

## New Connections for Cathode Flexibles in Aluminium Electrolysis Cells

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### Abstract

Cathode flexibles are one of the key components in aluminium electrolysis cells design as they provide the continuity of electrical current path from cathode of the cell to the busbar. An efficient cathode flexible design should provide long service life and enable fast cell turnaround time and thereby minimize the plant production losses. Over the last 35 years at Emirates Global Aluminium, the duty of cathode flexibles has become harder due to large amperage increase, which has increased temperature, voltage drop and copper corrosion. To address these issues, a new cathode flexible design has been put in place in EGA cell technologies. Contrary to the traditional cathode flexible design, where the flexibles are welded on cathode busbars and bolted on the cathode collector bars, the newly developed flexibles are welded at the end of the collector bars and bolted at the cathode busbar. This shifts the bolted contact surfaces to a much cooler region, gives easier access for the bolting and allows welding of the flexibles to the collector bars to be done outside of the potroom. In this paper, design, modelling, experimental evaluation and long term operational performance of newly developed connections for cathode flexibles across EGA cell technologies are presented.

Keywords: Cathode flexible design and modelling, bolted joint voltage drop, measurement of cathode flexible voltage drops, copper tab corrosion.

### 1. Introduction

In Hall-Héroult industrial reduction cells, the DC electrical current is fed into the anodic busbar which flows to the anode beam, to the anode rod, to the carbon anode block and through the liquid electrolyte. Thereafter it crosses the liquid metal pad and eventually is collected at the cathode blocks. Each cathode block is equipped with one or two collector bars, aligned along the length of the cathode blocks, usually made of steel, which are connected to the cathode busbar through flexible connections made of aluminium. Each such flexible connection extends between the end of the cathode collector bar and the upstream (US) and downstream (DS) cathode busbars as shown in Figure 1. It is connected to the cathode busbar on one end and to the cathode collector bar on other end either by bolting or by welding. The DC current collected by the cathode busbar is then fed into the anode busbar of the adjacent downstream reduction cell through anode risers from one cell to another in the same way.

The main aim of this publication is to present the historical background and performance overview of conventional, as well as, new generation cathode flexible connections used across EGA cell technologies. The other aim is to highlight the way flexible connections are mounted

on the cathode collector bars, as well as, on the cathode busbars. Mechanical flexibility is required in these connection members, for practical reasons, as it facilitates their handling and mounting, and avoids mechanical tension due to thermal expansion. Furthermore, the connection of the cathode collector bar to the cathode busbar should be of excellent electrical quality and reliability. In particular, it should not lead to a significant voltage drop, should not be subjected to excessive corrosion, and more generally it should not degrade over time.

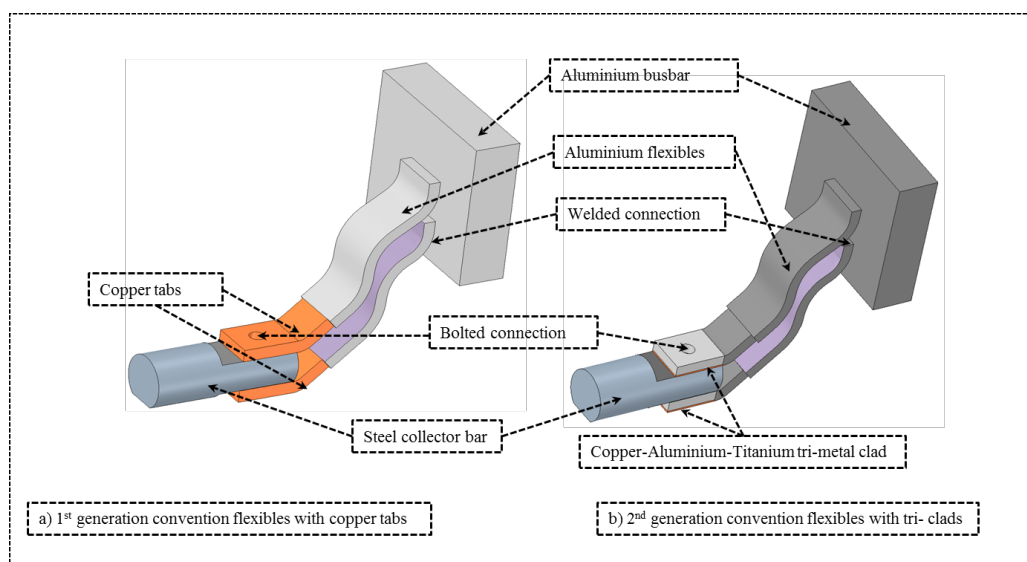
## 2. Conventional Cathode Flexibles Used in EGA Cells

In the sections 2.1 to 2.3 below, the overview of the conventional bolted cathode flexible connections used across EGA cell technologies is described. The following aspects are discussed in detail;

- Historical overview and design concept
- Performance evaluation
- Pot cut-out statistics linked to the failures in flexible connections

### 2.1. Historical Overview and Design Concept

The conventional cathode flexibles with copper tabs have been installed in various cell technologies ever since EGA began its operations in 1979. In these flexible connections, a number of thin aluminium sheets are grouped together and then welded to the copper tabs. The copper tabs are then bolted to the steel collector bar on one side. The other end of the aluminium flexibles are permanently welded to the cathode busbar. Each end of the collector bar has two sets of flexible connections wherein one copper tab is bolted on the top face of the collector bar and the other tab is bolted on the bottom face of the collector bar. The collector bar faces, which are bolted to the copper tabs, are machined with high quality surface finish to achieve excellent surface contact between the two contacting surfaces.



**Figure 1. Conventional cathode flexibles: a) with copper tabs b) with tri clads.**

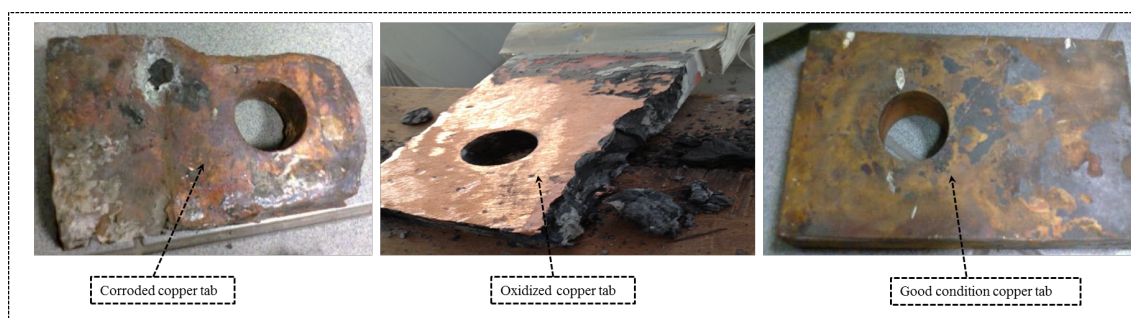
Figure 1 shows a 3D Inventor geometrical model of the first generation cathode flexibles with copper tabs and more recently modified second generation conventional flexibles with tri-metallic clads. During pot turnaround, the copper tabs are unbolted from the collector bar ends. The flexibles, along with the copper tabs, are left in the potroom as they are permanently welded onto the cathode busbars. The quality of the bolted contacts is controlled with the periodic measurements of the combined voltage drop. The combined voltage drop at EGA is measured

between top of the cathode block (liquid metal) and a fixed location in the anode busbar for the selected cell. Cells showing high combined voltage drops (HCD) are then analyzed in more details by subtracting the cathode voltage drop from the combined drop. The individual contact voltage drops or full cathode flexible voltage drops are then derived from the resulting combined voltage drops. Only the contacts with voltage drops above a specified upper limit are re-tightened.

