Energy Modulation of Aluminium Smelters

THIS DOCUMENT SETS OUT THE LIMITATIONS ON HOW SMELTERS CAN VARY THEIR POWER USAGE, AND HOW IT CAN BE DRAMATICALLY IMPROVED USING ENPOT TECHNOLOGY

STATUS QUO (WITHOUT MODULATION TECHNOLOGY)

Aluminium smelters operate with a specific energy consumption per tonne of aluminium produced (controlled both in terms of amperage and voltage), as well as a designed heat loss, which is critical to maintaining the heat balance of the reduction cells (pots). Operation can only exist within a very small window around this set-point, and operation outside of this window requires compensatory actions to be taken to avoid potentially catastrophic harm to the process.

Without EnPot, any period of energy use below the set-point will cause an energy deficit to accumulate, (as the rate of heat loss cannot be altered and pot is no longer "heat balanced".) This causes the internal temperature of the pot to drop. If the internal pot temperature drops to below the 'freezing' point of the electrolyte, catastrophic failure will occur. With a full power outage this can occur in as little as 4 hours.

Every period of energy deficit therefore requires a subsequent compensating period of energy surplus to increase internal heat and restore the set-point heat balance in the pot, – a 'recharging phase' in other words.

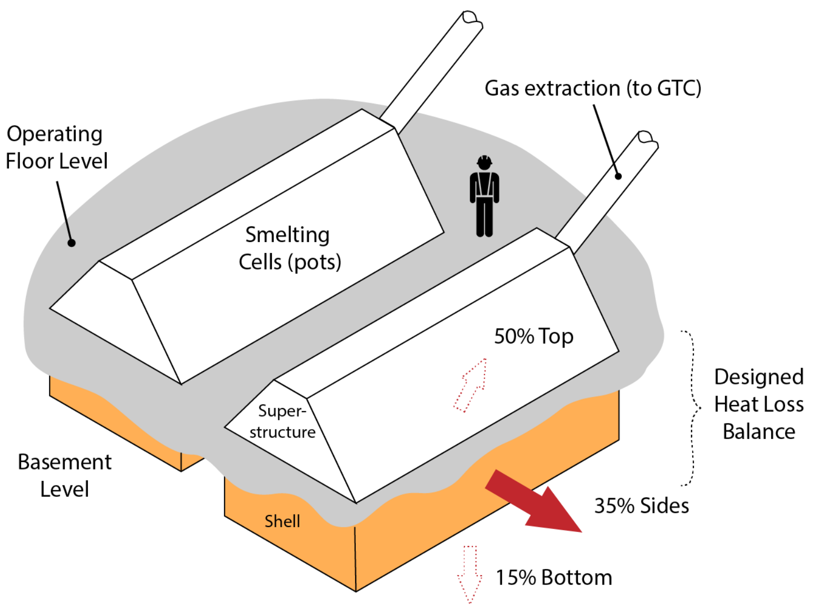

Figure 9 - DESIGNED HEAT LOSS *Approximately half of the energy consumed in an aluminium reduction cell is used to make metal, while the remaining half must be lost as waste heat to preserve the delicate energy balance of the cell. Of the heat lost, approximately 50% is from the top of the pot is by way of fume gas extraction to the Gas Treatment Centre. Natural convection to the pot surrounds from the sides (35%) and bottom (15%) account for the remainder.*

- There are two methods of restoring heat balance (recharging):
  1. increasing amperage above the set point (while maintaining set point voltage).
  2. increasing voltage above the set point (while returning to set point amperage).
- It should be noted here that the rate of production of aluminium is directly proportional to the amperage used. Therefore, any change in amperage (either plus or minus) will result in a directly correlated increase or decrease in production. An increase in voltage, however, restores heat, but does not increase production, so is partially wasted energy.
- In the same manner as decreasing energy, when the energy use is increased above the set point, the internal temperature of the pot starts to rise because more internal heat is being generated, but the same amount of heat is being lost from the sidewalls.

