Modernizing Power in Poland







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Introduction

Since Cementownia Kujawy became a member of the Lafarge group in the 1990s, it has been modernised in several stages. One of the biggest steps was the construction of the 4500 tpd dry kiln line, which replaced the three existing wet kiln lines. This project extended from receipt of raw material from the quarry to transport of the clinker into the existing clinker silo. It therefore included raw material transport, the prehomogenisation bed, the raw mill, the preheater and kiln, cooler and clinker transport to the silo, coal handling, the coal mill and feeding of the coal to the kiln.

The complete line was built beside the three existing wet kilns. This enabled the continuation of cement production during the construction phase, while the dry kiln line could be handled almost like a green field project. The erection and construction work had, however, to take into account the limitations in space and logistics because of the ongoing production at the plant.

Contractual setup

The building of the dry kiln line was a turnkey contract, including civil construction. The general contractor was Polysius. ABB and the German branch of French engineering company ICER were responsible for the electrical and control systems of the plant. The project also included the integration of those control systems that had been supplied in previous modernisation steps of the plant.

Although the dry kiln line was a turnkey contract,



Figure 1. Main substation (GPZ).

the whole project was executed in close co-operation with the client, Lafarge. Lafarge's project management responsibility was handled by its Centre Technique Europe Centrale (CTEC) in Vienna, and Lafarge members who were to finally operate and own the plant were included in the CTEC project team. Thus it was ensured that the interests of the end user could be fully taken into account throughout all project stages.

The responsibilities of the electrical contractors ABB and ICER included:

- The interface to the 6 kV side of the main substation.
- The 6 kV switchgear.
- The LV switchgear.
- The major fixed and variable speed drives.
- The plant control system, with its interfaces to either the existing control systems or to subsystems of the dry kiln line, which have their own dedicated sub control systems.
- The lighting of the dry kiln line.
- Earthing and lightning protection.
- Reactive power control and the non standard instrumentation, as well as the incorporation of the standard instruments, which were supplied together with the mechanical equipment.

Design of the power supply

The Kujawy cement plant has a very conservative power supply concept, which is designed for high availability and supply security. The public electric utility supplies the cement plant Kujawy via three 110 kV overhead lines. Each of these lines terminates in its own dedicated step down power transformer, which in turn supplies a double busbar section of the 6 kV main switchgear. The main station (GPZ) setup permits bus coupling of the busses between these three sections, but during normal operation the sections are not interconnected. The complete 6 kV system has an ungrounded neutral.

In each section one feeder is dedicated to the dry kiln line power supply. The dry kiln line contract starts at the terminals of these feeders. Figure 1 shows a simplified single line of the main substation.

This main power supply concept gives the plant a two out of three security of the electric power supply. In case one 110 kV feeder is lost, the respective bus coupler on the 6 kV side is closed and the respective 6 kV section can continue its supply to the plant. The independence of the three sections limits the short circuit current on the 6 kV side because there is only ever one power transformer connected to a busbar. The independence of the three bus sections also minimises the possibility that an electric fault in one part of the plant disrupts power supply to the rest of it.

The dry kiln line is supplied from electric rooms, which are located close to their dedicated plant section. In total there are four electric rooms:

- The prehomogenisation substation.
- The raw mill substation.
- The preheater substation.
- The cooler substation.

Each of these substations contains the distribution transformer for their dedicated plant section, the MCCs, the control system, the variable speed drives plus the subsystem control panels of their plant section. In case a variable speed drive is so big that it needs a converter transformer, this is also located in the respective substation. Figure 2 shows the single line of the dry kiln 6 kV substation.

The low voltage power supply is at 500 V 3 phase again with an ungrounded neutral. The power supply for the plant lighting is completely separated from the process power supply. It has its own transformer and its own supply level of 400 V 3 phase. Its neutral is solidly grounded.

Medium voltage system

The voltage level of the MV distribution system in the

plant is 6 kV. The fault level is 25 kA. The switchgear is designed as metal-clad type. Each switchgear feeder has two compartments, one for 6 kV and one for the low voltage circuits. The low voltage compartment is air insulated and accessible. The 6 kV compartment is filled with SF_6 and sealed. The insulation level enables the station to operate even when the SF_6 pressure has dropped to 1 atmosphere. Each feeder plus the incomer has a vacuum circuit breaker with a spring-operated mechanism. The disconnect switch is a so-called three way switch. It has three positions:

- Closed: The feeder is connected to the busbar.
- Open: The feeder is disconnected from the busbar.
- Earthed: The disconnector is connected to the ground. The final earthing, however, needs the closure of the feeder circuit breaker.