## 2.2. Performance Evaluation

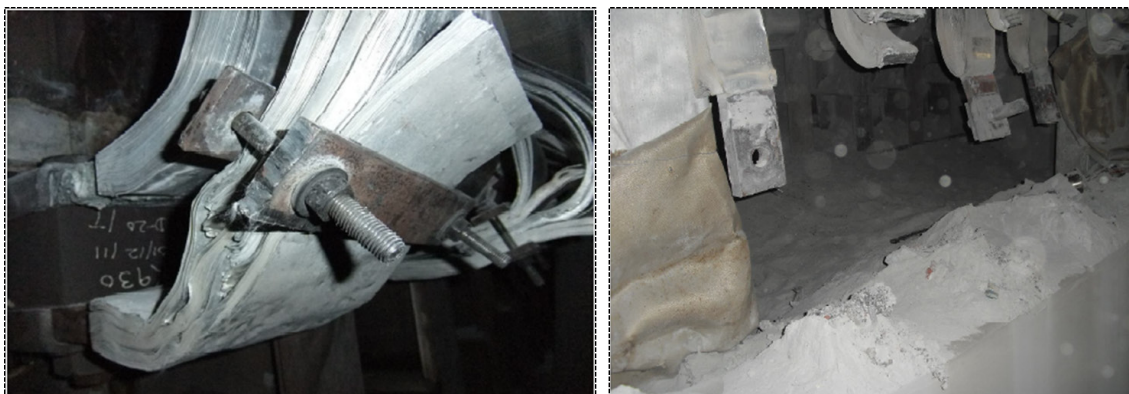
Since EGA began its operations in its Jebel Ali smelter, the conventional flexible and copper tabs have been the usual choice for all cell technologies installed across EGA, whether they need to be installed with the new cells or to replace the old and damaged flexibles. From the beginning, EGA's operations team management has increased cell amperage to increase metal production whilst leaving cell size the same. The increase in cell amperage has increased the collector bar and cathode flexible current densities on one hand and added larger heat generation (in the cell) on the other hand. This has resulted in more Joule heat generation in the cathode flexibles and additionally more heat had to be lost from the potshells to the potroom. All these factors combined have increased the outside collector bar and cathode flexible temperature by 100 - 150 °C. Additionally loose materials, such as alumina and crushed bath, accumulate continuously on collector bar and cathode flexibles, due to the operational work practices, and form an additional layer of thermal insulation, leading to further increase in the temperature.

Higher temperature, coupled with the high air humidity, are one of the most important factors that can trigger the air oxidation and corrosion of the copper tabs. Due to severe air oxidation and corrosion of the copper tabs, the contact surface area between the tab and the collector bar is significantly reduced. This increases the electrical contact resistance, in and around contact surfaces, and an increase in current density locally, which again, result in increasing flexible contact voltage drop and tab temperature. Ultimately this leads to uneven current distribution in the collector bars. All these factors combined are believed to weaken the mechanical integrity and long term performance of the flexibles and therefore increase the frequency of tab replacement, resulting in an escalation of tab replacement cost. Figure 2 shows the surface condition of few copper tabs due to air oxidation and severe corrosion as compared to the tab with good condition.



**Figure 2. Copper tabs showing severe corrosion, air oxidation and good condition.**

Due to the repair work difficulties and other practical work challenges, many of these flexibles and tabs have to be kept in the cell as long as possible. Figure 3 shows the damaged cathode flexibles and highlights the complexity of the repair work associated with the conventional flexible connections. The copper tabs in these flexibles have considerable amount of mass per tab and copper being relatively costly further makes them an expensive design component, especially when the copper tabs need to be replaced frequently.



**Figure 3. Damaged aluminium flexibles of generation 1 design.**

The major disadvantage of these flexible designs is that in case of damaged flexibles in an operational cell, the repair work has to be done onsite. Any onsite welding activity close to a potshell and surrounding cathode busbars is both uncomfortable and unreliable and it is therefore desirable to minimize routine welding operations in such an environment for several reasons. First of all, space between two neighboring pots is very limited, forcing the welder to work in a rather constrained environment. Any kind of prolonged precision work at a distance of less than one meter from an operating reduction pot is uncomfortable. As a consequence, the efficiency of the welder and the quality of the weld may be decreased when the welding operations are carried out onsite. Furthermore, magnetic fields will interfere with the welding equipment and welding arc, thus making a reproducible welding quality difficult to achieve. Indeed, it is observed that welding seams produced under these conditions are usually not very good, especially those for the first three or four end cathode collector bars in a pot, where the magnetic field is strongest. Welding seams of poor quality may lead to an additional voltage drop and a non-uniform collector bar current distribution which decreases the energy efficiency of the reduction cell. Safety is an issue too. Because neighboring pots and their busbars are energized, electrical shock hazard exists. Finally onsite connection repair contribute to increasing pot turnaround time which will eventually lead to the loss of the metal production and overall productivity of the smelter.

### **2.3. Pot Cut-out Statistics Linked to the Failures in Flexible Connections**

Figure 4 to Figure 6 show pot cut-out statistics at EGA's Jebel Ali site due to high combined voltage drops (HCD). The high external voltage drops derived from the measured combined voltage drops are indicative of damaged cathode flexible connections, since the other voltage drop components within the external voltage drop such as busbar voltage drop and riser drops etc. do not vary much. This type of failure was almost non-existent in EGA pre 2014 and reached its peak cut-out rate in 2015 at 13 % of all plant cut-outs as shown in Figure 4. Since repair work on these damaged flexibles was not practically feasible due the reasons explained in Section 2.2 above, the only way to keep the cell in operation was to increase the cell resistance set point until the pot naturally failed. However the plant could not wait for typical signs of failure linked to collector bar iron attack and was therefore forced in this case to cut-out pots due to the high combined voltage drop, thereby mitigating the safety and efficiency risks of running these pots any longer.

Therefore, in addition to all the issues described in previous sections, a major cost implication on the plant through these failing cathode flexible connections was their impact on reducing pot life as well as higher pot turnaround time. The overall negative impact on plant capital cost and metal production, through lowered pot life and pot availability, made it imperative to re-evaluate the flexible design concept.

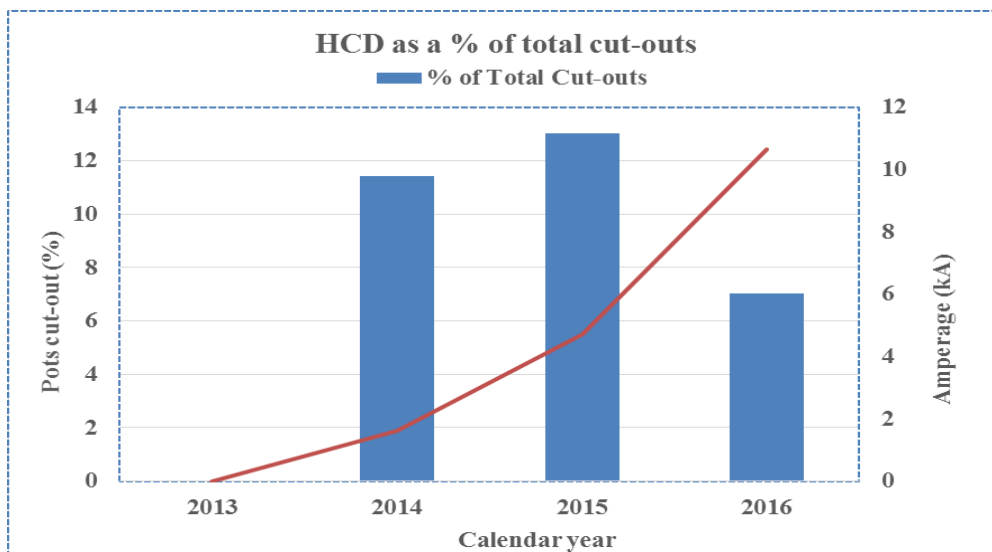


Figure 4. Pot cut-outs due to high combined drop (HCD). Red curve shows amperage increase.

