# Successful Potline Operation During Reduced Power at Egyptalum

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**Abstract**

The Aluminium company of Egypt was forced to reduce its energy consumption within 25 days from 18 January to 11 February 2010 during the peak electricity consumption hours (17:00 h to 23:00 h) during the second shift (starting at 15:30 h and ending at 23:30 h). The main goal of Egyptalum was to secure the six prebaked potlines from any harm and to keep the thermal balance as stable as possible. This paper shows the efforts of Egyptalum to deal with the crisis and to get a fast return to normal operation. The cell parameters were studied before, during and after the crisis period. As a result of the individual actions in each potline, varying results were obtained regarding anode effect frequency, cryolite ratio (CR), voltage addition, cell resistance, iron content in the aluminium metal and the total energy consumption.

**Keywords:** Energy reduction, power shut-down, anode effects, iron content in the metal, cryolite ratio

## 1. Introduction

The Egyptian government was interested in building an aluminum smelter "Egyptalum" at of Nag Hammadi desert, main reason for this was the construction of the high dam and surplus of electricity at that time. After many industrial expansions at Egypt and increasing population density, Egypt became in need of multiple sources of electricity after the smugglers generated from the high dam were not enough [1] Egypt has already diversified its sources of electricity and has a unified electricity network with multiple sources.

Egyptalum has six potlines which produces primary aluminium and each line have two potrooms, and each potroom cell has 46 cells, number of cells at the smelter 552 cells and the total production capacity of Egyptalum has reached 320 000 tons of metal per year. Potlines power consumption equals 520 MW and when energy supply reduced the Ministry of Electrical and Energy enforced Egyptalum to reduce its power consumption from 520 MW to 440 MW. This reduction is for eight hours per day throughout the problem period, and the main cause of the reduced energy was heavy rains which knocked out some of high voltage transmission lines from Aswan Governorate to Nag Hammadi city. Egyptalum depends basically on the hydroelectric power which supplied from the high dam, then Egyptalum found itself facing a big problem, that needed a quick solution strategy. Egyptalum has four power stations (A, B, C, D), as shown in Figure 1 which are supplying the electricity to the production lines. Electrical power station A is supplying potlines 1 and 2, electrical power station B is supplying Potline 3, electrical power station C is supplying potlines 4 and 5 and electrical power station D is supplying potline 6.

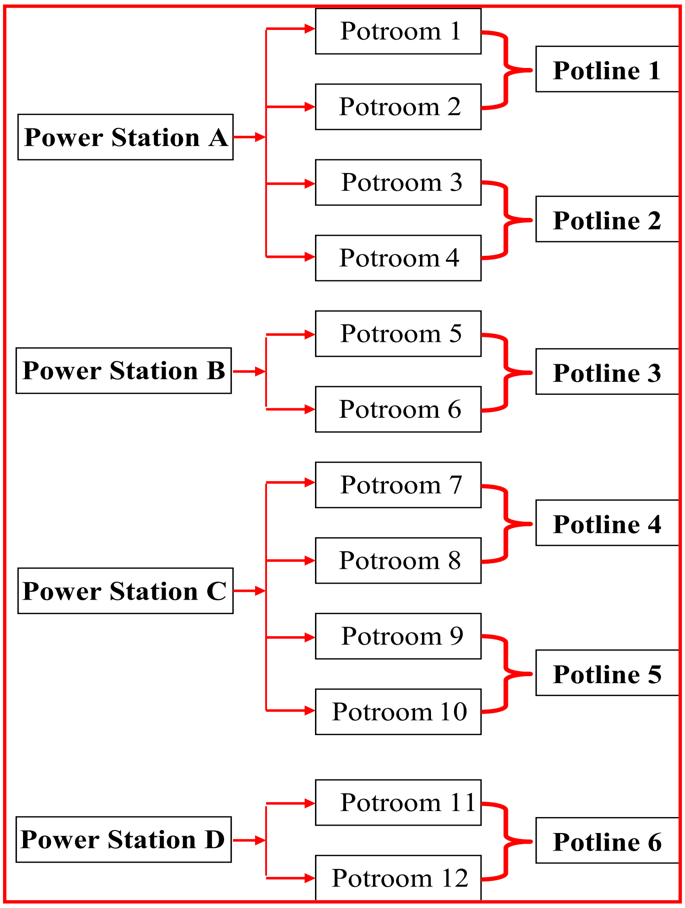


**Figure 1. Power stations and potlines.**

## 2. Strategy

The suggested strategy depended on two possible action plans:

1. Shutdown some pots. In this action Egyptalum must shutdown some pots which compensate the amount of energy reduction.
2. Alternate current off (maneuver) from one potline or more to another for two hours and reduce current for some potlines.

