NEW CENTRAL CONTROL SYSTEM ARCHITECTURE FOR ANODE BAKING FURNACES

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Abstract

Conventional anode baking firing and control systems are composed of several mobile pieces of equipment with their own local controller to manage the high speed local tasks. Redundant central control units synchronize the actions of each local controller.

A fast real time Ethernet network implementation allows simplifying the existing control system architecture: it uses only one real time central controller and remote Inputs/Outputs for each mobile piece of equipment.

The robustness and reactivity of the control as well as the required safety loops are preserved. The maintenance and day to day operation are simplified.

Furthermore, real time network and accurate time synchronisation between the pieces of equipment open new perspectives to improve the baking process management and to enhance safety.

Introduction

Aluminium is produced through Alumina electrolysis by means of carbon anodes. Prior to use in the pot lines, the green anodes produced from petroleum coke and coal tar pitch need to be baked in an Anode Baking Furnace (ABF) fitted with a Firing and Control System (FCS).

Covered with a building, the ABF is made of refractory brick walls built in a concrete casing. (See Figure 1) The ABF is divided in several sections (from 34 to more than 70). Each section is composed of 7 to 10 flue walls delimiting 6 to 9 pits in which the anodes are baked by thermal conduction. One or two Furnace Tending Assembly (FTA) cranes are moving above the FCS pieces of equipment located on top of the Furnace, to load and unload the anodes in/out of the furnace pits.

The Firing and Control System is composed of several mobile ramps that are grouped by Fire (1 Exhaust Ramp (ER) + 1 Temperature & Pressure Ramp (TPR) + 2 to 4 Heating Ramps (HR) + 1 Zero Point Ramp (ZPR) + 1 Blowing Ramp (BR)) – The Fires are located on top of the Furnace and are distributed over the various firing sections.

As part of the normal operation, each Fire moves one section forward every day to bake the green anodes loaded in the front part of the fire and to allow unloading the baked anodes from the back part of the fire. For a 4-Fire Furnace with a 24 hour baking cycle time, 20 ramps (4 ER + 4 TPR + 4 HR + 4 ZPR + 4BR) are relocated inside the building every day. At each Fire moving, as part of normal operation, the ER is always replaced by a new ER and sometimes a ramp can be changed by a spare one, for maintenance purpose.

In addition to the ramps, one PLC named Auxiliary Equipment (AE PLC) ensures the interface between the ramps and the Furnace Fume Treatment Plant (FTP), the Furnace fuel supply loop and some other Furnace utilities (for example, emergency stop and explosion vents).

Conventional Control System architecture

All the ramps are locally controlled by a Programmable Logic Controller (PLC) to manage the high speed local tasks (such as injector pulse generation, damper positioning, Heating Ramp fuel circuit process and interlock management).

In the past to achieve the same level of safety as expected by most users and as promoted by Fives Solios, a dedicated safety loop was powering down the furnace power plugs of the ramps, to safely stop the fuel injection in case of FTP draught problem. The use of Safety Integrated PLC (SIPLC) on the key ramps (AE, ER & HR) allows managing the same safety loop while assuring a continuous follow-up of the process data. Indeed, with SIPLC, the ramps can continue displaying their data for the operator follow-up because they can stay power-up while safely stopping the fuel injection.

Safety Integrated PLCs can manage simultaneously process tasks and safety loops within the same controller. They can manage local safety loops (Input and Output on the same PLC) but also manage safety loops across the Network (Input on one PLC and output on another PLC).

The ramps are controlled and monitored by two hot redundant computers (Central Control System) located inside the ABF control room. The master computer makes calculations based on data collected from each ramp through the communication network and sends commands to the ramps. All commands are sent to each ramp using the same Communication Network.
These data are also displayed on the supervisory computer screens (Real Time Supervisory) for operator follow-up and stored in the Data Management computer (Data Management System).

Few industrial networks with a good bandwidth allow hot connecting and disconnecting of a User without trouble. One of the best available nowadays is Ethernet.

Ethernet is a frame-based computer networking technology for Local Area Networks. It defines wiring and signalling for the physical layer, and frame formats and protocols for the media access control (MAC) (data link layer) and common addressing format. Ethernet is standardized as per IEEE 802.3. Most of the present networks use Ethernet TCP/IP type of networks (IP stands for network layer and TCP (TCP/UDP) stands for transport layer). This choice of technology allows using wireless networks (See Figure 2).

In theory, the Ethernet TCP/IP network of the FCS is open and could be used for several application of the ABF. However because this network is such a critical part of the FCS, it is very often dedicated only to this purpose. A Wired Ethernet TCP/IP Network has a star network topology requiring a heavy infrastructure (Enough Ethernet switches dispatched inside the Furnace building to have one port for each section and wiring up to each section). The infrastructure and the protocol introduce latency time in the communication. WiFi network has simplified the infrastructure. However, the ramp section numbers are not anymore identified automatically by the system and longer communication latency time between the ramps has been introduced. Moreover, WiFi networks are difficult to install, to configure and to maintain because they can be disturbed by other Wireless Networks or radio users (such as meteorological and army radars) [1].

**New Central Control System Architecture**

A fast real time Ethernet network implementation allows simplifying the existing control system architecture: it uses only one real time central controller and remote Inputs/Outputs for each ramp and for the Auxiliary Equipment (AE PLC) (See figure 3).

![Figure 2 - ABF Control System Architecture](image1)

**Figure 2 - ABF Control System Architecture**

![Figure 3 - New ABF Control System Architecture](image2)

**Figure 3 - New ABF Control System Architecture**

The day to day operation is simplified, because there is only one controller, there is only one programmed behaviour (no more choice between remote control or local control), one set of parameters and most importantly for the operator only one type of HMI (Human Machine Interface - Control Screens). On the proposed architecture, the ramp screens and their dedicated HMI are replaced by at least one touch screen located on each side of the ABF. These screens are Real Time Supervisory (RTS) HMI as the ones inside the control room.

WiFi tablet PC also with a RTS software similar to the one in the control room could be used for a local control close to each ramp. Therefore, WiFi Access Points are needed inside the furnace but this WiFi network has very few constraints compared to the ones when the network is used for the whole FCS communication.

Signalling and commands located on the ramps are limited to safety functions only: emergency stop, field validation by the operator that the ramp can be remote controlled by the Central Controller and electrical insulation of both flue wall injectors if for any reason, such as maintenance (injector not set on the flue wall) or process management, the operator chooses that they must not be operated.

**Anode Baking Process Improvement**

Real time network and accurate time synchronization between the ramps open new perspectives to improve the baking process management. One of the main improvements is the accurate