The feeders are functionally assigned to the four substations. As the coal feeding is functionally part of the kiln, the coal mill feeder and the feeder to the coal mill distribution transformer are part of the preheater substation.

A second design target was to try to assign approximately equal load to each of the three main busbars in GPZ. This was the reason why the transformer for the utilities was assigned to the cooler substation.

All the distribution and converter transformers of the dry kiln line are dry type cast coil transformers. Although the initial investment in these transformers is higher than for oil transformers, they simplify the civil construction of the bays because they need no oil



Figure 2. Single line diagram of the Kujawy dry kiln line power supply.



Figure 3. Layout of the third harmonic filter



Figure 4. Field bus topology for the cooler.

sump so weigh less. The foundation can therefore be smaller. They also have less losses than oil transformers and the fire hazard is significantly lower than with an oil transformer

Power factor compensation and filtering

To improve the power factor cos ø of the entire plant, as well as the reduction of the contribution of plant harmonic sources to the voltage harmonic distortion, a central power factor compensation and filtering system

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was installed at the 6 kV level of the plant. The power factor compensation had the following design targets:

- The total power factor: 0.96 < 1.0 (avoid becoming capacitive).
- Voltage distortion at the network side: below the values stated in IEC 1000-3-6 environment class 2.

These values had to be reached with the existing low voltage power compensation connected to the power supply. The analysis of the existing low voltage reactive power compensation showed that there is the potential of a resonance at the third harmonic.

The single line shows that each substation has variable speed drives connected. They are the main source

of harmonics of the dry kiln line. The concentration of the harmonic sources is in the preheater substation.

Therefore each substation got a filter circuit at the 6 kV bus. The raw mill and the cooler substation had a filter power of 1250 kVAr. These filters were tuned to the fifth harmonic. The preheater substation got a 2000 kVAr filter tuned to the third harmonic. All of the filters have a damping resistor to improve the robustness of the circuit. The 2000 kVAr filter, with its low tuning frequency, has the capacitor bank split to minimise the flow of power frequency current through the damping resistor, which is bypassed for the power frequency current by the series connection of the low voltage capacitor and the filter reactor, parallel to the damping resistor.

A dry type iron core reactor permitted a compact filter design for indoor use. Figure 3 shows the layout of the third harmonic filter.

A dedicated controller, which is completely independent of the process control system and is located in GPZ, decides when a filter shall be connected or disconnected.

The preheater substation has a capacitive power of 2000 kVAr connected to the busbar, but only a 650 kW medium voltage motor connected. In order to avoid damage to the motor in case the feeder to preheater substation is tripped by the feeder protection in GPZ, a hardware trip is wired from GPZ to the filter feeder in the preheater substation.

Motors and drives

The raw mill motor, fan motor and the coal mill motor have a power rating higher than 200 kW and are therefore directly connected to the 6 kV bus of their respective medium voltage substation. Due to their power, each of them has a liquid starter instead of an oil starter, which permits a continuous reduction of the rotor resistance during the start of the motor. The starters are located outside. Due to the low temperatures during winter, their basic electrolyte liquid is a mixture of water and glycol.

Variable speed drives

The dry kiln line uses only variable speed drives with frequency converters feeding squirrel cage

asynchronous motors. As with the fixed speed motors, those drives with a shaft power rating above 200 kW are connected to the 6 kV bus via a converter transformer. The latter are all three-winding transformers to achieve twelve pulse operation of the large variable speed drives. The cooler has four variable speed drives with a power around 200 kW. All four converters of these variable speed drives are directly connected to 500 V and therefore act as six pulse converters for the supply network. In order to avoid any problems arising from the joint operation of the four converters, they each have their own dedicated 6kV/0.5kV two-winding transformer, which separates them from the rest of the consumers.

For the preheater fan, a water cooled ACS 1000 unit was used, with a water-to-air recooler unit. All other variable speed drives used the ACS 600 family and have air cooling. Those variable speed drives with a shaft power rating below 200 kW had 6 pulse behaviour at the supply network.