RESTORING HEAT BALANCE THROUGH INCREASED AMPERAGE
(WITHOUT ENPOT)

Figure 10 shows the effect of reducing amperage by 20% for 2 hours and restoring heat balance through increasing amperage 5% beyond the setpoint.

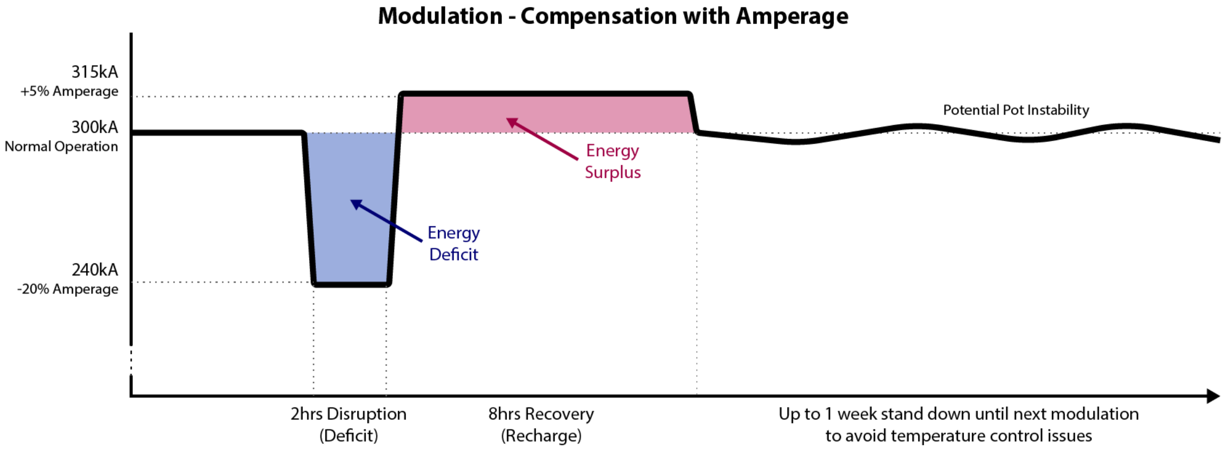

Figure 10

Amperage compensation would result in a greater amount of metal being produced during the energy surplus phase, so overall the same quantity of metal is produced at the same specific energy per tonne of Al produced as when at the normal set point. The lesser metal production during the energy deficit period will be 'made up for' by greater metal production during the energy surplus period.

RESTORING HEAT BALANCE BY INCREASING VOLTAGE
(WITHOUT ENPOT)

Many smelters (by design and installed infrastructure) have setpoints very close to their amperage ceiling and cannot recharge faster, therefore to restore lost heat in the pots they alternatively are required to increase voltage.

This model shows the effect of reducing amperage by 20% for 2 hours and restoring heat balance through increasing voltage above the setpoint.