The aluminium company of Egypt chose the second action and in the same time faced many of problems but we successfully overcame these hard times in trying to maintain the thermal balance as stable as possible and reducing the anode effect frequency.

### 2.1. Production Sectors Plan for the Second Action Plan

**First: The effect of power reduction on the cell performance:**
A disturbance in the thermal balance of the cell had happened before which cooled the cell with the result:

- Increased cell ledge [2],
- Extensive ledge toe,
- Increased cell instability,
- Increased anode effect frequency,
- Reduced bath height.

The thickness of the ledge is the result of the complex interaction between heat balance, amperage, bath chemistry, cell resistance, bath movement, etc.

**Second: The change in the work strategy during this period**
The work strategy was changed by implementing some procedures to keep the cells warm, such as:

- The metal height was reduced by 3 - 4 cm in agreement with cast house,
- Increase bath cryolite ratio (decrease excess aluminium fluoride) target [3],
- Raised cell CR set-point from 2.6 - 2.75,
- Increase cell voltage by 100 - 250 mV,
- Increase bath height from 19 to 21 cm by adding solid bath,
- Fresh alumina was added to the cells to decrease the excess aluminium fluoride in the bath,
- Increase anode change cycle from 30 days to 34 days,
- Increase in the anode cover height from 12 to 16 cm,
- Stop of gas exhaust during the current cut-off or during the current reduction,
- Avoid the anode change during the current cut-off shift,
- Do not start-up the shutdown cells,
- Change the cell control system to manual during the current reduction.

**Third: the plan applied to face this event:**

- Feed increased amount of alumina and use green poles to quench anode effects.
- Organize the roles of operators and shift-engineers

**Fourth: losses due to this event**

- Reduction in production due to current efficiency decrease from 94.0 % to 92.1 %).
- Corrosion of anode stubs,
- Increase of iron content in the metal,
- Increase of fumes in the potroom during the period of stopping the gas exhaust,
- Consumption of large quantity of green poles,
- Increase the exertion of the operators**.**

## 3. Operating Parameters

A large number of operating parameters was analysed with respect to the period when all power stations in the company were in operation during the period from 5 January 2010 to 22 January 2010.

### 3.1. Potline Current

Figure 2 shows the steep drop in potline current, where the minimum current during January reached 164 kA where the current was cut-off or reduced during the shift of the peak consumption hours. Thereafter the current started to return to the normal values in February with 205 kA until it reached 210 kA in the second-half of February after the crisis ended.

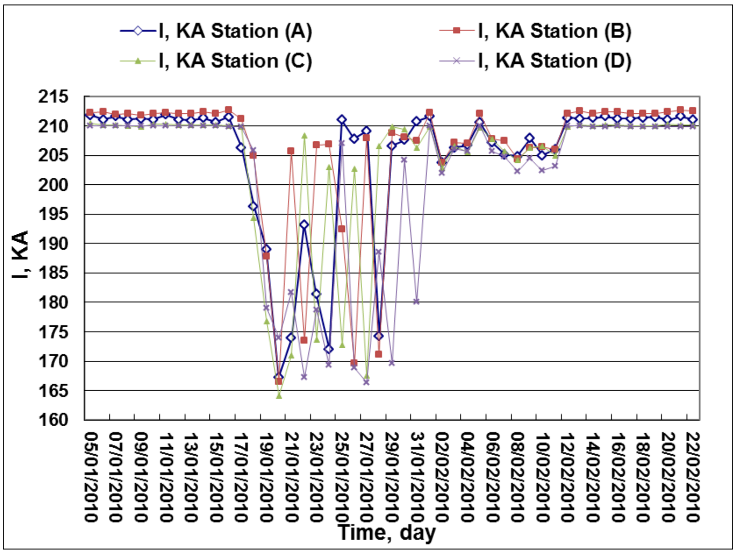


**Figure 2. Variation in potline current for power stations A, B, C and D.**

## 3.2. Pot Setpoint Resistance

Figure 3 shows the variation in setpoint resistance ($R_c$) where the goal is to raise the value of $R_c$ corresponding to cell voltage of 100 - 110 mV to maintain the thermal balance as stable as possible and avoid cooling of the bath.

