

# A Bypass Bridge Design for the Installation of Additional Cells in an Operating Potline

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## Abstract

To add extra cells in an operating potline represents a considerable engineering challenge, for it involves, apart from the installation of the new pots themselves, modifications to the existing conductors as well as tying the new cells to the gas treatment centre. The complexity of such a task is further increased if the selected location for the installation of the new pots lies in the middle of a potroom, involving replacement of an existing set of passageway linkage busbars. Given that existing operational cells cannot be stopped for the duration of the construction work, the usage of a bypass bridge is required. This article describes the joint efforts of an integrated EGA-HATCH-SNC team to increase the metal production of DUBAL Potline 8 by installing two additional reduction cells in the short passageway of each of the two potrooms while operating at full potline current. This was achieved using a dedicated bypass bridge, sized to carry 400 kA and connected to existing pot-to-pot circuits strictly by means of bolted busbar connections. Finally, the commissioning and performance of said bypass bridge is discussed.

**Keywords:** Aluminium electrolysis cells; brownfield potline expansion; bypass busbar bridge; bolted aluminium busbar connections; installation and performance of bypass busbar bridge.

## 1. Introduction

Dubai Aluminium (“DUBAL”, also known as “Jebel Ali Operations”) (Figure 1), an operating subsidiary of Emirates Global Aluminium (“EGA”) in Jebel Ali, Dubai, currently has 1 577 cells and a total production of more than one million tonnes of aluminium per year.



Figure 1. Aerial view of the DUBAL smelter in Jebel Ali, Dubai.

DUBAL has been involved in technology development for more than 25 years. Its Technology Development & Transfer Department (“TD&T”) has in-house capabilities in cell modeling, design and engineering which over the years have birthed different families of pots including the former P69 Kaiser cells converted to D18 and D18+; CD20, D20; and, more recently, DX, DX+ and DX+ Ultra. The focus of technology development at EGA has constantly been on improving productivity, reducing energy consumption and improving environmental performance, while reducing capital cost.

Following the successful implementation and more than seven years of operation of EGA’s proprietary DX Technology in the DUBAL smelter, EGA management decided to increase the smelter throughput by installing additional reduction cells at minimum cost. DUBAL Potline 8 was selected for the following reasons:

- Its passageways were originally designed in such a way that two extra cells could be added per potroom, for a total of four additional extra pots.
- All required building and infrastructure facilities were already in place to house the new cells.
- It presented the opportunity to implement and test new design features in DX cells, which could be later adopted by EMAL, whose Potlines 1 and 2 operate 756 of those pots.
- Potline 8’s proximity to TD&D makes it easy to conduct in-situ validation measurements and other commissioning-related tasks.

## 2. Options for Existing Potline’s Extension

To add extra cells in an operating potline represents a considerable engineering challenge, for it involves, apart from the installation of the new pots themselves, modifications to the existing conductors, as well as tying the new pots to the gas treatment centre. One potential strategy, most often used to accomplish such a task, is to increase the length of the pot rows by adding new cells at the end of the potrooms near the existing crossover (as shown in Figure 2). This requires moving the existing crossover (yellow) further away (green) to make room for the new pots (green).