Figure 4 shows the correlation between amperage increase and percentage of pots cutting out due to the high combined drop. Starting in 2014 most cathode flexibles found damaged during pot changeover were replaced with the modified second generation flexible connections having tri-metal clads as shown in Figure 1. The second generation tri-metal clads as a design have only 5 mm thick copper, 1 mm thick titanium and rest is aluminium. Additionally there was a change in collector bar design from round shape to rectangular in 2011 (that resulted in an increased cross sectional area and so reduced bar temperature). These factors may explain the decreasing trend in HCD failures in 2016 despite increasing amperage. When analyzing HCD per technology, CD20 was the main contributor each year ranging between 20 % and 35 % of all CD20s cut-out as shown in Figure 5.

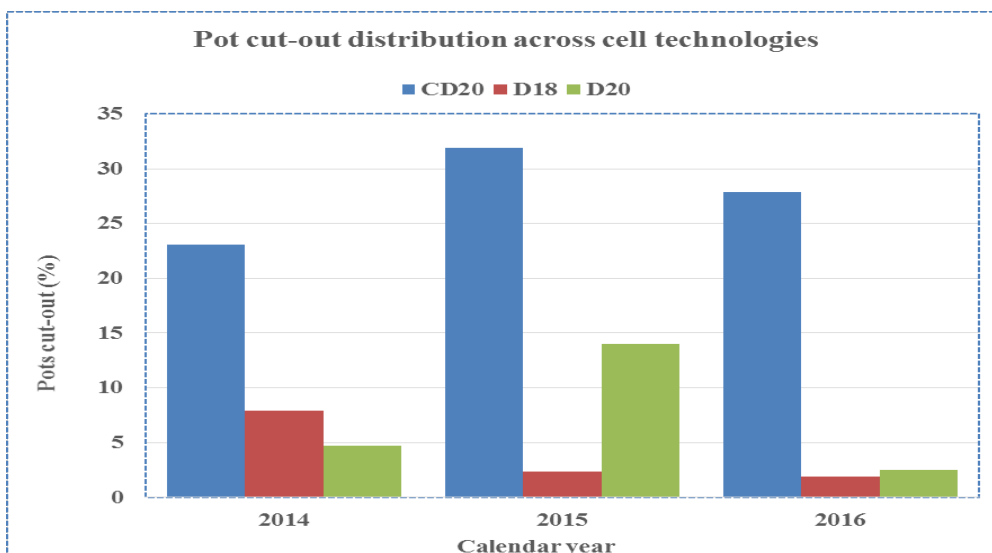
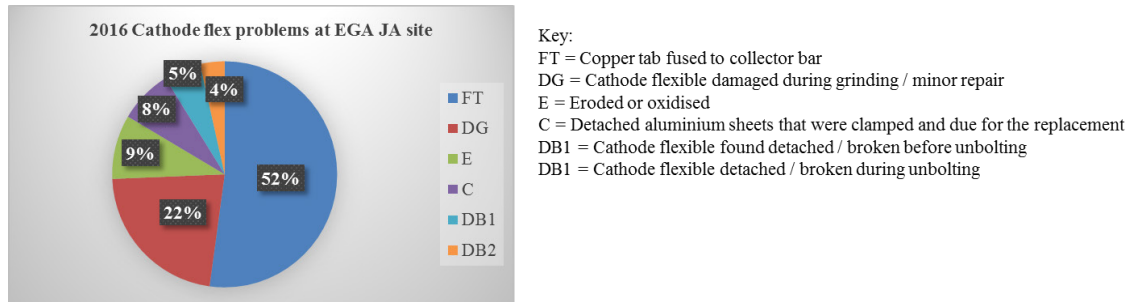


Figure 5. Pot cut-outs due to high combined drop in three EGA pot technologies.

From the pots failed due to high combined drop it was of interest to determine what specific types of cathode flexible damages were taking place. Accordingly a study on cathode flexible condition during cut-out was performed. Figure 6 shows the failure mode distribution from all reduction cells cut-out in 2016 at EGA’s Jebel Ali smelter. Around 50 % of the pots cut-out

were found to have some part of the copper tabs fused onto the collector bar. The next most prevalent damage failure mode was detachment on grinding of cathode flexibles and copper tabs during the reconnection to the new cell. The third was eroded or oxidised tabs. Together these damages represented 83% of total damage to cathode flexible connections observed. Therefore tackling these issues would ensure a significant decrease in cathode flexible connection replacement cost. Failure modes FT and DG in Figure 6, were found to be a result of high bolted tab temperature.



**Figure 6. Pot cut -outs due to high combined drop.**

### 3. New Cathode Flexible Connections

#### 3.1. Concept and Design

As an alternative to the conventional connections discussed in section 2, EGA's modelling and engineering teams together conceptualized and developed new cathode flexible connections which offer multiple benefits. The main aim of designing the new flexibles was to have a simplified flexible design making them more reliable, easier to mount and unmount and decrease pot turnaround time at the same time. Another design goal was to find most economical solution wherein overall cost could be minimized. Finally determining any voltage drop reduction across the assembly and capitalizing on it was targeted.

Figure 7 shows the cross sectional drawings of the two design concepts of new cathode flexible connections designed for D18+ cell technology and have been published in [1]. At present the first generation new flex design shown in Figure 7, has been implemented successfully in EGA's Jebel Ali smelter during the conversion of D18 cells to D18 + cell technology, comprising more than 500 pots. The much improved second generation flexible connections are to be implemented in the next generation of D18+ cells. Another flexible connection concept shown in Figure 8 has also been developed and has been implemented in seven trial cells of D20+ cell technology, four trial cells of DX cell technology and five trial cells of DX+ Ultra cell technology.

The main benefits of flexible design shown in Figure 8 over the flexible connection used in D18+ technology is the much shorter flexible length as the bolted connection has been shifted to the bottom of the cathode busbar and collector bar length outside of the potshell has been reduced to 50 mm, thereby achieving shorter path and further reduction in flexible voltage drop. ALBA's Potline 6, consisting of 424 DX+ Ultra Cell Technology cells will be equipped with the new flexible design concept shown in Figure 8 at an industrial scale.

In the new flexible design concept, the bolted connection has been shifted onto the busbar side and flexibles are welded on the steel collector bar with the help of steel-titanium-aluminium tri-metal transition joints also known as clads. Due to the space constraints and accessibility in the D18+ cells, the bolted connection was shifted to the top of the cathode bus bar. This allowed easy access during bolting and unbolting activities. The shifting of the bolted connection

towards the busbar side has very unique advantage as the temperature of the bolting surfaces is less than 200 °C. This is in contrast to the conventional flexibles where the bolted joint is located on the collector bar, and which have temperatures in the range of 350 - 500 °C. Achieving temperatures below 200 °C at bolted connection became the main design criterion during the development phase of the new flexible connections as it would almost eliminate the air oxidation of copper tabs.

Additionally the shifting of bolted connection to cooler busbar side allowed for the use of cheaper aluminium to aluminium bolted tabs. Aluminium-to-aluminium bolted joints cannot support as high temperatures as copper-steel joints. This is due to the nature of contacts: bolted electrical contacts conduct electrical current only through a certain number contact spots, which occupy a small percentage of the overall contact area. At a certain temperature, called softening point, considered to be 150 °C for the aluminium joints, the contact spots soften and flatten under contact pressure. This makes the contacts loose over time as there is always some thermal cycling in the joint and the contacts become loose when the temperature changes from higher to lower. From the measurements of contact voltage drops in the new flexible designs it is apparent that, in the long term, the joint contact may become poor more rapidly at temperatures of 200 °C and above.

