New superconductive material for long-distance energy transmission

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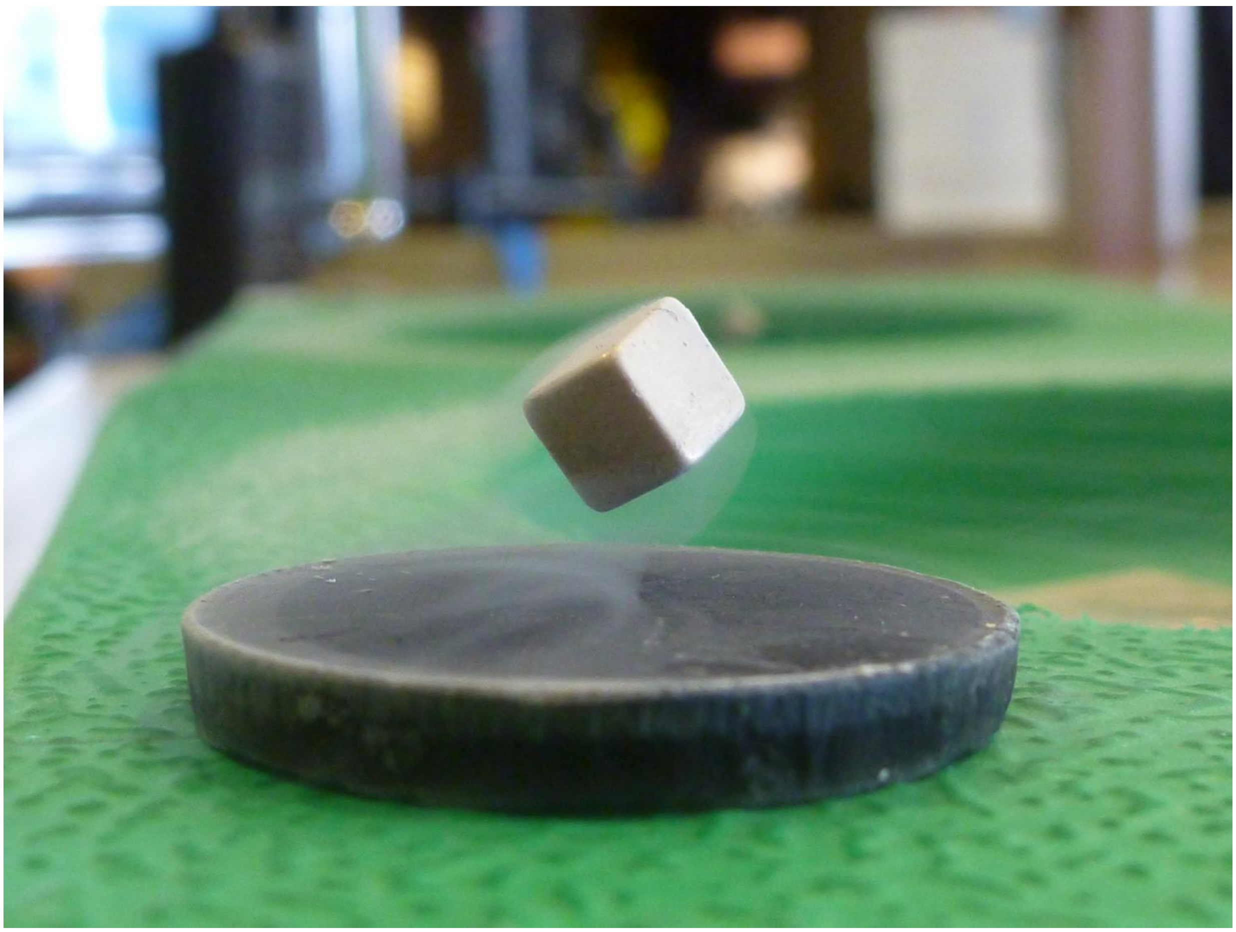

The Meissner effect: one of the most spectacular effects that reveal the presence of a superconductor. Credit: Trevor Prentice

The energy landscape in Europe is changing rapidly and the percentage of renewables is steadily increasing. For example, in Germany, solar and wind power provided an average of 33% of the total electricity production in 2015. And the phase-out of nuclear power, as part of the country's energy transition or *Energiewende*, will result in the expansion of the local electricity grid.

