High Current Compact Generator

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Energy costs are key to industrial competitiveness, particularly in energy intensive industries where energy accounts for a significant proportion of total production costs. magniX has developed, built and tested high current generators and we subsequently combined our experience into a new generation of generators.

magniX's High Current Compact Generator (HCCG) utilises our null field technology, specially designed for high field superconducting magnets and liquid metal current collectors. The unique arrangement of the superconducting coils delivers
a high static drive field as well as sufficient shielding for the field critical sliding contacts.

This superconducting product has been successfully prototyped and tested and is now being designed for high current applications such as smelting.
The basis of the generator is a patent homopolar superconducting technology. A homopolar generator is able to supply direct current, reducing power supply costs by eliminating the need for a rectiformer.

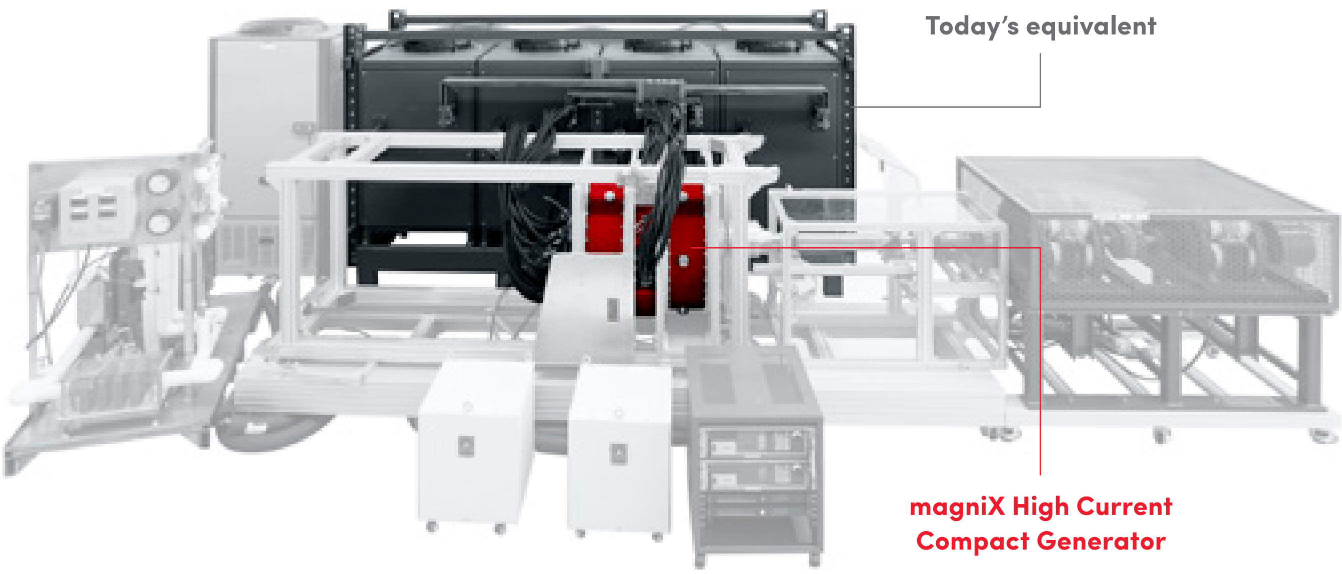
Technology Overview

Homopolar Generator

- Homopolar machines convert mechanical power to electrical power (generator) or electrical power into mechanical power (motor).
- Homopolar machines operate using only direct currents (DC) and static magnetic fields in contrast to most electric machines that use alternating currents (AC) and changing magnetic fields for energy conversion (i.e no commutation).
- This characteristic of DC current generation is advantageous for many electrochemical processes that require a direct current source at low voltage and high current.
- Homopolar machines are an excellent application of superconducting magnets as they can generate very high magnetic fields efficiently without DC resistive loss.
- The use of superconducting magnets allows the strength of the magnetic field to be dramatically increased in a very efficient manner. The high magnetic field also allows optimal rotor speed, enabling efficient brush operation at low voltages and high currents that are required for many practical applications.

