Decarbonisation of Aluminium Production by Demand Side Response

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Abstract

Many smelters in future will need to reduce their dependence on baseload power generation and increase their usage of renewable energy, to create lower emission products, and assist decarbonization of global power grids. One pathway to do this is power modulation, to align smelter power consumption with variable energy availability. The retrofittable EnPot technology can enable +/-20 % modulation at any time, while maintaining cell heat balance, or larger modulations for extended periods. Decarbonizing the power system provides by far the greatest driver to reduce the carbon footprint of aluminium and firming of Variable Renewable Energy (VRE) via smelter modulation is the cheapest way to achieve this, thereby attracting governmental attention and potential funding. A detailed energy market analysis shows that beyond the decarbonization benefits, modulation is also economically advantageous, and opens the door to several ways of sharing the value of lower energy prices between smelters, generators, and grid operators.

Keywords: Power modulation, Emissions, Decarbonization, Heat transfer, Energy.

1. Introduction

Heat balance control allows the smelter power usage to be modulated significantly both upwards and downwards, where previously almost constant power loads have been required. Being able to vary loads will make aluminium smelters much more compatible with future power grids featuring more variable renewable energy (VRE), as well as providing valuable services to support more renewable grids. Because power generation is by far the largest component of the aluminium industry's CO_2 emissions, enabling the transition away from power generation via fossil fuels is the single most significant way to accelerate the decarbonization of aluminium smelting as we know it today.

2. EnPot Technology

EnPot is a breakthrough technology for smelting cell heat balance control that was developed by the Light Metals Research Centre at the University of Auckland. The key feature of EnPot technology is the patented shell heat exchanger (SHE) units which cover the upper sidewall of each smelting cell and are connected to a duct network with suction fans (Figure 1). The airflow through the system can be varied, such that high airflow gives significantly increased heat transfer from the sidewalls, while lower airflow, below a base demand, results in cell insulation [1,2].
Power modulation in a smelter means increasing or decreasing line amperage. At higher amperage cells need to shed more heat while at lower amperages it is necessary to retain more heat in the process. The cooling and insulation capability of EnPot enables smelters to modulate their power usage by approximately ±20 % at any time, for any duration, where the heat balance

of the pots is always maintained. Larger modulations of up to ±30 % are also possible when coupled with other process changes such as anode cover thickness, or pot suction draught rates, which may take approximately one month (one anode cycle) to practically implement, and so cannot be used spontaneously. The insulating ability of EnPot furthermore allows full shutdown of potlines for approximately twice the duration that can be achieved naturally, while allowing safe restart of pots afterwards, as well as enhanced protection at times of unexpected power loss.

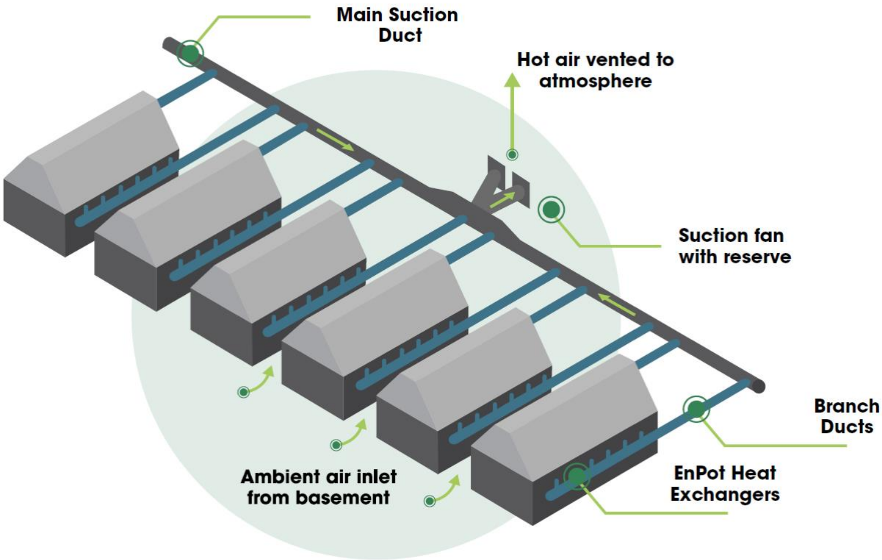

Figure 1. Ducted network for a section of aluminium smelting cells with installed EnPot heat exchangers.