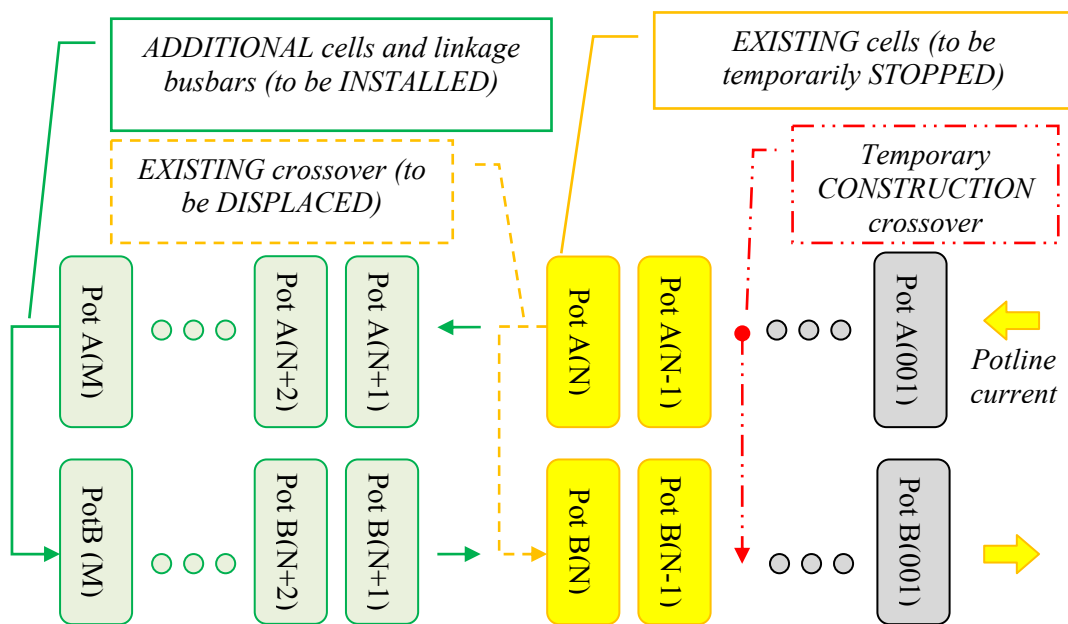


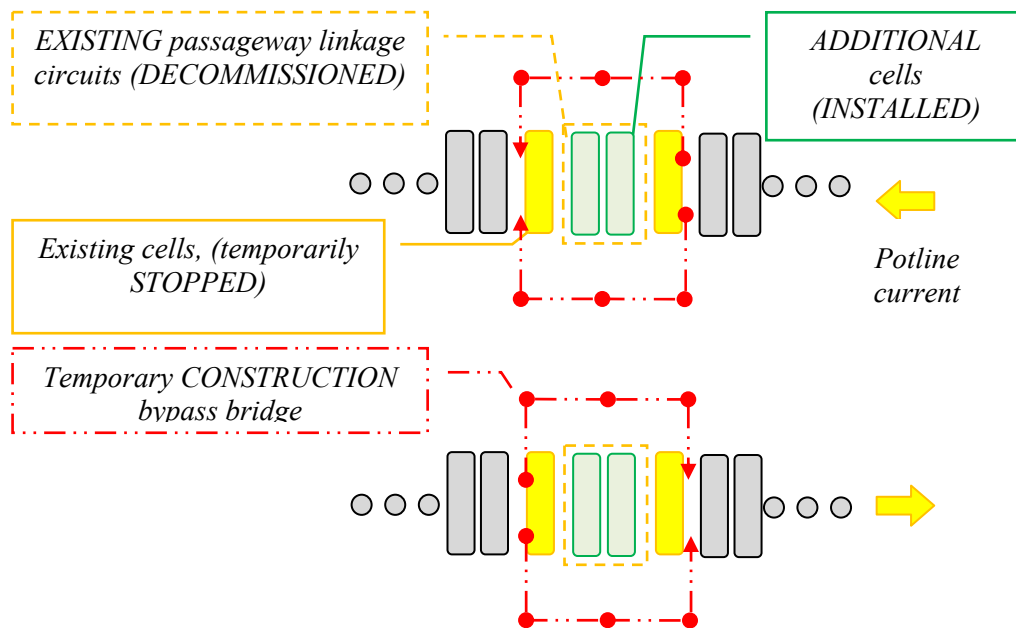
Figure 2. Increase of installed capacity by means of adding new cells at the end of the potrooms.

In this scenario, a fraction of the construction effort may be accomplished with the potline operating at full capacity in a greenfield environment. The installation of the new pieces of equipment closer to the existing facilities, however, often requires the stoppage of a given number of pots and the usage of a temporary construction crossover. It is important to note that, depending on the construction planning, the existing crossover busbars may be kept functional for some time as a risk mitigation strategy, should the temporary construction circuit fail.