Homopolar Applications

- DC Generator
- DC current source, no rectification required
- Integrated into a DC bus and DC distribution network
- High current, low voltage applications
- Smelting
- Hydrogen production
- High Power DC–DC Conversion



Liquid Metal Brush Technology

While homopolar generator technology has existed for some time, the metal fibre and carbon brushes used to conduct the large current away from the generator have limited the successful commercialisation of the technology. magniX's liquid metal brush and patented null field technology overcome this limitation. The generator requires less maintenance, as it doesn't use carbon brushes to conduct electricity to the rotor and eliminates the need to replace carbon brushes.

- Silver Fibre Brushes (SFB) work well in machines where the brushes are exposed to low surface speeds, low wear and low friction as well as operating at moderate currents.
- Liquid Metal Current Collector (LMCC) allows extreme surface speeds, current densities and currents and is best suited for electrical machines in the multi-MW ranges. Despite obvious disadvantages of the material handling, the LMCC is an inexpensive solution for scaling up homopolar devices, especially high-speed machines.

	Silver Fibre Brush (SFB)	Liquid Metal Current Collector (LMCC)
Surface speed	30 m/s	100–125 m/s
Cooling	Indirect, inefficient due to inherent design features.	**Indirect**, very efficient due to inherent design features/ **Direct**, very efficient, allows to cool not only the collector itself, but rotor and stator as well.
Mechanical Performance	SFBs creates substantial frictional losses of ~ 5 kW at 1800 rpm, faster speeds causes thermal run away.	LMCC generates about 2 kW at 1800 rpm and can operate up to 3600 rpm, and heat can be removed efficiently.
Electric performance	Electrical internal resistance becomes critical at high currents of ~ 10kA, reducing machine performance, as I^2R becomes very high.	Resistance of LMCCs alone is in the order of hundreds of nΩ, allowing them to transfer tens of thousands of amps.
Overall peak performance	6000 A, 1300 rpm	20,000 A, 1500 rpm Speed can be increased up to 3600 rpm, current can be increased substantially as the machine operates well under critical current density.

** Comparison based on equivalent rotor size.*

Why is high power and efficiency needed?

Case Study — Hydrogen Production

Electrolysis uses DC current to drive a chemical process and is used to produce hydrogen from water. Hydrogen production is an energy intensive process. Conventional generators are bulky and generate low power for their footprints. Operating efficiency, low voltages and high currents are key to electrolyser viability for hydrogen production. Conventional generators for an electrolyser have an efficiency of 60–70%. magniX HCCG generates high currents at low voltages in a much smaller footprint with a generator efficiency of up to 99%. The next generation of multi MW electrolysers will require generators with high power density and efficiency.

The benefits of using the magniX High Current Compact Generator for hydrogen production are:

1. A greater efficiency in producing hydrogen from water using the magniX HCCG.
2. A deployable system for areas in which the power grid does not accommodate high current, low voltage transformations.
3. The technology is adaptable to be driven by wind turbines eliminating carbon emissions.

Why is high power and efficiency needed?

Case Study — Hydrogen Production

Process Overview

- Electrolysis of water is the decomposition of water (H_2O) into oxygen (O_2) and hydrogen gas (H_2) due to an electric current being passed through the water.
- Production of hydrogen from electrolysis of water (H_2O) by use of reversible fuel cells is considered as one of the major pathways for increased use of renewable energy sources and for direct reduction of greenhouse gas emissions.
- During electrolysis, direct electrical current is applied to an electrolyser cell where the water molecule is split. The full chemical reaction occurring in electrolyser is $2H_2O = O_2 + 2H_2$.
- There are two main technologies available on the market, alkaline and proton exchange membrane (PEM) electrolysers.
- The yield of all electrolyser technologies relies on the external source of DC current. The process of water electrolysis is essentially low voltage, as the standard potential for splitting water at normal conditions at 25° is 1.481 V. And as with any electrolysis process the higher the current, the higher the yield. For example to attain a single cell production rate of 1 kg/hour requires a DC current of approximately 27,000 Amps.

