New Cell Preheat Shunt Design in EGA Al Taweelah Potline 3

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Abstract

Cell relining, preheat and start-up are required for replacing reduction cells at the end of their life. EGA Al Taweelah Potline 3 has 458 cells operating at 468 kA. Each cell is produces approximately 4.5 tonnes of aluminium per day. A power reduction of 90 minutes is required for each cell start-up. Stopping the production of 457 cell for 90 minutes at each start-up, costs 1 million USD per year. It also impacts the environment by increasing HF emission and operational disturbances. We have developed a system to avoid the production loss and associated problems in the entire plant. We have designed a power bypass system (shunt) for cells at restart to eliminate power reduction of 150 kA and the usage of split-wedge shunts. The new design of the shunt is useful for both EGA plants, at Jabel Ali and Al Taweelah. In Al Taweelah Potline 3, also all early cell failures were re-started using the shunts, to prolong the cell life and to save the cost of building a new cell. This is saving 1 million USD per year.

Keywords: Power reduction at cell start-up, Cell start-up shunts, Reduction of HF emission, Cell life improvement, Cell instability reduction.

1. Introduction

EGA Al Taweelah Potline 3, the world's longest potline with 458 cells was started at 440 kA from September 2013 to June 2014, and is operating at 468 kA now. This potline contributes approximately 20 % of EGA's annual hot metal output. Potline 3 originally utilised Generation 1 cells of DX+ design, which were upgraded to Generation 2 cells in 2018-2019. This upgrade included the implementation of copper-inserted collector bars to optimise energy consumption.

However, in 2021, an unforeseen disturbance necessitated the premature shutdown of certain cells before they reached their full-service life, requiring a mandated restart. Restarting these cells poses significant challenges due to the non-uniform wear of the cathode surface, resulting in graphite islands of varying thickness. Applying the full line load during the restart process risks overloading specific collector bars, potentially leading to their failure.

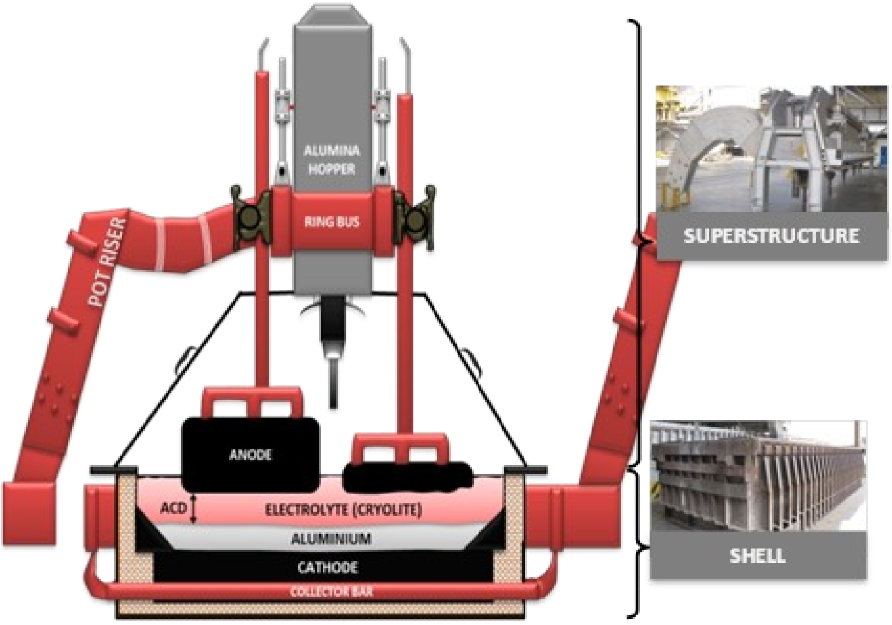

Figure 1. Schematic of a cell and superstructure. The true shape of DX+ pot risers is shown in top right picture.

2. Preheat Process

2.1 Energising a Pot

The primary objective of preheating a cell before bath-up is to increase the cathode surface temperature as close as possible to the operating cell bath temperature. This facilitates a smooth transition from a cold to an operational cell, preventing thermal shock to both the cathodes and anodes, and ensuring the controlled baking of the ramming paste used in cell construction. Additionally, effective cell preheating is crucial for managing the electrical resistance of the cell components and minimising large thermal gradients within the cathode, thereby reducing energy wastage during startup.

