themselves with their new plant. After the return of the trainees from Germany during the final phase of erection, a second onsite training at the Sargberg plant was conducted. This consisted of a 2-day SIMULEX® refreshment course for the employees trained in Germany, and a 3-week course for new staff, including onsite inspections (Figure 7) and 8 days of simulator training.

A second training course for new control room operators was held at TulaCement’s currently erected cement plant in Novogurovsky, near Moscow (Figure 8). Again the simulator was adapted to the local plant layout and optimised to fit customer requirements. To minimise complexity and transportation costs of the computer equipment, the simulator was provided via remote access. During an 8-day course, the trainees were given the chance to experience work with a control system. During previous onsite trainings in different plants they had the ability to monitor the work in control rooms but could never manipulate the system on their own. The SIMULEX® system encourages independent work and learning through trial and error, motivating the participants.

Conclusion

The education of qualified personnel is a permanent challenge among manufacturers in the cement industry. The reasoning behind customers’ continued desire for appropriate training can be seen by the high degree of fluctuation among control room operators. However, the erection of greenfield plants, as well as revamping of existing plants with new technologies, induces further training demand.

The VDZ Research Institute, which has developed training expertise for years, conducts well adjusted, didactically optimised basic lectures, as well as practical lessons that are attended by experienced instructors.

Operator training, along with traditional lecture-based training in a classroom situation, can be reinforced by the concurrent usage of a process simulator. This enhances the understanding of the attendees, as well as considerably improving motivation and commitment of the plant operators. Furthermore, it moves a considerable part of practical education, traditionally derived from the job, back into the classroom.

In conclusion, the duration of education will be reduced, commissioning times can be decreased, and desired plant efficiency can be reached earlier. All this contributes to cost reduction. The combination of VDZ attended training, in conjunction with the KHD simulator, has proven to be very successful, according to multiple examples.