The kiln drive was designed to supply a torque in 1 minute during start up, which is 2.5 times its nominal torque. This was one of Polysius' and Lafarge's requirements.

Polysius controls the kiln outlet gas pressure within tight tolerances, which requires that the frequency converters are able to quickly reduce the speed of the speed variable cooler fans and the clinker cooler off gas fan. These variable speed drives were therefore equipped with braking resistors in addition to the raw mill and the coal mill separator drives.

The concept of direct torque control of all variable speed drives achieved the control accuracy required by Lafarge without a feedback signal from a tachometer.

Process control system

As the two previous modernisation steps in the Kujawy

cement plant resulted in the use of the ABB distributed control system Advant OCS (Open Control System), based on the controller families AC 410 and AC 450 respectively, the same system was used to control the dry kiln line. This made the integration of the existing control system into the dry kiln line control system to form a plant-wide control system easy, as the same product family was used throughout the plant.

The Advant OCS used the standard ABB concept for cement plants. Dedicated controllers are responsible for their assigned part of the plant. The assignment basically followed the plant sectioning defined by Lafarge. Depending on the number of tasks or I/Os that a controller had to handle for its dedicated part of the plant, either a controller of the type AC 450 or AC 410 was chosen. The interface to the plant process was provided by S800 remote I/Os. Unix based work stations were used for the operator interface. The subsystems, which were delivered with their own independent subcontrol systems, primarily utilised Siemens S7 controllers.

The real challenge for the design of a comprehensive control system, however, was the communication among the various systems, which needed to be integrated into a plant-wide control system. The Kujawy plant control system relied to a large extent on communication via busses. Bus links within the same electric room used conventional copper connections, e.g. twisted pair cables. Bus lines that interconnect two or more buildings were established by fibre optic cables.

The data exchange between the ABB controllers and the operator stations uses the ABB MB300 bus. This bus was extended to permit the integration of the controllers for the cement mill and quarry

The data exchange between the S800 I/O units and the controller to which they were assigned uses the



ABB Advant Field Bus AF 100. In Kujawy the variable speed drives were integrated into the AF 100 field bus. The communication with the S7 subcontrol systems is done using Profibus DP. In this way the process oriented control systems were integrated into the plant control system. Figure 4 shows the field bus communication network for the cooler.

In addition, the following higher-level control systems had to be integrated into the plant control system.

- The Lafarge expert system LUCIE (kiln control).
- The Lafarge raw meal preparation system QMC.
- The plant data collection and reporting system IP 21.
- The Polysius raw material analysing system POLAB[®] AOT.
- The ABB power control and supervision system MICROSCADA.

All these systems need access to data, which is in the plant control system. The kiln control system, the raw meal preparation system and POLAB[®] AOT also need to be able to change reference values in the process controllers.

These systems communicate with the plant control system via the standard OPC interface. For this reason a dedicated OPC server was integrated into the Masterbus MB300. All the above higher level systems became client to this OPC server.

The OPC interface enabled each of the above systems to develop to a large extent independently of each other, as each of them only sees the OPC Server in the Masterbus MB300 and its standard OPC interface, despite, for example, the fact that raw meal preparation needs data from POLAB® AOT. Microscada, which is Kujawy's interface to the power utility, needs to collect data according to the requirements in power transmission systems. Therefore it interfaces directly with the bay control units REF542 plus in the MV Switchgear.

In order to fulfil the utility requirements it uses the LON bus to collect data from the MV Switchgear, which permits a highly accurate sequence of event-recording in case of an electrical failure. Figure 5 shows a simplified overview of the control system.

Instrumentation

The standard instruments were within the scope of supply of the mechanical suppliers, primarily Polysius. The electrical contractor had to integrate them into the plant control system, which was done by conventional wiring into the S800 I/O's.

ABB's scope of supply consisted of:

- Four gas analyser systems.
- The kiln shell scanner.
- A spyrometer for the kiln.
- A conventional pyrometer and a camera for the cooler.
- An environmental measuring system.

The gas analysers are located at the kiln inlet, precalciner, preheater outlet and at the coal mill filter. The two gas analysers at the kiln inlet and at the precalciner use water cooled retractable probes to collect gas samples. As both probes are located basically perpendicular to the gas flow, the ABB probe type H with a plunger to clean the gas sampling nozzle is used (Figure 6). The other two probes were fixed probes in the gas flow.





