

Danieli Digimelter® for sustainable, competitive, green steelmaking

The Digimelter® represents a technological breakthrough in electric steelmaking, with lower power and electrode consumption thanks to the Q-One power feeder. This has no impact on the power grid, making the use of renewable energy possible and so is ideally suited for the conversion of existing blast furnace plants to more environmentally friendly electric steelmaking production.

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THE ELECTRIC ARC FURNACE

Electric arc furnace (EAF) technology has continuously evolved in the last 50 years (see Figure 1) towards increased efficiency, with electric energy consumption halving, tap-to-tap time reduced by four times, and electrode consumption reduced more than five times. These results have been achieved thanks to the introduction of chemical energy through oxygen blowing and gas burners, design improvement, such as water-cooled walls, EBT, lances and bottom stirring, and enhanced process controls. Another important trend has been the increase in the average power for individual furnaces, which has led to the development of Ultra High Power EAFs capable of producing in excess of 360t of steel per hour.

EAFs can have a severe impact on electric grids, with consequences such as flicker and negative impacts on power electronics, such as inverters in a rolling mill, or similar processes. The arc furnace also creates harmonic distortion and power factors with potentially significant voltage drops. These affect plant auxiliaries and can cause machine stoppages. Solutions such as Static Var Compensators (SVCs) and Voltage Source Converters (VSCs), have been developed to compensate for such disturbances.

AC EAFs are the most common technology, where the voltage and current are controlled by positioning the electrodes. DC furnaces use rectifiers to impose the current of the arc, but this has significant implications for equipment design and related maintenance. DC furnace technology reduces flicker generation and improves furnace control, but requires a more expensive mechanical and electrical design. DC furnaces are more maintenance intensive and the bottom shell refractories require more attention.

THE DANIELI DIGIMELTER® FOR SCRAP AND DIRECT REDUCED IRON (DRI)

Digimelter® is the Danieli answer for modern, clean, competitive and sustainable green steelmaking, to melt scrap and DRI. This Danieli-patented technology is a combination of power, intelligence, and environmentally

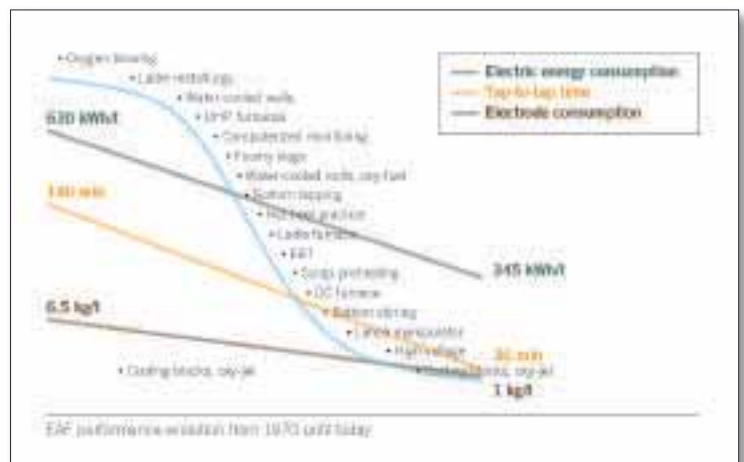


Fig 1 Evolution of EAF performance

friendly equipment, achieving 15,000 heats per year with minimal OpEx, low environmental impact and high raw materials flexibility. Key features are:

- The Q-One electrical feeder which provides a high power factor and low network flicker, due to real-time arc control. It achieves a 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 a Q-Reg+ electrode regulator, Lindarc laser off-gas analyzer, and Melt-Model self-learning optimizer.
- The Zero-bucket concept is accomplished by the Endless Charging System (ECS®) continuous scrap charging and preheating as well as continuous hot DRI feeding, reducing environmental impact and increasing energy savings.
- The Eco-Pro airtight design has been conceived to minimize pollutants. Digimelter® Eco-Pro reduces scope 1 direct emissions of CO₂ by more than 50% and scope 2 emissions by 25%.

