AL31 - Quick and Safe Replacement of an Existing Pot Control System by ALPSYS

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Abstract

Pot control systems are like people: they live, evolve, improve, and eventually grow old. With this comes the need to move onto a new system. This inevitably leads to the crucial questions "Which system is going to work out for us?" but also "How can we perform the switch-over to a new system safely and without affecting operations?"

Throughout the years our activities have encouraged us to build a robust and flexible process that allows us to answer these questions for any smelter running with any sort of pot technology. For us, the ALPSYS team, it is essential to provide a process control solution that fulfills the highest performance and quality standards, while always guaranteeing the safety of the people working on the pots. The transition period from an old to a new process control system is no exception. Such a transition is a very specific project, creating specific risks and challenges. This paper describes the different steps of our process from the first contact with a smelter to the final pot switching over to ALPSYS.

Keywords: Pot control system, ALPSYS, System switchover, Reduction pot supervision system, Safety.

1. Introduction

Rio Tinto has its own pot control system (PCS), named ALPSYS, that is operating potlines for more than 25 years now. It is an integral part of the Aluminium Pechiney pot technology and is one of the key elements in achieving the high performances of today's pots.

The ALPSYS system is presently installed worldwide on 42 potlines in 22 smelters. The first systems installed approximately 25 years ago are still running and operating with their original pot controllers.

If you are working in one such plant, and your PCS is still working correctly, you know that it will one day need to be replaced by a newer system. This is of course, true whatever the PCS system you are using, whether it is ALPSYS or any other technology.

The process control system is the heart of an aluminum plant. Replacing it could be compared to a heart transplantation. A very difficult situation where you need to replace the thing that is keeping your potline alive. This of course raises legitimate concerns and doubts but at one point in the smelter's life, this operation must be done.

In 2004 we replaced the PCS system of the Saint-Jean-de-Maurienne smelter in France. It was one of the first replacement projects on a live potline with ALPSYS and, at that time, the method to do this safely and efficiently was not clearly defined. To do this, we developed a method to smoothly pass from the old system to the new one. This being a success, we have kept applying and improving our method on different technologies including old ALPSYS ones. The goal of this paper is to describe this method.

2. How to Prepare the Change-over of Your Pot Control System?

As previously said, concerns and doubts about replacing your aging PCS by a newer one are perfectly legitimate. If you are considering installing ALPSYS on your potline, you need to ask yourself the following questions.

2.1. What is a Pot Control System?

A pot process control system in an aluminum smelter refers to a computer system that regulates and monitors the operations of all the pots on a potline. The system also supplies important information to the people working on the potline, quickly detecting irregularities, and helping to deal with them. The system plays a crucial role in ensuring efficient and stable pot operations.

The system is generally divided into 3 levels:

- Level 0 corresponds to all physical equipment: sensors, pot controller cabinet (called PCC), safety equipment installed in the potline. Generally, there is one set for each pot (in green in Figure 1).
- Level 1 corresponds to the software and hardware relevant to the process real time acquisition control and command. With ALPSYS, you can have one set per pot or one set for two pots (in blue in Figure 1).
- Level 2 corresponds to the software and hardware relevant to the pot and potline supervision and management application, servers and workstations, networking and communications between the equipment and the software of all systems with which it relates (in red in Figure 1).