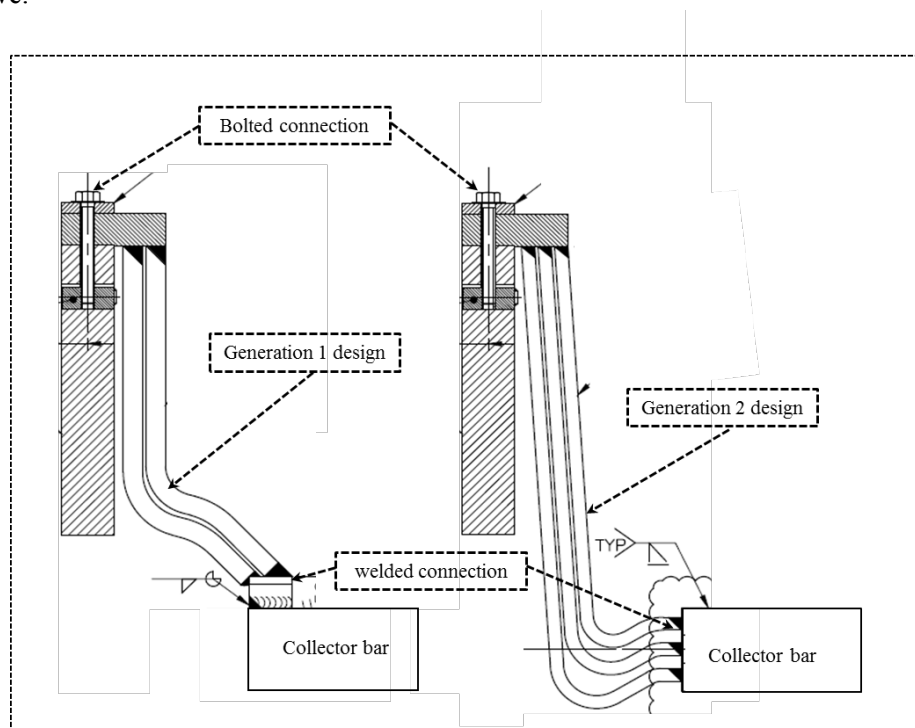
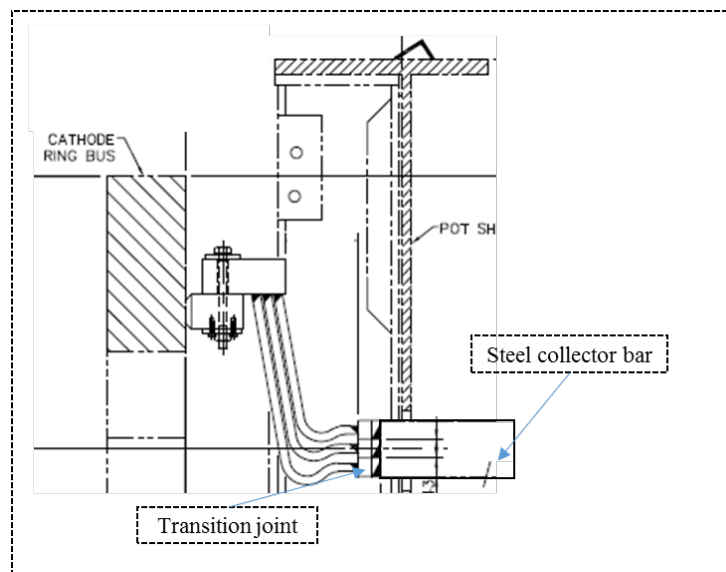


Figure 7. D18+ generation 1 and generation 2 new concept cathode flexible designs [1].

The other key design improvement of the new connections is the absence of very expensive copper tabs and thereby eliminating the major issues of air oxidation associated with the copper tabs of the conventional flexible design. Moreover the traditional cathode flexible connections require two pieces of copper tabs for each end of the collector bar which makes it even more expensive solution. On the contrary, the new connections require only two to three small pieces of steel-titanium-aluminum tri-metal clads which are much cheaper to buy and would be much cheaper to replace in future should they need to be. The other big advantage of the new connections is that, the entire welding operation can be carried out in a much more conveniently located workshop rather than the potroom. The relatively smaller disadvantage associated with the new flexible design is during the cathode replacement when the welding between the steel cathode collector bar and the transition joint has to be cut thereby damaging the tri-metal clads.



**Figure 8. New concept cathode flexible designs installed in D20+ cell technology.**

To achieve the specific goal of reducing the overall flexible voltage drop in the long term for the new flexible connection shown in Figure 8, two sets of trial have been planned. In one variant, both top and bottom plates which are bolted together are made of aluminium, whereas in the second variant the top and bottom plates would be made of copper-titanium-aluminium explosion bonded tri-metal clads. The design trials would help us to evaluate and compare the long term performance of the bolted joints, especially the deterioration of the contact surfaces over time and reusability during the pot changeover.

### 3.2. Mathematical Modelling

After finalizing the flexible connection design concept shown in Figure 7 and Figure 8, 3D thermo-electric finite element mathematical models of flexibles of D18+ and D20+ cell technologies were developed in-house, using commercially available ANSYS software. Mathematical modelling has become a primary design and optimization tool of aluminium electrolysis cells at EGA. Over the last 10 years EGA has developed full capabilities of mathematical modelling as described in [2]. The main advantage of having a well calibrated mathematical model is that the design parameters can be evaluated very precisely before the availability of the actual test results. Over the last several years mathematical models developed at EGA have been validated by conducting series of measurements across all EGA cell technologies.

Figure 9 to Figure 13 below show finite element 3D models, voltage and temperature contour plots of the new cathode flexible connections. Taking the advantage of mirror (reflective) symmetry, only half cross section of the one end of the flexible was modelled. Appropriate thermo-electrical boundary conditions were applied at the cut boundaries. For D18+ flexible models shown in Figure 9, at the hot end of the collector bar, 430 °C fixed temperature and 2710.5 A of average electrical current was applied. On the other end of the flexible where it is bolted to the busbar, 120 °C fixed busbar temperature and coupled voltage degree of freedom was applied. Adiabatic thermal boundary condition was applied at the symmetry faces. Natural convection and radiation boundary conditions were applied on the rest of the surfaces. Bolted joint between busbar and the flexible was not modelled for the D18+ flexible connections as the main aim of these two set of models was to compare the voltage drop gain between first and second generation designs.

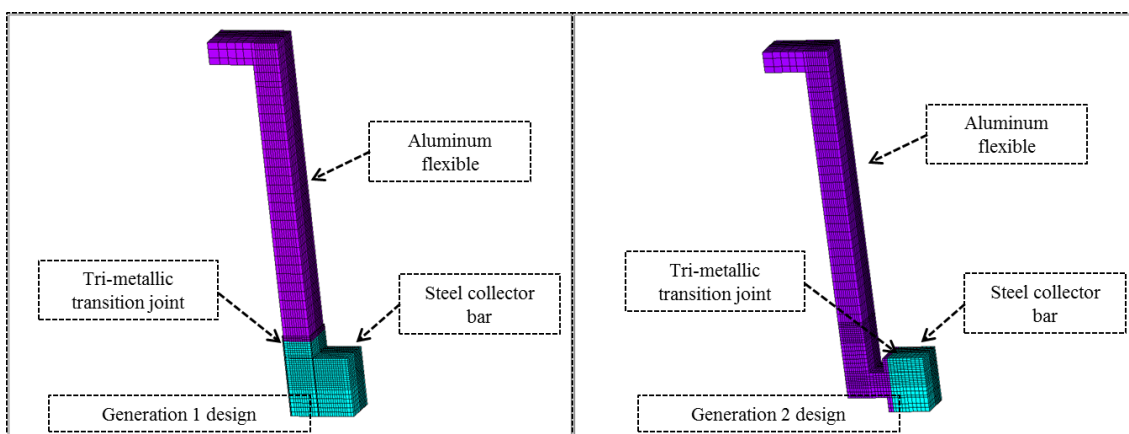


Figure 9. 3D finite element Ansys models of D18+ cell technology cathode flexible designs.

