D20+, the New EGA Optimized Version of D20 Technology for Lower Energy Consumption

Ali Alzarouni[1], Sergey Akhmetov[2], Mahmood Abdulmalik[3], Yousuf Juma Ahli[4] and Ali Jassim[5]

1. Executive Vice President Midstream
2. Senior Vice President- Reduction
3. Senior Manager Technology Engineering
4. Senior Manager Potlines
5. Senior Manager Plant Optimization and Process.Development

Emirates Global Aluminium, Jebel Ali Site, Dubai, United Arab Emirates

Corresponding author: abanjab@ega.ae

Abstract

Emirates Global Aluminium (EGA) commenced operation in 1979 with 3 potlines of 120 D18 cells at its Jebel Ali site, then known as Dubai Aluminium. Today, with smelters at both Jebel Ali in Dubai and Al Taweelah in Abu Dhabi, EGA has an annual production of 2.5 Mt of primary aluminium. EGA has focused on technology development for over 25 years. As part of this work, in 2014 a project was launched to accelerate development of a more advanced cell design with minimum capital investment by modernising and improving EGA's existing CD20 and D20 cell technologies into D20+. The work in this paper demonstrates the evolution of the D20+ cell design from D20 Cell Technology. It also summarises the industrial performance after one year of operation in the boosted amperage section while targeting energy consumption of less than 13.0 DC kWh/kg Al. Further process optimization and feasibility analysis are in progress to fully assess the best path forward for industrial implementation of D20+ Cell Technology.

Keywords: EGA, D20+ Cell Technology, low energy reduction cells.

1. Introduction

Emirates Global Aluminium began production in 1979 as Dubai Aluminum with Kaiser P69 cell technology (and later upgraded to D18) in three potlines with 120 pots in each potline. Annual production in 1980 was 36 300 tonnes.

Since then, through amperage increases, brownfield and greenfield expansions, production has grown significantly. Today Emirates Global Aluminium operates two smelters – one in Dubai and the other in Abu Dhabi – and has a production capacity of 2.5 Mt per year.

EGA is currently expanding upstream and internationally. EGA is building a bauxite mine and associated export facilities in the Republic of Guinea in West Africa. In Abu Dhabi, EGA is building the UAE's first alumina refinery next to its Al Taweelah smelter.

EGA has focused on technology development for over 25 years to reduce the amount of energy required to produce each tonne of aluminium, saving costs and environmental emissions. Significant upgrades in the process at EGA have been achieved over the years to improve energy efficiency and carbon footprint and have resulted in lowering cell specific energy from 15.50 DC kWh/kg Al to less than 12.99 DC kWh/kg Al in its newest technologies: D18+, D20+ and DX+ Ultra (Figures 2 - 4) [1 – 3].

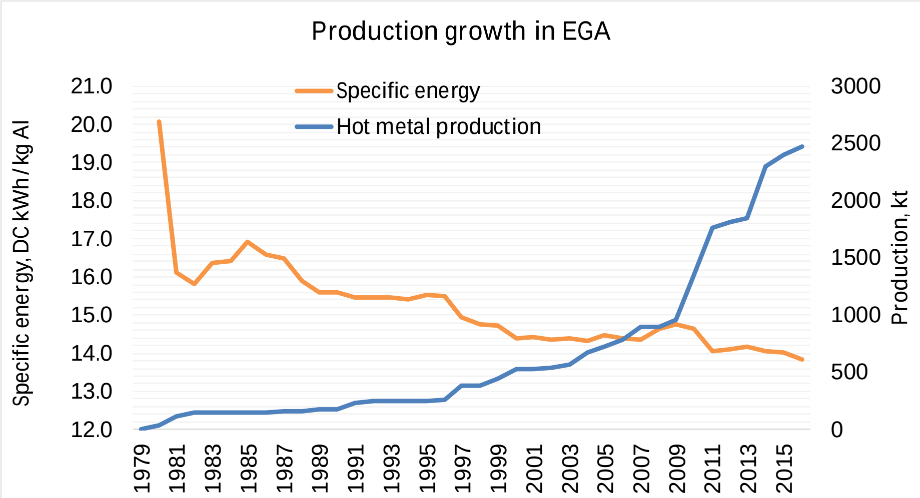

Figure 1. Production growth at EGA.