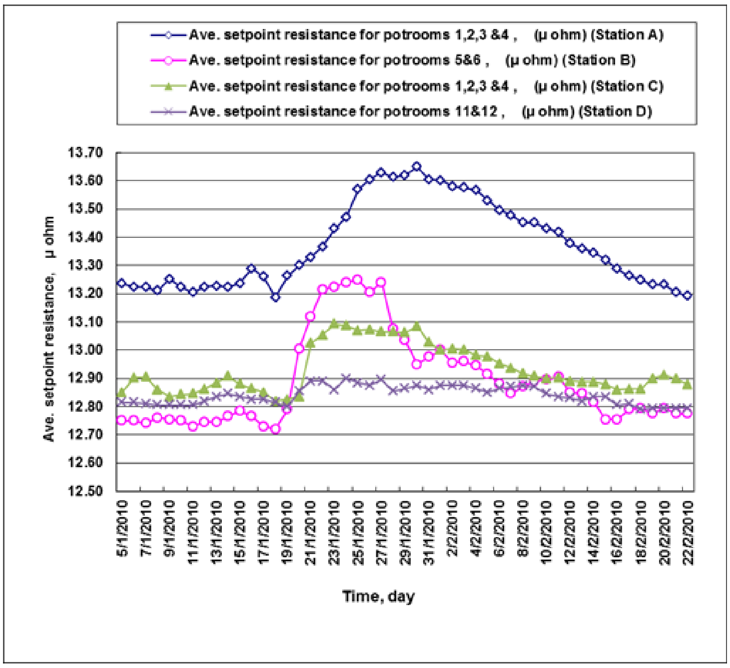


**Figure 3. Variation in set-point resistance for power stations A, B, C and D (average values).**

## 3.3. Cell Voltage

Figure 4 shows the daily oscillation in the cell voltage through the period of reduced power period which is due to the anode effects and the slow anode change cycle. The average cell voltage value under normal conditions at Egyptalum was 4.350 V, during this period average cell voltage value 4.400 V.

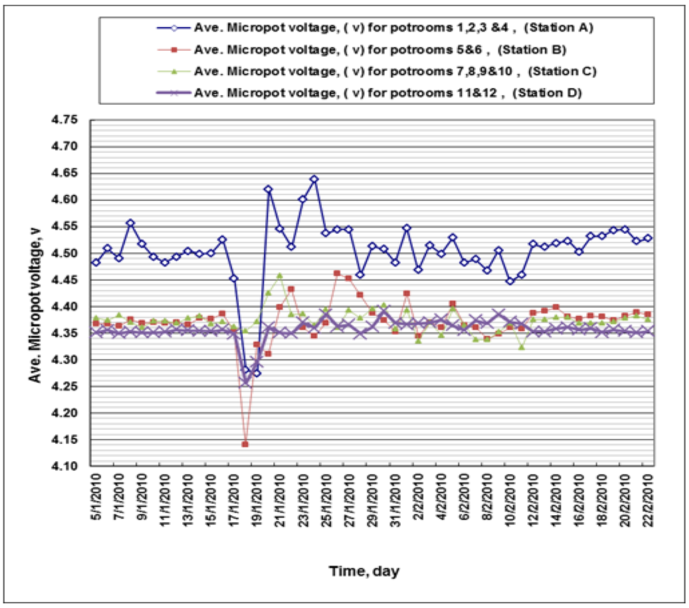


**Figure 4. Average cell voltage for power stations A, B, C and D.**

## 3.4. Anode Effect Frequency (AEF)

Figure 5 shows the increase in the number of anode effects for all the smelter. We can see that after first five days of beginning of power reduction, the operators began to have greater control of anode effects. The average AEF under normal conditions at Egyptalum was 0.116 - 0.210 per cell-day, but during these five days, the average AEF was from 0.51 to 0.57 per cell-day.