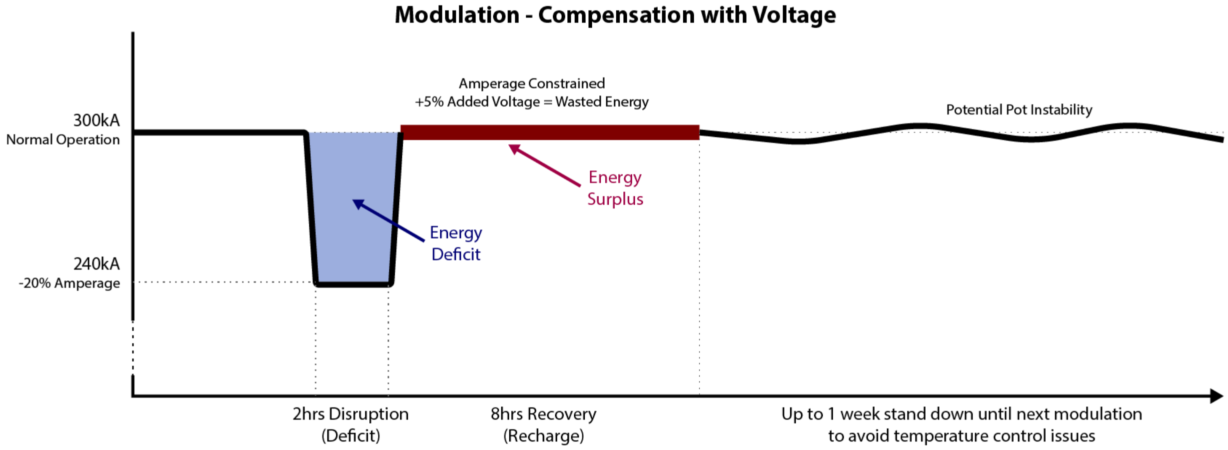

Figure 11

Increasing the voltage will increase the specific energy use per tonne of Al produced, as this extra energy input is only as heat and does not contribute to extra metal production (as increased amperage does).

Accordingly, the lesser metal production during the energy deficit period will not be 'made up for' during the energy surplus period. Therefore, the total metal production is less, and the metal produced in the recharge period will use more energy per tonne than when at the setpoint.

Energy Use Window Over Time with EnPot Energy Modulation technology

GOING DOWN IN AMPERAGE WITH ENPOT

The EnPot heat exchangers, when used in insulating mode to reduce the heat transfer rate through the sidewalls, can achieve a new heat balance at a lower overall energy input, therefore maintaining stable operating temperature inside the pot. (see 'How EnPot Works').

Figure 12 shows the instantaneous amperage reduction available with EnPot is circa -20%, with a further -10% available if the potlines are subsequently stepped-down further over a longer transition period (this is useful to respond to longer duration market conditions or in the case of a seasonal downturn.)

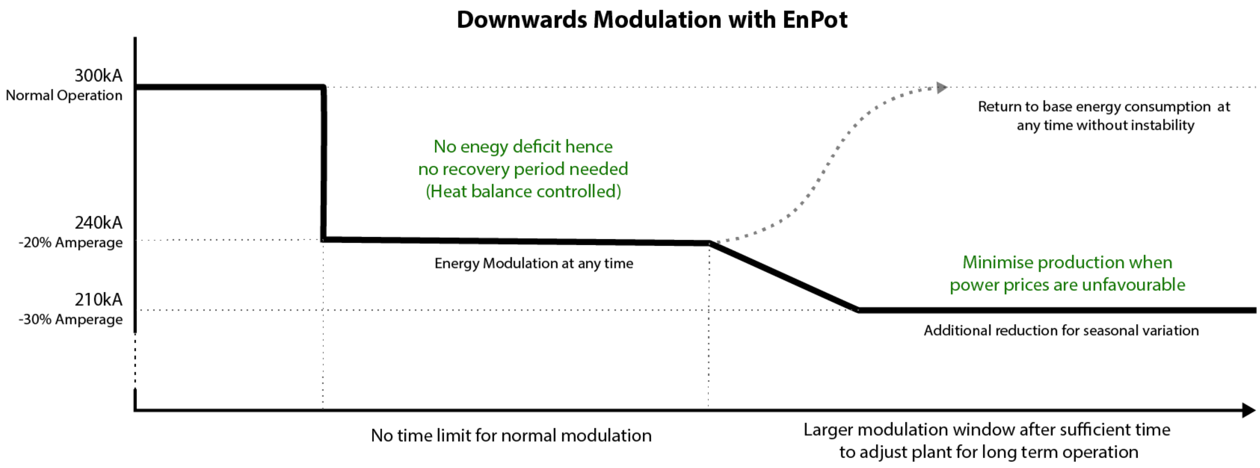

Figure 12

Because the pot is always operated in an energy balanced mode, there is no deficit of energy accumulated during the reduced energy period. Therefore, no recharge phase is required when returning to the setpoint, and the specific energy consumption per tonne of aluminium produced is not affected following modulation down.