Unlike the above strategy, the production increase programme in DUBAL Potline 8 was achieved by installing the new cells in replacement of two existing sets of passageway linkage busbars, thus requiring execution of the following associated actions:

- Dismantling the existing passageways linkage busbars.
- Modifying the existing cathode busbars from cells located both upstream (US) and downstream (DS) of said passageways.
- Installing new pot and busbar supports.
- Installing the new cells as well as their connection to both Gas Treatment Centre (“GTC”) and pot feed system.

Furthermore, to ensure continued operation of the existing DUBAL Potline 8 cells, a dedicated 402 kA bypass bridge had to be designed and installed in place of the aforementioned passageway circuits (see Figure 3) for the duration of the works, executed in two distinct phases (one per potroom). To facilitate construction and interfacing between the new and existing cells, as well as the construction of the bypass bridge, one existing cell at each end of the passageways was stopped.



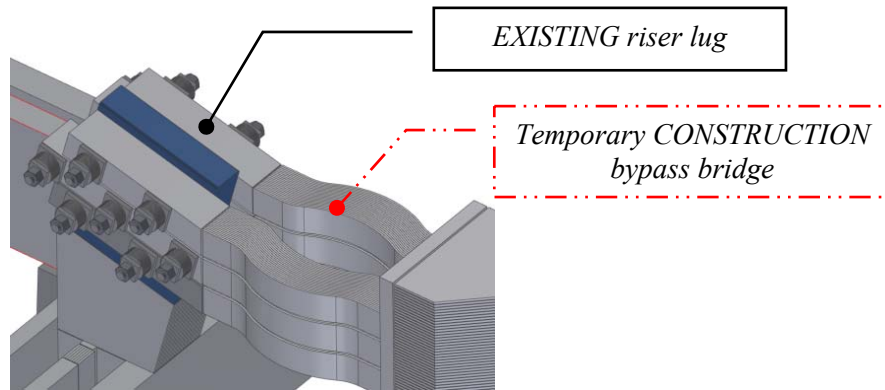
**Figure 3. Additional DX cells installed in replacement of two existing sets of passageway linkage busbars.**

### 3. Bypass Bridge Design

The dedicated bypass bridge which enabled the installation of the four additional DX cells in DUBAL Potline 8 is sized to carry the full nominal potline amperage (402 kA) for a temperature rise of approximately  $\Delta T_{bridge} \approx 75$  °C above ambient temperature, corresponding to a busbar

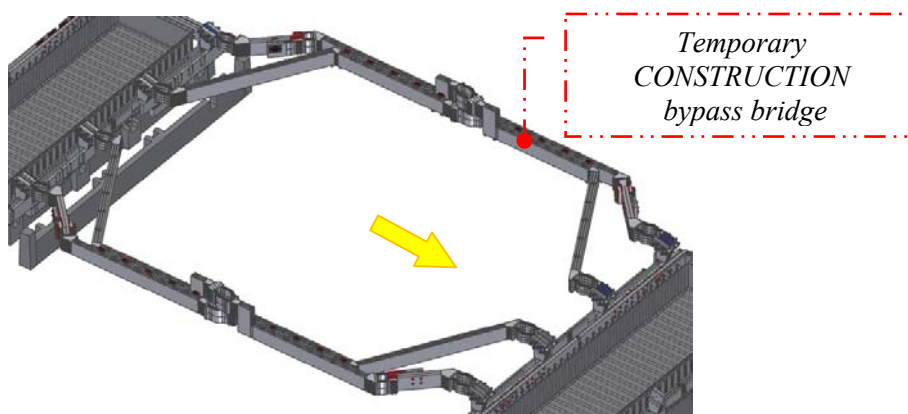
current density of approximately  $J_{bridge} \approx 664 \text{ kA/m}^2$ . The fundamental design philosophies behind the construction bridge are briefly described below:

- Ease of assembly: While complex segments were to be prefabricated in shop, only bolted connections were to be assembled on site, including tie-in to existing pot-to-pot circuits. To take advantage of proven designs, while minimizing the intervention to the pots to be kept in operation, the bypass bridge was tied-in to the existing bolted connections of the anode risers as shown in Figure 4.