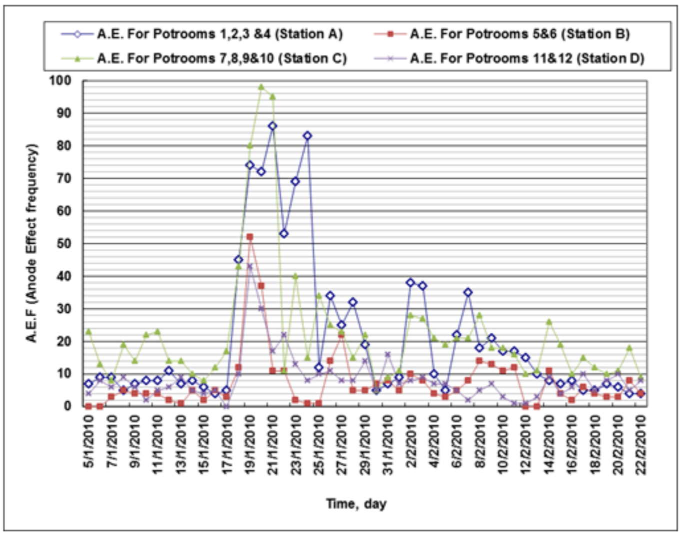


**Figure 5. No. of anode effects per day for power stations A, B, C and D.**

## 3.5. Anode Effect Duration

Figure 6 shows anode effect duration for power stations A, B, C and D and the average values of these duration are 193, 194, 230 and 211 seconds respectively. Average anode effect duration under normal conditions at Egyptalum around 180 seconds.

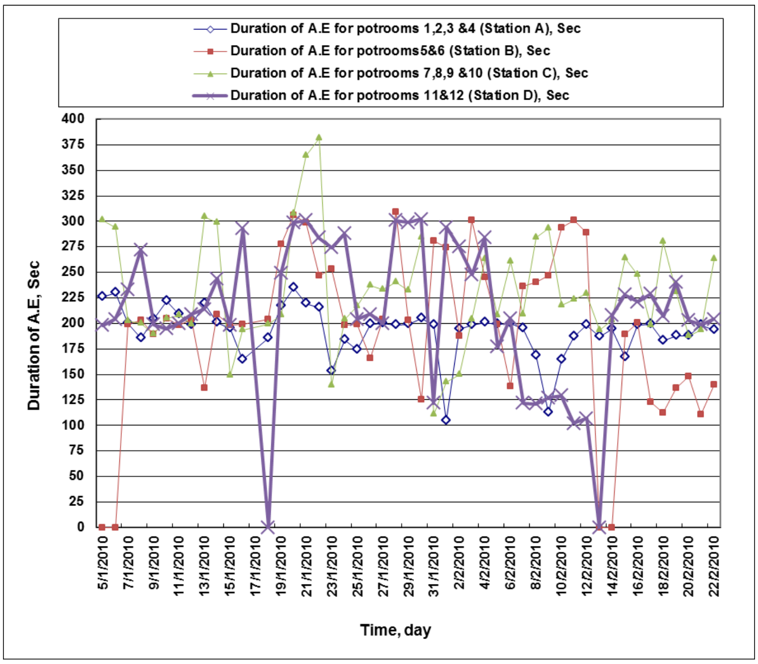


**Figure 6. Anode effect duration per day for power stations A, B, C and D.**

### 3.6. Anode Effect Overvoltage

Anode effect overvoltage is calculated as the average anode effect voltage over the anode effect duration minus average normal pot voltage. Figure 7 shows large increase in anode effect overvoltage during the first two days of the crisis due to increase of the number of anode effects, then it returned to normal number of anode effects but there is still high overvoltage due to the increased duration of anode effects. The total sum of overvoltages during the 25 days of power reduction period for all pots was equal 8348 V; therefore, distributed to 552 cells, the anode effect overvoltage was 15.123 V during the average anode effect duration of 207 seconds.

