WIRELESS COMMUNICATION FOR SECURED FIRING AND CONTROL SYSTEMS IN ANODE BAKING FURNACES

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Abstract

Anode baking requires firing and control systems which move every day, as the fire progresses around the furnace. Wired connections between moving equipment and the central control unit have always been an operation and maintenance concern. Wireless networks became the logical modern solution with standard PLCs. Modern furnace control requires new safety loops between firing equipment. However, whenever safe communication between safety PLCs are used for secured control of the baking furnace, wireless communication has encountered numerous drawbacks due to the nature of safety communication protocol and the interference with other WiFi systems in the baking furnace area.

Extensive development work was completed with major PLC suppliers to find the right combination of modems and antenna and to fine tune the PLC's and WiFi systems so that operation performance and safety requirements are fully met. WiFi is now available for the secured baking of anodes.

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).

The ABF is made of refractory bricks walls built in a concrete casing located inside a metallic building. (See Figure 1) For 66 sections: the building is around 260 m long x 40 m wide x 25 m high, 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.

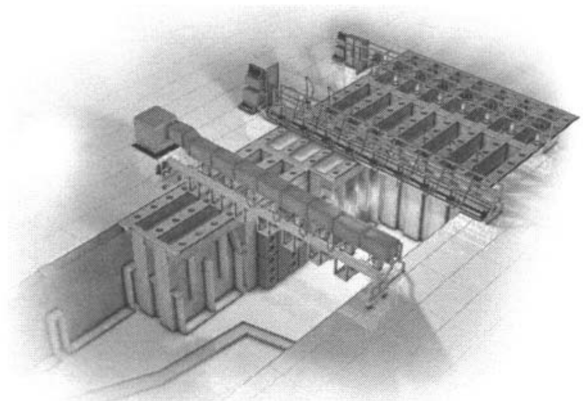

Figure 1 – Anode Baking Furnace

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) + 3 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. They 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 that it collects 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).

As part of the normal operation, each Fire moves one section forward every day. 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. Consequently, the Programmable Logic Controller (PLC) controlling the ramps to be moved is stopped before the move and restarted once the ramp is set in its new location. 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). For user-friendly management of spare ramps, Solios Carbone is also using this PLC to manage communication between ramps. Under normal operation ramps exchange process and safety data with the AE PLC and between each other through the AE PLC. All these exchanges take place on the Communication Network. The Communication Network must have the same performance on all the Furnace sections, because at some point, each section will host a ramp.

Communication Network

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. The Wired Communication Network for a Firing and Control System needs each section of the Furnace to be equipped with a communication plug to connect the ramp. A Wired Ethernet Network is 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). Moreover, this Network will suffer from the same problems as other Wired Networks, plugs, sockets and cables are cumbersome and cannot endure cyclic change-over. Consequently, wireless connections appear to be the logical modern solution. (See Figure 2)

WiFi is a radio network using frequency bands, named channels, located around 2.4 GHz (up to three distinct 20 MHz wide channels) and 5 GHz (up to twenty distinct 22 MHz wide channels). These frequencies have been opened to free usage in most countries in the world. Although, sometimes an authorisation may be required from local regulation authorities regarding frequency usage and/or for radio modems themselves. Moreover for 5 GHz channels, it is necessary to check which are non DFS (not subject to apply the Dynamic Frequency Selection procedure as described in relevant standards, i.e. in Europe EN 301 893) because the channels that must apply the DFS procedure might have to switch off from time to time in case of radar detection.

A WiFi Network is controlled by the Access Points. They are radio modems, that follow the WiFi standard (IEEE 802.11 a/b/g/n) and they are connected to the field Ethernet Wired Network linking together the Central Control Computers and Auxiliary Equipment.

According to the purpose of the WiFi Network (such as public WiFi Free Zone, domestic network), the settings will follow different practices for Service Set Identifier (SSID – commonly the network name), security management, channel allocation and roaming parameters. This publication describes one kind of WiFi Network suitable for the Solios Carbone Firing and Control System for an Anode Baking Furnace.

The Access Point sets the essential parameters of the WiFi Network: Standard 802.11a (5 GHz), 802.11b/g (2.4 GHz) or 802.11n (2.4 or 5 GHz), Channel, SSID and encrypting key. Because of the size of the building several Access Points are located inside the Furnace. Adjacent Access Points must use non overlapping channels so there is no interference with each other. However they share the same SSID and the same encrypting key.

Ramps are connected to a radio modem named "Client". Client and Access Point can have the same hardware but they could also be built around different ones. Each Client must be parameterized with the network Access Point channels, SSID and encrypting key so that it can connect itself to any Access Point within the WiFi Network deployed inside the Furnace.

When a Client modem is started, it connects itself only to one Access Point and they remain connected. However, the Client can choose to disconnect, to connect to another Access Point with a better signal level (Roaming phenomena) offering a natural redundancy and enhancing process continuity. Indeed, the Anode Baking Furnace radio coverage offers all the time, at least two Access Points, close enough for the Client to connect to. Radio exchanges occur only between the Access Point and the Client. Client to Client communications are routed through the Access Points.