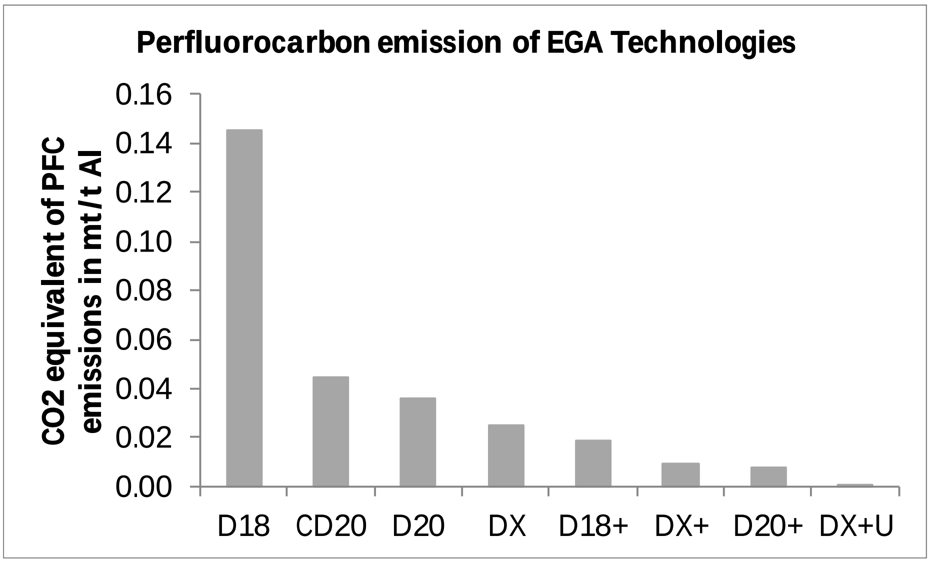

Figure 2. Perfluorocarbon (PFC) emissions across EGA technologies for the period from 1 June 2016 to 1 June 2017.

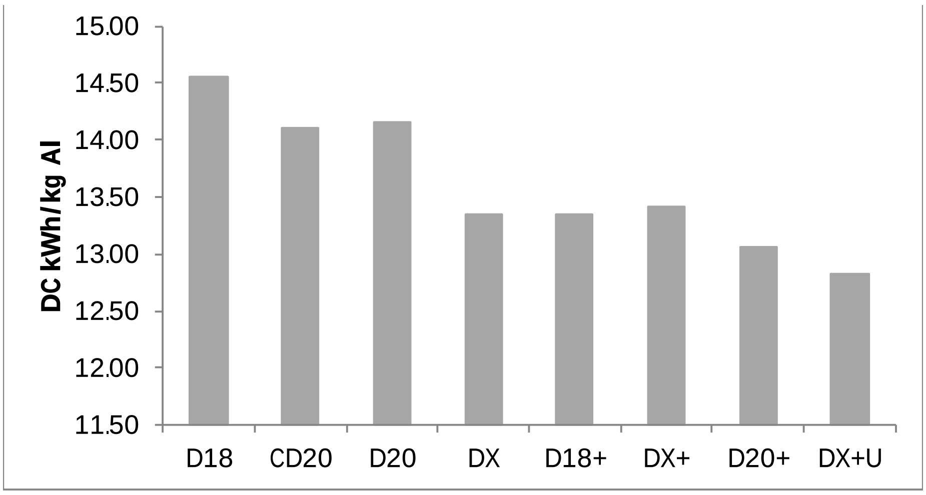

Figure 3. Specific energy consumption across EGA technologies for the period from 1 June 2016 to 1 June 2017.