**Figure 4. Bypass bridge-to-existing riser lug bolted connection.**

- Bolted joints: The quality of electrical bolted connections is highly dependent, among other things, on both contact surfaces' preparation and contact pressure. The construction bridge bolted joints were designed to meet the following criteria:
  - Keep appropriate contact pressure during both in- and off-duty conditions. Note that best design practices [1] recommend a nominal (tightening) contact pressure between 6 MPa and 8 MPa in a bolted joint.
  - Keep the tie-rods within the elastic domain at all times.
  - Provide a maximum contact resistance of  $R_{contact} \leq R_{contact,target} = 0.03 \mu\Omega\text{m}^2$ , while considering maximum contact current density of  $J_{contact} \leq 300 \text{ kA/m}^2$  thus, yielding a target contact voltage drop of  $\Delta V_{contact} \leq 9 \text{ mV}$ .
- Impact on existing pot-to-pot current distribution: To keep the design current distribution between anode risers in normal operation throughout the construction work, the construction bridge was designed to have four parallel branches of equal resistance, as shown in Figure 5.

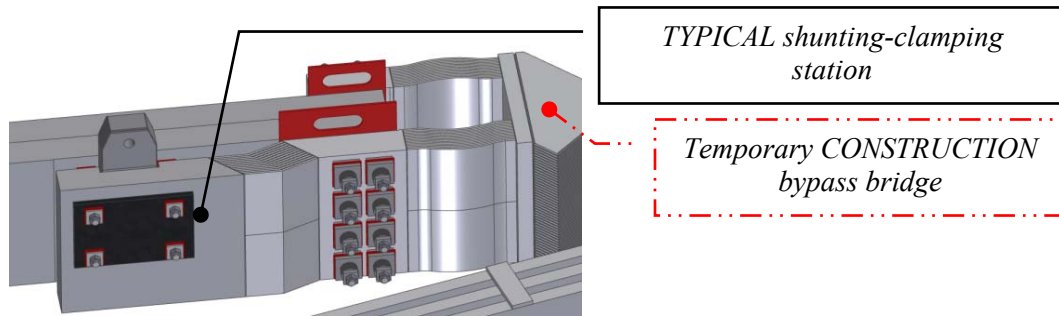


**Figure 5. Construction bridge was designed to keep design current distribution between anode risers.**

- Construction in a brownfield environment: The existing passageways' basement and adjacent areas were expected to become quite congested as a direct result of the works. So

as not to hinder the progress of the construction (and dismantling) effort, the bypass bridge was installed at the level of the potroom floor. The aim of this was to enable the movement of material to and from the construction site at both the basement level and through the opening left by the removal of the existing concrete slabs. It also allowed the prefabricated segments of the construction bridge to be manipulated by means of an overhead crane.

- *Impact on potline operations*: To cut the construction bridge in and out without potline shutdowns, its design included typical shunting-clamping stations, shown in Figure 6. Appropriate electrical insulating components were added to allow for proper separation of electrical potentials during both the assembling and disassembling phases.



