Danieli presents the Digimelter

The Digimelter for sustainable, competitive, green steelmaking

A technological breakthrough in electric steelmaking, with lower power and electrode consumption thanks to the Q-One power feeder, for zero impact on the power grid and the possibility to use renewable energies.

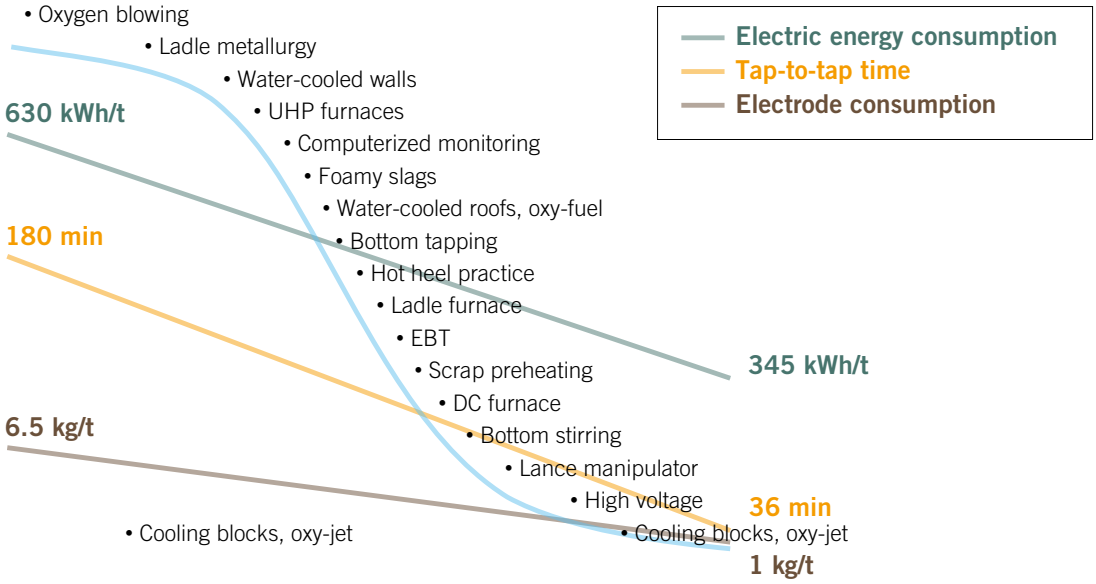
Electric arc furnace technology has seen a continuous evolution in the last 50 years (see fig.1), towards increased efficiency, with electric energy consumption halved, tap-to-tap time reduced by four times, and electrodes consumption reduced more than five times. These results have been achieved thanks to a combination of chemical packages (oxygen blowing, burners), design improvement (water cooled walls, EBT, lances, bottom stirring) and enhanced process controls.

Another important trend has been the increase in average power for individual furnaces, which has led to the development of Ultra High Power EAFs capable of producing in excess of 360 tonnes per hour of steel.

Electric Arc Furnaces have a powerful impact on electric grids: the more powerful the EAF, the more severe are the effects on the grid, with consequences like flicker, a phenomenon characterised by quick voltage variations that are visible in bulbs (flickering) and that can negatively affect power electronics, such as inverters in a rolling mill or similar processes. The arc furnace also impacts harmonic distortion and power factors with possible significant voltage drops, again impacting all plant auxiliaries, in the worst cases causing machine stoppages.

Many solutions have been developed over the years to dynamically compensate for such disturbances, namely SVCs (Static Var Compensator) and VSCs (Voltage Source Converter). These are high-power electronic systems designed to superimpose controlled reactive power to mitigate the impact of furnace disturbances.

The possible solutions for electric power transfer to the arc were the AC furnace and DC furnace. While the AC furnaces are the most common technology applied, where arc voltage and current are controlled thanks to the positioning of electrodes, DC furnaces use rectifiers to impose the current of the arc, but



50-year EAF performance evolution.

Q-One power feeder for total arc control and zero impact on the network.

with some significant implications for equipment design and related maintenance.

DC furnace technology reduces flicker generation and improves furnace control but requires a different and more expensive mechanical and electrical design. Therefore, DC furnaces are more maintenance-intensive and the bottom shell refractories require much more attention.

The Danieli Digimelterfor scrap / DRI

Digimelter is the Danieli answer for modern, clean, competitive, sustainable green steelmaking, recognised by the market as the new benchmark technology for electric steelmaking to melt scrap / DRI.