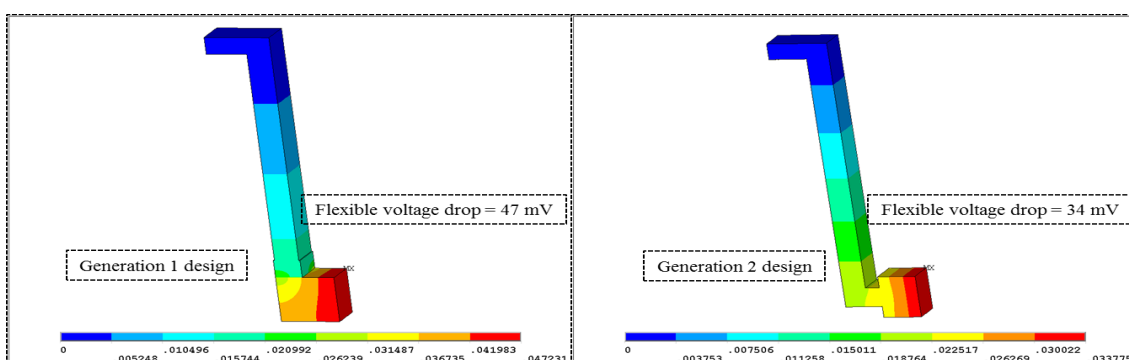


Figure 10. Voltage contour plots of D18+ cell technology cathode flexible designs.

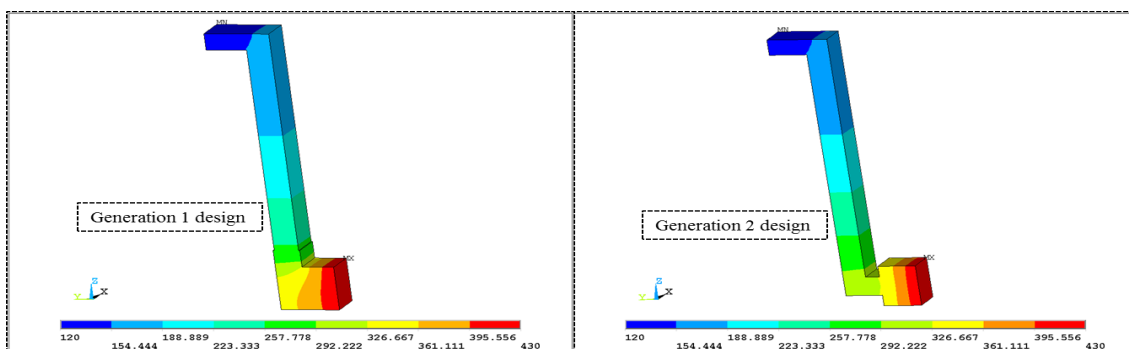


Figure 11. Temperature contour plots of D18+ cell technology cathode flexible designs.

As per the model calculations shown in Figure 10, 13 mV of voltage drop reduction was estimated between the two designs. The saving of 13 mV in the second design is largely due to the bigger contact area between transition joint (clad) and collector bar which was achieved by shifting the clad from top of the collector bar to the end of the collector bar.

For D20+ flexible models shown in Figure 12, at the hot end of the collector bar, 500 °C fixed temperature and 3068 A of average electrical current was applied. On busbar side face where the electrical current would be exiting other than the symmetry line, a coupled voltage degree of freedom was applied. Adiabatic thermal boundary condition was applied at the symmetry faces. Finally, natural convection and radiation boundary conditions were applied on the rest of the surfaces to complete the minimum required thermo-electrical boundary conditions. Figure 13 shows temperature and voltage contour plots along with the electrical current density vector

plots. Estimated total flexible voltage drop including the bolted joint for this design is approximately 34 mV at 270 kA cell current.

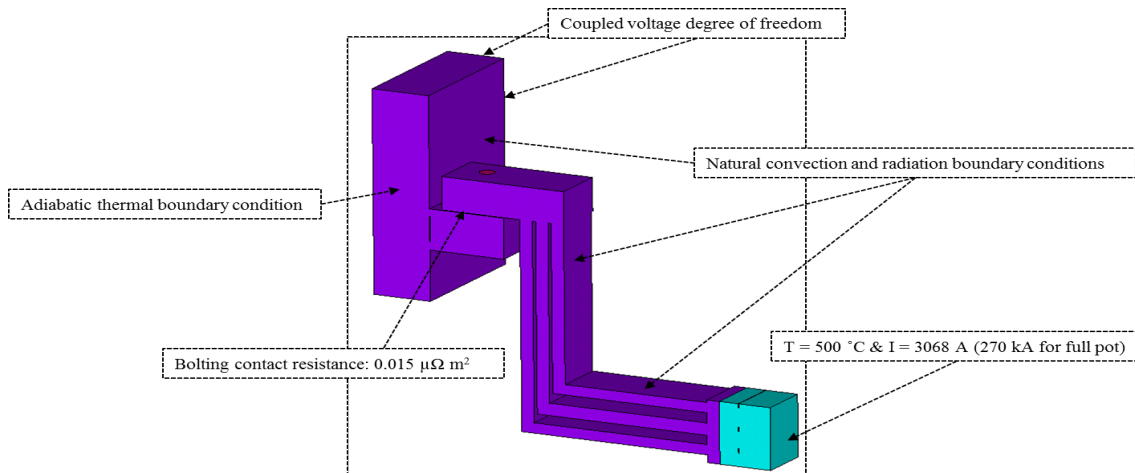


Figure 12. D20+ new concept cathode flexible designs Ansys 3D model set-up.

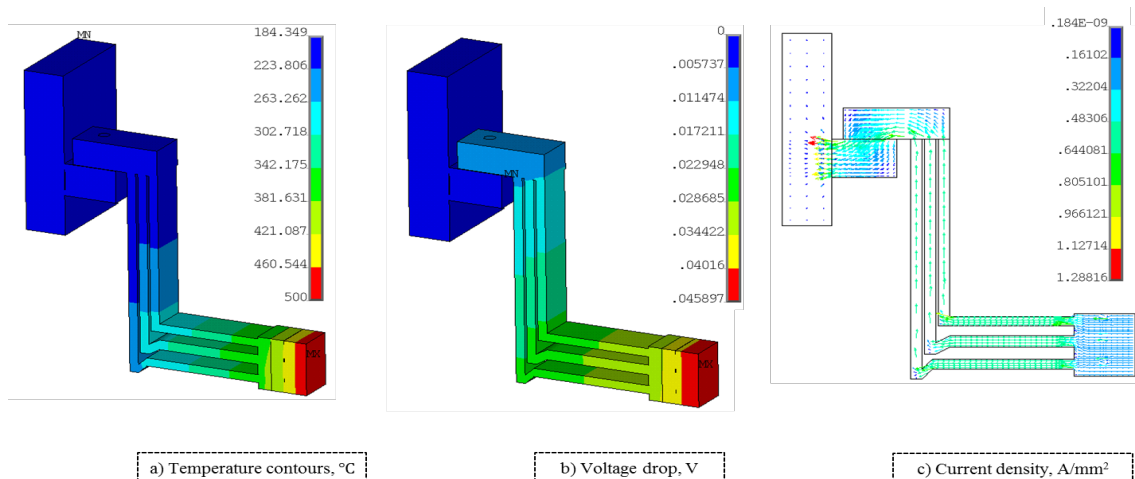


Figure 13. D20+ new concept cathode flexible designs thermo-electrical model results.

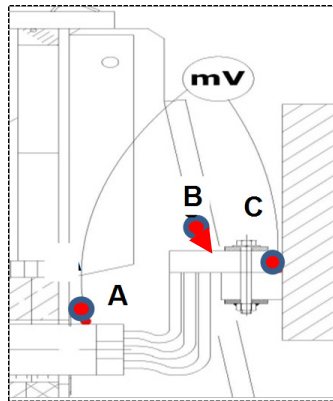
### 3.3. Experimental Evaluation and Model Validation

Cathode flexible voltage drop measurements were carried out to estimate the voltage drop across the flexible connections of both D18+ and D20+ designs. The measurement data was also used to estimate the quality of the bolted connections. The bolted joint tabs would be retightened if the bolted tab measured voltage drop is above a specified upper limit, fixed to 10 mV for D18+ and D20+ cell technologies. The upper limit has been fixed to 15 mV for DX+ ULTRA cell technology due to higher amperage and much increased tab current density. The measured parameters were voltage drops and temperature. Figure 14 shows the schematic details for the cathode flex and tab measurements. The measurements were carried out in three parts:

- A – B is the “**flex only voltage drop**” without the bolted tabs and is reported as Flexible voltage drop in the Tables 1 to 3. This was also used for the estimation of the collector bar current distribution.
- A - C is the “**full flex and tab voltage drop**” and is reported as Total flexible voltage drop in the Tables 1 to 3.