A newly lined cell features a flat cathode surface, allowing for a uniform bed of resistor graphite pads during preparation for energisation. In contrast, a restart cell has an uneven cathode surface, resulting in a significant increase in the amount of resistor graphite required. Our observations indicate that the graphite consumption for preparing a restart cell is nearly five times higher than that for a new cell, despite no changes in the graphite island dimensions. Typically, our new cells have a voltage of less than 4 V at cut-in with an average preheat rate of 20 °C.

Figure 2 illustrates the process of laying the resistor graphite pad bed onto the cathode surface of a newly lined cell. The uniform cathode surface ensures that the bed thickness is solely determined by the shape of the wooden panels. The preheat team is trained to verify the quality of the template before laying the pad, ensuring consistent thickness under all anodes. This arrangement guarantees uniform resistance to the current flow from individual anodes through the cathode to the collector bars.

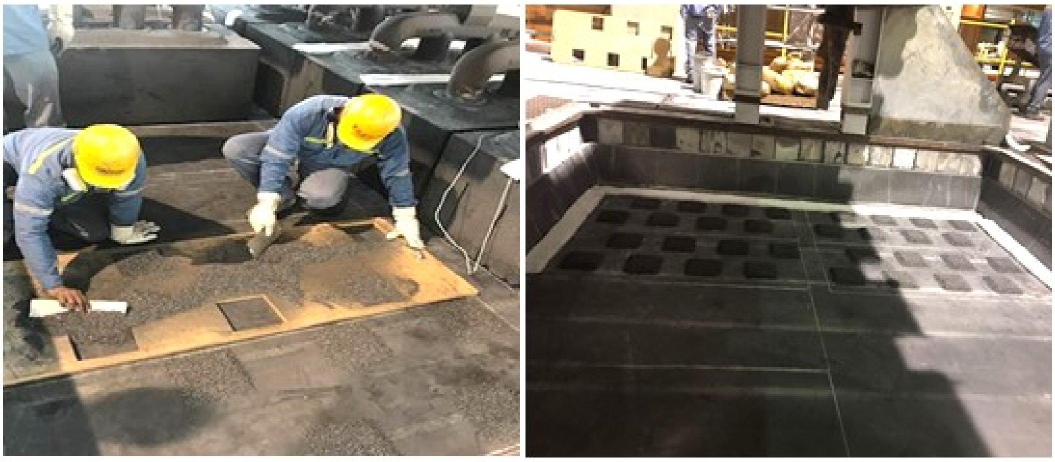

Figure 2. Surface of newly lined cathode and laying of resistor pads.

2.2 Energising a Restart Cell

If a cell fails for any reason before completing its predicted life, the cell lining team will clean the cavity of the failed cell. Based on the inspection of the cathode surface, the preheat team will then restart the cell as recommended.

Figure 3 shows the cathode surface of a cell scheduled for restart. The uneven cathode surface results in a non-uniform bed of graphite pads beneath the anodes, creating areas with varying electrical resistance. During the energisation of restart cells, we observed that some collector bars initially draw more current than others. Over time, the other collector bars begin to draw current as well, but until then, the overloaded collector bars are at high risk of damage.

Figure 3. Cathode surface of a cell to be restarted

At the beginning of our restart processes, we encountered issues with excessive current flow through the restart cell at cut-in. To address this, we implemented the use of split wedge shunts in the wedge slots. However, the removal of wedges from their slots during energisation caused a critical delay between cut-in and the installation of split wedge shunts. This delay was reflected in higher cell voltages at energization, with restart cells typically showing voltages above 4 V at 468 kA.

To achieve lower voltages and reduce the load on lower resistance collector bars at cut-in, we reduced the line amperage by 150 kA. After removing the wedges, we inserted split wedge shunts and gradually increased the line amperage with each shunt installation. Figure 4 illustrates the line amperage and cell voltage behaviour during a typical restart cell cut-in process. The orange line represents the amperage increases corresponding to each pair of split wedge shunt installations. For this cell, it took approximately 65 minutes to normalise the amperage to 468 kA post-energisation, a duration influenced by the ease of split wedge shunt installation. On average, we observed a 90-minute disturbance in amperage, with an average reduction of 150 kA from the target amperage.

Figure 4. Typical behavior of cell voltage and line amperage during a restart energisation.