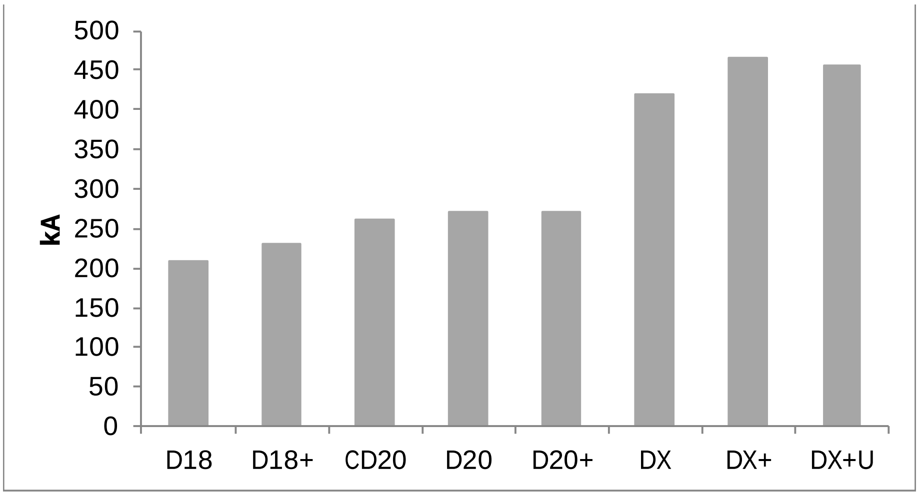

Figure 4. Amperage across EGA technologies for the period from 1 June 2016 to 1 June 2017.

2. Upgrade of D20 Cell Technology

In 2013 a development program was initiated to upgrade existing CD20 and D20 technologies, which have operated at EGA Jebel Ali since 1996, to improve their cell energy efficiency. The work included review of the cell busbar design, lining materials, reduced anode current density and improved cell control logic. The D20 technology operates with 20 prebaked anodes with four-point alumina feeders and four side risers (Figure 5); there are 480 CD20 cells and 528 D20 cells currently in operation at Jebel Ali. Unlike other retrofit projects at EGA such as the D18+ cell design, where the busbar and superstructure were completely revised and replaced [1], the D20 pots underwent only partial busbar re-engineering to cope up with higher operating limits and enhanced magnetohydrodynamic stability [2]. To maintain low project CAPEX, D20+ cells were designed to use the same shell and superstructure with partial modification to accommodate the increase in the number of cathode from 19 to 22 and the number of anodes 20 to 24 per cell. The same cell support was used since the increase in overall weight and dimension was relatively minor. D20+ cells have the same width as D20 while the length is by 1.7 m longer.

Figure 5. D20 and D20+ Cell Technologies [2].

In 2016 seven D20+ trial cells were started in Potline 5 at Jebel Ali in order to validate the cell performance. To minimize metal production loses while converting, one pot retrofit was carried out at a time with the total conversion process lasting for 128 days.

The D20 technology originally started operation at 220 kA. Through in-house development and upgrading of the process capability the D20 technology operate at amperage beyond 270 kA.

3. Performance of D20+ Test Cells

Seven D20 cells were selected in Section 10, Potline 5 (Figure 9) to validate the performance of D20+ technology based on cell age, ease of logistics such as overhead crane access to retrofit into D20+ cells. The reduction work pattern was converted to a 12-hour shift to allow accessibility of the civil crew to perform the required modifications in the other 12 hours of the day. The overall conversion period lasted for 128 days, starting on 9 April 2016 and completed on the 15 August 2016.

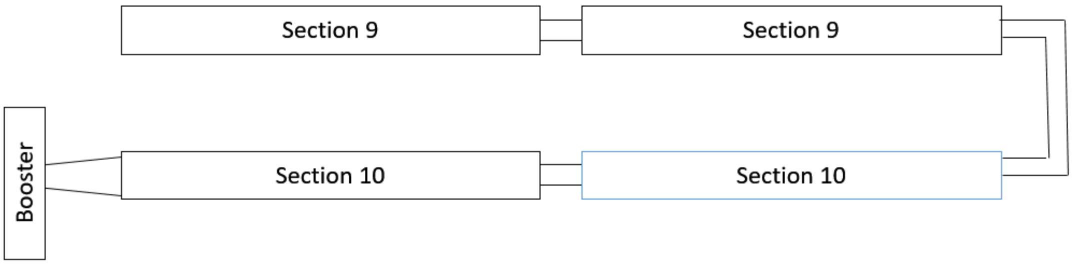

Figure 6. Schematic diagram for D20+ Cell Technology in Potline 5 in Jebel Ali site.