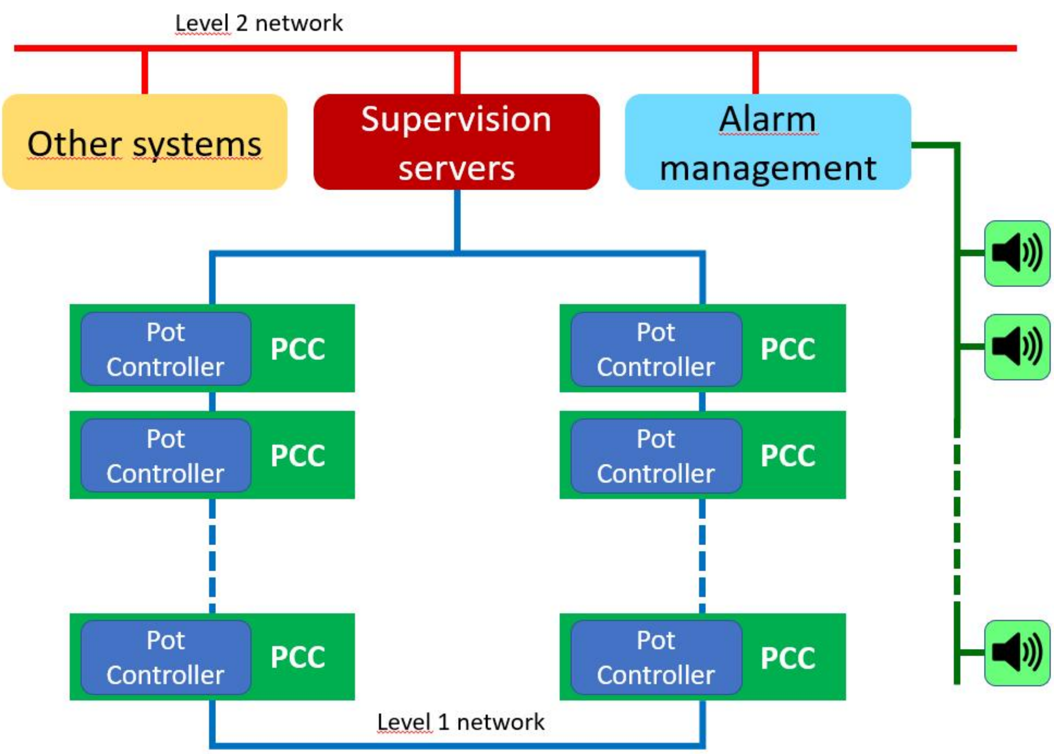

Figure 1. Architecture of a PCS.

2.2. Will the ALPSYS Process Control System Work for my Smelter?

A question you will ask yourself before installing a PCS is whether this new system will operate safely and efficiently on your potline.

If the existing system is an old version of ALPSYS, or an even older version of an Aluminium Pechiney system predating ALPSYS, there is no risk. The newest system runs based on the same principles as the older ones. As many improvements have been made over the years, the new system will run better than any older versions.

If your existing system is not ALPSYS, the answer will depend on your pot technology. If ALPSYS has never operated your pot technology, the risk of the system not performing efficiently is remote. ALPSYS presently operates 6 different pot technologies, 3 of which are non-AP pots. Based on this experience, we can estimate the risk for any pot technology. Then, what we propose is to test ALPSYS in **your** smelter, on **your** potline, on **your** own pots.

The test is done by installing a small-scale temporary PCS system on a few live pots and let the system run the pots for a few days.

Some preparation is needed in advance but mostly limited to:

- Installing a small temporary network between the control room and the test pots.
- Installing a temporary electrical cabinet to host the pot controllers during the test.

An example of a trial set-up is shown in Figure 2, with one pot controller (in the middle) temporarily replacing two existing pots controllers.