3. Aluminium Decarbonisation

The aluminium smelting process emitted an average of 12.3 tonnes of CO_2-equivalent emissions from per tonne of primary aluminium globally in 2019. This includes 2.0 t CO_2e/t Al direct emissions from the reduction process (Scope 1), and 10.3 t CO_2e/t Al emissions from electricity generation (Scope 2) [5]. The much larger Scope 2 component occurs because of the carbon-intensive sources of power used worldwide for aluminium production, largely consisting of coal (64 %) and gas (10 %) powered generation, with only 27 % of production from low-carbon sources such as hydro [5].

Previous articles have investigated possible pathways for the global smelting industry to decarbonize and reach 'net zero' by 2050 [3, 10], utilizing key technologies including inert anodes, energy efficiency improvements, and avoiding scope 2 emissions by changing the sources of energy generation. Figure 2 shows a 'high growth' scenario of 3.8 % annual production increases until 2050, and the relative impacts of these technologies to reach net zero carbon. Decarbonisation of the power system, by reduction of Scope 2 emissions, is clearly the much larger and more pressing aspect when compared with Scope 1 reductions.

7. Barriers for Adoption

The technical development of the EnPot system was completed via trial at several smelters by the Light Metals Research Centre at the University of Auckland [1, 11, 12]. It is currently operational on a full potline at the TRIMET Essen smelter [2, 13] and a 10-pot section at TRIMET Hamburg. A key barrier for further adoption is general industry acceptance of the performance and robustness of the technology, and EnPot's intention is to prove this via subsequent demonstration trials on other pot technologies, operating in other electricity markets. EnPot is ready for full-potline or smelter implementations once the technology has been accepted by a smelter.

Depending on the electricity market and prevailing conditions, paybacks have been calculated from between 1 and 4 years for an EnPot installation. At the longer end, this can be challenging when some smelters are operating with short power purchase agreements of similar duration. Power purchase agreements also need to be updated to appropriately value modulation by the smelter. Rapidly changing power markets and increasing value for modulation as detailed above may give shorter and more favourable payback periods, however these rapid changes and instability may also discourage investments. It is encouraging however that governments, energy providers, and wider industry are all rapidly pivoting towards net-zero carbon emission goals, and funding is becoming available for investments such as EnPot. Involving multiple partners such as governments, energy grid operators, green funds, as well as smelters may result in complicated and slow-moving negotiations however, which may be less preferable than smelter-funded.

8. Conclusions

Decarbonisation of power systems by increasing VRE generation is by far the most impactful way to reduce Scope 2 CO_2 emissions of aluminium smelters. However, VRE has significant firming requirements be useful for smelters that have traditionally required very stable energy input. EnPot technology is the most cost effective solution to deal with varying power availability, to firm up to 40 % of smelter power needs, and allow smelters to benefit commercially from providing these firming services to their electricity markets.

Modelling was undertaken to examine the value of smelter modulation in a specific energy market, showing value of € 34 M p.a for a 500 MW smelter, based on expert forecasts from 2020-2040. Rapid changes in energy markets, and energy crises in the last two years however have shown that value could have increased to as much as € 67 M p.a already, making payback periods for an EnPot installation much shorter. These energy market challenges are expected to continue into the foreseeable future, or at least until the end of 2024, according to the World Bank [18]. Combined with increased governmental, corporate and consumer desires to decarbonise, smelter power modulation is a very attractive proposition.

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