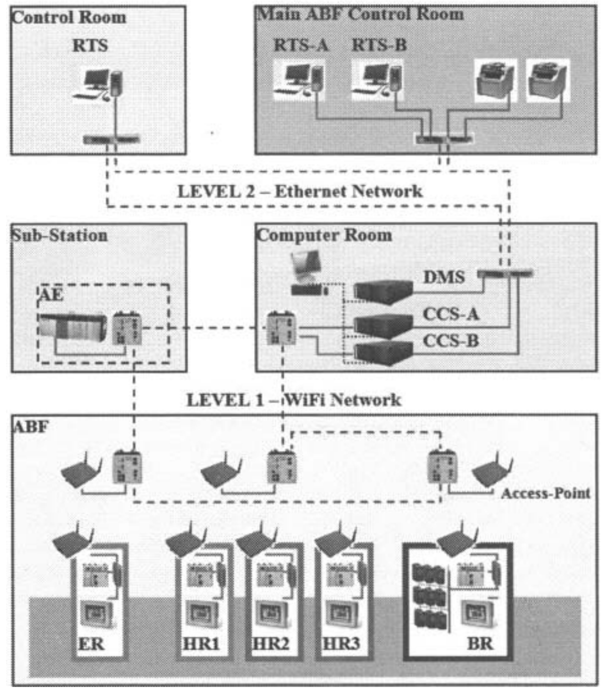

Figure 2 - ABF Control System Architecture

Control Systems

All the ramps are locally controlled by a PLC. Depending on the smelter projects and customer specifications these PLCs may either be standard or safety.

The safety PLC manages local safety loops (Input and Output on the same PLC) but also manages safety loops across the Network (Input on one PLC and output on another PLC). Both kinds of PLCs use the same Wireless and Wired Ethernet Network but the communication mechanisms are different when safety PLCs exchange safety tags through the Network.

Over the past years Solios Carbone has accumulated successful experiences regarding installation of Baking Furnaces using Wireless Network either with standard (3 projects) or safety (3 projects) PLC.

Feedback from Qatalum

During the recent start-up of Qatalum Smelter, new communication problems occurred that requested extensive development work in collaboration with the PLC supplier to eliminate the communication disruptions. The aim was to find the right combination between WiFi hardware installation and fine tuning of PLCs and WiFi systems parameters, so that operation performance and safety requirements were fully met.

Qatalum is an Aluminium Smelter in Qatar. It is equipped with two Anode Baking Furnaces based on an Aluminium Pechiney technology: One of 66 sections with 4 Fires and one of 50 sections with 3 Fires. Both furnaces are end to end in the same building with a common Communication Network and the Firing Ramps can be used on both furnaces.

At the request of the customer, the ramp PLCs are « Guardlogix » safety PLCs from Rockwell Automation. During the project engineering phase, the PLC manufacturer was not proposing any proprietary solution for the Wireless Network. Consequently, Solios Carbone decided to use the WiFi Network equipment from another supplier already proven in service in past projects. Even though, the platforms tests done before dispatch were successful, quickly during commissioning phase untimely ramp stoppage occurred due to problems linked with safety data exchanges between PLCs.

On the one hand, all indicators (such as coverage, bit rate, retry rate, ratio signal/noise) normally used to characterise a radio network performances did not show any problem. On the other hand, when the Wireless Network was substituted by a Wired Network, there were no stoppages. Consequently, it was concluded that the WiFi Network and the PLC were working properly individually and that the problem was linked to the PLC safety communication mechanisms and the way it was handled by the WiFi Network.

In theory a properly installed WiFi Network should not be different from a wired Ethernet Network. There are, however, some differences, such as:

- ❖ The WiFi Network introduces latency time as an Access Point communicates to only one Client at a time.
- ❖ The WiFi Network doesn't handle "multicast" and "broadcast" traffic as well as a Wired Network. Effectively, most of the time, the time slot reserved to transmit these packets is reduced and they have to be forwarded systematically to all associated Clients. Moreover, for this kind of traffic, there is no reception acknowledgment between the Access Point and the Client, as for "unicast" traffic. (A "broadcast" message is sent to all network devices without distinction. Multicast messages are basically broadcast messages that can be routed, using specific functions of the manageable Ethernet network switches, only to the devices that have requested them. Whereas a "unicast" message is sent only to one designated network device.)
- ❖ The lapse of time before a Client chooses to disconnect from an Access Point when they can not communicate anymore with each other must be set carefully, because it could introduce additional unexpected latency in the wireless communication.
- ❖ From our experience, a WiFi Network has more retry or even lost packets than a Wired Network.

Because of these drawbacks, it was empirically found that communication timeout (maximum time expected between two valid packets) on the WiFi Network should be significantly increased compared to the Wired Network. The PLC software must be optimized to take this into account in order to avoid any impact on the process.