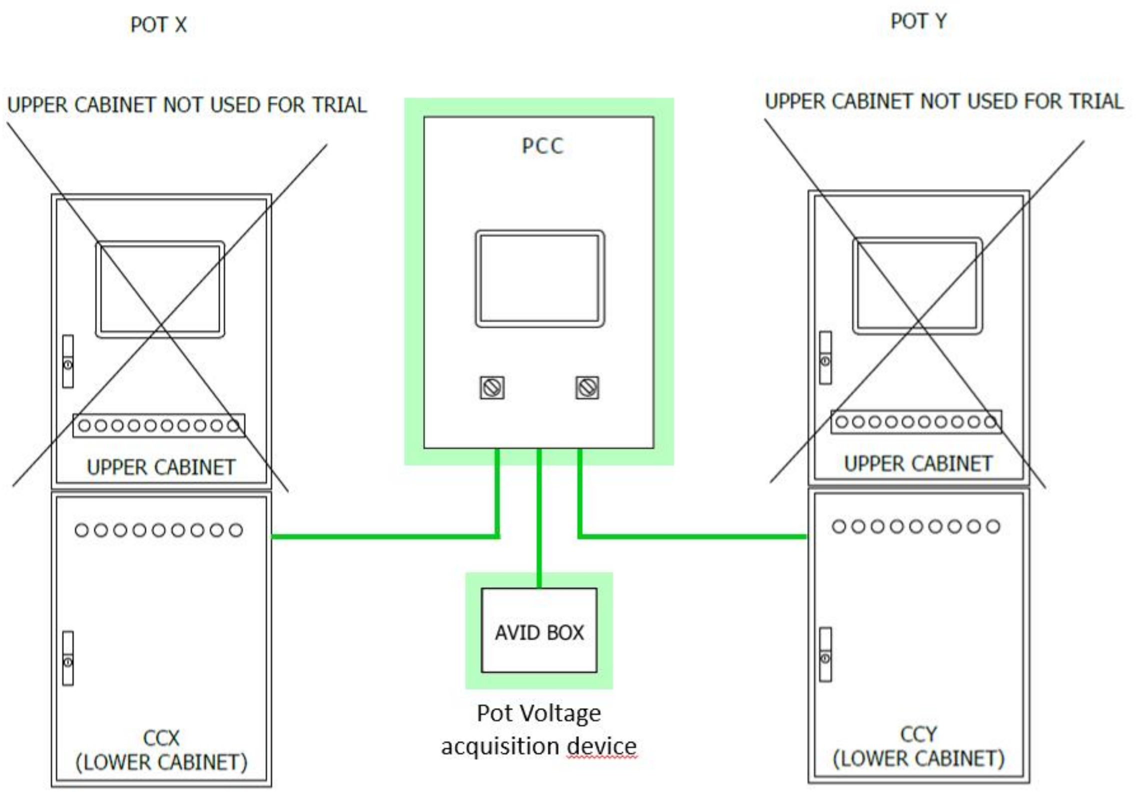

Figure 2. Test equipment set-up - Arrangement of pot control equipment.

This has already been done at three different smelters around the world between 2011 and 2018 on three different non-AP pot technologies. The replacement procedure is now well-established.

Before the test, an engineering study is done to identify the technology differences between the site pot technology and the usual AP technology. These differences are discussed with the smelter to identify what is necessary for the test. All safety related features [1] are of course considered.

The most frequent differences are the number and type of breaking/feeding devices and the number of motors.

- Some pots have 2 coupled breakers/feeders (breaking and feeding simultaneously with only one common command) while others have 6 breakers and 6 feeders independent from each other (so 12 different commands are required).
- AP technology pots have one motor, but some do have 2 motors. They are commanded simultaneously, but a specific monitoring is required to detect and compensate for the inevitable drift of one motor in relation to the other.

All safety related features are of course also considered. They can be divided in two categories: software safety features or hardware related safety features.

Software safety features are protections that work only on the usual acquisitions (pot voltage and line current) and are not relying on any other equipment. Typically, in ALPSYS, software safety features include the following:

- Monitoring of pot cut-out wedges,
- Current and pot voltage acquisition faults,
- Open circuit, line current shutdown and current decrease detection,
- Anode effect detection,
- Successive order monitoring,
- Automatic detection of metal tapping operation,
- Monitoring pot resistance during operations,
- Pot instability detection.

Features already existing in ALPSYS are easy to consider in the test as no change is required for them to work. For features not already available in ALPSYS, changes in the system are required, but they are limited to software modifications.

On the other hand, hardware related safety features are protections that need specific equipment to work. Those are particularly important since they are frequently used to monitor the anode beam movement, so they are a key component for protection against open circuit [1]. Features already included in ALPSYS are typically the following:

- Anode beam power supply monitoring,
- Anode beam contactors fault monitoring,
- Anode beam position monitoring,
- Anode beam heeling.

Most of the time, the existing electrical cabinet differs significantly from ALPSYS standard cabinet. For example:

- Some smelters control the anode beam power supply us a circuit breaker, while others use a contactor.
- Some smelters have a timer relay to stop too long orders, others do not have this option.
- Some smelters are measuring the anode beam position using an encoder, others are using pulse counters, while many do not measure the position, etc.

If a safety feature is present on site and not in ALPSYS, then it needs to be included in ALPSYS. Sometimes a mitigation action can be considered to avoid changing the system, but most of the time mitigation actions are less effective than a PCS feature so our most preferred solution is to integrate it in the test. A few examples of such features that were integrated in ALPSYS for tests in the past are:

- Too long order monitoring using a timer relay:
  - As described in [1], ALPSYS standard is based on a software protection to detect too long orders, and on contactor feedback to detect contactor failure.
- Pot alarm devices
  - One client smelter uses one set of alarm lamps activated by pot controller per pot while ALPSYS uses potline alarm lamps activated through the Level 2 system.