Conventional Products' Drawback	User Impact		magniX's Products' Advantages	User Benefits
Lower Power Density	Conventional generators are bulky and generate low power for their footprint	→	High Power Density	magniX High Current Compact Generator is able to generate high power for an electrolyser with a smaller footprint and naturally delivers a low voltage at very high currents – a requirement for many electrochemical processes;
Low Operating Efficiency	Operating efficiency is key to viable hydrogen production. Conventional generators for electrolysers have an efficiency of 60–70%.	→	High Operating Efficiency	magniX's product has efficiency up to 99%. Only DC magnetic fields used – eliminating any AC loss (limits ultimate efficiency of a generator)
Lower Power Output	Conventional generators have lower output. Multiple smaller units of electrolysers are stacked together to achieve high power output.	→	Higher Power Output	As electrolysers are moving towards MW-class, generators with high power output will be most suitable for electrolyser applications.

Why is high power and efficiency needed?

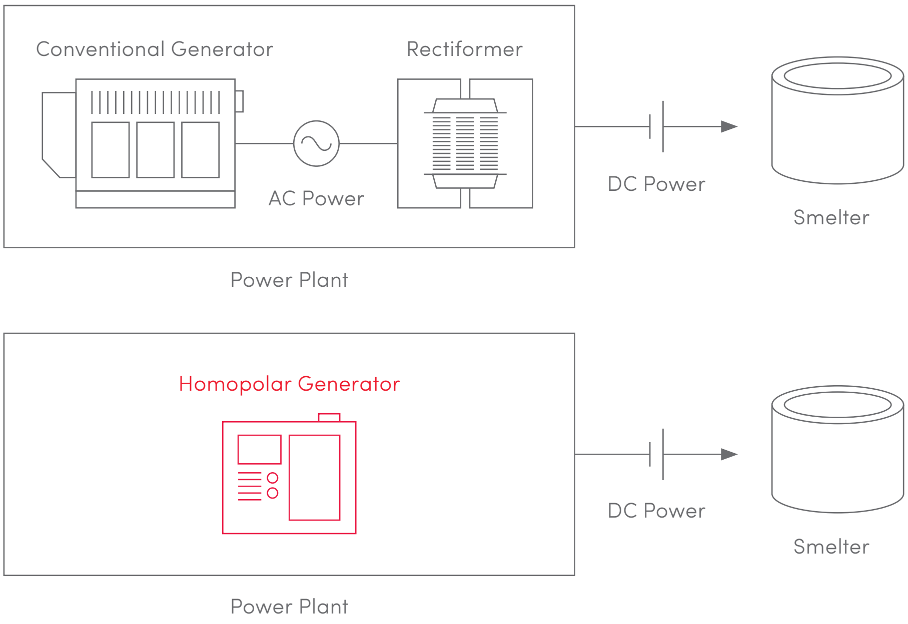
Case Study — Smelting

The smelting of aluminium is an energy intensive process. Energy cost is the major operating cost for a smelting plant. Over 80% of smelting greenhouse gas emissions are electricity consumption related and contribute as much as 40% to the production cost of aluminium. Increasing the efficiency of energy production via onsite generation can net large savings due to the volume of electricity consumed (14MW/ton).

To generate the high currents needed, a transformer and rectifier convert the AC power to a high DC current. A typical smelter plant generally requires 5–6 rectiformers (transformer + rectifier). magniX HCCG removes the necessity for a transformer and rectifier, as it is capable of generating high currents without the need for rectification. In addition to generating high currents, magniX HCCG has a higher system efficiency compared to the use of a rectifier and transformer, enabling cost savings to be achieved through reduced power draw from the grid. New aluminium smelters consume up to 2400MW of electrical power making energy efficiency key. Modelling shows that economic gains are significant, up to US$ 50M over the life of the equipment for a 300,000-ton smelter.

Why is high power and efficiency needed?

Case Study — Smelting



magniX HCCG efficiently generates high DC currents directly from the mechanical rotation of a prime mover, eliminating the need for multiple stages of energy conversion, increasing overall efficiency and substantially reducing the machine footprint. magniX HCCG can replace the traditional combination of an AC generator, transformer and semiconductor rectifier for onsite DC power generation. Our approach also allows the smelter to be split into smaller independent potlines with higher efficiency and with increased reliability.