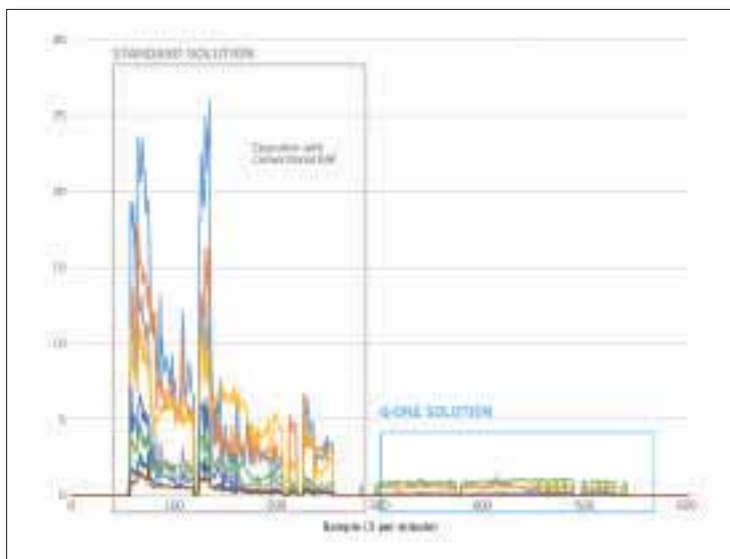


Fig 2 Q-One Comparison of harmonic currents

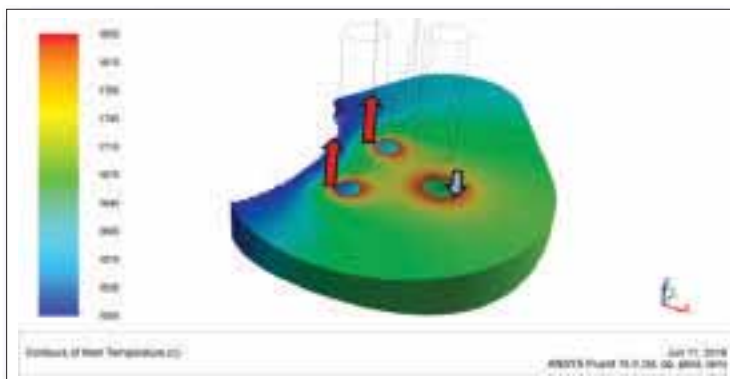


Fig 3 Q-One / Digimelter Phase Unbalancing

Q-ONE – A BREAKTHROUGH TECHNOLOGY

Q-One is the Danieli Automation patented key technology at the basis of Digimelter®. In 2016, Danieli Automation installed Q-One, as the first industrialized application of power electronics to control electric arc current and voltage in the EAF. Using a conventional furnace design, this solution imposes arc current, with benefits in process stability and a reduction in the impact on the connecting electric network. Q-One operates with a power factor at medium voltage above 0.96, generating very low flicker and avoiding the use of compensation systems, because harmonic generation is well below IEEE limits (Figure 2).

The system is modular by design. The power required can be adjusted by selecting the number of modules and 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 improves reliability and plant availability, with the possibility to keep melting at reduced power by disabling one module, or with two phases instead of three. High availability is vital and that's why modules have been designed with the same components and inverters, minimizing spare parts. 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, 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 (Figure 3). Lower frequency means a lower inductive reactance and lower consumption. Results show that up to 10% extra energy savings come from low-frequency operation. The control of arc current gives a more stable operation of the furnace, due to the absence of cooled-cables swaying and electrodes oscillating. The outcome is a reduction in electrode consumption of 15%, and 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) and advanced control solutions. Q-Melt advanced process control offers dynamic and automatic optimization of the melting profile. The system has been designed with Danieli Intelligent Plant architecture for continuous learning and improvement of the process. Q-Melt furnace automation is fully integrated upstream with an automatic scrap-yard management system to optimize melting process control



Fig 4 Q-Melt Control pulpit



Fig 5 ECS horizontal charging system

for accurate and consistent set-up and quality. The control pulpit is ergonomically designed to integrate human expertise and machine precision, to achieve unique performances and superior quality with best cost strategy (Figure 4). There is a no-man-on-the-floor philosophy, using advanced automation. The adoption of robots in the field to perform dangerous and repetitive operations, achieves safe steelmaking.