Since start up, a dedicated technical team was assigned to monitor and ensure a smooth start up process. The team ensured that the best safety and operations practices were followed for the retrofit in an operating potline and since project commissioning. To confirm precise reporting of current efficiency, a monthly metal inventory measurement was made for the test cells and dedicated tapping crucibles were assigned to the test section during the tapping operation.

The aluminium electrolysis cell obeys the principle of energy conservation. The difference between heat inputs and outputs is the heat accumulation. The energy inputs are expressed by the enthalpy associated with the materials entering the cell and the cell electrical energy generation. The heat outputs are expressed by the enthalpy associated with the materials leaving the cell control volume and by the heat dissipation to the environment [4]. Thus, the D20+ side lining material was reviewed to support the new operating strategy. The heat balance in the test cells was slightly affected by the lower energy input during early stages of operation which was reflected by lower operating superheat and higher cell instability; this affected alumina mixing and dissolution. Spatial variation in anode currents, superheat and bath flow due to the instability, resulted in anode problems such as spikes and splits which affected the overall cell thermal balance due to uncontrolled heat generation.

The cell thermal balance was therefore fine-tuned with a higher anode cover thickness as well as heat deflectors that were fixed on the outer side of the potshell (Figure 7) to help retain heat and to increase the operating superheat to a window of 10 - 15 °C (Figure 8).

Improved busbar design, increased anode and cathode surface area and usage of EGA designed copper insert collector bars has allowed the D20+ cell to operate at a voltage close to 400 mV lower than D20 cells. Figure 9 and Table 1 show the performance of D20+ cells in comparison to D20 for 8 months of stable operation from 1 January to 31 August 2017.

Figure 7. Heat deflectors used to increase side- and end-wall insulation of D20+ cell.

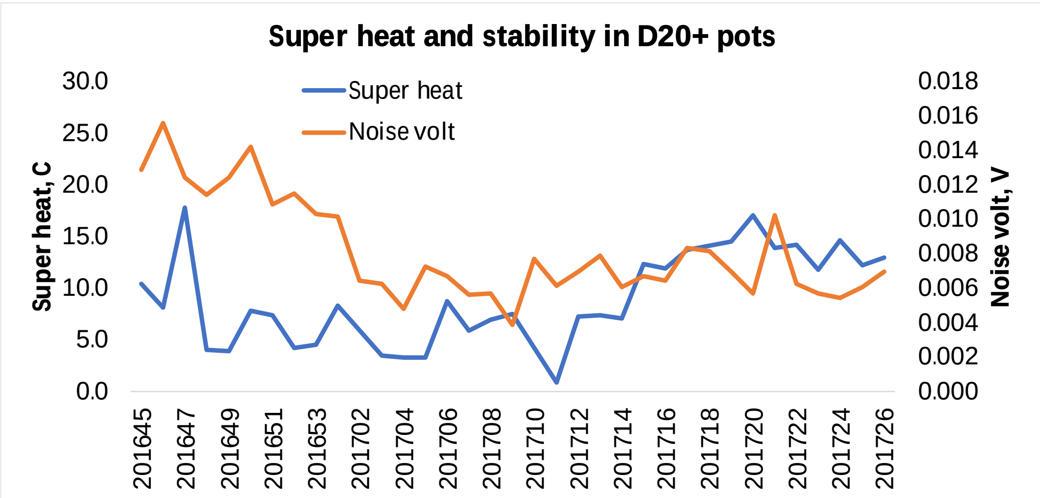

Figure 8. Operating superheat and noise of D20+ cell.

Figure 9 and Table 1 show the ability of D20+ to operate above the designed amperage limit of 270 kA. Most notable are 1.23 kWh/kg Al (9 %) lower specific energy consumption and improved environmental performance, with 73 % lower equivalent CO_2 of PFC emissions. There were several contributing factors for the improved performance of D20+ Cell Technology in comparison to D20 Cell Technology:

- The modifications of the busbar design, which increased MHD stability of the cells and enabled operation at lower ACD (Figure 10).
- Increased number of anodes which decreased operating anode current density and bath voltage drop.
- Increased number of cathode blocks, which decreased cathode current density and helped decrease the cathode voltage drop.
- Copper inserts in the cathode blocks, which decreased the cathode voltage drop.
- Good control of anode current distribution.