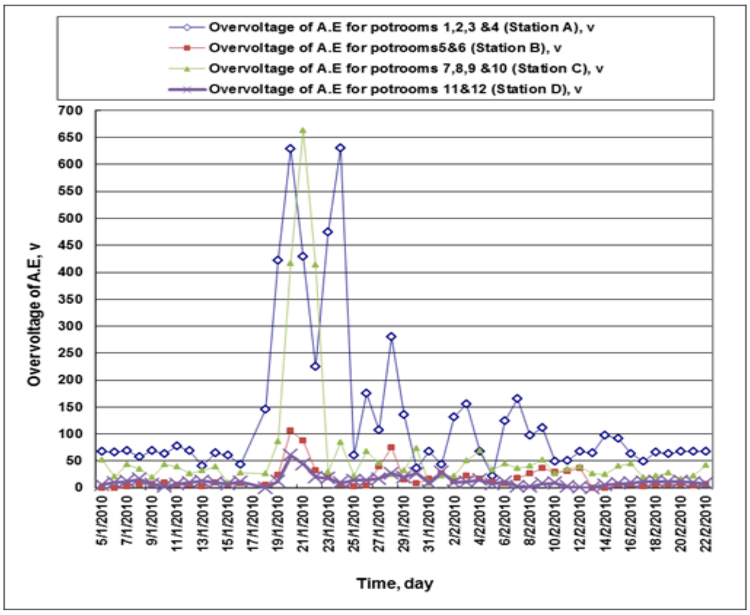


**Figure 7. Overvoltage for power stations A, B, C and D.**

### 3.7. Energy Consumption (kWh/t Al)

Figure 8 shows gross DC energy consumption (which includes potline busbar linkages) for power stations A, B, C and D. During that period average energy consumption was 14 396 kWh/t Al, this is within acceptable limits, considering the challenges we were facing during that period. The average value of energy consumption in normal conditions at Egyptalum 14 000 – 14 100 kWh/t Al.

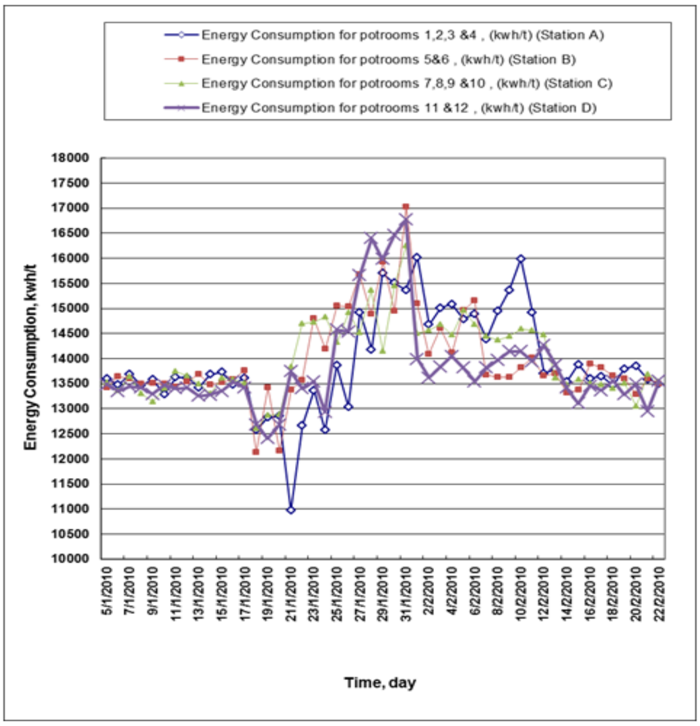


**Figure 8. Energy consumption for power stations A, B, C and D.**

### 3.8. Duration of Current Cut-off

Figure 9 shows duration of current cut-off where the duration of zero value means that potrooms had only reduced current. Periods of electric current cut-off, based on our decision, ranged from 36 to 92 minutes alternating between the production lines to maintain the thermal balance of the cells as much as possible. Total hours of current cut-off during that period was about 34 hours.