Safety communication mechanisms are different from one manufacturer to the other:

- ❖ The duration and the way the PLC handles the reconnection after a timeout is different.
- ❖ Siemens would use "unicast" messages for their safety exchanges whereas Rockwell Automation would use "multicast" messages. The method using "multicast" messages is a good solution for Wired Network but not easily handled by Wireless Network. In the coming months, Rockwell Automation is to release a new firmware to allow the use of "unicast" messages for their safety communication mechanisms.
- ❖ The possibility to extend the timeout duration for the safety communication is different and is limited by PLC firmware, which can be subjected to supplier modification. Indeed, the firmware release specified for Qatalum project has a reduced timeout adjustment range.

For the Qatalum project, it was not possible to return to the previous firmware release to adjust the safety communication timeout parameter as high as it was successfully set on in the past on other Furnaces. Also, it was not possible to use the other communication mode of the standard PLC using "unicast" packets because the project had specified that safety data exchanges had to be done using the safety communication mechanisms of the PLC.

Modification of the WiFi system

Rockwell Automation recently signed a partnership with CISCO and said that they will warranty their PLC architecture only with CISCO Wireless Network. In order to solve quickly the issue this project was facing, it was decided to follow the PLC manufacturer recommendations and to deploy a CISCO Network: all the ramp Client modems and furnace Access Points were changed.

A new "Site Survey" and "Spectral Analysis" were conducted to confirm the number of Access Points, their location inside the furnace, type of antenna to be used and modems settings (for example channels, emission power). The "Site Survey" and "Spectral Analysis" are two main tools enabling a check of the conditions required for a successful Wireless Network installation:

- ❖ Availability of channels in particular non DFS.
- ❖ External disturbances (Such as other Wireless Networks, meteorological and army radars).
- ❖ Number of Access Points and type of antenna to have a good coverage with the requested Ethernet bandwidth using lower emission power in order to avoid wave reflection inside the metallic building.
- ❖ Clients emission power and type of antenna.

The preliminary and post-installation analyses are even more important for the Firing and Control System as the Furnace building is a real challenge to the operation of a high performance Wireless Network:

- ❖ A metallic building (walls, roof and even most of the time floor) favours wave reflection,
- ❖ Only the longer lateral walls are accessible to fit the Access Points, (Below or above the FTA rails)
- ❖ The anodes waiting on the mobile trolley in the middle of the Furnace make an obstacle to wave transmission,

- Carbon dust settling on antennas,
- One or two big metallic FTA cranes that are moving on top of the Firing Control Equipment,

Interference with other WiFi systems

For Qatalum, during commissioning of the CISCO solution as it was defined during the preliminary study, a new problem arose. From the four required non DFS channels available in Qatar and that were reserved for the Firing and Control System for coverage of both Baking Furnaces only two were still available because the FTA initially using channels in the 2.4GHz band was moved to the 5GHz frequency band to solve communication problems.
As more than two Access Points were required for both baking furnace coverage, in this particular case, extensive on site engineering managed to limit channel overlapping by adjusting the number, location and emission power of Access Points.

Moreover, even though the CISCO Network was commissioned with the parameters defined during engineering phase, some communication problems still persisted. It was necessary to fine tune all the parameters again to achieve operation performance and safety requirements:

- Modification of PLC software to optimise exchange between PLCs.
- Optimisation of PLC recovery duration in case of timeout on a safety tag.
- Optimisation of Access Point coverage using the two channels available, only.
- Optimisation of multicast traffic, (Ethernet manageable switches, Access Points and Client modems parameters).

The Qatalum project shows that several radio networks can work at the same time inside the same building. However, it also highlights that for future project, it would be better for all the suppliers to share a common Wireless Network deployed inside the Anode Baking Furnace building. This common Network could be designed and specified by the EPCM.

Firstly, it would allow a check that conditions are met for a Wireless Network (such as enough channels available, no interference) before the Smelter is erected. Secondly, it would help in reducing conflicts between the various suppliers for sharing the channels available taking into account that 2.4 GHz band only has 3 usable channels that are most of the time polluted by an increasing number of wireless devices (for example, cell phone Bluetooth headset, WiFi smartphone, printer, laptop, microwave oven) and sometimes, only a small number of channels are available within the 5 GHz band (depending on the local radio regulation authority).

The WiFi equipment must be selected carefully during engineering phase for an industrial Wireless Network such as the one used for the Anode Baking Furnace. Because, even if all of the WiFi equipment follow the same standard and suit most day to day general public usage (such as access to internet in public space), all equipment do not have exactly the same ways to handle the communication. The project must check that the chosen WiFi equipment is compatible and validated with the specific communication mechanisms used by the chosen PLCs.

A single common Wireless Network would also call for a strict management of the Ethernet bandwidth because the Firing and Control System, with its process and safety exchanges, requires a high availability of the Network due to the nature of its communication.

Conclusions

With the experience of the Qatalum start-up, Solios Carbone has been able to understand better the complexity of combining safety PLC controls with wireless communication for firing systems on ABF. Most of the issues have been solved. A similar solution will be implemented for the Hindalco projects of Mahan and Aditya in India.
Further improvements will come from the management of a common wireless communication for the whole ABF. However, as of today Solios Carbone can provide Firing and Control Systems using complete Wifi solutions with Siemens and Rockwell Automation safety or standard PLC's. WiFi is now available for the secured baking of anodes.

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