EnPot has been proven to improve the specific energy consumption per tonne of Al produced (even when operating at the nominal potline amperage), by improving the heat balance of the pot and allowing optimisation of the anode-cathode-distance (ACD). Furthermore, because EnPot ensures the pots remain in heat balance when modulating down, smelters are able to stay at the reduced amperage indefinitely or may go down and back up in amperage multiple times for varying durations, as may be required to match energy availability.

GOING UP IN AMPERAGE WITH ENPOT

Once installed, the EnPot modulation technology allows for both upwards and downwards modulation, by as much as 30%.

As mentioned earlier however, smelters may have energy use ceilings which means they cannot increase amperage by design and with the existing plant, and may require infrastructure upgrades in order to deliver more amperage to the pots.

Figure 13 shows the instantaneous amperage increase available with EnPot is circa +20%, with a further +10% available if the potlines are subsequently stepped-up further over a longer transition period.

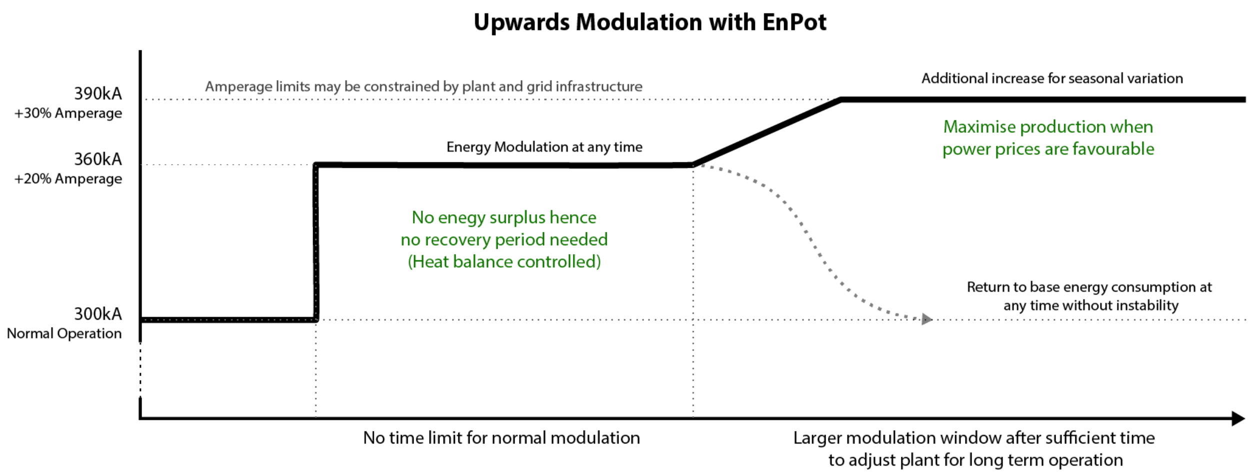

Figure 13

The EnPot heat exchangers, when used in cooling mode to increase the heat transfer rate through the sidewalls, can achieve a new heat balance at a higher overall energy input, therefore maintaining stable operating temperature inside the pot. (see 'How EnPot Works').

Because the pot is always operated in an energy balanced mode, there is no surplus of energy accumulated during the increased energy period. Therefore no discharge phase is required when returning to the setpoint, and the specific energy consumption per tonne of aluminium produced is not affected.

DAILY MODULATION NOW POSSIBLE WITH ENPOT

The EnPot heat exchanger technology allows both upwards and downwards modulation of energy in the same 24 hour period.

Figure 14 shows how EnPot allows a smelter to more closely match their daily energy use with the peaks and troughs of demand in the grid, as the enlarged energy-use window allows smelters to repeatedly modulate amperage within the ± 20% band without affecting heat balance.