- B – C is the “**bolted joint tab voltage drop**”. This was measured for the control of the bolted joint quality.

All three measurements were done at the same time, even though one of them could be obtained from the other two. Measuring all three components was an additional check for the quality of the readings. The collector bar was pinned with (+) probe only once at point A while the other probe on aluminium is placed on B and then C. Then the first probe is displaced from A to B.



**Figure 14. Cathode flex and bolted tab measurements.**

Experimental evaluation and model validation of the new cathode flexible connections is discussed next. Tables 1, 2 and 3 show the summary of the measured flexible voltage drops and corresponding mathematical model values for D18+, D20+ designs and DX+ ULTRA designs. All measured voltage drop components were normalized to the same current used in the mathematical model calculations in order to have an accurate comparison. After comparing the results, it can be said that the measured and modeled values have excellent agreement within  $\pm 5$  mV accuracy.

**Table 1. D18+ flexible voltage drop summary at 206 kA.**

Parameters	Unit	D18+ flexibles					
		Measurement data					Model
		Cell 64	Cell 65	Cell 66	Cell 67	Avg.	Avg.
Cell amperage	kA	206	206	206	206	206	206
Total flexible voltage drop	mV	48.7	45.9	50.7	50.5	<b>48.9</b>	NA
Bolted joint drop	mV	5.6	6.2	6.2	9.5	<b>6.9</b>	NA
Flexible voltage drop	mV	43.1	39.7	44.5	41.0	<b>42.1</b>	<b>42</b>

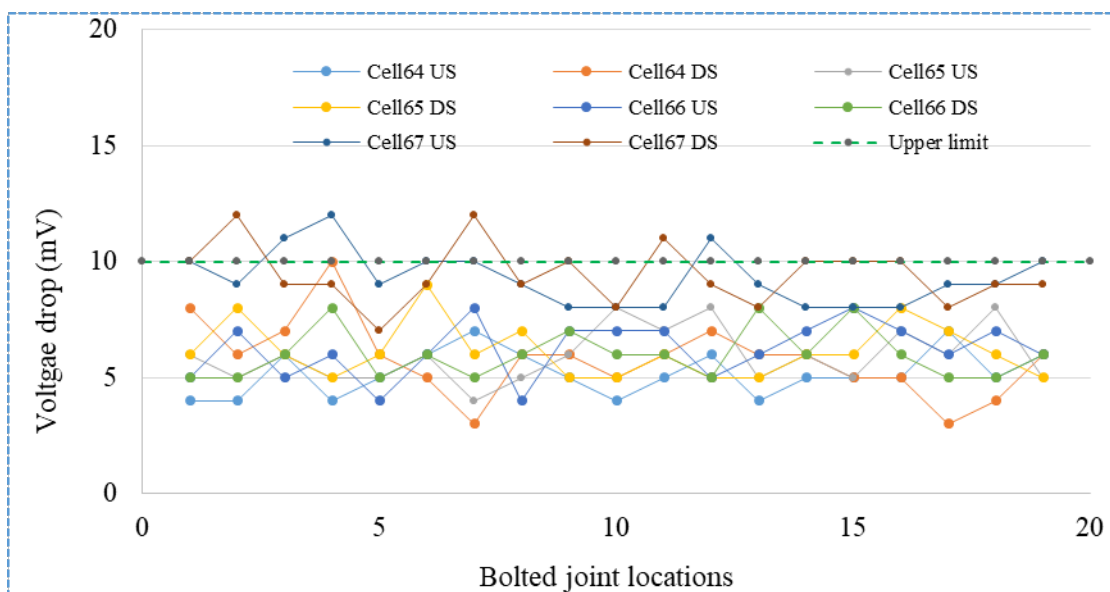
**Table 2. D20+ flexible voltage drop summary at 270 kA.**

Parameters	Unit	D20+ flexibles				
		Measurement data				Model
		Cell 259	Cell 260	Cell 261	Avg.	Avg.
Cell amperage	kA	270	270	270	270	270
Total flexible voltage drop	mV	29.5	26.7	30.2	<b>28.8</b>	<b>34</b>
Bolted joint drop	mV	5.0	5.2	5.9	<b>5.4</b>	<b>7.3</b>
Flexible voltage drop	mV	24.6	21.6	24.2	<b>23.5</b>	<b>26.7</b>

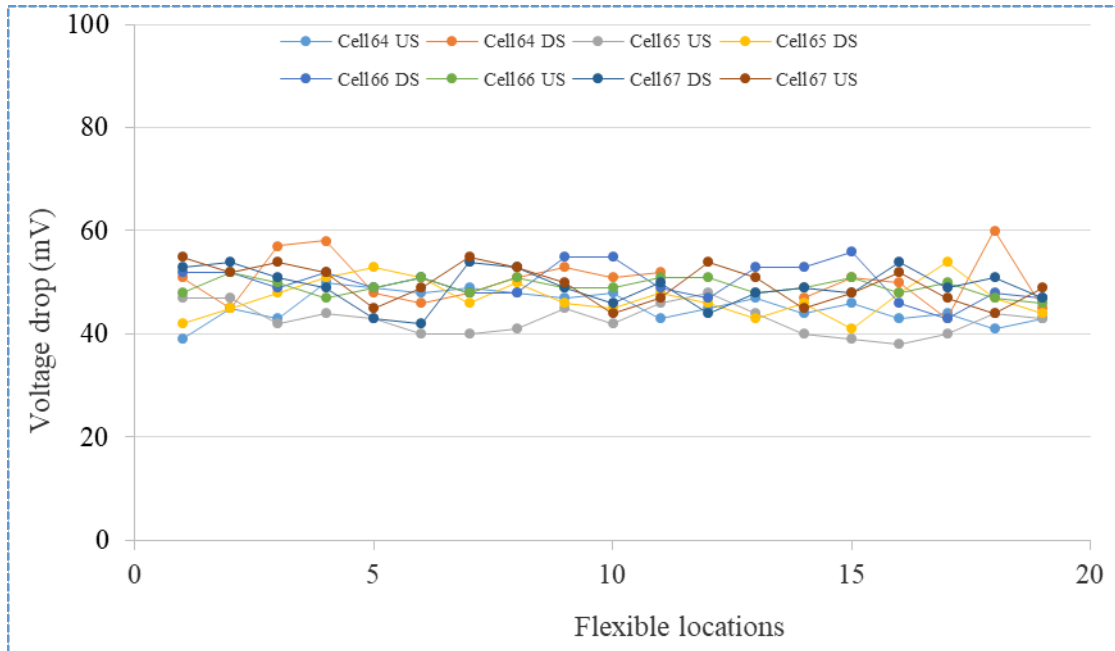
**Table 3. DX+ ULTRA flexible voltage drop summary at 455 kA.**

Parameters	Unit	DX+ ULTRA flexibles						
		Measurement data						Model
		Cell 273	Cell 274	Cell 275	Cell 276	Cell 277	Avg.	Avg.
Cell amperage	kA	455	455	455	455	455	455	455
Total flexible voltage drop	mV	38.5	36.6	NA	38.4	35.8	<b>37.3</b>	<b>32</b>
Bolted joint drop	mV	11.4	8.9	11.5	11.8	9.9	<b>10.7</b>	<b>11</b>
Flexible voltage drop	mV	27.1	27.6	NA	26.7	25.7	<b>26.8</b>	<b>21</b>