Figure 6. Tip of probe H with plunger in normal position (left) and during nozzle cleaning (right).



Figure 7. Basic UPS circuit.

The steel structure, which carries the tertiary gas tube above the kiln, plus the steel structure of the preheater tower resulted in 'shadows' for the kiln shell scanner. In order to get the thermal image of these areas, three additional pyrometers were installed and the scanner PC got special software, developed by the scanner manufacturer, which integrates the thermal image of the scanner itself with the thermal image of the three additional pyrometers.

The scanner has the capability of 8 binary outputs, which go high in case the temperature in a certain definable section of the kiln exceeds a predefined limit. This capability of the scanner was used to provide the possibility to switch the kiln cooling fans automatically on and off in five groups.

The environmental

system measures the following values in the off gas:

- CO.
- O₂.
- SO₂.
- SO₂.
 NOx.
- NOX.
 Tomporate
- Temperature.
- Dust.
- Gas flow.

The values measured by these systems are processed in a dedicated PC to comply with Polish environmental standards. A second PC was supplied for the central control room, which shows the values of the main PC in the control room, but does not give the control room operator access to the main PC.



Emergency power supply

Each electrical room has an uninterruptible power supply, which can maintain its power for 30 minutes. The UPS basic diagram is shown in Figure 7.

All the UPS systems have an output of 230 V AC single phase. The normal input to the UPS is 500 V 3 phase from the respective MCC (net 1). Each UPS has a second input from the lighting network (net 2). An integrated bypass switch (7) connects the 230 V of the lighting network to the UPS output in case the battery becomes low and the process power supply does not come back. This measure shall provide an additional level of safety for the power supply to the sensitive equipment.

The large consumers, which need emergency power, are supplied by an emergency power diesel generator. The diesel generator output is at 500 V 3 phase. It has its dedicated busbar, from where the emergency power is distributed to the individual MCCs that need emergency power. The Lafarge concept tries to maintain 500 V at the emergency power busbar at all times . For this purpose a feeder connects the emergency power busbar to the utility's MCC. In normal operation the emergency busbar receives its power from the utilities transformer. An under-voltage relay automatically starts the diesel generator should the voltage at the emergency power busbar drop.

Thus the emergency power supply is secured without any operator action, and its start is based on a simple criteria. This concept means that the emergency power generator also starts in case only the cooler substation or the utility feeder is tripped. Figure 8 shows the single line for the emergency power supply busbar.

In each MCC there is a separate busbar section, to which the emergency power consumers are connected. This busbar is connected to its distribution transformer as long as the incomer has voltage. If the incomer voltage disappears, an automatic changeover switch connects the emergency power busbar to the emergency power feeder, which, due to the supply concept of the emergency power supply, is always under voltage. When the power comes back the emergency power busbar in the MCC is automatically switched back to the distribution transformer.

With this concept the connection to the

emergency power is done based purely on local measurements. The automatic change from the main power supply to the emergency power supply avoids the emergency power diesel generator running parallel to the network. Thus a synchronisation for the

emergency power diesel generator is not needed even when it is started because only the utility distribution transformer is tripped.

Additional supplies as part of the electrical contract

The electrical contract also comprised the design and supply of the lighting for the dry kiln line including the electrical rooms, as well as street lighting for the road part, which was built for better access to the prehomogenisation storage.

Fire detection and alarms were supplied for the electric rooms plus the cable tunnel from GPZ to the dry kiln line. Lightning protection was also part of the electrical contract. The ground mesh was part of the civil supply. All electrical rooms were air-conditioned to maintain a reasonably constant climate for the electrical equipment that had been installed there. In addition, there is a slight overpressure in the electric rooms to minimise the intrusion of dust.

Conclusion

The Kujawy dry kiln line project involved a number of different organisations in different locations in Europe that united to form a project team, making the successful completion of the project possible

Although the Kujawy dry kiln line's 4500 tpd clinker production is within a range that employs state-of-the-art equipment, its electrical systems incorporate a number of special features that are not necessarily supplied to all cement plants of that production capacity. This equipment, however, proved itself well able to cope with all the requirements of the plant.

The Kujawy dry kiln line project demonstrated that by relying on standard interfaces, the ABB control system is able to integrate a number of different subsystems from different suppliers into a comprehensive plant control system, which enables access to the whole plant from the central control room.



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