ZEROBUCKET® ECS CONTINUOUS SCRAP CHARGE

Danieli Zerobucket® EAF is an environmentally friendly melting technology with a low CO₂ footprint. Characterized by high flexibility in raw materials, low energy consumption, very high reliability and utilization factor, low noise and pollution emissions, Danieli Digimelter® Zerobucket with ECS horizontal continuous charging system, answers the needs of steelmakers (Figures 5 & 6). A very stable and smooth process allows operators to optimize operating conditions, reducing the risks of delays and providing a fast learning curve.

ZEROBUCKET® HYTEMP CONTINUOUS HOT DRI CHARGE

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 ▶



Fig 6 Zerobucket® Installations



🕒 **Fig 7 Zerobucket® Hytemp pneumatic transport of DRI**

installations: Ternium, Emirates Steel #1, Emirates Steel #2 and Suez Steel, and about 40Mt of DRI have been transported. 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 fully sealed design (Figure 7).

ECO-PRO AIRTIGHT DESIGN

The Digimelter® Eco-Pro airtight design was conceived to minimize emissions of pollutants. Every detail of the Digimelter® has been carefully optimized to reduce air into the melting area. The furnace is 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 minimization of oxygen and carbon injection, ensuring the most efficient melting at the lowest CO₂ footprint.

HYBRID-READY BY DESIGN

Digimelter® supports a sustainable approach to steelmaking, by connecting the DC Link to renewable energy sources, such as photovoltaic, hydro or wind power, using the Q-One power feeder. With hybrid feeding, the OpEx and carbon footprint of a furnace is further improved. A software suite, named Q3-Jenius, has been designed to manage the different available sources, depending on their cost and availability, with consideration of forecast energy consumption for the specific products.

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 decarbonization by replacing blast furnaces with new arc furnaces melting scrap and DRI. Electricity networks close to integrated plants was typically not designed to supply high volumes of electric power for 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. The modularity of Q-One makes it suitable for the furnace evolution in phases, where hot metal can be charged as a high percentages in the first phase, with DRI and scrap mainly used, with higher power requirements, in a later phase.

DIGIMELTER ORDERS FOR EAF TRANSITION FROM BF

The industrial transition from ironmaking to electric steelmaking started with Algoma Steel in December 2021. It was the world's first steelmaker to convert fully from blast furnace to EAF steelmaking, giving a 70% CO₂ reduction. The new green steel shop at Sault Ste. Marie, Ontario, Canada, will start early 2024 and have a design capacity of 3.7Mtpa of liquid steel. Algoma Steel will operate two, 250t Danieli Digimelters®, powered by two Q-One digital power systems with a rated capacity in excess of 190MVA each. The design provides for best-in-class environmental performance with engineered enclosures for the two furnaces to minimize noise and emissions, while Q-Melt automatic process control will deliver superior energy efficiency. Two new off-gas treatment plants, including baghouses and a dedicated recirculating water treatment plant, will combine to provide best available technology for emission control and filtration, and water conservation.

Liberty Ostrava in the Czech Republic, was the first producer in Europe to take the step from ironmaking to electric steelmaking in August 2022. Two Danieli Digimelters® with a combined capacity of 3.2Mtpa, are to be start operation in 2025. With a target emission reduction of 80%, this is the first step for Liberty towards carbon neutrality. In the initial phase of the project two 200t Digimelters® will replace Ostrava's existing four, tandem steelmaking furnaces and perform decarburization with flexible inputs of hot metal and scrap, using up to 40% scrap in the charge. From 2027 and thanks to an enhanced electrical network, the furnaces will be able to melt HBI, DRI and scrap mixes, up to 100%. The Q-One, Digimelter® will ensure an almost negligible impact on the power network.