It is a Danieli-patented technology with a unique combination of power, intelligence, and environmentally friendly equipment for achieving 15,000 heats per year with minimal OpEx, lowest environmental impacts, and high flexibility for raw materials.

- The Q-ONE electrical feeder provides the highest power factor and very low network flicker due to real-time arc control. It achieves unprecedented high-power transfer thanks to independent control of arc current, voltage, and frequency, for each electrode.
- The Q-Melt intelligent controller runs EAF melting processes automatically, in a stable and adaptive way by making use of Q-Reg+ electrode regulator, Lindarc laser off-gas analyser, and Melt-Model self-learning optimiser.
- The Zero-bucket concept is accomplished by the ECS continuous scrap charging and preheating system as well as continuous hot DRI feeding from the roof, for reduced environmental impact and enhanced energy saving.
- The Eco-Pro airtight design is conceived to reduce pollutants to the minimum. Compared to a conventional EAF with the same charge mix, Digimelter Eco-Pro reduces the CO2 direct emissions (Scope 1) by more than 50% and overall CO2 emissions (scope 2) by 25%.

Q-One, a breakthrough technology

Q-One is the Danieli Automation patented, key technology at the basis of the Digimelter concept. In 2016 Danieli Automation installed the first Q-One, the first industrialised application of power electronics to control electric arc current and voltage in the EAF. In other words, using the conventional furnace design, this solution can impose arc current, with the consequent benefits in process stability and reducing drastically the impact on the connecting electric network.

In fact, Q-One operates with a power factor at medium voltage above 0.96, generating a very low flicker, avoiding use of compensation systems also because harmonic generation is well below IEEE limits. The system is modular by design: not only can the power required by the process be adjusted by selecting the number of modules, but also the solution can be designed for progressive growth in stages, meaning that initial power can be increased just by adding modules in a second stage.

This modularity also improves reliability and plant availability, considering the possibility to keep melting at reduced power (disabling one module) or even with two phases only instead of three. High availability is a must, and that's why modules also have been designed with the same components and inverters, which minimises the quantity and value of spare parts. The digital control allows for remote monitoring and troubleshooting.

The working points are no longer discrete, dictated by the taps on a transformer, but can be chosen freely according to process needs. One additional degree of freedom is given by the change of frequency, possible only in arc furnaces adopting Q-One. A frequency higher than network nominal improves arc stability and therefore is used during the boring stage, while a frequency below nominal, down to 20Hz –today used daily by our customers– is ideal for reducing energy consumption in the refining stage and for deeper penetration

of the arc in the molten bath, as well as to induce a beneficial stirring effect on the molten steel.

Lower frequency means a lower inductive reactance and consequently a lower consumption. Results from the field prove that up to 10% extra energy savings come from the low-frequency operation. The control of arc current implies a much more stable operation of the furnace, visible during melting, due to the absence of cooled-cables swaying and electrodes oscillating. The outcome is reduced electrode consumption, up to 15%, and at least 20% longer refractory life.

Q-Melt automatic furnace

The unique, reliable, and flexible green power solution of Q-One also benefits from Artificial Intelligence - AI applications and advanced control solutions. Danieli Q-Melt advanced process control offers dynamic and automatic optimisation of the melting profile. The system has been designed with the Danieli Intelligent Plant architecture for continuous learning and improvement of the process.

In addition, Q-Melt furnace automation is fully integrated upstream with an automatic scrap-yard management system in order to optimise melting process control for accurate and consistent working points set-up and quality assignment. To conclude, the control pulpit is ergonomically designed to integrate human expertise and machine precision to achieve unique performances and superior quality with best cost strategy. Most important, these results are achieved with a no-man-on-the-floor philosophy, powered by the advanced automation and the adoption of robots in the field to perform dangerous and repetitive operations, to achieve safe operation in steelmaking.

Zerobucket ECS continuous scrap charge

Danieli Zerobucket EAF is the most environmentally friendly melting technology with the lowest CO2 footprint. Characterised by high flexibility in raw materials, low energy consumption, very high reliability and utilisation factor, lowest noise and pollution emissions, Danieli Digimelter Zerobucket with ECS horizontal continuous charging system is the perfect answer to the latest needs of the steelmaking market. A very stable and smooth process allows the operators to easily bring the system to optimised operating conditions, reducing the risks of delays and providing extremely fast learning curve.