3. Impact of the Restart Process and Workaround

The approach of reducing amperage to restart cells had significant drawbacks, including production loss from a nearly 90-minute power reduction affecting the entire potline of 458 cells. This amperage reduction caused operational disturbances, halting anode changes and auxiliary activities. After restoring amperage, we observed high instability in many cells, often leading to anode effects due to bath cooling.

Figure 5 illustrates the typical behaviour of a normal cell following amperage restoration after cut-in. The high instability in cell voltage required operator intervention to stabilise, often requiring the pouring of liquid bath. These steps delayed scheduled activities for the operations teams and required additional resources such as bath tapping vehicles and crucibles. Additionally, we had to request our sister potlines to keep liquid bath on standby to assist with topping up cells urgently needing bath.


s for PF POT: 3B019 - AGE: 1264

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1 16:08 End: 17/08/2021 00:08

Figure 5. Typical behavior of a normal cell after amperage restoration.

The loss of heat and reduction in bath height in multiple cells following the amperage reduction led to numerous anode effects. This increased emissions from the potline on the restart day, posing potential long-term environmental risks. Figure 6 shows Anode Effect Frequency (AEF) of Potline-3 for August 2021, during which five cells were restarted with amperage reductions. The impact on AEF sometimes persisted into the second or the third day post-reduction, influenced by the availability of liquid bath and the potline size. Consequently, there was a determined effort to mitigate this issue by avoiding power disturbances during restart cell cut-in.

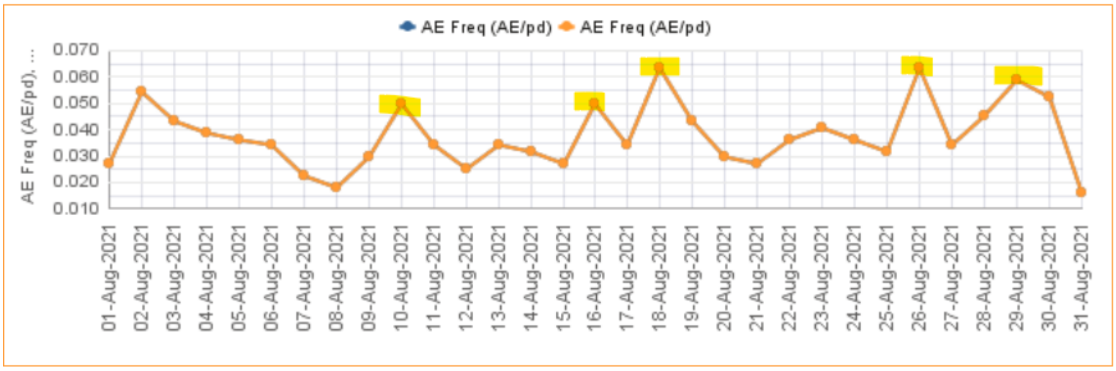


Figure 6. Anode effect frequency (AE/pd) for Aug 2021 when 5 cells were restarted.

4. Designing New Preheat Bypass Shunt for DX+

To avoid amperage disturbances, it was necessary to divert a portion of the line current from the restart cell during energisation. Although this could be achieved using shunts, the existing shunt design required placement in wedge slots, which were occupied by wedges in cut-out cells until energisation. Therefore, we needed shunts that could be positioned on the bus bars, enabling them to bypass part of the current as the wedges were being removed during energisation. Our goal was to bypass at least 150 kA.

We consulted the EGA Technology Development team, who provided a conceptual design for shunts that could be placed on the cathode ring bus. Computer simulations and modelling indicated that these shunts could effectively bypass more than 150 kA. Figure 7 below illustrates the arrangement we invented. Two shunts were placed on a cell to be energised—one at the tap end and the other at the duct end. As depicted in the schematic, the shunt was designed to short circuit the cathode ring bus of two adjacent cells via a higher resistance steel structure, with the downstream cell being the one to be energised. These shunts were fabricated in-house and subjected to trials.