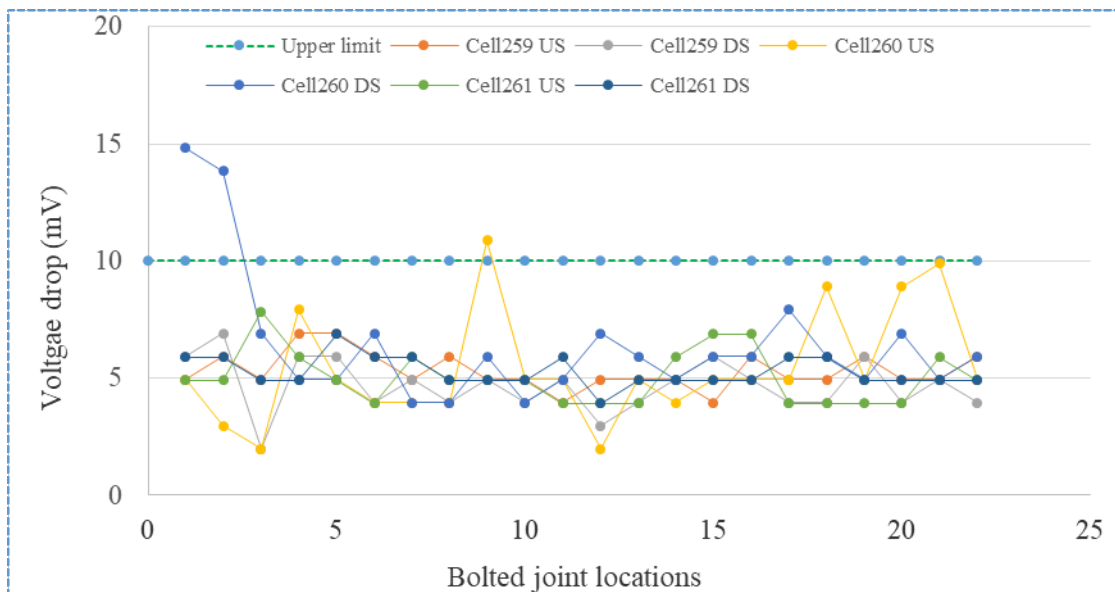
Figure 15 and Figure 16 show the measurement data of bolted joint and flexible voltage drops for a total of 4 cells of D18+ cell technology at 201.8 kA cell amperage, respectively. Figure 17 and Figure 18 show the measurement data of bolted joint and flexible voltage drops for a total of 3 cells of D20+ cell technology at 270 kA cell amperage. Figure 19 and Figure 20 show the measurement data of bolted joint and flexible voltage drops for a total of 5 cells of DX+ Ultra cell technology at 455 kA cell amperage. The main objective of the data presented in these graphs is to show the variation of the voltage drops of the individual flexibles and bolted joint drops and the quality of the bolted joints at the same time. By looking at the bolted joint voltage variations of D18+, cell number 67 in Figure 15 and D20+, cell number 260 in Figure 17, and DX+ Ultra, cell number 274 and 276, it is very evident that some of the readings are more than their respective fixed upper limits of 10 mV and 15 mV and require re-tightening of the bolts. All other readings are well below the respective fixed upper limits.



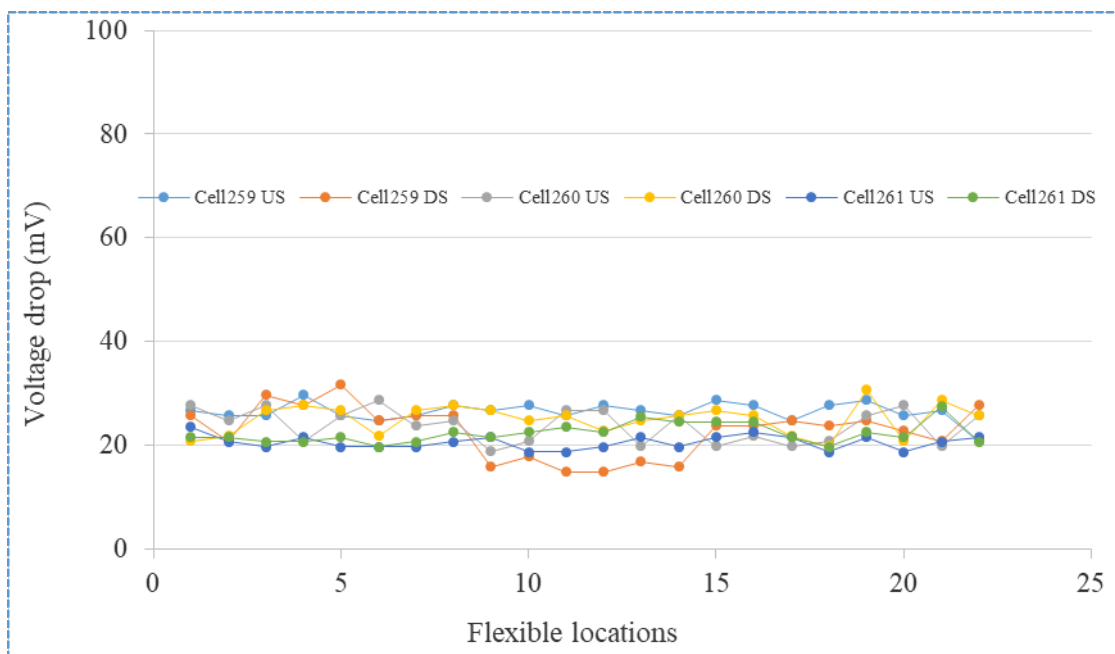
**Figure 15. D18+ flexible design, measured individual bolted joint voltage drops.**



