SIMULTANEOUS PREHEATING AND FAST RESTART OF 50 ALUMINIUM REDUCTION CELLS IN AN IDLED POTLINE

A new soft restart technique for a potline

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Abstract

Due to the global economical crisis a significant amount of primary aluminium production capacity has been shutdown. A number of different strategies to restart idled aluminium reduction cells have been discussed in the literature [1, 2]. This paper describes the successful development and execution of the start-up of 50 cells simultaneously in one potline. The procedure is based on restarting reduction cells using a cold metal plate. Contrary to electrical preheating of new cells with use of cokes or graphite, these cells have been prepared with anodes positioned in direct contact and on top of the cold metal plate. The rate of preheating of the cells and associated melting of metal is controlled by a gradual line current increase. The actual start-up of the cells is performed sequentially by the addition of liquid electrolyte and moving the anode beam upwards. In this respect 50 cells have been preheated and restarted in 8 days.

Introduction

A complete shut down and restart of a large number of cells is not a practice that a smelter carries out regularly, because of the time consuming characteristics and additional costs involved. At Aldel, the last shutdown and start-up was after a fire in the transformer building in 1977. However, due to the economical circumstances, Aldel has decreased its annual production capacity by 40% with the closure of Potline 1 in 2009. This capacity was partly taken into operation again by June 2010. Generally a pre-heat and start-up of a whole potline is carried out cell by cell. However, this is not possible at Aldel due to the configuration of the rectifiers. The rectifiers require a minimum voltage of 110 V, which is equivalent to 24 cells running at 142 kA. Since this is not achievable instantaneously, a new method was developed to restart one cell at a time while maintaining the total line voltage above the required level.

During the design and development phase of the restart method, it was clear that preheating a large number of cells simultaneously offered the best option in terms of maintaining the required voltage and associated stability of the line current. In contrast to cold crash starts this method provides a soft and fast sequential start-up of a large number of cells (50 cells in this case).

In order to develop a dedicated start-up procedure a number of industrial experiments were carried out in the remaining operating potline. In addition to the minimum required voltage, the current distribution within the cathode collector bars is of main concern.

The tests confirmed that a ‘gradual amperage increase’ start-up was possible and that the required minimum line voltage and a controlled current distribution within the cathode bars could be achieved. The main focus of the start-up procedure is keeping the line voltage high enough to prevent the rectifiers from increasing the amperage above safe operating levels.

Several methods for preheating were tested. Although these methods demonstrate more or less the same outcome in respect to the voltage characteristics per cell, the cathode current distribution between the individual collector bars shows large variations. The anode current distribution was identically sensitive to the rate at which the amperage was increased over time.

Restart restrictions

For the restart of Potline 1 a number of restrictions were identified that determine the characteristics of the new method. Prior to the shutdown these restrictions and associated actions were clarified.

Cell conservation

The shutdown procedure was linked to the condition of each cell in order to be prepared for preheat and restart. Cells that were not considered for restart were completely drained of metal. Cells that were suitable for the new preheating and restart method were preserved with a metal pad layer of 10 cm. This was undertaken to protect the cathode surface during the shutdown period, provide a flat and conductive base for positioning the anodes during preheat, and to protect the surface during liquid bath mass transfer (slow down the rate of increase of the cathode temperature).

Rectifiers

Potline 1 has five rectifiers with a capacity of 40 kA each. Four of these rectifiers were built by Siemens in 1965. The minimum voltage of these rectifiers in the lower voltage range is 110 V. If the voltage falls below this voltage, the rectifiers automatically compensate by increasing the amperage. In 2006 a new rectifier ("E11") was added to the potline in order to secure N-1 operation and to increase the line current. This rectifier operates in the range of 0-370 V.

Bath transfer

The liquid bath transfer during start-up of the first cells must be done from Potline 2. If cells are preheated simultaneously, the rate of bath supply is obviously higher than in a normal cell by cell.
restart. Also, the rate of bath production after start-up is much higher because of the smooth and complete preheating of the cells. With this bath production, the bath levels can increase fast creating the cells with high iron. In this respect the logistics and management of the bath transfers are of critical importance.

Testing

In preparation of the start-up of Potline 1, a number of preheating methods were developed and tested. These investigations were conducted in Potline 2 and were focused on the identification of potential constraints in respect to the preheating and start-up. A method was developed using a predefined metal thickness and a flat metal pad to ensure good electrical contact between the anode and the metal plate. An average resistance curve for a cell was determined, which was used as the basis for the ramp-up of the line amperage and the start-up of the cells in Potline 1.

At Aldel, two independent mechanisms according the overall line voltage development are important. These mechanisms are related to the preheating curve defined by the gradual stabilization of the anode and cathode current distributions, and the voltage behavior of a cell after liquid bath addition. Both mechanisms determine the balance between the rate of decrease in the overall line voltage due to preheating and the increase in the voltage due to sequential start-ups.

Test set-up of cell

During the shutdown of Potline 1, a strong emphasis was put on the conservation of the cell condition. However, it was found that the surface of the remaining metal pad was still not smooth enough to ensure good electrical contact. Therefore the cathode surface had to be flattened out by casting additional metal into the cell. Figure 1 shows the flattened surface with a number of anodes positioned on the surface in Potline 1.

The anodes were put on top of the flattened metal surface and surrounded by hardboard. Coarse grain crushed bath material was poured between the hardboard and the remaining side ledge to protect and build new side ledge during the start-up phase, and to generate additional bath material for the start-up of other cells. On top of the anodes a thick layer of insulation material and bath material was positioned to prevent anode airburn completely (given that the preheat period would extend for a number of days) and also to generate extra bath material. Figure 2 shows the set-up of a cell in Potline 2. The amount of bath material for covering cells in Potline 1 was increased in such a way that the insulation layer was not visible.

Figure 2: Test setup of cell in Potline 2

Preheat curve

Before the start-up of Potline 1 it was very important to get a clear indication of the voltage development related to the actual current and ramp-up rate. First of all, the cells needed enough voltage to generate 110 V across the line, for stability of the line amperage at a controlled target. Secondly, it was important to understand the characteristics of the voltage development during the preheating phase. Experiments showed a fast decline in the voltage during preheating. The rate of decline depends critically on the rate of line current increase, the actual current and the initial current distribution in the cathode bars. The latter itself dependents on the rate of current ramp-up - a more even current distribution is obtained when the current is ramped up more slowly over days.

Because the experiments were carried out in a running potline, the period of the ramp-up was limited to 2 hours. It was found that several connections between the cathode bars and bus bars were lost as a consequence of rapid current increase. Due to the end-to-end configuration of the potline most of the current enters and leaves the cell at the ends. However, it was not possible to predict the specific cathode bars causing most of the problems. In some cases a particular collector bar drew 50% of the total current during the ramp-up. It was found that hot cathode bars remain consistently above a line current of 40 kA. These bars had to be controlled with additional cooling above 80 kA. This phenomenon is probably due to the expansion of the cast iron in the cathode block during preheating.

Figure 3 shows the preheating curve of a cell tested in Potline 2. Initially the resistance is high - equivalent to 6 V at 120 kA. During the current increase one of the cathode bars disconnected from the cell. After approximately 9 hours at full current, the voltage drops gradually to 3 V. The cell stays at this level for 2 days. The temperature in this period is equally distributed and increased in the cell. The metal reaches an average temperature of approximate 400°C before the voltage decreases to 1.5 V. At this point, the metal is liquid, after which the cell can be started.