Once all the required features have been identified, they are incorporated in the ALPSYS system and extensively tested before arriving on site. The temporary pot control cabinet is then installed on the potline. The installation work may be done by the smelter personnel or by one of our suppliers. The photo in Figure 3 shows a temporary pot controller installed in a potline.

Figure 3. Temporary pot control cabinet.

Our team of experts then arrives on site. This team includes:

- A process control expert with a long experience of working in potlines,
- An ALPSYS expert with a deep knowledge of the system,
- A software programmer who will be able to immediately correct on site any issue identified.

This team remains on site until the completion of the tests. All the tests done in the past have lasted 1 to 2 weeks, depending on the smelter’s expectations. All the previous tests were successful, demonstrating that ALPSYS can manage any technology.

Once the demonstration has been made that our system is able to manage the pots safely and efficiently, the next question is:

2.3. For the New PCS to Operate my Pots Safely and Efficiently, do I Need to Replace Everything?

This question is to identify what to replace and what to keep of the existing equipment: from the sensors/actuators to the supervision servers.

You can replace all equipment, but this would be long and more expensive than necessary. It is better to keep as much of the existing equipment as possible, thus helping to reduce the duration and cost of the project. It also helps reduce the amount of work to be done on the potline, which will go a long way towards reducing safety risks during construction and at the same time reducing pot disturbances. If managed correctly, pot disturbances can even be eliminated altogether.

Pot sensors and pot actuators are never replaced. They are always maintained in good condition by the plant and do not require being replaced.

Pot control electrical cabinets are replaced only if there is a specific reason to do so. The main reason for replacing them is safety. If the existing cabinet lacks any important safety feature, then a replacement should be considered. If not, then there is no need to replace the cabinet. If there are significant differences with our standard, then we modify the PCS software to accommodate to these changes.

Pot controller replacement will depend strongly on what sort of pot control is in use. If it is an old ALPSYS pot controller it can be kept if it is in good condition. If it is not an old ALPSYS pot micro, then it will need to be replaced. If the pot control equipment is kept, the network equipment will also be kept. It would be too uncertain to replace it for no benefit.

If new pot control equipment is installed, then the network generally needs to be replaced. The old systems are frequently using a serial communication network between the pot controller and the supervision system while up-to-date PCS are using Ethernet communication. The old network is replaced by an optical fiber Ethernet communication network that will allow a much higher data flow. It is also an enabler for future strategic functions like big data or artificial intelligence algorithms. Moreover, it creates an electrical insulation between all the pot control equipment and the servers. Optical fiber being totally impervious to electromagnetic disturbances, it will also increase network reliability.

Finally, supervision servers are replaced as they are most of the time obsolete.

It is a good cost-effective solution to reuse existing equipment, however it should not be at the expense of safety. We regularly recommend changes if they are improving safety. For example, having the pot voltage coming directly to the pot controller is not a safety best practice. We recommend changing this for a remote version that sends the information to the pot controller via optical fiber.

3. How to Change the Pot Control System without Disturbing the Potline?

The installation should always be **performed safely**, **without disturbing the pot performances and without losing a pot.**

A precise preparation of the switch-over by the smelter’s project team, the production team and support team, the supplier’s team and Rio Tinto Aluminium Pechiney ALPSYS experts is key. A good coordination, cooperation, and communication between all is a must for the project to be a success. From experience we have noticed that full commitment from the smelter's team and particularly the reduction department team, is crucial to succeed.

To limit the risks that comes with the challenges and reduce the impact on the installations and the pots, the preparation work must be done jointly. This **preparation is mandatory** and should be done with the **highest quality** to ensure a safe deployment.

3.1. How to Switch a Pot onto the New PCS?

The principle is simple: the less work there is on the potline, the less risk there is during the switch-over. The shorter the switch-over, the less disturbance there is to the pot.

The preparation work aims to minimize switch-over time, thus reducing as much as possible the amount of work to do on the potline.