ZerobucketHytemp continuous hot DRI charge

The Hytemp pneumatic transport is the most efficient way to deliver hot DRI to the EAF at > 600 °C with no dust losses. It has been in operation since 1998 at four reference installations (Ternium, Emirates Steel #1, Emirates Steel #2 and Suez Steel), and about 40 million tonnes of DRI have been transported up to now. It shows outstanding reliability and availability close to 100%, with very low maintenance requirements. It is fully integrated with the DRP and Q-Melt furnace control systems, and matches the highest safety standards thanks to the inert carrier gas and the completely sealed design.

Eco-Pro airtight design

The Digimelter Eco-Pro airtight design is conceived to reduce to the minimum the emissions of pollutants and to minimise

Q-Sym automatic scrap management system

the CO2 equivalent. Every detail of the Digimelter has been carefully optimised in order to minimise air inlet to the melting area. The furnace is kept always sealed, thanks also to the Thor 3K automatic slag door and improved sealing between the furnace and the ECS conveyor.

The process itself is controlled automatically by the Q-Melt suite, leading to a minimisation of oxygen and carbon injection, ensuring the most efficient melting at the lowest CO2 footprint. Compared to a conventional EAF with the same charge mix, DigimelterEco-Pro reduces the CO2 direct emissions (Scope 1) by more than 50% and overall CO2 emissions (scope 2) by 25%.

Hybrid-ready by design

Digimelter fits very well the sustainable approach to steelmaking, thanks to the possibility to connect the DC Link to renewable energy sources, such as photovoltaic but also hydro or wind power, using the Q-One power feeder. With hybrid feeding, the OpEx of a furnace would be further improved, not to mention the reduction of its carbon footprint. A software suite, named Q3-Jenius, has been designed to manage the different available sources, depending on their cost and availability, with consideration also of forecast energy consumption for the specific products.

Continuous scrap charging system for scrap preheating and low emissions

Perfect for transition from BF to EAF using scrap / DRI

Having a very low impact on the grid, the Digimelter represents an ideal solution for the decarbonisation path, considering new arc furnaces melting scrap / DRI in place of blast furnaces. In fact, the electric network close to integrated plants typically was not designed to supply high volumes of electric power, required by arc melting, and the impact of traditional transformer EAF solutions on the electric grid is critical.

With Q-One, even for high-power furnaces, in most cases there is no need for any additional compensation system to meet the electric authority requirements. Furthermore, the modularity of the Q-One makes it suitable for the furnace evolution "in phases," where hot metal can be charged in high percentages in a first phase, while DRI and scrap will be mainly used, with higher power requirements, in a second stage.

Q-One for meltshop upgrades

Q-One also is very suitable for meltshop upgrades, including those that need renovation to boost productivity and performances. It is applicable to both EAFs and LFs and provides increased power input and operation savings in terms of electric power and electrodes, along with zero impact on the power grid and related benefits.

The first EAF upgrade dates back to 2016. Then, in 2019 at an 80-tonne capacity furnace at ABS Sisak, Croatia, +10% productivity, -8% energy consumption and -15% electrodes consumption were achieved. The latest order is from Cognor, Poland for the upgrade of a 48-tonne EAF. The first ladle furnace upgraded to Q-One power feeder is in operation at Tokyo Steel since mid 2021, having a capacity of 125 tonnes, and that of CMC Steel Arizona 1 at the Danieli MIDA minimill operating since early 2022, confirms the smooth and quick startup already performed at Tokyo Steel.

Scrap optimisation and management

Q-Melt interfaces with the Danieli Automation Q-SYM2 advanced, unmanned, upstream AI scrap-optimisation and management system. Q-SYM2 automatic scrap management system provides the furnace with best classified raw material and scrap processing machine interaction according to EAF/ scrap bay needs. Scrap is mapped from its arrival to the bay at the steelmaking plant to its use in the furnace, to ensure the incoming material quality and quantity according to the purchase order.

Real-time tracking allows for prompt, effective and simplified claim procedures when needed, thanks to artificial intelligence that makes possible automatic image acquisition and analysis. Real-time scrap inventory is made continuously available, reducing human errors and operational times. Scrap tracking handles scrap movement within the yard including loading and unloading bays. A native integration within the overhead cranes improves the yard management yield. Accurate "crane mission-generation" results in optimszed crane utilisation, with repetitive actions promptly executed based on scheduled and predetermined patterns.