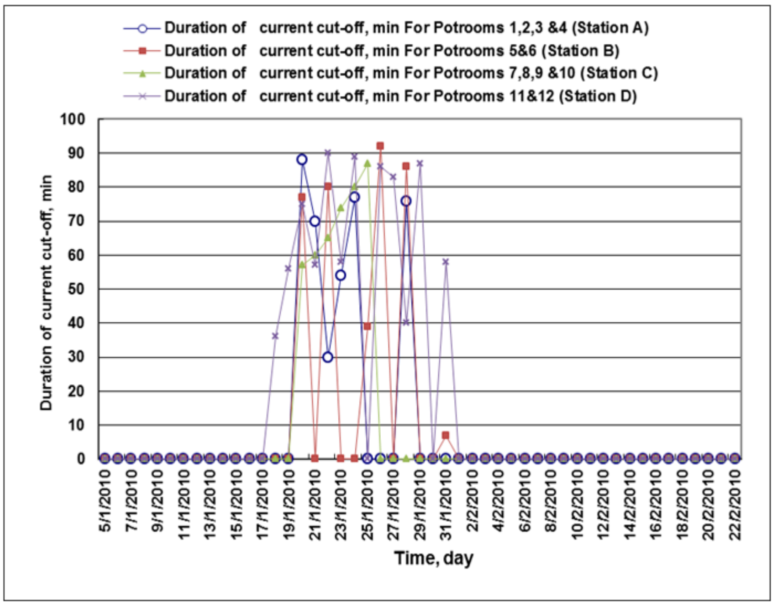


**Figure 9. Duration of current cut-off for power stations A, B, C and D.**

### 3.9. Average Bath Temperature During Second Shift

Average bath temperature by station is shown in Figure 10. Normal scheduled frequency of temperature measurement is twice a week but during the crisis it became once a week to keep the cell as hot as possible. The temperature range for all cells during this period was between 959 to 979 °C, except for Station A which was higher as seen in Figure 6. The average age of cells in station A was lower than the rest of the cells in the smelter. Therefore, we deliberately raised the heat of these cells in station A because they were more resistant to thermal stress, and more voltage compensation was applied after the period of current reduction.

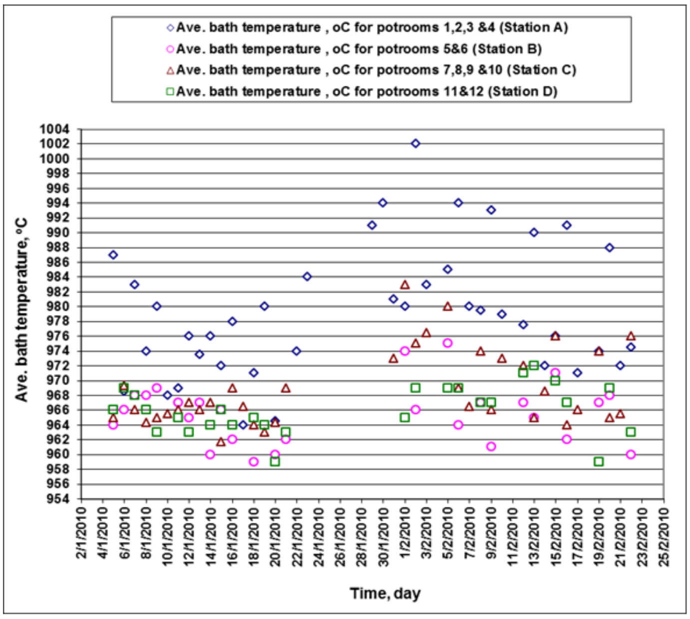


**Figure 10. Average bath temperature during second shift for power stations A, B, C and D.**

### 3.10. Average Iron Content

The delay in anode changing, which reached 34 days instead of 30 days, led to an increase in the iron content in the metal in a somewhat acceptable manner. This delay of anode change was intended to maintain the thermal balance of cells so that, as much as possible, the cell was not exposed to any operations performed which reduce bath temperature. The percentage of Fe in the metal ranged from 0.07 % to 0.27 % (Figure 11). Average Fe % in the metal during this period was 0.14 % in comparison to 0.05 % to 0.07 % in normal operation.