During all switchover activities, it is very important to minimize the amount of time that a pot will not be monitored and not fed with alumina. A pot cannot be left without a pot control system for more than 5 to 10 minutes. The most efficient way is to do the whole switch-over in a matter of minutes. Here are the two principal ways of doing this.

If the pot controller is to be installed within an existing cabinet, then a "Plug & Play" solution is preferable. The pot controller is packaged in smaller cabinet designed to fit inside the existing cabinet, using the existing cabling. The switch over is then done in a matter of minutes by just replacing the old cabinet by the new one. For example, the switch-over of a pot running with an older version of ALPSYS is done depending on the pot controller generation, in between 2 to 5 minutes. Figures 4 to 7 show an ALPSYS pot controller packaged for plug and play installation.

Figure 4. APM3 rear face.

Figure 5. APM3 front face.

Figure 6. APM3 Packaged for plug & play.

Figure 7. Old equipment.

If the pot controller is to be installed beside the existing cabinets, then it is installed, and the cabling is modified in advance to allow for a quick change from the old to the new system. This also enables the switch-over to be carried out in a matter of minutes. In some specific cases, however, it may not be possible for the switch-over to be carried out as quickly. If the electrical cabinet needs to be replaced, the switch-over can take several hours (for example, 2 hours for the St-Jean-de-Maurienne change-over). Here plug & play is not an option.

One solution is to use a temporary pot control system. A trolley equipped with electrical cabinets and a pot controller is connected to the pot and this equipment will control the pot while all the existing equipment is replaced. At the end of the switch-over, the pot from the trolley is unplugged and plugged back to the newly installed pot controller cabinet. With this method, pot feeding is not interrupted and there are no disturbances to the pot.

3.2. How Can this be Done on the Whole Potline?

The switch-over of a whole potline presents a completely different set of challenges than that of pot switching.

At the beginning, all the pots are managed by the existing pot control system. The target is to have all the pots managed by the new pot control system. To do this a transition phase is necessary, during which some pots are managed by the existing pot control system (the number of pots decreases during switch-over), while the rest of the pots are managed by the new pot control system (the number of pots increases during switch-over).

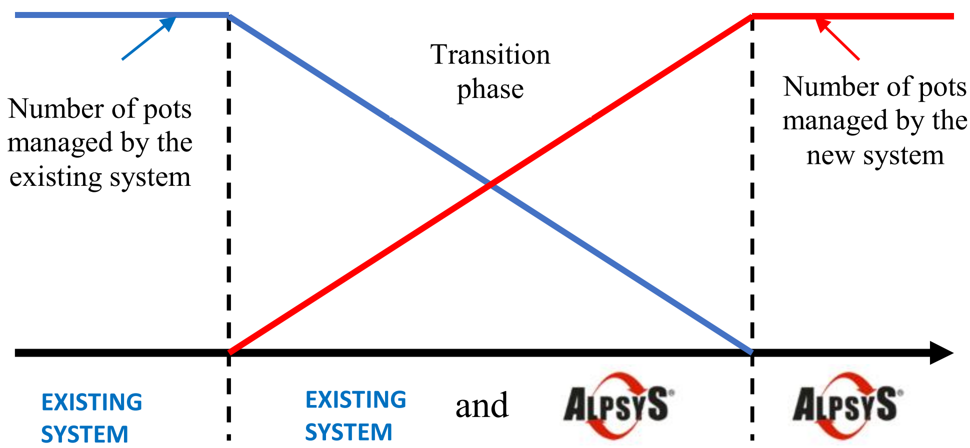

Figure 8. Transition from an existing to a new control system.

The transition phase is one of the main challenges as two pot control systems are managing the same potline at the same time. From a reduction line supervision point of view, this could be compared to managing two potlines. The second biggest challenge is to minimize the disturbances of the potline. To do this, operations and deployment must be organized to ensure maximum separation between intervention zones and operation zones.

As two systems are to be operating at the same time during the transition phase the management of the alarms can become challenging. The biggest risk is missing a dangerous event occurring on the potline that could lead to an eventual disaster. To prevent such a problem, a new PCS alarm box is generally installed in parallel to the existing alarm management system. This ensures that all the alarms will be triggered in the potline regardless of whether the alert comes from the existing system or the new system. A temporary alarm plate connected with the new PCS in the control room will allow the operators to identify from which system the alarm is coming from and react accordingly.

