Stabilizing Aluminium Reduction Cells by Oscillating Currents in Magnetic Compensation Loops

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Abstract

It was observed in a numerical study reported in [1] and [2] that the MHD stability of aluminium reduction cells can be increased by oscillating the current of the potline. A smelter performing this kind of potline current modulation would have modulated power demand that could be problematic for the power grid operation. For that reason, the effect of oscillating the currents in magnetic compensation loops on the cell stability keeping the potline current constant was studied. The same stabilizing effect is observed. Performing this current oscillation in magnetic compensation loops would reduce the modulated demand of the smelter. The smelter modulated demand would be reduced to zero if superconductor busbars are used to build those magnetic compensation loops.

Keywords: Aluminium reduction cells, Modeling and simulation, Magnetohydrodynamics, Cell Stability, Oscillating currents

1. Introduction

The idea of oscillating the potline current in order to increase the stability of the cells is originating from Prof. Douglas Kelley and his research group at Rochester University [1] and [2]. That idea was inspired by the physics of the Kapitza's pendulum [3]. The Kapitza's pendulum is a reversed rigid pendulum that has an unstable rest position at zero degree of inclination. Yet that position becomes stable when the pendulum is oscillating vertically. Reference [4] presents a stability analysis of the system identifying zone of stability in function of both the amplitude and the frequency of that vertical oscillation.

In order to theoretically investigate the idea of increasing the stability of an aluminium reduction cell by oscillating the current of the potline, the concept was tested on the "Davidson's mobile" [5]. The Davidson's mobile displayed in Figure 1 is a simple imaginary system that behaves very similarly to an aluminium reduction cell. Depending on the values of the different parameters like B_z, J_0 and h_0, the system can be stable or unstable.

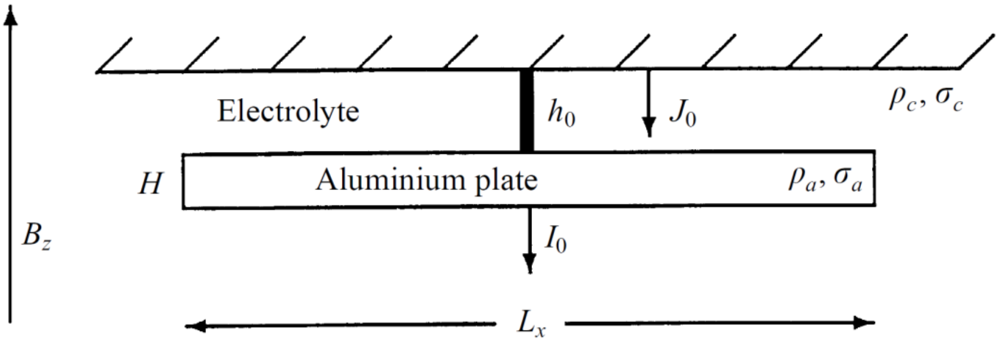

Figure 1. Davidson's mobile, Figure 4 of [5].

In a stability analysis very similar to the one presented in [4], it was demonstrated in [6] that oscillating the current J_0 increases the stability of the system depending of the selected amplitude and frequency of the oscillation.

As a next step, the MHD cell stability code MHD-Valdis was modified to incorporate the option to oscillate the potline current during the transient simulation of the interface wave evolution. Unfortunately, it is not possible to do a thorough investigation of the system stability situation for all possible combinations of the current oscillation amplitude and frequency as investigating a single combination requires an overnight run on the computer. Yet, as reported in [1] and [2], for the selected 180 kA TRIMET cell located in Hamburg, a 22 % potline current amplitude oscillation at 0.04545 Hz frequency or 22 s. period, increases the cell stability. As explained in [1] and [2], the stabilization is achieved by exciting a combined (4, 0) (0, 2) standing wave which is preventing the less stable combined (2, 0) (0, 1) (1, 1) rotating wave to grow.

Performing that 22 % current oscillation on the potline would produce about a 36 % power demand oscillation for that potline which in that case constitutes two third of the smelter consuming about 210 MW when operating at 180 kA. Even if the rectifiers could be adapted to deliver that 22 % current oscillation at 0.04545 Hz to the potline, the power grid would probably not appreciate the associated smelter continuous power demand oscillation at that frequency.

For that practical reason, it was decided to investigate another way to achieve the same stabilizing effect. One can speculate that oscillating the magnetic field B_z instead of the current in the Davidson's mobile system would produce the same stabilizing effect. This could be mathematically demonstrated, but that step was bypassed here. Instead, the MHD-Valdis code was again modified for this time add the option to oscillate the current in external magnetic compensation loops during the transient simulation of the interface wave evolution to be able to investigate if that oscillation would also increase the cell stability.

2. Addition of Two Magnetic Compensation Loops to the TRIMET 180 kA Cell

The Hamburg smelter was built by Reynolds Aluminum company using its P-19, side by side, end risers, side broken, 145 kA prebaked cell technology designed in the 60s. The smelter started its operation in 1974. About 20 years later, the busbar layout was retrofitted by VAW from four end risers to two end risers and two side risers. As presented in Figure 2 from [7], this change very significantly improved the cell stability by reducing the B_z intensity by close to 60 %. After this change plus the introduction of poor man point feeders and a longer anode, it became possible to increase the cell amperage to 180 kA.

Despite that major improvement of the B_z, the presence of the two remaining end risers still generates enough B_z to force operation at about 4.3 cm anode-cathode distance (ACD) in order to keep the cell stable. This is confirmed by the cell stability study presented in Figure 3. It would be possible to do much better these days as per example the retrofit of the SM-17SE into the SY-235 by SAMI [8]. But that would require again a major retrofit of the busbar network. Alternatively, it is possible to reduce the B_z intensity by adding two external magnetic compensation loops.

This option was tested using the same TRIMET 180 kA MHD-Valdis model developed in [9] and used in [1] and [2]. Figure 4 presents the B_z obtained using the base case MHD-Valdis model without magnetic compensation loops. The results are quite similar but not identical to those obtained in [7], but it was recently discovered that the pot row to pot row distance used to develop the model in [9] and used for this study was not accurate. In any case, the work presented here is just a theoretical exercise. Figure 5 is presenting the busbar network after the addition of the two magnetic compensation loops. Figures 6a shows the modified B_z when 20 kA is circulating into

7. Conclusions

It has been demonstrated that oscillating the current in compensation busbar, i.e., performing dynamic magnetic compensation, is also stabilizing the cell. The effect is cumulative over static magnetic compensation, so performing dynamic compensation over the optimum static compensation will further stabilize the cell, permitting further reduction of the ACD.

Performing dynamic compensation using superconductor busbar magnetic compensation loops should only have a marginal impact on a smelter dynamic power demand.

It is speculated that performing dynamic compensation should not significantly affect the cell current efficiency. Only industrial trials will permit to verify if that speculation is true or not.

8. References

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