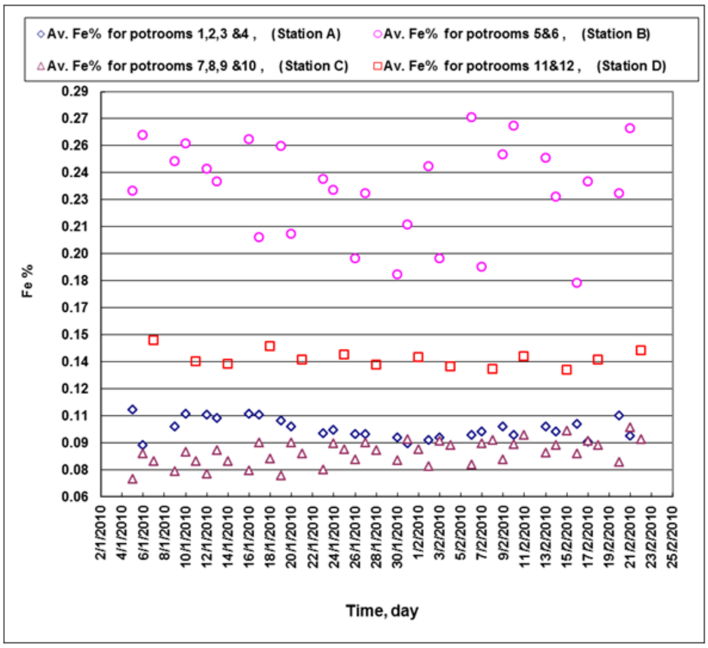


**Figure 11. Average iron content for power stations A, B, C and D.**

### 3.11. Average Cryolite Ratio

During this period, we decreased excess aluminium fluoride target in the bath. This procedure was done to keep the cell temperatures at their highest possible levels. Accordingly, the cryolite ratio (CR) increased as shown in Figure 12. The average value of CR under normal conditions at Egyptalum is 2.42. However, during this period, due to suspension of aluminum fluoride feeders, CR values ranged from 2.59 to 2.93 and the average value was 2.73.

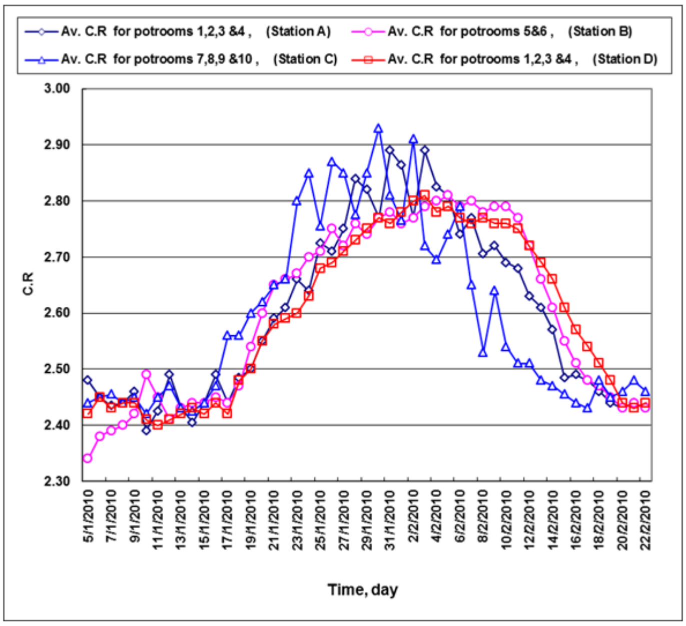


**Figure 12. Average cryolite ratio for power stations A, B, C and D.**

## 4. Conclusions

The actions taken were effective to maintain the control of the pots and to survive the critical power reduction. Of course, we faced operational difficulties such as increased number of anode effects which we decided to quenched manually.

This was a very hard time for Egyptalum team and the successful outcome was the result of good teamwork where the skills, and strengths of everyone were put together.

## 5. Acknowledgement

We would like to thank Mr. Said Abd EL Wahab (CEO) for unconditional support he gave us during this period. Special thanks also to the sectors and all the workers of Egyptalum for extra effort to pass the crisis of reduced power.

## 6. References

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