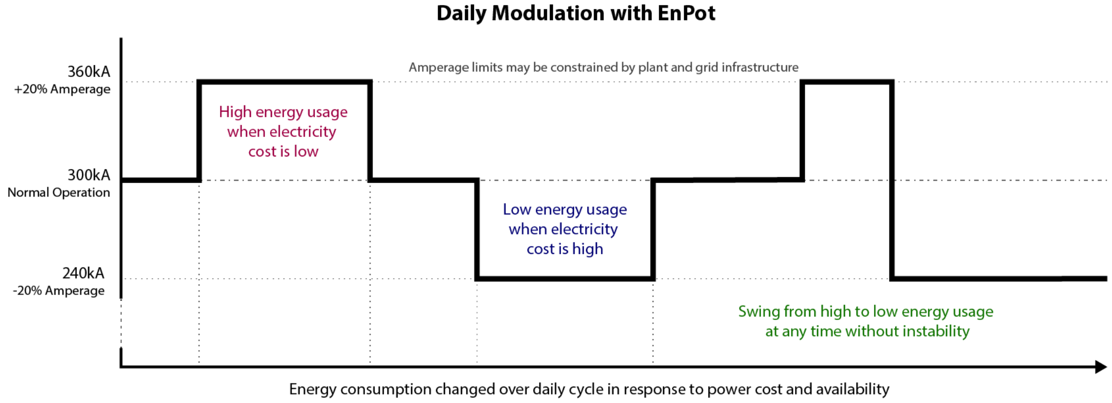

Figure 14

Because EnPot enables pots to be maintained in heat balance with the + and - 20% range, smelters may go up and back down in amperage multiple times for varying durations, such as to consume excess energy available.

A CHANGING ENERGY PARADIGM – WHY MODULATION IS IMPORTANT

A decade ago, little reason existed for aluminium smelters to modulate energy consumption. Smelters with their large and constant energy use were an ideal cornerstone stakeholder for thermal baseload generation. With the world moving rapidly towards low cost variable renewable electricity generation however, there has been a rapid erosion of the value of baseload.

Variable renewable electricity generation adds additional strain on grid operators to balance the grids, as generation and demand are often mismatched. With the percentage of electricity generated from variable renewable sources increasing, the percentage of generation from dispatchable (on demand) sources correspondingly has reduced. Adding to this shortage of dispatchable generation, many nations coal-fired and nuclear generation fleets are coming to end-of-life and will not be replaced due to cost and public consciousness.

Under this new energy paradigm, grid operators face an increasingly complex and difficult task of balancing the grid and maintaining the stable, reliable, power system we have all come to rely on. Grid operators require a new set of 'tools' at their disposal.

Big batteries, pumped hydro storage, and gas peaking plants, are all rapidly being developed and deployed. But these won't be enough. Demand side response (DSR) will be required as well. There is significant value in DSR, both to the DSR provider and to the grid itself. Not only is a grid with DSR cheaper to operate, the grid avoids the cost of building back-up generation that would sit idle waiting for 'peaks' in demand.

DSR providers will be able to exploit the energy arbitrage of 'selling' electricity back to the grid for more than it was purchased for (or not taking up contracted amounts during times of peak net load). They will also be able to benefit from cheap power when generation is high and net demand is low. Significant amounts of electricity will be negatively priced, which is an inherent feature of grids heavy with variable renewables.

Aluminium smelters, and indeed all large energy users, now have the opportunity to once again become valuable cornerstone stakeholders for the grid, by helping bridge the gap between generation and demand. The energy use flexibility of an aluminium smelter fitted with modulation technology is large enough to be of enormous value to the grid in terms of both peak-net-load- reduction (see Comparison Costs of Peak Net Load Reduction) and avoided cost of generation.

The new energy paradigm also offers incredible opportunity for smelters to use excess clean energy when it is freely available, much of it negatively priced. With electricity making up over 40% of the cost of producing aluminium, there will be strong business cases developed for modulating both up and down in energy consumption.

It really will be a case of making hay when the sun shines and the wind blows.