**Figure 6. Typical shunting-clamping stations were included in the dedicated bypass bridge design.**

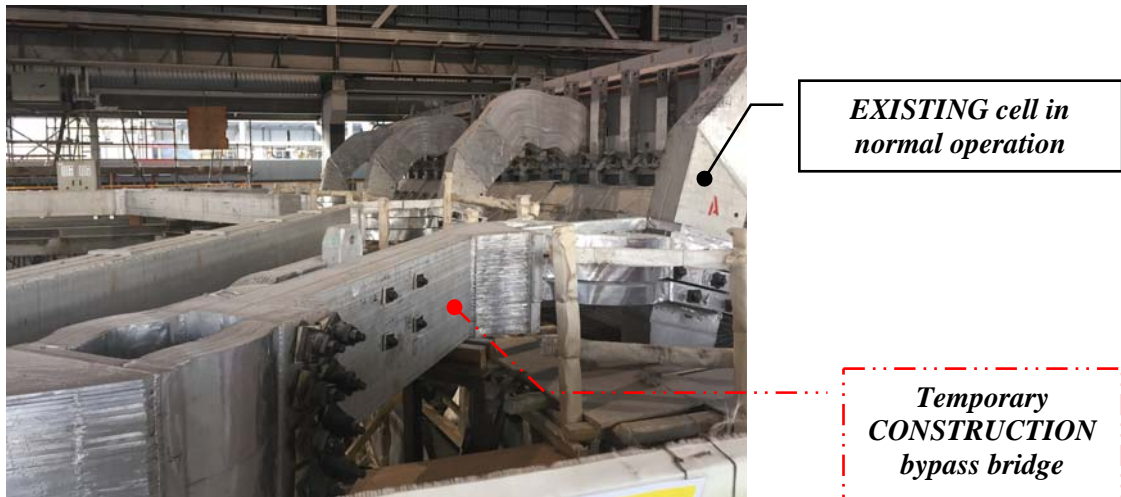
#### **4. Project Implementation**

Key factors enabling the project's overall success comprised, among others, well-planned design, forecast and careful management of health and safety ("H&S") challenges of the construction and implementation phases. Engineering work started in the fourth quarter of 2014 with the design of the construction bridge itself, as well as the required modifications to the cathode conductors of existing cells on each side of the existing short passageway linkage conductors.

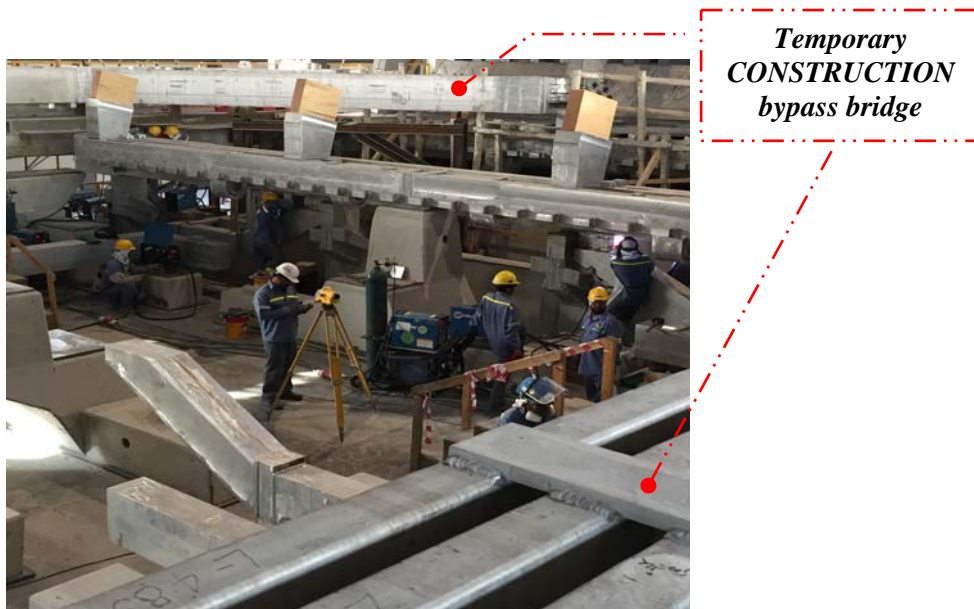
The construction phase begun in August 2015 by cutting the concrete slab of the first passageway in the first potroom, followed by both the installation and commissioning of the dedicated bypass bridge, as depicted in Figure 7. Note that the bolted joints had their contact surfaces prepared and bolts tightened according to a specific procedure. Furthermore, it is important to stress that neither electrical joint compounds nor seam (also known as "Z") welds were employed.

The existing passageway linkage conductors and their supports were then dismantled so as to make room for the new supports to be further installed. Next, the existing cathode busbars from cells located at both upstream and downstream of the passageway conductors were modified. Last, the new pot-to-pot circuits were installed (see Figure 8).