**Figure 16. D18+ flexible design, variation of measured individual total flexible voltage drops.**

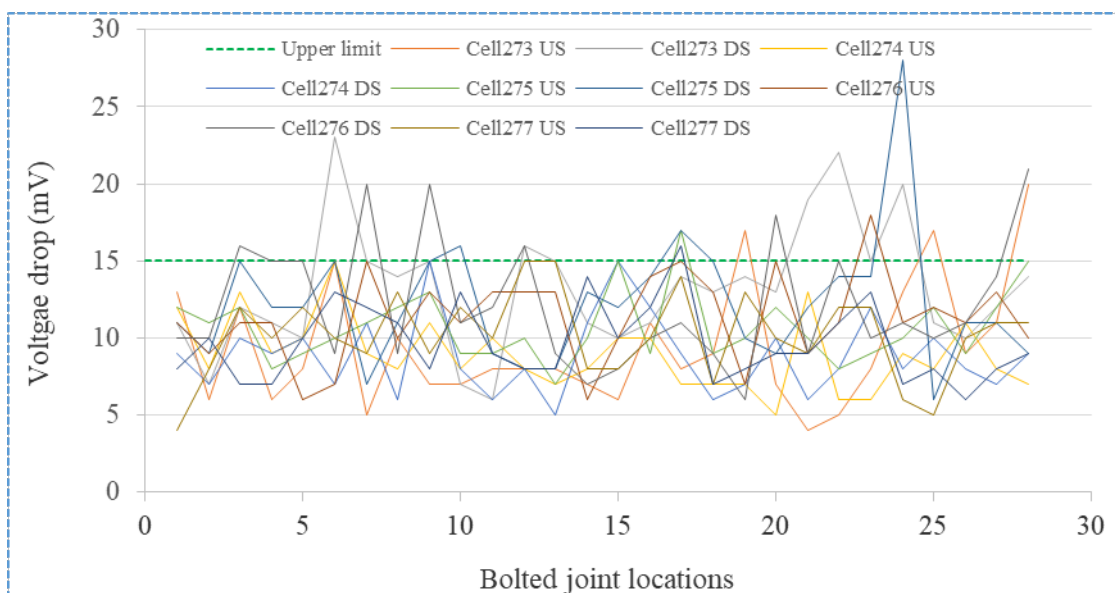


**Figure 17. D20+ flexible design, measured individual bolted joint (B-C) voltage drops.**

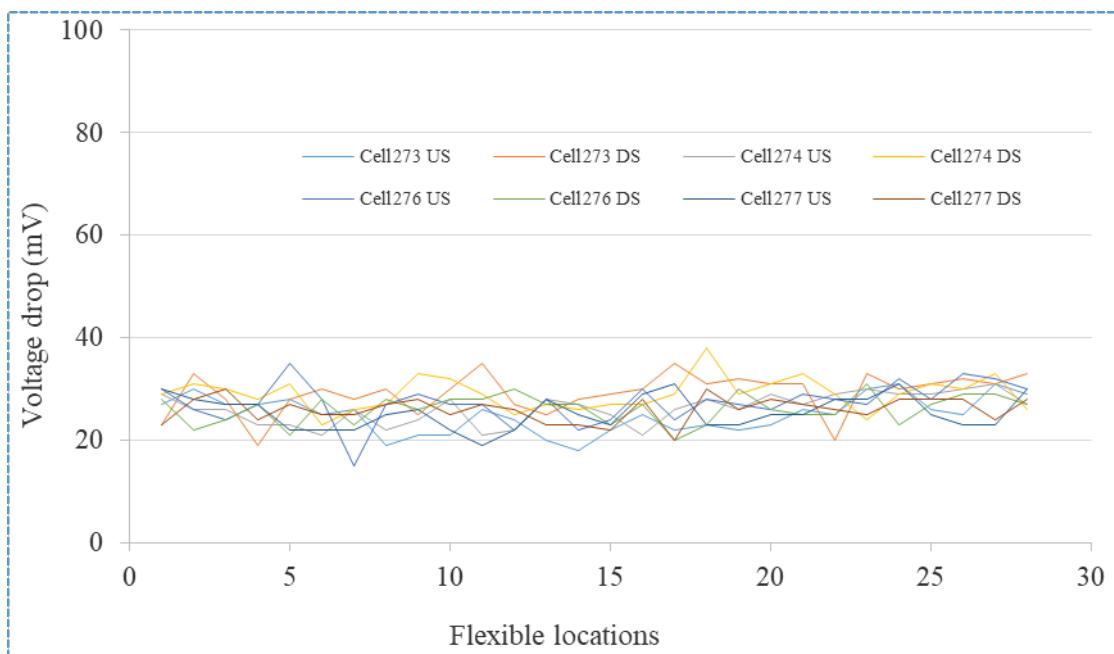


**Figure 18. D20+ flexible design, variation of measured individual flexible only (A-B) voltage drops.**

Figure 21 shows the long term bolted joint voltage drops variations of the D18+ technology cell number 63. The measurements were carried out between March 2012 and June 2015. The very first measurement reported here in March 2012 was done just after the bath up of the cell. At the beginning, the downstream side of the bolted joints were much above upper limit values and therefore required immediate retightening of the bolts. After the re-tightening of the bolts, the voltage drop distribution became normal. The measurement campaign carried out in May 2012 and June 2015 also showed that some of the downstream sides of the bolted joints needed to be re-tightened as bolted joint drops were higher than the fixed upper limit.

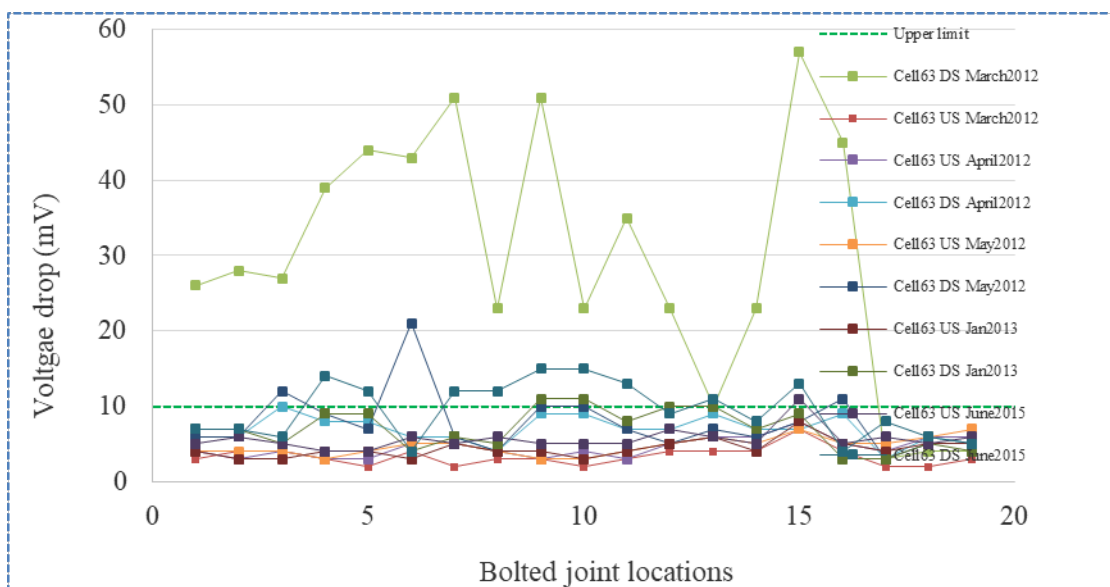


**Figure 19. DX+ ULTRA flexible design, variation of measured individual bolted joint (B-C) voltage drops.**



**Figure 20. DX+ ULTRA flexible design, variation of measured flexible only (A-B) voltage drops.**

Figures 15, 17, and 19 show that in some circumstances the aluminium-to-aluminium joint voltage drops can be higher than an acceptable limit, which is different for different flexible designs and cell technologies. The high voltage drops may be related to joint temperatures higher than 150 °C and thermal cycling, which soften aluminium contact spots and loosen the contact. However, the high joint voltage drops can be controlled with periodic joint voltage drop measurements and subsequent re-tightening of the bolts. It is particularly important, that this measurement be made during the first days after pot bath-up, when the joint temperatures are expected to be higher due to hotter potshells.



**Figure 21. D18+ flexible design long term measured bolted joint voltage drops of Cell 63.**

#### 4. Conclusions

EGA has successfully designed, modelled, tested and patented [3] the concept of new generation cathode flexible connections. After the successful test carried out in seven trial cells of D18+ cell technology, more than 500 D18 cells have been converted to D18+ cells [4 - 6], and have been installed with the new flexible connections at an industrial scale at EGA's Jebel Ali smelter. The new generation flexibles have also been successfully tested in five test cells of low energy DX+ Ultra cell technology and would be implemented at an industrial scale in ALBA's Potline 6, with 424 cells of DX+ Ultra cell technology. The new flexible connections have also been installed in seven trial cells of D20+ and four trial cells of DX Cell Technology.

Experimental evaluation of new cathode flexible connections shows an excellent agreement with the model prediction for D18+, D20+, DX and DX+ Ultra designs. These flexible connections have been standardized to be used for any future cell technology or expansion projects to be executed by the EGA. In the long run EGA will get the benefit of lower cost by implementing the new flexible connections both due to the saving in flexible voltage drop between 10 - 15 mV as well much lower flexibles cost. The pot turnaround and replacement cost is also favorable and these flexibles are expected to give better long term performance and quality of the bolted joints. Any deviation from acceptable contact voltage drop on aluminium-to-aluminium bolted joints can be controlled by periodic voltage drop measurements and subsequent joint re-tightening.

#### 5. Acknowledgements

Many other people contributed to the successful implementation of these flexible connections across the plant. The authors would like to specifically acknowledge the significant contributions made by EGAs pot repair team and Mr. Mohamed Tawfik Boraie Ahmed, Lead Engineer - Process Control Cell Lining Technical, to collect pot cut-out data of various cell technologies during the pot turnaround and change over periods.

#### 6. References

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