It is important to keep track of which pot is monitored by the existing system and which pot is monitored by ALPSYS. To simplify the identification, we recommend starting at the beginning of the line and switching one pot after another in the direction of the end of the potline, not by groups of pots scattered in the potline (Figure 9).

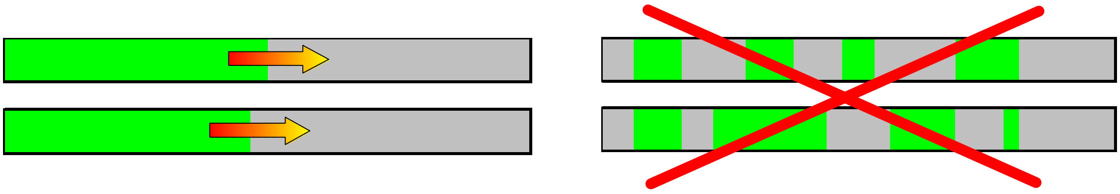

Figure 9. Recommended progression of switch-over in a potline.

Interference with operations needs be considered when elaborating the switching schedule. No metal tapping or anode change can be scheduled on a pot group where a switch over is being performed. This prevents any safety issues or conflicts between installation activities and ongoing operations. This is typically when the active involvement of a reduction representative is key to manage this organization.

3.3. A Fast or Slow Switchover?

The success in the deployment of a new pot control system during a modernisation project is based on a careful balance between duration and risks. The more time taken, the harder the transition phase, while proceeding too quickly will increase the risks.

Before being installed on site, all the equipment and software has been thoroughly tested. These tests, however, have been carried out in a testing environment that inevitably differ from the reality in the pot room, therefore, regardless of the intensity of the tests carried out, a 100% risk free installation cannot be guaranteed. It is for this reason; all changeovers start with a site validation phase.

The PCS is installed on a small group of pots and their performance is monitored. For potlines already running with ALPSYS, the monitoring phase is at least one week, for non ALPSYS potlines the monitoring phase is at least two weeks. This observation period allows to validate that the configuration is working, and the pots are being managed correctly while communication between all systems is running. In short: validate that the installation is giving the expected performances. This also gives the opportunity to perform any last adjustments.

After the test, all the pots are switched on to the new system one after another without stopping. Our record is 60 pots per day for the fastest transition, with the slowest being 8 pots per day. The speed of the changeover depends on the smelter, how comfortable people are with the new system, and how the reduction operations can accommodate the disturbances generated by the transition period.

3.4. What if Something Happens during the Switchover?

Whatever the level of preparation, there is always a chance for the unexpected to happen. A few simple safeguards are used to avoid and deal with any such events:

- Before working on a pot, the pot is overfed. This makes it possible to stop all control for the switchover duration without risk for the pot.

- Spare equipment must be available and ready in the event of a breakdown (pot controller, cables, power supply, etc.).
- A team of electricians from the smelter is available and ready to react.

To deal with more unusual events:

- A team of experts with extensive knowledge in reduction, process control systems and IT are on site to assist during the whole duration of the switch-over. The experts are there to monitor the activity and react to any detected abnormality. They are also available to answer questions and assist the smelter's personnel.
- In case of any significant issue happening, a rollback is always possible. It can be done at any time during the change-over to reinstall old equipment if newly installed equipment is failing, and the problem cannot be solved without avoiding a risk. A precise rollback procedure is prepared and tested. This procedure is to be understood by everyone.

After the installation is finished a warranty period starts. During this time the smelter can raise questions and have any issues corrected. The warranty period is followed by a maintenance contract that will warranty follow-up over time for the smelter.

4. Conclusions

Replacing a pot process control system safely and without disturbing the operations is a challenge that any smelter will face at one point. To successfully meet this challenge, the full commitment of both the provider and the site are paramount throughout the project.

This said, accurately identifying the scope of the project and performing the preparation activities are most important and must be performed with the highest quality standards. Communication is another key factor; with the right people, no action is difficult, the coordination between all the teams is the key to success.

5. References

1. Pierre Marcellin, Antoine Garnier, Protection against open circuit in ALPSYS pot control system, *Proceedings of 39th International ICSOBA Conference Virtual Conference,* 22-24 November, 2021, Paper AL24, *Travaux* 50, 877-888.