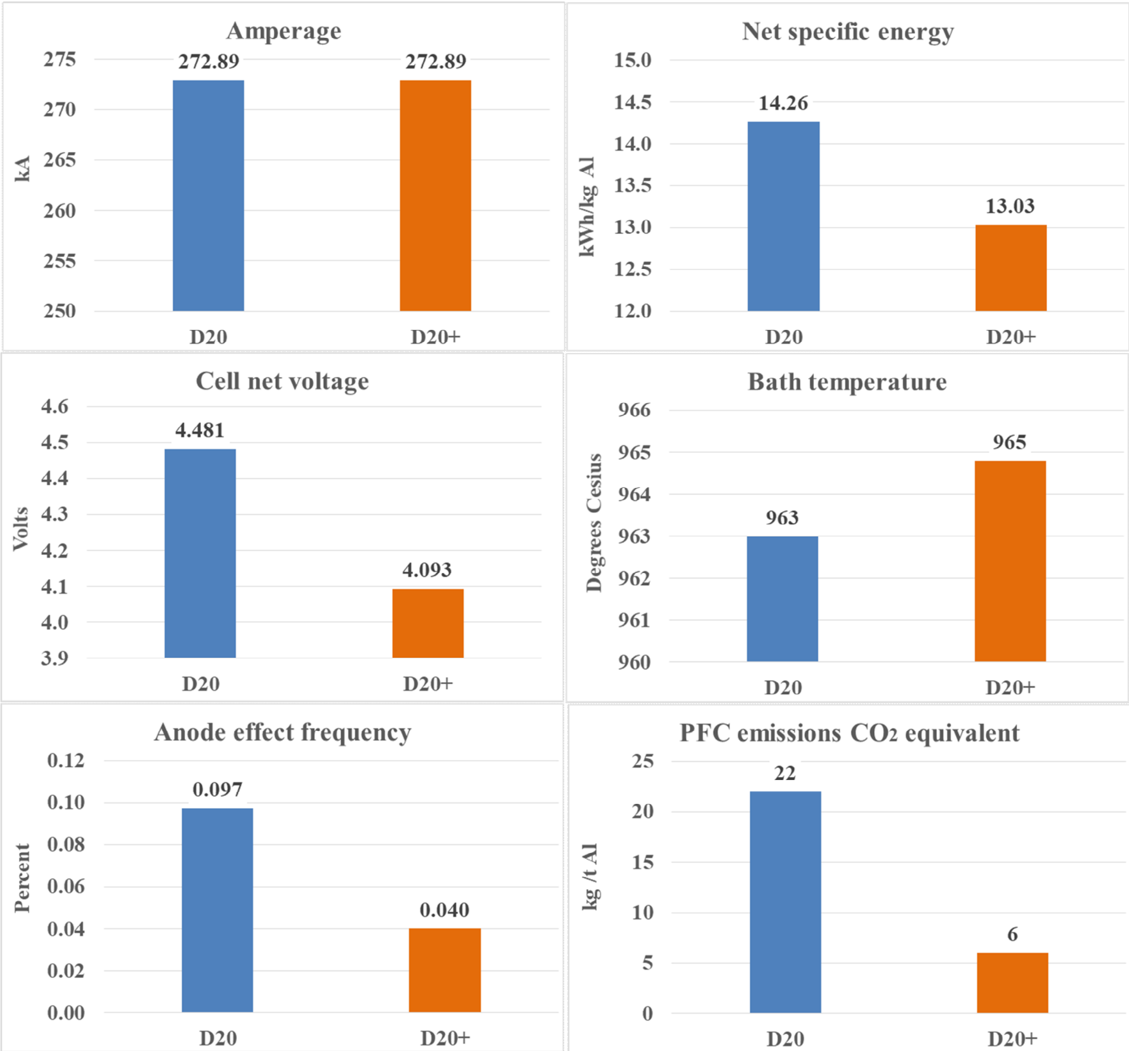

Figure 9. Operating key performance indicators of D20 and D20+ Cell Technologies from 1 January to 31 August 2017.