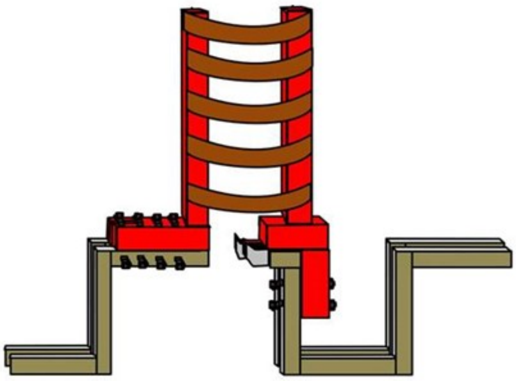
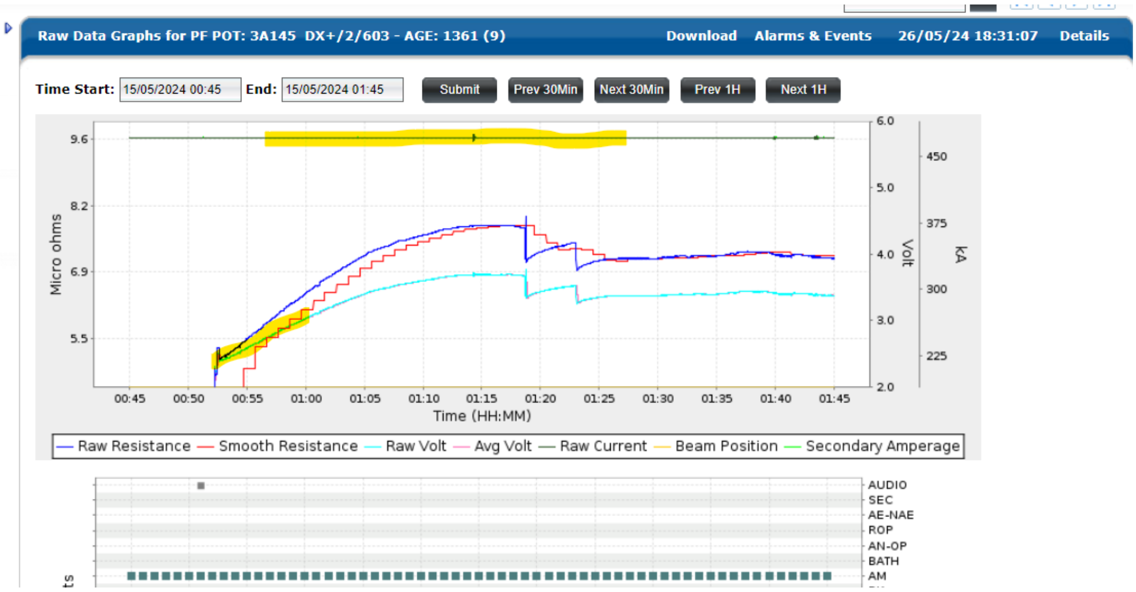


Figure 7. Shunt design and picture showing an installed shunt at the tap side of a cell.

Figure 8 illustrates the behaviour of cell voltage and amperage for a cell energised with the shunts placed as described above. Notably, the green line representing the line amperage remains steady, and the cell voltage at cut-in reached a maximum of 3.8 V.



Raw Data Graphs for PF POT: 3A145 DX+/2/603 - AGE: 1361 (9)

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Figure 8. Behaviour of cell voltage and line amperage at cut-in with shunts in place.

With the introduction of these devices, Al Taweelah Potline 3 successfully restarted 76 cells without causing any disturbances to the other operating cells or overall operations. This advancement also enhanced the safety of operators working around the restart cells by eliminating the need for numerous compressed air pipes previously used to control the heating of collector bars. As the cell voltage gradually decreases, we sequentially disengage individual shunt leaves, allowing us to achieve our target preheat parameters before bath pouring.

Additionally, we have observed a reduction in HF emissions following the implementation of this tool for restart cell cut-ins. Table 1 presents the data related to this improvement.

Table1. Results related to HF emissions before and after introducing shunt carrier.

Details of pot cut-in without Shunt Carrier		
Pot No	Cut in Date	mg/Nm^3
3B/061	4-Jul-2020	0.269
3B/053	31-Aug-2020	0.257
3A/185	7-Sep-2020	0.16
3B/058	9-Jun-2021	0.295
Details of pot cut-in with Shunt Carrier		
3B/067	15-Oct-2021	0.217
3B/070	15-Nov-2021	0.152
3A/152	14-Dec-2021	0.185
3B/056	5-Jan-2022	0.219
3A/176	24-Jan-2022	0.25

5. Conclusions

It was possible for Al Taweelah Potline 3 to restart 76 cells, which had been prematurely cut out, with the use of the shunts. The process of energisation and preheating of a restart cell with Cu inserts in collector bars is very different from the same for newly lined cells. This initiative not only improved the process efficiency, but also resulted in other EHS improvements and plant security with tangible financial benefit.