DIGIMELTER® INSTALLATIONS PART OF DANIELI MIDA MINIMILLS

Digimelter®, combined with high-speed casting and Danieli Universal Direct Rolling, is a key technology of the Danieli MIDA minimills for long and flat products. The

latest MIDA minimill orders from CMC Steel, Bashundara, Pacific Steel, Nucor Steel, Tata Steel and Unitex, incorporate Digimelter®:

- **CMC Steel Arizona 2, USA**, is the first plant in the world to produce merchant bars in endless mode. To be put in operation in early 2023 in Arizona, CMC Steel Arizona 2 is the third Danieli MIDA QLP minimill for CMC Steel and will produce 500,000tpa of rebar and small merchant sections. Hybrid-ready, it will melt local scrap using Danieli Digimelter® (Q-One, Zerobucket, Q-Melt).
- **Bashundhara, Bangladesh**, a Jumbo QLP® minimill to produce 1Mtpa bars and wire rod is being installed in Chittagong, for a mid-2023 start up. The mill was designed with Danieli Digimelter® ready for connection to renewable energies and will melt scrap. Straight rebar, ribbed and smooth wire rod will be produced in endless casting and rolling mode through a single-strand, 150-tph Octocaster® featuring FCC® and octagonal sections.
- **Pacific Steel Group, USA**, will be the world's first MIDA-QLP® hybrid minimill featuring Q-One® and Q-Jenius, making use of solar energy. To be installed in Mojave, California, the mill will start operation by early 2025, producing 380,000 short tones per year of straight and spooled rebar. Hybrid by design, Q-One will make use of solar energy generated on site, through Q-Jenius. This is a fully automated plant, starting from automatic scrap management through final product tracking, featuring Q3-Met for production scheduling and tracking.
- **Nucor Steel, USA**, have placed a third order for a MIDA-QLP® endless casting-rolling minimill for rebar. The mill will produce 410,000 short tons per year of quality rebars from recycled steel scrap, in Lexington, North Carolina. It will feature Digimelter® and LF powered by Q-One digital power feeder, with the possibility to utilize renewable energies. A single-strand, high-productivity Octocaster® will feed the rolling mill in full endless mode. Managed by Danieli Automation's advanced process technologies and artificial intelligence, the minimill will incorporate Q3 pulpits to support operators in supervising a fully automated plant, making extensive use of big-data analysis. Robotized solutions will increase plant safety according to the no-man on the floor concept. Production will start by summer 2024.
- **Tata Steel India**, produced 750,000 tons of quality rebar in a sustainable way thanks to Digimelter® and endless casting-rolling. The investment in a Danieli MIDA Hybrid QLP minimill for the production of long products is part of the Tata Steel commitment to invest in a circular economy and to transition to low-carbon steelmaking through the steel recycling route. The new



④ Fig 8 Q-One Control

MIDA QLP ordered by Tata Steel will be installed in the North of India, in Ludhiana, Punjab, and produce quality rebar, mainly in 550 SD grade. The minimill will feature the Danieli-patented Digimelter® (Q-One hybrid power feeder + Zerobucket scrap charge system + Q-Melt advanced process control suite) and Octocaster feeding an ultra-compact rolling mill. The start of operation is planned by the end of 2024.

- **Unitex Steel, Bangladesh**, will install a 1Mtpy minimill for bars and light sections featuring Digimelter® melting unit with continuous hot charge. A complete minimill, including auxiliary plants for fumes and water treatment as well as the most advanced electrical and automation systems, to guarantee continuous and reliable production. A highly efficient, 100t Digimelter® featuring Q-One digital power feeder and ECS continuous scrap charging and preheating systems will competitively melt scrap. A four-strand, quality conticaster featuring FastCast Cube™ oscillator, Eco-Power Mould™ and EMS, will feed a super-flexible merchant rolling mill in hot-charge mode. To be installed in the Feni district of Chittagong, in the eastern