However, renewable energy depends on local weather conditions, on the possibility of electric power being shunted from one region to another, and also on the construction of a new, long-distance network of transmission lines linking countries in Europe.

With the existing technology, high-voltage DC overhead lines are currently the cheapest option. However, the rural population and environmental groups strongly oppose this solution with its unsightly pylons.

An alternative is to bury copper or aluminium high-voltage lines underground, a solution used in populated areas, but this is unlikely to be applied over long distances due to the much higher cost versus overhead lines.

Another drawback of energy transport through copper or aluminium lines is transmission losses caused by the electric resistance of these wires. This resistance causes the heating of wires, and the loss of energy. For long lines, energy loss can be as much as 10 percent of the transmitted energy. On a European level, that is the equivalent output of 3 to 5 large power plants.

In 1911, the Dutch physicist Heike Kamerling Onnes identified superconductors. He discovered that when some metals are cooled down to temperatures close to absolute zero, they lose all electrical resistance. For example, a current flowing in a closed loop of niobium held at practically absolute zero will flow forever. The scientist suggested that superconductive wires might be a good idea for energy transport.

The first practical proposal was formulated 50 years ago by the American physicist Richard Garwin. He proposed that a transmission line of 1000 km, transporting 100 Gigawatt (at that time, all the energy produced in the U.S.) could be transmitted through a single underground superconductive cable, just a mere 30 cm wide, including its cooling system. The drawback was that cooling the wire down to a few degrees above absolute zero would have been too costly.

During the 1980s, scientists discovered new ceramic materials that become superconductive at much higher temperatures, up to 70 degrees above absolute zero. Although cooling would be much cheaper, these high-temperature superconductors are difficult to manufacture and too expensive for use over long distances. Because of the high cost, utility companies have remained skeptical about their use in energy transport.

But in 2001, researchers in Japan discovered that a quite simple compound, magnesium diboride (MgB_2), becomes superconductive at a temperature of 39 degrees above absolute zero (39 K). In 2011, at the Institute for Advanced Sustainability Studies (IASS) in Potsdam, Germany, the physics Nobel Laureate Carlo Rubbia initiated a research cluster investigating the application of superconductive lines for energy transport.

Magnesium diboride is only available in powder form, but researchers at Columbus Superconductors in Genoa, Italy, found the material could be manufactured in long strands by filling copper or nickel tubes with the powder and sintering them. "High costs barred the way for the energy transportation over long distances with superconductors. MgB_2 really changed the game," says Giovanni Grasso, director general and co-founder of the company.

In 2014, a first test of the MgB_2 wire at CERN confirmed that the material would be a good choice. "The MgB_2 wire was tested with a very high current, up to 20,000 amperes, and this experiment confirmed the potential of MgB_2 as the superconductor of choice for long-distance energy transport," says Adela Marian, a physicist at the IASS.

The institute is taking part in a study on superconductors under the European project Best Paths, with CERN, Columbus and other research groups. They are now planning a demonstration that will test a MgB_2 cable at conditions matching those of future energy transmission systems.

At a voltage of 200-320 kV, and a DC current of up to 10,000 amperes, the experiment will demonstrate the transmission of 3.2 gigawatts, the equivalent output of three large power stations, through a superconductive cable 12.5 mm across. This cable will be housed in a tube along with its cooling system that will keep it at an optimal temperature of 20 K.

The future design of the cooling system is still under investigation. It will work in two stages: First, an outer cooling system operating with nitrogen will bring the temperature down to 70 K, and then the temperature of the cable itself will be lowered to 20 K. The coolant will be either liquid hydrogen or helium gas.

"The cryogenic system, on which we still have to work, is the main aspect still limiting this application," says Christian Eric Bruzec, project leader at Nexans, a France-based company also part of the European project which assembled the strands produced by Columbus.

The jury is still out. Ultimately, though, underground MgB_2 cables are expected to compete even with overhead transmission lines, says Marian.

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