After installing the new potshells, bypass wedges were installed in all shunting-clamping stations and the recently added pot-to-pot cathode circuits were put into service for the first time. The construction bridge was therefore disassembled and transferred to the second potroom, where the above-described procedure was repeated once more. The construction was finally concluded in September 2015, when the last additional cell was started.



**Figure 7. Tie-in of dedicated bypass bridge to existing downstream cell.**



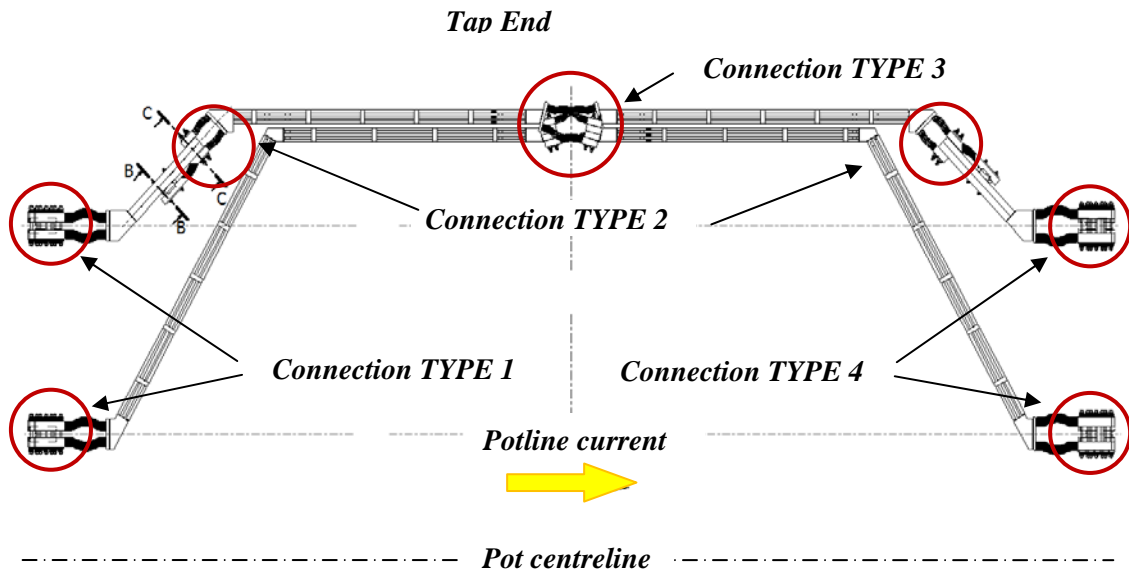
**Figure 8. Installation of new busbars and supports.**

#### 4.1. Management of electrical potentials and related safety during construction

The electrical potential of the working site with respect to earth was between 150 V and 250 V in the two construction areas during normal pot operation. As per DUBAL standard practice, the potential to earth was decreased to zero on the construction site by connecting the Mobile Earthing Trolley (“MET”) to the busbar at the construction site. By design, DUBAL Potline 8 has an earth grid with earthing stations installed in the basement every few columns apart. It was therefore easy to connect the construction site busbar to the nearest earthing station. This made the construction site secure for the workers and the equipment. The standard personal protection equipment (“PPE”) required for work in the potrooms was strictly adhered to. Project-specific work procedures were also developed. It is important to stress that no safety incident was recorded throughout the construction.

## 5. Commissioning and Performance of the Bypass Bridge

Figure 9 illustrates all bolted connection types that were considered during the dedicated bypass bridge design process. The same naming convention was kept to ease the identification of each joint for validation and performance monitoring.