However, maintaining lower energy input and electrolyte volume induces spatial variations as a result of operational activities such as anode setting, leading to the formation of spikes and imbalanced current distribution, all of which adversely impact performance. During anode setting, cell thermal and anode current balance are disturbed for several hours to reach normal operating conditions [6]. Anode setting activity causes the most frequent disturbance to cell MHD stability [7]; the disturbance occurs due to formation of bath freeze on the cold anode surface which insulates the anode and prevents current flow. The increase in number of anodes allowed increasing the anode setting shift rota which resulted in increasing the gap between each consecutive anode set activity.

Table 1. Summary of KPI's of D20 and D20+ cell technologies from 1 January to 31 August 2017. D20+ data are for 5 cells, representative of typical D20+ design.

Parameter	Unit	D20	D20+	D20+ - D20
Amperage	kA	272.89	272.89	0
Current efficiency	%	93.63*	93.63	0
Metal production	kg/pot-day	2058	2058	0
Cell net voltage	V	4.481	4.093	-0.388
DC net specific energy	kWh/kg Al	14.26*	13.03	-1.23
Gross carbon consumption	kg C/t Al	540	540	0
Net carbon consumption	kg C/t Al	418	422	4
Bath temperature	°C	963	965	2
Excess AlF_3	%	11.8	11.0	-0.8
Fe	%	0.097	0.086	-0.011
Si	%	0.026	0.022	-0.004
Anode effect frequency	AE/pot-day	0.097	0.040	-0.057
Anode effect duration	s	12.5	8.7	-3.8
PFC emissions CO_2 equivalent**	kg/t Al	22	6	-16
Cell noise (instability)	mV	9	6	-3
Metal height before tap	cm	25.4	17.7	-7.7

*Estimated.
****CO_2 equivalent is calculated as in Reference [5], using the Tier 2 method and SAR (Second Assessment Report).

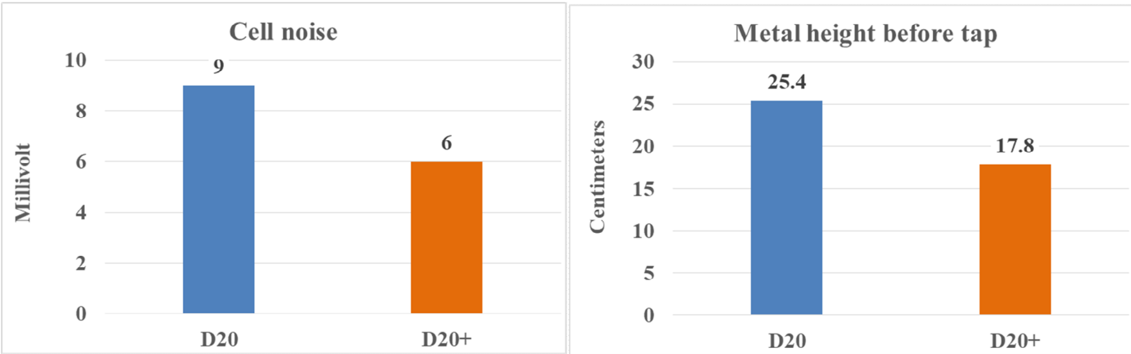

Figure 10. Average noise and metal height in D20 and D20+ Cell Technologies from 1 January to 31 August 2017.

Further optimization of D20+ cell performance is possible. For example, very low metal height target was introduced to keep more heat in the cells; increasing the metal height may help cell stability and current efficiency, but then another means of heat conservation has to be found or ACD has to be somewhat increased, which in itself will favour better current efficiency.

4. On-Line Anode Current Monitoring System

Cell voltage is the only continuous measured signal whilst other voltage components are either assumed constant or measured on a discrete basis. Automated cell control algorithms are used to regulate essential cell activities such as alumina feeding and energy input based on calculated pseudo-resistance which is calculated from:

$$R = \frac{V_{cell} - V_{extrap}}{I} \tag{1}$$

where: V_{cell} Cell voltage, V,
V_{extrap} Extrapopolated voltage (zero current intercept of V versus I), typically 1.65 V,
I Cell current, A.