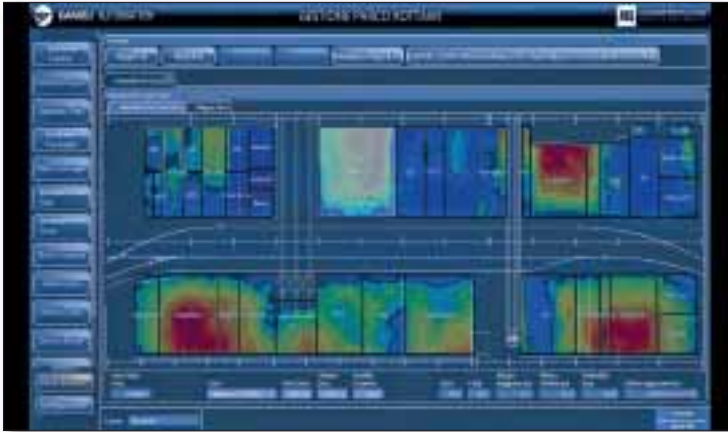


Fig 9 Scrap management inventory at the scrap yard

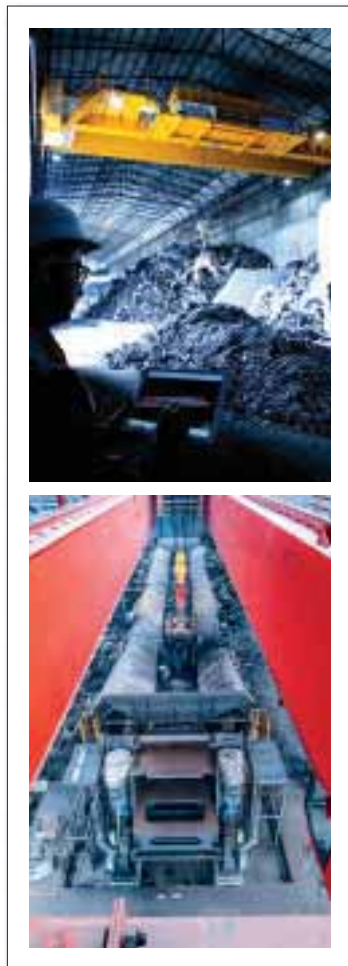


Fig 10 Scrap management integration of overhead cranes

region of Bangladesh, the minimill is scheduled to be started up in Q4 2024.

Q-ONE FOR MELTSHP UPGRADES

Q-One also is very suitable for meltshop upgrades, including those that need renovation to boost productivity and performances (Figure 8). 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. In 2019 an 80-ton capacity furnace at ABS Sisak, Croatia, achieved a 10% increase in productivity, and reductions of 8% in energy consumption and 15% in electrode consumption. The latest order is from Cognor, Poland, for the upgrade of a 48-ton EAF.

SCRAP OPTIMIZATION AND MANAGEMENT

Q-Melt interfaces with the Danieli Automation Q-SYM2 advanced, unmanned, upstream AI scrap-optimization 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, through the steel plant to the furnace, ensuring quality and quantity accords with the purchase order (Figure 9).

Real-time tracking allows prompt, effective and simplified claim procedures when needed, thanks to AI that makes possible automatic image acquisition and analysis. A real-time scrap inventory is made continuously available, reducing human error and operational time. Scrap tracking handles scrap movement within the yard including loading and unloading bays. Integration with overhead cranes, improve yard management and yield (Figure 10). Accurate "crane mission-generation" results in optimized crane utilization, with repetitive actions promptly executed based on scheduled and predetermined patterns.

CONCLUSION

The Danieli Digimelter®, powered by the patented and innovative Q-One, enables the substitution of blast furnaces/BOFs with EAFs of 300 tons and more. Thanks to the unique power control on the arc, Q-One allows for a new approach to the melting process, with frequency control and freedom of choice on working points, minimizing the impact on the grid, achieving minimum OpEx for furnace operation, with hybrid feeding, intelligent process controls and safe operation. Digimelter® is also widely used in modern minimills for efficient melting, and reduced energy and electrode consumption. **MS**

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