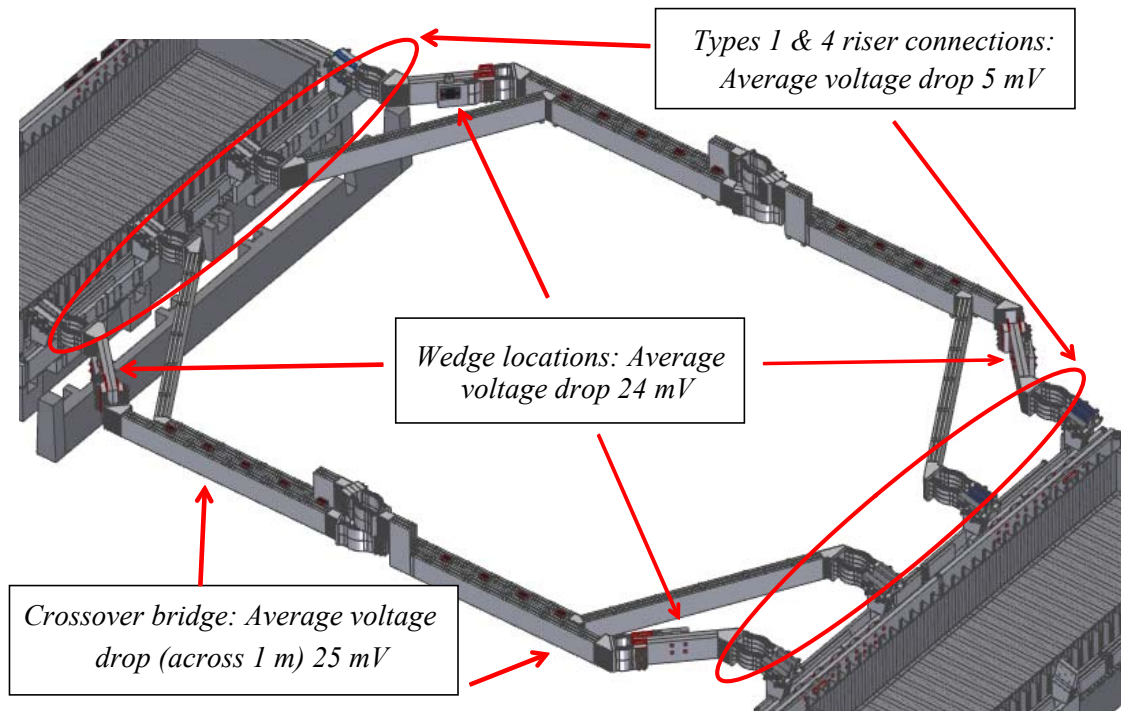


**Figure 9. Typical half of the bypass bridge indicating bolted connections. The design is symmetrical with respect to cell short axis.**

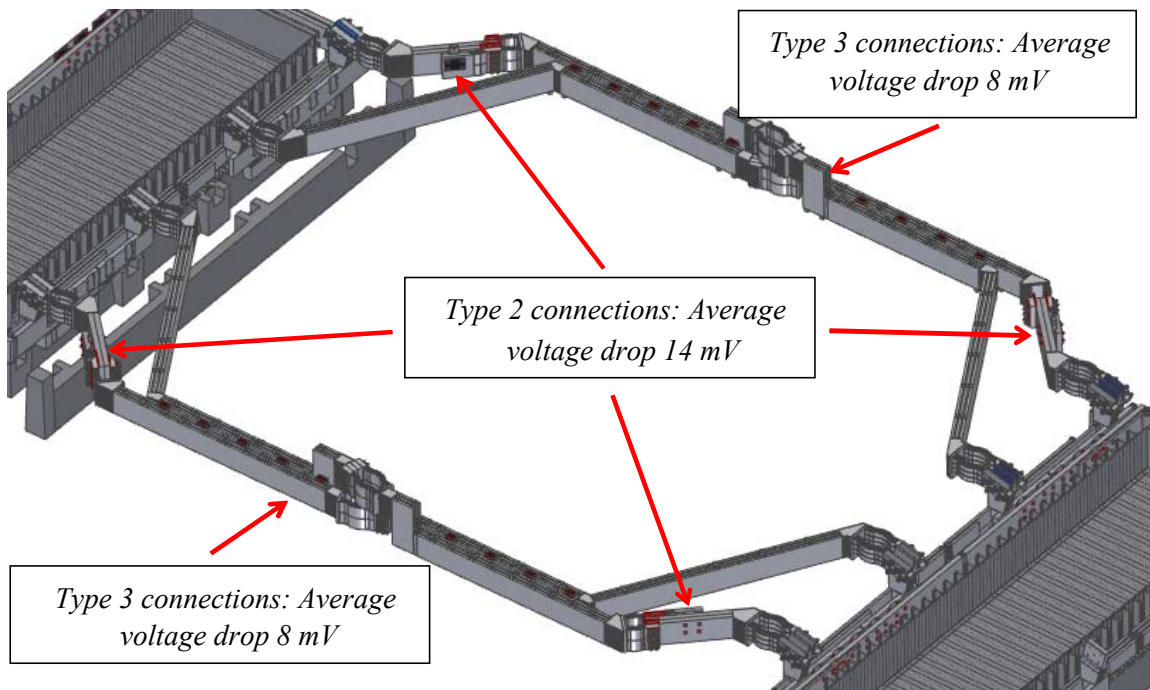
The integrated project team identified four distinct indicators to assess the continuous performance of the bypass bridge:

- **Good quality:** A bolted joint that operates within the specified design parameters, *i.e.*,  $R_{contact} \leq R_{contact,target} = 0.03 \mu\Omega m^2$ ;
- **Acceptable limit:** A bolted joint that behaves adequately although it presents a contact resistance up to twice as large as the target figure (*i.e.*,  $R_{contact} \leq 2R_{contact,target}$ ). It is usually associated with mildly oxidized or poorly prepared contact surfaces;
- **Follow-up:** A bolted joint that shows elevated contact resistance ( $2R_{contact,target} < R_{contact} \leq 4R_{contact,target}$ ) and requires close monitoring. It indicates a joint that might be experiencing a process of continuous degradation;
- **Intervention threshold:** A bolted joint of unacceptable quality (*i.e.*,  $R_{contact} > 4R_{contact,target}$ ) thus, requiring maintenance. Such a bolted joint must be opened and have its contact surfaces cleaned and prepared prior to retightening.

Figure 10 and Figure 11 show the performance of the dedicated bypass bridge, assessed by means of regular voltage drop measurements. Connections of types 1, 3 and 4 proved to be “good quality” joints while those of type 2 remained consistently within the “acceptable limit”. It is interesting to note that the type 2 joints were kept “opened” by means of electrical insulating plates (refer to Figure 6) until the temporary construction bridge was finally put into service, which most likely led to the formation of a mild layer of aluminum oxide on their contact surfaces. Finally, the bypass bridge shunting-clamping stations showed acceptable voltage drop readings, in line with expectations.



**Figure 10. Temporary construction bridge performance at 402 kA - typical shunting-clamping stations and bolted connection types 1 and 4.**



**Figure 11. Temporary construction bridge performance at 402 kA - bolted connection types 2 and 3.**

The installation of the bypass bridge was carried out in segments as per design, to allow better installation flexibility, control and handling in a busy, brownfield operational area. The installation, commissioning and validation of the bypass bridge took seven working days, while its disassembly and removal took two working days.

DUBAL Potline 8 operated at full current (402 kA) throughout the construction, without resorting to shutdowns. This was achieved by the inclusion of typical shunting-clamping stations to the bypass bridge design (see Figure 6), which reduced production losses and ensured the safety of the workers. The installation and coordination work of the bypass bridge was successfully executed without any incident, in spite of operational challenges of having live cells in operation nearby.

## **6. Conclusions**

The construction of four new cells in DUBAL Potline 8 was carried out while the line operated at full potline current. The temporary construction bridge allowed all construction work to proceed smoothly without interference to the potline operations. It also allowed welding of the new busbars without potline shutdowns. MET was used to provide a safe working environment and there were no safety incidents from the start to the end of the project. The bypass bridge was dismantled when the busbars of the pots in a section were in place to enable short-circuiting with regular wedges until the start-up of the stopped pots.

## **7. Reference**

1. *Aluminum Electrical Conductor Handbook*, Third edition, The Aluminum Association, 1989, page 13-41.