Calculated pseudo-resistance is used to maintain constant ACD which continuously changes due to the dynamic nature of the cell, while carbon electrodes are consumed and cathode metal pool is accumulated. Deterioration in cell MHD stability due to spatial or temporal changes in cell conditions are usually treated by either manual adjustment of individual anodes or ACD regulation. Studies have shown that limiting cell monitoring and control strategy to pseudo-resistance control is inadequate for prompt fault detection [8]. The increase in modern cell dimensions and aim to operate at a lower energy input has imposed difficulties in detecting spatial changes and thus a new control strategy based in individual anode current monitoring signal is essential. Thus, D20+ pots were equipped with the latest in-house developed design of anode current monitoring system using monitoring sampling frequency of 2 Hz. An example of individual anode currents is presented in Figure 11, showing anode change at 16 o'clock.

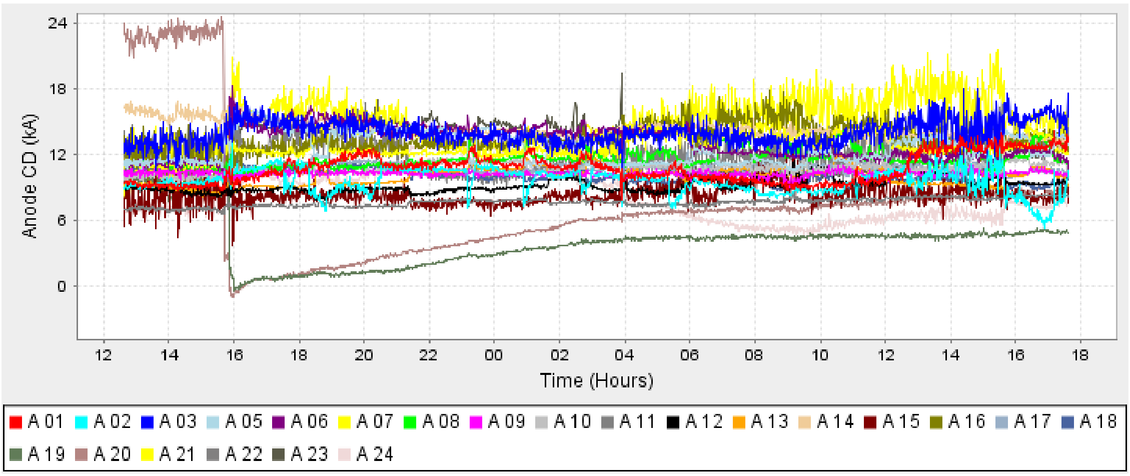

Figure 11. Individual anode current signals in a D20+ cell as reported in D20+ visual interface (iPots).

5. Conclusions

The intensive sophisticated work, modeling and optimization by EGA's technology development team has resulted in developing an improved busbar design for D20+ technology. The cells have had stable operation since January 2017 at a lower energy input than the existing D20 Cell Technology. The specific energy has been reduced by 1.23 kWh/kg Al from 14.26 DC kWh/kg Al to 13.03 DC kWh/kg Al at 272.9 kA. The aim is to achieve net energy consumption lower than 13.0 DC kWh/kg Al, which should be possible to attain with a few adjustments of operational parameters.

6. References

1. Daniel Whitfield et al., Implementation of D18+ Cell technology at EGA's Jebel Ali Smelter, *Light Metals* 2017, 749-757.
2. Daniel Whitfield, EGA's new D20+ cell technology decreases energy consumption, *International Aluminium Journal*, January 2017, 31.
3. Ali Alzarooni et al., DX+ Ultra - EGA high productivity, low energy cell technology, *Light Metals* 2017, 769-774.
4. Abdalla Al Zarouni et al., Energy and Mass Balance in DX+ Cells During Amperage Increase, *31st International Conference of ICSOBA, 19th Conference, Aluminium Siberia*, Krasnoyarsk, Russia, September 4 – 6, 2013, 494-498.
5. Ali Al Zarouni et al., DX+, an optimized version of DX technology, *Light Metals* 2012 697–702.
6. Ali Jassim, Use of individual anode current monitoring in Hall-Héroult reduction cells, *PhD Thesis, School of Chemical Engineering, University of New South Wales*, Sydney, Australia, 2016.
7. Martin Segatz, Christian Droste and Detlef Vogelsang, Magnetohydrodynamic effect of anode set pattern on cell performance, *Light Metals* 1997, 352–358.
8. Jeffrey Keniry and Eugene Shaidulin, Anode signal analysis - the next generation in reduction cell control, *Light Metals* 2008, 287–292.